Welcome to the

24th International Conference on the Application of Accelerators in Research and Industry (CAARI 2016)

October 30 –November 4, 2016

Renaissance Worthington Hotel

Fort Worth, Texas, USA

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CAARI 2016 COMMITTEES

Local Organizing Committee

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Barney L. Doyle	Co-Chair	Sandia National Laboratories
Arlyn Antolak	Co-Chair	Sandia National Laboratories
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Holly Decker	Conference Coordinator	University of North Texas
Cristina Castillo	Conference Assistant	University of North Texas
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William Barletta	USA
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Thomas Schenkel	USA
Lin Shao	USA
Valeriia Starovoitova	USA
Gyorgy Vizkelethy	USA
Yanwen Zhang	USA

Session Chairs

Osman Anderoglu	USA
Ani Aprahamian	USA
Eda Aydogan	USA
Melanie Bailey	USA
Dan Bardayan	USA
Roger Barlow	United Kingdom
Eva Birnbaum	USA
Salime Boucher	USA
Mark Bradley	USA
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Marc Caffee	USA
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Daniel Dale	USA
Max Doebeli	Switzerland
Osman El Atwani	USA
Alfredo Galindo-Uribarri	USA
Lyudmila Goncharova	Canada
Joseph Graham	USA
Geoffrey Grime	United Kingdom
Mark Harvey	USA
Anna Hayes-Sterbenz	USA
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Roger Webb	United Kingdom
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Harry Whitlow	USA
Shane Wood	USA
Haizhou Xue	USA
Shengqiang Zhou	Germany

Welcome to CAARI-2016

The organizers would like to welcome you to the 24th International Conference on the Application of Accelerators in Research and Industry. This conference is being hosted by the University of North Texas (UNT) in Denton, TX, Sandia National Laboratories (SNL) in Albuquerque, NM and Livermore, CA, and Los Alamos National Laboratory (LANL) in Los Alamos, NM. CAARI 2016 is also being supported by several other U.S. National Laboratories, industries and agencies most identified with accelerator technology. The Conference Co-chairs and the Topic Editors worked with the Session Chairs to develop the sessions and speakers.

This is the 24th International conference in the biennial series that began in 1968 as a *Conference on the Use of Small Accelerators for Teaching and Research* by Jerry Duggan, while he was a staff member at Oak Ridge Associated Universities. When Jerry moved to Denton, TX and joined the University of North Texas (UNT), he continued the Conference series in 1974, holding the meeting on the UNT campus. At this time, Jerry invited Lon Morgan to join him as a co-organizer. Lon Morgan brought in the industrial components of CAARI and it became known as the International Conference on the Application of Accelerators in Research and Industry (CAARI). CAARI was held in Denton for 30 years. In 2004, Jerry Duggan asked Floyd "Del" McDaniel and Barney Doyle to be co-organizers of the CAARI Conference Series. In 2004, Barney and Del moved the conference to Fort Worth, Texas, where it was held biennially from 2004-2012. In 2012 Yongqiang Wang and Gary Glass were invited to become co-organizers and the conference was held in San Antonio, TX. For the 2016 Conference, Arlyn Antolak has joined as a co-organizer and the conference has returned to the Renaissance Worthington Hotel in Fort Worth, Texas.

The CAARI Conference series is unique in that it brings together researchers from all over the world who use particle accelerators in their research and industrial applications. Each year the Topic Areas are reviewed and updated to reflect current research interests.

In addition to this brief Program Book with abstract titles and presenting authors, the program with complete abstracts may be found at www.CAARI.com.

We hope that you enjoy the conference and find it intellectually stimulating. In the schedule, we have provided several opportunities to renew friendships and talk science at this meeting: the Welcome Reception Sunday evening, the socials during each poster session Monday and Tuesday, the Conference banquet on Wednesday evening, the 2 O'Clock Band Concert on Thursday evening, and the Closing Ceremony on Friday at noon.

If there is anything we can do to make your conference experience and stay in Fort Worth, Texas, more enjoyable, just ask Gary, Del, Yong, Barney, Arlyn, Holly, or Carley. We are very happy you have joined us in Fort Worth and hope you have a memorable time!

Financial Support

Financial support from sponsors, exhibitors, and advertisers is an essential element of a successful conference. This support enables us to provide support for conference events, students, and other attendees. We are very grateful to the sponsors, exhibitors, and advertisers listed below for their support of CAARI 2016.

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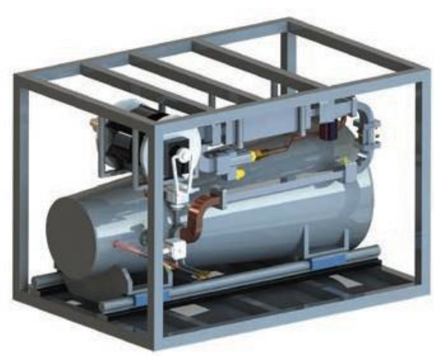

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- Singletron single ended accelerators up to 6.0 MV/TV
- Tandetron tandem accelerators up to 6.0 MV/TV

Research Ion Implanters

- Beam energies 10 - 60 MeV and higher
- Beam powers up to 25 kW

Systems for Ion Beam Analysis

- Rutherford Backscattering Spectroscopy (RBS)
- Particle Induced X-ray Emission (PIXE)
- Nuclear Reaction Analysis (NRA)
- Elastic Recoil Detection (ERD)
- Medium Energy Ionscattering Spectroscopy (MEIS)

Accelerator Mass Spectrometers

3H, 7Be, 10Be, 14C, 26Al, 32Si, 36Cl, 41Ca, 53Mn, 79Se, 129I, 236U etc.
analysis for use in

- Archeology
- Oceanography
- Geosciences
- Material sciences
- Biomedicine
- Etc.

Systems for Micro-beam applications

- Tandetron and Singletron based systems

Neutron Generator Systems

- DC and Pulsed Beam Systems

Electron Accelerator Systems

- Singletron electron accelerators up to 6.0 MV/TV

Components

Ion and electron accelerator tubes, ion and electron sources,
beam handling & monitoring equipment, etc.

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General Information

Oral Sessions

As with previous meetings in this conference series, there will be a mixture of plenary talks, invited talks, contributed talks, and regular poster presentations. The Plenary sessions will begin each day on Monday, Tuesday, Wednesday, Thursday, and Friday with two presentations each day. The oral presentations each day will consist of one 120 min. session in the morning and two 90 min. sessions in the afternoon (except Friday afternoon). There will be a total of 79 oral sessions and 2 poster sessions.

Guidelines for Oral Presenters

- **Very important**: Each presentation **MUST** be in a PowerPoint or PDF file and read from a memory stick or CD. All presentations will be downloaded on the existing computer in the meeting room. Screen and projectors provided by the hotel are 16:9.
- All memory sticks or CDs, MUST be given to the Session Chair or the Conference Assistant prior to the session, for downloading at least 15 minutes prior to the start of the session.
- At least 15-20% of your talk time should be reserved for questions and answers (Q&A). If your talk is 30 minutes, reserve 5 minutes for Q&A; if it's a 20-minute talk, reserve 4 minutes and for a 15-minute talk, reserve 3 minutes for Q&A.

Poster Sessions

All posters are to be put up on display boards no later than 1 pm on Monday, October 31st. Poster sessions will be held in the early evenings of Monday and Tuesday and authors are welcome to present their posters both of these days. The Student Poster Competition will be held Monday and Tuesday evening from 6-7 pm; please be available to present your poster both evenings in order to be considered for a prize. Posters are required to be taken down by end of the day Wednesday or they will have to be thrown away. All Poster Sessions will be held in the Grand Ballroom, alongside the Exhibitors. All posters in each session MUST be presented by an author in order to be published in the proceedings.

Guidelines for Poster Presenters

- Poster boards are portrait orientation and 3' Width x 4' Length. The posters will be attached with Velcro which you can obtain at the registration desk.
- Poster will be presented both days:
  - Monday- 6:00 pm to 8:00 pm
  - Tuesday- 5:30 pm to 7:30 pm

Manuscripts
The Proceedings of CAARI-2016 will be published by Elsevier's Conference Journal Physics Procedia. Physics Procedia (http://www.journals.elsevier.com/physics-procedia/) is an e-only and open access journal focusing entirely on publishing conference proceedings in a dedicated online issue on ScienceDirect, which is then made freely available and searchable worldwide. In line with the improvements to the CAARI conference, each paper shall consist of a minimum of 3 pages and a maximum of 10 pages. Each submitted manuscript will be reviewed by two referees. The Session Chairs, Topic Editors, and Conference Chairs will also be involved in the refereeing process to ensure that only high quality, original research work is included in the CAARI proceedings. Finally, the CAARI Chairs, in consultation with the Topic Editors, will recommend a small fraction of the reviewed manuscripts for consideration as a standalone publication in the Nuclear Instruments and Methods -B. (NIM-B) journal. This recommendation will be in the form of a cover letter along with reviewers' comments to be sent to the editors of NIM-B by the CAARI Organizers. The selected authors will submit their revised manuscripts to NIM-B along with the response letter to CAARI reviewers' comments.

- Please note that the initial manuscript deadline is Monday, January 30, 2017.

Industrial Exhibit Show
The Industrial Exhibit show will run from 10 am to 8 pm on Monday (Oct. 31) and Tuesday (Nov. 1), and from 10 am to 1:30 pm on Wednesday (Nov. 2) in the Grand Ballroom. We have a variety of Exhibitors this year, so please stop by, view their products, and say "thank you" to the representatives for continuing to support the CAARI conference. Without our exhibitors, CAARI would not be able to support our students.

Hotel Internet Connections
The Renaissance Worthington Hotel offers complementary wireless high-speed internet connection in each sleeping room as well as in the public areas of the hotel. The meeting area will have wireless internet which can be accessed with a password that will be provided.

Breakfast and Breaks
A continental breakfast, as well as morning and afternoon breaks (except Friday afternoon), will be served each day in the Grand Ballroom.

Lunch and Dinner
Lunch will be provided Monday through Wednesday in the Grand Ballroom. Dinner is on your own Monday, Tuesday, and Thursday. The banquet, which is included in your registration fee, will be held on Wednesday evening. We will have additional information at the information booth regarding local restaurants and attractions.

Social Events

Welcome Reception
A Welcome Reception will be held Sunday, October 30th from 6 pm to 8 pm in the Grand Ballroom.

Conference Assistant Briefing
The Conference Assistant Briefing will be held on Sunday evening @ 8 pm in the Bur Oak conference room (directly following the Welcome Reception). All Conference Assistants - please make sure to attend this meeting in order to receive important instructions and assignments for the conference.

Conference Student Appreciation Event
The Student Appreciation Event for students 18 and over will be held on Monday, October 31 at 8 pm at the T&P Tavern (221 W. Lancaster Ave.). Feel free to dress up for Halloween!

Topic Editors and Session Chair Appreciation Event
Topic Editors and Session Chairs are welcome to join the Conference Organizers on Tuesday, November 1 from 7:30 to 9:30 pm in the Hacienda Room. This event is held to show our appreciation, as well as review conference setup, sessions and to discuss improvements to CAARI 2018, which will be the 50th Anniversary Conference!!

Companion Outing
All registered companions are invited to attend a guided tour of the beautiful Fort Worth Botanical and Japanese Gardens on the afternoon of Wednesday, November 2. This outing is included in your registration fee. Complimentary transportation will depart the hotel lobby at 10 am and will return around 2 pm. Admission and lunch will be included.

Conference Banquet
The Conference Banquet will be held on Wednesday, November 2 at 6:30 pm in the Grand Ballroom. Entertainment will be provided.

UNT 2 O'Clock Band Concert
Join us on Thursday, November 3 at 6:30 pm on the Outside Terrace (accessed from the back of the Grand Ballroom) for light hors d'oeuvres and live music!

Closing Ceremony
All participants and accompanying persons are cordially invited to attend the closing ceremony. It will be held on Friday, November 4, in the Grand Ballroom Foyer at 12:30 pm.

CAARI 2016 Program Schedule

October 30 - November 4, 2016

Sun.

12 - 5 PM	Registration Open
6 - 8 PM	Welcome Reception - Grand Ballroom (2nd Floor)

Monday, 10/31

Time	Rio Grande	West Fork	Elm Fork	Trinity	Bur Oak	Post Oak
8:00 AM	Opening Ceremony					
8:30 AM	PS-01					
10:00 AM						
10:30 AM	AMP-04	AF-01	SD-01	AMS-01	IA-04	ISM-01
12:30 PM						
2:00 PM	TA-02	NM-01	SD-08	AMS-02	IA-06	NST-02
3:30 PM						
4:00 PM	TA-08	AF-03	SD-04	AMS-03	RE-02	NST-01
5:30 PM						
6:00 PM	Poster Social 1 - Grand Ballroom					
8:00 PM	Student Appreciation Event - T&P Tavern					

Tuesday 11/1

Time	Rio Grande	West Fork	Elm Fork	Trinity	Bur Oak	Post Oak
8:00 AM	PS-02					
9:30 AM						
10:00 AM	AMP-02	MA-05	SD-02	IBT-01	SP-01	ISM-03
12:00 PM						
1:30 PM	TA-04	MA-02	SD-05	IBT-05	RE-01	NST-03
3:00 PM						
3:30 PM	TA-09	MA-03	SP-11	IBT-02	RE-03	NST-04
5:00 PM						
5:30 PM	Poster Social 2 - Grand Ballroom					
7:30 PM	Topic Editor & Session Chair Appreciation Event - Hacienda Room					

Wednesday, 11/2

Time	Rio Grande	West Fork	Elm Fork	Trinity	Bur Oak	Post Oak
8:00 AM	PS-03					
9:30 AM						
10:00 AM	TA-06	MA-01	SP-09	AS-01	IA-03	AMP-01
12:00 PM						
1:30 PM	TA-07	MA-06	SP-08	AS-04	RE-06	ISM-04
3:00 PM						
3:30 PM	SP-13	MA-04	SP-12	IBT-03	RE-04	ISM-02
5:00 PM						
6:30 PM	Banquet - Grand Ballroom					

Thursday 11/3

Time	Rio Grande	West Fork	Elm Fork	Trinity	Bur Oak	Post Oak
8:00 AM	PS-04					
9:30 AM						
10:00 AM	TA-05	MA-07		TD-01	RE-05	AMP-03
12:00 PM						
1:30 PM		NBA-01	SP-10	IBT-04	RE-07	NT-01
3:00 PM						
3:30 PM	TA-01	NBA-02	SP-04	TD-04	RE-08	NT-02
5:00 PM						
6:30 PM	UNT 2 O'Clock Band Concert - Outside Terrace					

Friday, 11/4

Time	Rio Grande	West Fork	Elm Fork	Trinity	Bur Oak	Post Oak
8:00 AM	PS-05					
9:30 AM						
10:00 AM			SP-06	TD-02	IA-02	AMP-05
12:00 PM						
12:30 PM	Closing Remarks - Grand Ballroom Foyer					

Legend

AA - Accelerator-Based Analysis
- AMS - Accelerator Mass Spectrometry
- IBT - Ion Beam Techniques
- ATF - Accelerator Technology & Facilities
- NBA - Nuclear-Based Analysis
- NM - Nuclear Microprobes
- NT - Neutron Techniques

AC - Accelerators
- AF - Accelerator Facilities
- AS - Accelerator Stewardship
- TD - Technology Development

AP - Applications
- IA - Industrial Applications
- MA - Medical Applications
- SD - Security and Defense
- TA - Teaching with Accelerators

AR - Applied Research
- ISM - Ion Enhanced Synthesis and Modification
- RE - Radiation Effects
- NST- Nanoscience and Technology

PR - Physics Research
- AMP - Atomic and Molecular Physics
- SP - Subatomic Physics

PS - Plenary Sessions

- Session
- Session Break
- No session scheduled (in mtg room)

Welcome to CAARI 2016
Opening Ceremony

8:00 AM

Yongqiang Wang
Director
Ion Beam Materials Laboratory
Los Alamos National Laboratory

Gary A. Glass
Professor of Physics and Co-Director
Ion Beam Modification and Analysis Laboratory
University of North Texas

F. Del McDaniel
Professor of Physics and Co-Director
Ion Beam Modification and Analysis Laboratory
University of North Texas

Barney L. Doyle
Distinguished Member of the Technical Staff
Radiation Solid Interactions Department
Sandia National Laboratories

Arlyn Antolak
Principal Member of the Technical Staff
Rad/Nuc Detection Materials and Analysis Department
Sandia National Laboratories

Guest Speaker

Michael Monticino
Special Assistant to the President
Interim Chair, Department of Physics
University of North Texas

Teaching with Accelerators Series: Vacuum Class

Introduction: Vacuum is a key enabling condition for many types of scientific inquiry and experimentation, and is a critical component to any accelerator systems. CAARI-2016 is pleased to offer a complimentary vacuum class to our attendees as a part of our efforts to enhance Teaching with Accelerators topic area. Topics will include an introduction to high vacuum and ultra-high vacuum, gas behavior at low pressure, the elements of system pressure and total gas load, materials selection, pumping technologies from primary vacuum to UHV, pressure measurement gauges, and system operation. The vacuum class is excerpted from Agilent's one-day UHV Seminar and is intended to provide an introduction to ultra-high vacuum systems and practice for scientists, engineers, technicians, and students. The class is divided into two 90 min. seminars, designated as TA-08 and TA-09 sessions under the topic area of Teaching with Accelerators in the conference program. Attendees will receive a copy of Agilent's seminar handbook, "High and Ultra-High Vacuum for Science Research", 2011, 133 pages.

Instructor: Walt van Hemert, Senior Trainer, Vacuum Products Division, Agilent Technologies

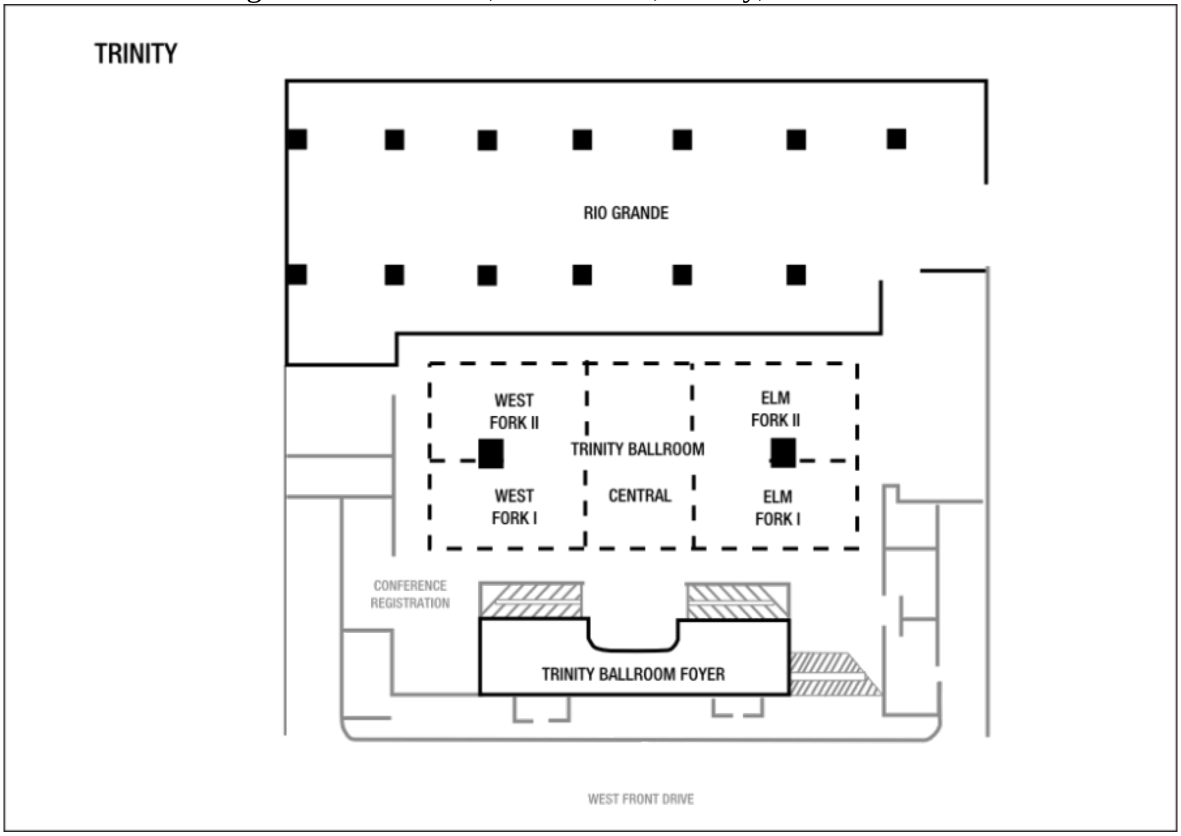
TA-08: Vacuum seminar – Part I: Physics of Vacuum
Monday, October 31, 4:00 – 5:30 pm Rio Grande Room

Introduction to high vacuum and ultra-high vacuum, gas behavior at low pressure, the elements of system pressure and total gas load, and materials selection for vacuum system.

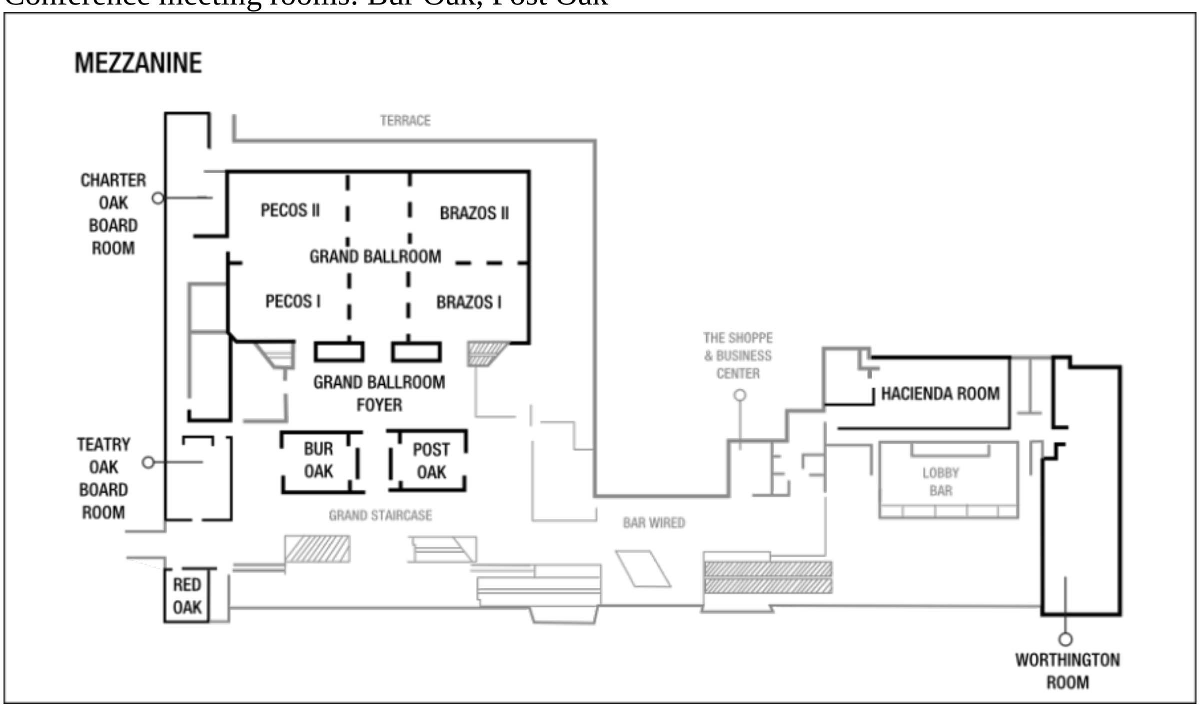
TA-09: Vacuum Seminar – Part II: Pumps and Gauges
Tuesday, November 1, 3:30 – 5:00 pm Rio Grande Room

Pumping technologies from primary vacuum to UHV, pressure measurement gauges, and integrated vacuum system operation.

Conference meeting rooms: Elm Fork, Rio Grande, Trinity, West Fork



Conference meeting rooms: Bur Oak, Post Oak



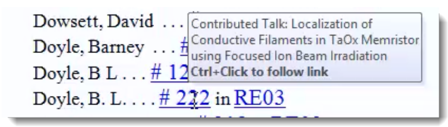
Using this Abstract Book

This Abstract Book contains:

1. the session summary,
2. full text of accepted abstracts, and
3. the index of authors and co-authors.

The Abstract Book can be downloaded from the conference website at http://www.caari.com and is available in several formats. All formats feature mutual hypertext links between the schedule, abstracts, and the author index.

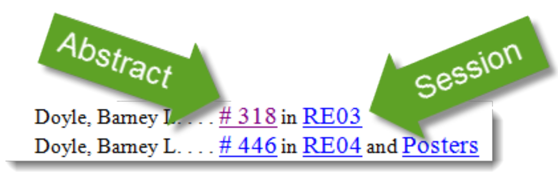
- Notebook, ultrabook, or desktop users: the Microsoft Word version offers popup hints - to see them, please, hover the mouse over the hyperlink. Alternatively, a PDF version is also available.



- Users of small mobile devices (tablets or smartphones): While you can certainly use the desktop Word and PDF versions if your device supports them, we have re-flown the Abstract Book to about 4" width so that if you are viewing the book you do not need to shift the screen horizontally. The mobile version of the Adobe Reader can be downloaded from the corresponding app stores, for example, from Google Play for Android.

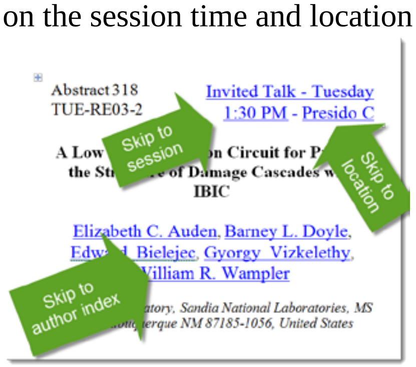
Based on the type of program you chose to read this book, you will be able to search for keywords in the abstracts that relate to your areas of interest or add your own notes or bookmars.

This listing contains information about each presentation including all of the authors and their affiliations. If you wish to find out, for example, when Barney Doyle's talk is to be given, just look up his name in the author index at the end of this book:



Then click on the abstract number to read the full abstract or the session code to view other presentations in the same session.

When you are viewing the abstract click on the author's name to skip to the author index again or click on the session time and location to see all other presentations in this session.



The abstract details include the abstract number: 318
The type of presentation: Invited Talk
The day and time Session RE03 starts: Tuesday 1:30 PM
The location: Presidio C

Hypertext structure of this Abstract Book was facilitated by Meeting247 tools

Session Summary

PS-AC: Plenary Session for Accelerators
Monday at 8:30 AM in Rio Grande

139 Moving Accelerator Technology Beyond the National Laboratories: The DOE Accelerator Stewardship Program *by Mark Palmer*

PS-AP-01: Plenary Session for Applications
Monday at 9:15 AM in Rio Grande

409 Non-Intrusive Active Interrogation for Various Threats Including Nuclear Materials: Status of Technology and Role of Accelerators *by Tsahi Gozani*

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390 Modelling of Cascade Defocussing in Irradiated Nanoporous Materials *by Lucio Dos Santos Rosa*
95 IAEA Stopping Power Database: Following The Trends in Stopping Power of Ions in Matter *by Claudia Carmen Montanari*

AP-MA-04: Start-up Logistics for New Particle-Beam Treatment Facilities
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437 Clinical and Administrative Aspects of Starting a Proton Therapy Center *by Gary Barlow*
438 Starting up a clinical proton center: Physics considerations *by Chang Chang*
385 Acceptance, Commissioning, Opening then Maintaining a Proton Center in a community with limited proton medical physics experience. *by Mark Pankuch*

AR-ISM-02: Swift Heavy Ion Modification of Materials - Nanostructuring
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302 Local formation of color centers in diamond without thermal annealing using swift heavy ions *by Thomas Schenkel*
60 Synthesis of HfO_2 Nanoparticles by RF Magnetron Sputtering Technique and Ion Irradiation Effects *by M Dhanunjaya yadav*
277 Synthesis of Silicates Analogous to Cosmic Dust Using Multiple Ion Implantations *by Joshua M. Young*

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Wednesday at 3:30 PM in Bur Oak

135 Effects of Cold Deformation, Electron Irradiations and Deformed by Extrusion on Deuterium Desorption Temperature Range from Zr-1%Nb Alloy *by O. Morozov*
223 Mechanical properties of steel miniature specimens irradiated with high-energy heavy ions *by Chonghong Zhang*
387 In Situ Analysis of Self-ion Damage Accumulation in Nanocrystalline Tungsten and Solute-stabilized Tungsten Alloys *by Jason R. Trelewicz*
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61 A supersonic jet target for the cross section measurement of the 12C(α; γ)16O reaction with the recoil mass separator ERNA *by David Rapagnani*
274 Study of the $^{14}N(d,alpha)$ $^{12}C^*$ reaction using SUGAR. *by EfraÃ-n Rafael ChÃ¡vez LomelÃ-*
237 Determining the $^{14}O(\alpha,p)^{17}F$ Astrophysical Rate with TwinSol Measurements *by D.W. Bardayan*
247 High Precision $^{236}U(n,\gamma)$ and $^{238}U(n,\gamma)$ Cross Section Measurement *by Bayarbadrakh Baramsai*

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441 Nuclear Data for Nuclear Reactor Antineutrino Flux Calculations *by A.A. Sonzogni*
442 Toward improved searches for tensor type interactions in β decay *by Oscar Naviliat-Concic*
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275 Electron Accelerators for Novel Cargo Inspection Methods *by Sergey V Kutsaev*
355 Near-monoenergetic photon sources for security applications *by Bernhard Ludewigt*
357 Development of a compact accelerator driven neutron generator for security applications *by Allan X. Chen*
113 Explosive Hazard Detection Using a Portable High-Flux Neutron Generator *by Mark Thomas*
321 Studies of a hydrocarbon fluid-based deuteron ion spark-source for neutron generators *by Paul R. Schwoebel*

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286 Utilizing Boron in Proton Therapy to Enhance Treatment *by Jacob Daniel Baxley*
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244 An Electrostatic Storage Ring for Interdisciplinary Physics Research at JPL *by A. Chutjian*
151 The cryogenic double electrostatic ion-storage ring, DESIREE. *by Henning T Schmidt*
365 SPARC collaboration: new strategy for storage ring physics at FAIR *by Thomas Stoehlker*
349 CRYRING@ESR - a new facility for low-energy highly charged ion research *by Michael Lestinsky*

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178 Triassico: A Sphere Positioning System for Surface Studies with IBA Techniques *by Cristiano Lino Fontana*
221 Geochemical Characterisation of Soil and Sediment Samples from Gold Mining Areas using Particle Induced X-ray Emission Technique *by Felix S. OLISE*
222 PIXE Characterisation of Mineral-Hosted Soil Samples: A Radiometric and Potential Toxicity Assessment *by Felix S. OLISE*
288 RBS analysis of down-conversion layers comprising two rare-earth elements *by David C Ingram*
335 TXRF Yield Formed by PXWR in Conditions of Ion Beam Excitation *by Vladimir Konstantinovich Egorov*
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341 Characterization of archeological pottery from Tyre historical site using PIXE technique and cluster analysis *by Mohamad Roumie*
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405 The Promise of PAA in Security and Forensics *by Douglas P Wells*
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PR-SP-01 # 236 Detail β-decay study of ^{77}Ga based on statistically significant γγ-coincidences *by U. Silwal*
PR-SP-08 # 6 Conducting Low Energy Nuclear Astrophysics Research Using the 1.7 MV 5SDH-2 Pelletron at the Louisiana Accelerator Center *by John Miller*
PR-SP-08 # 68 Searching for scintillation detector drift through analysis of recoil spectra from neutrons scattered from ^{12}C and γ-rays emitted from radioactive sources ^{137}Cs, ^{60}Co, and ^{241}Am *by S. G. Block*
PR-SP-08 # 116 Study of the $^{28}Si(d,\alpha)^{26}Al$ nuclear reaction at low energies *by Victoria Isabel Araujo-Escalona*
PR-SP-11 # 241 Eight Detector Setup for 11B(p,α)2α Reaction *by Jacob Daniel Baxley*

CAARI Abstracts

Abstract 139 MON-PS-AC-0 Plenary Talk - Monday 8:30 AM - Rio Grande

Moving Accelerator Technology Beyond the National Laboratories: The DOE Accelerator Stewardship Program

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The U. S. Department of Energy's Office of Science is working to broaden its accelerator R&D activities beyond its discovery science mission to supporting medicine, energy and environment, defense and security, and industry. Accelerators play a key role in many aspects of everyday life, and improving their capabilities will enhance U.S. economic competitiveness and the scientific research that drives it. Authorized for the first time in 2014, the Accelerator Stewardship Program has worked to facilitate access to national laboratory accelerator R&D infrastructure, fund high-impact accelerator R&D on specific applications, and bring together the accelerator community through workshops, studies, and other outreach activities. We will describe the evolution of the stewardship program, its mission, the broad criteria for participation, and the progress of program initiatives.

Abstract 409 MON-PS-AP-01-0 Plenary Talk - Monday 9:15 AM - Rio Grande

Non-Intrusive Active Interrogation for Various Threats Including Nuclear Materials: Status of Technology and Role of Accelerators

Tsahi Gozani

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The detection and interdiction of nuclear materials smuggled through any possible pathway (sea, land or air) is a major challenge facing the United States and the rest of the world. Detection of explosives, drugs and other threats at the same pathways and other locations inside the country are important as an integral part of counterterrorism effort.

Nuclear materials emit gamma rays and (in some cases) neutrons. Detecting these radiations is helpful and is commonly done these days, and referred to as "Passive Detection". However when embedded in cargo the detection precipitously declines because of the gamma ray high attenuation, due to their low energy. Explosives can sometimes be detected by their particulates contamination, though the latter can be readily avoided by experience perpetrators. X-ray radiography, useful for identifying shapes of objects with higher density than that of the rest, cannot determine whether the former is an explosive or nuclear threat and is prone to have high false alarm.

The Active Interrogation (AI), based on neutrons or photons (usually high energy x-rays) are employed to overcome the inherent limitations of the passive detection and x-ray radiography. The interrogating neutrons and photons are generated by accelerated charged particle (electrons, protons, deuterons etc.) interacting with appropriate targets. They penetrate deep into the cargo to reach the threat and stimulate characteristic isotopic signatures, some of which reach the detectors placed outside the inspected object. The main signatures are fission prompt and delayed neutrons and beta-delayed gamma rays for fissionable materials and discrete gamma rays from neutron inelastic scattering and/or radiative capture in explosive and other threats elemental (isotopic) content.

Over decades of research and development a variety of inspection techniques were investigated and some have been built and piloted. The techniques try to adapt to different operational scenarios and concept of operations, which cover wide range from inspection of "small" objects with $<1m^3$ volume to full size trucks and marine shipping containers, with volumes larger than $50m^3$. Those systems employed the tools and means available at the time. For example pulsed neutron generator with HV<100kV and (d,T) yield of about 10^8 n/s might suffice for the smaller object, but certainly not to the larger ones. Much stronger neutron generators, with 2 to 3 orders of magnitude, are required for the latter. High energy (8-10MeV) electron accelerators (e.g. e^- linac), generating high energy penetrating x-rays, are required to get suitable radiographic image of even laden container. The high energy part of the x-ray spectrum can also be used to stimulate fissions, if fissionable material is present. This double-duty functionality of the linac makes it very attractive and possibly the most viable source for full- size container inspection system.

The current status of inspection technologies and the role of available accelerators will be briefly reviewed. By comparing current accelerator specifications with those needed/desirable for inspection technologies, accelerator changes that can be implemented in the near term as well as those requiring longer term effort, will be discussed.

Abstract 74 MON-AA-AMS-01-1 Invited Talk - Monday 10:30 AM - Trinity

Overview of the AMS technique and its impact

Robin Golser

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Since its invention in the late 1970ies, Accelerator Mass Spectrometry has continuously broadened the field of application. A majority of studies utilize C-14, ranging from the DNA of an individual to phenomena on a global scale. It is mainly C-14, but not only, that drives development, both sample prep and overcoming technical challenges. But progress of the AMS technique continues to happen all across the table of isotopes. Also in the range of heavy masses advancements are astonishing. I will present some "milestones" of AMS from past, present and future.

Abstract 91 MON-AA-AMS-01-2 Invited Talk - Monday 10:30 AM - Trinity

Radiocarbon and The Authenticity of Natural Products

Randy Culp, Hai Pan, Gurazada Ravi Prasad

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Harold Libby, Nobel Laureate for his pioneering work on Radiocarbon dating, would have had no idea the breadth of his discovery or his first publication on radiocarbon in 1949 with J. R. Arnold: "Age determinations by radiocarbon content: Checks with samples of known age" in the journal **Science**. Especially when it pertains to the application of authenticating the origin of foods, flavors, beverages and other biobased materials. This field of chemistry began in earnest in the late 1970's with applications of stable isotope ratio mass spectrometry and the determination of the unique $^{13}C/^{12}C$ ratio signatures as a consequence of different photosynthetic pathways. Corn (a C4 plant) derived sugars could easily be distinguished from fruit (a C3 plant) sugars based on stable carbon isotopes alone. The early 1980's saw the introduction of ^{14}C measurement in the mix of stable isotope measurements, which by then included $^{15}N/^{14}N$, $^{18}O/^{16}O$ and D/H ratio analysis. However, none of these stable isotope pairs can offer the unambiguous determination of fossil fuel additions to natural products as ^{14}C abundance can. To this day, ^{14}C is used to substantiate the origin of a myriad of flavor chemicals, prior to manufacturing the final product as well as on the isolated chemical of interest on the grocery shelves ready for consumer selection. This paper discusses applications and classical cases of authenticity testing of foods and flavors, new applications to biobase product testing including biofuel apportionment and the challenges for the isotope/forensic chemist in the coming years.

Abstract 126 MON-AA-AMS-01-3 Invited Talk - Monday 10:30 AM - Trinity

Investigation of annual cosmic ray variation in the past

Fusa Miyake[1], Kimiaki Masuda[1], Toshio Nakamura[1], A.J.Timothy Jull[2], Irina P. Panyushkina[3], Lukas Wacker[4]

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Incoming cosmic rays produce cosmogenic nuclides such as ^{14}C in the atmosphere. Since ^{14}C becomes $^{14}CO_2$ and is absorbed by tree rings by photosynthesis, the ^{14}C contents in tree rings would record the past cosmic ray intensities. Although such past cosmic ray variations have been studied by measurements of ^{14}C contents in tree rings with 5-10 year resolution for the Holocene (IntCal dataset), there are few annual ^{14}C data. There is a little understanding about annual ^{14}C variations in the past.

We have investigated the past cosmic ray intensities with annual resolution by measuring ^{14}C contents in tree rings, and found two annual cosmic ray increase events (AD 775 and AD 994). It is considered that the origin of these events is an extreme Solar Proton Event. I will show not only a detail of these two cosmic ray events but also a recent measurement result in the 55th BC century.

Abstract 31 MON-AA-AMS-01-4 Contributed Talk - Monday 10:30 AM - Trinity

Measuring astrophysically relevant ^{36}Cl production cross sections

Tyler Anderson, Michael Skulski, Wenting Lu, Karen Ostdiek, Adam Clark, Austin Nelson, Mary Beard, Philippe Collon

Physics, University of Notre Dame, 225 Nieuwland Science Hall, Notre Dame IN 46556, United States

The short-lived radionuclide ^{36}Cl ($t_{1/2}$ = 0.301 Ma) is known to have existed in the Early Solar System (ESS), and evaluating its production sources can lead to better understanding of the processes taking place in ESS formation and their timescales. The X-wind model is used to explain ^{36}Cl production via solar energetic particles from the young Sun, but is lacking empirical data for many relevant reactions. Bowers et al. (2013) measured the $^{33}S(\alpha,p)^{36}Cl$ cross section at various energies in the range of 0.70-2.42 MeV/A, and found them to be systematically under predicted by Hauser-Feshbach statistical model codes TALYS and NON-SMOKER, highlighting the need for more empirical data for these cross sections. Recent results of the re-measurement of the $^{33}S(\alpha,p)^{36}Cl$ reaction, providing greater coverage of the same energy range as Bowers et al., will be presented. Future plans for measurement of other ^{36}Cl producing reactions will also be discussed.

Abstract 112 MON-AA-AMS-01-5 Contributed Talk - Monday 10:30 AM - Trinity

The carbon "bomb peak" information from tree rings in Mexico City.

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14C/12C relative concentrations were measured in tree rings from Mexico City and compared to concentrations measured in a tree from a forest away from anthropogenic carbon production for the period 1950-1993. This period includes the "bomb peak", an important increase of 14C concentration due to nuclear atmospheric detonations. An international agreement signed in 1963 prohibited all atmospheric nuclear tests producing then a maximum in the 14C concentration in that year. Such maximum is now known as the "bomb peak".

Significant differences are found, consistent with previous works in Nagoya and Valladolid. Possible interpretations include the effect of anthropogenic injection of CO2 from fossil fuel combustion. Fossil Carbon has no 14C, resulting in an anthropogenic reduction of the 14C/12C relative concentrations, this is commonly known as the "Suess Effect".

Abstract 172 MON-AC-AF-01-1 Invited Talk - Monday 10:30 AM - West Fork

The National Center for Electron Beam Research at Texas A&M University - an IAEA Collaborating Centre for Electron Beam Technology

Sohini S. Bhatia[1,2], Suresh D. Pillai[1,2]

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The National Center for Electron Beam Research (NCEBR) at Texas A&M University is a commercial scale electron beam resource that is focused on both commercial processing as well as furthering R&D in electron beam (eBeam) technology. The Center is equipped with two vertically mounted 10 MeV, 15 kilowatt linear accelerators (LINACs), as well as one single horizontally mounted 5 MeV, 18 kilowatt X-ray LINAC. This capability has been operational since 2002. Commercial eBeam processing is carried out to empower private industry to adopt the technology. The primary focus of the Center is to advance research in eBeam and X-ray technologies to find commercially sustainable solutions for environmental remediation, advanced therapeutics, food safety and security, and for developing advanced materials. To achieve our objectives, we routinely partner with private industry, government and academic researchers from around the world to build research teams to address a variety of scientific focus areas such as vaccine development, food pasteurization, sterilization applications, phytosanitary applications, irradiation biology, consumer and marketing studies, environmental remediation, and material modifications. Our mission is to advance eBeam technology to **"clean, heal, feed and shape this world and beyond".** Commercially, we treat over 250,000 lbs per year of imported fresh fruits (for phytosanitary treatment) and approximately 100,000 lbs per year of spices (for microbial decontamination). At one point, we were eBeam pasteurizing about 3 million lbs per year of frozen ground beef. In addition to the commercial and R&D activities, there is a strong emphasis on including graduate and undergraduate students in research, conducting formal university graduate/undergraduate level courses, as well as customized hands-on training programs in eBeam technology for private industry decision makers. The goal of our teaching, training, and outreach activities is to develop a pool of technically trained individuals as well as to enable the development of sustainable businesses centered around eBeam technology around the world. Given the strong focus of the Center to promote eBeam technology worldwide, the International Atomic Energy Agency (IAEA) in 2014 designated the NCEBR as the IAEA Collaborating Centre for Electron Beam technology for food, health and environmental applications.

Abstract 259 MON-AC-AF-01-2 Invited Talk - Monday 10:30 AM - West Fork

NIST Radiation Physics Division Capabilities

Paul M Bergstrom, Fred Bateman

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The Dosimetry Group of the Radiation Physics Division of the National Institute of Standards and Technology operates several accelerators to achieve its mission of establishing and maintaining the nation's physical dosimetry standards for ionizing radiation. Among these accelerators are the Medical-Industrial Radiation facility, which provides electron beams

from 7 MeV to 32 MeV, a Clinac 2100C, which provides electron beams from several MeV to 18 MeV and a lower energy Van de Graaff accelerator. We discuss the configuration of these systems and their availability for outside users

Abstract 101 MON-AC-AF-01-3 Invited Talk - Monday 10:30 AM - West Fork

The Brookhaven Accelerator Test Facility

Mark Alan Palmer

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The Accelerator Test Facility (ATF) at Brookhaven National Laboratory is a National User Facility supported by the Accelerator Stewardship Program within the US DOE's Office of High Energy Physics. The facility provides high brightness 80 MeV electron beams and 2 TW CO_2 laser capabilities to support a broad research program in advanced accelerator R&D. The current research program at the ATF is described as well as plans to upgrade the facility. The facility upgrade is targeted at providing much high CO_2 laser power as well as a much more flexible experimental space for user research.

Abstract 26 MON-AC-AF-01-4 Invited Talk - Monday 10:30 AM - West Fork

Illinois Accelerator Research Center

Charlie A Cooper, Thomas Kroc

Illinois Accelerator Research Center, Fermi National Accelerator Lab, PO box 500, Batavia Illinois 60510, United States

The Illinois Accelerator Research Center (IARC) hosts a new accelerator development program at Fermi National Accelerator Laboratory. IARC provides access to Fermi's state-of-the-art facilities and technologies for research, development and industrialization of particle accelerator technology. In addition to facilitating access to available existing Fermi infrastructure, the IARC Campus has a dedicated 36,000 sqft heavy assembly building (HAB) with all the infrastructure needed to develop, commission and operate new accelerators. Connected to the HAB is a 47,000 sqft Office, Technology and Engineering (OTE) building, paid for by the state, that has office, meeting, and light technical space. The OTE building, which contains the Accelerator Physics Center, and nearby Accelerator and Technical divisions provide IARC collaborators with unique access to world class expertise in a wide array of accelerator technologies. At IARC scientists and engineers from Fermilab and academia work side by side with industrial partners to develop breakthroughs in accelerator science and translate them into applications for the nation's health, wealth and security.

Abstract 180 MON-AP-IA-04-1 Invited Talk - Monday 10:30 AM - Bur Oak

Measuring Surface Bulk Elemental Composition On Venus

J. S. Schweitzer[1], A. M. Parsons[2], J. Grau[1], D. J. Lawrence[3], J. Miles[4], P. N. Peplowski[3], L. Perkins[4], R. D. Starr[5]

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Bulk elemental composition measurements of the subsurface of Venus are challenging because of the extreme surface environment (462 ˚C, 93 bars pressure). Instruments provided by landed probes on the surface of Venus must therefore be enclosed in a pressure vessel. The high surface temperatures require a thermal control system that keeps the instrumentation

and electronics within their operating temperature range for as long as possible. Currently, Venus surface probes can operate for only a few hours. It is therefore crucial that the lander instrumentation be able to make statistically significant measurements in a short time. An instrument is described that can achieve such a measurement over a volume of thousands of cubic centimeters of material by using high energy penetrating neutron and gamma radiation. The instrument consists of a Pulsed Neutron Generator (PNG) and a Gamma-Ray Spectrometer (GRS). The PNG emits isotropic pulses of 14.1 MeV neutrons that penetrate the pressure vessel walls, the dense atmosphere and the surface rock. The neutrons induce nuclear reactions in the rock to produce gamma rays with energies specific to the element and nuclear process involved. Thus the energies of the detected gamma rays identify the elements present and their intensities provide the abundance of each element. The GRS spectra are analyzed to determine the Venus elemental composition from the spectral signature of individual major, minor, and trace radioactive elements. As a test of such an instrument, a Schlumberger Litho Scanner* oil well logging tool was used in a series of experiments at NASA's Goddard Space Flight Center. The Litho Scanner tool was mounted above large (1.8 m x 1.8 m x .9 m) granite and basalt monuments and made a series of one-hour elemental composition measurements in a planar geometry more similar to a planetary lander measurement. Initial analysis of the results shows good agreement with target elemental assays.

* Mark of Schlumberger

Abstract 325 MON-AP-IA-04-2 Invited Talk - Monday 10:30 AM - Bur Oak

New Neutron-Generator-Based Oilfield Nuclear Spectroscopy Tool for State-of-the-Art Geochemical Logging

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(2)Schlumberger Houston Formation Evaluation Integration Center, 110 Schlumberger Dr. MD 110-10, Sugar Land TX 77478, United States

Recent advances at Schlumberger in Pulsed Neutron Generator (PNG) packaging and high resolution scintillator technology have enabled the development of a game-changing high-resolution neutron-induced gamma-ray spectroscopy tool for downhole applications. The Litho Scanner* tool is able to measure the formation lithology and the presence of carbon to deduce the Total Organic Carbon (TOC) in real-time. These quantities are critical for resource evaluation, especially in unconventional reservoirs containing shale oil or shale gas. This presentation highlights the fundamentals of nuclear formation evaluation measurements, the components of the Litho Scanner* tool, the methodology to achieve TOC answer downhole, and the potential for direct applications of this development to planetary geochemical studies.

*Service mark of Schlumberger

Abstract 401 MON-AP-IA-04-3 Invited Talk - Monday 10:30 AM - Bur Oak

Cancer Treatment with Boron Neutron Capture Therapy (BNCT): Experience Until Today and the Future

Hanna Koivunoro

Neutron Therapeutics Inc, 1 Industrial Drive, Danvers Massachusetts 01923, United States

In Boron Neutron Capture Therapy (BNCT), most of the tumor dose is derived from high-LET radiation resulting from ^{10}B neutron capture reaction [$^{10}B(n,\alpha)^{7}Li$] at thermal neutron energies. A high dose gradient may be achieved between the cancerous tissue and the adjacent normal tissues provided that the boron carrier compound is selectively taken up by the tumor cells. Traditionally research reactors have been used as a neutron source. Recently accelerator based neutron sources have been developed to replace the reactors and make BNCT available at the hospitals.

In 1999 to 2011, 249 cancer patients received boronophenylalanine (BPA)-mediated BNCT in Helsinki, Finland. This presentation reviews the Finnish experience on clinical BNCT with a research reactor and summarizes current status on clinical BNCT worldwide highlighting the development of accelerator based BNCT.

Abstract 25 MON-AP-IA-04-4 Contributed Talk - Monday 10:30 AM - Bur Oak

Characterization of a 6 MeV Accelerator Driven Mixed Neutron/Photon Source

Matthew Steven Hodges, Alexander Barzilov, Yi-Tung Chen, Daniel Lowe

Mechanical Engineering, University of Nevada, Las Vegas, 4505 S. Maryland Parkway, Las Vegas NV 89154, United States

There are many applications which require high yield radiation sources with mixed fluxes of photons and neutrons. In particular, such sources are necessary to test radiation detectors and materials. This study was concerned with the determination of photon and neutron fluxes generated by the interaction of a 6 MeV linear electron accelerator driven photon beam with a beryllium photoneutron converter. The double step procedure of an (e,γ) reaction followed by an (γ,n) emission results in a mixed radiation environment. The optimal converter geometry was determined by comparison of the computed neutron fluxes for each converter position. Computational results have shown that photon fluxes up to 10^8 photons/cm^2/s and neutron fluxes up to 10^6 neutrons/cm^2/s are achievable with the optimal setup. This talk will focus on the results of the MCNPX modeling and experiments and discussion of the converter orientation which leads to the largest radiation fluxes.

Abstract 372 MON-AP-IA-04-5 Contributed Talk - Monday 10:30 AM - Bur Oak

Accelerator-based Analytical Toolset for Shale Characterization in Support of Oil and Gas Exploration

Khalid Hossain

Analytical Laboratory, Amethyst Research Inc, 123 Case Circle, Ardmore OK 73401, United States

Over the past decade, advances in shale characterization and stimulation technology have opened hydrocarbon-bearing shale to exploitation. The success of all of these plays can depend on the proper characterization of the shale reservoir. To determine if favorable composition and structure are present, it is currently necessary to conduct a number of different analyses that are time consuming and expensive. With the decline in fossil fuel prices, it has become increasingly important to develop cost-effective analytical toolsets that provide an efficient integrated characterization of shale to assist oil and gas exploration.

In this regard a suite of analytical techniques derived from ion beam capabilities for direct measurement of C, H, and O content can effectively replace industry standard indirect measurement techniques e.g., mass spectroscopy and pyrolysis. Elastic recoil detection analysis (ERDA) for direct measurement of H present, and nuclear reaction analysis (NRA) to determine the amount of C and O have been found effective. Determining mineral composition using particle induced X-ray emission (PIXE), and ion beam induced luminescence (IL) for providing a direct and efficient process for mineral mapping have been explored. In addition a unique approach through the utilization of the nuclear microprobe and He-ion microscopy (HIM) for imaging organic matter and rock fabric, analyzing the spatial distribution of hydrocarbons and assessing the abundance and types of microporosity to provide an estimate of organic carbon transformation, thermal maturity, and the expected hydrocarbon type (dry gas, liquid-rich gas, or oil) would be revolutionary. Amethyst Research Inc. is developing an ion-beam analysis technology as a one-stop solution to advanced characterization of shale, and providing low risk productivity assessment for shale reservoirs.

Abstract 140 MON-AP-SD-01-1 Invited Talk - Monday 10:30 AM - Elm Fork

DNDO R&D Perspectives on Cargo Scanning

Namdoo Moon

Transformational and Applied Research Directorate, Domestic Nuclear Detection Office, Department of Homeland Security, Washington DC, United States

Over 10 M containers are imported thru sea ports into the United States per year. For this massive number of cargo containers, making rapid detection and clearing of cargos are challenging. The Domestic Nuclear Detection Office Transformational and Applied Research (TAR) Directorate seeks to address this challenge through expanding active interrogation techniques to this operational space. Prior research into the detection of shielded special nuclear material (SNM) has enabled an analysis of what is needed to pursue improved detection along this pathway. This presentation will discuss the SNM detection technology challenges endemic to cargo, the goals for cargo detection going forward, and what an ideal system may look like. This ideal system requires further development of technological components.

Abstract 348 MON-AP-SD-01-2 Invited Talk - Monday 10:30 AM - Elm Fork

High Duty Cycle Electron Beams Enabling Automated Threat Recognition in Cargo Screening

Seth Van Liew, William Bertozzi, Nathan D'Olympia, Wilbur A. Franklin, Stephen E. Korbly, Robert J. Ledoux, Cody M. Wilson

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Rapid and efficient screening of cargo at ports, borders, and key infrastructure establishments is a high priority for many governments. The necessity of locating and identifying contraband and nuclear materials is critical to security. Active interrogation systems using high energy x-rays are widely deployed at these checkpoints and have been effective at imaging these cargoes. Most of these systems rely on linear accelerators or betatrons that have low duty cycles and a high current per pulse. These have the advantage of excellent signal to noise within the pulse, however it makes other techniques that use photon counting or spectral analysis more challenging. Here we present a continuous wave high energy x-ray system that utilizes photon counting and other methods to identify contraband, nuclear materials, and provide superior imaging. Specifically we will present work on 3D image reconstruction (EZ-3D™), contraband/material identification with nuclear resonance fluorescence (NRF), and detection of nuclear materials with prompt neutrons from photofission (PNPF). In addition we will present updates on the recently deployed system at the Port of Boston.

This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract HSHQDC-12-C-00059. This support does not constitute an express or implied endorsement on the part of the Government.

Abstract 265 MON-AP-SD-01-3 Invited Talk - Monday 10:30 AM - Elm Fork

New Accelerator Technologies for Cargo Container Inspection Systems

Vinod Kumar Bharadwaj

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Recent developments in the understanding of breakdown phenomena in linear particle accelerators at the SLAC National Accelerator Laboratory have led to novel design methodology for linear accelerators structures. Compared with existing designs, these new structures are more efficient, are capable of much higher repetition rates and duty factors, are capable of extremely high accelerating gradients and are easier and cheaper to manufacture. TibaRay, Inc. is a recently incorporated company that plans to use this methodology to custom design and build electron accelerators for cargo scanning applications. In addition, TibaRay will commercialize and build novel high power RF klystrons that are more compact, need lower voltage modulators and are scalable to higher power as needed. These capabilities will allow for the custom and

matched designs for electron accelerators and associated RF sources needed for cargo scanning applications. This talk will describe the new technology and give some examples of parameters that could be achieved with these custom designed systems for use in cargo scanning applications.

Abstract 177 MON-AP-SD-01-4 Contributed Talk - Monday 10:30 AM - Elm Fork

Detection system of the first Rapidly Re-locatable Tagged Neutron Inspection System (RRTNIS), developed in the Framework of the European H2020 C-BORD project

Cristiano Lino Fontana[1], CÃ©dric Carasco[3], Krystian Grodzicki[2], Alessandro Iovene[5], Marcello Lunardon[1], Marek Moszynski[2], Giancarlo Nebbia[6], Bertrand Perot[3], Felix Pino[1], Guillaume Sannie[4], Alix Sardet[3], Pawel Sibczynski[2], Luca Stevanato[1], Lukasz Swiderski[2], Carlo Tintori[5], Sandra Moretto[1]

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The European project entitled "effective Container inspection at BORDer control points" (C-BORD) focuses on the development and in-situ tests of a comprehensive cost-effective solution for the generalised Non-Intrusive Inspection (NII) of containers and large-volume freight at the EU border. It copes with a large range of targets, including explosives, chemical warfare agents, illicit drugs, tobacco and Special Nuclear Materials. Within the C-BORD project, a new generation of Tagged Neutron Inspection System (TNIS) for cargo containers is foreseen. Unlike its predecessors, this system would be the first Rapidly Re-locatable TNIS (RRTNIS). It will be a second-line defense system, to be used on sealed containers in order to detect explosives, illicit drugs and chemical agents in a suspect voxel (elementary volume unit).

We report on the status of the RRTNIS system, in particular the overall design, the characterization of the large-volume gamma detectors, the digital analysis of the time measurements and the Data Acquisition System (DAQ).

Abstract 188 MON-AP-SD-01-5 Contributed Talk - Monday 10:30 AM - Elm Fork

Portal Monitor for Rapid Identification of Special Nuclear Materials Using Gamma Ray Imaging Induced by Fast and Slow Neutrons

David Koltick, Haoyu Wang

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Of the special nuclear materials ^{235}U is known as a "quiet material". It is difficult to detect due to its low spontaneous fission fraction of 7×10^{-11} and is a long-lived alpha-particle emitter with a half-life of 0.7 billion years. Its gamma signatures come from the decay of its daughters. An operational prototype Associated Particle Neutron Generator capable of Tomographic Neutron Elemental Analysis (TNEA) has been used to illustrate proof of principle of the concept of differentiating Special Nuclear Materials (SNM) from ordinary materials. TNEA uses coincidence gamma ray multiplicity from a single physical location in coincidence with the neutron production time. That is, the associated alpha particle starts a clock and the observed gamma ray coincidence stops the clock. Data has been collected using reactor fuel 20% enriched in U-235. The fuel cell contains only 15 grams of U-235 and 60 grams of U-238. A 4-dimensional contrast factor is used for differentiation of uranium and other common materials such as iron and copper. A complete cargo monitoring system is presented with estimated performance modeled using Monte Carlo techniques based on collected data.

Abstract 59 MON-AR-ISM-01-1 Invited Talk - Monday 10:30 AM - Post Oak

Preparation of Semiconductor Photoelectrodes by Ion Beam Technology for Hydrogen Production

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Development of high effciency photoelectrode materials using for hydrogen production by solar water splitting remains an important goal for affordable and environmentally friendly methods for energy conversion and storage. Ion beam technology is a novel for fabrication and modification of photoelectrode semiconductors. In this talk, we present our recent results in fabrication of TiO_2 nanorods and thin films by ion irradiation and ion implantation and sequential thermal annealing. We also present the influence of metal and non-metal ion doping on the photoelectrodes (ZnO, TiO_2, Fe_2O_3) by ion implantation to tailor the energy band structures of the photoelectrodes. Great increase of the photoelectrochemical performance of the photoelectrodes are achieved and corresponding mechanisms are proposed.

Abstract 266 MON-AR-ISM-01-2 Invited Talk - Monday 10:30 AM - Post Oak

Modification of the amorphous ion track formation in $SrTiO_3$: a synergistic effect

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In ion-solid interaction, the role of electronic stopping power is complex and its modification to target materials is not well understood. Here in a series of studies in single crystal $SrTiO_3$, radiation damage evolution was closely monitored under irradiations with a wide range of ion species and energies delivered from a Tandem accelerator system. The Rutherford backscattering spectrometry in a channeling geometry (RBS/C) results suggest a synergistic interaction of electronic energy loss by ions with the preexisting ion-induced defects. Amorphization with a negligible dpa (displacements per atom) value is found within a pre-damaged region. It is believed that the driving force of this extremely effective damage accumulation is an intense electronic stopping energy deposition, and the formation of amorphous ion tracks. By employing a direct impact model, the electronic stopping power threshold for ion track formation is estimated. The experimental and simulation results suggest that an initial damage state may modify locally the thermal conductivity, and trigger a melting-quench phase transfer of $SrTiO_3$ to produce amorphous core along ion path. The synergistic effect may have its potential to serve as a tool for material modification with good controllability, such as in the thin films of epitaxial $SrTiO_3$.

Abstract 62 MON-AR-ISM-01-3 Invited Talk - Monday 10:30 AM - Post Oak

Enhanced Photo-absorbance and Superparamagnetic behavior in Co implanted TiO_2

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TiO_2 has many exciting properties and has received immense attention for photocatalytic, photovoltaic and biocompatible properties [1-3]. Its large bandgap, however, poses severe limitation to its photocatalytic efficiency in visible region. Achieving narrower bandgap and high Visible light absorption have become critical issues for TiO_2. Here we report results of 200keV Cobalt implantation in single crystal rutile TiO_2. Preferential sputtering of TiO_2 surface creates Oxygen vacancies. Ti-rich zones, thus formed, promote nucleation of crystalline self assembled nanodots on the surface. A narrower bandgap along with significantly enhanced UV-Vis absorption has been observed for the nanodot patterned surfaces. These results have been achieved in the absence of any doping material. Excess O vacancy and Ti interstitials are responsible for the narrower band gap and the enhancement of visible light absorbance [4]. We have also explored the temperature and field dependent magnetic properties of rutile TiO_2 after it is implanted with Co ions. Presence of anisotropic super-

paramagnetic (SPM) character has been observed. Such anisotropy shows that though along one crystallographic axis magnetic moments are easily rotatable this is not the case along hard axis where spins are blocked.

[1] S. Majumder, D. Paramanik, V. Solanki, B.Bag and Shikha Varma, Appl. Phys. Lett. 98, (2011) 053105.

[2] Subrata Majumder, I. Mishra, U Subudhi, Shikha Varma, Appl. Phy. Lett. 103 (2013) 063103.

[3] Vanaraj Solanki, Subrata Majumder, Indrani Mishra, P. Dash, C. Singh, D. Kanjilal and Shikha Varma, Jour. Appl. Phy. 115 (2014) 124306.

[4] Shalik Ram Joshi, B. Padmanabhan, Anupama Chanda, V. K. Malik, N. C. Mishra, D. Kanjilal and Shikha Varma, Applied Physics A (2016) in press.

Abstract 202 MON-AR-ISM-01-3 Contributed Talk - Monday 10:30 AM - Post Oak

Synthesis and Characterization of Au-Zn Nanoparticle Implants in Sapphire

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Narrowing down the size distribution of metallic nanoparticle (MNP) implants in various transparent oxides is a serious challenge. This has led to difficulties in reproducing their optical response, a major limitation to related optical switch and sensor applications. To address this issue for Au NPs, we have carried out a series of Au-Zn dual implants in sapphire followed by annealing under various conditions. Our preliminary results show that the optical properties of Zn-Au implanted sapphire deviated significantly from those of Au in sapphire. The data suggests particles with narrow size distribution and interesting plasmonic properties and may be evidence of either the formation of Au-Zn alloy MNPs or interactions between Au MNPs and elemental zinc. In addition, our work has also raised some pertinent questions of interest to the scientific community. The goal of this talk is to present our preliminary results and discuss some current challenges as we continuously pursue this area of research.

Abstract 206 MON-AR-ISM-01-4 Contributed Talk - Monday 10:30 AM - Post Oak

Ion Beam Modification of polymer nanocomposites using Au, Ag and Nb ion implantation

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Novel nanocomposites based on epoxy resin/epoxy-functionalized polydimethylsiloxane reinforced with POSS were ion implanted at 1.5 and 1.7 MeV with ion doses ranging from 5e14 up to 5e15 ions/cm^2 with Au, Ag and Nb in order to improve their mechanical properties. Ion implantations were carried at the new 3 MV Tandetron^{TM} accelerator from "Horia Hulubei" National Institute for Physics and Nuclear Engineering - IFIN-HH, Măgurele, Romania. Morphology and hardness of these structures was measured using atomic force microscopy (AFM) by nanoindentention. Rutherford Backscattering Spectrometry (RBS) gave information regarding the Ag, Au and Nb implanted dose and samples stoichiometry. Here we report an increase in the hardness of all the samples from 0.6 to almost 4 GPa.

Abstract 102 MON-PR-AMP-04-1 Invited Talk - Monday 10:30 AM - Rio Grande

Dissociative electron attachment processes in biological molecules

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Recent renewed interest to dissociative electron attachment (DEA) processes has been stimulated by the role of low-energy electrons in radiation damage and ion-beam cancer therapy. This presentation will review recent theoretical work on DEA to a few simple biological molecules: formic acid, uracil, thymine, and aminobutanoic acid. The DEA process in these systems is controlled by shape resonances of the A' symmetry whose width is very large. Due to the long-range (dipolar and polarization) interaction between the incoming electron and the molecule sharp vibrational Feshbach resonances and threshold cusps appear at the vibrational excitation thresholds. For practical applications to radiation damage it is important to know how DEA processes are modified in a water environment. To answer this question, we investigate effects of clusterization using the multiple-scattering theory. The DEA cross section could be strongly enhanced in a water cluster environment due to the increase of the resonance lifetime and due to the negative shift in the resonance position caused by interaction of the intermediate negative ion with the surrounding water molecules.

Abstract 119 MON-PR-AMP-04-2 Invited Talk - Monday 10:30 AM - Rio Grande

Substituted building blocks of life under UV radiation:

Ultrafast excited state dynamics of 2-thiouracil vs uracil

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The photodynamic properties of molecules determine their ability to survive in harsh radiation environments and, as such, ultraviolet photostability may have been one of the selection pressures influencing the prebiotic chemistry on early Earth. Over the years, the photophysics of the canonical nucleobases have been studied extensively due to their importance as the genetic coding material of life and they are generally considered photostable. Here, we investigate the photodynamics of 2-thiouracil, a derivative of the nucleobase uracil, using time-resolved photoelectron spectroscopy to assess the effect of heavy atom substitution on recently proposed intersystem crossing pathways that compete with internal conversion to the ground state. Trapping in the triplet manifold and intersystem crossing back to the ground state are potential factors contributing to the susceptibility of molecules to ultraviolet photodamage.

Abstract 175 MON-PR-AMP-04-3 Invited Talk - Monday 10:30 AM - Rio Grande

Stepwise Electron Spectroscopy for Neutral Fragment Detection

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Electron attachment to a molecule triggers several dissociation pathways of transient molecular anions, each resulting in the formation of one negative ion and its counterpart. The counterpart can be a single neutral radical or several fragments. Currently, there are no studies that detect the neutrals formed from the dissociative electron attachment (DEA) process to molecules in the gas phase. Some results have been reported for radical neutral detection desorbed from thin films of thymine, bromo-uracil-substituted oligonucleotides [1], modified forms of 11-mercaptoundecanoic acid [2], and DNA [3]. In the case of gas-phase experiments, some effort has been made, but only for much higher electron energies than those at

which DEA occurs [4]. In these studies, appearance mass spectrometry was used, which is based on the difference between the appearance potential for ionization of radicals and that for dissociative ionization of the precursor molecules.

The detection of neutral radicals can be essential from the point of view of radiation damage to DNA, particularly in the case of double strand breaks by low energy electrons [5]. It has been shown that formation of a transient molecular anion can lead to single strand breaks in DNA due to the direct interaction of a low energy electron with the sugar-phosphate backbone of DNA or due to electron capture by the nucleobase and charge transfer to the DNA backbone [5]. However, it is still not clear how a single electron with energy between 5 and 15 eV can cause a double strand break. The molecular description of the mechanism for double strand breaks can possibly support more complex decomposition pathways and still needs further investigation. Therefore, the detection of neutrals formed via DEA is undoubtedly important. Our approach to solve this challenge will be discussed.

[1] H. Abdoul-Carime, P-C. Dugal, L. Sanche, **Radiation Research**, 153, 23 (2000)

[2] J. Houplin, L. Amiaud, V. Humblot, I. MArtic, E. Matar, R. Azria, C.M. Pradier, A. Lafosse, **Physical Chemistry Chemical Physics**, 15, 7220 (2013)

[3] Y. Chen, A. Aleksandrov, T.M. Orlando, **International Journal of Mass Spectrometry** 277, 314 (2008)

[4] T. Nakano, H. Sugai, **Journal of Physics D**, 26, 1909 (1993)

[5] B. Boudaiffa, P. Cloutier, D. Hunting, M.A. Huels, L. Sanche, **Science** 287, 1658 (2000)

Abstract 224 MON-PR-AMP-04-4 Invited Talk - Monday 10:30 AM - Rio Grande

Radiation chemistry of nuclear plant processes and materials simulated by Ion beam irradiation

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The University of Manchester's Dalton Cumbrian Facility (DCF) represents a major investment between the University and the UK's Nuclear Decommissioning Authority to provide a state of the art facility for research into materials and processes related to all stages of the fuel cycle in civil nuclear power generation.

A significant component of the research facilities at the DCF is the ion beam accelerator suite to provide both high fluence ion beams for radiation damage and low fluence for radiation chemistry experiments in a wide range of materials.

We report on the current status of the DCF accelerator suite and recent radiation chemistry experiments conducted using it.

An important aspect of understanding the radiation hardness in materials and processes used in the fuel cycle concerns chemical alterations induced by radiation from the fuel. Radiolytic decomposition of the nitric acid used in the PUREX purification process for spent fuel results in the formation of redox active nitrogen species. This change in the redox chemistry affects extraction of actinides in fuel reprocessing and the evolution of nitrous acid can lead to corrosion in stainless steel storage tanks. Understanding the chemistry of nitric acid radiolysis is clearly important and recent studies conducted at the DCF have measured nitrous acid yields from different nitric acid concentrations under different doses of 5 MeV H^+ ions.

Also recently studied are the effects of Pu-α decay occurring during long term storage of PuO_2 powders. The α-radiolysis of absorbed water will create reactive H_2 and O_2 species and the incidence of radiation can also affect the recombination rate back to H_2O. Studies of ion beam irradiation of artificially created H_2-O_2 gas mixes in a variety of concentrations is providing insights into whether a steady state can be achieved between the radiolysis and recombination reactions.

Abstract 257 MON-PR-AMP-04-5 Contributed Talk - Monday 10:30 AM - Rio Grande

Biological effects of H, He, and C ions on dry Brassica Rapa seeds

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Space Radiation, one of the impediments of human space exploration, consists of protons and high energy and charge (HZE) nuclei, affects biological system, but is difficult to mimic on earth because accelerators produce unidirectional ion beams. High energy ions can cause ionization events along their path through the target, which can induce biological effects ranging from cancer to mutations. Despite the use of energetic ions to induce mutations in plants, the ion species–energy combination on biological systems, especially plants, is still unknown. To examine the effect of ionizing radiation on plants, we used low MeV H, He, and C ions to irradiate **Brassica rapa** seeds . The stopping and range of ions in matter (SRIM), Monte Carlo based code predicted the effective range of 0.6 MeV $^{1}H^{+}$, 2.24 MeV $^{4}He^{2+}$, and 9.0 MeV $^{12}C^{5+}$ ions to about 12 µm. The linear energy transfer energies for H, He and C ions were approximately 33 keV/µm, 154 keV/µm and 833 keV/µm, respectively. The germination rate, root length and survival rate of the irradiated seeds were comparable between non-irradiated seeds in vacuum and standard conditions; increased ion fluence resulted in reduced germination with an LD50 of 1100 Gy for all ions.

Supported by NASA grant NNX13AN05A

Abstract 420 MON-AA-AMS-02-1 Invited Talk - Monday 2:00 PM - Trinity

AMS Radiocarbon Dating Applied to Archaeology, Artifacts and The Need to Improve the Calibration Curve

A J T. Jull[1,2,3], T. E. Lange[2], I. Hajdas[4], I. Panyushkina[5], C.L. Pearson[5], G. Hodgins[2], S. Leavitt[5], R. E. Taylor[6], M. Molnar[3]

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The application of radiocarbon dating to archaeology and interesting art works has been an important aspect of the field since its inception. For example, the first "curve of knowns" (Arnold and Libby, 1949) shows this interest. It is interesting to note that improvements to the radiocarbon calibration curve is an important topic which continues to this day. Nowadays, attention is turning to annual-based calibration of the ^{14}C signal against known-age tree rings (e.g. Miyake et al., this conference). It turns out that radiocarbon dating applied to important artifacts of significant interest have been an important part of making this dating method well-known to the public since the beginning of the field. There are many such examples. Some of Libby et al's first publications involved samples of the Dead Sea Scrolls, which were followed up by several later studies of these writings (e.g. Bonani et al. 1990; Jull et al. 1995). In this study, we will review some of the issues arising from some of the more controversial objects and also the important use of radiocarbon in determining important time-

markers in the archaeological record. We will present some interesting examples and reinterpretations of these measurements.

Abstract 63 MON-AA-AMS-02-2 Invited Talk - Monday 2:00 PM - Trinity

PRIME Lab Biomedical Program

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The biomedical program at PRIME Lab will be discussed. Number of samples run, types of research projects, and overall direction of the effort will be examined. The results of high level secondary standards and interlaboratory comparisons of samples prepared from biological matrices will be shown. Some of the unique challenges of making measurements for a community that is not typically aware of the chemical preparation techniques, the analytical capabilities, and limitations of AMS will be presented. Finally, recent work where ^{41}Ca measurements at PRIME Lab were used to determine the effect of a high calcium diet on coronary artery disease in Ossabaw miniature swine will be shown. Pigs were broken into two groups with one group getting adequate calcium (0.33 percent by weight) and the second getting a high calcium diet (1.9 percent by weight). Calcium-41 measurements were made in serum and in pig arteries obtained at sacrifice. It was found that serum disappearance of ^{41}Ca and total ^{41}Ca artery accumulation did not differ between groups. AMS was especially important in this work, since many of the arterial samples had ^{41}Ca:Ca ratios $<10^{-11}$. Finally, several future projects will be revealed.

Abstract 43 MON-AA-AMS-02-3 Contributed Talk - Monday 2:00 PM - Trinity

The new ETH 300 kV multi-isotope AMS system

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In the past decade great progress has been made at ETH Zurich in building compact and easy to handle AMS machines. The use of He as a stripper gas was a major breakthrough, since at low energies the mean charge state is high and scattering losses are significantly reduced compared with other stripping gases. Routine radiocarbon measurements are for example possible with the MICADAS system operated at 200 kV terminal voltage with a transmission of more than 47 % and a ^{14}C/^{12}C blank level in the low 10^{-15} range.

Additionally, it was demonstrated that a large number of other important AMS nuclides such as ^{10}Be, ^{26}Al, ^{41}Ca, ^{129}I or actinides can be measured at compact AMS machines as the ETH 500 kV TANDY facility with a performance sufficient for a broad variety of applications in earth, environmental or biomedical sciences.

As a next step it is planed to build a new 300 kV multi-isotope AMS facility at ETH Zurich, which is based on the TANDY spectrometer layout and the vacuum insulated acceleration unit of the MICADAS system operated at 300 kV. In this presentation the concepts implemented in this new system will be introduced and first results of preliminary experiments are discussed.

Abstract 198 MON-AA-AMS-02-4 Contributed Talk - Monday 2:00 PM - Trinity

RoAMS - The new AMS center in Bucharest

Tiberiu Bogdan Sava, Corina Anca Simion, Dan Gabriel Ghita, Doru Pacesila, Iuliana Stanciu, Gabriela Odilia Sava, Bianca Stefan, Alexandru Vasiliu

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We present an insight of the new AMS facility at the Horia Hulubei - National Institute for Physics and Nuclear Engineering, starting with its official foundation in 2013. The HVEE 1MV Tandetron was installed to perform multi-isotopic AMS analysis, especially to determine infinitesimal quantities from the 14C, 26Al, 10Be, 129I, 239,240Pu isotopic species. Simultaneously, the radiocarbon group started to set-up the sample preparation laboratory for various material types, relying mainly on a modern automated graphitization station, produced by Ionplus AG. We present the measurement results for the reference and standard materials, along with the results for the SIRI (Sixt International Radiocarbon Inter-Comparison) proficiency test samples. Some of the typical inherent problems specific to radiocarbon dating laboratories, and their solutions are also listed. Finally, comments and conclusions for the current status of the RoAMS laboratory and projections for the future work are shown.

Abstract 225 MON-AA-NM-01-1 Contributed Talk - Monday 2:00 PM - West Fork

The GeV high energy microbeam facility at HIRFL

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Heavy ions have much higher linear energy transfer and produce severe ionizing damage (to DNA in biological sample or PN junction in microelectronics) along the ion trajectory. Heavy ion microbeam and high energy microbeam is attracting more and more interests because of the clinical spread of high energy particle cancer therapy using protons and carbon beams and care of space radiation effect (especially from cosmic heavy ion rays) in spacecraft and astronauts. Such a microbeam is a powerful tool to study the spatial radiation response or the local radiation effect both in materials and biological samples to simulate the space radiation at ground, and the high energy and long penetration of hundred MeV/u beam may also expand the application of the above mentioned microbeam application to large samples.

To study the radiation effect of high energy heavy ions in different kinds of materials, a focusing microbeam facility for ions with energies of several MeV/u up to 80 MeV/u was constructed at the TR0 terminal of the Heavy Ion Research Facility in Lanzhou (HIRFL) in the Institute of Modern Physics of the Chinese Academy of Sciences. This horizontal beam is bended vertically down to basement and focused into air by a triplet quadrupole magnets. This work introduces the interdisciplinary experimental system at the HIRFL microbeam, and the application of the high energy microbeam facility to the study of single event effects and material science.

Abstract 137 MON-AA-NM-01-2 Contributed Talk - Monday 2:00 PM - West Fork

Biocompatibility and Bioactivity of Au Ion Implanted PLC (Poly-L-Lactide Caprolactone) films

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Modifying a material surface to expand its application in biological systems always attracts interest. In this study MEVVA ion implantation system used to modify the material surface and gold (Au) cathodes have been chosen as an ion source during ion implantation process to enhance biocompatibility and bioactivity of poly (L-lactide/caprolactone)(PLC) films. Au ions implanted at various doses at the ion energy of 20 keV. The change of surface structure examined via atomic force

microscopy, contact angle measurement, FT-IR analysis, RAMAN and SEM imaging. These analyses showed that ion implantation changed surface characteristics, increased the roughness and decreased the hydrophobicity so that the surface became a desired platform for cell attachment. B35 neuroblastoma cell line used in the study of cell attachment and proliferation on both unimplanted and Au implanted PLC films. The ion dose of 1×10^{15} ions/cm^2 provided the most convenient surface for cell growth and proliferation among others. On the other hand, enzymatic degradation of Au implanted and unimplanted PLC films have been studied and the results showed that ion implantation decreased the degradation rate via initiating the bulk degradation. In conclusion, the evaluation of results indicates that ion implantation created a more sufficient environment for cell growth and the existence of Au ions on the surface initiated and supported neurite formation and elongation on the PLC surfaces. Hence, ion implantation improved the neural regeneration and development.

Abstract 422 MON-AA-NM-01-3 Contributed Talk - Monday 2:00 PM - West Fork

Imaging Single Collision Cascades with Nanobeam IBIC

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Heavy ions produce collision cascades that degrade the electrical performance of semiconductors, but a detailed physical understanding of how cascades develop into stable, electrically active defect clusters that promote electron-hole recombination remains elusive. This gap of understanding is disturbing because such clusters are known to be produced through atomic recoil processes by neutrons from fusion or fission reactors and high energy accelerators. In this paper we show how Ion Beam Induced Charge (IBIC) can be used to examine the influence of these collision cascades, including defect-clustering, on carrier recombination at defect complexes produced by high-energy single heavy ions in semiconductors. High IBIC contrast is needed to distinguish the signal reduction caused by carrier recombination from the stochastic variation in electron / hole pairs generated by each ion. In addition extremely high lateral resolution of the beam is required to resolve the submicron features of the cascade. These conditions were met by using Li+ beams at 100 keV focused to 10-20 nm dimensions and scanned in the vicinity of single collision cascades made in Amptek Si high-resolution (~150eV) x-ray detector diodes by 300-900 keV Kr implantation. In addition, a 2-axis Attocube goniometer held the detector diodes, and oriented them for ion channeling of the Li+ ions. Ion channeling ensured that the ions maintained high resolution as they penetrated the Si, and maximized the ionization while at the same time minimizing the atomic displacements produced by the beam. The initial results of this unique experiment will be presented.

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Abstract 160 MON-AA-NM-01-4 Contributed Talk - Monday 2:00 PM - West Fork

Beam diameter reduction by optimization of an extraction condition in a compact ion microbeam system

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Proton microbeam formed by a MeV class large device is useful for Proton Beam Writing (PBW) and Particle Induced X-rays Emission (PIXE) analysis with 1 μm level spatial resolution. Lab-On-Chip productions and biological cell analyses in the medical or hygiene field are expected through the microbeam applications. In order to realize this expectation for the commercial or the academic, a several hundred keV class compact ion microbeam system has been developed at QST in Takasaki, Japan, instead of a MeV class large device. The compact microbeam system is composed of a duoplasmatron type plasma ion source, an extraction stage and three acceleration stages. Each of the acceleration stages has a series of disk-shaped electrode with a small center hole (so-called acceleration lens), in which an ion beam is accelerated and strongly focused at the same time. When an energy of an extracted beam is smaller in the compact microbeam system,

demagnification is larger and in short the final beam diameter is smaller. However, reducing the extraction voltage causes weakening electric field intensity at the extraction stage, and then the brightness and high-quality components of the extracted beam required for the final microbeam formation is reduced.

In this study, the distance between the anode electrode and the extraction electrode in the extraction stage was made shorter, so that the electric field intensity did not change in spite of applying smaller extraction voltage. Then the demagnification was expected to be larger while the brightness of the extracted beam was kept. Experiments of proton microbeam formation were carried out to optimize the distance between the anode and the extraction electrodes for the smallest beam diameter. As a result, when the distance was approximately two-thirds of the previous, the beam diameter was 1.8 µm approximately one-third to 5.8 µm obtained previously. This result exceeded the expectation of the effect by the increase of the demagnification. The high-quality components of the extracted beam was probably increased, because collisions with neutral gas which occurred when the beam passed through the extraction stage was reduced due to the shortened distance between the two electrodes in the extraction stage.

Abstract 217 MON-AA-NM-01-5 — Contributed Talk - Monday 2:00 PM - West Fork

A Preliminary Study of Nok Sculptures in I. P. Stanback Museum with Instrumental Neutron Activation Analysis (INAA)

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The I.P. Stanback Museum is home to one of the premier African/African-American art collections in the United States. Among the valuable collections of the museum, a unique group is the Nok sculptures donated by tribal chiefs in West Nigeria. The sophistication of Nok sculptures has led scholars to believe that an older but undiscovered tradition must have preceded them. Some experts also believe that Nok sculptures have some relationship to later portrait arts. But all of these assumptions have not been proven yet.

This study aims to obtain further provenance information of Nok sculptures with instrumental neutron activation analysis (INAA). We collected several clay and soil samples at different points of the sculptures and irradiated them with thermal/epithermal neutrons from the PULSTAR research reactor. After irradiation, qualitative and quantitative information of the elements can be obtained from the decay spectra recorded by HpGe spectrometers. Experimental results show that (1) clay samples from the sculptures have different elemental concentrations with the mud samples buried the sculpture, which clearly confirms that the burial location is not the place where the sculptures were made. (2) samples from different sculptures of Nok have similar elemental concentrations, which indicates that terracotta figures may be made with the clay which from the same manufacturing location. Sculpture manufacture may be a large scale industry at that time.

Abstract 350 MON-AP-IA-06-1 — Invited Talk - Monday 2:00 PM - Bur Oak

Isotopes for Medical Applications produced by Los Alamos National Laboratory

Mark Brugh

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At the Los Alamos Neutron Science Center (LANSCE), the Isotope Production Facility (IPF) has been producing medical isotopes for over ten years since its commissioning in 2004. Routine large-scale production of Sr-82 (for cardiac imaging) and Ge-68 (for Ga-68 generator applications) using proton irradiated targets has ensured a continuous supply of these two isotopes for medical applications. Improvements associated with the accelerator, target designs and materials have been made or are planned to meet increasing demand. IPF has also been at the forefront of evaluating and producing other isotopes with potential medical applications. The most promising near term isotope is Ac-225 for cancer therapy.

Currently, a Tri-lab collaboration is underway to develop a national Ac-225 production capability that will meet the medical community's needs and will support clinical trials aimed at evaluating this isotope for a variety of cancer therapies. IPF is one of two high-energy accelerator facilities in the U.S. engaged in this production development effort. Other isotopes are currently being investigated to provide future tools for the medical community (as well as the broader research community) in their pursuit to improve diagnostic and treatment capabilities for various medical conditions.

Abstract 49 MON-AP-IA-06-2 Contributed Talk - Monday 2:00 PM - Bur Oak

Carbon isotope foil targets

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For low-energy nuclear physics research, isotopically-pure carbon targets, ^{12}C and ^{13}C, are requested in thicknesses about 1 mg/cm^2. These target materials are no longer commercially available. Neutron-rich isotopic ^{14}C targets would be in high demand at any thickness.

Applied Nanotech, Inc., has developed free-standing graphene foils for electron stripping of charged beams in heavy ion accelerators.[1] The foils were produced by pressure filtration of a reduced graphene oxide aqueous dispersion. We have used this process to develop a highly material-efficient means of producing carbon target foils from ^{13}C amorphous carbon powders. In a follow-on program, we plan to develop the means of producing ^{14}C targets at Argonne National Laboratory using stock material available at ANL. ^{12}C (^{13}C-depleted natural carbon) could also be used in accelerators for applications where low neutron activity is needed

We will present results of our effort to produce ^{13}C targets and discuss our plans for producing ^{14}C foils.

Acknowledgement: This material is based upon work supported by the U.S. Department of Energy, Office of Science, Nuclear Physics program under Award Number DE-SC-0015140

Abstract 115 MON-AP-IA-06-3 Contributed Talk - Monday 2:00 PM - Bur Oak

Industrial Applications of ECR-Based Neutron Generators

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Phoenix Nuclear Labs' (PNL) high yield deuterium-deuterium (DD) neutron generator, with measured yields greater than 3×10^{11} n/s, is based upon a proprietary gas target coupled with a 300 kV accelerator and a high-current microwave ion source (MWS). The ion injector is comprised of a MWS for deuterium ion generation and an extractor to produce a low emittance beam from the ion source for transport to a subsequent accelerating column. The PNL ion source utilizes 2.45 GHz microwaves and an 875 Gauss magnetic field to produce high plasma densities through electron cyclotron resonance (ECR) interactions. As no filaments are required to generate the plasma, the microwave ion source can operate with long lifetimes, on the order of years. The ion extractor, which is biased negatively with respect to the plasma chamber, pulls deuterium ions from the ion source into the accelerator. PNL ion sources have been operated with extracted deuteron currents as high as 90 mA as measured by a calibrated calorimeter located downstream of the extraction aperture.

Three prototype neutron generators have been delivered: one to the US Army for neutron radiography, one to Ultra Electronics' Nuclear Control Systems for neutron flux monitor calibration, and one to SHINE Medical Technologies for medical isotope production. Experiences operating and optimizing the various subsystems (ion source, accelerator, focus element, differential pumping stages, and gas target) for each application will be described. System requirements and tradeoffs for these diverse applications, including thermal neutron radiography, medical isotope production, nuclear instrumentation testing and calibration, and explosives detection, will be presented, along with preliminary results. Multiple next-generation systems are presently being designed and constructed at PNL with an emphasis on further increasing neutron yield and reliability and on decreasing physical size, weight, and price of the system. Modifications currently underway include further increases in beam current, the use of a solid target (e.g. for fast neutron radiography), and transitioning to a mixed deuterium-tritium gas target system. The latter modification will result in a neutron yield increase of approximately 50X. PNL is targeting delivery of three generators with neutron yields of 5×10^{13} DT n/s in 2018 to SHINE's molybdenum-99 production facility.

Abstract 273 MON-AP-IA-06-4 Contributed Talk - Monday 2:00 PM - Bur Oak

New 70 MeV Cyclotron Facility for Production of Medical Isotopes.

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A new facility for production of medical isotopes has been constructed in Indianapolis, IN and equipped with Cyclone 70P®, capable of delivering two simultaneous 70 MeV proton beams at 350 uA each. Cyclotron is manufactured in Belgium by Ion Beam Applications, S.A. This is the first commercial cyclotron with high energy proton beam dedicated to medical use in the United States.

The initial primary focus will be the commercial manufacture of Sr-82 for Rb-82 generators for use in the diagnosis of cardiovascular disease. The cyclotron will also be employed to produce a wide variety of other radionuclides for both research and clinical applications.

For this purpose the facility equipped with 6 target vaults and beam lines, two of which are currently equipped with target stations designed for irradiation of pneumatically transported targets.

First irradiations of metallic rubidium target developed in cooperation with INR (Troitsk, RF) and LANL (Los Alamos, NM) have been carried out at beam currents up to 150 uA. Future plans include increasing beam current and developing new targets.

Abstract 351 MON-AP-IA-06-5 Contributed Talk - Monday 2:00 PM - Bur Oak

MEDICIS-PROMED: innovative radionuclides for medicine applications

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A new facility, named MEDICIS, which will produce radionuclides for medical application is under completion at CERN. It will be constructed next to ISOLDE, radioactive ion beam facility with a 1.4 GeV proton beam and the on-line mass separator which allows the production of a spread variety of radioisotopes for different aims. MEDICISs facility will use the almost 85% of the incident beam which will not interact with ISOLDE target for radionuclides production toward an off-line mass separator. [1] May 2017 is the forecast date of completion of the facility and the first programmed tested target is a natural Titanium target for the production of Scandium radionuclides of interest for medical applications.

CERN- MEDICIS-PROMED is a Marie Sklodowska-Curie innovative training network of the Horizon 2020 European Commission`s program. The goal is to train young scientists to the production and use of innovative radionuclides and to develop a network of expert within Europe. The EU support consists of 15 PhDs based in different partner sites all over the Europe which are coordinated by CERN and it bridges together industries, research centers, universities and hospitals. It is a wide project that covers all the aspects from the radioisotope production to the medical application passing through the collection, shipment, safety control and radiochemical synthesis. The project started in April 2015 and will end in 2019. It will accompany the beginning of MEDICIS operations leading to strong foundation for further MEDICIS developments.

Within the MEDICIS-PROMED project, I am investigating the possibility to transfer the MEDICIS technology to the industry. The aim of my work is to infer the feasibility of producing innovative radioisotopes for theragnostic applications using a commercial middle sized high-current cyclotron while exploiting the technology of the mass separator developed within the MEDICIS-PROMED project. This will allow the production of high specific activity radioisotopes, not achievable with the common post-processing by chemical separation. The first step of my work was to determine radionuclide of interest for theragnostic application. A list of interesting radionuclides has been made evaluating the radiological properties for both imaging and therapy (half-life, decay and emission energy) as well as their chemical properties (i.e. labeling to peptides, antibodies). Four chemical elements have been identified and will be studied: yield evaluation, target preparation, chemical and mass separation.

During this talk, I will first present the MEDICIS project with current status of the facility. I will then present the MEDICIS project and the different tasks within that EU funded program and finally focus on the selection made for industrial transfer of the MEDICIS technology.

This research project has been supported by a Marie Skłodowska-Curie Innovative Training Network Fellowship of the European Commission's Horizon 2020 Programme under contract number 642889 MEDICIS-PROMED

References

[1] R. Augusto, L. Buehler, Z. Lawson, S. Marzari, M. Stachura, T. Stora, CERN-MEDICIS (Medical Isotopes Collected from ISOLDE): A New Facility, Applied Science 2014, 4, 265-281, ISSN 2076-3417.

Abstract 50 MON-AP-SD-08-1 Invited Talk - Monday 2:00 PM - Elm Fork

New Scintillators for MeV X-ray Imaging and Neutron Radiography

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MeV photon and neutron radiography imaging fidelity and throughput require scintillators offering high stopping power, light yield, and radiation hardness. Most imagers using MeV Bremsstrahlung or neutron sources employ amorphous silicon flat panel imagers with optically scattering phosphor coatings. Though optically somewhat more complex, lens-coupled computed tomography (CT) systems with thin sheet free-standing transparent scintillators can achieve better spatial resolution. While lens-coupled X-radiography can utilize $CdWO_4$ or CsI(Tl) crystals for small field-of-view (FOV) applications, scintillator glass is more typically used in >10 cm FOV imagers employing MeV Bremsstrahlung X-ray sources. Here, we describe a new X-radiography ceramic scintillator, $(Gd,Lu,Eu)_2O_3$, or "GLO," that provides 7x faster throughput in a 9 MeV X-ray CT system, as well as better spatial resolution, compared to IQI Tb-doped scintillator glass. We have scaled up to 12" x 12" GLO plates with excellent optical transparency. For lens-coupled MeV neutron radiography systems, standard plastic scintillator sheets detect neutrons via proton recoil. To improve neutron radiography contrast and dynamic range, we are developing a new plastic scintillator, employing a spin-orbit coupling fluor for 3x higher light yield than standard scintillators. Fabrication of large (>100 cm^2) sheets may be accomplished via established plastic fabrication methods. Optical properties, scintillation and imaging performance of these new scintillators will be reported.

Acknowledgements

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Abstract 171 MON-AP-SD-08-2 Invited Talk - Monday 2:00 PM - Elm Fork

Detectors for Active Interrogation Applications

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In a time when peaceful uses of nuclear energy are globally increasing, technology for monitoring nuclear materials is needed more than ever. There are also ongoing initiatives in nuclear weapons states to reduce worldwide nuclear stockpiles, creating an urgent need for accurate and robust technologies for characterizing special nuclear material (SNM). The majority of existing detection systems operate in passive mode. However, highly enriched uranium, which is widely regarded as the most accessible SNM, has few easily detectable passive emissions. To overcome this difficulty, an external source may be employed to produce secondary particles that can then be detected. This approach creates an environment that is particularly challenging from a radiation-detection standpoint: the elevated background levels from the source can mask the desired signatures from the SNM. Neutron-based interrogation experiments have shown that nanosecond- level timing is required to discriminate induced-fission neutrons from the scattered source neutrons. Previous experiments using high-energy bremsstrahlung X-rays have demonstrated the ability to induce and detect prompt photofission neutrons from single target materials; however, a real-world application would require spectroscopic capability to discern between photofission neutrons emitted by SNM and neutrons emitted by other reactions in non-SNM. Using digital pulse shape discrimination, newly developed stilbene scintillators are capable of reliably detecting neutrons in an intense gamma-ray field. Photon misclassification rates as low as 1 in 10^5 have been achieved, which is approaching the level of gaseous neutron detectors such as ^{3}He without the need for neutron moderation. These scintillators also possess nanosecond-timing resolution, making them candidates for both neutron- and photon-driven active interrogation systems. Future development of active interrogation systems will be discussed to address the emerging challenges in the areas of nuclear nonproliferation, safeguards, and treaty verification.

Abstract 185 MON-AP-SD-08-3 Invited Talk - Monday 2:00 PM - Elm Fork

New developments in scintillators for security applications

Jarek Glodo

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Radiation is an important part of security space, and it is either detected passively in search of special nuclear materials (SNM), or used to actively interrogate objects followed by the detection. Either case requires radiation detectors. The most common detectors are based on scintillating materials, which convert hard radiation into the light detected by a photodetector. The last decade has seen development of many new scintillation materials, which was driven in part by the security applications. The push started with the search for ^{3}He replacement technologies, which resulted in development of neutron sensing scintillators such as Cs_2LiYCl_6 (CLYC) or more recently $Cs_2LiLa(Br,Cl)_6$ (CLLBC). These materials are slowly penetrating into the detection market, not only replacing ^{3}He detectors but also as dual mode gamma/neutron detection systems. Organic and, in particular, plastic scintillators have also been under active development. For example, in the last few years, plastic scintillators gained the capability for pulse shape discrimination akin to liquid scintillators, becoming more versatile dual-mode materials. Currently, there is active research into increasing their gamma-ray stopping power through incorporation of heavy metals. Another example includes established materials, such as $CdWO_4$ or $PbWO_4$,

which are being re-evaluated and might potentially be replaced by novel scintillators. In this presentation we will discuss current advancements in the field of scintillator-based detectors in the context of security applications.

Abstract 64 MON-AP-TA-02-1 Invited Talk - Monday 2:00 PM - Rio Grande

Opportunities for Undergraduate Research in Nuclear Physics

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University of Dallas (UD) physics majors are offered a variety of undergraduate research opportunities in nuclear physics through an established program at the University of Kentucky Accelerator Laboratory (UKAL). The 7-MV Model CN Van de Graaff accelerator and the neutron production and detection facilities located there are used by UD students to investigate how neutrons scatter from materials that are important in nuclear energy production and for our basic understanding of how neutrons interact with matter. Recent student projects include modeling of the laboratory using the neutron transport code MCNP to investigate the effectiveness of laboratory shielding, testing the long-term gain stability of C_6D_6 liquid scintillation detectors, and deducing neutron elastic and inelastic scattering cross sections for ^{12}C. Results of these student projects will be presented that indicate the pit below the scattering area reduces background by as much as 20%; the detectors show no significant gain instabilities; and new insights into existing ^{12}C neutron inelastic scattering cross-section discrepancies near a neutron energy of 6.0 MeV are obtained.

Abstract 382 MON-AP-TA-02-2 Invited Talk - Monday 2:00 PM - Rio Grande

Development of an External PIGE Beamline for Fluorine Analysis of Ground Water samples.

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An undergraduate research program on environmental measurements of chemicals of concern in ground water and consumer products has been established at Hope College. Traditional Ion Beam Analysis Techniques such as PIXE and PIGE are used with student-centered projects to optimize the organohalogen measurements on hundreds of environmental samples. The students are involved in every aspect of these studies, including chain of custody oversight, target preparation, data acquisition and analysis, and even dissemination. The students gain a great deal of experience in terms of day-to-day project management and experimental design, Recent IBA successes will be presented in several environmental fields, and the impact of this experience on the student will be discussed.

Abstract 153 MON-AP-TA-02-3 Invited Talk - Monday 2:00 PM - Rio Grande

Undergraduate Research and Training in Ion-Beam Analysis of Environmental Materials

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We have an active undergraduate research program at the Union College Ion-Beam Analysis Laboratory (UCIBAL) focused on the study of environmental materials. Accelerator-based ion-beam analysis (IBA) is a powerful tool for the

study of environmental materials because it can provide information on a broad range of elements with high sensitivity and low detection limits, is non-destructive, and often requires little or no sample preparation. It also provides excellent training for undergraduate students. Beams of protons and alpha particles with energies of a few MeV from the 1.1-MV tandem Pelletron accelerator (NEC Model 3SDH) in UCIBAL are used to characterize environmental samples using IBA techniques such as proton-induced X-ray emission, Rutherford back-scattering, proton-induced gamma-ray emission, and elastic recoil detection analysis. Recent projects include the characterization of atmospheric aerosols in the Adirondack Mountains, depth profiling of diffusion in geological samples, the study of heavy metal pollutants in soil and sediments, the investigation of possible mercury emissions from crematoria, and the search for heavy metals in artificial turf in-fill. We will describe our research program and discuss a few of the recent projects in detail.

Abstract 379 MON-AR-NST-02-1 Invited Talk - Monday 2:00 PM - Post Oak

Sub-Surface Semiconductor-Metal Heteroepitaxy: Growing Nanocrystals inside Voids

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Inner surfaces of different shapes created by ion implantation and annealing of semiconductors can be sites for nucleation of films of metal diffused from the surface and, in some cases, for growth of those films into fully dense nanoparticles. An opportunity is presented to synthesize available literature on traditional thin film growth and radiation effects to leverage a new composite material, which, for instance, could be useful to make silicon more sensitive to the solar spectrum. The choice of chemically active or inactive ion species (e.g. H, He) yield both different types of open cavities, such as platelets or voids, as well as differing environments inside the cavity during film nucleation and growth. Results of experimental and theoretical investigations of Ag and Au diffusion and growth inside monocrystalline Si implanted with He and H ions are presented. Different annealing schemes realize different inner surface geometries and differing amounts of metal gettering leading to nanoparticle nucleation and growth. We will show that Ag nanoparticles seeded in faceted voids (created by He ion implantation and annealing) are hetero-epitaxial, using a 4:3 coincident site lattice, proven by alignment of Ag and Si atomic planes observed both macroscopically by RBS in channeling mode and microscopically by high resolution transmission electron microscopy.

Abstract 24 MON-AR-NST-02-2 Invited Talk - Monday 2:00 PM - Post Oak

Ion beam assisted synthesis of high volume fraction quantum dots

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We have used both MeV ion bombardment as well as Ion Beam Assisted Deposition techniques in order to produce nanoclusters of metal ions, such as gold and silver in Infrasil. In fact for the past thirty years the ion beam users have, successfully, produced nanocrystals of various elements in all variety of substrate. Also, a large number of workers have tried to control the size, distribution, and volume fraction of such nanocrystals on the surface and inside substrate by ion beam. As of today, only two groups, Hubler et al [1] and ILA et al [2] have produced high volume fraction of metal nanocrystals in order to infer the creation of pseudo-quantum dot lattices which have been shown in a series of research works initiated during the past decade. The researchers have theoretically shown the enhancement of the thermoelectric figure-of-merit in regimented quantum dot super lattices [3, 4]. For this presentation we have selected simple systems of metal such as gold, silver and/or copper in silica (SiO_2) and techniques such as Ion Beam Assisted Deposition (IBAD), using argon beam, and post bombardment by 5 MeV Si beam. In this work, we use the term quantum dots for quantum confined nanocrystals as small of at about 1 nm diameter. Using these two methods we produced highly efficient conformal thermoelectric materials, figure 1, which can operate at room temperatures and at temperatures as high as 973K [2, 5]. During this lecture we will review the results from past decades and present our most recent finding which resulted in production of thermally high insulating but electrically high conductive materials with high Seebeck coefficients produced by IBAD and produced by post bombardment by MeV ion beam.

1. Hubler et al, Nucl. Instr. and Meth. in Phys. Res. B I27/ 128, 566 (1997)

2. D. ILA, High efficiency thermoelectric device, USPTO No. US 8841539 B2

3. A. Balandin and O. L. Lazarenkova, Appl. Phys. Lett. 82, 415 (2003)

4. O. L. Lazarenkova and A. A. Balandin, Phys. Rev. B 66, 245319 (2002)

5. D. ILA, Thermoelectric systems: Ion beam enhanced thermoelectric properties, Applied Surface Science Volume 310, 217 (2014).

Abstract 165 MON-AR-NST-02-3 Contributed Talk - Monday 2:00 PM - Post Oak

Ion Beam Surface Engineering: Control and Directability of Nanomaterial Assembly

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The emergence of 1D nanoscale materials has enabled the realization of novel device architectures in the electronics industry. However, a key step in the integration of these architectures is reliant on the ability to control the synthesis of nanostructures in a predictable, scalable fashion. This requires understanding the response of nanocrystals to external stimuli, e.g. changing a surface lattice constant. This talk demonstrates the ability to exert control over the directionality of forming nanocrystals by tuning the lattice constant of the substrate surface via focused ion bombardment. The dependence of the threshold for epitaxial synthesis on the distribution and concentration of ions incident at the surface is discussed. This approach to nanoscale synthesis is expected to impact the epitaxy of mismatched semiconductor heterojunctions and lead to a realization of ultrathin heterojunctions in 1D and 2D materials.

Abstract 37 MON-AA-AMS-03-1 Invited Talk - Monday 4:00 PM - Trinity

The PRIME Lab Gas-Filled-Magnet: Development and Applications

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Although AMS techniques have been in routine use for about three decades, the technique is still improving. We have recently begun routine use of a gas-filled-magnet for the nuclides ^{10}Be, ^{26}Al, and ^{36}Cl. We are also investigating the use of this instrumentation for ^{41}Ca. While AMS is capable of rejecting many of the interferences that compromise a measurement, pure isobars can make AMS measurements difficult in many instances. There are other instances in which the presence of an isobar requires the injection of an ion that is not the most efficient, **i.e.** Al^- rather than AlO^-.

Many of the commonly run radionuclides are accompanied by an isobar (^{10}B, ^{26}Mg, ^{36}S, ^{41}K). The gas-filled-magnet (GFM) suppresses isobars by placing them on a different trajectory within the vacuum chamber of a dipole magnet, preventing them from entering the **dE/dx** detector. The lower backgrounds result in improved detection sensitivity. The most dramatic improvement occurs for ^{26}Al. Most AMS laboratories inject Al^- since Mg^- is unstable and does not interfere with ^{26}Al detection. AlO^- currents are ~ 10 times higher, but MgO^- is likewise formed and cannot be resolved with standard **dE/dx** techniques. Low Al currents have always limited the precision for this nuclide, and accordingly, the applicability ^{26}Al measurements. The compromised ^{26}Al measurement is especially problematic for those geologic studies employing the

^{10}Be-^{26}Al pair. With the GFM we are now able to inject AlO^-, which has a current comparable to BeO^-, and the precision of the ^{26}Al measurements is essentially equivalent to that of ^{10}Be measurements. Cl-36 measurements can now be done without increases in background from ^{36}S. We are also investigating the use of the GFM for ^{41}Ca measurements. Reduction of the ^{41}K isobar could potentially enable the routine measurement of extra-terrestrial samples.

Abstract 70 MON-AA-AMS-03-2 Invited Talk - Monday 4:00 PM - Trinity

Ion So(u)rcery: Past Magic, Present Research, Future AMS

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Accelerator mass spectrometry (AMS) depends, to date, on production of negative ions from sample material by the cesium sputter ion source that was perfected in the final decades of the last century, primarily by Roy Middleton at the University of Pennsylvania. One theory of operation was based on concepts from low fluence sputtering that was unable to explain any of Middleton's "magic" ion production in high fluence sputtering and predicted no useful paths for future ion source development. Middleton's hypothesis that ion production arose in the blue plasma seen in recessed samples or sputter pits has been explored in recent years. The plasma arises from the photo-dense cloud of neutral Cs sputtered from the sample surface in which Cs atoms are excited to high states by low energy secondary sputtered electrons retained in the low electric fields of pits and recesses. These excited atoms then exchange electrons with the dominant (≈90%) neutral flux of sputtered sample atoms to form anions. Photo-excitation of Cs states also produces anion currents. This ionization was first thought to be resonant but quantum calculations show it to be non-resonant, while suggesting photo-excitation techniques that could eliminate elemental isobars directly in the ion source for anions with low electron affinities, such as Ca^- and Fe^-. Photo-excitation should also produce elemental anions such as Be^- and Al^- efficiently from their oxides with elimination of O^- competition. These predictions from the plasma-ionization theory of sputter source operation point toward lower acceleration potentials now required for post-acceleration separation of isobars. The use of pulsed lasers in photo-excitation will introduce time-of-flight spectrometers for continued miniaturization of instruments quantifying rare, long-lived isotopes.

Abstract 154 MON-AA-AMS-03-3 Contributed Talk - Monday 4:00 PM - Trinity

Search for Doubly Charge Negative Atomic Ions using Accelerator Mass Spectrometry

Elisa Romero-Romero[1,2], Alfredo Galindo-Uribarri[1,2], Keith Fifield[3], Michaela Froehlich[3], Blaine Heffron[1,2], Yuan Liu[1], Stefan Pavetich[3], Steve Tims[3], Anton Wallner[3]

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Strong correlations between component particles are the common thread linking a number of fascinating physical systems, including high-temperature superconductors, quark-gluon plasmas, organic superconductors and - under some conditions - clouds of ultracold atoms. An important goal of negative ion physics is to better understand the role played by electron correlation in the structure and dynamics of many-electron systems. Single negative ions have been a key in understanding a number of areas of physics and chemistry. Doubly charge atomic ions in gas phase are still unseen. This work present a technique to assess and identify doubly charged negative ions. We want to demonstrate that the conventional mass spectroscopy is not enough for the search of the doubly charged negative ions. Accelerator Mass Spectroscopy plays a crucial role in proving their existence.

Abstract 28 MON-AA-AMS-03-4 Contributed Talk - Monday 4:00 PM - Trinity

A 150kV AMS System and its Applications

Shan Jiang, Ming He, Kangning Li, Yiwen Bao, Qubo You, Qingzhang Zhao, Yijun Pang, Yueming Hu, Kejun Dong, Yinggen Uoyang

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Without doubt, ^{14}C is the fist important nuclide for AMS measurement and its applications. But the applications are more about on research, less about on industry. However ^{14}C still has many interesting applications in the industry, if the AMS system can be more small and the measurement can be more fast.

In order to measure ^{14}C for industry applications, a small 150 kV AMS system for ^{14}C measurement will be introduced. A few industry applications such as (1) monitor source of carbon from the air pollution (gaseous PM2.5) need to measure ^{14}C very fast. (2) Monitor of ^{14}C from the nuclear power station need to measure it on-line. And (3) 14C tracing for medical diagnose in a breath will also be discussed at the conference.

Abstract 334 MON-AC-AF-03-1 Invited Talk - Monday 4:00 PM - West Fork

National Centre for Accelerator Based Research: A New Low Energy Ion Implantation, Irradiation and Ion Beam Analysis Facility Using 3.0 MV Pelletron Accelerator in India.

Parmendra Kumar Bajpai, Tarkeshwar Trivedi, Shiv P Patel, C Mallik, Pushpita Chandra, Rakesh Kumar Pandey

National Centre for Accelerator Based Research, Department of Pure & Applied Physics, Guru Ghasidas Vishwavidyalaya, Central University, Central University Campus, Koni, Bilaspur Chattisgarh 495009, India

Accelerators have an important role to play in the material modifications, synthesis of noble materials and characterizing them using ion beam analysis techniques. During last couple of decades, accelerators have become more easily accessible in different fields of science & Technology including material science, Biology, Medical usage, agriculture, food processing, etc. This has made accelerators as a potential research tools especially for interdisciplinary researches. A number of such applications demands relatively high current with low energy so as the nuclear and electronic loss competes.

National Centre for Accelerator based Research (NCAR) at the Department of Pure & Applied Physics, Guru Ghasidas Vishwavidyalaya (A Central University) at Bilaspur, India has been commissioned as a national facility for interdisciplinary research using ion beams based on 3.0 MV Pelletron accelerator (9SDH, NEC) with high current TORVIS (for H, He ions) and SNICS (for heavy ions) ion sources, and two beam lines for ion beam analysis (IBA) and ion implantation/ irradiation. The first beam was demonstrated in Nov. 2014 and acceptance test report was signed on Dec. 2014. the accelerator conditioning was done over a period of time and desired level of terminal voltage and vacuum in the accelerator tank was achieved in 2015. The radiation safety procedures and beam transport data for a number of beam including that for 50 uAmp proton has been obtained and a transmission of over 85% in the low energy beam line and almost 100% for the post accelerated beam have been achieved. A number of test experiments have also been performed to demonstrate the capabilities of the facility commissioned in the beam hall.

This flagship program is supported by University Grant Commission, New Delhi, Department of Atomic Energy through Board of Research in Nuclear Physics (BRNS), Mumbai, India. It is intended to provide state of the art research facilities

on University campus for pursuing competitive and cutting edge researches in the areas of material science, nanotechnology, environment sciences, polymer chemistry, material chemistry, conservation of bio-diversity, life sciences, radio-biology, biotechnology, Pharmaceuticals, molecular biology, etc. In addition, the facility will be used to train the man power on various advanced technology used in the accelerators including cryogenics, vacuum technology and accelerator physics, radiation safety.

In the present talk, current status of the facility, salient features of the beam lines and ion beam techniques available as well as the research program chalked out will be discussed. Beam transport, source optimization data as well as some results obtained through ion implantation / ion beam analysis techniques using the facility will also be presented.

Abstract 254 MON-AC-AF-03-2 Contributed Talk - Monday 4:00 PM - West Fork

Ion Beam Analysis Facilities at the National Centre for Accelerator based Research using 3 MV Pelletron Accelerator

Tarkeshwar Trivedi, Shiv p Patel, P Chandra, P. K. Bajpai

National Centre for Accelerator based Research, Department of Pure & Applied Physics, Guru Ghasidas Vishwavidyalaya, Bilaspur Chhatisgarh 495009, India

Accelerators are versatile tools to do researches in the interdisciplinary areas. The advances in accelerator technology coupled with state-of-the-art detection systems have provided scope of studying various areas of Science & Technology including nuclear physics, material science, life sciences, agriculture, food processing etc. A 3.0 MV Pelletron (9 SDH 4, NEC, USA) based low energy ion accelerator has been recently commissioned at the National Centre for Accelerator based Research (NCAR) at the Department of Pure & Applied Physics, Guru Ghasidas Vishwavidyalaya, Bilaspur, India. The facility is aimed to carried out interdisciplinary researches using ion beams based on with high current TORVIS (for H, He ions) and SNICS (for heavy ions) ion sources.

Presently, facility includes two dedicated beam lines, one for ion beam analysis (IBA) and other for ion implantation/ irradiation corresponding to switching magnet at +20 and -10 degree. A 17" diameter scattering chamber is used for ion beam analysis consisting of facilities for Rutherford Back scattering (RBS), Particle Induced X-ray Emission (PIXE) and double slit for channelling. After completion of installation a number of test experiments have been carried out to demonstrate the capabilities of the facility. Particle induced X-ray emission experiments have been carried with proton beam on several targets like ZnO, gold on glass and various coins and some other samples. For X ray analysis a Silicon Strip Detector (SDD) is mounted at a backward angle relative to the incident beam to reduce the possibility of scattered protons entering the detector. Similarly, for depth profile of individual elements, Rutherford Back scattering (RBS) experiments were performed using Helium beam. The scattered He particles from the target are analyzed by a Silicon Charge particle detector (50 mm active area with energy resolution of 11 keV and 300 micron depletion) positioned at a back scattered angle with respect to the incident ion beam. One of the important features of this accelerator is availability of high current proton beam (~ 50 micro ampere) which can be used for generating neutrons and hence a dedicated facility for neutron based research at the Centre is being planned. The generated neutron flux will provide unique opportunity for neutron-induced cross sections measurements especially in low energy region where very limited information are available.

The salient features of this newly installed low energy high current Pelletron accelerator along with ion beam techniques and extension of facility for neutron generation shall be presented along with the demonstrative test results.

Abstract 109 MON-AC-AF-03-3 Contributed Talk - Monday 4:00 PM - West Fork

Versatile 500 kV Air-Insulated Medium Current Ion Implanter

Nicolae C. Podaru, M. Klein, F. v.d. Hoef, D.J.W. Mous

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High Voltage Engineering Europa (HVE) developed, tested and commissioned two new medium current 500 kV ion implantation systems. On the high voltage platform ion beams are extracted from a newly developed robust industrial Indirect Heated Cathode - ion source, model SO-140. In addition to running gasses, this ion source can be equipped with a high-temperature vaporizer (300 - ~2000 °C) or a sputter target, thus being able to create ion beams from virtually any chemical element. The versatility of creating virtually any ion beam covers all possible application in the field of ion implantation technology. The system complies with relevant safety regulations for process gasses and substances such as BF_3, PH_3, and AsH_3. The 90° injector magnet with higher order corrected optics and a mass resolution M/ΔM ~ 300 located on the high voltage platform analyzes the ion beams extracted from the ion source. The ion beam injector delivers ion beam currents well in excess of 2 mA for $^{11}B^+$, $^{31}P^+$, and $^{75}As^+$ which is set as a limit for the accelerator column. The ion beam energy range for singly charged ions is between 20 keV and 500 keV, including extraction voltage. The ion implanter can be configured in a multitude of configurations, e.g. multiple implantation beamlines, different endstations (experimental, semi-industrial). Irregular shaped samples or wafers ranging from 1" to 300 mm can be can be processed at 0-60° implant angle. The ion beam scanning is performed with a set of X/Y electrostatic plates followed by a 7° neutral trap. Four Faraday cups positioned at 4 corners around the wafer ensure accurate dosimetry. Adding to versatility, the substrate to be processed can be also cooled down to 77 K or heated up to ~1100 K. To meet industrial standards, HVE has developed a new software control platform, named Argus. The PLC of the new control software is based on the global EtherCAT standard Beckhoff TwinCAT 3, enabling fast control (μs) and signal handling. The supervisory control layer is responsible for access control, operator HMI, alarm handling, trending and logging from multiple workstations, also via remote control protocols for further factory/lab integration. The footprint of the system is approx. 11.6 m × 6.2 m..

Abstract 301 MON-AC-AF-03-4 Contributed Talk - Monday 4:00 PM - West Fork

The new compact TT50 Rhodotron : development status and target performances

Philippe Dethier

Industrial, IBA, Chemin du cyclotron, 3, Louvain-la-Neuve Brabant Wallon 1348, Belgium

IBA designs and manufactures electron and proton accelerators for medical and industrial applications. IBA's high energy electron beam accelerator product range is called Rhodotron. The Rhodotron is a recirculating accelerator where electrons gain energy by crossing a coaxial-shaped accelerating cavity several times. IBA's Rhodotron is unique amongst E-beam accelerators by providing one or several beam outputs from 2 to 10 MeV and with power going from 35kW to 700 kW.

IBA is currently developing the "Second Generation Rhodotron" including features improvements and two new Rhodotron models. This talk will focus on the development status of the new compact, low cost, 10 MeV TT50 Rhodotron. The new TT50 Rhodotron innovates in many ways. It uses permanent deflection magnets, its single accelerating cavity has a diameter of about 30 inches and unlike traditional Rhodotrons, its installation is vertical. The new TT50 Rhodotron is the biggest development program of the past 10 years in IBA's electron beam accelerator product range. The speaker will review the TT50 development status, design uniqueness and target performances.

Abstract 168 MON-AC-AF-03-5 Contributed Talk - Monday 4:00 PM - West Fork

High power DC electron accelerators of ELV type for industrial application

Nikolay Kuksanov, Yury Golubenko, Rustam Salimov, Sergey Fadeev, Petr Nemytov, Alexey Korchagin, Alexey Semenov, Dmitry Kogut, Evgeny Domarov, Denis Vorobiev, Alexander Lavruchin, Victor Cherpkov, Mikhail Golkovsky, Ivan Chakin

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The electron-beam technologies are extensively used in industries. The most perfect instruments for radiation treatment are powerful industrial electron accelerators. Parameters of accelerator determine the rate of processing. Optimizing the method of electron beam irradiation of products it is possible to sufficiently improve the irradiation quality and the efficiency of a beam.

BINP develops and manufactures high power electron accelerators for industrial application. Mainly they are ELV accelerators. The ELV electron accelerators are DC machines purposed for wide application in various technological processes. They use high voltage rectifier and accelerating tube inside it. Development of these machines had started 1970-s. From that time over 140 accelerators were delivered both inside Russia or former USSR and abroad (from Germany in West, Malaya and Philippines in East). ELV accelerators are the most popular accelerators not only in Russia, but in China and South Korea also.

We study the requirements of accelerators market and follow the requests of electron beam technologies users. Lifetime of accelerators usually is some tens of year. Very often the modification of accelerator is more attractive in comparison with installation of new machine. So very often old accelerators have upgrade and continue operation.

Our Institute develops not only accelerators but under beam equipment also. It increases technological possibilities of accelerator. There are system of 2- and 4-side irradiation, circular irradiation, system for improving of dose uniformity during irradiation of film and band, extraction of focused beam into atmosphere, under beam transportation system for cable and pipe. ELV accelerators can be easily integrated in technological processing. There are two possibilities: the beam is controlled by technology and technology is controlled by beam.

The set of ELV accelerators covers the energy region from 0.4 to 2.5 MeV, maximum beam current 100 mA and maximum beam power - 100 kw. Accelerator with power of extracted beam 400 kW was developed and manufactured for environmental application.

Abstract 361 MON-AC-AF-03-6 Contributed Talk - Monday 4:00 PM - West Fork

Industrial Applications of Laser and Electron Beam Facilities at the Brookhaven National Lab. Accelerator Test Facility

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Combined laser/particle facilities offer a broad range of options for industrial applications, facilitating R&D in advanced accelerators, radiation sources and instrumentation. They also present opportunities for materials interactions research, including radiation hardness and damage testing.

The Brookhaven National Lab. Accelerator Test Facility (ATF) is an Office of Science User Facility with a major focus on service to industry. With its 80 MeV electron accelerator synchronized to multiple high power lasers, including its unique 2 TW, 10 μm wavelength CO_2 laser, the ATF provides resources for both proprietary and non-proprietary industry based research. Recent efforts include R&D for extreme ultraviolet lithography, THz radiation generation, mono-energetic proton production for medical applications and a range of instrumentation development and materials testing.

Abstract 169 MON-AP-SD-04-1 Invited Talk - Monday 4:00 PM - Elm Fork

Outcome of the IAEA Technical Meeting (IAEA Ref. F1-TM-52459) on Enhancing Nuclear Technologies to Meet the Needs of Forensic Science

Melanie J Bailey[1], Roger P Webb[2]

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The University of Surrey will host the IAEA Technical Meeting (IAEA Ref. F1-TM-52459) on Enhancing Nuclear Technologies to Meet the Needs of Forensic Science on 5-9 September 2016. The meeting brings together for the first time key members of the forensic community with representatives from the ion beam community, with a view to developing a Coordinated Research Programme in the area. This talk will summarise the outcomes of this meeting.

Abstract 429 MON-AP-SD-04-2 Invited Talk - Monday 4:00 PM - Elm Fork

Enhancing the scope of trace evidence analysis for forensic applications by nuclear methods

Skip Palenik[1], Chris Jeynes[2]

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Trace evidence collected for examination in connection with crimes and civil litigation is analyzed by techniques employing the physical and biological sciences. Since the quantity of material available for analysis is usually vanishingly small, this evidence is analyzed by microscopical, spectroscopic and chromatographic methods to first identify it and then most often to compare it to one or more suspected sources. Unlike the sciences which it employs, the goal of these analyses is ultimately to individualize the evidential material and thus determine the likelihood that the questioned and known items could have originated from the same source. Thus after the substance itself has been identified, further analyses must be performed that can bright to light minute similarities or differences in the physical, elemental or chemical properties of the materials under investigation. The sensitive analytical instrumentation employed in nuclear research, which is at present unavailable in all but the a few of the largest, state run forensic laboratories, offers the possibility of achieving the goal of individualization for certain classes of materials. This presentation will describe some of the types of microscopic trace evidence that are commonly encountered in real-life forensic practice and the contributions that nuclear analytical methods can provide in increasing its probative value both at the investigative stage and in court.

Abstract 284 MON-AP-SD-04-3 Invited Talk - Monday 4:00 PM - Elm Fork

Cocaine distribution in the hair shaft assessed by MeV-SIMS

Luka Jeromel[1], Nina Ogrinc Potocnik[1,2], Zdravko Siketic[3], Primoz Vavpetic[1], Zdravko Rupnik[1], Bostjan Jencic[1], Klemen Bucar[1], Mitja Kelemen[1], Katarina Vogel-Mikus[1,4], Janez Kovac[1], Matjaz Vencelj[1], Ron M.A. Heeren[2], Bryn Flinders[2], Primoz Pelicon[1]

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If present in human body, cocaine is accumulated in hair during its growth. The fluctuations in the cocaine concentration along the growth axis of hair could be either assessed by chemical extraction and analysis of consecutive sections, or by imaging mass spectrometry applying minute desorption of hair material and mass analysis of ionized fraction of the desorbed material. In this work, we analysed the cocaine in hair samples by MeV-SIMS, a method characterized by high yields of non-fragmented molecular ions from the surface of intact biological materials. Hair samples were cut along the axis of growth, leaving half-cylindrical shape to access the interior structure of the hair. Focused 5.8 MeV $^{35}Cl^{6+}$ beam was scanned across an intact, chemically non-processed hair structure and a non-fragmented protonated $[M+H]^+$ cocaine peak at m/z eq. 304 u was detected in the Time-Of-Flight mass spectrum as a function of beam position. The cocaine signal intensity exhibits strong fluctuations along the direction of the hair's growth, with pronounced peaks as narrow as 50 micrometres, corresponding to a hair growth time of approx. three hours.

Abstract 191 MON-AP-SD-04-4 Invited Talk - Monday 4:00 PM - Elm Fork

Designs for Mobile Urban Radiation Search (MURS) System

Nicole Kelley[1], Mark Swanson[1], Ben Altieri[1], Seth Henshaw[1], Daniel Chivers[1], Austin Kuhn[1], John Kua[1], John Lacis[1], Michael Joseph King[1], Ren Cooper[2], Joey Curtis[2], Ross Meyer[2]

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One of the important grand research and development challenge topic areas supported by the Domestic Nuclear Detection Office (DNDO) is the Wide Area Monitoring and Search (WAMS) of nuclear material. This topic addresses the challenges of the detection of nuclear threats such as Radioactive Dispersal Devices or Improvised Nuclear Devices at US borders and densely populated areas. To address the challenge, the Mobile Urban Radiation Search (MURS) system is being developed as an in-vehicle standoff passive radiation detection system. The goal of the system is to detect, identify and locate a source of radiation at a distance consistent with a given set of concepts of operation. In the system being developed, imaging is achieved through distinct signal patterns generated by the self-attenuation of the detector geometry. Various geometries and their imaging capabilities will be discussed.

This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under contract HSHQDC-14-X-00197. This support does not constitute an express or implied endorsement on the part of the Government.

Abstract 434 MON-AP-TA-08-1 — Invited Talk - Monday 4:00 PM - Rio Grande

Ultra-High Vacuum Seminar

Walt van Hemert

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This class provides an overview of the unique nature and requirements of ultra-high vacuum (UHV) which is a key enabling condition for many types of scientific inquiry and experimentation. Topics in session one will include an introduction to high vacuum and ultra-high vacuum, gas behavior at low pressure, the elements of system pressure and total gas load, and materials selection. The curriculum for this 90 minute class is intended to provide an introduction to ultra-high vacuum systems and practice for scientists, engineers and technicians. Attendees will receive a copy of the seminar handbook, "High and Ultra-High Vacuum for Science Research", 2011, 133 pages.

Abstract 195 MON-AR-NST-01-1 — Contributed Talk - Monday 4:00 PM - Post Oak

Top-down Direct Write Nanofabrication of Donors in Silicon and Defect Centers in Diamond

Edward Bielejec[1], Jose Pacheco[1], John Abraham[1], M Singh[1], R Camacho[1], M P Lilly[1], D R Luhman[1], M S Carroll[1], A Sipahigil[2], R Evans[2], D Sukachev[2], H Atikian[2], M Loncar[2], M Lukin[2], M E Trusheim[3], T Schroder[3], D Englund[3]

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We present on-going work using top-down direct write nanofabrication to create deterministic single atom devices for both research into quantum computation using single donors in silicon and diamond nano-photonic devices using SiV defect centers. This work is carried out using Sandia's nanoImplanter (nI). This is a 100 kV focused ion beam system setup for both mass resolution using an ExB filter and single ion implantation using fast blanking and chopping. We combine this with a lithography pattern generator for high resolution nanofabrication. Additionally, we have demonstrated the single ion detection on both Silicon and Diamond substrates using ion beam induced charge (IBIC) collection. The combination of single resolution direct write fabrication and integrated single ion detection allows for the fabrication of single atom devices.

The creation of single donor based quantum computing goes back to Kane [1]. We have implemented a fabrication pathway that combines focused ion implantation with **in-situ** counted ion detection. We have integrated avalanche photodiodes with quantum transport nanostructures and demonstrated low temperature transport in counted samples [2]. We have detected Sb ions down to 20 keV generating at most ~1200 e-h pairs/ion with a SNR of 2. This focused ion beam approach allows for a positioning accuracy of <35 nm, defined by the beam spot size.

Color centers in diamond have been used for a range of applications from metrology to single photon sources for secure quantum communication [3]. Here we will discuss the ability to deterministically implant ions into photonic nanostructures with high spatial resolution. Separately, we have demonstrated the ability to detect single ion implants using an **in-situ** diamond detector with a SNR approaching 10 for detection of single 200 keV Si ions.

In sum, direct write nanofabrication has been demonstrated for single atom devices in both silicon and diamond substrates using a top-down ion implantation approach.

This work was performed, in part, at the Center for Integrated Nanotechnologies, an Office of Science User Facility operated for the U.S. Department of Energy Office of Science. Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

[1] B. E. Kane, Nature **393**, 133-137 (1998)

[2] M. Singh **et al.,** Appl. Phys. Lett. 108, 062101 (2016)

[3] I. Aharonovich **et al.,** Rep. Prog. Phys. **74**, 076501 (2011)

Abstract 304 MON-AR-NST-01-2 Contributed Talk - Monday 4:00 PM - Post Oak

Single ion detection for engineered quantum systems in diamond

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Color centers in diamond hold promise for a range of applications from metrology to quantum computing. The lack of fabrication techniques to deterministically form color centers is a critical limitation for translating their promise to actual devices. The key challenges for fabrication are (1) spatial localization and (2) activation yield. The first challenge can be addressed by focused or masked ion beam implantation [1] [2], while the question of yield remains. In this talk, we will describe our experimental effort to deterministically fabricate single Silicon-Vacancy (SiV) diamond color centers. Specifically, the yield of SiV formed by ion implantation is typically low (<10%) and yield optimization studies are obfuscated by uncertainty in the number of implanted ions due to the Poisson statistics associated with the ion implantation process. We propose to address this challenge by adapting an in-situ low energy single ion detection technique developed for Silicon [3] [4] to diamond.

To this end, we fabricated, modeled, and measured a surface electrode detector on diamond [5]. We demonstrated low energy single ion detection with a signal-to-noise ratio (SNR) approaching 10 for 200 keV Si ions. This SNR results in an expected ion counting error rate of < 1%, effectively removing Poisson statistics. Additionally, measurements and modeling indicate that the charge collection efficiency of the detector is a sensitive probe of substrate sub-surface damage. Currently, we are in the process of developing an in-house confocal microscope capability for confirming single SiV formation. We anticipate that single ion detection will serve as a platform to develop an understanding of how activation yield depends on factors such as the local number of vacancies, anneal parameters, and surface termination.

This work was performed, in part, at the Center for Integrated Nanotechnologies, an Office of Science User Facility operated for the U.S. Department of Energy Office of Science. Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

[1] S. Sangtawesin, T. O. Brundage, Z. J. Atkins and J. R. Petta, **Appl. Phys. Lett.,** vol. 105, p. 063107, 2014.

[2] S. Tamura, G. Koike, A. Komatsubara, T. Teraji, S. Onoda, L. McGuinness, L. Rogers, B. Naydenov, E. Wu, L. Yan, F. Jelezko, T. Ohshima, J. Isoya, T. Shinada and T. Tanii, **App. Phys. Express,** vol. 7, p. 115201, 2014.

[3] D. N. Jamieson, C. Yang, T. Hopf, S. M. Hearme, C. I. Pakes, S. Prawer, M. Mitic, E. Gauja, S. E. Andresen, F. E. Hudson, A. S. Dzurak and R. G. Clark, **Appl. Phys. Lett.,** vol. 86, p. 202101, 2005.

[4] J. A. Seamons, E. Bielejec, M. S. Carroll and K. D. Childs, **Appl. Phys. Lett.,** vol. 93, p. 043124, 2008.

[5] J. B. Abraham, B. A. Aguirre, J. L. Pacheco, G. Vizkelethy and E. Bielejec, **Appl. Phys. Lett.,** vol. 109, p. 063502, 2016.

Abstract 255 MON-AR-NST-01-4 Contributed Talk - Monday 4:00 PM - Post Oak

Radiation Resistant Mask Coatings for Ion/Neutral Atom Lithography

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In masked ion or neutral-atom beam lithography, a stencil mask is illuminated by a broad beam of light ions/atoms, and transmitted beamlets transfer the mask pattern with or without demagnification to the surface of a substrate. Common mask materials, including silicon, silicon nitride and most polymers are heavily damaged by the particles that are blocked by the mask. This damage is manifested by changes in mask tension that lead to placement errors in the printed pattern. The mask life issue was recognized in early work with Li^+ ions (U. Behringer and R. Speidel, **Optik 62**, p. 59, 1982), where it was shown that a gold ion-absorbing coating could provide a partial solution to the problem of radiation damage to the supporting membrane. A significant advance in the context of ion projection lithography was the discovery (Wasson et al., J. Vac. Sci. Technol. B **15**, p. 16, 1997), that ion-beam vitrified graphite could provide a mask life of 10's of millions of chip exposures, even with the exacting pattern placement requirements of ULSI. Two serious issues remained; the first was that a hydroscopic graphitic layer remained between the ion-implanted layer and the support membrane, requiring that the mask be handled in a completely dry environment. The second was the high cost of ion implantation. Hudek et al. (J. Vac. Sci. Technol. B **17**, p. 3127, 1999) sought to use the substrate bombardment that occurs during sputter deposition for direct deposition of an ion-stabilized film (without a separate ion-implantation step). As deposited, these films are stable in atmosphere. However, the implanted layer is initially hygroscopic under ion bombardment, only becoming stable in atmosphere with very high doses. This is a major advance over Wasson et al. in that the implanted film is supported by an unimplanted layer that not, itself, hygroscopic. The cost of the implant required to completely stabilize the film against water vapor adsorption remains a serious concern.

In this paper, we explore the process space for radiation resistant films formed by plasma-enhanced chemical vapor deposition in a parallel plate reactor with methyl-methacrylate (MMA) precursor. Films are grown on the powered electrode to maximize ion bombardment of the growing film. Power, pressure, and MMA fraction in the helium carrier gas

control the deposition rate, intrinsic stress, and the molecular weight distribution of the films. Post-deposition annealing will also be studied as a means of modifying the density, stress, and porosity. Surface analysis data will also be presented. Our goal is to obtain atmospherically stable, radiation resistant, films with an initial intrinsic stress in the 5-100 MPa (tensile) range and changing by ~5-10 % over an exposure range from 0- 1 C/cm^2 for 50 keV He^+ ions.

Abstract 292 MON-AR-NST-01-5 Contributed Talk - Monday 4:00 PM - Post Oak

Smoothing metallic glasses without introducing crystallization by gas cluster ion beam

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We show that 30 keV Ar cluster ion bombardment of $Ni_{52.5}Nb_{10}Zr_{15}Ti_{15}Pt_{7.5}$ metallic glass (MG) can remove surface mountain-like features and reduce the root mean square surface roughness. X-ray diffraction analysis reveals no crystallization after cluster ion irradiation. Molecular dynamics simulations show that, although damage cascades lead to local melting, the subsequent quenching rate is a few orders of magnitude higher than the critical cooling rate for MG formation, thus the melted zone retains its amorphous nature down to room temperature. These findings can be applied to obtain ultra-smooth MGs without introducing crystallization.

Abstract 39 MON-AR-NST-01-6 Contributed Talk - Monday 4:00 PM - Post Oak

Cluster ion beam induced nano ripple structures and their biological applications.

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Nano ripple glass pattern formed by gas cluster ion beam irradiation show more bacterial growth than on a plain glass slide. The comparison of bacteria growing on nano ripple glass pattern inside and outside the magnetic field has shown different behavior as well. The bacteria growing on the nanostructures outside the magnetic field tends to make larger colonies. Magnetic field seems to affect the growth of bacteria by decreasing the size of the colonies. Non-uniform field shows pattern following magnetic field lines. On the other hand nano metallic ripple structures show localized surface plasmon resonance effect. It is a simple and cost-effective scheme for bio-sensing. These localized surface plasmon resonance (LSPR) based bio sensors have the advantage of easy configuration, label free real time analytical detection, large surface area coverage, monolayer scale sensitivity and specific selectivity. Changes in the plasmonic properties of the nano-ripple can be determined by the nano surface morphology hence the plasmonic response is tunable. By functionalizing the surface with a stable and sterically accessible monolayer of antibody and loading different concentrations of the specific antigen we identified the shift in the LSPR peaks triggered by the change of dielectric function in the vicinity of the structures. The nano ripple LSPR based biosensor was used to detect antibody-antigen reaction of rabbit X-DENTT antibody and DENTT blocking peptide (antigen). The sensor can be further developed to study real-time analytical-reaction dynamics. Its capability to selectively manipulate bio-materials with high-sensitivity can lead to various biomedical and clinical applications.

Abstract 298 MON-AR-RE-02-1 Invited Talk - Monday 4:00 PM - Bur Oak

Development of transmission electron microscopes interfaced with accelerators and its application to in-situ microstructural observations of radiation effects in crystalline materials

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The development of the transmission electron microscope interfaced with an accelerator (TEM-accelerator facility) has been greatly extending the capability of physical and/or chemical interpretations of radiation effects in solid materials, especially metals, semiconductors and ceramics.

Generally when crystalline substances are subjected to heavy and energetic particle irradiations, a sequence of atomic displacements is introduced leaving dense and localized distribution of point defects, namely displacement cascades. Since the energy density of the displacement cascades reaches extremely high as the order of 1 eV/atom or even higher, variations of defects, such as secondary defects (dislocation loops and others) or phase transformation (amorphization or chemical disordering) will be introduced during the cooling process of cascades. The accumulation and annealing behaviors of those phenomena govern the intelligence of the material; so-called radiation integrity. The simultaneous observations of those phenomena will directly give us such the insights under the fixed condition; such as temperature and microstructure and geometry.

In the presentation, the authors will review their knowledge on development of the TEM-accelerator facilities in the last decades, as well as the scientific and engineering insights of radiation damage. .

Abstract 72 MON-AR-RE-02-2 Contributed Talk - Monday 4:00 PM - Bur Oak

Accumulation of dislocation loops in the α phase of zirconium Excel alloy under heavy ion irradiation

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In-situ heavy ion irradiations were performed on the high Sn content Zr alloy 'Excel', measuring <a> type dislocation loop accumulation up to irradiation damage doses of 10 dpa at a range of temperatures. The high content of Sn which diffuses slowly and the thin foil geometry of the sample provide us a unique opportunity to study an extreme case where displacement cascades dominate the loop formation and evolution. The dynamic observation of dislocation loops evolution under irradiation at 200 °C reveals that the dislocation loops form directly from the collapse of the displacement cascade. The size of the dislocation loop increase slightly with irradiation damage dose. The mechanism controlling loop growth in our study is different from that in neutron irradiation; in our study larger dislocation loops can condense directly from the interaction of displacement cascades and the high concentration of point defects in the matrix. The size of the dislocation loop is dependent on the point defect concentration in the matrix. A negative correlation between the irradiation temperature and the dislocation loop size was observed. A comparison between cascade dominated loop evolution (this study), diffusion dominated loop evolution (electron irradiation) and neutron irradiation suggests that heavy ion irradiation alone may be not enough to accurately reproduce neutron irradiation induced loop structures. An alternative method is proposed in this paper. The effects of Sn on the displacement cascades, defect yield, and the diffusion behavior of point defects are established.

Abstract 364 MON-AR-RE-02-3 Contributed Talk - Monday 4:00 PM - Bur Oak

The Role of Grain Size and Grain Boundary Structure on Defect Absorption and Denuded Zone Formation in Irradiated Nanocrystalline Iron

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Nanocrystalline materials are postulated as radiation resistant materials due to their high grain boundary area that can function as sink and particle sinks. Recent research has focused on the grain boundary sink efficiency and correlated it to the experimentally observed denuded zone formation near grain boundaries. Several factors, however, affecting the defect densities in the grain matrices, grain boundary sink efficiency and denuded zone formation are still not well understood.

In this work, in-situ helium irradiation/TEM studies were performed on nanocrystalline Fe samples of less than 100 nm grain size. The in-situ TEM/irradiation experiments were performed on the samples using the in-situ TEM facility in the Department of Radiation Solid Interactions at Sandia National Laboratory. In-situ automated crystallographic orientation microscopy (ACOM) was also performed via NanoMEGAS ASTAR precession diffraction enabling grain boundary-local strain effect studies (via Nye tensor maps) at different irradiation doses to reveal local strain effects on regular/irregular defect absorption and uniform/non-uniform denuded zone formation. Defect densities vs grain size graphs are plotted and discussed based on grain size regimes. Effects of grain size, misorientation angle, grain boundary type on denuded zone formation are discussed. The conclusions derived from this work is essential for nuclear and materials engineering communities working on irradiation resistant-nanocrystalline materials.

Abstract 142 MON-AR-RE-02-4 | Contributed Talk - Monday 4:00 PM - Bur Oak

Direct Observations of Structural Changes due to Sequential and Concurrent He Implantation and Heavy Ion Irradiation

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Materials used in a range of complex radiation environments must accommodate both displacement damage resulting from primary knock-on events in addition to the incorporations of transmutation products including hydrogen and helium isotopes. The In-situ Ion Irradiation Transmission Electron Microscope (I^3TEM) developed at Sandia National Laboratories' Ion Beam Lab permits direct, real-time nanoscale observation and correlation of the materials evolution in various radiation environments, including conditions that favor either displacement damage or ion implantation. This presentation will provide an overview of work done at this unique facility over the last five years exploring the effect of sequential and concurrent irradiation in materials including high-purity Au, Ni, Pd, and Mo, as well as a range of engineering metals. Through in-situ TEM irradiation, we have shown that bubble nucleation occurs at lower doses under concurrent He implantation and self-ion irradiation in Au. We have also shown that bubble-to-cavity evolution is more strongly dependent on temperature than implantation dose, dose rate, or displacement damage level. Finally, the combination of precession electron diffraction (PED) orientation mapping with in-situ irradiation and implantation was employed to reveal the role local microstructure plays in radiation damage nucleation and evolution. We demonstrate that not all nanocrystalline metals have improved radiation tolerance, as in the cases of Ni and Au.

Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin company, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Abstract 389 TUE-PS-AP-02-0 | Plenary Talk - Tuesday 8:00 AM - Rio Grande

Medical Application-Driven Advances in Bioequivalent Dose Planning and Imaging in Particle Beam Radiation Therapy - Building a National and World-Wide Research Network

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In February 2015, the U.S. National Cancer Institute, in collaboration with the Department of Energy, awarded two planning grants (P20) to plan up to two National Centers of Particle Beam Radiation Therapy (PBRT) in the U.S. In response, a team of investigators at UCSF, LBNL, and Loma Linda University formed the National Alliance of Particle Therapy (NAPTA), an alliance of leading U.S. academic institutions, National Accelerator Laboratories, investigators from CERN, and international ion beam centers in Germany, Austria, Italy, and Japan. The main objective of NAPTA is to secure a future for particle beam therapy research in the U.S. by integrating and developing new clinical, biological and technical knowhow that addresses existing shortcomings in available technologies and lack of collaborations to improve them. Within this effort, international collaboration is encouraged, but U.S. participation mandatory. In this plenary talk, examples of P20 pilot research projects including new concepts in bioequivalent dose planning and low-dose imaging to PBRT will be presented, and opportunities for accelerator physicists to get involved will be suggested.

Abstract 404 TUE-PS-AP-03-0 Plenary Talk - Tuesday 8:00 AM - Rio Grande

Particle Beam Therapy: Evolving Technological Developments and Expanding Clinical Indications

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New technological developments in particle therapy have been driven by an increasing need for efficiency; safety and treatment complexity needed for optimal patient care. Within the x-ray based treatment realm 3-dimensional treatment planning, image guidance, motion management and adaptive planning are readily available with the use of advanced delivery, imaging and planning approaches. These advances are now becoming increasingly available for particle therapy. Pencil beam scanning has allowed increased flexibility of dose delivery to very complex targets. Motion management through gating, immobilization and breath hold techniques are being evaluated and used in many particle therapy centers

As better understanding of the biologic variation within the proton beam develops, biologic planning to match resistant and more sensitive target and normal tissues will be performed. More clinical outcomes data with heavier ions may become available in the near future will allow further optimization of biologic planning for patients.

Overall as the technologies become more available and affordable, clinical indications will expand including complex targets, re-irradiation, large volumes, and moving targets.

Abstract 368 TUE-PS-AP-04-0 Plenary Talk - Tuesday 8:45 AM - Rio Grande

The DOE Isotope Program at Los Alamos National Laboratory

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The Department of Energy (DOE) Isotope Program produces and distributes radionuclides and stable isotopes that are not commercially available or whose domestic demand exceeds supply. Radionuclides are supplied to users for medical,

industrial, and research/development applications. Two high-intensity proton accelerator facilities with the DOE Isotope Program, the Isotope Production Facility (IPF) at Los Alamos National Laboratory, and the Brookhaven Linac Isotope Producer (BLIP) at Brookhaven National Laboratory, provide a domestic capability for bulk radionuclide production. A historical context for these facilities along with planning for future activities and associated upgrades will be presented. Details will be provided on present-day radionuclide production portfolios and associated capabilities as well as strategic planning to meet North America's anticipated radionuclide-related service needs.

Abstract 220 TUE-AA-IBT-01-1 Invited Talk - Tuesday 10:00 AM - Trinity

Chemical Analysis with swift heavy ions: Opportunities and future challenges

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Secondary particle emission under ion irradiation provides unique opportunities for not only insight on ion collision with matter but also material analysis. In particular, molecular ion emission from organic molecules is of interest for practical applications of chemical analysis, and secondary ion mass spectrometry (SIMS) is now widely used in material analysis of polymers and biological samples, as well as semiconductors, ceramics.

Secondary molecular ion emission yield with swift heavy ions is higher than that with conventional keV monomer ion beams, because of their dense excitation during ion impact. Desorption Mass Spectroscopy (PDMS) has been reported and was widely used for analysis of organic samples [1]. In this energy range, most of the deposited energy by incoming ions is used for electronic excitation, although nuclei excitation is dominant for the conventional SIMS technique using low energy (keV) ions. This gives a new opportunity for high sensitive chemical analysis of organic materials. We have demonstrated the technique of molecular imaging with swift heavy ion beams (MeV-SIMS) in biological material analysis [1, 2]. The molecular distribution (up to 1 kDa) was clearly imaged with a lateral resolution of around 5 mm, opening a new opportunity of chemical imaging. MeV-SIMS technique has been developed in various ion accelerator laboratories in the world to establish it as a new ion beam analysis (IBA) technique.

Furthermore, swift heavy ion beams (>MeV) have a high transmission capability in matter, which allows their use for analysis of volatile samples such as liquids, solid-liquid interfaces and wet samples under atmospheric pressure. Since most of liquid molecules are organics and have high vapor pressure, it is hard to use conventional surface analysis technique. We have demonstrated MeV-SIMS under ambient pressure for the first time [4]. Water droplets are clearly observed with "Ambient SIMS".

Recent progress in this MeV-SIMS will be presented and discussed along with its possible applications for organic material analysis.

Acknowledgement

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References

1 A. Hedin, P. Hakansson, M. Salchpour and B. U. R. Sundqvist, Phys. Rev. B, 35, 7371, (1987)

2 Y. Nakata, Y. Honda, S. Ninomiya, T. Seki, T. Aoki and J. Matsuo, J. Mass Spectro., 44, 128 (2009)

3 J. Matsuo, S. Ninomiya, H. Yamada, K. Ichiki, Y. Wakamatsu, M. Hada, T. Seki, T. Aoki, Surf. Inter. Anal., 42, 1612 (2010)

4 M. Kusakari, M. Fujii, T. Seki, T. Aoki and J. Matsuo, J. Vac. Sci..Technol. B 34, 03H111 (2016)

Abstract 131 TUE-AA-IBT-01-2 Invited Talk - Tuesday 10:00 AM - Trinity

MeV-ToF-SIMS/SNMS: accessing the sputtered neutrals

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ToF-SIMS is a powerful tool for investigating the chemical composition of surfaces and has been in use for decades. Even with such wide-spread use, some fundamental questions, such as how ions form during the sputtering process, remain unsolved. Theories which target this question consider electronic excitation at the surface during particle emission as a parameter in calculating the ionization probability of a sputtered particle. Even though these approaches show that electronic excitation of the target surface is crucial for ionization, general predictions on the ionization probabilities for sputtered particles are still not possible.

The research presented here includes the design, methodology development and latest results of the recently installed MeV-SIMS/SNMS instrument at the M1 branch of the UNILAC beam line at GSI in Darmstadt, Germany. In order to integrate the SIMS experiment into the UNILAC beam line and make use of the pulses delivered by the accelerator (3.6 to 11.3 MeV/u), a multi-extraction timing scheme was developed to take the long primary ion pulses (several ms) and low repetition rates (<50 Hz) into account. The experimental setup is designed to focus on investigating and comparing the ionization of sputtered material in swift heavy ion and keV ion bombardment, respectively. To access the neutral fraction of sputtered material, known from many SIMS experiments to represent the vast majority of sputtered material, the use of post-ionization techniques is necessary. The experiment presented here uses a single photon ionization scheme and is for that purpose equipped with an F_2 excimer laser, affording the possibility of investigating the neutral sputtered material and comparing it to the corresponding secondary ions using the same mass spectrometer. To date, no other instrument has been able to compare sputtered ions and post-ionized neutrals under swift heavy ion bombardment simultaneously.

Using the capabilities of the instrument described above, we used a 4.8 MeV/u Au ion and a 4.8 MeV/u Ca ion beam to investigate sputtered ions and neutral material from metals, ionic crystals and organic layers. By comparing the neutral fraction to the emitted secondary ions under swift heavy ion and 5 keV Ar^+ bombardment we were able to calculate the absolute and relative ionization probabilities of indium and molybdenum. Additionally, studies on thin silver films revealed an increase in the sputtering yield during the transition from a continuous film to nanometer sized silver islands on silicon substrate. The results presented in this study may contribute to a better understanding of the emission and formation of ions during sputtering.

Abstract 42 TUE-AA-IBT-01-3 Contributed Talk - Tuesday 10:00 AM - Trinity

MeV SIMS capillary microprobe with secondary electron trigger

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An MeV SIMS probe has been designed and constructed based on a glass micro-capillary. This allows to collimate the primary ion beam diameter to the low micrometer range. Imaging is achieved by means of an XY piezo sample raster stage. Positive secondary ions are detected by a simple linear time-of-flight (ToF) spectrometer. The start signal for the ToF measurement is obtained from secondary electrons emitted from the sample surface by simultaneous extraction of negative particles to the side opposite to the ToF spectrometer. This permits to detect secondary ions very efficiently with a continuous primary beam current of only a few fA. A gas ionization detector in transmission geometry provides an alternative ToF start trigger and can be used for simultaneous STIM measurements of thin samples. Example raster images and key performance figures will be presented and discussed.

Abstract 248 TUE-AA-IBT-01-4 Contributed Talk - Tuesday 10:00 AM - Trinity

Ambient Pressure MeV SIMS - aspects of development and optimisation

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MeV SIMS, the mass spectrometry of secondary ions, is an IBA technique which offers high sensitivity and high-spatial resolution mass imaging of organic species[1]. MeV SIMS finds its background in the PDMS technique which was suppressed and finally abandon due to the rise of new, competitive techniques such as MALDI and DESI, lack of understanding of fundamental mechanism of desorption and ionisation of secondary species from the sample and unpracticality of handling with the radioactive ^{252}Cf source[2]. Ambient Pressure MeV SIMS as a special application of MeV SIMS shares the same underlying mechanism with PDMS which is electronic sputtering unlike keV SIMS where nuclear sputtering dominates over the electronic one and in which a collision cascade model can be used to describe the energy deposition and transfer among constituent atoms of the analysed species. Some other differences between MeV SIMS and keV SIMS such as achieving greater ion yields and lower degree of fragmentation when MeV swift ions are used instead of keV ions enable analysis of molecules up to few kDa which is particularly useful for biomolecules, such as proteins[3]. A further advantage of using MeV ions is that they can be extracted into air which opens a new possibility of developing a fully ambient system. In University of Surrey Ion Beam Centre such a beam is extracted through a 100 nm thick Si_3N_4 window and hits a target at normal incidence. Desorbed species are pushed into capillary of a QTOF mass spectrometer with support of He gas flowing from a second capillary which is placed opposite the capillary of the mass spectrometer.

In Ion Beam Centre we have been gradually modifying the AP MeV SIMS system in order to satisfy the technical requirements needed to carry out the experiments for optimising of the technique. The process of optimisation is more complex for the ambient analysis due to substantial abundance of ambient peaks. Hence various approaches for increasing the ion yield and signal to noise ratio have to be assessed. This work will provide an overview of different optimisation parameters such as the heating of mass spectrometer capillary, applying an electrical bias on the capillary and setting the optimal sampling geometry which includes alignment of the mass spectrometer and He flow capillaries in respect to each other, beam exit window and the sample as well as a comparison between an oxygen and chlorine primary ion beam[4].

1. Jenčič, B. **et al.** Molecular imaging of cannabis leaf tissue with MeV-SIMS method. **Nucl. Instruments Methods Phys. Res. Sect. B Beam Interact. with Mater. Atoms** (2015). doi:10.1016/j.nimb.2015.10.047

2. Macfarlane, R. D. Principles of californium-252 plasma desorption mass spectrometry applied to protein analysis. **Methods Enzymol. 193,** 263-80 (1990).

3. Jones, B. N. **et al.** Comparison of MeV monomer ion and keV cluster ToF-SIMS. **Surf. Interface Anal. 43,** 249-252 (2011).

4. Warmoltz, N., Werner, H. W. & Morgan, A. E. The dependence on the angle of incidence of the steady state sputter yield of silicon bombarded by oxygen ions. **Surf. Interface Anal. 2,** 46-52 (1980).

Abstract 80 TUE-AA-IBT-01-5 Contributed Talk - Tuesday 10:00 AM - Trinity

Enhanced Spatially-Resolved Trace Analysis Using Combined SIMS-Single-Stage AMS at the Naval Research Laboratory

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Secondary ion mass spectrometry (SIMS) provides spatially resolved trace analysis of solid materials, but can encounter uncertainty in signal identification due to unresolved abundant molecular isobars. By adding a single-stage accelerator mass spectrometer (SSAMS) in an MS-MS configuration to a Cameca ims 4f SIMS, one can measure positive ions from the SIMS while removing molecular isobars, something a tandem accelerator cannot provide. As positive ions are more abundant for most elements of the periodic table, this combination allows for very low abundance trace element and isotope analysis by SIMS-SSAMS.

This presentation will describe important features of the integrated system, including the benefit of using charge state 1+ ions, key capabilities such as electrostatic peak switching and beam imaging, operational control of all components, measurement methods of both atomic and molecule-fragment ions, and performance capabilities. Transmission loss will be compared to molecule destruction as gas flow to the molecule-destruction cell increases. As most measurements tolerate more modest abundance sensitivities than for ^{14}C analysis, a lower gas flow is acceptable, so good transmission of 20-50% for ions of interest can be maintained for a broad range of ion masses. This new instrument has measured isotope ratios for uranium, lead, rare earths, and other elements from particulates and localized regions, with molecule destruction enabling the measurement, as examples will show.

This new and world-unique instrument provides improved capabilities for applications in nuclear and other forensics, geochemistry, cosmochemistry, and the development of optical, electronic, multifunctional, and structural materials.

Abstract 447 TUE-AP-MA-05-1 Invited Talk - Tuesday 10:00 AM - West Fork

Detector Technology for Imaging, Monitoring, and Verification of Radiation Therapy

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Our ability to prevent, diagnose, and cure disease has become amazingly sophisticated and exquisitely refined. In part this has been enabled by key technological achievements driven by advancements in particle detection technology. We are accustomed to detector technologies making inroads within imaging and radiation therapy fields, but other areas impacted include personal radiation protection and basic radiobiological research. Looking forward, to perfect proton and heavy ion therapy, a critical challenge before us is to determine the beam range in vivo to high precision. Many exciting approaches to do so are now under active development and make use of the latest technologies, including CdZnTe photon counting detectors, GEM, and Micromegas. The landscape of particle detectors will be related to the needs and goals of medicine. Detector specifications and requirements that are necessary to overcome specific challenges and barriers faced by medical physics and bioengineering fields will be presented and discussed. A special emphasis will be given to systems currently under development to reduce the range uncertainty of proton and heavy ion therapeutic beams.

Abstract 201 TUE-AP-MA-05-2 Contributed Talk - Tuesday 10:00 AM - West Fork

Results from a Prototype Proton-CT Head Scanner

Robert Preston Johnson, Tia E. Plautz[1], Hartmut F.-W. Sadrozinski[1], Vladimir Bashkirov[2], Robert Ford Hurley[2], Reinhard Schulte[2], Keith Schubert[3], Blake Schultze[3], Valentina Giacometti[4], Andriy Zatserklyaniy[1], Pierluigi Piersimoni[2]

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We are exploring low-dose proton radiography and computed tomography (pCT) as techniques to improve the accuracy of proton treatment planning and to provide artifact-free images for verification and adaptive therapy at the time of treatment. Here we report on comprehensive beam test results with our **prototype (**Phase 2) pCT head scanner. The system consists of two silicon-strip telescopes that track individual protons **before and after the phantom** and a novel multistage scintillation detector that measures a combination of the residual energy and range of the proton, from which we derive the water equivalent path length (WEPL) of the protons in the scanned object. The detector system and data acquisition attain a sustained rate of more than a million protons individually measured per second, allowing a full CT scan to be completed in **six** minutes of beam time. The set of WEPL values and associated paths of protons passing through the object over a 360° angular scan is processed by an iterative parallelizable reconstruction algorithm that runs on modern GP-GPU hardware. In order to assess the performance of the scanner **for proton radiography as well as** computed tomography, we have performed **numerous** scans **of phantoms** at the Northwestern Medicine Chicago Proton Center including a custom phantom designed to assess the spatial resolution, a CATPHAN 404 phantom to assess the measurement of relative stopping power, a dosimetry phantom, and a pediatric head phantom. **Images, p**erformance**,** and dosimetry results from those phantom scans are presented together with a d**escription of the instrument, the data acquisition system, and the calibration methods.**

Abstract 210 TUE-AP-MA-05-3 Contributed Talk - Tuesday 10:00 AM - West Fork

Calibration and GEANT4 Simulations of the Phase II Proton Compute Tomography (pCT) Range Stack Detector

S. A. Uzunyan[1], G. Blazey[1], S. Boi[1], G. Coutrakon[1], A. Dyshkant[1], K. Fransis[1], D. Hedin[1], E. Johnson[1], J. Kalnins[1], J. E. Rauch[2], P. Rubinov[2], G. Sellberg[2], P. Wilson[2], M. Naimuddin[3]

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Northern Illinois University in collaboration with Fermi National Accelerator Laboratory (FNAL) and Delhi University has been designing and building a proton CT scanner for applications in proton treatment planning. The Phase II proton CT scanner consists of eight planes of tracking detectors with two X and two Y coordinate measurements both before and after the patient. In addition, a range stack detector consisting of a stack of thin scintillator tiles, arranged in twelve eight-tile frames, is used to determine the water equivalent path length (WEPL) of each track through the patient. The X-Y coordinates and WEPL are required input for image reconstruction software to find the relative (proton) stopping powers (RSP) value of each voxel in the patient and generate a corresponding 3D image. We describe tests conducted prat the proton beam at the Central DuPage Hospital in Warrenville, IL, focusing on the range stack calibration procedure and comparisons with the GEANT~4 range stack simulation.

Abstract 375 TUE-AP-MA-05-4 Contributed Talk - Tuesday 10:00 AM - West Fork

A Real Time Image Reconstruction System for ParticleTreatment Planning Using Proton Computed Tomography (pCT)

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Proton computed tomography (pCT) is a novel medical imaging modality for mapping the distribution of proton relative stopping power (RSP) in medical objects of interest -- phantoms for now but human patients eventually. Compared to conventional X-ray computed tomography (XCT) where range uncertainty margins are often in the order of 3.5%, pCT has the potential to provide more accurate RSP measurements (i.e., within 1%). This improved accuracy could prove invaluable in proton-therapy planning and pre-treatment verification. We have developed the second phase of a pCT imaging system with proton tracking and residual energy detectors, a fast data acquisition system, and an advanced image reconstruction program. These features are aimed at making RSP images available within minutes for use in clinical settings. Our reconstruction software is based on distributed computing that utilizes parallel processors and general-purpose graphical processing units. The performance of our pCT system has been evaluated with phantom scans at the Northwestern Medicine Chicago Proton Center and its future applications will be discussed.

Abstract 181 TUE-AP-MA-05-5 Contributed Talk - Tuesday 10:00 AM - West Fork

Characterisation of a CZT Detector for Dosimetry of Molecular Radiotherapy

Lucy H McAreavey[1], Laura J Harkness-Brennan[1], Samantha J Colosimo[1], Daniel S Judson[1], Helen C Boston[1], Andrew J Boston[1], Paul J Nolan[1], Dave Seddon[1], Glenn D Flux[2], Ana M Denis-Bacelar[3], B Harris[4], Ian Radley[5], Melvyn Carroll[6]

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Molecular radiotherapy (MRT) involves the internal administration of radiopharmaceuticals to deliver high radiation doses to targeted tissue whilst minimising the dose to surrounding healthy tissue. Although MRT has been used clinically for around 75 years, there are no established dosimetry practices for calculating the absorbed dose delivered to tumour targets or organs at risk from the administered activity. Current MRT treatment plans are undesirably generic as the administered activity is often fixed for a given procedure, or scaled according to the weight of the patient. However, the uptake and retention of the MRT therapeutic agents and hence the radiation dose can vary by up to two orders of magnitude between patients due to the wide range of biokinetics and disease status. This means the outcome of the treatment is somewhat uncertain. Single photon emission computed tomography (SPECT) can be used to image gamma rays emitted in MRT, however quantitative dosimetric information is lost due to dead time in current diagnostic SPECT systems because they are not optimised for the high activities of the isotopes administered in MRT. Therefore a custom-designed compact SPECT system is being developed as part of the DEPICT project to facilitate quantitative dosimetry for MRT based on a collimated, pixelated cadmium zinc telluride (CZT) detector. The system will give an assessment of the radiation dose delivered to the patient, tailored specifically for MRT of the thyroid with ^{131}I. CZT is a direct band-gap semiconductor with superior energy resolution, spatial resolution and stopping power, compared to conventional scintillator based SPECT detector systems. Good energy resolution is required to discriminate gamma-rays that are scattered as they are emitted from the body and within the collimator, and high photon throughput it essential due to the high activities of isotopes administered in MRT. The inherent CZT detector properties have been investigated and operational parameters such as bias voltage and peaking time have been selected to optimise the performance of the system. Uniformity plots were created and planar images of the medical imaging isotopes ^{99m}Tc and ^{123}I were acquired by coupling the detector to a prototype collimator, thereby demonstrating the suitability of the detector for the DEPICT project.

Abstract 428 TUE-AP-SD-02-1 Invited Talk - Tuesday 10:00 AM - Elm Fork

Current and Future Radiological Imaging Interdiction requirements

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Many tactics are employed including radiographic imaging system during interdiction efforts at border crossings nationally and internationally. Imaging system utilize gammas sources, linear accelerators, reflective X-Ray, and betatrons to generate images of internal structures of interest in commerce transports, baggage, mail, and non-commercial vehicles. Current accelerators are physically large, have high power consumption, require complex electronics, and have narrow tolerances to generate images of sufficient quality for inspection purposes. It is generally accepted that national and private organizations continue to seek advanced accelerator designs for radiographic imaging that have improved sensors and beam properties for auto-detection applications, low power consumption and physical size, while based on mature design and reliable, well-tested components. This discussion will focus on requirements for accelerator functional and operational design to meet the challenges of the evolving threat.

Abstract 294 TUE-AP-SD-02-2 Invited Talk - Tuesday 10:00 AM - Elm Fork

Vehicle and Cargo Scanning for Contraband*

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There is a need to inspect vehicles and their contents for Special Nuclear Material (SNM) and general contraband. The most widely used technology for scanning vehicles, ranging from vans and trucks to railcars, is gamma-ray and x-ray radiography. New technologies require higher penetration to reduce insufficient penetration alarms and to improve image quality and material discrimination to increase detection at higher speeds for increased throughput and to enable scanning fast-moving trains. In most cases, the scanning footprint, which includes the radiation exclusion zone, must be small due to the limited space available at the inspection sites. Some of these conflicting requirements have been addressed by employing adaptive intensity and/or energy modulation of the x-ray source. Any alarms produced by these primary systems need to be cleared or confirmed to avoid labor-intensive manual inspection. Various technologies have been proposed and used for secondary inspection, mainly based on the detection of fission signatures. Such systems should preferentially require minimal infrastructure and cost should be kept reasonably commensurate with the performance improvements to allow for wide deployment. A summary of primary and secondary technologies is given.

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Abstract 97 TUE-AP-SD-02-3 Contributed Talk - Tuesday 10:00 AM - Elm Fork

A Distributed Data Acquisition System for the Sensor Network of the TAWARA_RTM Project

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We discuss here a distributed Data Acquisition System (DAQ) developed for the TAWARA_RTM project (TAp WAter RAdioactivity Real Time Monitor). The aim is detecting the presence of radioactive contaminants in drinking water; in order to prevent deliberate or accidental threats. Employing a set of detectors, it is possible to detect alpha, beta and gamma radiations, from emitters dissolved in water. The Sensor Network (SN) consists of several heterogeneous nodes controlled by a centralized server. The SN cybersecurity is guaranteed, in order to protect it from external intrusions and malicious acts. The nodes were installed in different locations, along the water treatment processes, in the waterworks plant supplying the aqueduct of Warsaw, Poland. Embedded computers control the simpler nodes, and are directly connected to the SN. Local-PCs (LPCs) control the more complex nodes, that consist signal digitizers acquiring data from several detectors. The DAQ in the LPC is split in several processes communicating with sockets in a local sub-network. Each process is dedicated to a very simple task (e.g. data acquisition, data analysis, hydraulics management...) in order to have a flexible and fault-tolerant system. The main SN and the local DAQ networks are separated by data routers, to ensure the cybersecurity.

Abstract 363 TUE-AR-ISM-03-1 Invited Talk - Tuesday 10:00 AM - Post Oak

$SrTiO_3$ under ion-beam irradiation at high electronic excitation densities: evidence for self-trapped electrons

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Energetic ions produce high densities of electronic excitation along their trajectories. Luminescence induced by ion-beam irradiation is an **in-situ** technique to investigate radiation-induced processes. Visible luminescence in stoichiometric $SrTiO_3$ has been studied under irradiation with different ions (H, O, Si, Cl, Ti) at energies ranging from 3-20 MeV and at temperatures of 100 K, 170 K and RT. With ion energies on the order of MeVs and above, the deposited energy density to target electrons is comparable to femtosecond laser irradiations. The wide range of electronic (Se) (from ~ 0.04 to 8.5 keV/nm) and nuclear stopping powers allows standing out the differences between nuclear and electronic processes in their dynamic roles in the luminescence process.

The IL reveals a broad spectrum that can be resolved into three main Gaussian bands at 2.0 eV, 2.5 eV and 2.8 eV, whose relative contributions depend strongly on irradiation temperature and electronic energy loss. All bands are intrinsic and associated with electron-hole recombination. The 2.8 eV band is attributed to recombination of free (conduction) electrons with self-trapped holes. Self-trapped excitons are considered suitable candidates for the 2.5 eV band. The well-defined band at 2.0 eV, which dominates at 100 K, has previously been observed in heavily strained and amorphous STO, and is, here, attributed to **d-d** transitions from self-trapped electrons at relaxed Ti^{3+}centers. In fact, the intensity of the band is observed to grow as the accumulation of irradiation damage creates distorted TiO_6 octahedra, hindering the translational symmetry in the crystal. Based on the systematic study, a new framework is presented for the interpretation of the IL emission bands, and the role of the excitation densities, electronic energy loss and nuclear collisions will be discussed.

This work was supported in part by the U.S. Department of Energy, Office of Basic Energy Sciences, Materials Sciences and Engineering Division.

Abstract 336 TUE-AR-ISM-03-2 Invited Talk - Tuesday 10:00 AM - Post Oak

Characterization of He implanted pyrochlores using complementary diffraction microscopy techniques

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Nuclear waste forms will undergo α-decay damage for hundreds of thousands of years in a geological repository. As such, the response of pyrochlores to irradiation induced phase transformations, including amorphization, has been the focus of many past studies. The effects of concomitant He accumulation have, to the best of our knowledge, not been explored systematically. While some pyrochlores, such as $Gd_2Ti_2O_7$, have been found to amorphize under irradiation, $Gd_2Zr_2O_7$ transforms to the defect-fluorite phase but remains crystalline at extremely high doses and is generally considered resistant to radiation damage. This work provides experimental evidence that $Gd_2Zr_2O_7$, often considered the most radiation resistant pyrochlore, is in fact susceptible to radiation damage and undergoes unit cell volume swelling of about 3.056% due to He accumulation and the nucleation of 1-3 nm He bubbles, some of which were observed to coalesce into chains 10-30 nm in length, during the first ~1 million years of storage. Such modifications can have a huge implication on the performance of pyrochlore waste forms at the high damage doses expected during long-term geological disposal. Similar results will also be presented for He implanted amorphous $Gd_2Ti_2O_7$. Through the present talk we will try to demonstrate the use of diffraction techniques in complement to microscopy techniques in understanding radiation induced modifications. We will also present the current state of understanding in the use of diffraction techniques like High Resolution X-ray diffraction (HRXRD) and X-ray Reflectivity (XRR) techniques in characterizing ion beam induced modifications.

Abstract 358 TUE-AR-ISM-03-3 Invited Talk - Tuesday 10:00 AM - Post Oak

Properties of ion beam synthesized B20-type ternary $Fe_{(1-x)}Co_xSi$ thin films

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Ternary metal silicides have been by far less studied than their binary counterparts despite the fact that they have interesting magnetic and electronic properties for realization of spintronic, magneto-opto-electronic and thermoelectric device materials systems. In this study ternary $Fe_{(1-x)}Co_xSi$ B20 phase was formed by implanting Fe & Co consecutively into Si substrate at 50 keV energy. An external magnetic field was used to enhance the formation of ternary phase in substrate during the ion implantation process. The applied external magnetic field was perpendicular to the incoming ion direction and parallel to the substrate surface, which is much stronger compared to the earth's magnetic field. Then, samples were annealed in vacuum at 500 ^oC for 60 minutes. X-ray diffraction (XRD) and X-ray photoelectron spectroscopy (XPS) results indicate formation of $Fe_{(1-x)}Co_xSi$ B20 structure with lattice parameter 0.453±0.003 nm. Magnetic property measurements indicates typical diamagnetic response for as-implanted sample with weak ferromagnetic contribution. This diamagnetic behavior comes from the silicon substrate and the implanted Iron and Cobalt forms some ferromagnetic structure during the implantation process to contribute the weak ferromagnetic contribution in the as-implanted sample. Further, magnetization of as-implanted sample does not show strong temperature dependence which indicates strong diamagnetic behavior in the sample. After the heat treatment, the sample shows ferromagnetic behavior at 3 K & 300 K temperature. Further results shows coercivity which corresponds to typical ferromagnetic materials. Studies shows that $Fe_{(1-x)}Co_xSi$ B20 phase has helical magnetic ordering. But these experimental observations contradict previous claims on $Fe_{(1-x)}Co_xSi$ B20 phase structure by showing coercivity values. Moreover, a magnetic phase transitions was observed around ~ 50 K.

Abstract 215 TUE-AR-ISM-03-4 Contributed Talk - Tuesday 10:00 AM - Post Oak

Ion Beam Analysis of Interstitial Complexes in GaAs(Bi)N Alloys

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Due to their significant band-gap narrowing with minimal change in lattice parameter, dilute nitride semiconductor alloys are useful for a variety of applications, including long-wavelength lasers and detectors, ultra-high-efficiency solar cells, and high performance heterojunction bipolar transistors. However, N-related point defects often contribute to carrier scattering and recombination, leading to degraded carrier mobilities and optical efficiencies. For GaAsN and related alloys, co-alloying with larger group V elements such as Sb or Bi is expected to lead to significant energy bandgap narrowing using a substantially lower N fraction, and a correspondingly lower concentration of N-related defects. For GaAsN, several groups have suggested that N shares an arsenic site with either arsenic or another N atom, often termed $(N\text{-}As)_{As}$ or $(N\text{-}N)_{As}$ split interstitials [2][3][4][5]. In the case of GaAsNBi, the published experimental work has focused primarily on growth parameters and optical properties, without addressing the mechanisms for N and Bi co-incorporation during epitaxy. To identify N-related defects, we compare channeling Rutherford backscattering and nuclear reaction analysis spectra with Monte Carlo-Molecular Dynamics simulations along the [100], [110], and [111] directions. Using this combined computational-experimental approach, we have identified $(N\text{-}As)_{As}$ is the dominant interstitial GaAsN [6]. For GaAsNBi, a comparison of NRA and x-ray rocking curve analyses reveals enhanced N incorporation in the presence of Bi. Furthermore, ion channeling measurements reveal non-substitutional incorporation of the extra N. We are currently considering the nature of the N interstitial complexes in GaAsNBi, including the relative concentrations of $(N\text{-}N)_{As}$, $(N\text{-}As)_{As}$, and $N_{tetrahedral}$.

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[1] T. Dannecker, J. Buckeridge, S. Fahy, Y. Jin, C.F. Gorman, R.S. Goldman, H. Cheng, C. Kurdak, C. Uher, Phys. Rev. B **82**, 125203 (2010).

[2] P. Carrier, S.-H. Wei, S. B. Zhang, and S. Kurtz, Phys. Rev. B **71**, 165212 (2005).

[3] K. Laaksonen, H.-P. Komsa, T. T. Rantala, and R. M. Nieminen,J. Phys.: Condens. Matter **20**, 235231 (2008).

[4] M. Reason, H. McKay, W. Ye, S. Hanson, V. Rotberg, and R.S. Goldman, Appl. Phys. Lett. **85**, 1692 (2004)

[5] S.B. Zhang and S.H. Wei, Phy. Rev. Lett. **86**, 1789 (2001).

[6] T. Jen, G. Vardar, Y. Q. Wang, and R. S. Goldman. Appl. Phys. Lett. **107**, 221904 (2015)

We gratefully acknowledge support from the National Science Foundation (Grant No. DMR 1410282) and the U.S. Department of Energy Office of Science Graduate Student Research (SCGSR) Program.

Abstract 212 TUE-AR-ISM-03-5 Contributed Talk - Tuesday 10:00 AM - Post Oak

Impact of Crystallinity on the Luminescence of Si Implanted Alumina Films

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Si nanoclusters (Si-NCs) embedded in dielectric materials have been the subject of intense research due to their potential applications in optical and optoelectronic devices. A number of research studies have focused on Si-NCs made by implanting Si ions in SiO_2. However, the mechanism by which Si-NCs luminescence is not fully understanding due to the

difficulty in distinguishing between luminescence originating from defects in the SiO_2 matrix and Si-NCs.[1-3] Gaining an understanding of these processes would aid in the development of a Si- based light source, which is key to the development of high efficiency optical and optoelectronic devices. It is for these reasons that we have chosen to study the luminescence of Si implanted Al_2O_3 films. Al_2O_3 possesses a band gap energy that is adequate for charge carrier confinement and a high dielectric constant which makes it a promising candidate for charge storage devices. Using Al_2O_3 allows for better interpretation of the luminescence spectra and its transparency makes it suitable of the fabrication of transparent devices.[4]

We have implanted Si ion into crystalline and amorphous Al_2O_3 followed by an annealing process. The amorphous Al_2O_3 films used were synthesized by anodization of Al foils, and crystalline samples were purchased from MTI Corporation and Valley Design Corporation. An in-depth analysis of the structure, composition and optical properties of the samples produced was conducted. A number of ion beam analysis techniques were used to the study the composition of the samples produced these techniques include particle induced x-ray emission (PIXE), Rutherford backscattering spectroscopy (RBS), elastic recoil detection analysis (ERDA). Other complimentary techniques such as photoluminescence (PL) spectroscopy, cathodo-luminescence (CL) spectroscopy, scanning electron microscopy (SEM), powder x-ray diffraction (XRD), Fourier transform infrared spectroscopy (FT-IR) and x-ray absorption near edge spectroscopy (XANES) were also utilized to study the structure and optical properties the samples. From these analyses we conclude that the luminescence of this type of system is impacted by both the crystallinity of the matrix and the hydrogen content with in the Al_2O_3 matrix.

References

[1] Giorgis, F., et al. Phys. Rev. B 61 (2000) pp 4693.

[2] Wang, M., et al. Appl. Phys. Lett. 90 (2007) pp 131903.

[3] Canham, L. T. Appl. Phys. Lett. 57 (1990) pp 1046.

[4] Yanagiya, S., et al. Journal of Electronic Materials 28 (1999) pp 496.

Abstract 218 TUE-AR-ISM-03-6 Contributed Talk - Tuesday 10:00 AM - Post Oak

Ion beam analysis of antiferrodistortive cubic to tetragonal structural phase transition and lattice distortion in perovskite $SrTiO_3$

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Rutherford Backscattering Spectrometry-Axial Ion Channeling is used to probe displacive phase transition & lattice distortion in perovskite $SrTiO_3$. It provides direct evidence of incoherent lattice fluctuations as function of temperature across non-ferroelectric (FE) 2^{nd} order antiferrodistortive (AFD) structural phase transition from cubic to body-centered tetragonal at Curie-Weiss T_0=105 K, caused by antiphase tilting of TiO_6 octahedra.This phase transition is described by minimizing Gibbs free energy with respect to AFD-rotation angle. AFD-rotation opens the bandgap & weakens the FE instability by reducing cross gap hybridization. Jahn-Teller (JT) effect occur for degenerate filled & empty molecular orbitals. Critical channeling angle ψ_c & ratio of minima of angular RBS-ICh spectral yield χ_{min} for Sr & Ti sublattices determine JT lattice distortion in transition element (Fe, Cr etc.) implanted $SrTiO_3$. Similar values of $\boldsymbol{\psi}_{1/2}$ for Sr sublattice indicates no displacement of Sr. Distortion of Ti sublattice infers implanted transition element is actually located in Ti positions but not in interstitial positions. Temperature dependence of Thermal vibrational amplitudes of lattice atoms (Sr & Ti) and the displacements of Ti^{4+} are calculated based on Linhard's continuum model. Defects in semiconducting $SrTiO_3$ narrows large band gap & raises Fermi level into conduction band & ensures conductivity. Implanted $SrTiO_3$ shows a minor tetragonal phase corresponds to lattice expansion along the c-axis and it's not randomly oriented. Structural defects can induce lattice expansion or contraction along normal of free surface, XRD peak shift & broadening. RBS - Ion

channeling made it possible to obtain direct evidence for manifestation of structural phase transition and Jahn-Teller effect in $SrTiO_3$ lattice.

Abstract 107 TUE-PR-AMP-02-1 Invited Talk - Tuesday 10:00 AM - Rio Grande

Fully Differential Study of Ionization in p + H_2 Collisions near Electron - Projectile Velocity Matching

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We have measured scattered projectiles and singly charged recoil ions, both fully momentum-analyzed, in coincidence for 75 keV p + H_2 collisions [1]. From the data we extracted fully differential cross sections (FDCS) for target ionization. Earlier, measured FDCS for this process were reported for a large variety of different kinematic settings [2]. However, in all of these studies the electron speed was always small compared to the projectile speed. In the present work we report FDCS for electrons with a speed nearly equal to the projectile speed. Theory predicted that the fully differential angular electron distribution for this kinematic regime is dominated by a very large and narrow peak structure at 0^o (relative to the projectile beam axis). Surprisingly, the FDCS at 0^o are rather weak and the most important feature is the so-called binary peak occurring in the direction of the momentum transfer vector. The very strong suppression of the 0^o peak is probably due to a strong coupling between the ionization and capture channels, which is not accounted for by the existing theoretical calculations. As a result, electrons moving at the same speed and in the same direction as the projectiles are very likely to be captured, especially at small scattering angles, so that the flux in the ionization channel is correspondingly reduced.

This work was supported by the National Science Foundation.

[1] A. Hasan et al., J. Phys. B 49, Letter, 04LT01 (2016)

[2] M. Schulz and D.H. Madison, International Journal of Modern Physics A21, 3649 (2006)

Abstract 127 TUE-PR-AMP-02-2 Invited Talk - Tuesday 10:00 AM - Rio Grande

Charge-exchange processes in collisions of H^+, H_2^+, H_3^+, He^+, and He_2^+ ions with CO and CO_2 molecules at typical Solar-wind velocities (<1000 eV)

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Ions are very important components of interstellar matter. Usually they travel at high speeds through the Universe, influencing every molecule they encounter. Stars are the main source of ions and most common particles in the stellar wind are protons H^+, with small admixture of a few percent of He^{2+} and He^+ ions. Other heavier components (beside hydrogen and helium ions) are present in very small traceable amounts. There is also the possibility of forming a molecular H_2^+ ion flux, when H_2 molecules from a local interstellar medium or outgassed interplanetary dust is ionized and pickup by primary stellar wind ions.

Velocities of stellar wind ionized particles range from about 20 km/s for cooler stars (e.g. red giants) up to 2000 km/s for hot massive stars. Our Sun is a medium sized star that continuously emits ionized particles with velocities (depending on the Solar activity) from 200 km/s up to 700 km/s (an equivalent to a 0.2-2.6 keV energy range for protons).

CO and CO_2 are one of the most abundant molecules observed in interstellar matter, in comets or in the atmosphere of certain planets after H_2 or water. The ions passing through molecular media could excite, ionize, dissociate the molecules, or in addition neutralize themselves through charge exchange processes (CE). However, at this particular velocity range (approx. < 20 keV) the charge exchange processes are the most important. The interaction of a continuous stream of ionized particles with interstellar medium is of importance for cosmochemistry. Interstellar evolution models rely heavily on accurate laboratory data, e.g. on reaction rates or cross sections. Inaccuracy of this data could lead to significant errors in determination of the abundances of interstellar media components.

Using the technique of measuring the attenuation of ions passing through the media layer at a given length and concentration, we have determined the charge exchange absolute cross sections for several hydrogen and helium ions: H^+, H_2^+, H_3^+, He^+ and He_2^+ ions in CO and CO_2 molecules at typical Solar wind velocities (<1000 eV) [1]. Measurements for the H^+ and He^+ ions have been performed many times in the past. However, they could be used as a control to check the method in order to measure the CE cross sections for other interesting ions, i.e. H_2^+, H_3^+, and He_2^+.

The cross section dependencies on the number of ion projectile atomic centers can be explained on the basis of the assumption of asymmetric near-resonant CE process including the Doppler broadening of the target molecules and the energy defect of the reactions. In addition to the CE cross sections, observation of the excited collision products in a laboratory [2,3] gives access to estimates for luminescence cross sections and to the identification of different collision channels that could be observed indirectly in space through telescopes.

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[1] S.Werbowy, B.Pranszke, Phys. Rev. A, 93 (2016) 022713

[2] S.Werbowy, B.Pranszke, Astrophys. J, 780 (2014) 157

[3] S.Werbowy, A.Kowalski, B.Pranszke, Chem. Phys. Lett., 641 (2015) 136

Abstract 374 TUE-PR-AMP-02-3 Invited Talk - Tuesday 10:00 AM - Rio Grande

Electron emission from condensed-phase targets induced by fast ions

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Absolute doubly differential electron emission yields from solid targets following the passage of fast ions are presented. The targets include polycrystalline metals (gold and copper) and thin films of frozen molecular targets (hydrocarbons and amorphous solid water). These targets were bombarded with fast protons and light ions (carbon and fluorine), and the secondary electron emission yields were measured using electron time of flight. The experiments were conducted in the ion

beam facilities at East Carolina University and at the J.R. Macdonald Laboratory at Kansas State University. Applications for the secondary electron spectra, which range from testing track structure codes for radiation damage to nanoparticle enhancement of killing tumor cells in hadron therapy for cancer treatment, will be discussed.

Abstract 207 TUE-PR-AMP-02-4 Contributed Talk - Tuesday 10:00 AM - Rio Grande

Versatile Device to Probe Quantum Properties of Small Molecular Ion Beams

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We are presenting the progress made on the development of a versatile device that probes quantum properties of small molecular ions. H_2^+ is a simple but fundamental example of such an ion. These molecular ions are important because they are abundantly found in space, and might also briefly exist in other settings, including living organisms. In the case of diatomic molecular ions, the two atoms of the molecule behave very similarly to two weights on a classical spring which vibration is quantized. Our device is meant to probe these discrete states and is comparable to a thermometer reading a low temperature for a cold object and high temperature for hot one. It will provide data that will help to understand how the vibrational states affect their environment during slow interactions with other particles.

Not well understood, these slow interactions, such as low energy charge transfer, are known to play important roles in the interstellar medium, in the cold part of nuclear fusion plasma, and in the processes of DNA strand breaks, etc. Alas, it is often almost impossible to compare laboratory measured cross sections to existing theories and calculations because the vibrational state distribution of the molecules is not known. However, the proposed quantum probe device will ultimately upgrade the heretofore absolute cross section measurements to vibrationally resolved ones, enabling detailed comparison between theoretical and experimental results. The technique is similar to the one used in 3-D imaging by Urbain et al. [1] for which the molecular ion undergoes a resonant dissociative charge exchange with an alkali atom and releases its vibrational energy in form of kinetic energies of the two fragments. The detection of the positions of the daughter particles and their flight time differences, which is equivalent to taking a time resolved snapshot picture of both the molecular ion fragments, allows the reconstruction of the molecular ion's initial vibrational energy via simple dynamics. The whole is envisioned to be a portable device which could be easily transported to and used by other research facilities.

[1] X. Urbain, N. de Ruette, V. M. Andrianarijaona, M. F. Martin, L. FernÁndez Menchero, L. F. Errea, L. Méndez, I. RabadÁn, and B. Pons, "New Light Shed on Charge Transfer in Fundamental H^++H_2 Collisions" Phys. Rev. Lett. **111**, 203201 (2013)

Abstract 440 TUE-PR-SP-01-1 Invited Talk - Tuesday 10:00 AM - Bur Oak

Testing the Standard Model via superallowed nuclear beta decay

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Very precise measurements in nuclei can offer demanding tests of the Standard Model. In particular, superallowed nuclear beta-decay between 0^+ analogue states is a sensitive probe of the vector part of the weak interaction, with the established strength - or F t value - of each such transition being a direct measure of the vector coupling constant, G_V. Each transition's F t value depends on the half-life of the parent nucleus as well as on the Q-value and branching ratio for the transition of interest. It also depends on small (~1%) transition-dependent theoretical corrections, of which the most sensitive accounts for isospin symmetry breaking. The most recent survey of world superallowed-decay data [1] includes 222 individual measurements of comparable precision obtained from 177 published references; it establishes the F t values of 14 separate superallowed transitions to a precision of order 0.1% or better. These results, which cover a wide range of parent nuclei from ^{10}C to ^{74}Rb, constitute a very robust data set.

Excellent consistency among the average F t-values for all 14 transitions - an expected consequence of the conservation of vector current (CVC) - confirms the validity of the correction terms; and measurements that closely compare pairs of mirror superallowed transitions are beginning to provide a powerful new test of the correction terms' validity [2].

With CVC upheld, the average result for G_V in turn yields the value of $\mathbf{V}_{ud}$, the up-down quark mixing element of the Cabibbo-Kobayashi-Maskawa (CKM) matrix. Not only is this the most precise determination of V_{ud}, it is the most precise result for any element in the CKM matrix. The CKM matrix is a central pillar of the Standard Model and, although the model does not predict values for the matrix elements, it demands that the matrix itself be unitary. The experimental value for V_{ud} obtained from superallowed beta-decay leads to the most demanding test available of CKM unitarity.

Neutron beta decay can also be used to determine V_{ud}, but experimental problems have so far limited the precision that can be attributed to averages obtained from neutron world data. Though substantially less precise, neutron data yield a value for V_{ud} that is statistically consistent with the value from superallowed decays. Prospects for future improvements to V_{ud} will be discussed.

[1] J.C. Hardy and I.S. Towner, Phys. Rev. C **91**, 025501 (2015).

[2] H.I. Park **et al**., Phys. Rev. Lett. **112,** 102502 (2014).

Abstract 412 TUE-PR-SP-01-2 Invited Talk - Tuesday 10:00 AM - Bur Oak

Effect of MTAS results on decay heat and reactor anti-neutrino spectra

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The Modular Total Absorption Spectrometer (MTAS) is a large solid-angle γ-ray detector constructed and commissioned at the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory. It consists of 19 hexagonal shaped modules, representing more than 1 ton of NaI(Tl). The photopeak efficiency approaches 80% under 1 MeV and 70% for 5-MeV. The total efficiency is roughly 96-98%.

Total absorption spectroscopy is an ideal technique for establishing an accurate map of β-decay feeding. From this, one can determine the distribution of γ, β, and anti-neutrino energy released in the decay of fission products.

The anti-neutrino energy spectrum is often used to calculate the total anti-neutrino flux emitted by reactor cores and the number of interactions that should occur within a detector. The number of measured anti-neutrino interactions is about 6% smaller than expected, which has been called the reactor anti-neutrino anomaly [1]. The γ and β energy spectra are important for the determination of the decay heat released from fission products during nuclear fuel cycle. Existing theoretical simulations of decay heat show significant deviations from experimental data [2,3]. These discrepancies are believed to be partially due to the incorrect or incomplete β-decay schemes.

In this contribution we present the results of a total absorption measurement performed with MTAS at the HRIBF using proton-induced fission of ^{238}U and on-line mass separation. In particular, we focus on several β-decaying nuclei that are abundantly produced in reactor cores. The results and their impact on the reconstruction of the decay heat and anti-neutrino spectrum will be presented and discussed.

Abstract 326 TUE-PR-SP-01-4 Contributed Talk - Tuesday 10:00 AM - Bur Oak

High-Statistics β-Decay Study of ^{122}Xe

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The Xe isotopes are centrally located in the Z > 50 , N < 82 region that displays an extraordinarily smooth evolution of simple collective signatures. However, the collectivity of excited states in this region is poorly characterized because of a general lack of spectroscopic data for low-spin states that provide measures of collective properties such as relative and absolute B(E2) decay strengths and the occurrence of E0 decays. There are spectroscopic hints to unusual structures in this region. The third 0^+ states in $^{124-132}Xe$ are very strongly populated in (^3He; n) reactions [1], suggesting a pairing vibrational structure influenced by proton sub-shell gaps, perhaps leading to shape-coexistence that could give rise to strong E0 transitions. Recent work on ^{124}Xe [2] has established nearly identical quadrupole collectivity for the pairing vibrational third 0^+ band and the ground state band. However, in ^{122}Xe, the third 0^+ state has not been firmly identified.

The experiment to study the β decay of ^{122}Cs was performed at the TRIUMF-ISAC facility located in Vancouver, B.C., Canada. A 65- A, 500-MeV proton beam from the TRIUMF cyclotron was delivered to the ISAC facility and bombarded a thick nat Ta foil target. Products of the spallation reaction diffused to the surface of the Ta target foils, were ionized with a Re surface-ion source, and passed through a magnetic mass separator that was set to select singly-charged A = 122 ions. The high-intensity beam of ^{122}Cs was delivered to the centre of the 8π γ-ray spectrometer and implanted into a FeO-coated mylar tape. The 8π spectrometer, consisting of 20 high-purity Ge detectors, was used for γ-ray detection and PACES, an array of five Si(Li) detectors for conversion-electrons, was located immediately behind the beam deposition point. The decay scheme has been considerably extended through a γ-γ coincidence analysis, and new 0^+ states have been identified via angular correlations. The status of the data analysis and preliminary results will be presented.

[1] W.P. Alford, et al., Nucl. Phys. A323 , 339 (1979).

[2] A.J. Radich et al. , Phys. Rev. C 91 , 044320 (2015).

Abstract 352 TUE-PR-SP-01-5 Contributed Talk - Tuesday 10:00 AM - Bur Oak

Characterizing the future site for PROSPECT

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The discovery of neutrino oscillations commenced exploration of a rich field of science at the intersection of nuclear, particle and astrophysics. This brought a number of interesting questions related to the neutrinos to the forefront of scientific literature. PROSPECT, the Precision Reactor Oscillation and Spectrum Experiment, aims to help answer some of those questions by precisely measuring the antineutrino flux and energy spectrum 7-9 meters from the highly enriched ^{235}U reactor core at Oak Ridge National Laboratory's High Flux Isotope Reactor (HFIR) with the goal to better probe sterile neutrino best fit region. For this reason a detailed characterization of the background radiation field is needed.

Here we present DANG (the Detector Array to measure Neutron and Gamma radiation), an array of detectors deployed at HFIR to characterize spatial and time variations of the emitted background radiation. The array scans the entire proposed volume of the future PROSPECT location, providing a 3-D map of the background. Additionally, the array allows the study of the time evolution of HFIR correlated background to better understand how the reactor's prompt and activation radiation changes as function of the reactor cycle. Both a discussion of the construction and operation of the array will be given as well as a look at first results.

Abstract 369 TUE-PR-SP-01-6 — Contributed Talk - Tuesday 10:00 AM - Bur Oak

The ^{13}C(α,n)^{16}O reaction: A background source for underground astrophysics measurements and geo-neutrino measurements.

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In addition to its astrophysical importance to the s-process for stellar nucleosynthesis, the ^{13}C(α,n)^{16}O reaction serves as a source of (α,n) background neutrons in underground nuclear astrophysics measurements as well as for background in measurements of geo-neutrinos. In the detection of geo-neutrinos, the large organic liquid scintillator detectors used for such measurements naturally contains approximately 1.1% 13C. Alpha emitting radionuclide impurities present in the liquid such as ^{210}Po can induce ^{13}C(α,n)^{16}O reactions which are often indistinguishable from a true antineutrino signal [1]. The 2.2 MeV Q-value of the ^{13}C(α,n)^{16}O reaction permits neutron production from the population of the ^{16}O ground state as well the higher excitation states over the range of alpha energies present from the radionuclide impurities. In this study, we present results for a neutron spectroscopic study of the ^{13}C(α,n)^{16}O reaction between E_α = 3.5 - 7.5 MeV performed at the University of Notre Dame Nuclear Science Laboratory. This measurement was performed with deuterated liquid scintillator detectors that are capable of extracting neutron energy spectra via a spectral unfolding technique without the need for neutron time-of-flight measurement [2]. This permits the extraction of the ground state and excited state contributions to the total reaction cross section. The usefulness of this technique for the measurement of beam-induced neutron background sources in deep underground nuclear astrophysics measurements will be shown. Results showing the contributions of excited state components to the total cross section will be given and their implication to geo-neutrino measurements will be discussed.

[1] S. Harissopulos, et al, Phys. Rev. C 72, 062801 (2005) [2] M. Febbraro, et al., NIM A784 (2015) This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, NSF grant PHY0969456, PHY1401343, and Defense Nuclear Nonproliferation R&D (NA-22).

Abstract 433 TUE-PR-SP-01-7 Contributed Talk - Tuesday 10:00 AM - Bur Oak

Pionic Fusion detection using the Partial Truncated Icosahedron (ParTI) Phoswich Array and Fast-Sampling Digital Electronics

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The pionic fusion reaction 4He + 12C →16N + π+ has been measured at the Texas A&M University Cyclotron Institute using a 55 MeV/nucleon alpha beam provided by the K500 superconducting cyclotron. Pionic fusion is the process by which two nuclei fuse during a collision and then deexcite by the exclusive emission of a pion. The resulting compound nucleus is left in or near its ground state. The process requires that nearly all of the available kinetic and potential energy in the colliding system be concentrated into two degrees of freedom - the rest mass and kinetic energy of the emitted pion. Thus, the energy of the emitted pion is limited by the number of available final states of the fusion residue. The combination of limited available energy and the extreme coherence required in the process ensures that the pionic fusion channel is greatly suppressed. Indeed, measured pionic fusion cross sections range from hundreds of nanobarns for the lightest systems (He + He) to hundreds of picobarns as one moves to larger systems.

The Partial Truncated Icosahedron (ParTI) phoswich array was designed and constructed for the purpose of measuring low-energy pions produced in pionic fusion reactions. The array consists of 15 plastic/CsI(Tl) phoswich detector units arranged in a partial soccer ball shape covering approximately one hemisphere of the solid angle. The plastic and CsI scintillating components are optically coupled together and read out by a single Hamamatsu R1924a photomultiplier tube. The data acquisition for the phoswiches is handled by a Struck SIS3316 fast-sampling (250 MS/s) digitizer so that the waveform in each phoswich event could be written. By integrating over gated regions of the phoswich waveforms, light charged particles (π, p, d, t, α) can be identified by means of ΔE-E particle identification. Pions are further identified using the characteristic shape of their waveforms caused by their decay structure. Advanced trigger logic was implemented in the on-board FPGA of the 3316 module in order to reduce background events and retain an acceptable live time. The ParTI phoswich detectors have undergone extensive testing using beams from the K500 cyclotron at the Texas A&M University Cyclotron Institute. The detectors were also tested at the Paul Scherrer Institut in Switzerland using direct pion beams.

As a complement measurement to the pions in the ParTI array, the Momentum Achromat Recoil Spectrometer (MARS) was used to transport the 16N fusion residues to the spectrometer focal plane for detection using a silicon stack. The combination of the two detector systems has allowed us to attempt the first charged pionic fusion coincidence measurement. The experimental setup as a whole has been shown to be capable of identifying pionic fusion reactions with sub-nanobarn cross sections.

Abstract 280 TUE-AA-IBT-05-1 Invited Talk - Tuesday 1:30 PM - Trinity

Chemical imaging of biological tissue with MeV-SIMS

Primoz Pelicon[1], Bostjan Jencic[1], Luka Jeromel[1], Nina Ogrinc Potocnik[1,2], Marjana Regvar[1,3], Primoz Vavpetic[1], Zdravko Rupnik[1], Klemen Bucar[1], Matjaz Vencelj[1], Mitja Kelemen[1], Shane Ellis[2], Ron M.A. Heeren[2], Zdravko Siketic[4], Katarina Vogel-Mikus[1,3]

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Secondary Ion Mass Spectrometry with high-energy heavy ions (MeV-SIMS) is emerging as a promising Imaging Mass Spectroscopy (IMS) technique for chemical imaging of biological tissue [1]. Linear Time-Of-Flight (TOF) mass spectrometer was incrementally added to the existing detection setup at the high energy focused ion beam facility in order to extend elemental imaging of biological tissue with molecular imaging using Secondary Ion Mass Spectrometry with heavy high energy ions (MeV-SIMS).

In a pulsed mode, primary 5.8 MeV $^{35}Cl^{6+}$ beam is prepared in short bursts to define the TOF start signal whereas the secondary ions hitting microchannel plate detector at the end of TOF telescope trigger the TOF stop signal. Due to the limited brightness of primary Cl ion beam formed in a conventional sputter source, this mode features limited lateral and mass resolution. Nevertheless, it enables chemical mapping of tissue slices prepared by shock-freezing and freeze-drying [2].

To overcome the low lateral resolution, continuous beam mode was developed for work at thin slices of biological materials. In this mode, the arrival of each primary ion is detected with continuous electron multiplier (channeltron) positioned behind the sample as a TOF start. At low primary beam fluxes required for this mode of operation, we can form a probing beam with a size of cca 800 x 800 nm^2. With a better time definition of TOF start pulse also the mass resolution is significantly improved in comparison with the pulsed mode.

If the TOF telescope is equipped with a fast position-sensitive detector for secondary ions, so-called stigmatic imaging process [3] may form the chemical image of the sample with a broad primary beam, as each starting point for secondary ions at the sample corresponds to the well-defined striking position at the end of the TOF telescope. First MeV-SIMS results obtained with Timepix detector will be presented.

[1] Y. Nakata, Y. Honda, S. Ninomiya, T. Seki, T. Aoki, J. Matsuo, Applied Surface Science 255 (2008) 1591-1594.

[2] B. Jenčič, L. Jeromel, N. Ogrinc Potočnik, K. Vogel-Mikuš, E. Kovačec, M. Regvar, Z. Siketić, P. Vavpetič, Z. Rupnik, K. Bučar, M. Kelemen, J. Kovač, P. Pelicon, Nucl. Instr. Meth. B 371 (2016) 205-210.

[3] J. H. Jungmann, L. MacAleese, R. Buijs, F. Giskes, A. de Snaijer, J. Visser, J. Visschers, M. J.J. Vrakking, R. M.A. Heeren, Jour. Amer. Soc. Mass Spect. 21 (2010) 2023-2030.

Abstract 100 TUE-AA-IBT-05-2 Invited Talk - Tuesday 1:30 PM - Trinity

Molecular imaging of biological and cultural heritage samples using MeV-SIMS

Zdravko Siketic, Iva Bogdanovic Radovic, Milko Jaksic, Valentin Stoytschew, Marijana Popovic Hadzija, Mirko Hadzija

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Time of flight Secondary Ion mass Spectrometry (TOF-SIMS) is a well-known technique used for the mass identification of ions released from the sample surface by the primary ion beam. The choice of the primary ion for TOF-SIMS is critical because it determines the sensitivity of the detection for certain secondary molecular ion. For the analysis of organic materials by TOF-SIMS, energy deposited at the surface by the primary ion beam has to be high enough to desorb substantial number of the intact molecules, with low amount of the fragments, keeping in the same time chemical damage very low. Among the all mass spectrometry techniques, there are only few of them, like TOF-SIMS using C-60 and Ar cluster primary beams or MALDI, which fulfil those requirements.

It has been recently demonstrated that the use of MeV, instead of the keV ions, is significantly suppressing fragmentation and simultaneously enhancing the secondary molecular ion yield, especially for molecules with higher masses (100-1000 Da). This is due to the fact that the secondary ion formation is completely different when MeV ions are used, since the dominant energy loss is through the electronic stopping, which causes desorption of intact secondary molecular ions. This is contrary to the case when keV ions are applied where dominant nuclear stopping is causing more fragmentations of ejected molecular ions. As a consequence, MeV-SIMS is a good candidate for molecular imaging of organic samples.

The minimum analysed area for molecular imaging depends on the minimum achievable beam spot size as well as on the sensitivity. For MeV-SIMS measurements at the Ruder Boskovic Institute, the most commonly used primary (pulsed) beams are oxygen and silicon ions between 5 and 20 MeV. In order to obtain a sufficiently narrow timing pulse width (<5 ns), which is essential for a high mass resolution, and high enough current in a pulsed mode for sufficient secondary molecular ion yield, the primary ion microbeam current has to be greater than 100 pA. This limits the lateral beam resolution to ~10 µm, due to the large opening of the object and collimator slits, and also limits the minimum spot size for the molecular mapping which could be significantly smaller since the sensitivity of the method is very high. Therefore, in order to improve the beam lateral resolution, instead of using pulsed beam, we decided to use a continuous primary ion beam by closing the microprobe object slits. Also, trigger for a timing signal was provided using ion detector placed behind the transparent target. This approach, keeping the same primary ion current and thus secondary molecular ion yield, beam lateral dimension was reduced by an order of magnitude.

In the present work, examples of the MeV-SIMS analysis of the culture heritage samples, in the pulsed primary ion mode, will be shown. Also, high resolution molecular imaging of the single biological cells and tissue section will be presented (transmission MeV-SIMS, continuous mode). Selection of the primary ion beam for MeV-SIMS analysis will be discussed.

Abstract 73 TUE-AA-IBT-05-3 Invited Talk - Tuesday 1:30 PM - Trinity

Heavy ions PIXE: the IAEA Coordinated Research Project F11019 its objectives and actual results

Alessandro Zucchiatti

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Presented on behalf of the IAEA CRP F11019 members

The development of SIMS at MeV energies is advancing strongly and promises to offer the community a new analytical methodology. Due to its emerging relevance it is the object of coordinated research, promoted by IAEA on "Development of molecular concentration mapping techniques using MeV focused ion beams". Due to IBA multi-technique character, the development opens also the way to the combination of the MeV-SIMS with other IBA techniques, in particular heavy ion PIXE. Several data exist already for ionization and production X-sections. However one has to observe that lesser direct results are found for X-ray production. A concerted protocol and a cross check procedure in different laboratories and at energies convenient also for heavy-ions SIMS has been established. An extended list of cases of interest, that would be convenient both as a reliable operative tool and as an experimental base on which test theoretical models, has been agreed within the CRP and work is in progress. We will review the scope of the CRP and present the most recent results on heavy ions PIXE.

Abstract 403 TUE-AP-MA-02-1 Invited Talk - Tuesday 1:30 PM - West Fork

Is Proton Therapy A Clinical Standard for Children?

Anita Mahajan

Radiation Oncology, MD Anderson Cancer Center, 1515 Holcombe Boulevard, Unit 097, Houston TX 77030, United States

Proton therapy has become increasingly available worldwide due to the reduction in integral dose to normal structures with effective tumor control. This potential advantage is particularly appealing in children and has lead to an increasing acceptance of the use of proton therapy for pediatric malignancies.

Despite this theoretical benefit we need to objectively evaluate the benefit of proton therapy in children due to the increased cost and potential effect on national health care paradigms.

In this talk, the definition and development of clinical standards will be discussed. The evidence that is available to support the role of proton therapy in children will be reviewed, and an critical evaluation of current and future efforts to improve our understanding of proton therapy in children will be presented.

Abstract 400 TUE-AP-MA-02-2 Invited Talk - Tuesday 1:30 PM - West Fork

Proton Therapy for Adults with Brain Tumors:

Is it a clinical standard?

Paul Brown

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The role of proton radiotherapy remains controversial in adult patients with brain tumors. We will review the available literature, ongoing trials, and future directions for proton radiotherapy in the treatment of adult patients with brain tumors. At the conclusion of the presentation the audience should have a better understanding of the role of proton radiotherapy in this patient population.

Abstract 414 TUE-AP-MA-02-3 Invited Talk - Tuesday 1:30 PM - West Fork

Proton Therapy for GU Malignancies: Current Status

Andrew Lee

Texas Center for Proton Therapy, Texas Oncology, 1501 West Royal Lane, Irving TX 75063, United States

Proton therapy has been used to treat prostate cancer for several decades. The initial dose-escalation trials were done with proton therapy 10 years before similar trials were attempted with photons. The initial proton techniques were relatively crude by today's standards but the disease control and toxicity results were quite good compared to other therapies of that era. Proton therapy for prostate cancer has seen significant advances in the past 10 years including better image guidance and utilization of pencil-beam scanning. This presentation will discuss the progress in this technology as well as the corresponding clinical results. Recent published data utilizing more modern proton techniques will be presented as well as a discussion on patient-reported quality of life using validated standardized instruments.

Abstract 411 TUE-AP-MA-02-4 Invited Talk - Tuesday 1:30 PM - West Fork

Innovations in spatial mapping of the RBE of scanned particle beams

Fada Guan[1], Lawrence Bronk[2], Matthew Kerr[1], Darshana Patel[1], Christopher Peeler[1], Dragan Mirkovic[1], Uwe Titt[1], David Grosshans[2,3], Radhe Mohan[1]

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The physical properties of particles used in radiation therapy, such as protons, have been well characterized to show their superior dose distributions to photon-based treatments. However, particle therapy may also have inherent biologic advantages that have not been capitalized on. Biologically optimized charged particle treatments could expand the therapeutic index of radiation therapy by selectively placing areas of the beam with high biological effectiveness so as to enhance tumor cell kill and simultaneously spare normal tissues from harm. However, to date, methods for acquiring the data necessary to guide novel treatment planning approaches are lacking, in part because of the reliance on low-yield, historic techniques for assessing cell survival after irradiation. This study presents an innovative, interdisciplinary approach to acquiring large amounts of high-accuracy, high-precision spatial data on the biological effectiveness of particle therapy for a wide variety of biological samples. We used scanned particles beams (protons at MDACC, and protons, helium and carbon ions at DKFZ/HIT) and high-throughput clonogenic survival assays in patient derived cell lines to demonstrate the potential of such methods. After the successful acquisition of survival data for cancer cell lines, this method was expanded to investigate the necrosis effect of normal tissues. Rat brain organoids have been irradiated using the scanned protons at MDACC. The observations of our high-throughput studies have shown the complexities in accurately determining the biologic effects of particle therapy. It is necessary to make deeper studies to investigate biologic responses of particles at the cellular and DNA level in terms of their physical interactions. The innovations of high-speed computation capacities, high-accuracy physical detections and high-throughput biological techniques have the potential to bring out unprecedented treatment outcome of particle therapy.

Abstract 281 TUE-AP-SD-05-1 Contributed Talk - Tuesday 1:30 PM - Elm Fork

Effective Atomic Number, Mass Attenuation Coefficient Parameterization, and Implications for High-Energy X-Ray Cargo Inspection Systems

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The most widely used technology for the non-intrusive active inspection of cargo containers and trucks is x-ray radiography at high energies (4-9 MeV). Technologies such as dual-energy imaging, spectroscopy, and statistical waveform analysis can be used to estimate the effective atomic number (Z_{eff}) of the cargo from the x-ray transmission data, because the mass attenuation coefficient depends on energy as well as atomic number Z. The estimated Z_{eff} of the cargo then leads to improved detection capability of contraband and threats, including special nuclear materials (SNM) and shielding. In this context, the exact meaning of effective atomic number (for mixtures and compounds) is not well-defined. Physics-based parameterizations of the mass attenuation coefficient have been given in the past, but usually for a limited low-energy range and definitions of the Z_{eff} have been based, in part, on such parameterizations. Here, we give an improved parameterization at low energies (20-1000 keV) which leads to a well-defined Z_{eff}. We then extend this parameterization up to energies relevant for cargo inspection (10 MeV), and examine what happens to the Z_{eff} definition at these higher energies.

Abstract 282 TUE-AP-SD-05-2 Contributed Talk - Tuesday 1:30 PM - Elm Fork

Background-Source Cosmic-Photon Elevation Scaling and Cosmic-Neutron/Photon Date Scaling in MCNP6

James R. Tutt, Casey A. Anderson, Gregg W. McKinney

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Cosmic neutron and photon fluxes are known to scale exponentially with elevation. Consequently, cosmic neutron elevation scaling was implemented for use with the background-source option shortly after its introduction into MCNP6, whereby the neutron flux weight factor was adjusted by the elevation scaling factor when the user-specified elevation differed from the selected background.dat grid-point elevation. At the same time, an elevation scaling factor was suggested for the cosmic photon flux, however, cosmic photon elevation scaling is complicated by the fact that the photon background consists of two components: cosmic and terrestrial. Previous versions of the background.dat file did not provide any way to separate these components. With Rel. 4 of this file in 2015, two new columns were added that provide the energy grid and differential cosmic photon flux separately from the total photon flux. Here we show that the cosmic photon flux component can now be scaled independently and combined with the terrestrial component to form the total photon flux at a user-specified elevation in MCNP6.

Cosmic background fluxes also scale with the solar cycle due to solar modulation. This modulation has been shown to be nearly sinusoidal over time, with an inverse effect - increased modulation leads to a decrease in cosmic fluxes. This effect was initially included with the cosmic source option in MCNP6 and has now been extended for use with the background source option when: (1) the date is specified in the background.dat file, and (2) when the user specifies a date on the source definition card. A description of the cosmic-neutron/photon date scaling feature will be presented along with scaling results for past and future date extrapolations.

This work has been supported by the U.S. Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract/IAA HSHQDC-12- X-00251. This support does not constitute an express or implied endorsement on the part of the Government.

Abstract 84 TUE-AP-SD-05-3 Contributed Talk - Tuesday 1:30 PM - Elm Fork

Source effects on image quality in active interrogation applications

Joseph Harms, Paul B. Rose, Jr., Anna S. Erickson

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In cargo scanning for special nuclear materials, beam source and detector response influence output image quality, which ultimately determines whether SNM can be detected. While bremsstrahlung beams are the industry standard, the continuous spectrum of bremsstrahlung is non-ideal. The spectrum is low-energy peaked leading to poor penetration and poor detector statistics at higher energies.

Many of the problems induced by bremsstrahlung beams could be alleviated by using monoenergetic beams. Low-energy nuclear reactions produce quasi monoenergetic beams; for example $^{11}B(d,n\gamma)^{12}C$, produces prominent gamma peaks at 4.4 and 15.1 MeV. Inverse Compton scatter is another technique which produces monoenergetic photons, and has the advantage of being tunable, allowing the user to select the beam energy.

With Geant4, we evaluate both imaging sources and compare to bremsstrahlung beams. We create images which measure transmission and Z_{eff}. For image quality assessment, we measure pixel error, noise standard deviation, and contrast-to-noise ratio. Pixel error measurement will determine the confidence with which a system will be able to determine the presence of SNM. Noise STD and CNR are commonly used to determine system sensitivity, allowing for a quantitative study of image quality. Furthermore, simulation of the $^{11}B(d,n\gamma)^{12}C$ source is compared to experimental data for model validation.

Abstract 234 TUE-AP-SD-05-4 Contributed Talk - Tuesday 1:30 PM - Elm Fork

Delta Ray Production in MCNP6.2.0

Casey A Anderson, James R Tutt, Michael R James, Gregg W McKinney

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Secondary electrons in the form of δ-rays, also referred to as knock-on electrons, have been a feature of MCNP for electron and positron transport for over 20 years. While MCNP6 now includes transport for a suite of heavy-ions and charged particles from its integration with MCNPX, the production of δ-rays was still limited to electron and positron transport. In the newest release of MCNP6, version 6.2.0, δ-ray production has now been extended for all energetic charged particles. The basis of this production is the analytical formulation from Rossi [1] and ICRU Report 37 [2]. This paper discusses the MCNP6 heavy charged-particle implementation and provides production results for several benchmark/test problems.

[1] B. Rossi, **High Energy Particles**, Prentice-Hall, Inc., Englewood. (1952)

[2] **Stopping Powers for Electrons and Positrons**, ICRU Report 37. (1984)

This work has been supported by the U.S. Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract/IAA HSHQDC-12-X-00251. This support does not constitute an express or implied endorsement on the part of the Government.

Abstract 77 TUE-AP-SD-05-5 Contributed Talk - Tuesday 1:30 PM - Elm Fork

GEANT4 Modifications for Accurate Fission Simulations*

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To achieve an accurate fission model for event-by-event studies in fissionable material identification applications, the Monte Carlo fission simulation package in Geant4 was modified to correct inaccuracies and to add new capabilities. The fission model developed by the Lawrence Livermore National Laboratory[1] was integrated into neutron-induced fission modeling package. The photofission modeling used the neutron-induced fission library under the assumption that nuclei fission in the same way, independent of the excitation source. The optimized fission models provide the correct multiplicity of prompt neutrons and gamma rays, and produce delayed gamma rays and neutrons with time and energy dependencies that are consistent with the available references. In addition, delayed neutrons are now directly produced by a custom package that bypasses the fragment cascade model. The modifications were made for U-235, U-238 and Pu-239 isotopes, but the new framework allows adding new isotopes easily. Results of the modified Geant4.10.1 package for neutron- and photo-induced fission for prompt and delayed radiation are compared with references and with results produced with the original package.

[1] Simulation of Neutron and Gamma Ray Emission from Fission and Photofission, Verbeke et al, Lawrence Livermore National laboratory UCRL-AR-228518.

* This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract HSHQDC-15-C-B0031. This support does not constitute an express or implied endorsement on the part of the Government.

Abstract 407 TUE-AP-SD-05-6 Contributed Talk - Tuesday 1:30 PM - Elm Fork

Verification of Plutonium Content in PuBe Sources using MCNP6 1.2 Beta with TENDL 2012 Libraries

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Although the production of PuBe neutron sources has discontinued, hundreds of sources with unknown or inaccurately declared plutonium content are in existence around the world. Institutions have undertaken the task of assaying these sources, measuring and calculating the isotopic composition, plutonium content, and neutron yield. The nominal plutonium content, based off the neutron yield per gram of pure ^{239}Pu, has shown to be highly inaccurate. New methods of measuring the plutonium content allow a more accurate estimate of the true Pu content, but these measurements need verification.

Using the TENDL 2012 nuclear data libraries, MCNP6 has the capability to simulate the (α,n) interactions in a PuBe source. Theoretically, if the source is modeled according to the plutonium content, isotopic composition, and other source characteristics, the calculated neutron yield in MCNP can be compared to the experimental yield, offering an indication of the accuracy of the declared plutonium content. In this study, three sets of PuBe sources from various backgrounds were modeled in MCNP6 1.2 Beta, according to the source specifications dictated by the individuals who assayed the source. Verification of the source parameters with MCNP6 also serves as a means to test the alpha transport capabilities of MCNP6 1.2 Beta with TENDL 2012 alpha transport libraries. Good agreement in the comparison would indicate the accuracy of the source parameters in addition to demonstrating MCNP's capabilities in simulating (α,n) interactions.

Abstract 118 TUE-AP-TA-04-1 Invited Talk - Tuesday 1:30 PM - Rio Grande

Growing the Nuclear Workforce Through Outreach

Micha Kilburn

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Many students don't encounter physics in the classroom until college or the end of high school. Most college students never encounter nuclear physics in the classroom. In order to grow the nuclear science workforce, students need to be aware of the field much earlier in their education. However, teaching teens about nuclear science can be a daunting task at the outset. I will present and describe successful outreach curricula and programs that can be duplicated by any college, university, company or laboratory. These include workshops for boy scouts and girl scouts as well as teaching nuclear science with magnetic marbles. I will also present some results from assessments of JINA-CEE's more intensive programs aimed at recruiting youth to the field.

Abstract 124 TUE-AP-TA-04-2 Invited Talk - Tuesday 1:30 PM - Rio Grande

Teaching with TOTEM DATA EXPRESS

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Students in High School want to understand what scientists are looking for and why they choose the subjects they do to be studied. I would like to present an activity that has been created to use data from the TOTEM experiment at the Large Hadron Collider. This activity allows students to work with authentic data from the experiment at the same time it reinforces many high school topics such as wave interference, and duality of particles and waves. The high school students can find an upper limit on the diameter of the proton. For many students the idea of being able to find that type of information with high school skills is a strong motivator to continue studying science.

Abstract 155 TUE-AP-TA-04-3 Contributed Talk - Tuesday 1:30 PM - Rio Grande

The Radiation Data Laboratory - A Cloud-Based Collaborative Ecosystem

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Historically, the education and training of accelerator and nuclear scientists and engineers have been limited to a small number of research universities and national laboratories that have the required specialized tools and knowledge base. But, with the emergence of internet connected devices (Internet of Things IoT) and cloud-computing infrastructure, previously confined resources can now reach a much broader audience of young scientists and allow data transparency and more

efficient collaborations. The Radiation Data Laboratory (RDL) envisions an architecture that leverages cloud computing services that streamlines data ingress, curation, analysis and visualization workflows. In order to integrate accelerator and detector data ingress with open-source tools, RDL has developed Application Programming Interfaces (API) that allow the user to seamlessly collect, curate and analyze the data without physically being in the lab or having to architect the cloud-computing framework. Berkeley Applied Analytics has developed and tested an architecture for streaming real-time data to the cloud with various sensor types (e.g. NaI detectors) and web-based visualization and analytics tools (e.g. JupyterHub).

Abstract 158 TUE-AR-NST-03-1 Invited Talk - Tuesday 1:30 PM - Post Oak

Compositional patterning in self-organized dot and ripple structures produced by medium energy implantation with metal incorporation

A. Redondo-Cubero[1], K. Lorenz[2], F.J. Palomares[3], M. GarcÃ-a-HernÃ¡ndez[3], B. Galiana[4], C. Ballesteros[4], R. HÃ¼bner[5], J.L. Pau[1], L. VÃ¡zquez[3]

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Ion beam sputtering (IBS) is a widespread technique that can be used for the production of nanopatterns in a large range of materials and scales [1], being silicon the most studied target material. In the last years, the key role of metal impurities for the initial formation of the pattern in mono-elemental targets has been clearly established [2], changing the field in a significant way. Still, several questions remain open, such as the segregation effect of metal silicides [3], the relevance of preferential sputtering for the different metal species [4], or the threshold metal concentration needed for nanopatterning at given experimental conditions. Most of these works are restricted to low energetic beams (0.5-5 keV) produced with conventional ion guns and different set-ups to induce indirect metal co-deposition [5]. However, in order to have an appropriate control of the metal species more dedicated systems, where metal could be also directly incorporated, are becoming essential.

In this communication, we will present our recent experimental works on IBS nanopatterning of Si at medium energies (20-160 keV) with simultaneous metal incorporation [6,7]. We evaluate the relevance of the compositional patterning in the dot and ripple formation for normal (0º) and grazing incidence (60º) configurations, respectively. In both cases, irradiation was carried out in a high-flux ion implanter. The effect of the ion energy and the fluence is studied using atomic force microscopy to characterize the pattern morphology and to quantify the surface roughness and pattern wavelength. Metal content was determined with Rutherford backscattering spectrometry and the formation of silicides mapped with X-ray photoelectron spectroscopy. High resolution transmission electron microscopy was also used to unambiguously prove the compositional patterning of the samples. We will discuss the main differences arising from the different metal incorporation paths, paying special attention to the local metal arrangement, the threshold contents, and the directional effects required to trigger the pattern and form metal silicides. Finally, we will comment on the successful application of these patterns as templates for the growth of plasmonic Ga nanoparticles.

1. J. Muñoz-GarcÍa et al., Mater. Sci. Eng. R-Rep. 86, 1 (2014)

2. C. Madi et al., Phys. Rev. Lett. 101, 246102 (2008)

3. M. Engler et al., Nanotechnology 25, 115303 (2014)

4. R. Gago et al., Nanotechnology 25, 415301 (2014)

5. K. Zhang et al., Nanotechnology 25, 085301 (2014)

6. A. Redondo-Cubero et al., Phys. Rev. B 86, 085436 (2012)

7. A. Redondo-Cubero et al., Nanotechnology 27, in press.

Abstract 129 TUE-AR-NST-03-2 Invited Talk - Tuesday 1:30 PM - Post Oak

Reverse epitaxy: Nanopattern formation by vacancy self-assembly upon low energy ion irradiation of crystalline semiconductor surfaces

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Uniform crystalline nanostructures are sought-after in many fields of research and technology, ranging from ranging from catalysis [1] to electronics [2]: crystalline nanostructures have the potential of becoming the building blocks of future information technology or of boosting development in energy conversion and storage.

Crystalline nanostructures are successfully grown in wet-chemical procedures [3] or by molecular beam epitaxy (MBE) [4]. Reverse epitaxy [5, 6] is an alternative approach to fabricating highly ordered arrays of crystalline nanostructures on large areas of semiconductor surfaces. In contrast to ion irradiation under non-normal incidence at room temperature, where ripples are formed on the amorphized semiconductor surface [7], reverse epitaxy occurs at substrate temperatures above the recrystallization temperature, which ensures that the semiconductor surface retains its crystallinity.

Based on the kinetically restricted diffusion (Ehrlich-Schwoebel barrier for crossing atomic steps) of vacancies created by low energy ion irradiation, this subtractive process is considered analogous and complementary to the additive homoepitaxial growth via MBE. The resulting nanostructure morphology can be controlled via easily accessible parameters such as substrate material, surface orientation, temperature, ion species and fluence. Possible morphologies include sawtooth facets and square or hexagonal pyramidal pits with feature sizes of a few tens of nanometers.

We discuss the underlying principles and the mechanism of nanostructure formation by reverse epitaxy. The variety of nanopatterned morphologies on different semiconductor surfaces will be highlighted. We hope to stimulate discussion by presenting recent examples of our research and proposing possible applications.

[1] H. G. Yang et al., Nature 453, 638(2008)

[2] Y. Huang et al., Science 291, 630 (2001)

[3] W. Li et al., Nanotechnology 27, 324002 (2016)

[4] C. Teichert, Phys. Rep. 365, 335 (2002)

[5] X. Ou et al., Phys. Rev. Lett. 111, 016101 (2013)

[6] X. Ou et al., Nanoscale 7, 18928 (2015)

[7] W. L. Chan et al., J. Appl. Phys. 101, 121301 (2007)

Abstract 134 TUE-AR-NST-03-3 Invited Talk - Tuesday 1:30 PM - Post Oak

Virtually Defect-Free Ripples and Terraced Topographies Produced by Ion Sputtering

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Bombarding a solid surface with a broad ion beam can lead to the emergence of surface ripples with wavelengths as short as 10 nanometers. The primary obstacle that has prevented the adoption of ion bombardment as a nano-fabrication tool is the high density of defects in the patterns that typically form. Our simulations indicate that a simple modification to the experimental setup could solve this problem --- ion bombardment may produce nearly defect-free ripples on the surface of an elemental solid if the sample is concurrently and periodically rocked about an axis orthogonal to the surface normal and the incident beam direction.

The anisotropic Kuramoto-Sivashinsky (AKS) equation has been used to model the formation of ripples during oblique-incidence ion sputtering for two decades. However, when the angle of incidence is large, intriguing phenomena are observed in experiments that are not reproduced by this equation. We have introduced an equation of motion for the surface of an ion-bombarded material that differs from the AKS equation by the inclusion of a cubic nonlinearity. Our simulations establish that this term has a crucial influence on the dynamics --- it can lead to the formation of a terraced topography that coarsens in time, in accord with experimental observations for high incidence angles. In the future, regular terraced surfaces produced by templating the surface prior to sputtering may be used as blazed diffraction gratings.

Abstract 161 TUE-AR-RE-01-1 Invited Talk - Tuesday 1:30 PM - Bur Oak

Defects in two-dimensional materials: their production under irradiation, evolution and properties

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Following isolation of a single sheet of graphene, many other 2D systems such as hexagonal BN sheets and transition metal dichalcogenides (TMD) were manufactured. Among them, TMD sheets have received particular attention, as these materials exhibit intriguing properties. Moreover, the properties can further be tuned by introduction of defects and impurities using electron and ion beams. In my talk, I will present the results [1] of our theoretical studies of defects (native

and irradiation-induced) in inorganic 2D systems obtained in collaboration with several experimental groups. I will further discuss defect and impurity-mediated engineering of the electronic structure of 2D materials.

[1] https://users.aalto.fi/~ark/publist.html

Abstract 27 TUE-AR-RE-01-2 Contributed Talk - Tuesday 1:30 PM - Bur Oak

Graphene stripper foils for medical isotope cyclotrons

I. Pavlovsky[1], R.L. Fink[1], S. Korenev[2], R. Dishman[2], A.M. Yerba[3], N. Mesheriakov[4], I. Smirnov[4]

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Applied Nanotech, Inc., has developed free-standing graphene foils for electron stripping of charged beams in heavy ion accelerators[1]. The foils were produced by pressure filtration of a reduced graphene oxide aqueous dispersion. The foils with an area density of approximately 0.5 mg/cm^2 have demonstrated lifetimes under ion beam bombardment that were significantly longer than those typically observed with amorphous carbon foils.

These same graphene foils were also tested under 11 MeV negative hydrogen ion beams in various Siemens Eclipse cyclotrons that are used in production of the fluorine-18 isotope in the ^{18}O (p, n) => ^{18}F reaction for the radiopharmaceuticals industry. The foils of the same area density have demonstrated the lifetime over 18,000 μA·h at a typical beam current of 70 to 100 μA. Considering a typical ion energy loss in the stripper foil being 1%, the total dissipated power of the proton beam in Eclipse cyclotrons is approximately 10W at 90 μA beam current. High thermal conductivity of graphene helps mitigate thermally induced damage to the foils. The graphene foils also showed a significant increase in the transmission factor (the ratio of the beam current on the stripper foil to the current on the target), which was on the order of 90%.

Provided that the high volume price of the graphene foil material is comparable with the price of conventional carbon foils, the demonstrated advantages of using graphene in medical cyclotrons makes it an attractive stripper alternative for existing and future cyclotron instruments.

1. I. Pavlovsky, R.L. Fink. Graphene stripper foils. J. Vac. Sci. Technol. B 30, 03D106 (2012)

Abstract 208 TUE-AR-RE-01-3 Contributed Talk - Tuesday 1:30 PM - Bur Oak

INT-WS_2 Niobium Implantation Studies

Mihai Straticiuc[1], Alla Zak[2], Magdalena Nistor[3], Elena Matei[4], Mihaela Manea[5], Ion Burducea[1], Florin Gherendi[3], Pavel Dinca[6]

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Ion beam implantation was applied on tungsten disulfide inorganic nanotubes powder (INT-WS_2) synthesized in a fluidized bed reactor (FBR) [1]. Niobium ions ($^{93}Nb^{+1}$) accelerated in a 3 MV Tandetron™ machine impinged into the INT-WS_2 pellets with an energy of 1.5 MeV, providing a dose of $6x10^{14}$ ions/cm^2 [2]. Various analysis techniques were applied to determine the electric, structural and morphological modifications induced by the $^{93}Nb^{+1}$ irradiation of the inorganic nanostructures: Scanning Electron Microscopy (SEM), Hall effect measurements, Raman Spectroscopy, X-ray Diffraction (XRD), Energy Dispersive X-ray Spectroscopy (EDX) and Particle Induced X-ray Emission (PIXE).

[1]. A. Zak et al., Nano 04, 91, 2009

[2]. I. Burducea et al., NIM B 359, 12-19, 2015

Abstract 182 TUE-AR-RE-01-4 — Invited Talk - Tuesday 1:30 PM - Bur Oak

Effective interlayer distance for 2D - 2D tunneling in van der waals heterostructure

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Heterostructure, as an emerging research area, has been revealed to have unusual properties and new phenomena, compared to layered materials with single components such as graphene and other two - dimensional materials. The electronic tunneling between adjacent layers provides the heterostructure promising photonic and electrical functions. However, as the heterostructure is hold together by the van der waals, layered materials do not have a close contact with each other and the heterostructure may be padded by the interlayer space. The interlayer space will affect the electronic tunneling. Furthermore, functions of the heterostructure will be weaken. It is interesting to identify the effective interlayer distance (space) for electronic tunneling in van der waals heterostructure. In this work, we constituted a heterostructure by the graphene and WSe2. The interlayer space in this heterostructure was artificially controlled by the ion beam technology. The ion irradiation process compressed the heterostructure and the average thickness of the heterostructure was decreased from 15 nm to 2.4 nm. Due to the layer - layer compression, the contact and interaction between layers were adjusted. The saturable absorption of the heterostructure was investigated as a probe for the electronic tunneling. With the average thickness approaching 2.4 nm, a drastic variation of the saturable absorption of the heterostructure was observed. And the effective interlayer distance of the heterostructure for the electronic tunneling in the G - W heterostructure was determined to be ~ 4.5 nm. Our work offers a new strategy to estimate the quality of the heterostructure.

Abstract 339 TUE-AA-IBT-02-1 — Invited Talk - Tuesday 3:30 PM - Trinity

Quantitative surface and in-depth analysis by LEIS: Selection of the optimum experimental conditions

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Advances in nanoscience and nanotechnology heavily rely on the availability of analytic techniques that can validate and support new procedures for the synthesis of nanomaterials. The atomic composition of the outer atomic surface is derived from the surface peaks in LEIS (Low-Energy Ion Scattering, 1 - 10 keV). The choice of the noble gas ion (He+, Ne+, Ar+

or Kr+) depends on the required mass resolution. Using He+ ions the tails of the surface peaks, which result from reionised He atoms that are backscattered in deeper layers, give valuable non-destructive in-depth information (0 - 10 nm). Typical applications are the growth and closure of ultrathin layers, surface modification, diffusion and surface segregation and catalysts [1]. At low energies the depth resolution improves, although this is restricted by the increasing importance of multiple scattering. To take full advantage of the information contained in the tails, more insight in the backscattering and the reionisation process is needed. The energy distribution of the backscattered He is calculated with an improved fast version of the TRBS simulation code, which has been shown to be suited for the LEIS regime [2]. Since the neutralization of He+ ions is very fast, the reionisation process only results in backscattered He+ ions if the reionisation occurs just before leaving the surface. Thus this process is determined by the atomic composition of the outer atomic layer (which can be determined by LEIS) and the energy of the backscattered He. It will be shown how the combination of LEIS and TRBS simulations is a valuable support in the selection of the optimum experimental conditions. Due to atmospheric contamination and O-atom cleaning, oxygen is an important surface contaminant. Since O-atoms are known to be effective in reionising He atoms, special attention will be paid to the reionisation probability for oxygen atoms as function of the kinetic energy of the He atoms. Also, in cases where the intensity of the tails is relatively low, adsorption of a fraction of a monolayer of oxygen can be used to increase the tail intensity. The results will be illustrated with state-of-the-art applications for ALD growth and supported catalysts.

[1] H.H. Brongersma, "Low-Energy Ion Scattering" in Characterization of Materials, Ed. E.N. Kaufmann, Wiley & Sons, (2012) 2024-2044.;

[2] P. Brüner, T. Grehl, H.H. Brongersma, B. Detlefs, E. Nolot, H. Grampeix, E. Steinbauer, P. Bauer, J. Vac. Sci. Technol. (2015) A33: 01A122.

Abstract 313 TUE-AA-IBT-02-2 Invited Talk - Tuesday 3:30 PM - Trinity

Medium energy ion scattering for the post-silicon era

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The search for new devices to replace conventional silicon CMOS has stimulated research into a wide assortment of materials and architectures. In development programs ranging from carbon-based electronics to unconventional piezoelectronic devices, our knowledge of materials behavior both limits and guides device design. Despite being largely confined to strictly planar, un-patterned sample configurations, there is a wealth of information that can be derived from carefully designed MEIS experiments. We will illustrate this by drawing examples from graphene growth, carbon nanotube contacts, and rare-earth chalcogenide layers for piezoresistive applications. In all of these efforts, mastery of a new set of materials is crucial to success, and characterization is a valuable tool for progress.

Abstract 393 TUE-AA-IBT-02-3 Contributed Talk - Tuesday 3:30 PM - Trinity

Low energy ion scattering characterization of materials for hydrogen applications

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Hydrogen-surface interactions are relevant to many technologies, including solid storage for fuel cell electric vehicles [1], hydrogen energy infrastructure [2], and plasma-facing materials for magnetic fusion [3]. In contrast to electron- and photon-based spectroscopies, element (and isotope) specific detection of hydrogen on surfaces is a unique strength of low energy ion scattering (LEIS) and direct recoil spectroscopy (DRS). The full potential of these techniques for hydrogen

applications has yet to be fully realized, partly because the complexity of the ions-surface interaction makes the scattering result difficult to interpret.

In this report, we explore recent progress in several aspects of characterizing hydrogen chemisorption with LEIS and DRS. We use low energy scattering maps to determine the hydrogen binding configuration on several tungsten and beryllium crystal planes. These materials will comprise the plasma-facing surfaces of the ITER magnetic fusion experiment under development. To determine the exact bond length between the hydrogen and the neighboring substrate atoms, we relied on detailed comparisons between our experiments and computational models. To accurately reproduce the scattering physics, we developed a molecular dynamics model; quantitative comparisons with experiments enable the height of the hydrogen above the surface to be determined to within ±0.1 Å.

We have also studied hydrogen chemisorption on and desorption from practical metal hydride powders relevant to fuel cell electric vehicles. For this purpose we considered both Ni-doped Mg powder and Ti-doped $NaAlH_4$ materials. These powders were prepared in an inert glove box environment, pressed into soft metal foils (In and Pb alloy), and loaded into a clean transfer cylinder. This enabled us to characterize the surface impurities of the as-prepared material without adventitious contamination from air exposure. We examined uptake of both molecular and atomic hydrogen to decipher how dopants accelerate H chemisorption. Using LEIS, we examined the surface composition evolution of $NaAlH_4$ doped with 2% mol. $TiCl_3$ during in-situ thermal desorption. We find that the Na concentration at the surface increases at higher temperatures, perhaps due to segregation of Na to the surface or release of volatile AlH_x species during heating.

The advancements represented by the aforementioned experiments offer the potential to study hydrogen-surface interactions with much greater fidelity. We foresee no insurmountable obstacles to applying these techniques other materials systems where hydrogen effects are of importance.

[1] L. Schlapbach and A. Züttel, Nature **414**, 353 (2001).

[2] C. S. Marchi, B. P. Somerday, X. Tang, and G. H. Schiroky, Int. J. Hydrogen Energy **33**, 889 (2008).

[3] R. A. Causey, J. Nucl. Mater. **300**, 91 (2002).

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Abstract 344 TUE-AA-IBT-02-4 Contributed Talk - Tuesday 3:30 PM - Trinity

Medium energy elastic recoil detection for thin films and monolayers

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Medium energy ion scattering is a powerful tool for depth profiling, with depth resolution of 5-10Å in the near surface region with electrostatic energy analyzer (ESA). It was applied successfully in the past to analyze for elements heavier than carbon, typically on light substrates. It is potentially interesting to extend this technique to perform elastic recoil detection analysis (ERDA) of light elements, such as H, D, or Li. Unfortunately, it is difficult to achieve similar depth resolution with ERDA, since recoiled particles have smaller kinetic energy compared to backscattered ions. In the past this approach has been already demonstrated successfully by Copel, et al [1], using time-of-flight detector, and Nishimura, et al [2], using modified version of ESA. Our implementation (ME-ERDA) is based on using medium energy incident beam ions without

negative ion fractions and detect negative H- using existing ESA detector. Selection of the incident beam is influenced by favorable recoil cross-sections, scattering kinematics and low-to-moderate sputtering yields. We applied this technique to the analysis of H-terminated Si (001), self-assembled monolayers of alkane thiols, hafnium silicate films grown by atomic layer deposition on Si (001) substrates. While using 300-700keV Si^+ incident ions, H- with the energy around 3-5keV are recoiled from the surface with the width of ~0.5keV for H terminated Si (001). We observe some dependence of the H^- fraction on recoil angle, H- ions are not observed at any emerging angles above 80^o, while the data reported by Marion-Young predicts H- fraction of 3-5% in this energy range. The H- fraction is expected to increase with decreasing energy of the recoils (incident energy). We were also able to detect residual hydrogen presence in Hf silicate thin films grown by atomic layer deposition. The width of the H^- ion peak can be correlated well with the film thicknesses in the 3.6-16 nm range, while conventional ERDA does not differentiate them. We also comment of the limitations of medium energy elastic recoil detection analysis.

[1] M. Copel, R.M. Tromp, Rev. Sci. Instrum. 64 (1993) 3147-3152.

[2] T. Nishimura, A. Ikeda, T. Koshikawa, et al. Surf. Sci. 409 (1998) 183-188.

Abstract 213 TUE-AA-IBT-02-5 Contributed Talk - Tuesday 3:30 PM - Trinity

Mechanism of Titanium Oxidation by High Resolution Depth Profiling

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Ti has many important applications in both scientific research and industry. For example, Ti is a ubiquitous in biomedical applications as implants, due to its low reactivity with the surrounding tissues. This is due to the surface properties of a naturally forming TiO_2. The oxide is stable thermodynamically and few reactions occur on the surface of the implants. However, many factors can impact this process through modifications of its surface energy: composition, structure, roughness and the tissue or fluid environment. For example, electrochemically formed oxide films on Ti can be amorphous or crystalline depending on final anodic potential and electrolyte involved. This can directly affect biocompatibility of Ti, as thickness and crystallinity (rutile vs. anatase) can affect the degree of adsorption from human plasma: i.e. rutile has closer packed structure with less ion diffusion compared to anatase. Thus understanding the oxidation at an atomistic level is necessary if you wish to develop better protective films. Ultra-thin Ti films were deposited by magnetron sputtering, onto a Si (001) substrate followed by in-situ exposure to isotopic, O^{18} water to form a TiO_2 ultra-thin layer. Next, the TiO_2/Ti/Si(001) samples were electrochemically oxidized in $D_2{}^{16}O$ water.Thicknesses and stoichiometry of the films including their surfaces and interfaces were determined by X-ray Photoelectron Spectroscopy (XPS), Rutherford Backscattering (RBS), and Medium Energy Ion Scattering (MEIS), Nuclear Reaction Profiling (NRA), Elastic Recoil Detection (ERD) and Neutron Reflectometry (NR).

The relative concentration of O isotopes as a function of depth can be determined from the MEIS and NRA spectra. From such depth profiles, the principles governing oxidation can be inferred. The depth profiles suggest that after consecutive isotopic oxidations, ^{18}O remain in greater concentrations near the TiO_2/Ti interface corresponding to new oxide growth at the liquid phase/TiO_2 interface. New oxide increases nearly linearly with increasing oxidation voltage. No deuterium incorporation was detected within the detection limits of ERD. Two possible mechanisms are possible with isotopic exchange with O as a mobile species or alternatively with Ti and O being mobile species. Further details of the mechanism will be discussed.

Abstract 16 TUE-AP-MA-03-1 Contributed Talk - Tuesday 3:30 PM - West Fork

Progress of Demon Heavy Ion Cancer Therapy Facility in China

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Heavy ion beam has been considered to be the most optimal radiation for tumor treatment in the field of radiotherapy due to a high ionization density and a high relative biological effectiveness (RBE), culminating in a sharp maximum at a discrete penetration depth that coincides with the maximum physical dose around the so-called Bragg peak. It is important to develop the hospital-based heavy-ion-therapy facility to make the treatment accessible for public tumor patients. IMP, in cooperation with Lanzhou Kejin Taiji Co. LTD, a company of IMP absolute holding, developed the hospital-based tumor therapy facility HIMM (Heavy-Ion-Medical-Machine).

In HIMM, heavy ion beams of C^{5+} from ECR source are accelerated to 7 MeV/u by the cyclotron injector. C^{5+} ions are striped to C^{6+} at the medium-energy transport line, and then injected to the synchrotron. The carbon ion beams will be accumulated and accelerated to the maximum energy of 400 MeV/u corresponding to a range of 27cm in human body. After accelerated to the expected energy in the ring according to clinical requirement, the beams are extracted to the treatment terminal passing through the high-energy transport line. The radiation fields of 200×200 mm^2 may be formed after the scanning by the magnet. There are 4 treatment terminals, including one horizontal terminal, one vertical terminal, one combined terminal of horizontal and vertical direction, and one 45º terminal. All the terminals are equipped with beam delivery system, dose monitoring and recording system, patient positioning system, and safety interlock system. Compared with Linac injector, compact cyclotron injector has the advantages as lower cost and simplicity of operation. In addition, with the circumference of 56m the synchrotron is a compact ring for heavy ion therapy, and it is the first heavy ion accelerator for tumor therapy with independent intellectual property rights in China.

Two demo centers of heavy-ion-tumor-therapy facility HIMM, one in Wuwei, and another one in Lanzhou are under construction. Wuwei Demo Heavy-Ion Tumor Therapy Center is located in Ronghua Community in Wuwei, covering an area of 2 million square meters. It is planned to build a comprehensive community including tumor radiotherapy, teaching, scientific research and nursing home. The project construction began in May 2012. The installation of HIMM Wuwei facility has been finished and the first beam was obtained on Dec. 23, 2015. The registration detection is now in progressing. The clinical trial of 30 patients will be followed after the detection. Lanzhou Demo Heavy-Ion Tumor Therapy Center Project covers an area of 0.13 million square meters. The construction started in September 2012. The HIMM Lanzhou is now in installation, and the installation will be finished at the end of 2016.

We drafted 'the product standards of heavy ion medical accelerator" presenting the specifications of heavy ion medical accelerator, the methods of the registration detection, and particular requirements for the safety of electrical equipment. The Quality Management System (QMS) for the production of heavy-ion-therapy facility was established. The production license for medical devices in group III has been obtained.

Abstract 391 TUE-AP-MA-03-2 Invited Talk - Tuesday 3:30 PM - West Fork

The Evolving Role of Heavier-Ion Therapy: An Overview of the Potential Clinical Benefits and Risks

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Charged particles heavier than protons (e.g., helium and carbon ions) have increasingly been used worldwide for therapeutic treatment of cancer. Beams of these heavier charged particles, when compared with X-rays, exhibit the unique combination of improved 3D-dose distribution and increased relative biologic effectiveness (RBE). The greatest potential clinical benefit for treatment with heavier ions may be the RBE enhancement in eradicating those populations of cancer cells that are historically quite resistant to being killed by radiations of lower linear energy transfer (low-LET), such as X-rays and protons.

The accelerator technology is now rapidly developing to improve the efficiency and distribution accuracy of delivering these heavier ions clinically. Important frontiers remain, however, regarding optimization of dose and fractionation parameters in the treatment of various cancer types and of the range of normal-tissue-injury constraints mandated in different anatomical regions. As more clinical experience has been developed to supplement the **in vitro** cellular and laboratory-animal findings of prior decades, there has been a steady improvement in the therapeutic ratio of tumor-cell kill to normal-tissue injury. This overview presentation highlights the enhanced therapeutic potential and associated risks of treatment with these heavier ions.

Abstract 417 TUE-AP-MA-03-3 Invited Talk - Tuesday 3:30 PM - West Fork

Carbon-Ion-Radiotherapy in Japan

Tadashi Kamada

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Carbon-ion radiotherapy (CIRT) has progressed rapidly in technological delivery, indications, and efficacy. Owing to a focused dose distribution in addition to high linear energy transfer and subsequently high relative biological effect, CIRT is uniquely able to target otherwise untreatable hypoxic and radio-resistant disease while opening the door for substantially hypo-fractionated treatment of normal and radiosensitive disease. To date, nearly 70 protocols have been conducted at National Institute of Radiological Sciences to delineate CIRT efficacy, safety, optimal treatment indications, and dose fractionation. While initial protocols began with low doses delivered over an average of 18 fractions, deeper understanding of particle-beam radiobiology coupled with ongoing technological development has, after critical review of clinical data, enabled an average fractionation scheme today of 11 to 12, with single- or double-fraction treatment becoming standard for indicated lung and liver disease, respectively. In this paper, we aim to review update on the expanding role of CIRT in cancer treatment as of 2016.

Abstract 435 TUE-AP-TA-09-1 Invited Talk - Tuesday 3:30 PM - Rio Grande

Ultra-High Vacuum Seminar

Walt van Hemert

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This class provides an overview of the unique nature and requirements of ultra-high vacuum (UHV) which is a key enabling condition for many types of scientific inquiry and experimentation. Topics in session two will include pumping technologies from primary vacuum to UHV, pressure measurement gauges, system operation. The curriculum for this 120 minute class is intended to provide an introduction to ultra-high vacuum systems and practice for scientists, engineers and technicians. Attendees will receive a copy of the seminar handbook, "High and Ultra-High Vacuum for Science Research", 2011, 133 pages.

Abstract 183 TUE-AR-NST-04-1 Invited Talk - Tuesday 3:30 PM - Post Oak

Self-organized Ge & Si nanostructures by heavy-ion irradiation

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Heavy ions like Bi or Au of a few tens of keV deposit a high energy density into the collision cascade volume of due to (i) their high mass and (ii) their low projected range. At higher energies, this density becomes diluted as the cascade volume increases super-linearly with ion energy. Compared to monatomic ions, heavy polyatomic ions deposit an even higher

energy density. This is sufficient to form a pool of a localized, almost classical melt in a semiconductor surface lasting up to half of a nanosecond.

Local melting and re-solidification by single polyatomic ion impacts is proven by molecular dynamics calculations. Well-ordered, self-organized dot patterns on Si and Ge surfaces have been found after heavy polyatomic ion irradiation, which can be attributed to impact-induced local transient melting. Similar patterns were found with monoatomic ions at elevated substrate temperatures, where the energy per substrate atom exceeds a critical value within a larger volume.

The kinetics of localized melt pools leads to a generic, Kuramoto-Sivashinsky-type (KS) partial differential equation for the surface evolution. Whereas so far the mechanisms of ion-induced surface pattern evolution are assumed to be surface-curvature-dependent ion erosion or ion-momentum-induced mass drift of surface atoms, for heavy polyatomic ions we have identified a completely different mechanism.

The local melting and quenching process is so far from equilibrium that particularities of phase diagrams like the Bi state in Si or Ge are frozen into the nanostructure of the re-solidified volume. This opens the possibility to study extremely fast solid-liquid phase transitions.

The authors thank the German Research Foundation for financial support.

Abstract 200 TUE-AR-NST-04-2 Invited Talk - Tuesday 3:30 PM - Post Oak

Self-Organisation of plasmonic templates by Ion Beam Sputtering

Francesco Buatier de Mongeot

Dipartimento di Fisica , UniversitÃ di Genova, Via Dodecaneso, 33, Genova 16146, Italy

I will report on self-organised nanopatterning of metal-dielectric substrates induced by ion beam sputtering in view of large area photon harvesting and plasmonic applications.

In the first part of my talk I will describe the mechanisms which lead to the formation of a highly ordered array of faceted glass ripples when an amorphous glass substrate is exposed to defocused Ion Beam Sputtering (IBS). I will in particular highlight the mechanisms which determine the accelerated kinetics of formation and faceting of the high aspect ratio nanostructures. In a second step the faceted glass template is employed for the confinement of arrays of Au nanoclusters with plasmonic functionality.

In the simplest approach, by performing gold deposition at glancing angles, we form Au nanostripe arrays which provide a sharp plasmonic response in the visible spectral range; in a more complex approach the response is shifted in the NIR spectral range by stacking two stripes separated by a dielectric layer, thus forming coupled "nanosandwiches". The strong near-field enhancement at the plasmon resonance of the nanosandwiches can be exploited for plasmon enhanced spectroscopy applications. I will e.g.show the successful application of the templates for the enhancement of SERS (Surface Enhanced Raman Scattering) and SEIRA (Surface Enhanced Infrared Absortion) signals.

Abstract 143 TUE-AR-NST-04-3 Invited Talk - Tuesday 3:30 PM - Post Oak

Bio-applications of nano ripple pattern fabricated by gas cluster ion beam.

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The surface nano pattern formation has generated a promising application in clinical and biomedical related industry. Localized surface plasmon resonance effect is observed in the gold nano-ripple pattern formed by gas cluster ion beam irradiation. This nanostructure offers a simple and cost-effective scheme for biosensing. The gold nano ripple biosensor is capable of label-free real-time analytical detection and also shows high sensitivity and specific selectivity. The plasmonic response is based on the nano surface morphology, hence is tunable. By immobilizing a uniform and sterically accessible monolayer of antibody on the nano ripple surface and loading different concentrations of the specific antigen we identified the shift in the LSPR peaks triggered by the change of dielectric function in the vicinity of the structures. The LSPR biosensor was used to detect the antibody-antigen reaction of rabbit X-DENTT antibody and DENTT blocking peptide (antigen). The sensor can be further developed to obtain real-time analytical-reaction dynamics. Preliminary results on biological cell adhesion show anisotropic properties, which is important in the directional guidance of biological cells. The comparison of bacterial growth on nano ripple glass surface inside and outside the magnetic field was also observed. Bacteria grows more on nano ripple glass substrate than on a plain glass surface.

Abstract 229 TUE-AR-RE-03-1 Invited Talk - Tuesday 3:30 PM - Bur Oak

Application of Helium Ion Microscopy to study radiation damage

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Helium Ion Microscopy (HIM) is well known for its exceptional imaging and nanofabrication capabilities [1]. After a brief introduction of this relatively young technique, I will focus on the localized creation of defects in metals and insulators.

Point defects created by the impinging He beam can be exploited to create sub-micron sized luminescent areas in appropriate materials (NaCl) [2]. This combination of the nano sized beam of the HIM with ionoluminescence also allows to study fundamental processes of the defect formation and interaction [3]. A technological relevant application of low fluence irradiation in the HIM is the formation of arbitrary shaped nano scale ferromagnetic areas in an otherwise para-magnetic matrix. In the particular case $Fe_{60}Al_{40}$ has been irradiated with fluences of only $6\times10^{14}cm^{-2}$ to create spin valve structures with a critical spacer length of only 20 nm [4].

Going beyond normally used ion doses allows to investigate defect agglomeration, blister formation and the subsequent surface restructuring [5]. We present examples of materials modification at doses starting from 1×10^{17} cm^{-2} up to 1×10^{20} cm^{-2}. Examples of surface structures formed under extreme ion fluencies at different temperatures will be presented for a wide range of materials including technological relevant materials for nuclear applications (Gold, Tungsten, Iron).

References:

[1] G. Hlawacek, V. Veligura, R. van Gastel, and B. Poelsema, J. Vac. Sci. Technol. B Microelectron. Nanom. Struct. **32**, 020801 (2014).

[2] V. Veligura, G. Hlawacek, U. Jahn, R. van Gastel, H. J. W. Zandvliet, and B. Poelsema, J. Appl. Phys. **115**, 183502 (2014).

[3] V. Veligura, G. Hlawacek, R. van Gastel, H. J. W. Zandvliet, and B. Poelsema, J. Phys. Condens. Matter **26**, 165401 (2014).

[4] F. Röder, G. Hlawacek, S. Wintz, R. Hübner, L. Bischoff, H. Lichte, K. Potzger, J. Lindner, J. Fassbender, and R. Bali, Sci. Rep. **5**, 16786 (2015).

[5] V. Veligura, G. Hlawacek, R. P. Berkelaar, R. van Gastel, H. J. W. Zandvliet, and B. Poelsema, Beilstein J. Nanotechnol. **4**, 453 (2013).

Abstract 36 TUE-AR-RE-03-2 Invited Talk - Tuesday 3:30 PM - Bur Oak

He irradiation effects and annealing behaviour on Ti_3SiC_2

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The $M_{n+1}AX_n$ (MAX) phases are a new group of nanolayered, machinable, ternary carbides or nitrides which could have high radiation damage tolerance due to their special structures, and considered as one kind of novel damage self-healing material. In this study, 110 keV helium ion implantation of titanium silicon carbide (Ti_3SiC_2) at room temperature was carried out with doses of $5\times10^{16}cm^{-2}$ and $1\times10^{17}cm^{-2}$ and the subsequent evolutions of damage as well as the helium bubbles at different annealing temperatures were investigated using grazing incidence X-ray diffraction (GIXRD), Raman spectrum analysis and transmission electronic microscope (TEM).

He implantation introduces an additional factor to the damage produced by atomic collisions in Ti_3SiC_2. Implantation by keV ions at room temperature produces collision cascades which result in point defects in damaged Ti_3SiC_2 leading to TiC nanocrystal formation and ultimately amorphisation of Ti_3SiC_2. If He ions are used, then in addition to the damage just mentioned, the growth of He bubbles at defect sites will impede defect annealing at high temperatures and lead to the creation of more defects through the bubble growth.

Two types of structural transformation are found during the irradiation at room temperature. At low dose the Ti_3SiC_2 is damaged and in some cases decomposes to TiC nanocrystals through the loss of the mobile constituent Si. With increasing dose at room temperature, TiC is damaged and a significant proportion of the material is made up of damaged TiC. The other structural transformation into TiC crystal phase with a large grain size is driven due to He bubble growth. The punching out of matrix Si atoms adjacent He bubbles along the Si layer via bubble growth and/or production inter-bubble fracture between the bubbles by compressive stress of the bubbles are possible reasons of the structural transformation.

Depending on the level of He damage induced during the irradiation, a significant recovery of He irradiation damage to Ti_3SiC_2 can occur at moderate temperatures e.g. ~750?? for 5×10^{16} cm^{-2} He. As well, with annealing there is a change in bubble structure from isolated dense spherical shape to sparse platelet-like shape orienting in the direction of layered structure.

Abstract 360 TUE-AR-RE-03-3 Contributed Talk - Tuesday 3:30 PM - Bur Oak

Detrimental Effects of Bubble-loaded Grain Boundaries in Nanocrystalline and Coarse-grained Tungsten via Nanoindentation

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Nuclear materials exposed to helium ion bombardment have been shown to suffer from different morphological changes due to high bubble densities formed in grain matrices. Among the solutions proposed to mitigate this irradiation damage is the use of ultrafine and nanocrystalline materials of high grain boundary (helium and defect sink) density. Helium trapping on grain boundaries, however, can lead to bubble-loaded grain boundaries for which the impact on the mechanical properties of these materials is not well understood. In this study, we bombarded coarse, ultrafine, and nano-grained tungsten (NCW) with low-energy (2-4 keV) helium ions at two temperatures of 773 and 1223 K, and probed their mechanical properties through instrumented nanoindentation. Large bubble formation on grain boundaries was observed from in-situ TEM irradiation experiments on ultrafine and nanocrystalline tungsten. Nanoindentation on both irradiated and non-irradiated regions of the samples demonstrated detrimental effects on the indentation hardness and modulus of NCW following ion bombardment, which had little-to-no impact on the mechanical properties of the coarse-grained tungsten samples. Helium desorption also led to pore and crack formation on the grain boundaries in NCW, further exacerbating the negative influence of bubble-loaded grain boundaries. The mechanical properties of irradiated NCW will be an important consideration in the application of grain boundary engineering to control the radiation tolerance of tungsten in the context of plasma facing components for magnetic nuclear fusion applications.

Abstract 163 TUE-AR-RE-03-4 Contributed Talk - Tuesday 3:30 PM - Bur Oak

Rapidly screening the structure and properties of irradiated nanocrystalline zirconium with small-scale mechanical testing

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New nuclear reactor concepts that promise enhanced safety, efficiency, and service lifetimes require materials that withstand extremes of both radiation damage and mechanical loading. Experimental methods that enable expedited screening of candidate materials are invaluable in facing this challenge. Ion irradiation has been used for decades to rapidly cause radiation damage, allowing damage accumulation on timescales of hours or days instead of years of operation conditions. In the past decade, quantitative mechanical testing of small-sized samples has emerged as a way to probe fundamental material properties. The present work combines these two active research areas by creating miniaturized test samples suitable for combined radiation and mechanical testing.

Zirconium films were deposited onto silicon wafers, and a microfabrication technique was employed to create freestanding zirconium tension specimens affixed to elastic silicon test frames. These samples were loaded into a TEM holder that incorporates a quantitative nanoindenter with sub-μN load resolution and nm displacement resolution, which was used to actuate the load frames. The samples were subjected to ion irradiation performed **in situ** in the TEM with 1.4 MeV Zr^{2+} ions to nominal damage levels of 0.26, 2.6, and 26 dpa. Subsequently, the samples were tested in tension **in situ** in the TEM to failure. This work demonstrates the viability of combined radiation and mechanical testing of small-scale samples for rapidly testing the response of irradiated nanocrystalline zirconium, with potential applicability to many other material systems.

This research was funded by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences, Division of Materials Sciences and Engineering. Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin company, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Abstract 125 TUE-PR-SP-11-1 Invited Talk - Tuesday 3:30 PM - Elm Fork

The Edwards Accelerator Laboratory at Ohio University

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The Edwards Accelerator Laboratory at Ohio University is the hub for a vibrant program in low energy nuclear physics. Research performed with the lab's 4.5MV tandem accelerator spans a variety of topics, including nuclear astrophysics, nuclear structure, nuclear energy, homeland security, and materials science. The Edwards Lab hosts a variety of capabilities, not least the unique beam swinger combined with a neutron time-of-flight tunnel, enabling experiments to be performed with low-to-medium mass stable ion beams using charged-particle, gamma, and neutron spectroscopy. This presentation will provide an overview of the current and near-future research program in low energy nuclear physics at Ohio University, including a brief discussion of the present and planned technical capabilities.

Abstract 167 TUE-PR-SP-11-2 Invited Talk - Tuesday 3:30 PM - Elm Fork

Current Facilities and Research at the University if Notre Dame's Nuclear Science Laboratory

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The Nuclear Science Laboratory (NSL) is a Low Energy accelerator laboratory based at the University of Notre Dame. The main program of the facility is conducted with the use of two electrostatic accelerators of 11 MV and 5 MV. The main research program currently centers on reactions of interest for nuclear astrophysics and structure, utilizing amongst other techniques, direct reactions, recoil mass separation and accelerator mass spectrometry. Other research highlights also include a radioactive beam facility and ion trapping techniques. With extensive graduate and undergraduate participation, the laboratory utilizes a hands on approach for student teaching opportunities, while operating a research program at the forefront of physics.

Abstract 251 TUE-PR-SP-11-3 Invited Talk - Tuesday 3:30 PM - Elm Fork

Research at the University of Kentucky Accelerator Laboratory

Michael A. Kovash

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The Department of Physics & Astronomy at the University of Kentucky operates a 7 MV CN Van de Graaff accelerator that produces primary beams of protons, deuterons, and helium ions. An in-terminal pulsing and bunching system operates near 2 MHz, and is capable of providing 1 nsec beam bunches at a current of a few micro-amperes. Nearly all of the ongoing research program involves secondary pulsed beams of neutrons produced with a variety of solid targets, as well as with cells containing gaseous deuterium or tritium. Most experiments are done at a target station positioned over a deep pit, so as to reduce the backgrounds created by backscattered neutrons.

Three recent experiments will be described. The total cross section for neutron-proton scattering has been measured at neutron energies from 90 to 1800 keV. This transmission experiment used a pulsed and well-collimated neutron beam and a set of polyethylene samples. Neutrons transmitted by the sample were detected in a deuterated liquid scintillator. These results have been used to determine the n-p effective range parameter. Also, the response of the plastic BC-418 below 1 MeV has been measured by detecting low-energy neutrons scattered by an active scintillator target. The light produced by recoil protons which are "tagged" in this way is calibrated against gamma- and X-ray sources down to energies of a few 10s of keVee. Finally, the radiative capture reaction, np->d gamma is investigated by detecting both the capture gamma rays

and the recoil deuterons in coincidence. This reaction is believed to have produced the first nuclei approximately 2 minutes after the occurence of the Big Bang. The present status of this ongoing experiment will be discussed.

Abstract 450 TUE-PR-SP-11-4 Invited Talk - Tuesday 3:30 PM - Elm Fork

The Triangle University Nuclear Laboratory: An overview of the Accelerator Facilities and Research Program

C.R. Howell

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The Triangle Universities Nuclear Laboratory (TUNL) is a research consortium of Duke University, North Carolina State University and the University of North Carolina at Chapel Hill. The consortium operates three accelerator facilities at Duke University: the High Intensity Gamma-ray Source (HIGS), the Laboratory for Experimental Astrophysics (LENA), and the tandem Van de Graaff accelerator laboratory. The main research programs at these facilities include studies of nucleon structure, nuclear structure and nuclear astrophysics. In addition, the beam and detector systems at these facilities are used for applied research in the areas of nuclear security, plant biology and municipal water purification. The faculty conducting research at the TUNL accelerator facilities have a long tradition of educating graduate students with opportunities for hands-on experiences and for participation in all stages of a research project from conception to dissemination of results. These signature traits are foundational in preparing students for a broad range of careers in academia, research and industry. An overview of the beam capabilities and research programs at the TUNL accelerator facilities will be presented.

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Abstract 410 WED-PS-AR-0 Plenary Talk - Wednesday 8:00 AM - Rio Grande

Computational Modeling and Materials Research Needs for Plasma Facing Components and Materials for Fusion Reactors beyond ITER

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The performance of plasma facing components (PFC) is one of the main issues facing ITER and future magnetic fusion reactors. Tungsten will be used in ITER as the PFC material and is considered to be one of the primary candidates for future reactors. However, recent experiments that exposed tungsten to He plasma exposure or He ion irradiation with ion energy less than about 100 eV (well below the threshold energy for physical sputtering or Frenkel pair production in tungsten) reveal significant surface modification, including the growth of nanometer-sized "fuzz", and formation of a layer of nano-bubbles in the near-surface region [1,2]. It is widely accepted that He atoms in tungsten, like in other metals, are insoluble and tend to form small clusters, which serve as the nucleating event for the formation of larger gas bubbles. It is also clear from atomistic simulations [3,4] that the processes of trap mutation produce W interstitial atoms that lead to surface morphology modification as the interstitials diffuse to and annihilate at the surface, in addition to plastic flow and dislocation loop punching processes driven by high compressive stresses caused by over-pressurized clusters, or nanometer-sized bubbles, and these processes can alter both the tungsten surface morphology and the He clustering dynamics.

One of the challenges with describing these effects for the large-extrapolations in performance required for the PFCs in next-step devices beyond ITER is the large span of spatial and temporal scales of the governing phenomena and, therefore, the theoretical and computational tools that can be used. Fortunately, recent innovations in computational modeling techniques, increasingly powerful high performance and massively parallel computing platforms, and improved analytical experimental characterization tools provide the means to develop self-consistent, experimentally validated models of plasma materials interactions that govern the performance and degradation of the divertor and PFCs in the fusion energy environment. This presentation will describe the challenges associated with modeling the performance of divertor PFCs in a next-step fusion materials environment, the opportunities to utilize high performance computing and present examples of recent progress to investigate the dramatic surface evolution of tungsten exposed to low-energy He and H plasmas, as well as the coupled He-defect evolutions in bulk structural materials exposed to high-energy He and neutron irradiation before laying out a vision for developing a computational materials modeling framework for fusion materials behavior.

[1] S. Takamura, et al., Plasma Fusion Res. 051 (2006) 1.

[2] M. J. Baldwin and R. P. Doerner, Nucl. Fusion 035001 (2008) 48.

[3] F. Sefta, et al., Nucl. Fusion 073015 (2013) 53.

[4] A. Lasa, et al., NIMB 156-161 (2013) 303.

Abstract 392 WED-PS-AA-01-0 Plenary Talk - Wednesday 8:45 AM - Rio Grande

Low energy ion scattering: Recent advances and future applications

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Low energy ion scattering (LEIS) offers high sensitivity to light adsorbates, as well as the ability to simultaneously probe surface structure, composition, and electronic properties. Since its initial development [1], LEIS has been applied to a variety of specialized research areas. The difficult task of interpreting the complex interactions between the low-energy ions and the surface had previously presented a considerable barrier to its wider adoption. However, recent advancements in computational modeling and experimental methods have motivated several new areas of active research. Coupled with new detector geometries, the extreme surface specificity of LEIS has revealed the compositional details of ultra-thin surface layers such as graphene [2] as well as topological insulators [3]. Mapping techniques, where scattered ion intensities are acquired over a large angular sector, now allow for quantitative determination of surface structure and the binding configuration of light adsorbates such as hydrogen [4]. Furthermore, the recent discovery of fast atom diffraction at gazing incidence [5,6] now provides a real-time diagnostic of insulator surface structure. The aforementioned advancements highlight the potential to apply LEIS to a variety of more complex materials systems. In this report, we will highlight two such applications: hydrogen storage applications for fuel cell electric vehicles and ion surface interactions for magnetic fusion energy.

[1] D. P. Smith, **J. Appl. Phys. 38** (1967) 340.

[2] S. Průša, P. ProchÁzka, P. BÁbor, T. Šikola, R. ter Veen, M. Fartmann, T. Grehl, P. Brüner, D. Roth, P. Bauer, and H. Brongersma, **Langmuir 31** (2015) 9628.

[3] X. He, W. Zhou, Z. Y. Wang, Y. N. Zhang, J. Shi, R. Q. Wu, and J. Yarmoff, **Phys. Rev. Lett. 110** (2013) 156101.

[4] R. D. Kolasinski, N. C. Bartelt, J. A. Whaley, and T. E. Felter, **Phys. Rev. B 85** (2012) 115422.

[5] A. Schüller S. Wethekam, and H. Winter **Phys. Rev. Lett. 98** (2007) 016103.

[6] P. Rousseau, H. Khemliche, A. G. Borisov, and P. Roncin, **Phys. Rev. Lett. 98** (2007) 016104.

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Abstract 33 WED-AC-AS-01-1 Invited Talk - Wednesday 10:00 AM - Trinity

Opening the National Labs: Technology Transfer at Argonne

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Argonne National Laboratory (ANL) is collaborating with RadiaBeam on development and testing of high gradient S-band accelerating structures. The Argonne RF Test Facility (ARTF) at ANL\\APS has been established for testing of S-band RF structures for the electron linac. This facility has been upgraded and used for the testing of an S-band high-gradient structure designed and built by RadiaBeam for high pulsed RF power operation in electron accelerators. The 5-cell structure demonstrated 52 MV/m acceleration field at 2 μs 30 Hz RF pulses. The successful test demonstrates that the ARTF is available for industry for testing of S-band RF structures. High gradient accelerating structures are being developed at RadiaBeam in collaboration with ANL for compact ion linacs with primary application in proton and carbon therapy. High power testing of these structures is planned at ANL facility.

Abstract 78 WED-AC-AS-01-2 Invited Talk - Wednesday 10:00 AM - Trinity

Opening the National Labs: Technology Transfer at Brookhaven

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Recently, funded by the Accelerator Stewardship Test Facility Pilot program, BNL has collaborated with Euclid Techlabs to test a field emitter cathode in a SRF gun. The experiments **are currently being carried out at the BNL SRF testing facility.** The SRF testing facility, including a qualified clean room, cavity baking oven and two **Vertical Testing Facilities, is a modern facility capable of performing various tests on SRF cavities**. **In this facility, we have** tested multiple SRF guns and cavities such as 704MHz SRF gun, Light source II cavities, 56MHz QWR cavities and 704 five cells cavities.

In this talk, we will show the department's accelerator capabilities and current R&D activities. we will **also** present the progress of ultra-nano-crystalline diamond film field emitter testing in the BNL 1.3GHz SRF gun.

Abstract 99 WED-AC-AS-01-3 Invited Talk - Wednesday 10:00 AM - Trinity

Technology Transfer in Electromagnetic Simulation Using High Performance Computing at SLAC

Cho-Kuen Ng

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Microwave (rf) accelerator technology is a core capability at SLAC, which has evolved out of years of development and operation of its accelerators. The transfer of SLAC's rf technology to US Industry, such as high power klystrons for commercial rf power sources and compact linear accelerators for industrial and medical applications, increases the societal impact of these Government investments. The Accelerator Stewardship Program is providing a vehicle to further promote this technology transfer, funding a SLAC-Industry collaboration to develop a new class of high-efficiency high-power klystron, and another to develop a compact, high-efficiency rf accelerator for industrial applications. Another unique SLAC capability is ACE3P, a parallel finite-element simulation suite for large scale, high fidelity electromagnetic modeling, which can be applied to a wide range of modeling applications in industry and academia. Under a recent Accelerator Stewardship Test Facility Pilot Program (ASTFPP) collaboration, between SLAC, Stanford University and Simmetrix Inc., ACE3P has been used to perform realistic simulations on CAD models of human phantoms characterized by a number of tissues. These simulations investigated electromagnetic wave propagation that revealed the phenomenon of harvesting implanted devices using wireless powering coupled from external sources. Employing an optimized power source with a specific pattern of field distribution, the propagation and focusing of electromagnetic waves in the phantom has been demonstrated. Substantial speedup of the simulation is achieved by using multiple compute cores on the supercomputer facilities at NERSC. Potential future applications to other areas of medical research such as microwave imaging will be discussed.

Work supported by the US DOE under contract DE-AC02-76SF00515.

Abstract 296 WED-AC-AS-01-4 — Invited Talk - Wednesday 10:00 AM - Trinity

Opening the National Labs: Accelerator Technology and Tech Transfer at Berkeley Lab

Thomas Schenkel

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Berkeley Lab has a long history in the invention and development of accelerators and its Accelerator Technology and Applied Physics Division (http://atap.lbl.gov/) is now the home of a series of exciting new developments in accelerator science and technology. In my presentation I will highlight several of these topic areas including accelerators based on laser-plasma acceleration (for both electrons and ions), high field magnets and emerging MEMS based accelerators. I will describe the process for technology transfer and the many ways for colleagues from industry, academia and from other labs to collaborate and work together with us and to bring novel accelerator technology from the lab into the market place.

Abstract 121 WED-AP-IA-03-1 — Invited Talk - Wednesday 10:00 AM - Bur Oak

Accelerator Technology Development at Tri Alpha Energy

Artem Smirnov

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Dramatic improvement in the plasma stability and confinement, which have been demonstrated in advanced, beam-driven field-reversed configuration (FRC) plasmas [1], point to the prospect of a beam-driven FRC as an intriguing path towards a fusion reactor. To support its current and future experimental efforts, Tri Alpha Energy, in collaboration with Budker Institute (Novosibirsk, Russia), has established a program on accelerator technology development.

For the TAE current experimental device, C-2U, a highly versatile, robust, and reliable positive-ion-based neutral beam injection (NBI) system was developed. The system can deliver up to a total of 10 MW of hydrogen beam power (15 - 40 keV, various pulse lengths from 10 ms to 1 s), by far the largest ever used in compact toroid plasma experiments. The injectors feature flexible, modular design based on a triode ion optical system with multi-aperture inertially cooled grids and ballistic beam focusing. The plasma sources generate up to 50 Amps (RF) and 180 Amps (arc) of extracted ion current.

To further the beam-driven FRC research effort, a reactor relevant prototype (1 MeV, 5 MW, 1000 s) of a negative-ion-based neutral beam injector is being developed [2]. Compared to conventional designs, several breakthrough innovations were introduced in this system, which increase the beam reliability, robustness, and power efficiency. The development of injector components is carried out in parallel to enabling full prototype demonstration on a megavolt acceleration test bed, which is now under commissioning.

This talk will provide a comprehensive overview of the TAE beam technology, including its potential applications outside of fusion.

References

[1] M. Binderbauer **et al**., Phys Plasmas **22**, 056110 (2015)

[2] A. A. Ivanov **et al.**, Rev. Sci. Instrum **85**, 02B102 (2014).

Abstract 192 WED-AP-IA-03-2 Invited Talk - Wednesday 10:00 AM - Bur Oak

A compact, lightweight, superconducting electron accelerator for environmental applications

Thomas K Kroc, Jayakar C Thangaraj, Charles A Cooper, Lance D Cooley, Robert D Kephart

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Accelerators developed for Science now are used broadly for industrial, medical, and security applications. While more than 30,000 accelerators touch over $500B/yr in products producing a major impact on our economy, health, and well being, new industrial applications require higher average beam power than what is presently available. Industrial accelerators must be cost effective, simple, versatile, efficient, and robust. Exploiting recent advances in Superconducting Radio Frequency (SRF) cavities and RF power sources as well as innovative solutions for the SRF gun and cathode system, a collaboration of Fermilab, CSU, NIU, and industrial partners has developed a design for a compact SRF high-average power electron linac. This class of accelerators will be capable of up to 250 kW average power, continuous wave operation and will produce electron beam energies up to 10 MeV. These accelerators will be small and light enough to mount on mobile platforms or to be incorporated into existing plant layouts. Such accelerators will enable new in-situ environmental remediation methods at wastewater and biosolid treatment facilities. A biosolid treatment project is currently is currently being investigated in cooperation with the Metropolitan Water Reclamation District of Greater Chicago. Mobile versions will allow on-site remediation. More importantly, we believe this accelerator will be the first of a new class of simple, turn-key SRF accelerators that will find broad application in industry, medicine, security, and science.

Abstract 386 WED-AP-IA-03-3 Invited Talk - Wednesday 10:00 AM - Bur Oak

Superconducting RF Linacs Driving Subcritical Reactors for Profitable Disposition of Surplus Weapons-grade Plutonium

Rolland P. Johnson

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Acceptable capital and operating costs of high-power proton accelerators suitable for profitable commercial electric-power and process-heat applications have been demonstrated by the ORNL Spallation Neutron Source (SNS). Scaling from its 6% duty factor with 1.4 MW of beam on target to CW operation by appropriate upgrades of components, the traditionally considered Accelerator-Driven System (ADS) goal of 10 MW at 1 GeV is easily surpassed. However, studies have pointed out that even a few hundred trips of an accelerator lasting a few seconds would lead to unacceptable thermal stresses as each trip causes fission to be turned off in solid fuel structures found in conventional reactors. The newest designs based on the GEM*STAR [1] concept, however, take such trips in stride by using molten-salt fuel, where fuel pin fatigue is not an issue. Other aspects of the GEM*STAR concept, which addresses all historical reactor failures, include an internal spallation neutron target and high temperature molten salt fuel with continuous purging of volatile radioactive fission products such that the reactor contains less than a critical mass and almost a million times fewer volatile radioactive fission products than conventional reactors like those at Fukushima. GEM*STAR is a reactor that without redesign will burn spent nuclear fuel, natural uranium, thorium, or surplus weapons material. It will operate without the need for a critical core, fuel enrichment, or reprocessing making it an excellent candidate for export. While conventional nuclear reactors are becoming more and more difficult to license and expensive to build, SRF technology development is on a steep learning curve and the simplicity implied by subcritical operation will lead to reductions in regulatory hurdles and construction complexity. We describe the design and discuss the prospects for funding a pilot plant for the profitable disposition of surplus weapons-grade plutonium by using process heat to produce green diesel fuel for the DOD from natural gas and renewable carbon.

[1] C.D. Bowman, R.B. Vogelaar Edward G. Bilpuch, Calvin R. Howell, Anton P. Tonchev, Werner Tornow, R.L. Walter, "GEM*STAR: The Alternative Reactor Technology Comprising Graphite, Molten Salt, and Accelerators", Handbook of Nuclear Engineering, DOI 10.1007/978-0-387-98149-9_24, Springer Science and Business Media LLC, 2010.

Abstract 242 WED-AP-IA-03-4 Contributed Talk - Wednesday 10:00 AM - Bur Oak

Validation of Nuclear Data Important for Spent Nuclear Fuel Transmutation

Lukas Zavorka[1,2], Jindrich Adam[1], Valery Victorovich Chilap[3], Walter Ilich Furman[1], Jurabek Khushvaktov[1], Alexander Alexandrovich Solnyshkin[1], Milena Stoyanova[4], Martin Suchopar[5], Pavel Tichy[1,2], Vsevolod Mikhailovich Tsoupko-Sitnikov[1], Sergey Ivanovich Tyutyunnikov[1], Radek Vespalec[1,2], Jitka Vrzalova[1,5], Kamila Wilczynska[6], Miroslav Zeman[1,7]

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(4) Sofia University St. Kliment Ohridski, Sofia, Bulgaria
(5) Nuclear Physics Institute, Rez, Czech Republic
(6) AGH - University of Science and Technology, Krakow, Poland
(7) Brno University of Technology, Brno, Czech Republic

Transmutation of spent nuclear fuel in fields of spallation neutrons has been systematically investigated at the Joint Institute for Nuclear Research, Dubna, almost for three decades. Since recent years, activation experiments have been performed with the massive natural uranium spallation target and relativistic proton, deuteron and carbon beams to study the possibility of burning actinides in Accelerator-Driven Systems (ADS) under a wide range of physical conditions. The ongoing research primarily concentrates on benchmarking relevant radiation transport codes, spallation models and nuclear data libraries.

In this work we present results of experiments focused on investigation of both production and fission incineration of actinides ^{233}U, ^{235}U, ^{236}U, ^{238}U, ^{237}Np, ^{238}Pu, and ^{239}Pu. Transmutation efficiency was measured using radioactivation foil technique with sandwiches made of these elements. The foils were installed in different positions inside the uranium spallation target during irradiation with the intense 660 MeV proton beam which generated the secondary spallation neutron flux reaching its maximum approx. 10^{10} n cm^{-2}s^{-1} at the center of the target.

The experimental yields of (**n,f**), (**n,γ**), and (**n**,2**n**) reactions in actinides were compared to the results of predictions using the MCNPX 2.7 code for calculation of particle flux and ENDF/B-VII.0, JENDL/HE-2007, TENDL-2015, and TALYS 1.8 tools for determination of reaction cross sections. Although a good agreement between experiment and simulation was

found for the samples on the periphery of the spallation target, the centrally located sandwiches did not perform to expectations. The results indicate that there are still areas in nuclear data to be improved, especially at energies above 20 MeV which are particularly important for ADS research.

Abstract 323 WED-AP-IA-03-5 Contributed Talk - Wednesday 10:00 AM - Bur Oak

Application of sum coincidence corrections for study of reaction rate of residual nuclei in fission and spallation.

Fariza Fariza Sagimbaeva[1,2,3]

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Nowadays, problem with managing of spent nuclear fuel is an important issue. Therefore development of advanced nuclear systems is essential. Our group in the Joint Institute for Nuclear Research focuses on accelerator driven systems. It uses special set-ups made from spallation target and subcritical blanket. The set-ups are irradiated by relativistic proton or deuteron beam and a vast amount of neutrons comes into existence. Use of activation detectors for measurement of the neutron production is a reliable and very convenient method. When reaction rates of residual nuclei from fission and spallation reactions are evaluated, corrections of sum coincidence effect need to be taken into consideration.

Abstract 22 WED-AP-IA-03-6 Contributed Talk - Wednesday 10:00 AM - Bur Oak

Elemental Analysis of Selected Toys by RBS, Electron Microprobe, and XPS

Christina Han Young[1], Chibu O Umerah[1], Zhiping Luo[1], John Derek Demaree[2], Daryush Ila[1]

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Some polymeric toys may contain heavy metal elements as lead, mercury, and others, which can be toxic to children, especially with long term exposure or ingestion (e.g., when they place the toys in their mouths). Most countries exporting cheap toys often use inexpensive and unregulated materials in their manufacturing processes, and organizations such as the Consumer Product Safety Commission (CPSC) have set many strict standards for toy safety (e.g., according to CPSC "The standard of lead in children's products should be no more than 100 ppm of total lead content in accessible parts"). In this study we have used Rutherford Backscattering Spectrometry (RBS), X-ray photoelectron spectroscopy (XPS), and electron microprobe techniques in order to determine the elemental content of selected toys readily available in the market. RBS is a standardless technique which provides elemental information in the first few micrometers of a surface with parts-per-thousand sensitivity; electron microprobe probes somewhat deeper, but is somewhat reliant on standards; and XPS is a highly surface-sensitive technique that measures the both the elemental composition and chemical bonding information for the first 10 nm of a material. Together, the three techniques can provide a view into the possible presence of harmful metals in a number of polymeric toy materials. In this paper, we will present our findings on a number of sample products, and provide a comparison with allowable limits.

Abstract 235 WED-AP-MA-01-1 Invited Talk - Wednesday 10:00 AM - West Fork

Important Developments in Proton Therapy and an Update on the Current Clinical Uses of Proton therapy.

Niek Schreuder, Michael Bozeman, Joe Matteo, Jon Treffert, Jeff Pelletier, Laddie Derenchuk

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Pencil beam scanning (PBS) is the generic name for delivering the radiation dose to a target using individually controlled small pencil beams of accelerated protons to cover a target in 3 dimensions. Today PBS is in routine clinical use in the majority of proton therapy facilities across the globe. The increased flexibility in shaping the dose which enables a much better dose conformation, especially to large and non-contiguous targets, truly revolutionized proton therapy during the last few years.

Although most modern day Proton Therapy Systems offer PBS delivery techniques, many important features are still missing from many of the commercially available proton therapy systems. The ProNova SC360 Proton Therapy System, which will receive FDA approval during the second half of 2016, is the newest complete and compact system and addresses the major historic shortcomings in proton therapy systems. The SC360 combines many new developments from several research institutes in a single highly optimized compact setting to provide the world's most modern proton therapy system to the radiation therapy community and will allow the further exploitation of PBS to treat even a larger cohort of patients than possible previously.

A highlight of the ProNova system is that it utilizes compact super conducting magnetic achromats to transport the protons to the patient a in a full 360 degree gantry that is 40%-60% smaller and up to 4 times lighter than other conventional 360 degree room temperature gantries. Footprint reductions alone can reduce constructions costs up to 42% dramatically impacting overall project costs. In addition, the SC360 offers couch integrated 3D volumetric image guidance at isocenter (medPhoton GmbH) supplemented with high precision optical tracking systems in order to ensure the accuracy of the robotic patient-positioning arm (Leoni AG). ProNova will leverage the power of the imaging system to develop an adaptive planning capability to further improve patient outcomes.

The beam transport system, similar to the system used at the IU Health Proton Therapy Center (Indiana University, Bloomington, IN, USA), offers individual energy modification systems for each treatment room that together with Lambertson magnets and fast kicker magnets allows rapid room to room beam switching in under 3 milliseconds. The control software was developed by ProNova engineers and Physicists according to well researched clinical specifications and with direct input from the clinical teams that are treating more than 75 patients per day at the Provision Center for Proton Therapy (PCPT). This interaction ensures that the clinical user will experience an efficient workflow similar to best-in-class LINACs.

The general utilization of proton therapy has now been expanded to almost all sites in the body and the use of the ProNova SC360 system will allow users to treat the more complex sites with greater efficiencies. This presentation will address the main technological advances that the ProNova system brings to the user. Since we have treated more than 1200 patients with PBS at PCPT we will also share clinical examples of cases that are now being treated with PBS protons.

Abstract 56 WED-AP-MA-01-2 Invited Talk - Wednesday 10:00 AM - West Fork

Accelerators for particle therapy: what is so Special?

Marco Schippers

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Most particle (ions) accelerators have been developed in laboratories for nuclear and high-energy physics. Their successful application in particle therapy has initiated several of these laboratories and especially industry to modify these accelerators such that they are applicable in a clinical environment.

The specific requirements of accelerators for radiation therapy will be discussed. The focus will be on accelerator and beam transport design aspects, but also operational and formal aspects. For this clinical application there are special requirements to reach a high reliability for the patient treatments as well as an accurate delivery of the dose at the correct position in the patient. It will be shown that also the used dose application technique imposes special operating characteristics of the accelerator.

The requirements of the beam parameters are quite different from those in a nuclear physics laboratory. For example for therapy one needs a special matching of the emittance of the accelerated beam, requirements on beam intensity and stability and a prevention of activation. The way of operating a medical device requires not only operators, but especially one needs an efficient and safe machine operation by non-accelerator specialists operating in different control rooms in such a facility.

Certification and legal aspects play an important role in a medical device. THerefore these and their consequences for daily operation will also be discussed.

Last but not least size, weight and price are important for a in a hospital based facility. This is encouraging new developments and has stimulated novel accelerator types, of which a few examples will be described.

Abstract 230 WED-AP-MA-01-3 Invited Talk - Wednesday 10:00 AM - West Fork

Small Gantries for Proton and Carbon Cancer Therapy with the Fixed Magnetic Field during the Whole Patient Treatment

NIcholaos Tsoupas, Stephen Brooks, Brett Parker, Mike Anerella, DEJAN TRBOJEVIC

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We present an update on the large momentum acceptance gantries for the hadron cancer therapy. The gantries are based on the Non-Scaling Fixed field Alternating Gradient principle and can propagate protons and carbon ions in the energy range required for the patient treatment. The proton gantry is made of the small permanent magnets Halbach type with a spot scanning system above the patient. The proton gantry kinetic energy range is from 35- 250 MeV. The carbon large momentum acceptance gantry using the superconducting combined function magnets and has energy range from either 195-400 MeV/u or from 95-195 MeV/u.

Abstract 120 WED-AP-MA-01-4 Contributed Talk - Wednesday 10:00 AM - West Fork

Clinical Outcome and Technological Developments for Carbon-Ion-Radiotherapy at HIMAC

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Heavy Ion Medical Accelerator in Chiba (HIMAC) at National Institute of Radiological Sciences, Japan, started the Carbon-Ion-Radiotherapy (C-ion RT) in 1994, and patients exceeding 10,000 were treated until 2016. Clinical outcome revealed the efficacy of C-ion RT, being summarized as (1) significant anti-tumour effect, (2) lower toxicities, and (3) drastic reduction of an overall treatment period. While the treatment continues, big improvements for irradiation system were carried out in recent years. One is the ultra-fast scanning system which is applicable to the moving organs. The newly

developed irradiation system is in daily use at HIMAC. Ion-beam Radiation Oncology Center in Kanagawa (i-ROCK), which started the treatment at the end of the last year, employed the new irradiation system. The other is the Compact Rotating Gantry for Carbon (CRGC) using super-conducting magnets and equipped with the ultra-fast scanning system. The gantry had been assembled in the treatment room G, and is under commissioning.

Abstract 55 WED-AP-MA-01-5 Invited Talk - Wednesday 10:00 AM - West Fork

Miniaturizing Proton Therapy: A Technical Challenge With Unclear Clinical Impact

Marco Schippers

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Recent technical developments in proton therapy on the miniaturization of the irradiation equipment and the increasing interest in smaller proton therapy facilities, have strengthened the motivations to obtain cheaper therapy and a wider use of particle therapy. Although smaller facilities are already in clinical operation, the major technological steps to take this to the next level will typically need in the order of 10 years, as the necessary time between first trials and their introduction into clinical practice.

An overview of these developments will be given. The advantages of these new developments will be discussed, together with possible limitations. Also the approximate current status will be reviewed. In this respect we will focus on recent developments in gantry design, as well as those in accelerator development. At a more general level, also the balance between the essential high treatment quality and cost efficiency will be discussed. In the conclusions it will be explained that it is expected that the developments need to proceed in moderate steps, in order to keep the high quality of this type of treatment.

Abstract 279 WED-AP-MA-01-6 Contributed Talk - Wednesday 10:00 AM - West Fork

Development of a manufacturing process for 4-channel neural probes on optical fiber substrates

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The function of a neuron depends on its microcircuitry - the inputs it receives from local and long-range connections and the outputs it sends to other neurons. Mapping these connections is typically done by stimulating a population of neurons chemically, electrically, or optically, and recording the induced extracellular action potentials using implanted neural probes. Optogenetics uses genetic manipulation to insert opsin-containing ion channels into a target population of neurons. Then, light can be used to optically stimulate and/or silence spiking activity with very high cellular specificity and spatio-temporal resolution. In this paper, we discuss the fabrication of a novel 4-channel neural probe with integrated, thin film conductor and dielectric coatings on the cylindrical surface of fine optical fibers. The use of optical fibers as probe substrates provides high intensity, multi-spectral light delivery with essentially no coupling loss, as well as the strength and stiffness required for deep-brain applications.

Lithography for forming micron-scale integrated structures on optical fibers requires a) a conformal resist process, b) a large depth-of-field, and c) a technique for registering the layers of the device. Our approach uses ion beam proximity

lithography, where a broad beam of energetic light ions illuminates a stencil mask and transmitted beamlets transfer the mask pattern to resist on a fiber. The resist is plasma-deposited styrene, which becomes insoluble in amyl acetate developer when cross-linked by energetic particle exposure [Fong et al. 1988; Parikh et al. 2008]. Mask-to-fiber alignment is accomplished using a micromachined silicon-jig formed by two families of intersecting V-grooves anisotropically etched into opposite sides of a silicon wafer (100). The window formed by the intersection of the top and bottom grooves defines the width of the resist line; the upper groove is designed so that the fiber protrudes above the wafer-plane where it can be clamped by a light metal spring, resulting in the exposure of a perfectly aligned resist line when the ion beam impinges on the bottom of the jig. A similar approach is used to pattern the openings (**via**s) in the dielectric overcoat where the metal line contacts cerebro-spinal fluid. Metal lines are formed by DC-magnetron sputtering and ion milling. The cross-linked resist that remains after the last lithography step forms the protective, insulating jacket of the finished probe. Probes have been fabricated on 50μm, 65μm, and 430μm multimode silica fibers.

Comparisons were made between the impedance spectrum of a single gold electrode as-manufactured and after 3 week life test. This test included a) 11 days with 1KHz continuous stimulation at ~1mA/cm^2 in room temperature phosphate buffered saline (PBS), b) repeated insertion in agar (which has the consistency of brain tissue), and c) an 11 day soak in PBS at 37 degrees Celsius. A detailed analysis showed that the differences between these spectra were not statistically significant. High quality recordings of photostimulated neural activity were acquired in the primary visual cortex of a bush baby.

The yield and throughput of the manufacturing process and the **in-vivo** reliability of 4-channel probes will be reported at the conference.

Abstract 445 WED-AP-TA-06-1 Invited Talk - Wednesday 10:00 AM - Rio Grande

Graduate education in accelerator science

William A Barletta

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Despite the widely recognized importance of accelerator science and technology to discovery science and national economies worldwide, formal graduate programs or even single courses introducing accelerator science remain scarce in American universities. Fortunately the past several years has seen some slow growth in relevant university programs. Crucial contributors in filling the training gap both in the US and overseas have been the regional accelerator schools which have forged alliances between universities and national laboratories. This paper explains the successful approach taken by the US Particle Accelerator School in providing graduate level education across the wide range of relevant technologies and raising the academic presence of accelerator science in US universities.

Abstract 88 WED-AP-TA-06-2 Invited Talk - Wednesday 10:00 AM - Rio Grande

A Laboratory for Experimental Nuclear Astrophysics as a Hands-On Educational Environment

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Improving models of stellar evolution depends on having accurate nuclear reaction rate measurements at energies where primary nucleosynthesis processes occur. Working with colleagues over the last 15 years, we have created at the Triangle Universities Nuclear Laboratory (TUNL) a Laboratory for Experimental Nuclear Astrophysics (LENA) where we produce beams for very accurate (p,γ) capture reaction measurements. As the beam energy drops through the Gamov window, where most important stellar nucleosynthesis reactions occur, resulting count rates can be under 10/day because cross sections drop exponentially from Coulomb repulsion. Measure-ments are feasible only with very high beam intensities to maximize the real count rate, and with very well shielded detectors and innovative data extraction techniques to pull tiny signals from continuous environmental backgrounds. Our laboratory provides unique opportunities for exceptional student

training in designing, building, maintaining, and using accelerator, ion source, detector, and computational systems. Among these are a upgraded HVEC 1 MV Model JN Van de Graaff accelerator, and a separate, compact, high-current ECR ion source with a 80-to-240 kV beam acceleration and transport system capable of providing up to 2.5 mA of pulsed proton beam on target. An overview of specific student experiences gained while working on these systems will be provided.

Abstract 166 WED-AP-TA-06-3 Invited Talk - Wednesday 10:00 AM - Rio Grande

Rare Isotope Beams in Nuclear Science and Education

Antonio C.C. Villari

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Most of the recent progress in Nuclear Physics at low energies, including spectroscopy, Nuclear Astrophysics and reactions, were done using Rare Isotope Beams as probe. This is due to the fact that Rare Isotope Beams allows to reach distant zones of the Segré Table of nuclides, which were unaccessible using stable targets and beams. The production, preparation and acceleration of these Rare Isotopes are always challenging and request special devices and methods, meant to optimize efficiency - rare isotopes are "rare" - as well as rapidity - rare isotopes are short living. All these aspects, from the point of view of production and acceleration of rare isotopes as well as educational will be discussed.

Abstract 381 WED-AP-TA-06-4 Invited Talk - Wednesday 10:00 AM - Rio Grande

A New Ion Beam Analysis Facility at Notre Dame - and Student Training Opportunities

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The University of Notre Dame is in the process of installing a new tandem accelerator to pursue nuclear physics applications. These ion beam analysis applications will be varied, but they will have a common purpose in not only making novel measurements of some phenomenon that can be studied by IBA, but by educating students on experimental design and execution, sample collection and preparation as well as data analysis and interpretation. By designing a series of applied studies that need to be pursued, and creating a series of protocols for the process, this applied physics program will also be used extensively for new student training in accelerator operation. We anticipate using this facility to train all graduate students in the Nuclear Structure Lab before they work on the larger accelerators at Notre Dame.

Abstract 40 WED-PR-AMP-01-1 Invited Talk - Wednesday 10:00 AM - Post Oak

Multiple ionization by electron, positron, proton and antiproton impact in the rare gases

Claudia Carmen Montanari, Jorge Esteban Miraglia

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We present a comparison of multiple ionization cross sections by impact of electrons, positrons, protons and antiprotons, including our theoretical results [1,2] and a detailed compilation of experimental data for these |Z|=1 projectiles and four different targets. We consider the rare gases Ne, Ar, Kr and Xe, and final charge states from +1 to +3 (Ne), +5 (Ar) and +6 (Kr and Xe).

Our theoretical development relies on three approximations:

1. The independent particle model (IPM): the ejected electrons ignore the fate of each other, neglecting the correlation in the final state. The probability of MI is expressed as a multinomial combination of independent ionization probabilities.

2. The continuum distorted-wave eikonal initial state approximation adapted in the case of light particles, such as electrons or positrons, to take into account the finite momentum transferred, the non-linear trajectory, and the energy threshold for the multiple ionization. The energy thresholds for electron and positron impact have been calculated separately and imposed within the multinomial expansion.

3. The post-collisional ionization due to Auger type processes is independent of the projectile. Thus, it is included in a semi empirical way by incorporating the experimental branching ratios of the charge-state distribution after a single initial vacancy.

We obtained good results for quadruple, quintuple and sextuple ionization cross sections. This is related to the good description of the deep-shell contribution and the influence of Auger type processes in the final charge state [3]. For highly-charged ion production by light particles, the post collisional ionization is the dominant ionization channel in the whole energy range, even close to the threshold. Unfortunately the particle-antiparticle comparison can be made up to triple ionization because there are no experiments for higher levels of multiple-ionization.

[1] Montanari C C and Miraglia J E, 2014, J. Phys. B 47, 105203.

[2] Montanari C C and Miraglia J E, 2015, J. Phys. B 48, 165203.

[3] Tavares A C et al, 2014, J. Phys. B 48, 045201

Abstract 47 WED-PR-AMP-01-2 Invited Talk - Wednesday 10:00 AM - Post Oak

Analysis of historic glass by IBA - towards optimization

Ziga Smit

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The complex composition of glass typically requires a combined analytical approach based on detection of light elements through their gamma rays, and medium and heavy elements through their K and L X-rays, respectively. As glass analysis represents major part of our archaeometric research, the following improvements regarding speed and accuracy were introduced. Both photon spectra are measured simultaneously for the same dose and corrected for the dead time effects. Only one X-ray detector is used, which is now equipped with a funny filter for optimal balance between light and heavy elements. A concentration evaluation algorithm was developed which can in principle work without measuring the proton dose, exploiting the fact that the sum of all metal oxides equals unity. For evaluation of gamma spectra, a simple fitting program was made. It subtracts background through top filtering and is capable of auto-calibration according to strong sodium lines. Several examples of recent analyses will be shown, like glass beads that are used for dating early medieval graves.

Abstract 250 WED-PR-AMP-01-3 Contributed Talk - Wednesday 10:00 AM - Post Oak

Total cross section for Compton Scattering of photons from atoms

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Compton scattering of photons from electrons bound in atoms is the dominant photon-atom interaction over a wide range of energies for all elements. Typically this range extends from incident photon energies well above the K shell ionization threshold, where it becomes more important the the atomic photoeffect, to energies above the pair production threshold, where pair production eventually dominates. These cross sections usually are determined by calculations that rely on simplifying assumptions about atomic structure or the photon-electron interaction or both. We show that simplifying assumptions about atomic structure lead to vastly different predictions for the total cross section for Compton scattering at low incident photon energies.

Abstract 20 WED-PR-AMP-01-4 Contributed Talk - Wednesday 10:00 AM - Post Oak

Low Energy Stopping Cross Sections of H, D and He in Several Light Gases; Evidence of the Threshold Effect and Nuclear Stopping Effects for D in He Gas

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Electronic stopping occurs when an energetic particle interacts with the electrons of a target material, causing charge exchange, excitation, and ionization of the atomic electrons and a corresponding energy loss for the impinging particle. Charge exchange between the projectile and target, in the form of electron capture and electron stripping, is the dominant mode of energy transfer for low energy projectiles in the keV region. In the case of protons in Helium gas, the difference between the ground state energy level of an ionized H atom and the first ionization energy of a Helium atom is large (11.0 eV), and so the process of electron capture is suppressed at very low energy. This leads to a reduction in the stopping cross section known as the Threshold Effect, and a resultant deviation from the velocity proportionality which is otherwise characteristic of this low energy regime.

We present the results obtained by using time-of-flight techniques to directly measure the stopping cross section of various target gases for the light ions H+, D+, and He+ using projectile energies between 2.4 - 22 keV/u. Measurements were obtained using a low-energy linear accelerator fed by an RF ion source. System accuracy was checked with a projectile-target pair which has been well measured in the past using gaseous targets in the energy regime of interest (He-N2). Data were accumulated for several projectile-target pairs (H-He, D-He, H-N2, D-N2, H-Ne, D-Ne, He-H2, He-He, He-Ne). Results show that the stopping cross section of H, D in He does exhibit a threshold effect for projectile energies lower than ~20 keV/u. This work provides an independent measurement of this interaction, for which we find only two previous data sets below the threshold energy whose results differ by an order of magnitude below 6 keV/u. This work also provides measurements of several other projectile-target pairs for which there exist only limited experimental results in this very low energy regime, and also provides experimental evidence of nuclear stopping effects for D in He gas.

Abstract 96 WED-PR-AMP-01-5 Contributed Talk - Wednesday 10:00 AM - Post Oak

M-shell X-ray production cross section measurements in $_{73}$Ta and $_{78}$Pt caused by $B^{3+,4+}$-and $N^{2+,3+,4+}$-ions

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Literature survey shows that the measurements of only the total or $M_{\alpha\beta}$ and M_{γ} X-ray production cross sections in Ta and Pt by protons, α-particles and few other heavy-ions like C and O have been made. To arrive at better understanding of the mechanism of ion-atom interaction, more and more experimental data (by changing projectile-target combinations, charge state and energies of the impinging ions) is required. The single broad M X-ray peak may be good enough for PIXE analysis of high-Z targets due to the large M-shell cross section values w.r.t the L-shell X-ray lines yet more refined data is needed for the various component lines of the broad M X-ray peak to enable the atomic physicists to understand the physics underlying the M-shell ionization. The lack of experimental data on M-shell ion-atom collision is due to limited energy resolution of the available X-ray detectors, large absorption of low energy X-rays and single broad M X-ray peak required

to be fitted into various component lines. In this paper, we report the M-shell X-ray production cross sections in $_{73}$Ta and $_{78}$Pt caused by the bombardment of 35 to 60 MeV $B^{3+,4+}$ - ions and 3 to11 MeV $N^{2+,3+,4+}$-ions for Mξ(M_5N_3, M_4N_2), Mδ(M_4N_3,M_3N_1), Mα($M_5N_{6,7}$,O_3), Mβ(M_4N_6,$O_{2,3}$), Mγ($M_3N_{4,5}$), $M_3O_{1,4,5}$, (M_2N_4 + $M_1N_{2,3}$), $M_2O_{1,4}$ and $M_1O_{2,3}$ X-ray lines. In contrast to the earlier measurements carried out with protons / other ions on these elements, we have separated the Mαβ into Mα and Mβ and also separated the group of lines falling under M_{m1} into $M_3O_{1,4,5}$ and (M_2N_4 + $M_1N_{2,3}$) and M_{m2} into $M_2O_{1,4}$ and $M_1O_{2,3}$ lines. The measurements were carried out at 9SDH2 3MV Tandem Pelletron Accelerator at Institute of Physics Bhubaneswar and 16 UD Pelletron Accelerator at Inter-University Accelerator Centre (IUAC) Delhi. The ion beams were bombarded on thin targets evaporated on an ultrapure carbon backing of 10 µg/cm2. The targets fixed on a steel ladder were placed in an evacuated (<10-6 Torr) scattering chamber at 45° each to the beam direction and to the Si(Li) detector. The recorded M X-ray spectra recorded were deconvoluted into various components of the M X-ray lines using the computer code after subtracting suitable background. The experimental results have been compared with the theoretical values by converting the M-subshell ionization cross sections based on the PWBA and ECPSSR direct-ionization theories taking into effect the sub-shell fluorescence yields, Coster-Kronig transition probabilities and transition rates based on Dirac-Fock and Dirac-Hartree-Slater models. The results will be presented and discussed.

PACS number(s): 32.30.Rj, 34.50.Fa, 34.80.Dp, 79.20.Rf

Abstract 83 WED-PR-SP-09-1 Invited Talk - Wednesday 10:00 AM - Elm Fork

Resonant ionization laser ion sources at TRIUMF and other isotope separator on-line facilities: current status and physics opportunities

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In the course of the past decades resonant ionization laser ion sources (RILIS) have become one of, if not the the most used ion source at on-line isotope production and separator facilities. This is because (a) a major part of the ion sources complexity can reside outside the high radiation, high temperature environment of the isotope production target and ion source volume, and (b) that RILIS provides element, at times even isotope selective ionization with high efficiency. The enhanced radioactive ion beam purity, as well as the achieved intensities are the reason why currently more than 50% of all radioactive ion beam requests are specifying RILIS as the ion source of choice.

The principles of RILIS, the current capabilities and status of RILIS sources, and the direction of ongoing developments at TRIUMF and other facilities will be presented and physics opportunities enabled will be highlighted.

Abstract 346 WED-PR-SP-09-2 Invited Talk - Wednesday 10:00 AM - Elm Fork

Laser stripping of hydrogen ion beams for the Spallation Neutron Source accumulator ring injection

Yun Liu

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Charge-exchange injection scheme is a widely used technology of stacking high-intensity proton beam and has been utilized in a number of accelerator based neutron sources including the Japan Proton Accelerator Research Complex (JPARC) and the Spallation Neutron Source (SNS) for short-pulse neutron production. The technology relies on a carbon foil for stripping electrons from hydrogen ions and converting H^- beam to proton beam. Since the carbon foils might induce uncontrollable beam loss and radiation activation at high beam intensities, a non-intrusive stripping approach using a laser beam, referred to as laser assisted H^- stripping or laser stripping scheme, has been studied. Following a successful proof-of-

principle demonstration using a Q-switched laser, a more advanced experiment, or a proof-of-practicality experiment was recently proposed by SNS and funded by U.S. Department of Energy (DOE) High Energy Program. The goal of the project is to demonstrate high-efficiency H^- beam stripping at an operational accelerator setting. A typical neutron-production H^- beam at SNS is bunched in a macropulse structure where each macropulse consists of 30-ps micro-pulses repeating at 402.5 MHz.

In this talk, we describe the design and implementation of the laser stripping experiment. The parameters of the ion and laser beams have been tailored using a number of innovative approaches to reduce the laser power requirement by 5 orders of magnitude, which makes it possible to strip operational ion beams with practically achievable laser technology. A macropulse laser system has been customized to provide picosecond pulses with multi-MW peak power at 355 nm. A laser transport line (LTL) has been implemented to deliver UV beam over a 60-meter long complicated beam path at a 70% efficiency. The maximum stripping efficiency was over 90% that is comparable to the conventional foil stripping scheme. While the experiment was conducted on 10 us-long ion beams at the SNS accelerator, the general design concept can be adapted to any temporal beam structures in pulsed accelerators.

Abstract 416 WED-PR-SP-09-3 Contributed Talk - Wednesday 10:00 AM - Elm Fork

Development of Ultrasensitive Analytical Techniques to Detect Trace Elements

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Efficient ion sources are needed for qualitative and quantitative analysis of the unwanted impurities in the materials constructing the detectors for ultralow-background experiments. A specific example is the Majorana Demonstrator (MJD) experiment [1] designed to search for neutrinoless double-beta-decay of the isotope 76Ge. The MJD is a 40-kg detector array made from enriched 76Ge and natural germanium and is being built to demonstrate the feasibility of a future ton-scale experiment. We have evaluated two ionization sources for the applications of detecting uranium and thorium impurity levels in the high purity copper materials used for the MJD experiment. The first is a hot-cavity surface ionization source (SIS) and the second is a laser ionization source (LIS). The performance of the ion sources is characterized using uranyl nitrate and thorium nitrate sample materials with sample sizes between 20 - 40 mg of ^{238}U or ^{232}Th. The ionization efficiencies for U and Th obtained with the SIS are about 1% and 3% with Ta and W cavities, respectively. It has been demonstrated that the surface ionization efficiency can be increased by a factor of 6-7 with a noble gas added and the largest enhancement is obtained with Kr. The LIS is based on multi-step resonance ionization. With newly developed three-step laser ionization schemes for both U and Th, we have obtained overall ionization efficiencies of about 18% and 40% for U and Th, respectively.

[1] N. Abgrall, **et al.**, Advances in High Energy Physics, Vol. 2014, Article ID 365432

Abstract 130 WED-AC-AS-04-1 Invited Talk - Wednesday 1:30 PM - Trinity

Opening the National Labs: Technology Transfer at Fermilab

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In the Spring of 2015, several workshops were held at national laboratories for the Accelerator Stewardship Test Facility Pilot Program. Fermilab entertained several potential opportunities, and evenutally formed partnerships with two companies. Work with Euclid Test Labs, LLC, sought to develop a new type of power coupler for low-loss superconducting cavities, for which Fermilab's coupler test facility, RF designers, and RF engineers have played a central

role. A program with PAVAC, Inc., sought to explore the application of highly conductive aluminum to niobium, for which Fermilab's material test facilities and recent expertise with aluminum-bonded superconductors has been important. The presentation will describe the process by which the partnerships were formed, obstacles that were encountered, how the statements of work were arrived at, project outcomes, and opportunities for future work. The presentation will also outline improvements to the way that the laboratory conducts external business.

Abstract 57 WED-AC-AS-04-2 Invited Talk - Wednesday 1:30 PM - Trinity

Technology Transfer at JLab

Drew Weisenberger, Andrew Hutton

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Jefferson Lab has a good track record of transferring its core technologies to universities and industry. For example, the detector technology that was originally developed for our nuclear physics research program was successfully transferred to a local industry for breast cancer detection using a nuclear medicine imaging technique known as molecular breast imaging (MBI). The resulting devices have obtained FDA approval and been successfully commercialized; to date, over a 100 devices have been sold worldwide.

The DOE Stewardship Program offered us an outreach opportunity to broaden the application of our superconducting radiofrequency (SRF) technology. In 2015, Old Dominion University received funds from this program to develop a new kind of SRF cavity that could be the heart of small, high power accelerators for producing tunable X-rays and other uses in a university or industry. In 2016, General Atomics received funding to evaluate the use of high current, low energy SRF accelerators to reduce harmful emissions from coal-fired power plants.

In this talk, we will describe these and other technology transfer success stories, as well as provide an overview of the present and future technology developments at Jefferson Lab.

Abstract 423 WED-AC-AS-04-3 Contributed Talk - Wednesday 1:30 PM - Trinity

Panel Discussion

Eric Colby

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Panel Discussion is meant to (1) increase general awareness of capabilities, (2) identify unmet accelerator R&D needs, and (3) identify opportunities to improve both the R&D facilities and the tech transfer process.

Abstract 415 WED-AP-MA-06-1 Invited Talk - Wednesday 1:30 PM - West Fork

Bioequivalent Treatment Planning for Charged-Particle Therapy: Algorithmic and Generic Approaches

Richard Philip Levy

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Accelerated charged particles of lower linear energy transfer (low-LET), such as and protons and helium ions have demonstrated relative biologic effectiveness (RBE) properties close to that of X-rays for a wide range of dose-fractionation selection and for the dose tolerance of different end-organs that may be irradiated in the treatment field. However, even

low-LET irradiation may exhibit clinically significant RBE variations under certain dose-fractionation conditions. For heavier charged particles (e.g., carbon and oxygen ions), these RBE properties and their potential non-uniformity have a much greater impact in designing and delivering bioequivalent doses to the delineated target volumes.

This consideration has led to several strategies designed to compensate for these RBE factors. One strategy has been to use an algorithmic approach that incorporates the biophysical parameters of ion selection and velocity and expected nuclear fragmentation to calculate the RBE on a voxel-by-voxel basis. Another strategy has been to use a more-generic approach for RBE estimation of a more-uniform distribution on a volumetric basis. Either strategy requires the modification (either uniform or on a voxel basis) of the delivered physical dose to achieve the desired bioequivalent effect on the target volume and on adjacent normal tissues.

As more clinical experience has been developed to evaluate these radiobiological effects, there has been a steady improvement in the therapeutic ratio of tumor kill to normal-tissue injury. This overview presentation highlights the strategic efforts that have been employed to achieve these results.

Abstract 449 WED-AP-MA-06-2 Invited Talk - Wednesday 1:30 PM - West Fork

Significance of Biological Parameters for Modeling Proton Treatment Planning

Marcelo E. Vazquez, James M. Slater

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The knowledge of the radiobiology properties of particle beams, necessary in treatment planning systems, is expressed through the evaluation of the relative biological effectiveness (RBE). The goal of the RBE determination is to help in prescribing the appropriate photon-equivalent dose for which the radiation-oncologists have accumulated an extensive pre- and clinical experience. The complexity in translate relevant biological effects to generate accurate mathematical models that link dose and LET spectra to clinical response remains one of the main problems. Current models do not account for any intrinsic inter-patient or intra-organ radiosensitivity variations in their present form, or for tumor cell proliferation or tissue oxygenation, or 3-D structures vs. 2-d cell layers, or other clinical factors influencing control and complications, such as concurrent chemotherapy, patient's age, gender and preexisting medical conditions. Large uncertainties are involved in the currently in vitro RBE estimations which were fitted to set of experimental cell survival data for protons and carbon ions. This report will discuss different biological parameters that need to be taking into consideration in order to enhance the use of radiobiological modeling for proton and carbon ion treatment.

Abstract 418 WED-AP-MA-06-3 Invited Talk - Wednesday 1:30 PM - West Fork

Biological Modelling for Carbon-Ion Radiotherapy at NIRS

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Elevating energy loss toward range end associated with increasing biological effectiveness renders heavier ions such as carbon ions attractive for treating deep-seated tumours. In the treatment planning of Carbon-ion radiotherapy (CIRT), it is indispensable to handle the change in the biological effectiveness appropriately. At National Institute of Radiological Sciences (NIRS), a pragmatic biological model, based on Human Salivary Gland cell response coupled with clinical experience from fast neutron radiotherapy, was developed and utilized. The clinical outcome was in good agreement with the model expectation. The model has been upgraded recently to cope with the scanning irradiation. The new model offers versatile estimation of the biological effectiveness of various radiations based on their microdosimetric information while harmonizing with the original approach with rigid consideration on the biological effectiveness. In this paper, we aim to review the progress of our biological model for CIRT.

Abstract 451 WED-AP-MA-06-4 Invited Talk - Wednesday 1:30 PM - West Fork

Biological aspects to consider during routine clinical proton therapy

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With the clinical realization of pencil beam scanning (PBS), single beams are now used more frequently to treat certain disease sites e.g. breast treatments with single en-face beams. This is possible since with PBS one can achieve proximal dose conformation and therefore achieve a highly conformal dose with a single beam. This was not possible with previous double scattering or uniform scanning techniques. The enhanced biological dose at the end of the proton range is very well documented but not exactly quantified. This lead to the recommendation by the ICRU78 team not to make end of range or definitive RBE corrections in proton beam therapy other than using a constant RBE factor of 1.1. Anferov **et.al.** recently published a paper showing the increased dose at the end of the proton range based on certain doses per fraction and typical alpha/beta ratios for a few tissue types [1]. One of the benefits of PBS is that the physical dose can be easily modified in 3D. This allows for dropping the physical dose by a few percent in the distal region of the beam if deemed clinically feasible to compensate for the expected increase in biological dose. We use this technique in clinical practice at PCPT. Some clinical examples and the clinical justification of this approach will be discussed.

Abstract 75 WED-AP-TA-07-1 Invited Talk - Wednesday 1:30 PM - Rio Grande

Nuclear Physics at Ohio University

Zach Meisel

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The nuclear physics program at Ohio University spans a variety of topics, from nuclear astrophysics to applications, and energy ranges, from the high energies of hadronic physics to the low energies used to probe bulk nuclear phenomena. This presentation will touch on each of these research foci, with an emphasis on the local program at the Edwards Accelerator Laboratory. Particular attention will be paid to the renewed efforts in low energy nuclear physics research pertaining to explosive astrophysical environments.

Abstract 105 WED-AP-TA-07-2 Invited Talk - Wednesday 1:30 PM - Rio Grande

Hands-on Nuclear Science Education at UMass Lowell

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The experimental nuclear-physics program at UMass Lowell has a strong focus on both fundamental science and an established in-house infrastructure that is harnessed to support numerous advanced projects on detector development, instrumentation, and applied nuclear science. Research topics in basic nuclear physics span far-from stability studies that include spectroscopy of light and very heavy nuclei, medium-mass nuclei along the proton drip-line, and beta-decay measurements of neutron-rich nuclei. The UMass Lowell Radiation Laboratory houses a 5.5 MV CN Van de Graaff accelerator, a 1 MW research reactor, and a ~100-kCi 60Co gamma irradiator located within the same building complex. Currently, detector development projects being pursued by the group include large 7Li-enriched C7LYC detectors, neutron-damage studies of large-area segmented planar HpGe detectors, digital data acquisition development, and re-commissioning of the LBL Total Absorption Spectrometer. A 6-element Compton-suppressed Ge array has been assembled, and is currently being used for both medical isotope assays and cross-section measurements, in collaboration with NNDC and BLIP at BNL, as well as a spectroscopic tool for quantifying burn-up in reactor fuel elements at the UML reactor. A proton

microprobe has also recently been commissioned for interdisciplinary science. Together, these facilities and projects provide a unique opportunity for our students, enabling them to develop experiences ranging from hands-on work to fundamental experimental and theoretical research at the edge of nuclear science. Our Nuclear Instrumentation course, for instance, makes strong use of these resources and provides a solid foundation in instrumentation to a diverse set of students. In this talk I will present our current research activities, focusing on those that directly utilize our accelerator and laboratory resources and how they advance the education of our graduate and undergraduate students.

Abstract 194 WED-AP-TA-07-3 Invited Talk - Wednesday 1:30 PM - Rio Grande

Underground Accelerator Facilities for Stellar Reaction Studies

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For many years, the drive of nuclear astrophysics has been to extend the limits of reaction measurements to lower energies. As current laboratory experiments approach this stellar burning window, the rapid drop off of the rate of reaction is a significant barrier and drives the need for higher intensity accelerators, more robust and isotopically enriched target material and lower background interference. The natural background suppression of underground accelerator facilities enables the extension of current experimental data to the lower energies needed. New facilities around the world are coming on-line with a view to capitalizing on underground cosmic-ray suppression, each offering unique techniques and capabilities. Essentially studying the stars in the sky, from being deep underground.

Abstract 299 WED-AP-TA-07-4 Invited Talk - Wednesday 1:30 PM - Rio Grande

The Graduate Program in Nuclear Physics at the National Superconducting Cyclotron Laboratory at Michigan State University

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The National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU) hosts a broad graduate student program in nuclear and accelerator physics, which includes experimental and theoretical areas of research. The program aims to build on best practices in graduate education and workforce development, and to employ innovative approaches to improve the graduate school experiences and outcomes for a diverse graduate student population. In addition, as a National User Facility, NSCL strives to provide graduate students from other universities to have an equally rewarding experience when they come and perform research at the Laboratory. The construction of the Facility of Rare Isotope Beams (FRIB) at the site of NSCL in MSU comes with exciting new opportunities for graduate education and research, for student in and outside of MSU.

The presentation will provide an overview of the graduate program in nuclear and accelerator physics at MSU, and focus on opportunities, accomplishments and challenges associated with a hosting such a program at a rapidly evolving Laboratory.

Abstract 82 WED-AR-ISM-04-1 Invited Talk - Wednesday 1:30 PM - Post Oak

Application of ion beams to fabricate and tune properties of dilute ferromagnetic semiconductors

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Combining semiconducting and ferromagnetic properties, dilute ferromagnetic semiconductors (DFS) have been under intensive investigation for more than two decades. Mn doped III-V compound semiconductors have been regarded as the prototype of the type. In this contribution, we will show how the implantation technique, a standard method for doping Si in microelectronic industry, can be utilized in fabricating and deeper understanding of DFS. First, ion implantation followed by pulsed laser melting (II-PLM) provides an alternative to the widely used low-temperature molecular beam epitaxy (LTMBE) approach in the preparation of diverse DFS. The prepared DFS materials exhibit pronounced magnetic anisotropy, large X-ray magnetic circular dichroism as well as anomalous Hall effect and magnetoresistance [1-9]. Going beyond LT-MBE, II-PLM is successful to bring two new members, GaMnP and InMnP, into the family of III-Mn-V. Both GaMnP and InMnP films show clear signatures of ferromagnetic coupling and an insulating behavior. Second, helium ions can be used to precisely compensate the holes while keeping the Mn concentration constant [10-12]. We monitor the change of Curie temperature (T_C) and conductivity. For a broad range of samples including (Ga,Mn)As and (Ga,Mn)(As,P) with various Mn and P concentrations, we observe a smooth decrease of T_C over a wide temperature range with carrier compensation while the conduction is changed from metallic to insulating. In the low compensation regime, we can tune the uniaxial magnetic easy axis of (Ga,Mn)(As,P) from out-of-plane to in-plane with an isotropic-like intermediate state. These materials synthesized or tailored by ion beams provide an alternative avenue to understand how carrier-mediated ferromagnetism is influenced by localization.

[1] M. Scarpula, et al., **Phys. Rev. Lett.** 95, 207204 (2005).

[2] D. Bürger, S. Zhou, et al., **Phys. Rev. B** 81, 115202 (2010).

[3] S. Zhou, et al., **Appl. Phys. Express** 5, 093007 (2012).

[4] M. Khalid, …, S. Zhou, **Phys. Rev. B** 89, 121301(R) (2014).

[5] Y. Yuan, … S. Zhou, **IEEE Trans. Magn.** 50, 2401304 (2014).

[6] M. Khalid, …, S. Zhou, **J. Appl. Phys**. 117, 043906 (2015).

[7] Y. Yuan, …, S. Zhou, **J. Phys. D: Appl. Phys.** 48, 235002 (2015).

[8] S. Zhou, **J. Phys. D: Appl. Phys.** 48, 263001 (2015).

[9] Y. Yuan, …, S. Zhou, ACS Appl. Mater. Interfaces**,** 8, 3912 (2016).

[10] L. Li, S. Yao, S. Zhou, et al., **J. Phys. D: Appl. Phys.** 44 099501 (2011).

[11] L. Li, …, Shengqiang Zhou, **Nucl. Instr. Meth. B** 269, 2469-2473 (2011).

[12] S. Zhou, et al., **arXiv:1602.06790** (2016).

Abstract 162 WED-AR-ISM-04-2 Invited Talk - Wednesday 1:30 PM - Post Oak

Modification of the Thermal Properties of Zirconium Diboride by Heavy Ion Irradiation

Joseph Turner Graham, Carlos Henry Castano

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Owing to its exceptional high temperature strength and thermal conductivity, zirconium diboride (ZrB_2) is an attractive ceramic material for use as a burnable poison within nuclear reactor fuel pellets or within nuclear reactor control rods. Degradation of the mechanical and thermal properties of this material, however, must be better understood to determine its viability in future fission reactor applications. We present data from thin film line heater thermal measurements, grazing incidence X-ray diffraction (GIXRD) measurements and transmission electron microscopy (TEM) observations, showing the effects of 5 MeV and 10 MeV Au ion irradiations on the thermal and microstructural properties of ZrB_2.

Abstract 196 WED-AR-ISM-04-3 Contributed Talk - Wednesday 1:30 PM - Post Oak

ZnO Defect Modulation for More Efficient Photocatalysis

Emmanuel Njumbe Epie, Wei-Kan Chu

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Toxic wastes ranging from industrial effluents and metabolic poisons are matters of serious health and environmental concern. An environment-friendly and cost-effective method for such waste treatment is photocatalysis. Of the many metallic oxide semiconductors currently used as photocatalyst, ZnO is particularly attractive because of its biocompatibility, biodegradability, non-toxicity, high surface reactivity and high photoefficiency. It has been demonstrated that increasing the near surface defect concentration of ZnO nanostructures, greatly enhances the rate of ZnO assisted photocatalytic waste degradation. However, defect modulations in ZnO has been predominantly achieved through thermal annealing in air alone.

In this presentation we demonstrate using **ionoluminescence** (IL) that a judicious combination of low-energy **self-implantation** and **thermal annealing** in Ar is a more effective method for increasing near surface defect concentration in ZnO. IL results of our modified ZnO samples suggest an increase in the near surface defect concentration by a factor of 18 compared to that of ZnO annealed in air alone. We believe our defect modulation approach, if applied to ZnO nanostructures can further enhance their photocatalytic efficiency.

Abstract 205 WED-AR-ISM-04-4 Contributed Talk - Wednesday 1:30 PM - Post Oak

Modifications induced in the structural and optical properties of tin oxide thin films due to 25keV nitrogen ion implantation

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Tin oxide thin films were deposited on quartz substrates (1cm*1cm) using thermal evaporation followed by thermal oxidation at 600^{o}C. The synthesized films were then implanted with 25keV N^+ ions at different fluences ranging between 3E15 and 1E16ions/cm^2. The effect of implantation on the structural and optical properties was studied through RBS, XRD, and UV-Vis Spectrometry techniques. The RBS spectra of the implanted samples revealed the presence of nitrogen ions in the SnO_2 lattice. The XRD patterns reveal polycrystalline nature of SnO_2 thin films. Also, the intensity of all the major peaks increased with implantation with lowest fluence of nitrogen ion (3E15ions/cm^2), however, on implantation with higher fluences, the intensity of the peaks decreased. The crystallite size shows a decrease from 16.32nm to 15.38nm with increase in ion fluence. UV-Vis spectrometry was used to understand the variation of band gap with increase in ion fluence. The band gap calculated using Tauc's plot were found to be 3.51eV, 3.71eV, 3.59eV and 3.41eV for pristine and samples implanted with increasing fluence of nitrogen ions. The structural and optical modifications observed in tin oxide thin films have been explained on the basis of the concept of collision cascade and the resultant defect formation.

Abstract 367 WED-AR-RE-06-1 Invited Talk - Wednesday 1:30 PM - Bur Oak

Search for Radiation Resistance Materials: As Revealed by Computer Simulations

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Recently, there have been a large number of researches dealing with radiation resistance by introducing high-densities of defect sinks, such as secondary phases, grain boundaries and multi-layers, which are popular ways for reducing residual defects in irradiated materials. We will firstly discuss these approaches for investigating radiation damage in different materials, focusing on their advantages and disadvantages. Then, we will demonstrate unprecedented mechanisms of radiation tolerance and suppression of void formation in multicomponent single-phase alloys by simulating the migration behavior of point defects and nano defect clusters in Ni, NiCo and NiFe.

We will highlight several striking mechanisms controlling irradiation resistances in multicomponent alloys. The results show that that the similar migration energy of vacancy clusters and interstitials in NiFe enhances defect recombination, thus improving its radiation resistance. Another important mechanism for the enhanced swelling resistance in NiFe is attributed to interstitial cluster motion in the alloys from a long-range one-dimensional mode to a short-range three-dimensional mode that leads to a dramatically enhanced recombination of interstitials and vacancies, significantly suppressing void formation as compared with that in Ni. Based on these mechanisms, we have developed a new model to predict the possible compositions of NiFe alloys that give rise to radiation resistance, which is also validated by experiments.

Abstract 233 WED-AR-RE-06-2 Invited Talk - Wednesday 1:30 PM - Bur Oak

Predicting He behavior at Cu-V interfaces to mitigate He-induced damage in plasma-facing materials

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[(2)]Materials Science and Engineering, Texas A&M University, 3003 TAMU, College Station TX 77843, United States

Solid-state interfaces in metallic composites are preferential sites for precipitation of implanted helium (He). We aim to predict the distribution of He network precipitates at interfaces to improve performance of plasma-facing materials in fusion devices. We use O-lattice theory to determine the initial distribution of He precipitate nucleation sites and phase-field methods to model the growth, interaction, and coalescence of He bubble networks. These methods can be used to design next generation multilayered metallic composites with enhanced resistance to He damage. We demonstrate our computational methodology on a Cu-V interface and compare our simulations to transmission electron microscopy studies on He-implanted metal bilayers.

Abstract 413 WED-AR-RE-06-3 Contributed Talk - Wednesday 1:30 PM - Bur Oak

Comparing SRIM simulations and experimental results for shallow implantation of Sb into Si

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Accurate placement of dopant atoms or defects in electronic or optical substrates is critical to further reduce device size and create novel nano-scale devices such as those relying on the quantum properties of a single atom. Using state-of-the-art implantation techniques, it is possible to place a single Sb atom in a Si substrate ~10nm below the surface within a sphere of 5nm in radius; the range and the straggle in this example are based SRIM simulations. However, in this low energy regime, the literature shows large disagreements between SRIM predictions and experimental results. Furthermore, treating collisions via the binary collision approximation (BCA) as is done in SRIM may not be appropriate as the implantation energy is lowered. In fact, different models for nuclear stopping show good agreement for high energies but orders of magnitude differences for low energies (i.e., Bohr vs. Thomas-Fermi). We have performed a series of experiments comparing the ion range as predicted by SRIM to the experimentally measured values. We have done this for Sb ions implanted into Si substrates with energies ranging from 10keV to 150keV. The experimental implantation range is independently measured using both Rutherford backscattering spectrometry (RBS) and secondary ion mass spectrometry (SIMS). Implantation saturation and target sputtering as well as ion channeling can skew the measured ion range and must be accounted for. Our results show that the SRIM predicted ranges match the experimentally determined ranges (from both RBS and SIMS) within the experimental error of ~4nm. Typically, SRIM simulations are generally not applicable in situations where afore mentioned effects are present, instead dynamic-TRIM (Tridyn), crystal-TRIM, or Marlowe are more appropriate.

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000

Abstract 152 WED-PR-SP-08-1 Invited Talk - Wednesday 1:30 PM - Elm Fork

Constraining Hauser-Feshbach cross sections for the p-process nucleosynthesis.

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Description of the p-process nucleosynthesis requires several thousands of rates for gamma-induced reactions frequently involving exotic, short lived nuclei. These reaction rates have been measured only if very few cases near stability; vast majority relies on the Hauser-Feshbach models. Since the predictions of those models vary significantly due to a large number of input parameters, constraints provided by experiments are of key importance. This presentation focuses on measurements of proton and alpha capture reactions, time inverse of the p-process reactions, and their impact on constraining the Hauser-Feshbach predictions. The presentation will provide an overview of experimental efforts that use a variety of techniques, from gamma-detection to measurement in inverse kinematics using recoil separators.

Abstract 328 WED-PR-SP-08-2 Contributed Talk - Wednesday 1:30 PM - Elm Fork

Direct reaction measurements using GODDESS

S. D. Pain[1], A. Ratkiewicz[2], T. Baugher[2], M. Febbraro[1], D. W. Bardayan[3], J. A. Cizewski[2], M. R. Hall[3], A. Lepailleur[2], H. Sims[2], K. Smith[4], D. Walter[2]

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Direct reactions are well-established probes providing cornerstones of nuclear structure models. Though these reactions (including nucleon transfer, inelastic scattering and charge-exchange reactions) have been measured for decades in normal kinematics on stable targets, more recent developments have focussed on inverse-kinematic measurements applicable to both stable and radioactive beams. Such experiments typically rely on highly-segmented large-area silicon detectors for particle measurement, and HPGe detectors for the measurement of gamma rays. However, trade-offs are typically made

between between optimizing for charged-particle or gamma-ray detection - most notably between gamma-ray efficiency and charged-particle angular resolution.

GODDESS [1,2] (Gammasphere ORRUBA: Dual Detectors for Experimental Structure Studies) has recently been developed to facilitate such measurements, providing high-resolution charged-particle detection within Gammasphere [3], which is arguably the most powerful and well-characterized high-resolution gamma-ray detector in current use. The ~700-channel highly-segmented silicon detector array is based upon ORRUBA [4]), a large-area silicon detector array optimized for the measurement of light-ion ejectiles from transfer reactions. GODDESS provides charged-particle detection with ~1^o resolution in polar angle, between 15^o and 165^o with ~80% coverage in azimuthal angle. In addition, a compact fast ionization chamber is incorporated for measurement of beam-like species at zero degrees, capable of particle identification at rates over 1 x 10^5 pps.

GODDESS was commissioned in the summer of 2015 with a campaign of three experiments. This campaign included the first measurement of the ^{134}Xe(d,p γ)^{135}Xe reaction, the ^{95}Mo(d,pγ)^{96}Mo reaction as surrogate for statistical neutron capture, and a measurement of the ^{19}F(^{3}He,tγ)^{19}Ne reaction to constrain J^π assignments of states in ^{19}Ne that are important for nova nucleosynthesis. An overview of GODDESS and preliminary data from the first campaign of measurements will be presented.

[1] A. Ratkiewicz, **et al.**, AIP Conf. Proc. **1525**, 487 (2013)

[2] S.D. Pain, AIP Advances **4**, 041015 (2014)

[3] I-Y. Lee, **et al.**, Nucl. Phys. A **520** (1990) 641c

[4] S.D. Pain, **et al.**, Nucl. Instr. and Meth. in Phys. Res. B, **261** (2007) 1122

Abstract 76 WED-PR-SP-08-3 Contributed Talk - Wednesday 1:30 PM - Elm Fork

Absolute measurement of the ^{7}Be(p,γ)^{8}B cross section with the recoil separator ERNA

Raffaele Buompane[1,2], Antonino Di Leva[2,3], Lucio Gialanella[1,2], Antonio D'Onofrio[1,2], Mario De Cesare[2,4], Jeremias G. Duarte[1,2], Zsolt Fulop[5], Leandro R. Gasques[6], GyÃ¶rgy GyÃ¼rky[5], Fabio Marzaioli[1,2], Lizeth G. Morales[2,7], Giancarlo Palumbo[9], Giuseppe Porzio[1,2], David Rapagnani[8], Vincenzo Roca[2,3], Mauro Romoli[2], Daniel Schuermann[1], Endre Somorjai[5], Filippo Terrasi[1,2]

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(3)Dipartimento di Fisica, UniversitÃ degli Studi di Napoli Federico II, Complesso Universitario di M. S. Angelo, Ed. 6 - Via Cintia, Napoli Napoli 80126, Italy
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(5)Institute of Nuclear Research - ATOMKI, Hungarian Academy of Sciences, Debrecen, Hungary
(6)Institute of Physics, University of Sao Paulo, Sao Paulo, Brazil
(7)Institute for Particle and Nuclear Physics, University of Edinburgh, Edinburgh, United Kingdom
(8)Dipartimento di Fisica e Geologia, UniversitÃ degli Studi di Perugia, Perugia, Italy
(9)Dipartimento di Economia, Management Istituzioni ? Laboratorio Chimico-Merceologico , UniversitÃ degli Studi di Napoli Federico II, Napoli, Italy

$^{7}Be(p,\gamma)^{8}B$ still represents one of the major uncertainties on the predicted high energy component of solar neutrinos. In fact, the discrepancy between existing data limits the precision of their extrapolation at astrophysical energy.

Previous experiments producing data with useful precision were performed in direct kinematics, using an intense proton beam on a radioactive ^{7}Be target. The complicated target stoichiometry and the deterioration under beam bombardment might possibly be the origin of these discrepancies. Inverse kinematics, i.e. a 7Be ion beam and a hydrogen target, would shed light on these systematic effects. Unfortunately, all attempts so far were limited by the low 7Be beam intensity.

Recently, a new experiment started, exploiting a high intensity ^{7}Be beam in combination with a windowless gas target and the recoil mass separator ERNA (European Recoil mass separator for Nuclear Astrophysics) at CIRCE (Center for Isotopic Research on Cultural and Environmental heritage), Caserta, Italy. Aim of the experiment is the measurement of the total reaction cross section by means of the direct detection of the ^{8}B recoils.

The experiment will be discussed and the first results will be presented.

Abstract 373 WED-PR-SP-08-4 Contributed Talk - Wednesday 1:30 PM - Elm Fork

Ion Source Applications for Low Energy Nuclear Astrophysics Measurements.

Rebecca Toomey[1], Michael Febbraro[2], Steven D Pain[2], Charles C Havener[2], Jolie A Cizewski[1], Mark E Bannister[2]

(1)Department of Physics and Astronomy, Rutgers University, 136 Frelinghuysen Road, New Brunswick NJ 08901, United States
(2)Physics Division, Oak Ridge National Laboratory, Bethel Valley Road, Oak Ridge TN 37381, United States

Ion sources at facilities that were designed with the purpose of running atomic physics experiments often have many desirable features that could be utilised for performing low energy nuclear astrophysics measurements. Some of these features include high beam currents at low energies, energy resolution, stability, and also the option of beam modulation for real time background measurements. An example of a facility that is easily adapted for these measurements is the Multicharged Ion Research Facility (MIRF) at Oak Ridge National Laboratory. Designed as a facility to study the interactions of atomic ions with matter, MIRF, in combination with advanced neutron detectors, is an ideal facility to measure direct astrophysical reactions at an above ground facility. MIRF is being used to measure the $^{13}C(\alpha,n)^{16}O$ reaction at astrophysically relevant energies with the aim of determining the cross section close to the Gamow window (~250 keV). The measured cross section from this study will constrain the extrapolations of the reaction rate for the main source of neutrons for the slow neutron capture process (s-process) for stellar nucleosynthesis.

This work is supported in part by the U.S. Department of Energy and the National Science Foundation.

Abstract 347 WED-PR-SP-08-5 Contributed Talk - Wednesday 1:30 PM - Elm Fork

Energy and Angle Correlations of Neutrons in Photo-fission

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(2)MS: J4-65, Pacific Northwest National Laboratory, 902 Battelle Blvd., Richland wa 99352, United States

It has been well established that the nearly back-to-back nature of the two fission fragments in fission gives rise to strong kinematical correlations between the fragments and the fission neutrons, and between the fission neutrons themselves. Due to the angular asymmetry of the fission fragments, photo-fission is expected to give rise to correlations which differ from those of neutron induced and spontaneous fission. Here, we report on initial measurements of these two neutron correlations in photo-fission using a pulsed electron linear accelerator to generate bremsstrahlung photons which impinged

upon an actinide target. A planned comprehensive set of measurements of two neutron correlations in the photo-fission of actinides is expected to shed light on several fundamental aspects of the fission process including the multiplicity distributions associated with the light and heavy fission fragments, the nuclear temperatures of the fission fragments, and the mass distribution of the fission fragments as a function of energy released. In addition to these measurements providing important nuclear data, the unique kinematics of fission and the resulting two neutron correlations have the potential to be the basis for a new tool to detect fissionable materials. A key technical challenge of this program arises from the need to perform coincidence measurements with a low duty factor, pulsed electron accelerator. This has motivated the construction of a large acceptance neutron detector array, and the development of data analysis techniques to directly measure uncorrelated two neutron backgrounds.

Abstract 305 WED-AA-IBT-03-1 | Invited Talk - Wednesday 3:30 PM - Trinity

Quantitation of synergistic ion beam analysis

Julien L. Colaux[1,2], Chris Jeynes[1]

(1)Ion Beam Centre, University of Surrey, Stag Hill, Guildford Surrey GU2 7XH, United Kingdom
(2)Synthesis, Irradiation and Analysis of Materials, University of Namur, 61 rue de Bruxelles, Namur 5000, Belgium

We have recently demonstrated that Rutherford backscattering (RBS) is a primary direct reference method capable of the best absolute accuracy available for non-destructive measurements of **quantity of material** in thin films; that is, standards can be **certified** as **reference materials** by RBS. It is clear that synergistic IBA (for example, simultaneous use of RBS and particle-induced X-ray emission - PIXE) is much more powerful than RBS alone, and that the accuracy of RBS can be inherited by the more general analysis method. Moreover, although the **quantity of material** in a sample is expressed as a simple number whose uncertainty is well-defined, IBA is most useful for **depth profiling**, and it is not yet clear how to express the uncertainty of depth profile functions. We will describe and discuss these problems of quantitation.

Ref: Colaux & Jeynes, Thin film depth profiling by IBA, **Analyst** (2016), doi: 10.1039/c6an01167e

Abstract 390 WED-AA-IBT-03-2 | Invited Talk - Wednesday 3:30 PM - Trinity

Modelling of Cascade Defocussing in Irradiated Nanoporous Materials

Lucio Dos Santos Rosa, Roger Paul Webb

Surrey Ion Beam Centre, University of Surrey, University of Surrey Ion Beam Centre, Guildford Surrey GU2 7XH, United Kingdom

Nanoporous materials have emerged very recently as a class of candidate structural materials for advanced nuclear reactors. It has been found that they are potentially more resistant to radiation damage than more normal bulk structures materials.

Computer modelling has been used to explore and explain the response of nanoporous materials to irradiation. The modelling has provided fundamental understanding of the atomistic processes responsible for the experimental observations. Were it has been noted that the internal structures are more robust against the displacement damage created by the passage of an energetic primary knock-on atom (PKA) created by neutron irradiation. However, a detailed investigation of the behaviour the cascade initiated by such a PKA reveals some interesting features. The presence of voids in the nanomaterials causes the cascade to spread-out around the void walls essentially defocussing the cascade and lowering the resulting displacement damage with the ultimate effect of changing the complexity, and hence stability, of remaining defects after the cascade has completed. Depending upon the size of the voids the cascades are more or less defocussed spatially. It is also noticed that the cascade is also defocussed in time as the lower velocity parts of the cascade spread across the void more slowly than the more energetic recoils. This affect further defocusses the cascade.

In the work presented here we use LAMMPS to simulate a PKA initiated cascade in both a crystalline Fe target containing a set of nanovoids of the order of 20nm in size and a set of Fe spherical crystalline nanoparticles of 20nm diameter which have random orientation with respect to each other. A 10keV PKA is then initiated from various positions and the ensuing cascade is followed and the distribution and density of defect production is observed as a function of time.

Abstract 95 WED-AA-IBT-03-3 Contributed Talk - Wednesday 3:30 PM - Trinity

IAEA Stopping Power Database: Following The Trends in Stopping Power of Ions in Matter

Claudia Carmen Montanari[1], Paraskevi Vivian Dimitriou[2]

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[(2)]Division of Physical and Chemical Sciences, International Atomic Energy Agency, International Center, Vienna, Austria

The aim of this work is to present an overview of the stopping power of ions in matter based on new developments in the stopping power database of the International Atomic Energy Agency (IAEA) [1]. This exhaustive collection of experimental data, graphs, programs and comparisons, is the legacy of Helmut Paul [2] who made it accessible to the global scientific community, and has been extensively employed in theoretical and experimental research during the last 30 years. The field of stopping powers in matter is continously evolving (some examples in [3-8]) with new trends in materials of interest, including oxides, polymers, and biological targets. Our goal is to identify areas of interest and emerging data needs to meet the requirements of a continuously developing user community.

[1] https://www-nds.iaea.org/stopping/. Original webpage by H. Paul in http://www.exphys.jku.at/stopping/

[2] H. Paul, **New results about stopping power for positive ions: Experiment and theory**, AIP Conf. Proc. **1525** 295 (2013)

[3] P. Sigmund and A. Schinner, **Progress in understanding heavy-ion stopping**, **Nucl. Instrum. Meth. in Phys. Res B** (2016) in press.

[4] Dib A **et al**, **Nucl. Instrum. Meth. in Phys. Res B 362** 172 (2015)

[5] Miksova R **et al**, **Nucl. Instrum. Meth. in Phys. Res B 371** 81 (2016)

[6] G. Schiwietz and P.L. Grande, Nucl. Instr. and Meth. B **273** 1 (2012); http://www.casp-program.org/

[7] S.P. Limandri, **et al**, **Nucl. Instrum. Meth. in Phys. Res B 68**, 194 (2014)

[8] J.F. Ziegler **et al**, The stopping and Range of ions in solids (Pergamon Press,1985); http:// www.srim.org

Abstract 436 WED-AP-MA-04-1 Invited Talk - Wednesday 3:30 PM - West Fork

Clinical and Administrative Aspects of Starting a Proton Therapy Center

Andrew K. Lee, Gary Barlow

Texas Center for Proton Therapy, Irving TX 75063, United States

Proton therapy has been used to effectively treat cancer in the U.S. for several decades. The field has seen significant advances in its technology as well as an expansion of the clinical scenarios where proton therapy can be utilized. Currently, there are over 15 operational proton centers in the U.S. and that number is expected to double in the next five years. Planning and initiating a new proton center requires significant research, vetting, and capital. The following presentations will discuss the various aspects of planning and initiating operations of a new center. Specific topics will include the clinical rationale for proton therapy, defining its clinical need within an area, technology and vendor selection. Independent

of the advanced technology, one of the most critical factors for any center is experienced and motivated personnel. Matters regarding center staff and clinical operations (e.g. intake staff, nursing, anesthesia, child-life) will be discussed. The complex nature of payer relations will be covered as well as the need for a robust financial office.

Abstract 437 WED-AP-MA-04-2 Invited Talk - Wednesday 3:30 PM - West Fork

Clinical and Administrative Aspects of Starting a Proton Therapy Center

Gary Barlow, Andrew Lee

Texas Center for Proton Therapy, Irving TX 75063, United States

Proton therapy has been used to effectively treat cancer in the U.S. for several decades. The field has seen significant advances in its technology as well as an expansion of the clinical scenarios where proton therapy can be utilized. Currently, there are over 15 operational proton centers in the U.S. and that number is expected to double in the next five years. Planning and initiating a new proton center requires significant research, vetting, and capital. The following presentations will discuss the various aspects of planning and initiating operations of a new center. Specific topics will include the clinical rationale for proton therapy, defining its clinical need within an area, technology and vendor selection. Independent of the advanced technology, one of the most critical factors for any center is experienced and motivated personnel. Matters regarding center staff and clinical operations (e.g. intake staff, nursing, anesthesia, child-life) will be discussed. The complex nature of payer relations will be covered as well as the need for a robust financial office.

Abstract 438 WED-AP-MA-04-3 Invited Talk - Wednesday 3:30 PM - West Fork

Starting up a clinical proton center: Physics considerations

Chang Chang

Texas Center for Proton Therapy, Irving TX 75063, United States

Proton therapy is one of the many applications of particle accelerators that experienced an expansion in recent years. Indeed the advent of second-generation beam delivery technique, i.e. pencil beam scanning, enables intensity modulation for proton therapy and as a result widens proton therapy's clinical indications. Here we summarize and present our experience in opening a new second-generation proton therapy facility in 2015. The emphasis is on the various physics considerations, such as clinical beam commissioning, measurement equipment selection, quality assurance program, treatment planning and oncology information system configuration and integration, as well as initial phases of external accreditation for beam physics. Staffing and workflow standardization will also be discussed in the context of transitioning the clinic from initial commissioning into routine clinical operations.

Abstract 385 WED-AP-MA-04-4 Contributed Talk - Wednesday 3:30 PM - West Fork

Acceptance, Commissioning, Opening then Maintaining a Proton Center in a community with limited proton medical physics experience.

Mark Pankuch

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Over the past several years the number of proton centers within the United States has doubled and many more centers are under construction or in the planning stages. These centers require active involvement by the onsite medical physics team in a very different environment that can be unfamiliar when compared to a standard photon clinic. Very few medical physics training programs include specific particle therapy training and the current experience pool of particle medical physicists is very limited. In addition, particle therapy possesses a very quickly evolving technology base which includes the rapid clinical implementation of such developments as Intensity Modulated Proton Therapy (IMPT), in room volumetric imaging and several different range verification methods. After commissioning is completed, the day to day clinical environment of the medical physicist continues to be new with novel considerations necessary for particle range uncertainty, effects of organ motion and the increased importance for adaptive planning. The rapid evolution of each of these methods dilutes the medical physicists' expertise even further.

The administrations of new particle centers should be aware of these increased demands and must be prepared to address this potential human resource limitations. The particle therapy professional communities through such organizations as the Proton Collaborative Group (PTCOG) and the American Association of Physicists in Medicine (AAPM) have made several efforts to build the resources available to its members. Such endeavors include development and publication of Task Group reports, dedicated educational sessions at annual meetings and the development of a culture with a highly collaborative community of particle medical physicists.

This presentation will include the experience of opening one of the first community based proton centers over six years ago and describe the challenges when opening, then keeping the center at the forefront of the changing technology. The lessons our center has learned will be shared along with the logic of our evolving technology roadmap.

Abstract 302 WED-AR-ISM-02-1 Contributed Talk - Wednesday 3:30 PM - Post Oak

Local formation of color centers in diamond without thermal annealing using swift heavy ions

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(2)The Molecular Foundry, Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley CA 94720, United States
(3)GSI Helmholtzzentrum fÃ¼r Schwerionenforschung GmbH, Planckstrasse 1, Darmstadt 64291, Germany

Color centers in diamond, such as the nitrogen - vacancy (NV) center, are being used as sensitive probes for magnetometry and they are promising candidates for spin - photon quantum bits in quantum information processing. Materials processing for reliable formation of high quality color centers in desired locations is a formidable challenge. We report on the formation of color centers in diamond using swift heavy ions (SHI, ~5 MeV/u gold ions). The intense electronic excitation of the diamond matrix from the passage of individual SHI locally forms color centers without an additional thermal annealing step. We have observed this for NV centers where nitrogen was present from growth in CVD diamonds and in diamonds were nitrogen had been introduced by low energy ion implantation. We also report on the formation of an erbium related center that we observe in erbium implanted diamonds after processing with SHI. In our presentation we will discuss mechanisms of color center formation by swift heavy ions and intense electronic excitations.

This work was performed in part at the Molecular Foundry at Lawrence Berkeley National Laboratory and was supported by the Office of Science, Office of Basic Energy Sciences, Scientific User Facilities Division, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

Abstract 60 WED-AR-ISM-02-2 Contributed Talk - Wednesday 3:30 PM - Post Oak

Synthesis of HfO_2 Nanoparticles by RF Magnetron Sputtering Technique and Ion Irradiation Effects

M Dhanunjaya yadav, S.V.S Nageswara Rao, A. P. Pathak

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Nano-crystalline Hafnium Oxide (HfO_2) thin-films have been successfully prepared by RF Magnetron Sputtering method. The HfO_2 Nano-particles (NPs) observed in these thin-films have been characterized by using High Resolution

Transmission Electron Microscopy (HRTEM), Field Emission Scanning Electron Microscope (FESEM), UV-visible Absorption, Photo Luminescence (PL) measurements. These measurements were performed before and after Swift Heavy Ion (SHI) irradiation with 100 MeV Ag ions. HRTEM measurements confirm that the particles are non-spherical in nature with average particle size of 2.8 nm. Particle size is found to increase from 2.8 to 4.3 nm with fluence. The Selected Area Electron Diffraction (SAED) patterns confirms d-spacing is 0.31 nm, 0.28 nm which correspond to (-111), (111) directions and inter planar spacing confirms the monoclinic phase. GIXRD measurements confirms the crystallization of HfO_2 NPs with irradiation. Before irradiation the PL measurement shows broad emission peak around 410 to 450 nm. After irradiation the dominant emission peak shifted to 390 nm and which increases with increase in fluence. This PL emission is attributed to "O" related point defects. The increase in the intensity of emission indicates an increase of defects in HfO_2 NPs.

Abstract 277 WED-AR-ISM-02-3 Contributed Talk - Wednesday 3:30 PM - Post Oak

Synthesis of Silicates Analogous to Cosmic Dust Using Multiple Ion Implantations

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A new process for laboratory synthesis of silicates analogous to circumstellar dusts formed by oxygen rich outflows in asymptotic giant branch (AGB) stars will be discussed. These silicates are compounds containing a silicon bearing anion (SiO_4^{4-}) along with Fe and Mg. The laboratory synthesis of Mg-Fe rich silicates has recently gained considerable interest due to their need for comparison of physical parameters (structural, compositional and morphological) while analyzing extraterrestrial dust samples.

The Fe-Mg mixed grains need some kind of processing able to supply sufficient energy to overcome the barrier for the diffusion of iron into the magnesium-rich silicate lattice. Irradiation of low energetic ion beam along with thermal-annealing is one of the most attractive processes for synthesis of nanostructured alloys via ion-beam mixing phenomena.

The technical content of the presentation includes information on the formation of silicate nano-clusters at near surface-regions. The Si targets were sequentially implanted with FeO, Mg, and O at < 80 keV energies. Prior to the experiment a dynamic ion-solid interaction code was used to simulate the surface sputtering, rise in temperature at molecular-level while the implanted ions are distributed in silicon matrix. The implantation ion doses and annealing temperatures were varied to form various silicate alloys within top-50nm of the substrate. The samples were analyzed for morphology and alloy-phase formation using various surface characterization techniques.

The results of this research clarify the growth of silicate minerals in the dynamic conditions near AGB stars. Diffusion of Fe into the Mg-rich silicate lattice will be reported, as it is not fully understood in the context of dust formation.

Abstract 387 WED-AR-RE-04-1 Invited Talk - Wednesday 3:30 PM - Bur Oak

In Situ Analysis of Self-ion Damage Accumulation in Nanocrystalline Tungsten and Solute-stabilized Tungsten Alloys

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Tungsten has emerged as the most promising candidate for the high heat flux regions of reactor-scale fusion devices due to its high temperature strength, sputtering resistance, and chemical compatibility with tritium. However, irradiation of tungsten leads to the onset of damage that can limit its technological utility as a plasma-facing material. One approach for enhancing radiation tolerance involves refining the grain size to the nanometer regime. In this work, self-ion irradiation damage in nanocrystalline tungsten was characterized as a function of total dose through **in situ** electron microscopy techniques using 3 MeV W^{4+} ions. The role of grain boundaries was explored through collision cascade simulations, and employed to understand the experimental damage evolution trends. Solute-stabilized nanocrystalline tungsten alloys were finally analyzed under identical irradiation conditions and the damage state contrasted with unalloyed nanocrystalline tungsten to identify design strategies for enhancing their stability and radiation tolerance.

Abstract 123 WED-AR-RE-04-2 Contributed Talk - Wednesday 3:30 PM - Bur Oak

Radiation defect dynamics studied by pulsed ion beams

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The formation of stable radiation damage in crystalline solids often proceeds via complex dynamic annealing processes, involving migration and interaction of ballistically-generated point defects. Our current understanding of the underlying physics is still not sufficient for predicting radiation damage even for Si, which is arguably the simplest and most extensively studied material. The complexity of radiation damage is closely related to radiation defect dynamics. We have developed a pulsed ion beam method to study defect interaction dynamics. This method allows us to measure effective time constants of defect interaction, defect interaction rates, and defect diffusion lengths. The strengths and limitations of the pulsed beam method will be illustrated with examples for Si, Ge, and SiC.

This work was performed under the auspices of the US DOE by LLNL under contract DE-AC52-07NA27344.

Abstract 270 WED-AR-RE-04-3 Contributed Talk - Wednesday 3:30 PM - Bur Oak

Use of accelerators to study radiation effects in advanced nuclear materials

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The goals of high efficiency, inherent safety and long lifetime of Generation IV nuclear reactors raise new challenges to the nuclear materials. One of the challenges is to develop and test advanced structural and cladding materials that sustain the high dose of radiation damage at elevated temperatures. In general, the structural material used in sodium-cooled fast reactors, one of the six types of Generation IV reactors, is expected to receive radiation damage of more than 100 displacements per atom (dpa) during its service time. Even more dpa will be received for the cladding materials. Compared with most test reactors that produce radiation damage in the order of 10 dpa/year, ion accelerators have the advantage of higher dpa rate: a heavy ion accelerator can damage the materials like steel to 10 dpa in less than 2 hours. Thus, it is of great importance to use accelerators as a tool to investigate the radiation effects in nuclear materials and understand the results as compared to neutron irradiations.

In this presentation we will demonstrate the radiation damages induced by heavy ion and proton radiation to a variety of materials including ferritic-martensitic alloys strengthened with nanostructures and high-temperature austenitic steels. The irradiations were conducted using ion accelerators. The radiation effects were characterized using nanoindentation techniques and transmission electron microscopies. Results were presented in multiple perspectives such as microstructure evolution, nanostructure stability and mechanical property changes due to irradiation. The effects of types of irradiation, radiation temperature and dose rate on microstructural evolution were investigated and will be shown in this presentation.

Correlations between the mechanical properties, microstructures and irradiation conditions will also be discussed. The results of this serial of accelerator-based studies demonstrated the accelerated understanding of radiation effects in nuclear materials thanks to accelerator techniques.

Abstract 228 WED-AR-RE-04-4 Contributed Talk - Wednesday 3:30 PM - Bur Oak

Accelerated radiation damage research in nuclear structural materials at the Dalton Cumbrian Facility

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The use of energetic ions as a surrogate for neutron induced damage in nuclear structural materials is a key tool in understanding and predicting the behaviour of materials under the extreme conditions of nuclear reactors. The ability to provide high damage rates compared to neutron test reactors, with negligible target activation, enables fast assessment of radiation induced damage in such structural materials. Well controlled experimental conditions such as temperature and damage rate must be in place when simulating neutron damage by the use of energetic ions.

An overview of the ion irradiation capabilities currently in place at the Dalton Cumbrian Facility, for low target activation requirements, will be presented. Experimental results for proton and heavy ion irradiations currently being investigated at this facility will be discussed, including radiation hardening and embrittlement in Vanadium alloys, radiation damage mechanisms at the grain boundaries in stainless steel cladding materials, and effect of alloying content on the defect structure formation and evolution in Tungsten-Tantalum systems.

This research was funded by the EPSRC and the DCF project, collaboration between the Nuclear Decommissioning Authority and the University of Manchester.

Abstract 345 WED-AR-RE-04-5 Contributed Talk - Wednesday 3:30 PM - Bur Oak

Nano-mechanical property changes and its atomic mechanism after He, W and He+W co-implanted W

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The plasma facing material faces not only harsh plasma erosion but also irradiation damage. W and W based alloys are preferred candidates as the plasma facing first wall material in fusion reactor. In order to identify relationship between mechanical property changes and irradiation, we applied three different ion beam radiations on W (He, W, and He+W) following by nano-indentation to get stress-strain curves in characterizing the local mechanical behavior. Combining with molecular dynamics simulations, we shed light on the atomic understanding of how radiation damage (created by W irradiation and He-cluster) block dislocations movement during nano-indentation, which is the key reason of W radiation hardening comparing with experimental results. On the other hand, we also simulated the process of how grain-boundaries trap He and grow into He-cluster to investigate the roles of grain-boundaries in mechanical properties changes after He irradiation.

Abstract 132 WED-PR-SP-12-1 Invited Talk - Wednesday 3:30 PM - Elm Fork

Reaction Measurements with the Jet Experiments in Nuclear Structure and Astrophysics (JENSA) Gas Jet Target

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Explosive stellar environments are driven by nuclear reactions on short-lived, radioactive nuclei. These reactions often drive the stellar explosion, alter the observable light curves produced, and dictate the final abundances of the isotopes created. Unfortunately, many reaction rates at stellar temperatures cannot be directly measured in the laboratory, due to the physical limitations of ultra-low cross sections and high background rates. An additional complication arises because many of the important reactions involve radioactive nuclei which have lifetimes too short to be made into a target. As such, direct reactions require very intense and pure beams of exotic nuclei. Indirect approaches with both stable and radioactive beams can, however, provide crucial information on the nuclei involved in these astrophysical reactions.

A major development toward both direct and indirect studies of nuclear reactions rates is the commissioning of the Jet Experiments in Nuclear Structure and Astrophysics (JENSA) supersonic gas jet target. The JENSA system provides a pure, homogeneous, highly localized, dense, and robust gaseous target for radioactive ion beam studies. Charged-particle reactions measurements made with gas jet targets can be cleaner and display better resolution than with traditional targets. With the availability of pure and localized gas jet targets in combination with developments in exotic radioactive ion beams and next-generation detector systems, the range of reaction studies that are experimentally possible is vastly expanded.

This talk will focus on the benefits of performing reaction measurements with a gas jet target, including discussion of several example cases using JENSA.

Research sponsored by the Laboratory Directed Research and Development Program of Oak Ridge National Laboratory, managed by UT-Battelle, LLC, for the U.S. Department of Energy. This work was supported by U.S. Department of Energy, NNSA, and National Science Foundation.

Abstract 61 WED-PR-SP-12-2 Contributed Talk - Wednesday 3:30 PM - Elm Fork

A supersonic jet target for the cross section measurement of the 12C(α; γ)16O reaction with the recoil mass separator ERNA

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12C(α; γ)16O plays a key-role in the determination of the C/O ratio at the end of stellar Carbon burning. Since stellar models predict an exceptional sensitivity of the following stellar evolution and nucleosynthesis on that parameter, the reaction cross section of 12C(α;γ)16O must be determined with the precision of about 10% at the relevant Gamow energy of 300keV . The ERNA (European Recoil mass separator for Nuclear Astrophysics) collaboration could measure, for the first time, the total cross section of 12C(α; γ)16O by means of the direct detection of the 16O ions produced in the reaction down to an energy of Ecm = 1.8MeV. To extend the measurement at lower energy, it is necessary to limit the extension of

the He gas target. This can be achieved using a supersonic jet, where the oblique shock waves and expansion fans formed at its boundaries confine the gas, that can be e fficiently collected using a catcher. A test version of such system has been realized and experimentally characterized as a bench mark for a full numerical simulations using FV (Finite Volume) method. The results of the commissioning of the jet test version and the design of the new system that will be used in combination with ERNA are presented and discussed.

Abstract 274 WED-PR-SP-12-3 Contributed Talk - Wednesday 3:30 PM - Elm Fork

Study of the ^{14}N(d,alpha) ^{12}C* reaction using SUGAR.

José Francisco Favela PÃ©rez[1], Luis Armando Acosta SÃ¡nchez[1], Victoria Isabel Araujo Escalona[1], Arcadio Huerta HernÃ¡ndez[1], Ghiraldo Macave Murillo Olayo[2], MarÃ-a Esther Ortiz Salazar[1], Rafael Policroniades Rueda[2], Pedro Humberto Santa Rita Alcibia[1], Armando Varela GonzÃ¡lez[2], JosÃ© Gustavo Vega Romero[1], EfraÃ-n Rafael ChÃ¡vez LomelÃ-[1]

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A new supersonic gas jet target (SUGAR) was put in operation at the 5.5 MV-CN Van de Graaff accelerator facility at the Physics Institute of the National Autonomous University of Mexico (IFUNAM). A general description of the system will be presented, as well as the ^{14}N(d,alpha)^{12}C* reaction. Excitation functions for the alpha_0, alpha_1, alpha_2 and alpha_3 particles using an angular distribution at backward angles with energies between 2 and 3MeV will be shown.

Abstract 237 WED-PR-SP-12-4 Contributed Talk - Wednesday 3:30 PM - Elm Fork

Determining the ^{14}O(α,p)^{17}F Astrophysical Rate with TwinSol Measurements

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The ^{14}O(α,p)^{17}F reaction is an important trigger reaction to the αp process in X-ray bursts. The best experimental constraints on its astrophysical rate come from measurements of the time-inverse reaction, ^{17}F(p,α)^{14}O. Previous studies of this inverse reaction have sufficiently characterized the high-energy dependence of the cross section but there are still significant uncertainties at lower energies. A new measurement of the ^{17}F(p,α)^{14}O cross section is underway at the University of Notre Dame TwinSol facility using an in-flight secondary ^{17}F beam. Initial test data will be presented along with plans for the completion of the measurement. This work is supported in part by the National Science Foundation, the U.S. DOE Office of Nuclear Physics, and the Joint Institute for Nuclear Astrophysics - CEE.

Abstract 247 WED-PR-SP-12-5 Contributed Talk - Wednesday 3:30 PM - Elm Fork

High Precision ^{236}U(n,γ) and ^{238}U(n,γ) Cross Section Measurement

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High precission cross section data on major and minor actinides are important for many applications including the stockpile stewardship, nuclear reactor design and advance fuel cycle
programs. We carried out a series of measurements to determine the capture cross section of Uranium isotopes using the Detector for Advanced Neutron Capture (DANCE) at the Los Alamos Neutron Science Center (LANSCE). A primary goal of the measurements was to improve existing uncertainties, for the incident neutron energy range from 1 keV up to about 1 MeV.

In this conference, we will present the results of ^{236}U and ^{238}U capture cross section measurement. The conference presentation will include the details about the experiments, off-line data analysis and considerations of the experimental conditions that affect the precision of the cross-section determination. The final results and R-Matrix analysis on resolved and unresolved resonance region will be presented.

This research is supported by the U. S. Department of Energy, Office of Science, Nuclear Physics under the Early Career Award No. LANL20135009.

Abstract 443 WED-PR-SP-13-1 Invited Talk - Wednesday 3:30 PM - Rio Grande

The Evidence for Sterile Neutrinos from LSND & MiniBooNE

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The LSND and MiniBooNE short-baseline neutrino experiments have provided evidence for neutrino oscillations at a mass scale of approximately 1 eV^2. When combined with oscillation measurements at the solar and atmospheric mass scales, these experiments imply the existence of more than three neutrino mass states and, therefore, one or more sterile neutrinos. Such sterile neutrinos, if proven to exist, would have a big impact on particle, nuclear, and astrophysics, and would contribute to the dark matter of the universe. The future Short-Baseline Neutrino (SBN) program at Fermilab will provide a definitive test of short-baseline neutrino oscillations and will have the capability of proving the existence of sterile neutrinos.

Abstract 441 WED-PR-SP-13-2 Invited Talk - Wednesday 3:30 PM - Rio Grande

Nuclear Data for Nuclear Reactor Antineutrino Flux Calculations

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By placing antineutrino detectors in the vicinity of large commercial nuclear power plants, the oscillation theta_13 has been precisely measured by the Daya Bay, Double Chooz and RENO collaborations. Two intriguing results were also observed, the total number of antineutrinos seems lower than estimates by about 5% and the shape of the spectrum is different from the predictions. An analysis of previous experiments has also revealed a deficit of antineutrinos at short distances not included in the three-flavor oscillations, the so-called reactor neutrino anomaly; the shape distortion, however, was unexpected. As more experiment experiments are planned using nuclear reactors, the need to accurately calculate the antineutrino spectra generated by a nuclear reactor has become crucial. Two methods are used in this regard; the first one, known as the conversion method, relies on the knowledge of the electron spectrum generated by the neutron rich fission products following the fission of the nuclear fuels. The other one, known as the summation method, combines fission yields with the decay data of those fission products. A numbers of refinements recently added to the summation method will be presented, including the effects of total absorption gamma spectroscopy data and updating fission yields, as well as the results of sensitivity studies to identify possible issues in the conversion method.

Work at BNL was supported by the Office of Nuclear Physics, Office of Science of the U.S. Department of Energy under contract No. DE-AC02-98CH10886.

Abstract 442 WED-PR-SP-13-3 Invited Talk - Wednesday 3:30 PM - Rio Grande

Toward improved searches for tensor type interactions in β decay

Oscar Naviliat-Concic

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Precision measurements in neutron and nuclear decays have played a crucial role in the development of the (**V-A**) theory of the weak interactions. Experiments in nuclear beta decay offer today a sensitive window to search for physics beyond the standard electroweak model, complementary to direct searches carried out at high energy colliders.

Several experiments in nuclear beta decay currently focus on the measurement of the shape of the beta particle energy spectrum in Gamow-Teller decays, in order to extract the Fierz interference term. Such an observable is sensitive to contributions of tensor type interactions which could arise by the presence of new bosons. Compared to many other correlation coefficients, the Fierz term is attractive since it is linear in those exotic couplings.

This presentation describes new efforts in nuclear beta decay aimed at reaching new levels of sensitivity by using a technique that eliminates the instrumental effect of back-scattering of electron on detectors. The first application of the technique in ^{6}He and ^{20}F decays will be presented.

Abstract 444 WED-PR-SP-13-4 Invited Talk - Wednesday 3:30 PM - Rio Grande

Preparing for decay studies at FRIB - beta delayed neutron spectroscopy

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Next generation radioactive beam facilities, such as FRIB, will ultimately provide us access to vast amount of very neutron-rich nuclei, which will be predominantly beta delayed neutron emitters. Thus, for many of the new nuclei, neutron spectroscopy will become the dominant tool to study their decay properties. In preparation for the future experiments, we have constructed Versatile Array of Neutron Detectors at Low Energy (VANDLE) and implemented in spectroscopic measurements on beta delayed neutron emitters, which can be studied presently. Selected result of several experiments performed with this array near doubly magic nuclei will be shown as well as proposed new generation neutron detector NEXT intended for high-resolution neutron spectroscopy.

Abstract 408 THU-PS-AP-05-0 Plenary Talk - Thursday 8:00 AM - Rio Grande

Advancing Technological Capabilities to Prevent Nuclear Terrorism

Joel Rynes

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The Transformational and Applied Research Directorate (TAR) of the Domestic Nuclear Detection Office (DNDO) within the Department of Homeland Security (DHS) is chartered to develop breakthrough technologies that will have a dramatic impact on the capabilities to prevent nuclear and radiological terrorism though an aggressive and expedited research and development (R&D) program. This R&D focuses on technology to detect material out of regulatory control and technology to attribute this material back to its sources though nuclear forensics. Recently, TAR released a technology roadmap that described five technical grand challenges derived from gaps in the Global Nuclear Detection Architecture (GNDA) and Technical Nuclear Forensics (TNF). This talk will provide an overview of DNDO and its approach to solve these technical grand challenges. Special emphasis will be given on the role of traditional and non-traditional particle acceleration techniques to help solve one of these challenges - the detection of nuclear threats even when shielded.

Abstract 293 THU-PS-AA-02-0 Plenary Talk - Thursday 8:45 AM - Rio Grande

Finding Edgar Degas' Lost Portrait with a Synchrotron

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We have applied a non-invasive, rapid, high definition X-ray fluorescence (XRF) elemental mapping technique to the painting "Portrait of a Woman" by Edgar Degas. The painting has historically been known to have a hidden portrait that was considered indecipherable using conventional imaging techniques. We collected 31.6 megapixel scanning XRF derived elemental maps of the painting and provided a novel image processing method to produce a false color representation of the hidden portrait. We believe this work has provided a sound methodology for both imaging and understanding the chemical composition of artworks, and enables scholarly understandings of cultural heritage.

Abstract 275 THU-AC-TD-01-1 Invited Talk - Thursday 10:00 AM - Trinity

Electron Accelerators for Novel Cargo Inspection Methods

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One of the main factors limiting the performance of conventional X-ray cargo inspection with material discrimination (MD) is the interlaced mode of system operation. Such systems use pulsed linac or betatron X-ray generators and produce alternate pulses with lower- and higher- end-point energies. Consequently, these systems demonstrate about 50 mm lower penetration then a system operated in a non-interlaced mode, have a limited range of cargo areal densities with valid MD, and cannot perform MD of objects smaller than the pulse separation. Also, the limited pulse repetition rate of X-ray generators in interlaced mode reduces the radiographic image quality at nominal commercial speeds of vehicles or trains. Several new low-dose methods of cargo inspection with MD were recently introduced [1-4] to address the above-mentioned limitations: a method with an intrapulse time-varying spectral content of the X-rays; a method with ramping-up energy packet of short X-ray pulses; and a method based on temporal separation of Cherenkov and scintillation detector signals. All these methods have electron accelerators as a core element. However, the accelerator requirements and, thus, their designs are different for each system as summarized in the table below, [5, 6].

Core parameters of accelerators for novel low-dose inspection systems under development at RadiaBeam Technologies (prospective parameters are specified in brackets)

Inspection system	Beam energy,MeV	Power source	Pulse rep. rate, pps	Pulse/packet duration, us	Anticipated ave. dose per raster line, cGy
R/road, portal	Ramping, 2-9	Klystron	1,000	16	0.125
Portal, mobile	Ramping, 4-6 (2-6)	Magnetron (Amplitron)	400	4 (8)	0.055
Mobile	6 (9)	Magnetron	500 (2,000)	0.5 (0.1)	0.028
Backscatter:					
mobile, portal	Ramping, 0.5 - 1.5	Magnetron (Amplitron)	400 (4,000)	4 (8)	-
Mobile	Multi-energy, 2- 7.5	Betatron	500	4	0.018

In this talk, we will discuss the requirements for the accelerators, some details about their designs, and present several novel solutions for current and prospective projects.

This work has been partly supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contracts HSHQDC-13-C-B0019 and HSHQDC-15-C-00032. This support does not constitute an express or implied endorsement on the part of the Government.

References.

1. A. Arodzero. Scintillation-Cherenkov Detector and Method for High Energy X-Ray Cargo Container Imaging and Industrial Radiography. US Patent Application 2011/0163236.

2. A. Arodzero, S. Boucher, A. Murokh, S. Vinogradov, S.V. Kutsaev. System and Method for Adaptive X-ray Cargo Inspection. US Patent Application 2015/1472051.

3. A. Arodzero, S. Boucher, S.V. Kutsaev, Finn O'Shea, V. Ziskin. Adaptive Cargo Inspection System Based on Multi-Energy Betatron. Provisional patent application.

4. A. Arodzero, S.V. Kutsaev, V. Ziskin. X-Ray Backscatter Inspection System. Provisional patent application.

5. A. Arodzero and S. Boucher. Accelerator Requirements for Low Dose Advanced Multi-Energy Radiography. Talk at DNDO Meeting on Development of Accelerator Requirements for Homeland Security Applications. Fermilab, August 5-7, 2015.

6. S. Kutsaev, R. Agustsson, A. Arodzero, S. Boucher, L. Faillace, V. Ziskin. Electron Linac with Deep Energy Control for Adaptive Rail Cargo Inspection System. IEEE-2015 Nuclear Science Symposium proceedings, N1CP-118.

Abstract 355 THU-AC-TD-01-2 Invited Talk - Thursday 10:00 AM - Trinity

Near-monoenergetic photon sources for security applications

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Compact, near-monoenergetic photon sources (MPSs) at MeV energies offer significant capability enhancement in radiography and active interrogation applications. Their advantages lie in the ability to select photon energy, energy spread, flux and pulse structure to deliver the photons needed for signature generation while suppressing extraneous dose and background that is associated with current bremsstrahlung sources. New sources in development promise high performance in compact systems, including selectable photon energies from 1 to 20 MeV, energy spreads from the 10% level down to below 1%, and ~10^8 photons/pulse at repetition rates up to 10s of kHz. To guide source development, nonproliferation applications where near-monoenergetic photon sources may have a high-impact have been identified and application and photon source requirements assessed. Screening of cargo containers and trucks for shielded SNM showed strong benefit from photon sources with moderate energy spread at the 20% level. Sources with narrowly collimated 'pencil' beams (e.g. Thomson scattering based MPSs) additionally mitigate scattering degradation of contrast suffered by current bremsstrahlung fan-beam sources. In secondary screening for alarm resolution using photofission the dose reduction exceeds a factor of 10 over a bremsstrahlung source. Similarly, highly specific Nuclear Resonance Fluorescence (NRF) measurements are enabled at MPS energy spreads ≤2% with orders of magnitude lower measurement times and doses. For the detection of concealed SNM via photofission where access to the object/container of interest is limited to one side, Thomson scattering sources with narrow angular divergence beams reduce overall dose to object and environment and improve detection of SNM at larger distances, of order 20 m. For the verification of nuclear warheads in treaty verification, NRF, and radiography are techniques for which MPSs could provide significant performance improvements.. In nuclear safeguards, narrow-divergence Thomson MPS-based cord transmission measurements could provide a solution for the verification of the content of spent fuel dry-storage casks that overcomes the primary challenge of severe attenuation and scattering in the thick cask walls, lids, and the fuel assemblies themselves for determining assembly basket occupancy. An update will be presented on the development of a compact MPS based on Thomson scattering. Applications of Thomson MPSs have in the past been restricted by the size of the required few-hundred MeV electron linac, scattering (photon production) system, and shielding for disposal of the high-energy electron beam. Experiments in progress will use laser-plasma accelerators (LPAs) to produce electron beams of several hundred MeV cm-scale plasmas. The LPA will be combined with control of the scattering laser to reduce the scattering laser size and/or electron beam current requirements, and with use of a plasma structure to decelerate the electron beam after photon production, reducing the size and mass of shielding required for beam disposal. Status of a facility designed to test these concepts will be discussed, along with the path towards meeting application needs.

Abstract 357 THU-AC-TD-01-3 — Invited Talk - Thursday 10:00 AM - Trinity

Development of a compact accelerator driven neutron generator for security applications

Allan X. Chen, Charles K. Gary, David L. Williams

Adelphi Technology Inc., 2003 East Bayshore Rd., Redwood City CA 94063, United States

Adelphi Technology is developing a compact neutron generator that is ideal for security applications. The ion source is based on our flagship ECR microwave technology operating in the over-dense mode. With clever design of the RF to plasma coupling, the microwave driver power consumption has been dramatically reduced while still maintaining the high current density characteristics of an ECR plasma. The acceleration section has been carefully designed to optimize the E-field of the high voltage electrode, minimizing arc discharge breakdown. The present generator is able to fit inside a 4" cavity from one end. Preliminary results of the neutron yield and ion beam simulations will be discussed at the conference.

Abstract 113 THU-AC-TD-01-4 — Contributed Talk - Thursday 10:00 AM - Trinity

Explosive Hazard Detection Using a Portable High-Flux Neutron Generator

Mark Thomas, Scott Christensen, Evan Sengbusch, Ross Radel, Rob O'Connell

Phoenix Nuclear Labs, 2555 Industrial Drive, Madison WI 53713, United States

Explosive hazards (IEDs, mines, and UXO) pose one of the greatest threats to the American warfighter today. Successful defense against these hazards requires the capability to rapidly detect and classify the hazard at safe standoff ranges. A neutron-based detection system is a viable technology solution, as described in this presentation. When neutrons interact with matter, gamma radiation is emitted with characteristic energy levels that provide signature information about the elemental composition of the object being interrogated. This radiation can be detected and rapidly analyzed via a computer algorithm to generate an alert that an explosive threat is nearby and further analyzed to identify the composition of the explosive material. The speed and standoff distance of detection is directly tied to the neutron source strength, and PNL's very intense neutron generator allows neutron-based explosive detection to be a practical solution. In this presentation, we present results of a quantitative analysis to determine how PNL's $1xE^{11}$ DD n/s neutron generator would improve upon past explosive detection performance, and the current progress of the laboratory effort validating those results. The analysis focused on the use of the Thermal Neutron Analysis (TNA) technique. TNA uses the absorption of neutrons via the (n,γ) reaction of thermal neutrons (approximately 0.025 eV) and identifies the activated material with the energy of the gamma ray signature. TNA is a common strategy for neutron-based explosives detection because of the large cross section for thermal neutrons compared to fast neutrons. The analysis was primarily performed using the MCNP (Monte Carlo N-Particle) code. The five parameters evaluated include explosive type and composition, explosive depth, distance from neutron source to explosive, and soil composition.

Abstract 321 THU-AC-TD-01-5 Contributed Talk - Thursday 10:00 AM - Trinity

Studies of a hydrocarbon fluid-based deuteron ion spark-source for neutron generators

Paul R. Schwoebel

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Experimental studies of a deuteron ion spark-source for neutron generators are reported. The ion source uses a spark discharge between electrodes coated with a deuterated hydrocarbon fluid. The fluid-based source can provide well in excess of 10^4 pulses as the fluid self-heals and thereby prevents permanent electrode erosion. With more advanced fluid management designs lifetimes could be increased significantly.

Operation of the ion source in a laboratory neutron generator has demonstrated that 0.5 A of atomic deuterium ions in an 5 μs pulse at a pulsing rate of 1 Hz can be delivered to the target with target voltages of 90 to 100 kV. The ions have been focused onto the target such that the majority are in a 1-cm diameter spot. The thickness of the hydrocarbon fluid in the spark gap and the consistency thereof from pulse-to-pulse influences the deuteron yield and plays a role in determining the beam focusing characteristics through the applied voltage necessary to break down the spark gap.

This work has been supported by the U.S. Defense Advanced Research Projects Agency (DARPA), under contract HR0011-15-C-0071. The views, opinions, and/or findings expressed are those of the authors and should not be interpreted as representing the official views or policies of the Department of Defense or the U.S. Government.

All authors are with SRI International, Menlo Park, CA 94025 USA (paul.schwoebel@sri.com).

Abstract 324 THU-AP-MA-07-1 Invited Talk - Thursday 10:00 AM - West Fork

Medical isotope production at TRIUMF - from imaging to treatment

Cornelia Hoehr

Life Science Division, TRIUMF, 4004 Wesbrook Mall, Vancouver BC V6T 2A3, Canada

TRIUMF has a long history of medical isotope production. The Life Science Division has produced positron emission tomography (PET) tracers for the local hospitals for over 40 years. Recently, we have taken on the challenge to expand our isotope repertoire.

As a consequence of the recent ^{99}Mo/^{99m}Tc supply shortages, we have developed an alternative production method for producing ^{99m}Tc directly using small medical cyclotrons; bypassing the need for nuclear reactors and with it enriched uranium targets. The team has demonstrated between 4.7 and ~32 Ci production levels on three different brands of cyclotron, sufficient quantities to supply some urban centres across the country with an alternative source of ^{99m}Tc. Currently, we are conducting clinical trials to seek full Health Canada approval for our method.

In addition to the more 'traditional' PET isotopes ^{18}F and ^{11}C, TRIUMF has established a novel production method for a number of radiometals (^{94m}Tc, ^{44}Sc, ^{86}Y, ^{89}Zr, ^{68}Ga, ^{61}Cu-61) using liquid targets. This approach utilizes the infrastructure which exists in many PET centres to produce the common tracer [^{18}F]FDG. By using this approach, TRIUMF has dramatically improved the availability of research, and in some cases clinical, quantities of radiometals without a solid target infrastructure or isotope generators.

Finally, efforts are underway to expand TRIUMF's capacity for production of alpha emitters for therapeutic applications. We have utilized the 500 MeV TRIUMF cyclotron to irradiate ^{238}U and ^{232}Th targets and have successfully isolated ^{221}At via ^{211}Rn, ^{209}At via ^{213}Fr and ^{225}Ac, and ^{213}Bi via ^{225}Ra using the laboratory's Isotope Separation On-line (ISOL) infrastructure. With access to all of the aforementioned isotopes, radiopharmaceutical development toward applications in targeted alpha-therapy is underway.

Abstract 353 THU-AP-MA-07-2 Contributed Talk - Thursday 10:00 AM - West Fork

MEDICIS-produced radioisotope beams for medicine

Marie Curie Innovative Training Network

Simon Stegemann[1], Thierry Stora[2], Thomas Elias Cocolios[1]

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(2)CERN, Geneva 23 CH-1211, Switzerland

MEDICIS-PROMED is a network that bridges different disciplines across fundamental research institutions, private companies and hospitals for the production of innovative medical isotopes and radiopharmaceuticals for the imaging and therapy of cancer.

Radioisotopes are commonly used for functional imaging and are expected to play an enhanced role in treatment of various types of cancer. Therefore, the new CERN-MEDICIS facility, which extends the capabilities of the ISOLDE facility, will provide dedicated medical batches for radiopharmaceuticals and develop new accelerator technologies for medical applications.

Outcome of this innovative training network will be a new generation of entrepreneurial scientists, who will take advantage of the different interdisciplinary fields, in order to develop medical systems for new personalized treatment. In particular, this includes the development of mass separated radioactive ^{11}C-beams for PET-aided hadron therapy, which combines treatment with online PET imaging, and thus permits direct determination of the irradiation field.

Abstract 343 THU-AP-MA-07-3 Invited Talk - Thursday 10:00 AM - West Fork

Argonne National Laboratory Support for Accelerator Based Domestic Production of Mo-99.

Sergey Chemerisov, Peter Tkac, Amanda Youker, John Krebs, David Rotsch, Michael Kalensky, Thad Heltemes, Kurt Alford, James Byrnes, Roman Gromov, Matt Virgo, Lohman Hafenrichter, James Jerden, Charles Jonah, Vakhtang Makarashvili, Kevin Quigley, John Schneider, Dominique Stepinski, Ken Wesolowski, George Vandegrift

Nuclear Engineering, Argonne National Laboratory, 9700 S Cass Ave, Lemont IL 60532, United States

The National Nuclear Security Administration (NNSA), in partnership with commercial entities and the US national laboratories, is working to accelerate the establishment of a reliable domestic supply of Mo-99 for nuclear medicine while also minimizing the civilian use of HEU. Argonne National Laboratory (Argonne) is supporting NorthStar Medical Technologies and SHINE Medical Technologies in their efforts to become domestic Mo-99 producers. NorthStar Medical Technologies, LLC is utilizing the photonuclear reaction in an enriched Mo-100 target for the production of Mo-99. In this approach a high-power electron accelerator is used to produce the required flux of high-energy photons through the bremsstrahlung process. Argonne is assisting in developing the irradiation system, target processing, and enriched-Mo recycle. SHINE Medical Technologies is developing SHINE, a system for producing fission-product Mo-99 using a D/T-accelerator to produce fission in a non-critical target solution of aqueous uranyl sulfate. Argonne is assisting SHINE in development Mo-99 recovery and purification systems. Production experiments supporting both commercial partners are conducted using a high power/medium energy electron LINAC at Argonne. In this presentation, we will review accelerator related aspects of the projects.

Work supported by the U.S. Department of Energy, National Nuclear Security Administration's (NNSA's) Office of Defense Nuclear Nonproliferation, under Contract DE-AC02-06CH11357. Argonne National Laboratory is operated for the U.S. Department of Energy by UChicago Argonne, LLC.

Abstract 388 THU-AP-MA-07-4 Contributed Talk - Thursday 10:00 AM - West Fork

Current Activities at Los Alamos National Laboratory Supporting Electron Accelerator Production of Mo-99

Gregory E Dale[1], Scott A baily[1], Kip A Bishofberger[1], Dale A Dalmas[1], Michael A Holloway[1], Charles T Kelsey[1], Michael Mocko[1], Angela Naranjo[1], Eric R Olivas[1], Eric B Rauch[1], Frank P Romero[1], Robert M Wheat[1], Keith A Woloshun[1], James T Harvey[2]

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(2)NorthStar Medical Technologies, LLC, 1800 Gateway Blvd., Beloit WI 53511, United States

Los Alamos National Laboratory (LANL) is supporting the commercial U.S. production of Mo-99 as part of the National Nuclear Security Administration (NNSA) office of Materials Minimization and Management (M3) program to accelerate the establishment of a reliable domestic supply of Mo-99 without the use of highly enriched uranium (HEU). The metastable daughter product of Mo-99, Tc-99m, is the most commonly used radioisotope in nuclear medicine. This radioisotope is used in approximately two-thirds of all nuclear medicine imaging procedures, amounting to approximately

50,000 diagnostic nuclear medicine procedures performed every day in the United States (US). Until recently, the entire US supply of Mo-99 for nuclear medicine has been produced in aging foreign reactors using HEU targets. Maintenance and repair shutdowns of these reactors have significantly disrupted the supply of Mo-99 in the US and much of the rest of the world.

As part of the M3 program and in partnership with several other national laboratories, LANL continues to provide engineering design and experimental support for U.S. domestic commercial production initiatives. For this presentation, we will discuss the support LANL is providing to NorthStar Medical Radioisotopes for the production of Mo-99 using electron accelerators. The NorthStar production process uses an electron beam from an electron accelerator incident on an enriched Mo-100 targets to produce Mo-99 through the (γ,n) photonuclear reaction. Areas we are currently focused on include target cooling, target optimization, quantification of side-reaction products, and beam diagnostics necessary for a production facility. Several scaled production and thermal tests have been performed on natural Mo and enriched Mo-100 targets using an electron accelerator at Argonne National Laboratory. This presentation will review the current status of these activities.

Abstract 286 THU-AP-MA-07-5 Contributed Talk - Thursday 10:00 AM - West Fork

Utilizing Boron in Proton Therapy to Enhance Treatment

Jacob Daniel Baxley, Tilo Reinert

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Like the Boron Neutron Capture Therapy(BNCT) reaction, the $^{11}B(p,\alpha)2\alpha$ reaction has a large cross-section at the broad resonance at 660 keV. It is this large cross section that gives promise to boron particles being used as a dose enhancer for proton therapy. When the boron-proton reaction occurs the reaction produces alpha particles capable of delivering a dose to a target cancer site.

The dose delivered to the target cancer site from the reaction is dependent on the number of alpha particles created at the site and their respective energies. This alpha-energy-product relies on the size of the boron particle at the target site.

We used Mathematica and tabulated reaction cross section data to calculate the alpha-energy-product of ^{11}B particles under proton irradiation of varying thicknesses. The calculated optimum particle radius was 4.3 micrometers.

Abstract 136 THU-AP-MA-07-6 Contributed Talk - Thursday 10:00 AM - West Fork

Production of ^{124}I Via ^{125}Te (p, 2n) Reaction Using Electroplated Targets

Faisal M. Alrumayan, Suliman Al-Yanbawi, John Schneider, Ahmed Al-Gaith, Ibrahim Al-Jammaz

Cyclotron and Radiopharmacuticles, King Faisal Specialist Hospital and Research Centre, Takhasosy Road, MBC 03, Riyadh Riyadh 11211, Saudi Arabia

The accelerating demands of Non-standard Positrons Emission Tomography (PET) radionuclides led to the development and optimization of different methods and applications for producing emerging radionuclides, especially Iodine 124 (^{124}I) . The low positron energy, the low abundance of gamma-radiation and the suitable half life, makes ^{124}I favorable radioisotope for most research institutes. The presently ^{124}Te (p, n) reaction, although, it produce very high radionuclidic purities, yet the yields are rather low.

Preliminary experiments were conducted on an electroplated target using Te-125 with a beam current of 5μA and 30 minuets of irradiation time. The cyclotron energies used in this experiment were 24, 20 and 17 MeV bearing in mind that the initial energy of the CS-30 cyclotron is 27 MeV.

As a result, this paper discuss the possibility of producing ^{124}I via ^{125}Te (P, 2n) and using electroplating technique of high activity.

Abstract 92 THU-AP-TA-05-1 Invited Talk - Thursday 10:00 AM - Rio Grande

Making Research Part of the Undergraduate Physics Curriculum

Mark Yuly

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Houghton College is committed to providing a rigorous and practical educational experience to undergraduates majoring in science. In addition to the wide range of traditional coursework offered in the division, there is a strong emphasis on hands-on experiences that will develop the problem solving and practical skills needed by scientists in the real world. Traditional coursework usually focuses on the content of the discipline, but not on developing the other traits needed to be a successful scientist. This talk will describe how the Houghton physics curriculum addresses this issue by requiring every student to complete a multi-year collaborative research project. After a brief overview, several accelerator-based student research projects will be highlighted, from small-scale projects like the Houghton cyclotron and our small electrostatic accelerator, to medium-scale nuclear physics experiments using accelerators at SUNY Geneseo and Ohio University, to larger neutron experiments at LANSCE. Student outcomes resulting from this program will be described.

Abstract 164 THU-AP-TA-05-2 Invited Talk - Thursday 10:00 AM - Rio Grande

Undergraduate use of the Edwards Accelerator Laboratory of Ohio University

David C Ingram

Physics & Astronomy, Ohio University, Edwards Accelerator Laboratory, ATHENS OH 45701, United States

Undergraduate research opportunities are available to all physics and astronomy students at Ohio University. We have a commitment to provide a research opportunity to all our undergraduate majors during their time with us. 75% of them have at least one period of research and some having multiple experiences and also successfully complete REUs at other universities. Many of the students are supported through federal grants and the rest on local funds. The facilities of the Edwards Accelerator Laboratory are used by many undergraduates in their research and I will highlight some of these in my presentation. Briefly, they have worked on detector development, nuclear reaction cross-section measurements, as well as materials analysis projects. The laboratory includes a 4.5 **MV** tandem accelerator with six beamlines in a well-shielded building. Two beamlines are dedicated to materials research. One beamline has a 30-**m** time-of-flight neutron detection facility that is well-shielded from the rest of the accelerator. It also has a swinging magnet that means the neutron detectors in the time-of-flight tunnel do not move as the angle is varied with respect to the ion beam and the neutron producing target from zero to 165 degrees. The other three beamlines are used primarily for low-energy nuclear physics research. In addition to supporting research, the laboratory also supports a formal laboratory course that all undergraduates take as juniors. This has a collection of experiments that include alpha and gamma spectroscopy with radioactive sources as well as using the accelerator to examine the properties of the Rutherford cross-section.

Abstract 46 THU-AP-TA-05-3 Contributed Talk - Thursday 10:00 AM - Rio Grande

Application of Accelerators in Undergraduate Materials Education

Daryush ILA[2], Zhiping Luo[2]

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As a requirement for students with materials minor track at the Department of Chemistry and Physics at Fayetteville State University, students were to complete a course with a materials research subject. As such, we designed the following three investigations; 1) Elemental Analysis of Small Toys by RBS, by Electron Microprobe, and by XPS; 2) AFM surface profilometry and hardness measurement of MeV ion implanted silica; 3) Measurement of Optical Properties of MeV Au and MeV Ag implanter Infrasil. The full description of the background, the objectives, and the materials used, methods used, and results obtained for each project will be presented by each student during this meeting, separately. During this presentation we will describe the design of the materials research subjects, the requirements for completion, the results obtained, and the outcome of the course.

Abstract 252 THU-AP-TA-05-4 Contributed Talk - Thursday 10:00 AM - Rio Grande

Radiation Dose Characterization Surrounding a 400 KeV Deuteron Accelerator

Andrew D Roberts, Donald Rudquist, Nicholas Miller, Morgan O'Brien, Wyatt Poulliot, Evan Koehler, Scott Arneson

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Radiation dose characterization is an important consideration for understanding accelerator performance and safety requirements, and has potential applications for moderate dose irradiation of biological and other samples. As a teaching tool the measurement of radiation dose both from primary beam interactions and secondary stray beam impact offers a wealth of opportunity for providing hands on training to undergraduate students. Radiation dose rates were mapped around the 400KV Van de Graaff particle accelerator at the Applied Nuclear Science Lab at Minnesota State University, Mankato. The purpose was to establish operation parameters for providing known radiation doses for studies in materials science and biology. The maximum radiation dose is centered toward the low energy end of the accelerator, dominated by x-rays produced with the high current scattered beam within the accelerator. Beam generation and acceleration control were optimized to maximize the radiation dose available. Tests of field uniformity, energy spectrum and operational stability were performed.

Abstract 337 THU-AP-TA-05-5 Invited Talk - Thursday 10:00 AM - Rio Grande

Nuclear Research, Experiments, and Outreach at Tarleton State University

Daniel Keith Marble, Chris Brian Marble, Kassie Scott Marble

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For more than fifteen years, Tarleton State University's nuclear laboratory has been providing educational labs and research activities to support both physics and non-physics majors. Using Internet based multichannel analyzers, these activities have also been provided to undergraduates at other Texas institutions in the Texas Physics Consortium (TPC) of which Tarleton is a founding member. The TPC consists of eight undergraduate institutions across Texas who share upper-level physics courses and jointly award a BS Physics degree with a five year graduation rate of more than 70 graduates. A discussion of the nuclear facility, the various educational activities, and the laboratory's K-12 outreach activities will be presented including the recent use of gamma analysis to investigate garnet based sands used by FMC to cut metal for oil & gas applications..

Abstract 316 THU-AR-RE-05-1 Invited Talk - Thursday 10:00 AM - Bur Oak

The Use of Radiation Facilities for Risk Reduction in Space Systems

Heather Quinn

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The space environment has a harsh radiation environment, which can cause spacecraft to fail. The predominant issue is from protons, electrons and x rays. These particles cause a variety of issues in electronics, including lifetime aging effects, structural damage, catastrophic failure, crashes and output failures. X rays cause a lifetime aging effect called total ionizing dose that degrades the switching parameters of the transitions. X rays can also transform to Bremsstrahlung radiation that can cause dose enhancement in the interior of the spacecraft. Neutrons and protons can cause structural damage to the Silicon lattice of electronics called displacement damage. Charged particles, such as protons, alphas and heavy ions, can cause catastrophic failures, crashes and output failures through single-event effects, where a single charged particle causes off transistors to turn on. While seemingly minor, turning on the off transistor can lead to the transistor to burn out permanently or to draw an infinite current.

Most spacecraft designers prepare for this harsh radiation environment by either selecting radiation-hardened and/or upscreening commercial electronic components. As the performance requirements for many satellites have increased over the years, it has become necessary to upscreen more parts. The upscreening process tests electronics for their sensitivities to different types and energies of ionizing and non-ionizing radiation. Given the range of possible radiation-induced failures, it is often necessary to test the components in a number of different radiation facilities.

Abstract 170 THU-AR-RE-05-2 Invited Talk - Thursday 10:00 AM - Bur Oak

TRIUMF Proton and Neutron Beams for Radiation Effect Testing

Ewart Blackmore, Michael Trinczek

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TRIUMF in Vancouver is one of the premier test facilities in the world for measuring the radiation effects of protons and neutrons on electronics, materials and biological systems. The proton energy range available up to 500 MeV is well-matched to the energy spectrum found in space and a 10-year mission dose in low earth orbit can be delivered in minutes to hours depending on user requirements. Many Canadian and international companies, universities and laboratories use this test capability to determine the suitability of electronic and electro-optical devices for space or to check for single event effects in the terrestrial environment for avionics and ground-based electronic systems. This presentation will briefly describe the space and terrestrial radiation environments, the radiation effects on electronics and materials, the TRIUMF proton and neutron test facilities and some examples of the types of measurements being carried out.

Abstract 278 THU-AR-RE-05-3 Invited Talk - Thursday 10:00 AM - Bur Oak

Radiation Effects Testing at the Cyclotron Institute at Texas A&M University

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Since 1994, the Cyclotron Institute at Texas A&M University has provided a convenient and low cost solution to commercial, governmental and educational agencies in need of studying, testing and simulating the effects of ionizing radiation on electronic systems. Starting at just 100 hours/year at inception, the demand for beam time has grown to ~3000 hours/year and has remained consistent at this level for the past several years. Two different cyclotrons provide either heavy ions or protons on separate and dedicated beam lines. From the K500 Superconducting Cyclotron, three beam energy series are provided: 15 MeV/nucleon (He, N, Ne, Ar, Cu, Kr, Ag, Xe, Pr, Ho, Ta, Au), 25 MeV/nucleon (He, N, Ne, Ar, Kr, Ag, Xe) and 40 MeV/nucleon (N, Ne, Ar, Kr). From the K150 (88-in) Cyclotron, protons in energies from 6 - 45 MeV are provided over a wide flux range of E1 to E10 p/s-cm^2. An overview of the facility will be presented.

Abstract 232 THU-AR-RE-05-4 Invited Talk - Thursday 10:00 AM - Bur Oak

The Los Alamos Neutron Science Center Spallation Neutron Sources

Suzanne F Nowicki, Stephen A Wender, Michael Mocko

P-27 LANSCE Weapons Physics, Los Alamos National Laboratory, P.O. Box 1663, Los Alamos NM 87545, United States

The Los Alamos Neutron Science Center (LANSCE) provides the scientific community with intense sources of neutrons with the capability of performing experiments supporting civilian and national security research such as nuclear physics and material science experiments for the defense program, basic science, and the radiation effects program. This talk focuses on the radiation effects program, which involves users from National laboratories, Industry and Universities.

When cosmic rays strike the earth's atmosphere, they cause nuclear reactions with elements in the air and produce a wide range of energetic particles. Because neutrons are uncharged, they can reach aircraft altitudes and sea level. These neutrons are thought to be the most important threat to semiconductor devices and integrated circuits. The best way to determine the failure rate due to these neutrons is to measure the failure rate in a neutron source that has the same spectrum as those produced by cosmic rays.

Los Alamos has a high-energy and a low-energy neutron source. Both are driven by the 800-MeV proton beam from the Los Alamos Neutron Science Center (LANSCE). The high-energy neutron source at the Weapons Neutron Research (WNR) facility uses a bare target that is designed to produce fast neutrons with energies from 100 keV to almost 800 MeV. The measured neutron energy distribution from WNR is very similar to that of the cosmic-ray-induced neutrons in the atmosphere. However, the flux provided at the WNR facility is 5×10^7 times more important than the flux of the cosmic-ray-induced neutrons. This intense neutron flux allows testing at greatly accelerated rates. An irradiation test of less than an hour is equivalent to many years of neutron exposure due to cosmic-ray neutrons. The low-energy neutron source is located at the Lujan Neutron Scattering Center. It is based on a moderated source that provides useful neutrons from subthermal energies to ∼100 keV and is used for condensed matter research, nuclear science and neutron radiography. The characteristics of these sources, and ongoing research programs for each facility are described.

Abstract 244 THU-PR-AMP-03-1 Invited Talk - Thursday 10:00 AM - Post Oak

An Electrostatic Storage Ring for Interdisciplinary Physics Research at JPL

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The rich return of absorption and emission spectra from atoms, molecules, and ions of many charge states from operational spacecraft - such as (**e.g.**) Hubble, Herschel/SPIRE, SOFIA, ALMA, Suzaku, Chandra, Newton, and the Trappist Telescope; and the expected data return from upcoming missions such as JWST, Solar Probe Plus, ESM-ESA, and TESS - place an ongoing need for lifetimes, spectroscopy, photon- and electron-ionization and dissociation cross sections of atomic and molecular ions, and of highly-charged atomic ions [1]. In addition, there is increasing need in medicine and biology to gauge the health of astronauts in long-duration human flight as regards possible cancers and cell aging induced by ionizing collisions (X-rays, cosmic rays, highly-charged ions) and microgravity, respectively. To meet these needs a program has been initiated at JPL to design and build an electrostatic storage ring (ESR). As is well known, ion storage in the ESR is mass-independent, depending only on the kinetic energy of the ions and not on their mass [2,3]. Hence one can store protons, ionic clusters, amino acids, and cancerous & aging cells for problems in astrophysics (**e.g.**, exoplanet absorption spectroscopy, the diffuse interstellar bands), and in human flight to Mars.

Reported earlier [4] was an initial lattice consisting of a double mirror-symmetry with a 90° split-bend of 10° parallel deflecting plate and an 80° cylindrical deflector in the corner. The 90° split-bend was preceded by a quadrupole doublet, then followed by a quadrupole singlet (see Ref. [4], Fig. 1). The stability of the lattice was verified using the CERN-MAD transfer matrix code [4,5]. Recently, the SIMION code [6] was used to simulate the different lattice elements and to track ions in this ring. These further in-depth SIMION simulations suggest that the use of quadrupole doublets instead of single quadrupole lenses enhances the stability of ion storage in the ring. These SIMION results will be presented, along with the CERN-MAD lattice stability results for the new quadrupole-doublet-only ESR design. Attention will again be given to the possibility of accommodating absorption and merged-beams experiments in the straight racetrack sections, as well as formation of foci (interaction points) for crossed-beams studies [7].

A.C. acknowledges support at JPL/Caltech through the Office of Chief Scientist and Chief Technologist.

[1] A. Chutjian, **Uses and Construction of an ESR for Measurements in Planetary Physics and Astrophysics** 2015 (JPL internal report, unpublished)

[2] S. P. MØller 1997 **Nucl. Instrum. Meth. A 394** 281

[3] H. T. Schmidt **et al.** 2013 **Rev. Sci. Instrum. 84** 055115

[4] A. Chutjian, M. O. A. El Ghazaly, D. P. Mahapatra, A. Moradmand 2015 J. Phys. Conf. Ser. **635** 32099

[5] MAD - Methodical Acceleration Design - at the CERN website, **http://mad.web.cern.ch/mad/**

[6] D. Dahl 2000 **J. Mass Spectrom 200** 3, and http://simion.com/

[7] K. E. Stiebing **et al.** 2010 Nucl. Instrum. Meth. A **614** 10

Abstract 151 THU-PR-AMP-03-2 Invited Talk - Thursday 10:00 AM - Post Oak

The cryogenic double electrostatic ion-storage ring, DESIREE.

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The Double ElectroStatic Ion-Ring ExpEriment, DESIREE, is a unique facility capable of storing simultaneously two ion beams (one negatively and one positively charged) at keV energies on 8.8 m closed orbits and with a 95 cm merging section where sub-keV center-of-mass reactions may be studied [1]. The rings and their vacuum chamber are cooled to cryogenic temperatures (12-13 K typically) and are mounted inside an outer vacuum chamber for thermal insulation. This low temperature results in an extremely high vacuum with residual-gas densities of the order of 10^3 cm^{-3} allowing for storage lifetimes of keV anions approaching one hour [2,3].

The early experiments in DESIREE have been focused on determining lifetimes of long-lived metastable excited states of atomic negative ions by storing an ion beam in one of the rings and then applying a state-selective laser photodetachment technique to monitor the metastable-state population as function of time after injection and thereby deduce the intrinsic lifetimes of these states. This technique has been used for the first determinations of metastable lifetimes for S^- [3], Ni^- [4], and Pt^- [5].

One key point for the DESIREE project and other cryogenic storage ring projects [6] has from the start been the prospect of being able to produce and maintain beams of vibrationally and rotationally cold molecular ions. Recently a study at the cryogenic storage ring, CSR, in Heidelberg on photodissociation of CH^+ molecular ions demonstrated for the first time the trend towards very low temperatures of the stored molecular ions [7]. We present first results on storage of cold OH^- ions for very long time and demonstrate by a selective laser photodetachment technique [8] for the first time that thermodynamic equilibrium with the cold surroundings can be reached.

The option to merge two stored beams and thus study interactions at low relative velocity between cold molecular ions is the truly unique feature of the DESIREE project. Work is ongoing to reach this ambitious goal and we can now present the first results from DESIREE of mutual neutralization at sub-eV collision energy between two atomic ion beams.

References:

[1] R. D. Thomas **et al**, Rev. Sci. Instrum. **82**, 065112 (2011)

[2] H. T. Schmidt **et al**, Rev. Sci. Instrum. **84**, 055115 (2013)

[3] E. Bäckström **et al**, Phys. Rev. Lett. **114**,143003 (2015)

[4] M. Kaminska **et al**, Phys. Rev. A, **93**,012512 (2016)

[5] KC. Chartkunchand **et al**, Phys. Rev. A, (2016) **submitted in July**

[6] H. T. Schmidt, Phys. Scripta, **T166**, 014063 (2015)

[7] A. P. O'Connor **et al.** Phys. Rev. Lett. **116**, 113002 (2016)

[8] R. Otto **et al.** Phys. Chem. Chem. Phys. **15**, 612 (2013)

Abstract 365 THU-PR-AMP-03-3 — Invited Talk - Thursday 10:00 AM - Post Oak

SPARC collaboration: new strategy for storage ring physics at FAIR

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SPARC collaboration at FAIR pursues the worldwide unique research program by utilizing storage ring and trapping facilities for highly-charged heavy ions. The main focus is laid on the exploration of the physics at strong, ultra-short electromagnetic fields including the fundamental interactions between electrons and heavy nuclei as well as on the experiments at the border between nuclear and atomic physics. Very recently SPARC worked out a realization scheme for experiments with highly-charged heavy-ions at relativistic energies in the High-Energy Storage Ring HESR and at very low-energies at the CRYRING coupled to the present ESR. Both facilities provide unprecedented physics opportunities already at the very early stage of FAIR operation.

Abstract 349 THU-PR-AMP-03-4 Contributed Talk - Thursday 10:00 AM - Post Oak

CRYRING@ESR - a new facility for low-energy highly charged ion research

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The heavy-ion storage ring CRYRING, formerly located in Stockholm, Sweden, was a very successful facility for atomic and molecular physics research for almost two decades. As a Swedish contribution to the future international research center FAIR in Darmstadt, Germany, it has been shipped to Darmstadt in 2013. Here, we are presently integrating it into the existing ion beam infrastructure downstream from the present ESR storage ring, where it soon shall recommence operation as CRYRING@ESR and will become the first operating experimental facility of FAIR. With the powerful accelerator chain as injectors, CRYRING will gain access to new classes of intense and pure beams of highly charged ions (HCI) of all ion species presently available at GSI but at small energies between 0.3-15 MeV/u.
Excellent vacuum conditions allow for long beam lifetimes even for the most extreme charge states at this low-energy beams. Various flexible installations will allow for experiments on e.g. atomic collision dynamics and precision spectroscopy in strong fields, or for studying nuclear processes relevant in stellar nucleosynthesis. A rich science program in the fields of atomic and nuclear research and at their intersections lies ahead. Furthermore, materials science or HCI interactions with biomolecules or astrophysically relevant molecules may be pursued in the future.
In this presentation, we will introduce the CRYRING@ESR facility, present our project status and timeline, and we will highlight some of the planned experiments and new research opportunities at this site.

Abstract 291 THU-AA-IBT-04-1 Invited Talk - Thursday 1:30 PM - Trinity

Application of Rutherford Backscattering (RBS) and Positive Ion X-ray Emission (PIXE) to Electrolyte Analysis of Homogeneous Thin Solid Films (HTSF) of Congealed Blood Prepared via HemaDrop™

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Medical diagnostics needs new methods of blood analysis using microliters of blood, or drops, rather than the standard large volume of 7 mL, to improve care and minimize the impact on patients from multiple blood draws, especially in neonates and chronically ill patients. This would reduce the blood volume sampled by a factor of 1000, and enable hourly blood draws, if in addition, blood analysis could be conducted in less than 30 minutes. A company called Theranos has been recently in the news for being shut down by the FDA for their claims about their "finger-stick method," where small blood drops were used for complete blood diagnostics, not just glucose. They were only approved for qualitative detection, rather than accurate blood composition. In addition, Theranos has never published scientific research to back up their claims, nor filed any patents. Motivated by these accuracy issues, and by our recent discovery on how to congeal microliters of biological fluids, into smooth, planar, Homogeneous Thin Solid Films (HTSF), we use MeV Rutherford Backscattering Spectrometry (RBS) to measure elemental composition of electrolytes (H, C,N, O, K, Mg, Ca, Na, Fe) on such HTSF formed from 5-6 microliters of blood. These planar films are prepared on super-hydrophilic substrates in a process that congeals blood drops quickly, without allowing phase separation, a technology we called HemaDrop™[1, 2] Measurements on HTSF prepared via HemaDrop™ with 5-6 µliters of blood are compared and found much more reproducible and accurate than those taken for comparison on classically dried blood drops. This includes the "Dried Dlood

Spot (DBS)" technique, which typically uses absorbent filter paper, can only be used in microvolume sampling for drug metabolism, not blood composition, and does require 30-100 µl. HTSF prepared with HemaDrop™ and analyzed by RBS yield reproducible elemental composition regardless of substrate used or area of analysis with < 2-6% sampling error. Ion damage from RBS is accounted for via the 0-dose intercept damage curve method [3], which graphs the RBS yield of elements detected, as a function of analyzing dose, using several sequential cumulative spectra. Positive Ion X-ray Emission (PIXE) is used to verify the reproducibility and accuracy of RBS. Thus, IBA can be used on HemaDrop™ homogeneous thin solid films congealed from blood, because the HemaDrop™ HTSF technique enables for the first time blood analysis via vacuum-based methods. Infra-Red Absorption Spectroscopy, TeraHertz Spectroscopy and Tapping Mode Atomic Force Microscopy (TMAFM) are also being investigated to add molecular identification and counting.

[1] US Patents Pending, Inventors: Herbots, N, Pershad Y, Krishnan A, Brimhall AL, Mangus MW, Wilkens BJ, Culbertson RJ, Culbertson EJ, et al (2016)

[2] Y. Pershad, A. A. Mascareno, M. R. Watson, A. L. Brimhall, N. Herbots, C.F. Watson, A. Krishnan, N. Kannan, M. W. Mangus, R.J. Culbertson, B. J. Wilkens, E. J. Culbertson, T. Cappello-Lee and R.A. Neglia. **Electrolyte Detection by Ion Beam Analysis, in Continuous Glucose Sensors and in Microliters of Blood using a Homogeneous Thin Solid Film of Blood, HemaDrop™**. **MRS Advances,** available on CJO2016. doi:10.1557/adv.2016.469 (2016).

[3] Shaw JM, Herbots N, Hurst QB, Bradley JD, Culbertson RJ, et al. **Journal of Applied Physics** 100(10):104109 (2009)

Abstract 333 THU-AA-IBT-04-2 Contributed Talk - Thursday 1:30 PM - Trinity

DAPNe-IBA : A new tool for the IBA community?

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With the emergence of MeV-SIMS and micro calorimeter X-ray detectors, our community have recently been presented with new opportunities for providing chemical speciation of samples. Whilst these techniques significantly increase the analytical power of IBA, their ability to provide trace molecular information is limited. Even for MeV-SIMS, the fragmentation of analytes precludes the detection of large molecules.

Direct Analyte Probed Nano Extraction[1] Mass Spectrometry (DAPNe-MS) is a method of selecting and removing a small quantity of material from a surface, using a capillary tip attached to a nanomanipulator. The extracted material is then introduced into a mass spectrometer via nanoelectrospray ionisation. The technique has achieved sensitivity at the attogram level and is particularly suited to picking up trace materials from surfaces. Unlike MeV-SIMS, there is minimal fragmentation, and this provides better selectivity.

The University of Surrey has been awarded a grant from the UK Electronics and Physical Sciences Research Council to install a system for Direct Analyte Probed Nano Extraction (DAPNe) to be used in conjunction with ion beam analysis. The basic concept is to provide a trace element or secondary ion image using IBA techniques and then seIect points of interest to be studied in greater detail using DAPNe. In this presentation, we will describe the technical set up of the recently installed system, show some preliminary results and discuss situations in which DAPNe-IBA can add significant value to analytical science.

[1] **Overcoming selectivity and sensitivity issues of direct inject electrospray mass spectrometry via DAPNe-NSI-MS**. Clemons K, Nnaji C, Verbeck GF, **J Am Soc Mass Spectrom** 2014, **25(5)** 705-11: doi: 10.1007/s13361-014-0842-y

Abstract 144 THU-AA-IBT-04-3 Contributed Talk - Thursday 1:30 PM - Trinity

Exploring the Effects of Ion Beam Raster and Dose Rates on Localized Heating

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Ion beam irradiation can be used to better understand Zircalloy-4 (Zr-4), the fourth iteration of a series of zirconium based alloys, behavior during long term exposure to extreme radiation environments. However, when these ion beam irradiation studies are utilized, there are concerns that arise due to dose rate and ion beam raster rate. Beam rastering is used because dose uniformity is required and in many cases the beam diameter is much smaller than the target diameter. Depending on the irradiation conditions, parts of the sample may experience more dose then other locations leading to an uneven dosage to the sample as well as uneven heating. This presentation will highlight some of the initial findings on dose rate and raster rate effects on thermal profiles performed at Sandia's Ion Beam Lab.

In this study, a 80mm^2 Zr-4 plate was irradiated with a 16 MeV Si^{3+} beam of 3.3mm^2 at an incidence angle of 45°. Furthermore, the plate was tested under the following conditions: a dose rate of 9.46E12 and 9.46E11 ions/cm^2-s, temperatures ranging from 100 - 500°C, raster rate of 1 - 0.01 Hz in the Y-direction, and a raster rate 8 - 0.08 Hz in the X-direction. Based on SRIM simulations, this would result in a maximum damage rate of 1.61E-2 and 1.61E-3 dpa/s, and an average damage rate over the ion range of 5.07E-3 and 5.07E-4 dpa/s in a given location for the sample. Maximum global displacements per atom were 20.13E-2 and 2.01E-2 dpa and average displacements per atom were 6.34E-2 and 0.63E-2 dpa. The thermal profile provided by a FLIR infrared camera was directly compared to a thermocouple spot welded onto a sample that was pressed onto a Heat Wave Labs button heater. This study demonstrates the ability to directly measure and compare the spatial and temporal localized heating in a sample to the temperature measured overall for the sample. It was found that increased raster rate increases sample temperature profile uniformity. In addition decreased dose rate also leads to increased temperature uniformity during rastered implantation. Care must be taken on the thermocouple placement so as to reduce artificial temperature spikes during beam rastering.

This research was partially funded by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences, Division of Materials Sciences and Engineering. Sandia National Laboratories is a multi-program laboratory operated by the Sandia Corporation, a wholly owned subsidiary of Lockheed Martin company, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Abstract 173 THU-AA-IBT-04-4 Contributed Talk - Thursday 1:30 PM - Trinity

Time detector design for Time-of-Flight Elastic Recoil Detection Analysis (ToF-E ERDA) revisited

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Time-of-flight-energy elastic recoil detection analysis (ToF-E ERDA) is a uniquely powerful thin-film analytical technique because it can be used to measure simultaneously the depth distributions of all elements in a thin-film sample. The basic design of the time detectors which are generally based on the electron mirror has not changed significantly over 25 years or so. In this presentation we overview factors that limit the time resolution of the detectors (electron transit jitter, multichannel plate jitter and propagation time spread of the electromagnetic wave over the anode surface to the coaxial waveguide) as well as the origin of "ghost" pulses from detection of stray electrons. We also consider perturbations to charged recoil trajectories. Different approaches to mitigate these problems are discussed.

Abstract 231 THU-AA-IBT-04-5 Contributed Talk - Thursday 1:30 PM - Trinity

Revealing crystal orientation and defects in the Helium Ion Microscope using channeling

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Helium Ion Microscopy (HIM) is well known for its exceptional imaging and nanofabrication capabilities [1]. HIM has an unprecedented surface sensitivity, and channeling can be utilized to maximize the signal to noise ratio, obtain information on the crystal structure and reveal defects such as dislocation networks.

Using a poly crystalline gold sample we show how channeling can be used to obtain crystallographic information in the HIM [2].

We demonstrate the resolving power of this technique using a thin (2 ML) silver layer on Pt(111). This is is representative example of a surface confined alloy widely studied in the field surface science. The obtained HIM results are compared to results obtained by low energy electron microscopy, spot profile analysis low energy electron diffraction (SPA-LEED), and atomic force microscopy phase contrast. In HIM single atom layer high steps can be visualized as a result of a work function change-across the otherwise atomically flat terraces-of only □20 meV. By utilizing the dechanneling contrast [3] mechanism also the surface reconstruction of this thin surface layer can be revealed. We find a threefold periodic structure of channeling (fcc stacking) and dechanneling (hcp stacking) areas. The periodicity of this structure-measured along the <11-2> surface directions-is 6.65 nm [4]. This is in excellent agreement with values obtained by SPA-LEED.

References:

[1] G. Hlawacek, V. Veligura, R. van Gastel, and B. Poelsema, J. Vac. Sci. Technol. B Microelectron. Nanom. Struct. **32**, 020801 (2014).

[2] V. Veligura, G. Hlawacek, R. van Gastel, H. J. W. Zandvliet, and B. Poelsema, Beilstein J. Nanotechnol. **3**, 501 (2012).

[3] G. Hlawacek, V. Veligura, S. Lorbek, T. F. Mocking, A. George, R. van Gastel, H. J. W. Zandvliet, and B. Poelsema, Beilstein J. Nanotechnol. **3**, 507 (2012).

[4] G. Hlawacek, M. Jankowski, H. Wormeester, R. van Gastel, H. J. W. Zandvliet, and B. Poelsema, Ultramicroscopy **162**, 17 (2015).

Abstract 243 THU-AA-NBA-01-1 Invited Talk - Thursday 1:30 PM - West Fork

Development of a High-Brightness, Quasi-Monoenergetic Neutron Source for Neutron Imaging

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Lawrence Livermore National Laboratory is developing a high-brightness, quasi-monoenergetic neutron source. The primary application for this source is fast neutron-based imaging. Other applications such as neutron-induced reactions for basic and applied science are also a part of our overall motivation. The intensity of the neutron source is expected to be 10^{11} n/s/sr with energy selections at 7 MeV or 10 MeV at 5% bandwidth at 0-degrees. A 7-MeV RFQ+DTL accelerator will drive the neutron source. The accelerator will deliver a 300-μA average current deuteron beam onto a pulsed deuterium gas target. To accommodate the high peak power of the pulsed beam, we are pursuing a windowless transmission-type deuterium gas target to achieve a high intensity, quasi-monoenergetic, forward-kinematically-collimated neutron fluence. To isolate the windowless gas target from the accelerator and beamline vacuum a robust differential system is being developed that will transition from the target pressure of ~3500 Torr to beamline pressure of ~10^{-7} Torr. In this presentation, we will discuss our source development and expected system performance for neutron imaging.

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Abstract 52 THU-AA-NBA-01-2 Contributed Talk - Thursday 1:30 PM - West Fork

Experimental determination of cross-sections of various (n,xn) threshold reactions and their usage for study of a spallation reaction and ADS models

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Spallation reaction is very useful tool for production of intense neutron fields. Such fields have many uses in various fields of physics. One of the most important fields is nuclear physics focused on production of energy and processing of the spent nuclear fuel.

Useful tool for these kinds of work is accelerator driven system (ADS). ADS contain a neutron spallation source and a subcritical blanket. Thanks to the intense neutron field produced in the spallation reaction it is possible to produce energy and transmute the minor actinides from the spent fuel and as a result to significantly reduce its amount and short the time necessary for keeping the spent fuel in special storage conditions.

To do this it is absolutely crucial to have good knowledge of the fast neutron field inside such assembly. For this reason various models are built in order to study the neutron field. Suitable method for this kind of studies is usage of various activation detectors and theirs threshold reactions. Unfortunately the knowledge of the cross-sections of reactions involving fast neutrons is rather poor.

For this reason several experiments were concluded in order to receive this kind of data. The experiments took place at the Nuclear Physics Institute of ASCR and at the Svedberg Laboratory of the Uppsala University. Both facilities use neutron sources based on 7Li(p,n)7Be reaction, but the main difference is in achievable energies and intensities.

The presentation will contain the detailed results from the experiments and their use in the analysis of the neutron fields inside the ADS model QUINTA.

Abstract 226 THU-AA-NBA-01-3 Contributed Talk - Thursday 1:30 PM - West Fork

Determination of the Secondary Neutron Flux at the Massive Natural Uranium Spallation Target

Miroslav Zeman[1,2], Lukas Zavorka[1,3], Jitka Vrzalova[1,3,4], Jindrich Adam[1], Karel Katovsky[2], Jurabek Khushvaktov[1], Alexandr Solnyshkin[1], Martin Suchopar[3,4], Pavel Tichy[1,3,4], Vsevolod Tsoupko-Sitnikov[1], Sergey Tyutyunikov[1], Radek Vespalec[1,3]

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A massive natural uranium spallation target was investigated using a set of monoisotopic threshold radioactivation detectors. Sandwiches made of thin high-purity Al, Co, Au, and Bi metal foils were installed in different positions across the whole spallation target. The gamma-ray activity of products of (n,x n) and other studied reactions was measured off-line with germanium semiconductor detectors. Reaction yields of radionuclides with half-life exceeding 60 min and with effective neutron energy thresholds between 3.6 MeV and 187 MeV provided us with information about the spectrum of spallation neutrons in this energy region and beyond.

The experimental neutron flux was determined using the measured yields and cross sections calculated with the TALYS 1.8 nuclear reaction program. Neutron spectra in coordinates of activation sandwiches were also modeled with the radiation transport code MCNPX 2.7. The flux based on experimental data from individual components of activation sandwiches provides a reasonable description of neutron spectrum inside the spallation target and is in general agreement with Monte-Carlo predictions. On the other hand, taking into consideration experimental data from the sandwiches as a whole, the construction of neutron spectrum leads to unreasonable results in some energy intervals.

In all likelihood the discrepancy is caused by some inconsistencies in mutual ratios of cross sections of elements of activation sandwiches, as discussed in more detail in this work. The results indicate that there should be implemented further improvements in nuclear models, especially at higher energies. The results also refer to the fact that those models are in urgent need of new experimental data for their validation, which is particularly important for research focused on Accelerator Driven Systems and other applications of spallation neutrons.

Abstract 260 THU-AA-NBA-01-4 Contributed Talk - Thursday 1:30 PM - West Fork

Neutron-imaging using fast neutrons with MONDE.

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First images produced by MONDE (Momentum Neutron Detector) at IFUNAM with the help of monochromatic fast neutrons are presented.

Each neutron is produced and tagged with the Associated Particle Technique (APT) using the $^{2}H(^{2}H,n)^{3}He$ reaction. Neutron energies were around 2 MeV. Detection of the 3He provides the external trigger needed to reduce background and made these measurements possible.

MONDE is a large area (160x70x5 cm^3) position sensitive detector for fast neutrons.

In this work we take advantage of a new way to match the response of the 16 Photomultipliers that constitute MONDE through the use of an external NaI detector that provides a trigger for the coincident detection of two gamma rays emitted simultaneously by a low activity ^{60}Co source.

We also present the comparison between two computer algorithms to extract the position of incident neutrons in the detector from the raw data and determine which one give us better space resolution.

Abstract 114 THU-AA-NBA-01-5 Contributed Talk - Thursday 1:30 PM - West Fork

Neutron Radiography using a High-Flux, Compact, Neutron Generator

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A novel neutron imaging system has been developed by Phoenix Nuclear Labs to nondestructively evaluate specimens when conventional X-ray imaging will not suffice. Nuclear reactor based neutron imaging is currently used in the aerospace industry for quality control of high-performance turbine blades, but has been limited from broader adoption due to cost, availability, and supply chain issues associated with research reactors. A first-generation electronic neutron generator is actively being used by the United States Army and is coupled with activation films for neutron radiography to inspect munitions and other critical defense and aerospace components. Neutron radiography is particularly effective for inspecting components when a dense exterior structure inhibits detection of low density internal materials by X-rays. A second-generation system, currently under construction with an anticipated delivery in mid-2016, will increase the total neutron output from an upgraded gaseous deuterium target to $3x10^{11}$ neutrons per second. This system will generate higher neutron flux at the imaging plane, dramatically reduce image acquisition time, and improve spatial resolution. A description of the neutron generator and imaging system, including the beamline, target and detector platform, will be given in this presentation. State of the art neutron moderators, collimators and imaging detectors will also be discussed in the context of increasing specimen throughput and optimizing image quality. High-resolution neutron images will be presented and discussed.

Abstract 189 THU-AA-NT-01-1 Contributed Talk - Thursday 1:30 PM - Post Oak

Energy Calibration of HPGe Detector Using Neutrons, Neutron Induced Ambient Background and Natural Background

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High Purity Germanium (HPGe) detector gamma ray spectroscopy has wide ranging applications. To proceed with data analysis the HPGe detector must be calibrated. That is, the relationship must be known between the energy deposited in the detector by a gamma ray and the amplitude of the corresponding amplifier output pulse. The energy range sensitivity of commercial spectrometer systems ranges from 3 KeV to over 12 MeV. Because the Ge crystal is a gain 1 device, it is standard practice to use a linear relationship between the channel scale and the energy scale. However, electron and hole drift from higher energy events are more likely to encounter crystal defects, causing non-linear effects. The level of non-linear contributions to the calibration is discussed. To measure accurately the calibration, gamma ray lines need to be identified over the full energy range. In this paper, over 21 lines between 3 KeV and 3 MeV useful for calibration are identified and presented. These lines are produced by neutrons, neutron-induced ambient background, beta decay transitions induced by neutrons, florescence, and natural backgrounds. The two-step calibration process involves first fitting the line shape and second combining all the fitting information into the detector calibration. A discussion of systematic energy shifts dependent on the selection of the line shape fitting parameters is presented.

Abstract 271 THU-AA-NT-01-2 Contributed Talk - Thursday 1:30 PM - Post Oak

Studies of 14.1 MeV neutrons signals in the Cosmic Ray Veto (CRV) counter prototypes of the Mu2e experiment

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The Mu2e experiment at Fermilab will search for the coherent neutrinoless conversion of a muon to an electron in the field of an atomic nucleus with a sensitivity of four orders of magnitude better than previous experiments. The Mu2e detector is surrounded by a cosmic ray veto (CRV) system that is required to reduce the cosmic-ray background to 0.10 events over the course of the run with an efficiency of 99.99%. The CRV consists of four layers of scintillator strips with embedded wavelength-shifting fibers and silicon photomultiplier (SiPM) readout. The SiPMs will be exposed to a neutron background which over time may damage the sensors and introduce dead time in the system. To study the response to neutrons, two Mu2e CRV dicounter prototypes were exposed to a 14.1 MeV neutron beam at Purdue University, West LaFayette, IN. Analysis of the response is discussed and compared to simulation.

Abstract 289 THU-AA-NT-01-3 Contributed Talk - Thursday 1:30 PM - Post Oak

Pulse Shape Discrimination in Liquid Scintillator Neutron Detectors

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Well-characterized mono-energetic neutron sources provide new opportunities for in situ calibration of tonne-scale low-background dark matter detectors, such as XENON1T, LZ, or DARWIN. As the size of these detectors grows beyond the mean free path of fast neutrons in liquid noble elements, double scatters provide the means to accurately reconstruct energy depositions from nuclear recoils within the detector. Any calibration source deployed in these detectors must have low rates because the detectors are not designed for high-rate operation. In order to understand low-rate neutron sources, we have acquired 3" EJ-301 liquid scintillator cells optimized for fast neutron detection. During calibration of direct dark matter detectors, neutron rates of interest are $10\text{-}10^3\ s^{-1}$. Therefore, several methods of pulse shape discrimination have been investigated, with an emphasis on low-energy performance and neutron acceptance. We find that there is only marginal improvement for methods based on Laplace and discrete Fourier transforms over traditional Charge Comparison methods. In collaboration with the Physikalisch-Technische Bundesanstalt (PTB), the absolute efficiency of these detectors was measured using a well-characterized 2.5-MeV neutron beam.

Abstract 290 THU-AA-NT-01-4 Contributed Talk - Thursday 1:30 PM - Post Oak

Characterization of a Deuterium-Deuterium Plasma Fusion Neutron Generator

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Tonne-scale liquid noble element dark matter detectors, such as XENON1T, offer new opportunities for nuclear recoil calibration using double scatters of fast neutrons. As these detectors are not designed for high-rate operation, any neutron source deployed in such a detector must emanate at a low rate, typically <10^4 neutrons/s. We have characterized a deuterium-deuterium plasma fusion neutron generator, manufactured by Gradel-Fusion and optimized for low neutron fluxes. The Bremsstrahlung rate has been measured and found not to significantly increase the background rate of dark matter detectors such as XENON1T. The functional dependence of the neutron flux has been determined to be linear with current and approximately cubic with high voltage for neutron rates of interest. Measurements taken at the Physikalisch-Technische Bundesanstalt (PTB) show the angular emission of neutrons relative to the generator's longitudinal axis to be peaked at 90 degrees. An unfolding of the measured energy spectrum shows a neutron energy spectrum with peaks at 2.31 and 2.61 MeV, and the contribution of the parasitic deuterium-tritium reaction to the emission spectrum has been quantified. Using GEANT4, a Monte Carlo simulation has been developed and matched to the measured energy and emission spectra in order to predict the expected response of XENON1T.

Abstract 199 THU-AR-RE-07-1 Contributed Talk - Thursday 1:30 PM - Bur Oak

High dose self-ion irradiation studies on 14YWT nanostructured ferritic alloys

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Nanostructured ferritic alloys (NFAs) are attractive materials for core components in Generation IV reactors because of their excellent high temperature strength, stability, and radiation damage resistance, thanks to the existence of the nano-oxides (NOs) having the size <5 nm. In this research, 14YWT NFAs, produced in thin-walled tubular form, were irradiated with 3.5 MeV Fe^{2+} ions up to 1100 peak dpa at 450 °C. Their initial and post irradiation microstructures were investigated using transmission electron microscopy (TEM), atom probe tomography (APT) and micro- and nanohardness techniques. It has been found that these alloys show almost zero swelling. Besides, both TEM and APT techniques indicate that the NOs are quite stable under irradiation at 450 °C.

Abstract 311 THU-AR-RE-07-2 Contributed Talk - Thursday 1:30 PM - Bur Oak

Towards local control of doping in YBCO

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Local control of dopant profiles and ordered doping in high T_c superconductors have the potential to greatly increase the transition temperature, T_c [1]. We report on experiments were we used focused electron beams to locally modulate the oxygen dopant concentration in commercial YBCO films (100 nm on $LaAlO_3$). Patterned exposure of YBCO samples to 10 keV electrons and fluences in the 10^20 e-/cm^2 range led to increases of T_c in the ~0.5 K range, consistent with earlier reports from broad beam exposures [2]. We discuss our results in relation to concepts of local oxygen depletion and chain ordering induced by ionizing radiation and outline possible processing paths to implement a form of modulation doping in YBCO by patterning with intense, short excitation pulses (e. g. of MeV ions [3]).

References:

[1] S. A. Wolf and V. Z. Kresin, J. Supercond. Nov. Magn. 25, 165 (2012)

[2] S. K. Tolpygo,J. Y. Lin, M. Gurvitch, S. Y. HOU, J. M. Phillips, Physica C 269, 207 (1996)

[3] P. A. Seidl, et al., J. of Physics: Conference Series 717, 012079 (2016)

This work was performed in part at the Molecular Foundry at Lawrence Berkeley National Laboratory and was supported by the Office of Science, Office of Basic Energy Sciences, Scientific User Facilities Division, of the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

Abstract 5 THU-AR-RE-07-3 Contributed Talk - Thursday 1:30 PM - Bur Oak

Using Luminescent Materials for Space Radiation Sensors

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Ionizing radiation poses a significant challenge for human and/or robotic space missions. Practical sensors based on luminescence will depend heavily upon research investigating the resistance of these materials to ionizing radiation and the ability to anneal or self-heal from damage caused by such radiation. In 1951, Birks and Black showed experimentally that the luminescent efficiency of anthracene bombarded by alpha particles varies with total fluence (N) as $(I/I_0) = 1/(1 + AN)$, where I is the luminescence yield, I_0 is the initial yield, and A is a constant. The half brightness ($N_{1/2}$) is defined as the fluence that reduce the emission light yield to half and is equal to is the inverse of A. Broser and Kallmann developed a similar relationship to the Birks and Black equation for inorganic phosphors irradiated using alpha particles. From 1990 to the present, we found that the Birks and Black relation describes the reduction in light emission yield for every tested luminescent material except lead phosphate glass due to proton irradiation. These results indicate that radiation produced quenching centers compete with emission for absorbed energy. The purpose of this presentation is to present results from research completed in this area over the last few years. Particular emphasis will be placed on recent measurements made with bright luminescent materials, such as europium tetrakis dibenzoylmethide triethylammonium (EuD_4TEA) and doped zinc sulfide. This groundbreaking research can be used to help determine if luminescent materials can be used as a real-time sensor to detect ionizing radiation.

Abstract 18 THU-AR-RE-07-4 Contributed Talk - Thursday 1:30 PM - Bur Oak

FEPE calibration of a HPGe detector using radioactive sphere source

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The calibration of hyper pure germanium detectors is required to calculate the activity of radioactive sources. To determine the activity, the detector full-energy peak (photopeak) efficiency is required. The full-energy peak efficiency gamma-ray HPGe detector for spherical sources is obtained by the use of direct analytical expressions. In addition, the source self-absorption and its effect on the full-energy peak efficiency has been studied

Abstract 432 THU-PR-SP-10-1 Invited Talk - Thursday 1:30 PM - Elm Fork

Improved Nuclear Forensics, Radiochemical Diagnostics, and Nuclear Astrophysics via Total-Cross-Section Measurements at the Los Alamos Neutron Science Center

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Total-cross-section measurements are feasible on a much wider range of radioactive samples than (n, γ) cross-section measurements, and information extracted from the former can be used to set tight constraints on the latter. There are many (n, γ) cross sections of great interest to radiochemical diagnostics, nuclear forensics, and nuclear astrophysics which are beyond the reach of current direct measurement that could be obtained in this way. Our simulations indicate that measurements can be made at the Manuel Lujan Jr. Neutron Scattering Center at the Los Alamos Neutron Science Center (LANSCE) for samples as small as 10 μg. There are at least 40 high-interest nuclides which should be measurable. Exploratory measurements were made during the last LANSCE run cycle and improvements to the apparatus are being made and new test measurements are planned during the current run cycle. I will describe the technique, proof-of-principle simulations, and the first test data.

Abstract 430 THU-PR-SP-10-2 Invited Talk - Thursday 1:30 PM - Elm Fork

First Data with HAGRiD

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The structure of nuclei provides insight into astrophysical reaction rates that are difficult to measure directly. These studies are often performed with transfer reaction and beta-decay measurements. These experiments benefit from particle-gamma coincident measurements providing information beyond that of particle detection alone. The Hybrid Array of Gamma Ray Detectors (HAGRiD) of LaBr3(Ce) scintillators has been designed with this purpose in mind. The design of the array permits it to be coupled with particle detector systems, such as the Oak Ridge Rutgers University Barrel Array (ORRUBA) of silicon detectors and the Versatile Array of Neutron Detectors at Low Energy (VANDLE). It is also designed to operate with the Jet Experiments in Nuclear Structure and Astrophysics (JENSA) advanced target system. HAGRiD's design avoids compromising the charged-particle angular resolution due to compact geometries often used to increase the gamma efficiency in other systems. First experimental data with HAGRiD coupled to VANDLE as well as ORRUBA and JENSA will be presented.

Abstract 431 THU-PR-SP-10-3 Invited Talk - Thursday 1:30 PM - Elm Fork

Development of the HabaNERO detector for astrophysical (,xn) reaction studies at NSCL

S. Ahn[1,2], S. Ayoub[1,3], J.C. Blackmon[4], K. Brandenburg[5], J. Browne[1,3], C.R. Brune[5], D.E. Carter[5], M. Couder[6], E. Deleeuw[1,3], S. Dhakal[5], P. Gastis[7], G. Gilardy[6], R. Giri[5], D.K. Jacobs[5], E. Lamere[6], J. Lighthall[4], T.N. Massey[5], Z. Meisel[5,6], F. Montes[1,2], S. Nikas[7], W.J. Ong[1,3], C.E. Parker[5], G. Perdikakis[7], J. Pereira[1], J.F. Perello[8], A. Richard[5], S. Akhtar[5], H. Schatz[1,2,3], K. Schmidt[1,2], C. Seymour[6], K. Smith[9], A. Voinov[5]

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(α,xn) reactions have been identified as the main production mechanism of Z=38-47 abundances in neutron-rich neutrino winds after core-collapse supernovae. Those conditions entail (n, γ) − (γ, n) equilibrium and temperatures between 3.5 and 5.5 GK in the late phases of the wind. Recent sensi- tivity studies showed that uncertainties in (α,xn) reaction rates directly affect calculated abundances in the neutrino-driven wind models with an impact that is comparable to that from astrophysical uncertainties. Current reaction rate uncertainties are relatively large since little experimental data exists for (α,xn) cross sections involved in the nucleosynthesis calculation.

We have developed the Heavy ion Accelerated Beam induced (Alpha,Neutron) Emission Ratio Observer (HabaNERO) for the measurement of relevant (α,xn) reactions in the neutrino-wind includ- ing 75Ga(α,xn). The HabaNERO is a neutron long counter system which consists of 44 BF3 and 36 3He gas-filled proportional tubes oriented in rings along the beam axis embedded in a polyethylene matrix. The configuration of the tubes in the matrix was optimized to obtain a high average neutron detection efficiency as constant as possible in the neutron range En = 0.1-19.5 MeV that corresponds to the neutron energies of interest.

We have performed the detector commissioning using mono-energetic neutron beams at Edward Accelerator Laboratory, Ohio University, as well as a 75Ga(α,xn) cross section measurement at the National Superconducting Cyclotron Laboratory. The construction, commissioning, and performance of the detector system will be presented. We will also describe how successfully to utilize this system for experiments of (α,xn) reactions using radioactive ion beams.

Abstract 303 THU-PR-SP-10-4 Contributed Talk - Thursday 1:30 PM - Elm Fork

Recent Developments in Deuterated Scintillators for Neutron Measurements at Low-energy Accelerators

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Deuterated liquid organic scintillators, unlike standard scintillators used for detection of few-MeV neutrons, can generate PSD-gated neutron energy spectra without need for time-of-flight (ToF). They are especially appropriate for measurements at high-intensity, low-energy accelerators where a narrow pulsed beam and beam-pulse selection is not available. Even when the latter are available, the loss in effective beam intensity combined with the need for suitable ToF measurements covering a large angular range can be very inefficient. In contrast, as we will show, the arrays of d- benzene scintillators (NE230 ; EJ315) and recently d-xylene (EJ301D) we have fabricated [1] in collaboration with Eljen,Inc. together with related DSP techniques can provide highly efficient, multi-angle neutron energy measurements e.g. for (d,n), (3He,n), (alpha,n) reactions at high-intensity small accelerators without need for ToF. These have also been shown to have important applications related to nuclear security [2]. Additional deuterated scintillators for lower-energy neutron measurements are under development and will be reported.

1) "Deuterated-xylene (xylene-d10; EJ301D):A new, improved deuterated liquid scintillator for neutron energy measurements without time-of-flight", F.D.Becchetti et al., NIM A820 (2016) 112-120; A. Di Fulvio, et al. (in press)

2) "Warhead Verification as Inverse Problem: applications of neutron spectrum unfolding from liquid-scintillator measurements", Chris C.Lawrence et al., J.Appl.Phys.120 (2016) 064501

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Abstract 376 THU-PR-SP-10-5 Invited Talk - Thursday 1:30 PM - Elm Fork

Probing Two- and Three-Nucleon Interactions using Neutron-Neutron Quasi-Free Scattering*

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Investigations of few-nucleon systems using reaction measurements interpreted with ab-initio calculations provide insights about the dynamical consequences of specific features of two- and three-nucleon interactions in the nuclear medium. Thorough assessments of the theoretical treatments of few-nucleon systems require high-precision data of a variety of reaction channels that span a wide range of reaction kinematics. In the tandem laboratory at the Triangle Universities Nuclear Laboratory (TUNL), we have the capability of performing high-accuracy measurements of reactions on few-nucleon systems induced using quasi-monoenergetic unpolarized and polarized neutron beams. In this talk I will present an overview of the neutron beam capabilities at TUNL, and as an example of the application of these capabilities, I will describe our recent measurements of neutron-neutron (**nn**) quasi-free scattering in neutron-deuteron breakup. This work was motivated by two experiments that reported cross-section data that were larger than theoretical predictions by more than 20% [1,2]. These results suggest that the strength of the $^1S_0$ **nn** interaction currently used in few-nucleon calculations should be increased by about 10% [3]. Our preliminary cross-section data will be presented and implications will be discussed.

[1] A. Siepe et al., Phys. Rev. C 65, 034010 (2002).

[2] X.C. Ruan et al., Phys. Rev. C 75, 057001 (2007).

[3] H. Witala and W. Gloeckle, Phys. Rev. C 83, 034004 (2011).

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Abstract 405 THU-AA-NBA-02-1 Invited Talk - Thursday 3:30 PM - West Fork

The Promise of PAA in Security and Forensics

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The International Chamber of Commerce estimates that the global value of counterfeit goods rose to a staggering $1.8 trillion in 2015, up nearly three-fold from the 2008 estimate of $650 billion. The impact of such counterfeiting is widespread in nearly every major sector of the economy: employment, health, transportation, defense, manufacturing, medicine and national security. Nuclear activation analysis using neutrons, charged particles and photons has a long history, with many applications in environmental, cultural and forensic disciplines. In security and forensics; however, especially regarding illicit international trade, non-destructive, high-sensitivity, multi-element probes remains of high interest. Photon Activation Analysis (PAA) has the potential to fulfill this promise of non-destructive materials identification. PAA has the potential to compare known and evidentiary samples, by a technique which may allow downstream testing, and preserve the integrity of original evidence through non-destructive analysis. The speed of throughput, penetrability, non-destructiveness and sensitivity of PAA may enable an important new tool for forensic science, especially for high-value security/forensic samples of interest. In conjunction with low-background gamma spectrometers, PAA is capable of non-destructive ppb detection limits for a broad spectrum of elements. The potential impact of PAA lies in its ability, still untested, to provide near-ideal analysis of evidence that could provide identity, provenance or authenticity without compromising or degrading the evidence.

Abstract 103 THU-AA-NBA-02-2 Contributed Talk - Thursday 3:30 PM - West Fork

Developing a tool for the detection of the relative amount of water in shale cores using Positron Annihilation Lifetime Spectroscopy

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Recent investigation of positron lifetime in Barnett Shale samples has shown a small intensity of positronium (Ps) formation. The samples studied have XRF information on 35 elements and chemical information on total organic carbon (TOC). Previous research has shown that Ps is not formed in dry quartz-rich sandstone, calcite-rich limestone or dolomite-rich rocks, which contain minerals that also constitute a significant part of most shale samples. Recent study of twenty-five different common rock-forming minerals has helped to clarify the Ps contribution of different minerals commonly found in shale and the effect of hydration of some minerals on Ps formation. As a result, a better understanding of how Ps can be formed in the shale samples is now available. It is suggested that the observed variation in Ps intensity in shale is due to variation in water content in the samples. While there is still no information about the possible PS contribution of organic carbon in the sample, it is expected to be small. Development of a novel laboratory tool for the characterization of the amount of water in shale core using Positron Annihilation Lifetime Spectroscopy is discussed.

The REU Physics and Astronomy program at TCU is funded by the National Science Foundation under grant PHY-1358770

Abstract 190 THU-AA-NBA-02-3 Contributed Talk - Thursday 3:30 PM - West Fork

Correction to HPGe Gamma Energy Spectrum for Double and Triple Pile-up Induced by Unsolved Event Pulses

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The method of accurately measuring the radioactive decay constant of a isotope by measuring the decay rate as a function of time requires that both the detector and environment be stable over time periods comparable to the life-time of the isotope. In addition statistical accuracy requires initial counting rates be high but limited by the dead time capability of the data collection system and the detectors double-event resolving time. A High Purity Germanium (HPGe) spectrometer has been built to measure radioactive decay constants to a level of $10^{-4} \sim 10^{-5}$ at a location only 6 meters from the core of the High Flux Isotope Reactor located at Oak Ridge National Laboratory. Such accuracy requires understanding of both the double and triple event pile-up in the observed spectrum. The approach taken is to fit the collected energy spectrum with invariant shapes, that is independent of event rate. By fixing the source-detector geometry and environmental conditions, the invariant shapes are (1) ideal energy spectrum without pile-up and background, (2) the ideal double event pile-up spectrum, (3) the ideal triple event pile-up spectrum, and (4) the stable background spectrum. A method is presented that finds these ideal shapes using the collected data in situ. Taking this approach the HPGe detector photopeak shape in the absence of background and pile-up is presented showing associated structure over a range of 7 orders of magnitude. A physical explanation of shape parameters is discussed.

Abstract 197 THU-AA-NBA-02-4 Contributed Talk - Thursday 3:30 PM - West Fork

Determining Concentrations of Elements with Different Reaction Channels in Photon Activation

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In photon activation, an element may be activated through different nuclear reaction channels and produce different radioisotopes. The radioisotopes follow their own decay schemes and generate characteristic gamma rays. This phenomenon usually is an interference in spectra analysis, but it also offers a theoretical possibility to determine the concentration of a single element through different reaction channels.

This paper aims to realize this possibility. It analyzes the possible origins of the interferences in gamma spectra, compares pros and cons in PAA calculations for each reaction channel, and explains the selection rules why certain reaction channel is the best for instrumental photon activation analysis (IPAA). In experiments, photon activation of both the samples and the references were conducted with electronic LINAC which has a peak energy around 35MeV. Several elements were chosen to validate this feasibility. The calculations of PAA were based on the internal monitor method. The experiments and data analysis have confirmed the advantages of current PAA reaction channel selection, and also indicate that it might be beneficial to calculate the concentration of same elements with different reaction channels on some occasions.

Abstract 258 THU-AA-NBA-02-5 Contributed Talk - Thursday 3:30 PM - West Fork

Medical electron linear accelerators as bremsstrahlung sources for photon activation analysis - a feasibility study

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The analytical application of an electron linear accelerator (LINAC) with 25 MeV maximum electron energy designed for radiotherapy is described. The particular feature of this device is its ability to provide a large bremsstrahlung field with fairly homogenous radial dose distribution. This offers the opportunity of non-invasive analytical studies of large items. Working procedures and analytical results of mineralogical material of environmental interest are presented. In a series of sand samples taken from various locations in Turkey the following elements could be determined quantitatively with satisfactory accuracy and precision: Sr, Ni, Mg, Fe, Zr, Cd, As, Ca, Br, Rb, I, Zn, Pb, Tl, U and Ba. In a first series of analytical experiments the accelerator was used "as is". The analyses described in this paper were carried out after several modifications to improve the performance of the linac, e.g. enhanced effective bremsstrahlung beam power. The PAA results were compared with those obtained by X-ray fluorescence (XRF). Satisfactory agreement was stated. Keywords: Soil, Photon Activation Analysis, HPGe, cLINAC

Abstract 285 THU-AA-NT-02-1 Contributed Talk - Thursday 3:30 PM - Post Oak

Customized Portable Neutron Activation Analysis System to Quantify Manganese (Mn) in Bone In Vivo

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In the US alone, millions of workers, including over 300,000 welders, are at high risk of occupational manganese (Mn) exposure. Those who have been chronically exposed to excessive amount of Mn can develop severe neurological disorders similar, but not identical, to the idiopathic Parkinson's disease. One challenge to identify the health effects of Mn exposure is to find a reliable biomarker for exposure assessment, especially for long-term cumulative exposure. Mn's long biological half-life as well as its relatively high concentration in bone makes bone Mn (BnMn) a potentially valuable biomarker for Mn exposure. Our group has been working on the development of a deuterium-deuterium (D-D)-based neutron generator to

quantify Mn in bone **in vivo**. This system mainly consists of two parts: a compact neutron generator based irradiation system and a high efficiency and resolution high pure germanium detector configuration. Mn-doped hand phantoms were used to calibrate the system. The detection limit was calculated to be about 0.64 mg Mn/g dry bone (ppm) with a radiation dose of 36 mSv to the hand. Approved by Purdue University's IRB, a pilot study was conducted to investigate the association between MnBn and neurological effects. Nineteen volunteers, including some workers who worked with metals, were recruited. **In vivo** neutron activation analysis system was used to quantify MnBn for these subjects. Purdue Pegboard was used to test the subjects' motor function especially movement coordination. We observed significantly higher MnBn in the subjects who reported using metal in hobbies or job compared to those who did not (0.53±0.15 ppm vs. 0.25±0.12 ppm). We also observed marginally significant decrease of Purdue Pegboard test scores with the increase of MnBn among the 19 subjects (p=0.15-0.35). The results indicate that MnBn May be a good biomarker to assess cumulative Mn exposure and for neurotoxicity study on Mn exposure.

Abstract 187 THU-AA-NT-02-2 Contributed Talk - Thursday 3:30 PM - Post Oak

Precision Cross Sections Measurement of ^{56}Fe(n,nγ) at 14.1 MeV using Associated Particle Neutron Generator

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Integral production cross sections for 846.8 keV and 1238.3 keV prompt gamma rays from 14.1 MeV neutrons interactions on ^{56}Fe are reported, using an associated particle neutron generator.

The experimental technique involves: (1) The development of a VME standard DAQ system and a MATLAB parallel cluster for offline signal analysis with full control of data flow; (2) The advantage of the 1.5 nanosecond coincidence timing resolution between the neutron production time and the gamma ray detection time to reject noise; (3) A large 30% solid angle gamma ray coverage by an array of NaI(Tl) detectors. The scattering angle coverage with respect to the neutron beam direction extends from 60 degrees to 120 degrees. The neutron flux is measured using the detected associated alpha-particle from the D-T fusion reaction produced using an associated particle neutron generator.

Present cross section measurements using other techniques with limited timing resolution and solid angle coverage are in agreement at neutron energies lower than 6 MeV. At higher neutron energies reported results can disagree by more than 20%. This more accurate technique presented using an associate particle neutron generator can distinguish between the differences in the reported results based on pulse-mode neutron source and neutron time-of-flight techniques, at higher neutron energies.

Abstract 269 THU-AA-NT-02-3 Contributed Talk - Thursday 3:30 PM - Post Oak

Measurement of D-^{7}Li neutron production in neutron generators using the threshold activation foil technique

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Measurements to determine the absolute D-D and D-^{7}Li neutron production rates with a neutron generator running at 100-200 kV acceleration potential were performed using the threshold activation foil technique. The threshold activation foil technique provides a clear measure of fast neutron flux and combined with a suitable model (e.g., with MCNP), the neutron output. This approach requires little specialized equipment and is used to calibrate real-time neutron detectors and to verify neutron output. We discuss the activation foil measurement technique and describe its use in determining the relative contributions of D-D and D-^{7}Li reactions to the total neutron yield and real-time detector response and compare to theoretical predictions.

Further, we describe an application that could benefit from having a mixed spectrum of neutrons, oil/gas well-logging. The D-^{7}Li reaction produces neutrons with a continuum of energies and a sharp peak around 13.5 MeV for measurement techniques outside of what D-D generators can perform. The ability to perform measurements with D-D neutrons alone, then add D-Li7 neutrons for inelastic carbon and oxygen gamma production presents additional measurement modalities with the same neutron source without the use of tritium. Typically, D-T generators are employed for inelastic scattering applications but have a high regulatory burden from both a radiological aspect (tritium inventory, liability concerns) and are export-controlled as dual-use technology. D-D and D-^{7}Li generators avoid these issues completely.

Abstract 295 THU-AA-NT-02-4 Contributed Talk - Thursday 3:30 PM - Post Oak

Approach to Opportunities for Generation ^{99}Mo-radionuclide by Neutrons with Accelerator Beam

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There is developed and implemented the technology for manufacturing of radionuclides ^{99}Mo as the end product of reaction ^{98}Mo(n, γ)^{99}Mo by irradiation of natural or enriched molybdenum in the channels of the research reactor WWR-M in the Institute of Nuclear Research (Kyiv, Ukraine). The resulting radionuclide - ^{99}Mo - is the parent nucleus for radionuclide technetium (^{99m}Tc), which used in 80% of applications **in-vivo** diagnostics. This corresponds to 30 million tests worldwide each year. The main statistical indicator of this trend in the health care system in the EU and the US is the number of radiological examinations, which are held against year on one thousand patients. In developed countries this figure is an average of 40 - 50, but in Ukraine, according to various estimates, it will not exceed three studies on the year. Nuclear-physical properties of the radionuclide ^{99m}Tc, especially the half-decay in 6 hours, are requiring of the conceptual search for alternative means of the parent radionuclide ^{99}Mo generating with approaching in space and time to the place of use. The most promising area for this search is the use of fast neutrons, which obtained in DD- and TD-generation. The logical further development of this area should be to develop compact (and transportable) settings for specific local use.

In view of the above on emergency needs, opportunities and options for working out of different radio nuclides for practical use - let stop on the genetic pair ^{99}Mo/^{99m}Tc - may be seen the conditions for the implementation of this project at the Institute for Nuclear Research in Kiev. This refers to the use of fast and DD- and DT-neutrons to obtain a radionuclide ^{99m}Tc from decay of parent ^{99}Mo nucleus as a product of nuclear reaction ^{98}Mo(n, γ)^{99}Mo.

First of all, there are the defined positive initial positions:

• an established and proven infrastructure developments couples genetic radionuclides ^{99}Mo/^{99}Tc the reaction ^{98}Mo(n, γ)^{99}Mo using thermal neutrons;

• availability of electrostatic accelerator EGP-10K and neutron generator NGP-11 for generation of the fast DD/DT-neutrons and testing of the technological chain for their use;

• availability of technological structure to manufacture of the neutron-generating Ti/T target;

• availability of appropriate measurement systems for metrology of neutron flux;

• finally, the main thing - the presence of qualified staff with years of experience, which was accumulated in this or a similar topic.

In recent years, this infrastructure was restored for experiments and measurements with fast neutrons with a beam of deuterons on the tandem accelerator EGP-10K. Also, there is a neutron generator of NGP-11. This unique facility in its characteristics - current beam of the accelerated hydrogen ions up to 2 mA and a voltage of 250 kV - provides an intensity of the DT-neutrons flux up to 10^{11} neutrons/sec.

In this paper will be considered the opportunity and the required characteristics and conditions for such techniques using beams of charged particle accelerator to generate by neutrons of ^{99}Mo/^{99m}Tc radioisotopes.

Abstract 371 THU-AA-NT-02-5 Contributed Talk - Thursday 3:30 PM - Post Oak

Application of Library Least Square Method in Neutron Inelastic Scattering and Thermal Capture Analysis

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Neutron inelastic scattering and thermal capture analysis method (NITA) has been applied to on-line measurement of critical parameters of coal. The system and associated data acquisition and processing system were developed. Prompt gamma ray spectra of coal detector system. Fast neutrons (14 MeV) were produced by a portable accelerator based neutron generator via reaction and the prompt gamma ray spectra of 25 different coal samples were recorded by a bismuth-germanate (BGO) gamma detector. These spectra were used samples were recorded to obtain experimental-library of the elements of interest in the coal. The experimentally obtained spectra have been significantly influenced due to the non-linear radiation effects such as pulse-pile up, complex background, and the non-linearity due to the electronics of the to calculate the elemental response of 10 element of interest in the coal samples. The elemental responses were then used in a linear-library least-square (LLLS) approach with an unknown coal sample to find its elemental content. The experiment was performed on an on-line coal analysis system. The precision of this system for ash content and calorific value of coal have reached 1.0% wt, 320 kJ/kg ,respectively which meets the power plants needs.

Abstract 227 THU-AC-TD-04-1 Invited Talk - Thursday 3:30 PM - Trinity

Miniature electron ionization sources integrating carbon nanotube (CNT) field emitters, low temperature co-fired ceramics (LTCC), and microelectromechanical systems (MEMS)

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Carbon nanotubes (CNTs) are attractive field emission electron sources that offer benefits over traditional thermionic filaments in terms of power, lifetime, and current density. Low temperature co-fired ceramics (LTCC) packaging of microelectromechanical systems (MEMS) devices are attractive due to the ability make three dimensional structures with internal cavities. They also have a similar coefficient of thermal expansion to silicon. Our group has pioneered the development of miniature electron ionization sources for mass spectrometry applications by combining MEMS devices with flip-up panels fabricated using the Polysilicon Multi-User MEMS Processes (PolyMUMPs), carbon nanotube (CNT) cold-cathode field emission electron sources, and LTCC scaffolds. In the ion source design, the cathode, grid, and repeller are fabricated via PolyMUMPs. CNTs are grown on the cathode before the panels are rotated into their final position. After

CNT growth, the device is then placed in an LTCC scaffold that provides electrical connections to the MEMS device as well as support for an extraction aperture and spatial filter to complete the ion source. We have developed two different electron ionization sources that are approximately 20 x 7 x 3 mm and incorporate MEMS, LTCC, and CNTs. This talk will describe the design and fabrication of the electron ionization sources, show results of finite element simulations, report on experimental characterization of the energy and angular dispersion of the ion source using a charge transimpedance amplifier ion array detector, and discuss our work incorporating these ion sources into miniature mass spectrometers.

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Abstract 283 THU-AC-TD-04-2 Contributed Talk - Thursday 3:30 PM - Trinity

Ultra-Compact 4 MeV RFQ Accelerator For Human-Portable Applications

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The development of a compact, portable, 600 MHz RFQ accelerator will be discussed. This accelerator receives its RF power from twelve compact planar triodes mounted directly to the RFQ cavity, which itself serves simultaneous functions as an accelerator and as the power-combiner for the final stage of RF power amplification. The recently-demonstrated use of an RFQ accelerator cavity as a power combiner will enable a dramatic reduction in system volume and weight by eliminating a separate power combining cavity. It is only 1.2 m in length, and achieves a mean acceleration gradient of approximately 3 MeV/m.

Developed as part of an initiative to create a portable, high-output neutron imaging platform (>10^{10} n/s), this accelerator will be incorporated into a system having a total size, weight, and time-averaged power draw of 160 L, 80 lbs., and 2 kW, respectively. Its form factor will allow it to be carried, set up, and operated by a two-person team in the field. Furthermore, this platform will be capable of accelerating deuterons to 3.86 MeV and protons to 1.93 MeV, thereby enabling forward-directed neutron production via D-D and p-^{7}Li reactions, respectively. Its sub-3mm beam spot size will enable high-brightness imaging techniques and magnification.

The broader applications for this accelerator are vast in scope, and range from industrial applications such as neutron generators, to ion injection systems for synchrotron sources used in proton therapy, to academic applications, where having a small, table-top accelerator would be an enabling advancement for both university and government research labs.

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Abstract 261 THU-AC-TD-04-3 Contributed Talk - Thursday 3:30 PM - Trinity

Accelerator-based AmBe Source Replacement via Dense Plasma Focus (DPF) Z-Pinch

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A dense plasma focus (DPF) is a compact plasma gun accelerator that can be used to produce neutrons with an AmBe-like spectrum. Ions inside a DPF are accelerated up to multiple MeV through strong potential gradients formed from instabilities during an implosion phase. The DPF can be used to produce high energy helium ions incident onto a beryllium target rather than relying on alphas generated by americium alpha decay. Although the alpha energy spectrum from a DPF is broad, and the alphas emitted from a radiological americium source are monoenergetic (5.5 MeV), the expected neutron spectra are similar. These accelerators could be used to replace radiological AmBe sources for a variety of applications, without the need for recalibration to a new spectrum. The main challenge in this R&D project is to generate sufficient helium beam above 1.8 MeV where the helium-beryllium cross section is significant. To demonstrate feasibility of this concept, we are running initial experiments on a 2 kiloJoule DPF. We are able to model this device with newly-developed kinetic simulations in the particle-in-cell code Large Scale Plasmas (LSP) which can predict neutron yield. Using these predictive simulations, we optimize anode shape and driver for higher yield as well as consistent shot-to-shot yield. Since consistency depends on repeatable formation of instability structures, we are investigating several ways to purposefully seed the instability which drives beam formation. We are also beginning to simulate the breakdown process in order to understand how the initial plasma sheath formation in the gun is affected by fill pressure, cathode plate shape, and insulator gap length. To address issues in timing of sheath formation, we are using a variety of pre-ionization schemes, including a UV flashboard and a spark ion source. We report on measured energy distributions of ions accelerated by the pinch, resulting neutron yields, and efforts to optimize and improve repeatability of pinch performance. This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. This work supported by US DOE/NA-22 Office of Non-proliferation Research and Development. Computing support for this work came from the LLNL Institutional Computing Grand Challenge program.

Abstract 319 THU-AC-TD-04-4 — Contributed Talk - Thursday 3:30 PM - Trinity

A compact MEMS-based ion accelerator

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Multiple Electrostatic Quadrupole Array Linear Accelerators (MEQALACs) provide an opportunity to realize compact radio-frequency (RF) accelerator structures that can deliver very high beam currents. MEQALACs have been previously realized with gap distances of the order of centimeters. Through advances in Micro-Electro-Mechanical Systems (MEMS) fabrication, MEQALACs can now be scaled down to the sub-millimeter regime and batch processed on wafer substrates. In this talk, we discuss the concept of a compact MEMS-based ion accelerator. First results will be presented which show proof-of-concept with accelerator structures formed from printed circuit boards using a 3x3 beamlet arrangement and noble gas ions at 10 keV. The next step is to implement the focusing elements and RF-acceleration stages with silicon wafers, which will also be discussed. The MEMS-based approach will enable a low-cost, highly versatile accelerator covering a wide range of beam energies and currents. Applications include ion-beam analysis, mass spectrometry, materials processing, and at very high beam powers, plasma heating.

Abstract 66 THU-AP-TA-01-1 — Invited Talk - Thursday 3:30 PM - Rio Grande

Accelerated Learning: Undergraduate Research Experiences at the Texas A&M Cyclotron Institute

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The Texas A&M Cyclotron Institute has had an NSF funded Research Experiences for Undergraduates program since 2004. Each summer about a dozen students from across the country join us for the 10 week program. They are each

imbedded in one of the research groups of the CI and given their own research project. While the main focus of their effort is their individual research project we have other activities to broaden their experience. One of those activities has been involvement in a group experiment. Because not every experimental group will run during those 10 weeks and the fact that some of the students are in theory research groups, a group research experience allows everyone to actually be involved in an experiment using the accelerator. As opposed to the REU students very focused experience, Texas &M undergraduates can be involved in research projects at the Cyclotron throughout the year, often for multiple years. This extended exposure enables Texas A&M students to have a learning experience that cannot be duplicated without a local accelerator. The motivation for the REU program was to share this accelerator experience with students who did not have that opportunity at their home institution.

Abstract 38 THU-AP-TA-01-2 Invited Talk - Thursday 3:30 PM - Rio Grande

Physics "in real life": accelerator-based research with undergraduates

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All undergraduates in physics and astronomy should have access to significant research experiences. When given the opportunity to tackle challenging open-ended problems outside the classroom, students build their problem-solving skills in ways that better prepare them for the workplace or future research in graduate school. Accelerator-based research on fundamental nuclear and particle physics can provide myriad opportunities for undergraduate involvement in hardware and software development as well as "big data" analysis. The collaborative nature of large experiments exposes students to scientists of every culture and helps them begin to build their professional network even before they graduate. In this talk I will present an overview of my experiences - the good, the bad, and the ugly - engaging undergraduates in particle and nuclear physics research at the CERN Large Hadron Collider and the Los Alamos Neutron Science Center.

Abstract 145 THU-AP-TA-01-3 Invited Talk - Thursday 3:30 PM - Rio Grande

"The Higgs boson, the Dark Universe, and the Large Hadron Collider"

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The Higgs boson discovery at the Large Hadron Collider (LHC) indicates that the Standard Model of particle physics, in addition to its many other successes, correctly incorporates electroweak symmetry breaking. It may also provide a portal to Dark Sector interactions. The discovery, ongoing searches using the Higgs boson as a doorway to new phenomena, and the LHC, will be described in this overview.

Abstract 219 THU-AP-TA-01-4 Invited Talk - Thursday 3:30 PM - Rio Grande

Accelerating the STEM workforce by violating the Liouville Theorem

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Accelerator physics is not only very unique but also one of the least known area for doing basic and applied sciences for students and faculty interested in STEM related careers. It is often misconceived to solely belonging to nuclear/high energy physics or medical facilities, and industrial settings. The urgency to increase a qualified STEM workforce in the US will require new and bold approaches that must include a diverse pool of talents. Presently, there is a limited number of accelerators in academic settings, and none at any under-represented institutions (e.g., Historically Black Colleges and Universities or Hispanic Serving Institutions). This talk will present two unique educational and research approaches based

on accelerator technologies specifically developed to expose and increase the interest and education of students, faculty and the minority communities as a whole. Additional international efforts to bolster science in Africa via the multi- and inter-disciplinary nature of accelerators will also be discussed.

Abstract 297 THU-AR-RE-08-1 Invited Talk - Thursday 3:30 PM - Bur Oak

Nuclear Science User Facilities Ion Beam Investment Options Workshop

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The Nuclear Science User Facilities (NSUF) was tasked by the U.S. Department of Energy Office of Nuclear Energy (DOE-NE) to hold an Ion Beam Investment Options Workshop (IBIOW) to develop a set of recommendations (i.e., a priority list) for funding domestic ion beam irradiation capabilities that would be available to researchers through the user facility. These capabilities were to be focused on the support of nuclear-energy research, development, and deployment in accordance with the R&D objectives outlines in the Nuclear Energy Roadmap (DOE-NE 2010). The recommendations were intended for use by DOE-NE when faced with decisions about investments in ion beam support, instruments, and facilities such as those that arise during the annual infrastructure funding cycle.

The workshop was held March 22-24, 2016, at the Idaho National Laboratory (INL) Meeting Center in the Energy Innovation Laboratory in Idaho Falls, Idaho. The 33 workshop participants were selected from various sources, i.e., Nuclear Energy University Program/Nuclear Energy Enabling Technology infrastructure applicants, universities with known expertise in nuclear engineering and materials science, and other developed sources.

Because the goal of the workshop was to provide recommendations to DOE-NE, a data-driven process was designed with the assistance of the INL Systems Engineering division. The assessment process started informally but later transitioned to the ThinkTank^{TM} collaboration software tool to support this effort. The workshop participants generated and weighted a list of criteria against which to compare the various ion beam facilities and estimate the need for future investment. The original criteria were generated by NSUF as a starting point for the discussion. Workshop participants then added criteria via email during the lead-up to the workshop. After much discussion at the start of the workshop, a set of 10 criteria were agreed upon by the workshop participants.

In addition to developing and weighting criteria, workshop participants viewed presentations from ion beam users and DOE NE R&D programs and then the 15 ion beam facility representatives. Following the presentations, the workshop participants assessed each ion beam facility against each of the criteria. This exercise was performed individually, although discussions and questions were allowed.

The result was a ranked list of the 15 facilities based on the community opinions generated during the workshop. Two of the top facilities received infrastructure funding in FY 2016 as a result of this effort and two more may become NSUF partners. The official record of the workshop is the NSUF Ion Beam Investment Options Workshop report (INL/EXT-16-38957 June 2016). Recommendations developed during the IBIOW were provided to DOE-NE in a separate report, Supplement **to the NSUF Ion Beam Investment Options Report: Initial Results and Recommendations** (INL/LTD-16-38580 April 2016).

Abstract 141 THU-AR-RE-08-2 Invited Talk - Thursday 3:30 PM - Bur Oak

Technical Aspects of Delivering Simultaneous Dual and Triple Ion Beams to a Target

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The Michigan Ion Beam Laboratory (MIBL) at the University of Michigan in Ann Arbor Michigan, USA, plays a significant role in supporting the mission of the U.S. DOE Office of Nuclear Energy. MIBL is a charter laboratory of the NSUF (National Scientific User Facility) and hosts users worldwide. MIBL has evolved from a accelerator laboratory to a highly versatile facility with 3 accelerators (3 MV Tandem, a 400 kV Ion Implanter and a 1.7 MV Tandem), seven beam lines and 5 target chambers that together, provide unique capabilities to capture the extreme environment experienced by materials in reactor systems. This capability includes simultaneous multiple (dual, triple) ion irradiations, an irradiation accelerated corrosion cell, and soon, in-situ dual beam irradiation in a transmission electron microscope (TEM) for the study of radiation damage coupled with injection of transmutation elements. The two beam lines that will connect to a 300 kV FEI Teknai G2 F30 microscope are expected to be operational by the end of 2017. Multiple simultaneous ion beam experiments involving light and heavy ions are already in progress. This presentation will focus on the new capabilities, some features of conducting high quality ion irradiation experiments, and examples of current and planned experiments.

Abstract 186 THU-AR-RE-08-3 Contributed Talk - Thursday 3:30 PM - Bur Oak

A facility for macroscale ion beam radiation damage studies involving significant sample activation

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This presentation reports on development of the first hotcell and activated materials handling and decay storage system for macroscale ion damage of nuclear materials. Proton-irradiation in the 5-10 MeV energy range with currents of 10-100 μA is a promising avenue for inducing ~few DPA radiation damage levels on macroscale samples in 1-10 days.

The use of charged particles as a surrogate for neutron damage opens the door to perform accelerated studies of radiation damage in reactor-relevant materials with systematic variations of experimental conditions and reduced levels of sample activation.

Protons in the 5-10 MeV energy regime allow irradiation depths of 100-400 μm in structural materials such as steels and zirconium alloys of interest to the nuclear industry. Damage on this scale allows whole-thickness stress corrosion cracking and tensile tests to be performed, giving important information in addition to that obtained through electron microscopy and nano- and micro- hardness measurements.

Nuclear reaction cross sections of many structural materials increase dramatically in the 1-10 MeV range. Empirical evidence shows that, for instance, ^{56}Fe(p,n)^{56}Co is energetically impossible below 5.445 MeV, has a lowest reported cross section of 800 μb at 4.8 MeV, increasing by 3 orders of magnitude to 410 mb at 10.1 MeV. Modelling work implies that prompt radiation from these irradiations will be extremely hazardous (~few Sv/hour at 1 m), furthermore activation during these irradiations will result in decay dose rate of ~10s mSv/hour at 1 m, depending strongly on sample composition and energy. Decay times of several months or years may be required before the sample is suitable for handling without specialist equipment.

A new hotcell, sample handling and storage facility has been developed and installed at the Dalton Cambrian Facility to enable studies resulting in highly activated samples. This paper reports on the facility development and capabilities and preliminary tests of capability. The irradiation facility will build on existing expertise in accelerator-driven radiation damage to deliver on-line current measurement, thermal monitoring and control up to 650 °C and activation measurement.

Aquila Nuclear Engineering Ltd., designed, manufactured and installed the plant/hot cells.

This research was funded by the EPSRC and the DCF project a collaboration between the Nuclear Decommissioning Authority and the University of Manchester.

Abstract 312 THU-PR-SP-04-1 Invited Talk - Thursday 3:30 PM - Elm Fork

Transfer reactions with compact silicon arrays at TRIUMF/ISAC-II

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TIGRESS (TRIUMF-ISAC Gamma-Ray Escape-Suppressed Spectrometer) is an array of 16 HPGe clovers complete with BGO suppressor shields for in-beam spectroscopy. It has been used for a wide variety of studies and in most cases requires the use of ancillary detectors to tag the reactions of interest. For direct transfer reactions, the workhorse of the collaboration is the SHARC (Silicon Highly-segmented Array for Reactions and Coulex) array, which is generally well-suited for most transfer reaction studies. However, when considering compact highly-segmented charged particle silicon arrays, there is no one-size-fit-all configuration. Hence, other silicon detector arrangements have been used as well. In the paper, I will show the results of transfer reaction experiments performed with TIGRESS at TRIUMF/ISAC-II using different Silicon detector configurations. I will also discuss the development of a new compact Silicon tracker to be used when enhanced coverage and resolution around 90^o is needed, an angular range notoriously difficult to study with solid targets. This work is partially funded by DOE grant DE-FG02-93ER40789.

Abstract 359 THU-PR-SP-04-2 Invited Talk - Thursday 3:30 PM - Elm Fork

Recoil Separators for Nuclear Astrophysics

Ulrike Hager

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Radiative capture reactions on hydrogen and helium play an important role in stellar nucleosynthesis and energy generation. However, due to the often small cross sections of the reactions, and because they often involve short-lived nuclides, they are difficult to access experimentally. Measurements in inverse kinematics using recoil separators have nonetheless made it possible to directly measure the cross sections of several important reactions. This talk will give an overview of current and future recoil separators, such at the DRAGON facility at TRIUMF and the future SECAR at MSU, and give examples of recent measurements.

Abstract 79 THU-PR-SP-04-3 Contributed Talk - Thursday 3:30 PM - Elm Fork

Performance of the gamma-ray tracking array GRETINA in experiments with fast beams of rare isotopes

Dirk Weisshaar

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Gamma-ray tracking arrays consist of segmented germanium (Ge) detectors and allow to measure the position and energy deposition of individual gamma-ray interactions within the Ge crystal segments. This sub-segment spatial resolution is obtained by analyzing the rise time and pulse shape of the detector signals as these carry information on the charge collection process within the semiconductor. Tracking algorithms are employed that combine the individual interaction

points, stemming for example from Compton scattering, into gamma-ray events. GRETINA is one of only two Ge detector arrays worldwide utilizing this novel concept. At present, GRETINA consists of thirty-six Ge crystals closely packed in cryostats housing four crystals each. GRETINA is a powerful device for in-beam gamma-ray spectroscopy at intermediate beam energies (~100MeV/u) as its spatial resolution allows for accurate correction of the Doppler shift of the gamma-rays emitted in-flight. This makes GRETINA an excellent gamma-ray spectrometer for experiments with the fast rare-isotope beams available at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University. Coupled to NSCL's S800 magnetic spectrograph, GRETINA is currently running a second experimental campaign. An overview of this setup and results of GRETINA's in-beam performance will be presented as well as some of the scientific accomplishments.

Abstract 320 THU-PR-SP-04-4 Contributed Talk - Thursday 3:30 PM - Elm Fork

Isochronous mass measurements of neutron-deficient ^{58}Ni fragments at CSRe

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Isochronous mass spectrometry (IMS) is a storage ring based technique for accurate mass measurements of short-lived nuclei. Masses of nuclides with half-lives as short as a few ten microseconds and production rates as tiny as a few ions per day can be addressed. In this contribution we describe experimental results obtained at the Experimental Cooler-Storage Ring (CSRe) at the Institute of Modern Physics in Lanzhou, China. The IMS was applied to the neutron-deficient ^{58}Ni fragments. Masses of series of $T_z = -3/2$ short-lived neutron-deficient nuclides including ^{41}Ti, ^{45}Cr, ^{49}Fe and ^{53}Ni were measured with a typical uncertainty of 30 keV. The impact of the new ^{45}Cr mass on the modeling of rp-processes in X-ray bursts were studied [1]. Recently, in other two experimental runs, masses of $T_z = -2$ and $T_z = -1$ ^{58}Ni fragments were measured. The preliminary results, technical challenges and future development plans will be discussed.

[1]X. L. Yan, H. S. Xu, Y. A. Litvinov, Y. H. Zhang, H. Schatz et al., The Astrophysical Journal Letters 766, L8 (2013).

Abstract 176 FRI-PS-PR-01-0 Plenary Talk - Friday 8:00 AM - Rio Grande

Status of the Chinese Circular Electron-Positron Collider and Super Proton-Proton Collider Study

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A circular electron-positron collider (CEPC) was proposed for the Institute of High Energy Physics (IHEP) of the Chinese Academy of Sciences after the Higgs boson was discovered at the Large Hadron Collider (LHC) at CERN. It is expected that the CEPC could be upgraded to a super proton-proton collider (SPPC) in the future. The CEPC would produce electron-positron collisions at a center-of-mass energy of 240 GeV, and proton-proton collisions at 70 TeV. Current studies are in progress on the physics, detector and accelerator. The CEPC-SPPC pre-Conceptual Design Report (CDR) was finished in the first half of 2015. In this talk, we will summarize the status of the study: including the site investigation, the tunnel design, the machine layout, main parameters and optics design, detector, and other key technology developments. Plans for other large circular colliders throughout the world will also be discussed.

Abstract 398 FRI-PS-PR-02-0 Plenary Talk - Friday 8:45 AM - Rio Grande

Commissioning and operating 12 GeV CEBAF

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The Continuous Electron Beam Accelerator Facility (CEBAF) located at the Thomas Jefferson National Accelerator Laboratory (JLAB) has been recently upgraded to deliver continuous electron beams to the experimental users at a maximum energy of 12 GeV, three times the original design energy of 4 GeV. The upgrade also added a fourth experimental end-station to CEBAF. The increased beam energy and additional experimental end-station will enable the next generation of hadronic physics experiments and probes of physics beyond the standard model. This paper will present an overview of the upgrade, highlights from recent beam commissioning results and details on the performance super-conducting radio frequency (SRF) cavities required to achieve the upgraded energy.

Abstract 8 FRI-AC-TD-02-1 Contributed Talk - Friday 10:00 AM - Trinity

LINAC-generated micro-bunched electron beam for tuneable, high-power, THz radiation source.

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Electromagnetic radiation with terahertz (THz) frequencies (from 0.3 to 10 THz (30 um -1mm)) has a wide range of applications including information and communication technologies, biology and medical sciences, non-destructive material diagnostics, and security. In this work we discuss a tuneable source of coherent high-power THz radiation (covering 0.3THz to 0.5THz) driven by a micro-bunched electron beam. We suggest generating the micro-bunch train by using the self-modulation instability (SMI) observed if a picosecond-long electron beam propagates in plasma channel, where the radial component of the wakefield modulates the beam into train of micro-bunches with a period set by the plasma frequency. The period of modulation can be as short as a few femtoseconds and the periodicity of the micro-bunch train can be controlled by changing the plasma wavelength (by changing the plasma density). Using the micro-bunched beam frequency-tuneable coherent THz radiation can be generated if the train propagates above a target with a high-impedance surface. Such a target can be manufactured by machining a shallow periodic grating onto the surface of a metal. The radiation will be generated at a frequency close to the period of beam modulation with the spectral line width proportional to 1/N where N is the number of micro-bunches in the train. In this work the generation of micro-bunch train and coherent THz radiation are analysed numerically and preliminary experimental data will be presented.

Abstract 149 FRI-AC-TD-02-2 Contributed Talk - Friday 10:00 AM - Trinity

Asymmetric Energy Recovery LINAC for compact source of coherent radiation - design and preliminary experimental studies

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To make the light sources compact and energy efficient an energy recovery Superconducting RF LINAC can be used. However introduction of the energy recovery stage may lead to appearance of beam break-up instabilities. We suggest using a dual-axis, asymmetric cavity insuring full overlapping of operating partial modes only. In this case start currents of HOMs are higher, allowing high average currents to be driven without loss.

The project presented aims: to build and test the warm (copper) prototypes of asymmetric superconducting (niobium) cavity cells for Energy Recovery Linac (ERL). At the current stage a copper prototype and aluminium prototype of the cavity are designed and built respectively. The technology developed at this stage will be used to build a superconducting AERL capable of driving THz, EUV and X-ray sources for security, quality control, environment monitoring and lithography. The compactness (to fit inside trailer) and efficiency of the accelerator will enable its transportation and application in modern space-limited environments leading to its acceptance by University and industrial R&D laboratories. The design of the LINAC is possible through combination of superconducting and energy recovery technologies. However, increasing the beam charge and repetition rate, which are required to increase the average current and thus photons' flux, lead (in ERLs) to appearance of beam break-up instabilities. Here we suggest using a dual-axis asymmetric superconducting cavity for a single turn ERL in which the electron beam transported through the system only once. The electrons are accelerated inside the acceleration section, while in the deceleration section most of the electrons energy is extracted and guided through a resonant coupler back into the acceleration section. Both accelerating and decelerating sections of this ERL consist of the same number of cells and tuned insuring overlap of operating partial modes only, forming the cavity operating eigenmode. As a result, the possibility for the multi-pass-regenerative BBU feedback mechanism to be established is reduced, HOMs start currents are increased. The asymmetry of the field distribution, achieved through the tuning of accelerating and decelerating arms, allows us to maximise (>1A) the beam current that the system is able to transport without loss. The two sections are linked by a resonant coupler and there is still field leakage from one section to another but as it will be shown, the effect is relatively small. The theoretical predictions will be compared with the preliminary experimental data and results will be discussed.

Abstract 148 FRI-AC-TD-02-3 Contributed Talk - Friday 10:00 AM - Trinity

UED Beamline Development at the KAERI

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Ultrafast Electron Diffraction UED is a powerful technique for mapping out structural transitions in chemistry and material sciences. We are developing compact accelerator facility at the KAERI (Korea Atomic Energy Research Institute) that can generate sub-100-fs electron bunches with a few pC charges utilizing an S-band co-axial RF photogun. It will serve as a user facility for the MeV UED, the ultrashort radiation pulses, and the time-resolved pump-probe experiments. We have measured the beam emittance by using the quadrupole scan technique with a short drift and without using the thin-lens approximation. We have developed a system consisting of an in-air Faraday cup (FC) and a preamplifier that capable of measuring the low-charge and ultrashort bunches with few MeV energies at 10 fC sensitivity. We have successfully observed diffraction patterns by using a polycrystalline aluminum foil as the sample.

Abstract 307 FRI-AC-TD-02-4 Contributed Talk - Friday 10:00 AM - Trinity

Intense, short ion pulses for pump-probe experiments to access the dynamics of radiation effects in materials

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Intense, short pulses of energetic ions can excite and heat materials uniformly for studies of phase transitions and they enable access to the dynamics of radiation effects. Here, ion pulses that excite materials dynamics can be paired with (ultra-) fast probes in pump-probe experiments. We report results from the Neutralized Drift Compression Experiment (NDCX-II), a pulsed induction accelerator at Berkeley Lab that delivers 2 to 30 ns long pulses of 1.2 MeV helium ions with peak currents of 0.5 A, where about 3x10^10 to 10^11 ions are focused to a few mm^2. We describe the status of the facility and outline the experimental capabilities for pump-probe type experiments to access the dynamics of radiation induced defects and to excite and track structural dynamics and phase transitions in materials for high radiation environments such as fission and future fusion reactors.

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Abstract 332 FRI-AC-TD-02-5 Contributed Talk - Friday 10:00 AM - Trinity

Tailoring keV Ion Beams by Transmission through Insulating Nano-Capillaries

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Charged particles, in particular slow highly charged ions, have shown to be guided through nanocapillaries in various insulating materials by self-organized charge patches on the inner walls of the channels due to initial ion impact [1,2]. The time dependent formation of the guiding potential has been demonstrated by measurements[3]. Recently, it was found that the exiting ion transmission profiles are tailored into rectangular and rhombic shapes, by using nanocapillaries of rhombic and rectangular cross section in mica, respectively [4]. The dominant role of the image force in this shaping effect was revealed [4, 5].

In this work, we report about the angular patterns of transmitted ions and neutrals for 70-keV-Ne^{7+}-incident ions through rhombic capillaries in a muscovite mica membrane. The transmitted Ne^{q+}- ions where analyzed by an electric field to be q=7 and separated from neutrals. It can be seen that the profile of the transmitted ions is of rectangular shape, while a banana-like shape appears for the neutrals. Trajectory simulations are performed by taking the image force [4], the Coulomb repulsive force from the deposited charge [5], as well as scattering from capillary walls into account. It shows good agreement with the data. More details on how the deposited - and image-charge deflects and shapes the ionic portion of the beam, differently from the neutral part, will be presented on the conference. The separation of the ions from neutrals and their very different behaviors together with simulations gives us further insight in the roles of guiding and scattering in transmission through nano-capillaries.

[1] N. Stolterfoht **et al**, Phys. Rev. Lett. 88, (2002) 133201

[2] K. Schiessl **et al**, Phys. Rev. A 72, (2005) 062902

[3] P. Skog **et al**, Phys. Rev. Lett. 101, (2008) 223202

[4] HQ. Zhang **et al**, Phys. Rev. Lett., 108 (2012) 193202

[5] HQ. Zhang **et al**, Phys. Rev. A 86, (2012) 022901

Abstract 13 FRI-AC-TD-02-6 Invited Talk - Friday 10:00 AM - Trinity

Corrector magnets for the C-beta and eRHIC projects and hadron facilities*

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The C-beta project[1] is a prototype electron accelerator for the proposed eRHIC project[2]. The electron accelerator is based on the Energy Recovery Linac (ERL) and the Fixed Field Alternating Gradient (FFAG) principles. The FFAG arcs of the accelerator are comprised of one focusing and one defocusing quadrupoles which are designed as Halbach-type permanent magnet quadrupoles[3]. We propose window frame electro-magnets surrounding the Halbach magnets to be used as normal and skew dipoles correctors and quadrupole correctors. We will present results from OPERA-3D calculations of the effect of these corrector magnets on the magnetic field of the main quadrupole magnets and the results will be compared with experimental measurements. We will also discuss applications of permanent magnets with such correctors for hadron beam facilities.

*Work supported by the U.S. Department of Energy under contract DE- SC0012704.

[1] http://arxiv.org/abs/1504.00588

[2] http://arxiv.org/ftp/arxiv/papers/1409/1409.1633.pdf

K. Halbach, "Design of permanent multipole magnets with oriented rare earth cobalt material" , Nucl. Instrum. Meth. 169 (1980) pp. 1-10

Abstract 12 FRI-AP-IA-02-1 Contributed Talk - Friday 10:00 AM - Bur Oak

Ultra-compact RF accelerator for industrial applications

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In this paper we present a novel design of an electron accelerating structure that has a significantly reduced transverse size. A typical RF linear accelerator is an iris-loaded copper waveguide. We propose to use a dielectric (ceramic) lined waveguide as the accelerating structure. Because of the high dielectric constant (~10 or 20), the transverse size of the structure is reduced by an order of magnitude (down to a pencil size for X-band). The structure is defined by the ceramic cylinder, with a copper layer sputtered on the outside, so the overall weight of the structure is dramatically reduced. Finally, due to the reduction of the transverse size there is a huge reduction in the bulk of the shielding required around the accelerator in industrial setting. We will discuss the issues of charging and multipactor in ceramic structures and approaches to mitigate these effects.

Abstract 45 FRI-AP-IA-02-2 Contributed Talk - Friday 10:00 AM - Bur Oak

Ion-Beam Sputtering System using Meter-Scale Ribbon-Beam Ion Source

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Albion Systems has developed a radical new ion source capable of generating ribbon ion beams of high current and low divergence over a wide range of energies, but optimized for about 1 to 5 keV, and high ion currents of up to 1A per meter breadth; breadths of several meters are possible. The current density is an order of magnitude higher than existing systems. Uniformity is intrinsically good and can be controlled in real-time. There are a number of interesting applications possible.

Albion Systems presents here a system capable of performing linear PVD processing by DC ion beam sputtering, suitable for reactive or high-vacuum deposition of dielectrics, metals, or magnetic materials onto conductive, insulating, or magnetic

substrates. This equipment can be installed on a single vacuum flange for mounting on a variety of vacuum systems, but linear flow systems are preferred. The ion source and the sputter target are mounted in close proximity to each other and to the target. The ion source is a radical new design with inbuilt uniformity control. A key feature is that this system is scalable from small lab equipment (say 100mm breadth) to large scale industrial processing of several meters breadth; the cross section of the equipment does not change.

The ion beam impinges on the sputter target at the optimum angle and energy, in a field-free region, and in high vacuum. This combination of conditions is unique. Beam incidence at 70 degrees to the normal maximizes sputter yield and minimizes target heating. Free choice of beam energy permits higher thermal efficiency. High vacuum means that the deposited atoms comprising the film retain the full energy of several eV that was produced in the sputtering process. The geometry further permits extremely simple and efficient jetting of reactive gases such as oxygen for the production of oxide films. The single broad-beam source has far higher current density and a far more compact layout than existing ion-beam sputtering systems, and can be installed in linear processing systems in a similar manner to linear magnetrons.

For certain films, e.g. aluminum oxide, the throughput can be 6 to 12 times greater than rates by other techniques. For others, e.g. magnetic films, there are additional advantages in more efficient use of the target material. Some specific throughputs and film details will be presented.

Abstract 315 FRI-AP-IA-02-3 Invited Talk - Friday 10:00 AM - Bur Oak

G-Values of Wood Polysaccharides and Lignin

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Ionizing radiation has been studied as a pretreatment process for a wood based bio refinery. Ionizing radiation treatment of wood chips has been shown to increase the amount of hemicellulose and lignin removed from the chips by hot water extraction. Ionizing radiation treatment has also been shown to decrease the molecular mass of cellulose. To try and better understand the process of wood irradiation, g-values were determined for cellulose, micro crystalline cellulose, xylan, organosolv lignin, cottonwood, glucose and amylopectin. Also studied was the "protective effect" that lignin has on cellulose and hemicellulose in wood.

Abstract 329 FRI-AP-IA-02-4 Invited Talk - Friday 10:00 AM - Bur Oak

Electron Beam Synthesis of Novel Fabrics for Extraction of Uranium from Seawater

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The world's oceans contain more than 4.5 billion tons of uranium; however access to this resource is limited by the ability to extract uranium from seawater efficiently. Lacing fabric substrates with chemical functionalities specific for uranium adsorption is one approach to meeting this challenge. Advanced adsorbent materials are being developed using polymeric substrates with high chemical stability, excellent degradation resistance and improved mechanical properties. Fabrics include polypropylene, nylon and advanced Winged Fibers from Allasso industries featuring extremely high surface areas

for improved grafting density. Using 10-32 MeV electron beam linear accelerator, the various fabrics have been irradiated over a wide range of dose rates, total doses and temperatures.

Innovative vinyl phosphate and oxalate exhibiting high distribution coefficients and selectivity for uranium along with excellent potential for free radical polymerization have been utilized in the functionalization of the fabric substrates. Azo compounds with higher selectivity have also been utilized but have required the use of a grafted chemical precursor. Attachment of the chelating adsorbent or its precursor to the substrate polymer is maximized through the optimization of numerous variables including monomer concentration, dose rate, total dose, solvent and temperature.

Following irradiation, fabrics are washed, dried and weighed to determine the degree of grafting (DoG). The presence of monomer in the fabrics is verified using numerous experimental techniques including X-ray photoelectron spectroscopy (XPS), scanning electron microscopy-energy dispersive spectroscopy (SEM-EDS), and Fourier-transform infrared spectroscopy-attenuated total reflectance (FTIR-ATR). Zeta potential measurements allow for surface charge measurements to confirm the negative charge required for uranium chelation. The fabric capacity for uranium extraction was tested by rotating samples for 7 days in a rotary agitator with actual seawater spiked with 0.2 or 1.0 mg·L-1 uranium. The fraction of uranium in the solution which was removed due to uptake on the fabrics was found to rise with increasing DoG at both uranium concentrations. SEM-EDS measurements are used to map the distribution of adsorbed uranium on the polymeric fibers.

Current work includes optimization of grafting density in addition to material characterization on the molecular level and analysis of the sample microstructure. Further testing in synthetic seawater will be conducted to compare the selectivity of each adsorbent fabric towards uranium compared to that of other species, in addition to determining the loading and adsorption rates under various conditions such as pH, temperature and salt concentration. Experiments in real seawater will consider effects of organics on the adsorbent materials, test for durability and reusability and determine kinetics and efficiency of the uranium extraction as a function of degradation.

Abstract 67 FRI-AP-IA-02-5 Invited Talk - Friday 10:00 AM - Bur Oak

X-ray scattering in the shielding of industrial irradiation facilities

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When high-energy X-ray photons impinge on thick shields, most of the incident energy is absorbed in the shielding material, but some of it scatters sideward or backward into the source room. This effect is important in facilities that have openings in the shields to allow the passage of products through the irradiation zone or mazes to provide access to this zone for operating personnel. Multiple scattering events can reduce the energies of the photons and the intensities of the emerging radiation to comply with applicable safety regulations. Basic equations and examples are presented to show how these scattering effects can be evaluated in the design of new irradiation facilities.

Abstract 69 FRI-PR-AMP-05-1 Invited Talk - Friday 10:00 AM - Post Oak

Universal empirical fit to recently compiled total L x-ray production cross sections by proton impact

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In a compilation covering data of L x-ray production cross sections (XRPCS) by proton impact up to 2013 [1], the data base for total XRPCS was increased by 94% as compared to those published earlier [2-4]. Using these data, a universal curve of the cross sections as a function of the projectile to electron target velocities ratio, $\mathbf{v}_1/\mathbf{v}_{2L}$, is presented. This curve has a

maximum at $\mathbf{v}_1/\mathbf{v}_{2L} = 1$, as predicted by all theoretical models, in particular with ECUSAR [5]. Excluding ^{18}Ar as target atom, it was found that, for $24 \leq \mathbf{Z}_2 \leq 95$, all the Data/Fit ratios (around 5 500 points) have an average value of 1.01, with a standard deviation of 32%. This proves that, in spite of the wide variety of experimental methods used to measure XRPCS, there is an excellent coherence within the database and its agreement with the proposed empirical fit.

References

[1] J. Miranda and G. Lapicki, ADNDT 100 (2014) 651-780.

[2] T.L. Hardt and R.L. Watson, ADNDT 17 (1976) 107.

[3] R.S. Sokhi and D. Crampton, ADNDT 30 (1984) 49.

[4] I. Orlic, C.H. Show and S.M. Tang, ADNDT 56 (1994) 1511.

[5] G.Lapicki, Nucl.Instrum.Methods B 189 (2002) 8.

Abstract 51 FRI-PR-AMP-05-2 Invited Talk - Friday 10:00 AM - Post Oak

Ion beam induced K x-rays of light elements with downsized high resolution x-ray spectrometer for use with focused ion beams

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We constructed downsized wavelength dispersive x-ray spectrometer based on the flat diffraction crystal and CCD detector for use with focused ion beams. The spectrometer can be used to measure x-rays in the energy range between 1.2 and 8.4 keV emplying ADP, PET or LiF(110) diffraction crystals. The x-ray energy resolution E/ΔE(FWHM) of 1850 and of 1580 has been achieved on Al and Si Kα induced by 2 MeV proton beams focused below 10 μm. This energy resolution enables study of secondary effects in K x-ray spectra of light elements, as well as measurements of clearly resolved L-shell spectra of medium Z elements and M-shell spectra from heavy elements. We describe the spectrometer and demonstrate its use on the study of high resolution Si and S K x-ray spectra obtained from selected compounds after excitation with 2 MeV protons and 20 MeV carbon ions focused to micrometer size. The results were compared with the existing data obtained by ions (protons and carbon), electron and photon induced ionization mechanisms.

Abstract 287 FRI-PR-AMP-05-3 Invited Talk - Friday 10:00 AM - Post Oak

Large Solid Angle Detector Array for PIXE Biological Applications

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The continued development of silicon drift detectors (SDD) during recent years facilitates the design of cost effective large solid angle X-ray detector arrays. Several concepts have been implemented, the optimized arrangement of individual SDDs

or multi-element arrays on a single chip with central hole. Geometric constrains limit the achievable solid angle to about 1.2 sr for one hemisphere.

Since a large portion of PIXE applications deals with thin samples, additional X-ray detectors can be installed in forward geometry, thus enabling even higher solid angles. However, a larger number of detectors requires additional pulse processing and suitable data acquisition systems, especially for microprobes.

We report on the design of the X-ray detector array at the new microprobe beam line of the ion beam laboratory at the University of North Texas. It combines a planar four element single chip SDD with central hole and a SDD array of four individual SDDs. The signals from all eight detectors are processed with a compact multi-channel digital data acquisition system.

The main applications of the large solid angle detector array are the ultra-sensitive PIXE elemental mapping and high throughput measurements of metal concentrations in thin biological specimens.

Abstract 378 FRI-PR-AMP-05-4 Contributed Talk - Friday 10:00 AM - Post Oak

An amplitude filter to autonomously remove noise

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The background continuum in a spectrum is generally removed by a mathematical filtering technique. In this presentation we explain the design of an amplitude filter that can retain peak amplitudes and autonomously remove noise by measuring the standard deviation of the noise and deriving a background threshold for the filter based on the fact that peak amplitudes are outliers to the noise and the 3-sigma rule for outliers. Few applications of the proposed amplitude filter are demonstrated by comparison with synthetic data set and a PIXE data set. Details of the filter are presented.

Abstract 58 FRI-PR-AMP-05-5 Contributed Talk - Friday 10:00 AM - Post Oak

Correlation between geometry, melanin content, and elemental levels in single hair fibres assessed by in-air PIXE and MeV TOF-SIMS

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Elements play a critical role in the physiological processes of the human body. Hair is often used to assess and monitor elemental levels since it bio-accumulates elements, provides a historical overview of elemental status depending on length, and is easy to sample and store. However, various internal and external factors may affect hair elemental levels. The aim of this pilot study is to assess the effect of hair geometry, specifically hair curl, and melanin content on elemental levels in single scalp hair fibres. In-air proton-induced X-ray emission (PIXE) will be used to assess bulk elemental levels in non-sectioned hair, whilst time of flight MeV secondary ion mass spectrometry (MeV SIMS) will be used to differentiate between endogenous and exogenous elemental content in longitudinally sectioned hair fibres. Hair elemental data,

complemented with geometrical and melanin concentration data will be analysed statistically and discussed. In conclusion, this study will add to the current knowledge base on confounding factors affecting outcome in hair elemental analysis.

Abstract 396 FRI-PR-AMP-05-6 Contributed Talk - Friday 10:00 AM - Post Oak

Ion-beam analytical methods for trace elements studies in bio-medical hard tissues

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Various Ion-beam analytical methods have been developed and applied to determine the elemental composition of calcified tissues (teeth and bones). Fluorine was determined by prompt gamma activation analysis through the $^{19}F(p, \gamma)^{16}O$ reaction. Carbon was measured by activation analysis with He-3 ions, and the technique of Proton-Induced X--ray Emission (PIXE) was applied to simultaneously determine Ca, P, and trace elements in well-documented teeth. Dental hard tissues: enamel, dentine, cementum, and their junctions, as well as different parts of the same tissue, were examined separately. Furthermore, using a Proton Microprobe, we measured the surface distribution of F and other elements on and around carious lesions on the enamel. The depth profiles of F, and other elements, were also measured right up to the amelodentin junction. The advantages of Ion-beam analytical method for studying trace elements in biomedical hard tissues or other hard substances would be discussed.

Abstract 424 FRI-PR-SP-06-1 Invited Talk - Friday 10:00 AM - Elm Fork

An electron-ion collider at Brookhaven National Lab from the experimenter's perspective

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The 2015 Nuclear Physics Long Range Plan has endorsed the realization of an electron-ion collider as the next large construction project in the US after FRIB. The machine is planned to be high luminosity, exceeding 10^33 cm^{-2}s^{-1}, with highly polarized electron and proton/light ion beams, wide kinematic reach and ability to collide a variety of hadron species from p to Pb. The facility and associated experiment(s) will address fundamental questions in QCD. A detector designed to efficiently register and identify deep inelastic electron scattering (DIS) processes in a wide range of center-of-mass energies available with the new collider is one of the key elements of such an upgrade. Equally important are polarimeters and other auxiliary detectors to measure particles that scatter very close to the beam line. The progress on the detector and interaction region design work will be shown, and the simulation results presented.

Abstract 15 FRI-PR-SP-06-2 Contributed Talk - Friday 10:00 AM - Elm Fork

Core power prediction for Nigeria research reactor-1 (NIRR-1) using measurements of dose-rate and neutron flux

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This study presents the results of Nigeria Research Reactor-1 (NIRR-1) power estimation using dose-rate and neutron flux. In this work, measurements of the dose rate and neutron flux were made for three different power levels (6.2 kW, 15.5 kW and 31 kW) at two stages: firstly, after the reactor start-up (0min). Secondly, at 105 minutes elapsed time of the reactor operation. The data obtained from the measurements were used to monitor the in-core reactor power. The values of the dose-rate obtained at 0 min (at 6.2 kW, 15.5 kW and 31 kW power levels) are 6.1 mSv/h, 15.0 mSv/h, and 34.2 mSv/h respectively and the corresponding estimated power are 6.8kW, 15.4 kW and 33.8 kW respectively. The values of the dose-rate obtained at 105 minutes (at 6.2 kW, 15.5 kW and 31 kW power level) are 7.8 mSv/h, 21.5 mSv/h and 37.4 mSv/h respectively, and the corresponding estimated power are 6.3 kW, 17.8 kW and 31.1 kW. The values of the of the thermal flux obtained at 0 min (at 6.2 kW, 15.5 kW and 31 kW power levels) are $2.07x10^{11}$ $ncm^{-2}s^{-1}$, $5.53x10^{11}$ $ncm^{-2}s^{-1}$ and $1.13x10^{12}$ $ncm^{-2}s^{-1}$ respectively and the corresponding predicted power are 6.2 kW, 16.6 kW and 33.9 kW . For 105 minutes, the values of the thermal flux (at 6.2 kW, 15.5 kW and 31 kW power levels) are $2.06x10^{11}$ $ncm^{-2}s^{-1}$, $5.70x10^{11}$ $ncm^{-2}s^{-1}$and $1.16x10^{12}$ $ncm^{-2}s^{-1}$ and the corresponding predicted power are 6.2 kW, 17.1 kW and 34.8 kW respectively. The result obtained at full power (31 kW) in this work compared well with 29.5 kW calculated from fitting formula based on the stimulation test data during initial startup as reported in the Nigeria Research Reactor -1 Safety Analysis Report and the rated thermal power by the manufacturer.

Abstract 263 FRI-PR-SP-06-3 Contributed Talk - Friday 10:00 AM - Elm Fork

High Power Positron Beams as a Novel Branch of the Experimental Basis for Apply and Fundamental Physics.

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It is now becoming clear that future applications of the readily available form of antimatter (especially in the form of power high-brightness positron beams) will lead to the excellent progress in a new avenue of inquiries of fundamental physics and,consequently,it will be useful for development of experimental basis for apply physics.Especially,this is concerning with clue and stubborn machines as high velocity macroparticles accelerator for shock waves research ,trims the size of heavy ion accelerator for ICF,coherent gamma-rays generator for giant resonance investigation and any others(See ref.1-3).In this report we will reveal that physical basis for such machines for both fundamental and apply physics quite probably can result from to-day technology.Also,the reporter will discuss"scientific road map"for the critical research and technology limitations of the basic principles.

1.V.V.Gorev

"Physical Ballistics and problem of macroparticle accelerator,based on electrostatic ablation". In:International Conference"IV Zababakhon Scientific Talks"(Snezinsk-95,Russia)1995,p.37

2.V.V.Gorev

"Power positron beams for HEDP". In: The 18th International Pulse Power Conference.Chicago(USA),2011,p.69

V.V.Gorev

"Power positron beams as a new branch of beaming" In:The 20th International Conference on high power particle beams.Washington DC(USA),2014., p.78

p

Abstract 310 FRI-PR-SP-06-4 Contributed Talk - Friday 10:00 AM - Elm Fork

Extended Stability of Gamma Spectrometer by Precise Environmental Control at the High Flux Isotope Reactor

Jordan M Heim[1], Jonathan Nistor[1], David Koltick[2]

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Utilization of nuclear reactors is becoming more prevalent for neutrino-based physics experiments, due to the very high production of anti-neutrinos. The stringent procedures necessitated at these facilities typically precludes user control of the local environment and can complicate accessibility to user-implemented installations. The performance of an automated, remotely accessible High Purity Germanium (HPGe) spectrometer system, featuring a highly stable, environmentally-controlled detector enclosure, is examined over its first 9 months of operation at the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL).

A thermally insulated platform, housing two HPGe detectors is located 6 meters from HFIR's core, immediately beyond the reactor pool wall. The enclosure is maintained at 10.0 ± 0.03 degrees C as part of an effort to achieve long-term, high-resolution spectral stability. Additional measures include continuous purging of the enclosure with ultra-high purity nitrogen and conditioning of the electrical service supplied to the DAQ electronics. The inert blanket of N_2 gas prevents the condensation of moisture on the detector pre-amplifier, which can degrade energy resolution, and flushes unstable gasses such as ^{40}Ar and ^{222}Ra from the system. Custom software provides control, logging, and remote alert generation, as well as remote real-time monitoring of system parameters. The temperature of the detectors, system components, enclosure, and ambient have been recorded every 60 seconds, along with the absolute pressure and relative humidity within the enclosure. Additional logged parameters include the local magnetic field and electrical line voltage and frequency characteristics. This has yielded 10^5 measurements for each logged parameter, with little human intervention and nearly no unplanned down-time.

Evaluation of the long-term stability of the detector gain, gamma-ray centroid, and energy resolution as a function of time and environmental parameters are presented. The detector performance has shown significant improvement under tightly controlled environmental conditions. Additionally, the fine-grained environmental data indicate the areas in which to focus future efforts to improve spectrometer stability even further.

Abstract 331 FRI-PR-SP-06-5 Contributed Talk - Friday 10:00 AM - Elm Fork

Background suppression achieved at the HFIR for a HPGe gamma spectrometer

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Both research and commercial nuclear reactors are becoming a rich environment for neutrino-based physics experiments, due to the incredible abundance of reactor-generated anti-neutrinos. One experimental challenge in these environments however, is the very high neutron and gamma backgrounds associated with nuclear reactions. An ongoing study is being conducted at the High Flux Isotope Reactor (HFIR) located at Oak Ridge National Laboratory (ORNL). Implementation of a long-term, stable High Purity Germanium (HPGe) spectrometer 6 meters from the core of the High Flux Isotope Reactor necessitates particular design considerations in order to address the significant gamma and neutron backgrounds. Moreover, the challenge lies not only in the sizeable background levels, but the effects of neutron activation of the spectrometer and shield materials. Long-term stability without sacrificing sensitivity requires careful consideration and selection of the

materials used for construction, so as to eliminate the gradual accumulation of activation products and their associated radiation products.

The spectrometer installation utilizes over 5.5 tons of bulk lead to shield against the gamma background, as well as a grated copper/aluminum liner to suppress the Pb fluorescence. The shielded spectrometer is encased by several inches of borated polyethylene for moderation of fast neutrons and absorption of thermal neutrons.

Typical background levels near the reactor pool wall, 6 meters from the core, are on the order of 10^4 Hz with the reactor ON, as seen by an unshielded 3" HPGe coaxial detector. During reactor outages, background levels are on the order of hundreds of counts per second. The shielded spectrometer has seen suppression of the backgrounds by a factor of approximately 3 x 10^3, yielding typical count rates of a few hertz. Notably, the observed reactor-on and reactor-off background levels have been measured and shown to remain stable to 0.05 Hz over a period of 9 months.

Abstract 98 Regular Poster - Poster Sessions

Acceptance tests for AMS radiocarbon measurements at iThemba LABS, Gauteng, South Africa

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IThemba LABS Gauteng, National Research Foundation, PRIVATE BAG 11, WITS GAUTENG 2050, South Africa

Recently low- and high-energy Accelerator Mass Spectrometer (AMS) detection systems were commissioned on the 6 MV tandem accelerator at iThemba LABS, Gauteng, South Africa. The tandem had previously been configured for ion beam analysis (IBA) and nuclear structure experiments. With the AMS development, measurement of the radionuclides ^{14}C, ^{10}Be and ^{26}Al measurements are possible, while there are long term plans to extend to other radionuclides that may also be relevant to research in the region. The three radionuclides will be measured in chronological dating applications ranging from commercial to academic research. Academic research will include assessments of landscape evolution in Southern Africa and the continent, and other related fields, through techniques known as exposure and burial dating. We hope to contribute to the knowledge of species evolution by dating, in partnership with local and international colleagues, caves and fossil sites in the region and the continent. We, therefore, are hoping to contribute in providing answers to the many scientific questions including African human origins.

The AMS upgrades necessitated various improvements, in particular to the vacuum system. This was achieved, by investment in cryo-pumps and reducing the tank pressure below the level at which our IBA colleagues operate. The lower tank pressure improved, and solved many of our problems, including a leak into the gas stripper. Additional effort was made to further dry the tank insulation gas to reduce conditioning events responsible for ion burst from the terminal stripper. There has been a significant decrease in these events, particularly during cooler weather conditions. These improvements also resulted in the reduction in the nitrogen background which was a disqualifying issue in radiocarbon measurements. This allowed the resolution of ^{14}C from ^{14}N background in the multi delta E ionisation chamber using 100 nm SiN detector window. The 1270 mm radius analysing magnet was scaled to detect ions in the 3+ state, with the tandem operated at 3 MV resulting in an ion energy of less than 1 MeV/nucleon. The first sensible spectra allowed us circumnavigate many persistent issues, improving the setup for the ^{14}C AMS measurements, such that we now have moved towards production runs for ^{14}C, with a precision better than 1% modern carbon, and our current blank levels correspond to 12 half lives of ^{14}C or ~68000 years. We may claim better precision once we have performed inter-laboratory comparisons. We have also started tests on ^{26}Al, while a foilstack that will be used in ^{10}Be detection has also been prepared.

Abstract 110 Regular Poster - Poster Sessions

The new ion beam facility based on a HVE Tandetron accelerator at MTA Atomki in Debrecen, Hungary

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In the middle of 2015 the installation of a 2 MV Tandetron accelerator was completed by High Voltage Engineering Europa (HVE) in Atomki. Nuclear physics using particle accelerators was one of the main research fields since the establishment of the Institute in 1954, nevertheless the application of particle accelerators in ion beam analysis and in other research fields like atomic physics and nuclear astrophysics was also continuously growing. The aim of the installation of the new accelerator was to satisfy this high demand which was not possible by the existing rather old machines. In this work, we present the ion beam facility including the building, the machine, and the existing beam lines and we report on the first performance of the whole facility including the calibration of the terminal voltage using several resonances of the $^{27}Al(p,\gamma)^{28}Si$, and one resonance of the $^{13}C(p,\gamma)^{14}N$ reaction.

Abstract 111 — Regular Poster - Poster Sessions

Newly developed 3.5 MV electron accelerator system for X-ray dosimetry applications

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High Voltage Engineering Europa (HVE) has designed a 3.5 MV Singletron™ electron accelerator system designed for X-ray dosimetry applications. With a footprint of approx. 10.4 m × 6.9 m, this particle accelerator system is capable of delivering on a custom designed high-Z target electron beam current intensities in a range of <1 pA up to 1 mA. An extreme dynamic range of electron beam current (10^9) is required to produce X-ray intensities between 0.1 μSv/hr and 100 Sv/hr. The terminal voltage reproducibility is specified 0.2% or better while the terminal voltage accuracy is better than 1%. The terminal voltage range is between 0.2 and 3.5 MV. The e-beam is scanned over the high-Z target to achieve in forward direction (within +/- 15° from normal incidence) a radiation uniformity in the horizontal plane of 5% or better. The machine software allows self-tuning and optimization of electron current intensity for time-efficient product manufacturing via predefined recipes. Special emphasis has been paid to radiation protection measures related to human safety and hardware safety.

Abstract 366 — Regular Poster - Poster Sessions

The Brookhaven National Lab Accelerator Test Facility: Facilities and Opportunities

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The Brookhaven National Lab. Accelerator Test Facility (ATF) is a DOE Office of Science User Facility, funded through the Accelerator Stewardship program. The ATF provides access to its 80 MeV electron accelerator facility, synchronized to its unique high-power, 10μm CO_2 laser, for both proprietary and non-proprietary industry-based research.

Facility users have access to synchronized solid-state laser systems, state-of-the-art electron beam and laser diagnostics, and on-site scientific, mechanical, electrical and vacuum engineering support. The mission of the ATF is to provide free* access to its facilities, for both international and domestic users.

***full cost recovery is in effect for proprietary research.**

Abstract 362 Regular Poster - Poster Sessions

Synthesis of Nickel Nanoclusters Embedded within Indium Phosphide via Low Energy Ion Implantation

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Transition metal (Cr, Fe, Co) doped Indium Phosphide (InP) has been studied for more than a number of decades for optoelectronics applications. Interesting magnetic properties are reported in Fe implanted InP single crystals with the formation of magnetic clusters after annealing the ion implanted InP samples. Formation of metal nanoclusters distributed at different depths surrounded by high quality InP lattice structures can contribute to the development of interesting spintronics devices. In this research we will demonstrate the formation of nickel (Ni) nanoclusters in single crystal InP. Initially, 50 keV energetic Ni ions are implanted with a fluence of 2×10^{15} cm^{-2} resulting in deposition at a depth of ~30 nm from the surface. Then 50 keV H ions are implanted with a fluence of 1.5×10^{16} cm^{-2} to create defect centers at a depth ~ 400 nm. The samples have been annealed at the temperature range of 500 - 700 °C. Upon annealing the hydrogen will typically vacate the lattice and leave behind nanocavities which will act as trapping sites for gettering the Ni atoms. We hypothesize that this will yield a ferromagnetic Ni layer in a region of the InP lattice that has minimal damages. This presentation will report the synthesis of Ni nanoclusters in InP and the correlation between the structural and observed magnetic properties.

Abstract 238 Regular Poster - Poster Sessions

A new method for the AMS measurement of the abundance of all U isotopes in environmental and structural samples.

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The measurement of the isotopic composition of U in environmental and structural samples is a very powerful tool to gain information about its origin in different matrices (natural, weapon grade, reactor burnup, fall out). AMS has proven to be characterized by an unparalleled sensitivity for rare isotopes detection via single ion counting, while current measurements in Faraday cups are used for normalization to abundant isotopes. At the Center for Isotopic Research on the Cultural and Environmental heritage (CIRCE) we routinely perform U AMS measurements. The relative abundances of the different isotopes may vary by several orders of magnitude - depending on the origin of the material analyzed - as well as the absolute yields both for rare and abundant isotopes - depending on the absolute elemental concentration. In particular, ^{235}U yield is often too low for accurate current measurements, but at the same time too intense for particle detection. We have performed an attempt to exploit the low isotopic abundance of ^{17}O in order to reduce the yield of ^{235}U measurements down to values compatible to the maximum count rate of the final detector. Actually, as U oxides ($^{xxx}U^{16}O^-$) are normally used for injection into the accelerator, $^{235}U^{17}O^-$ injection will result in a ^{235}U beam intensity 2.6 10^3 times lower with respect to normal ^{16}O molecules injection. This will provide a means to measure ^{235}U abundance, provided a negligible UOH^- molecules production takes place at the sputtering ion source. Similar considerations hold for ^{234}U detection using $^{234}U^{18}O$ injection.

In the present paper preliminary results about the application of the above described novel methodology will be presented. In particular, $^{234,235,236}U/^{238}U$ isotopic ratios and absolute concentrations, using a ^{233}U spike for normalization, have been measured using several samples of different isotopic composition and relative U concentrations, showing that UOH contamination is low enough and does not affect in any case the isotopic ratio results.

Abstract 267 Regular Poster - Poster Sessions

Evaluating the Distribution of Fluorine in Siliceous Archaeological Materials using μ-PIGE: A Contribution to the Development of Fluorine Diffusion Dating

Stewart Bragg Younger-Mertz[1,4], Quentin Lemasson[2], Laurent Pichon[2], Brice Moignard[2], Lee Bement[3], Robert Brooks[3], Amanda Regnier[3], Susan Vehik[4], Richard Drass[3], Claire Pacheco[2]

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The purpose of this work is to further develop the method of Fluorine Diffusion Dating (FDD) for determining the age of siliceous archaeological materials. Siliceous materials, such as chert and flint, are the most abundant materials in the archaeological record. However, archaeologists generally rely on stylistic and regional typologies to determine the age of siliceous archaeological materials, typically without the aid of instrumental methods of analysis. Thermoluminescence dating occasionally is used to determine the age of stone artifacts, however, this method is only applicable to artifacts that were heat-treated in the past. At the present, there are no universally applicable instrumental methods for determining the age of stone artifacts used in standard archaeological practice. The possibility of using the chemical affinity of silicon and fluorine as a chemical clock for determining the age of siliceous materials has not yet entered the mainstream archaeological consciousness. In general, fluorine is not a common constituent of chert/flint material. However, due to the trace concentrations of fluorine present in all natural ground waters throughout the world, fluorine gradually penetrates newly exposed surfaces (for example, surfaces present on chipped-stone tools) due to the chemical affinity of silicon and fluorine. Over time, fluorine continues to diffuse into the interior of artifacts, creating an elemental fluorine profile that can be measured using nuclear reaction analysis (NRA) and used to determine the relative age of artifacts. Future developments in FDD could eventually turn this powerful relative dating technique into an absolute dating method once the kinetics of fluorine diffusion in siliceous rocks is well understood, and the myriad environmental variables are identified and taken into account. Despite having the potential to revolutionize archaeological research and dramatically increase our understanding of prehistoric communities, very little time and resources have been invested in FDD, and virtually no research has been conducted to further develop the method since the turn of the century. One aspect of FDD that has not been extensively investigated is the homogeneity/heterogeneity of the distribution of fluorine across individual artifacts, a very important factor for evaluating the legitimacy of this technique for chronological studies. Herein, the distribution of fluorine has been evaluated for 20 chert (microcrystalline quartz) artifacts using elemental fluorine maps generated using μ-PIGE. The artifacts are associated with multiple time periods, ranging from 10,500 BC to the present, thereby representing the full range of human occupation in the state of Oklahoma. The results demonstrate that fluorine is homogenously distributed across individual artifacts, thereby providing additional support for the validity of Fluorine Diffusion Dating. The results warrant continued research for the development of FDD, and great efforts should be made to communicate the potential of FDD to archaeologists. A significant amount of time and resources should be invested in interdisciplinary collaborations been physicists, chemists, and archaeologists so that FDD can be transformed from an esoteric dating technique into a standard method used in mainstream archaeological practice.

Abstract 276 Regular Poster - Poster Sessions

Determining the Provenance of Native Copper Artifacts from the Spiro Mounds Archaeological Site, LeFlore County, Oklahoma: Preliminary Studies using Particle-Induced X-ray Emission Spectrometry

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This research is focused on determining the provenance of native copper artifacts recovered from the Spiro Mounds archaeological site in LeFlore County, Oklahoma (ca. 900-1450 AD). Archaeologists have speculated about the geological origins of these prestigious copper artifacts for decades. The presence of these artifacts in Oklahoma is intriguing since the nearest geological sources of native copper (for example, the Great Lakes region and Southern Appalachia) are hundreds of miles away, suggesting the presence of extensive and well-developed exchange networks. However, the directionality of these exchange networks is unclear due to the uncertainty of the geological source(s) of these native copper artifacts. In this project, PIXE was used to determine the minor and trace element constituents of native copper artifacts from Spiro, as well as raw specimens of native copper from known geological sources, in an effort to identify the source(s) of these artifacts. This study represents a first step in the construction of a PIXE-derived elemental database for native copper materials that will be used to determine the provenance of native copper artifacts with the aid of multivariate statistics.

Abstract 354 Regular Poster - Poster Sessions

Preliminary results of electrostatic doublet designed and built at UNT

Jack Elliot Manuel[1], Szabolcs Z Szilasi[1], Dustin Phillips[2], Alexander D Dymnikov[2], Tilo Reinert[1], Bibhudutta Rout[1], Gary A Glass[1]

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An electrostatic doublet microprobe has been designed and constructed at the Ion Beam Lab of the University of North Texas. The doublet is capable of focusing of up to 6.5 MeV ions independent of mass to nearly a 1 x 1 μm spot size. The lens system consists of four co-linear gold coated sections of quartz rod and orthogonal ground planes in a precision machined frame. Results of Cu calibration grid scans using μPIXE, grid shadow measurements, and spot size determination are presented.

Abstract 71 Regular Poster - Poster Sessions

Saturation Yields for Fluorine-18 (^{18}F) on a Siemens Eclipse Cyclotron with Grid Foils

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Grid stripper foils are proposed for the formation of multi-beams and to improve beam dynamics in isochronous cyclotrons with dual beam capabilities [1]. The experiments performed on the 11-MeV Siemens Eclipse Cyclotron shows the feasibility of these stripper grid foils. The grid foil is a carbon foil with a 10 microns thickness and laser drilled holes. The experiments involved the irradiation of Oxygen-18 enriched water for the production of the medical isotope Fluorine-18. The results show the transmission factor of the grid stripper foils with a 10 microns thickness is relatively the same as that of the standard 5 microns regular flat polycrystalline graphite foil with no holes, approximately 85%. The tests were conducted over several months and exhibit stable data for a saturation yield of grid foils which possess holes with a diameter of 0.5 mm shown increasing of saturation of yield medical isotope 18F on the 15-20% in compare with regular stripper based on the polycrystalline graphite foils. Reference: 1. S. Korenev. "Formation of multiple proton beams using particle accelerator and stripper elements", Patent USA No 9,215,7

Abstract 174 Regular Poster - Poster Sessions

Measurement of ionizing radiation intensity from a 60MeV electron accelerator using a PIN diode

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When we use an electron accelerator to generate either neutrons or X-rays using a converter, a mixed field of neutrons, X-rays, electrons, and even positrons from pair production reactions are also produced, making hard to eliminate unwanted contribution. To measure total ionizing radiation intensity from all the various reactions from all directions and sources, a cube shape PIN diode is specially developed to provide equal weighting factors for all directions. The measured current represents total carrier generation in the detector volume regardless their original reactions and recombination losses, an ideal reflection of charge collections in a Si semiconductor. Demonstration of the directional independency and calibration methods along with resultant data are presented. It will be a good graduate teaching tool that can show how the total contributions from all various reactions and recombinations are accomodated experimentally by a single diode without complicated reaction analyses.

Abstract 108 Regular Poster - Poster Sessions

HVE model SO110 sputter ion source: Technical improvements and performance

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The cesium sputter ion source model SO-110 is developed and manufactured by High Voltage Engineering Europa B.V. (HVE). It is designed for fulfilling the stringent requirements of the AMS systems. This includes a storage capacity of up to 200 samples, allowing prolonged unattended measurements. The ion source accepts solid as well as gaseous CO_2 samples. The samples are stored in a separate vacuum chamber and transported upon use into the hot environment of the ion source, thereby minimizing cross-talk between samples. The very open construction of the source head optimizes pumping of evaporated sample material, minimizing source memory. The geometry of the source head shapes the internal electrical field yielding a small sputter spot on the target with almost no halo, thus minimizing background for measurement of volatile samples. All cleaning and servicing of the source head can be done on a workbench, and no alignment is necessary after reinsertion into the housing.

The latest model SO-110C was introduced by HVE for the continuous production of high source output currents. High ion beam output currents require high sputter voltages and high cesium inflow. For this, sputter voltage has been extended to 12 kV. As a result, the SO-110C produced $^{27}Al^-$ outputs up to 2 μA, $^{9}BeO^-$ outputs of more than 30 μA and $^{12}C^-$ beams above 400 μA. Disposable parts are easier accessible compared to predecessor models, simplifying service. The ionizer is placed in a fitting ensuring precise alignment independent of operator skills, making the source operation reproducible after servicing.

Abstract 268 Regular Poster - Poster Sessions

Increased AMS ion source efficiency and ion currents by modifying SNICS cathode material and geometry

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A series of tests have been conducted at the Wood Hole Oceanographic Institution's NOSAMS facility to investigate increasing ^{14}C AMS efficiency and maximizing C^- beam currents, by modifying sample well geometry and sample cathode material. Tests for maximizing C^- beam current were performed on Aluminum cathodes that were prepared by drilling sample wells with various diameters, ranging from 0.50 mm to 1.50 mm, and depths ranging from 1.3 mm to 4.3 mm. Cathodes with sample well diameters of 1 mm and 0.75 mm had marginally better C^- current, while current for the larger sample wells was lower but more consistent. Depth tests showed an obvious difference in ion beam currents, with shallow wells significantly outperforming the deeper wells. Efficiency tests were first conducted on Al cathodes to find an optimum diameter. Cathodes with φ of 0.50 mm, 0.75 mm, and 1.00 mm were drilled to a depth of 2.3 mm, hand pressed with approximately 250 mg of Alfa Aesar graphite, and then run to exhaustion. The best performers were cathodes with φ of 0.75 mm, measuring as much as 16.5% efficiency compared to 13% from the 0.50 mm and 15% from the 1.00 mm cathodes. Cathodes with Zn inserts were then prepared in the same manner, with a 0.75 mm diameter, and showed further improvement, increasing the ion source efficiency to as much as 27%.

Abstract 249 | Regular Poster - Poster Sessions

Software accelerator stability control during long-running experiments

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The Center for Isotopic Research on the Cultural and Environmental heritage (CIRCE) operates since 2005 a 3 MV NEC 9SDH-2 tandem accelerator. The accelerator is used both to perform AMS measurements for high precision ^{14}C dating as well as for other rare isotopes (^{26}Al, ^{129}I, ^{236}U), on one side, and to deliver intense beams of different stable and radioactive (^{7}Be) isotopes on solid and gas targets for nuclear astrophysics and applied nuclear physics purposes, on the other side. Almost all of the above applications demand stable machine running for several days and minimum maintenance interruptions. In spite of the good stable operation conditions normally achieved, sometimes periodic instabilities of the terminal voltage, especially above ~2.5 MV, take place, which can affect the quality of acquired data. For this reason, the software used for machine conditioning purposes after tank openings has been modified to monitor, during long lasting experiments, the terminal ripple and other accelerator parameters (loss, vacuum, spark counter, etc.). The software is based on a state machine LabVIEW 2011 environment which interacts with the ACCELNET NEC database and, when necessary, performs automatically voltage cycles aiming at re-establishing stable operation conditions while setting in pause the running experiment. In the present paper we describe the voltage cycles performed and the results obtained in the tests performed.

Abstract 318 | Regular Poster - Poster Sessions

CLIC Drive Beam Gun Simulation and Evaluation

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The Compact Linear Collider (CLIC) is a proposed future electron-positron collider, designed to perform collisions at energies from 0.5 to 5 TeV, with a nominal design optimized for 3 TeV. CLIC generates three beams: the drive beam, the main electron beam and the positron beam. The drive beam is a high current electron beam accelerated in an S-band linac and then decelerated in 12 GHz structures to generate the RF to accelerate the colliding electron and positron beams. The drive beam employs a high current thermionic DC electron gun. The primary challenge for this gun is the required high average current and its implications on the Anode-Cathode spacing, surface electric fields, power on the grid voltage. The design employs an off the shelf robust, commercially available 3 cm2 cathode. Operating parameters within the cathode

specification limits were defined and beam parameters such as energy, current, emittance optimized. The mechanical integrity of the gun body as designed by CERN was reviewed and improvements recommended. This electron gun can also be used on high average power electron linacs for various industrial use.

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Abstract 338 Regular Poster - Poster Sessions

A new concept of High Voltage Power Supply System for the RF Amplifier of the CR Debuncher at FAIR

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A sophisticated power supply was developed, built and commissioned to operate the RF system of the Collector Ring, a storage ring of the future FAIR (Facility for Antiproton and Ion Research) complex. It supplies the power amplifier of RF: a total of 5 power supplies (anode, control grid, two screen grids, two filaments) and a controlled load.

The RF system will be operated in continuous wave (CW), with RF voltages of up to 2kV, and pulsed, with RF voltages up to 40kV. The power supply performs a fast switching between them (<200 µs) of the control grid voltage (700V versus 200V) and the anode voltage (6kV - 10A versus 25kV - 100A). Also the requirements for voltage stability, to be assured in every condition, are challenge: down to ±0.1% of set point.

The realized anode PS uses a modular design: many smart units precisely control their output voltage; PSM modulation fixes the overall output through IGBTs. A mix of centralized and distributed control strategy applies. The final PS is a high voltage - high energy switching converter, with reduced ripple, wide dynamic and integrated arc protection.

This paper presents the solution designed and the results obtained on the first prototype.

Abstract 157 Regular Poster - Poster Sessions

Application of rippled silicon templates produced by ion beam erosion for the self-organization of plasmonic Ga nanoparticles

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Gallium nanoparticles (NPs) have attracted a lot of interest in the last years for biosensing and photonic devices [1], since they provide a wide tunability of the plasmon resonance energy, from the UV to the IR spectral region. This resonance is controlled by the size, shape, interdistance and the refractive index of the surrounding media [2]. Ga NPs produced by evaporation typically exhibit a hemispherical geometry and, above a critical size, they start to merge and coarsen. However, this process depends to a large extent on the substrate properties such as the roughness, the polarity, the surface defects, etc.

In this work we analyse the effect of a nanopatterned substrate on the size and order of Ga NPs deposited by thermal evaporation. Rippled Si substrates were produced at room temperature by ion beam erosion using a 20 keV Xe^{+} beam extracted from an ion implanter. The ions impinged on the single-crystal Si (100) at 60º with respect to the surface normal, reaching a total fluence of 10^{18} cm^{-2}. At this grazing incidence the sputtering and mass transport induced by the ions result in a ripple pattern with a characteristic wavelength [3]. We analyse the morphology of the NPs by atomic force and scanning electron microscopies in both rippled and flat Si substrates. We demonstrate a clear improvement of the ordering for those sizes matching the wavelength of the pattern. This enhancement is explained by the preferential coalescence along the ripple pattern, which also results in a change of the plasmon resonance, measured by spectroscopic ellipsometry. Our results show that the absorption of the NPs can be tuned with a proper pattern wavelength, even for very small ripple heights.

[1] A. GarcÍa MarÍn et al., Biosens. Bioelectron. 74, 1069 (2015)

[2] K.A. Willets et al., Annu. Rev. Phys. Chem. 58, 267 (2007)

[3] J. Muñoz-GarcÍa et al., Mater. Sci. Eng. R-Rep. 86, 1 (2014)

Abstract 256 Regular Poster - Poster Sessions

Low keV energy ionization and electron capture of carbon monoxide by proton impact

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We have investigated the total relative ionization and dissociative electron capture cross section for protons on collisions within the energy range of 3 - 10 keV. Time of flight mass spectroscopy was employed in the measurements of ionization as well as the total ionic fragments of the molecular target leading to CO^{+}, O^{+} and C^{+}. Relative total ionization and total cross sections of ionic fragments were obtained and the contribution of the different channels was evaluated. Ionization was found to be the main reaction channel as expected, while the O^{+} fragment ions are found to be the dominant dissociative ionization fragments followed by C^{+} and O^{+} .

Abstract 236 Regular Poster - Poster Sessions

Detail β-decay study of ^{77}Ga based on statistically significant γγ-coincidences

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Starting from isobarically purified ^{77}Cu beam in Holifield Radioactive Ion Beam facility of Oak Ridge National Lab, we have studied the β-decay of the A=77 decay chain. In our measurement, data on γ-ray emission following β-decay, including βγ and γγ coincidences were obtained. Gated γγ spectra were analyzed to identify the statistically significant coincidence and decay schemes have been developed for all five nuclei within the decay chain. Presented here is the case for ^{77}Ga β-decay. In our purposed decay scheme, we have established 35 excited state and incorporated 55 γ-rays on it. We modified the placement of several gamma rays, identified some new γ-rays that feed on it and established many new higher lying Energy levels.

Abstract 159 Regular Poster - Poster Sessions

Defect induced magnetism in SiC

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Defect-induced magnetism is attracting intensive research interest. It not only challenges the traditional opinions about magnetism, but also has some potential applications in spin-electronics. SiC is a new candidate for the investigation of defect-induced ferromagnetism after graphitic materials and oxides due to its high material purity and crystalline quality [1, 2]. In this contribution, we made a comprehensive investigation on the structural and magnetic properties of ion implanted and neutron irradiated SiC sample. In combination with X-ray absorption spectroscopy and first-principles calculations, we try to understand the mechanism in a microscopic picture.

For neon or xenon ion implanted SiC, we identify a multi-magnetic-phase nature [3]. The magnetization of SiC can be decomposed into paramagnetic, superparamagnetic and ferromagnetic contributions. The ferromagnetic contribution persists well above room temperature and exhibits a pronounced magnetic anisotropy. By combining X-ray magnetic circular dichroism and first-principles calculations, we clarify that p-electrons of the nearest-neighbor carbon atoms around divacancies are mainly responsible for the long-range ferromagnetic coupling [4]. Thus, we provide a correlation between the collective magnetic phenomena and the specific electrons/orbitals.

With the aim to verify if a sample containing defects through its bulk volume can persist ferromagnetic coupling, we applied neutron irradiation to introduce defects into SiC [5]. Besides a weak ferromagnetic contribution, we observe a strong paramagnetism, scaling up with the neutron fluence. The ferromagnetic contribution only occurs in a narrow fluence window or after annealing. We speculate that defect-induced ferromagnetism rather locally appears in particular regions, like surface/interface/grain boundaries.

[1] L. Li, et al., **Appl. Phys. Lett.** 98, 222508 (2011).

[2] Y. Wang, et al., **Phys. Rev. B** 90, 214435 (2014).

[3] Y. Wang, et al., **Phys. Rev. B** 89, 014417 (2014).

[4] Y. Wang, et al., **Scientific Reports**, 5, 8999 (2015).

[5] Y. Wang, et al., **Phys. Rev. B** 92, 174409 (2015).

Abstract 272 Regular Poster - Poster Sessions

Synthesis of Ternary Transition Metal Silicide Nano-systems using low energy multiple ion implantation

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Ternary intermetallic compounds (e.g. Fe, Co, Ni, Mn, Ga, Si, etc.) can form interesting structures such as Heusler alloys. Due to their unique crystallographic structures and chemical phases, the Heusler alloys exhibit remarkable magnetic, electronic, and thermal properties. By reducing the alloy film dimensions to nanoscale, significant improvements have been achieved in the thermo-electric, spintronic, and ferromagnetic shape memory properties of these alloys. Various Heusler alloy thin films, involving Fe, Co and Si, have been grown as bulk materials or as thin films on the surfaces of GaAs and MgO surfaces using sputtering and chemical vapor deposition techniques. However, there is not much research done on the synthesis of self-assembled ternary metal-silicides or Heusler alloy nano-systems. Recently, because of proven industrial technology based on silicon, there is a greater desire for the growth of the Heusler compounds on the Si surfaces. Among the well-known synthesis techniques to form or to modify the composition and physical properties of thin films, low energy ion implantation (< 50 keV) is shown to be a very powerful technique.

In this project, we have implanted consecutively Fe and Co ions, both at 50 keV into commercially available Si nanowires grown on Si wafer to synthesize ternary metal silicide nano-systems. Since the ion implantation is a dynamic process, simulation models incorporating dynamic changes in the target layer compositions are used in this study to predict redistribution of the implanted ions and target atoms. The simulation shows that for 50 keV Fe ion implanted in Si, the Fe concentration is seen to be saturated at a fluence of 1.2×10^{17} atoms/cm^2 and higher. Then, subsequent simulation are performed taking the output data from the first simulation to find the saturation fluence for the Co implanted in to the Fe-Si nanowire system. It shows that the saturation fluence for the Co ions is the same as that for Fe ions. The results of these simulations show that for Si nanowires, having a diameter of 200 nm and irradiated with 50 keV Fe and Co, will facilitate formation of a ternary alloy nanowire system of a diameter ~110 nm due to the sputtering caused by the implanted ions. The implanted samples were annealed at different temperatures (500 - 800 °C) to form various phases of Co-Fe-Si ternary-silicide alloy nano-systems. We will report the structural and chemical composition of these ternary alloy nanostructures.

Abstract 241 Regular Poster - Poster Sessions

Eight Detector Setup for 11B(p,α)2α Reaction

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At low proton energies the 11B(p,α)2α reaction produces three alpha particles through two reaction channels. Unfortunately, there is an overlap in energies between α_1-particles of the second reaction channel and the α_{12}-particles from the decay of beryllium atoms. Previously published cross-section data has errors up to 30% and inconsistencies up to 50%. These cross sections were for the most part based on arbitrary convention.

One possible method to more accurately measure the reaction's cross section is to use a multi-detector setup with eight detectors. The eight detectors are placed in a cube-corner-arrangement.

Using the conservation of linear momentum and the conservation of mass-energy the angles and energies of each alpha particle group can be estimated. Recording the alpha particles in coincidence with the multi-detector setup assists in separating the individual alpha spectra. The detector signals are processed with a new digital data acquisition system that records energy, time and also the detector identification number.

Abstract 35 Regular Poster - Poster Sessions

New beam scansion device for active Beam Delivery System (BDS) in proton therapy

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In the frame work of a new proton therapy project, called AMIDERHA [1], a new Beam Delivery System (BDS) has been studied. It is characterized by an active scanning system which irradiates target with a pencil beam. The features of this project was the using of an accelerator Linac with variable final energies and the Robotized Patient Positioning System instead of the traditional gantry. The active BDS of AMIDERHA then does not include a gantry and a pencil beam scansion system with a relatively long Source to Axis Distance (SAD) could be used. In this contribution, the idea of using a unique new device capable of both horizontal and vertical beam scansion for the AMIDERHA active BDS will be presented and discussed. Furthermore, a preliminary design of that device with some simulations will also be shown.

[1] AMIDERHA project: PON02_00675- Progetto PON02_005763329762

Abstract 90 Regular Poster - Poster Sessions

A low-cost charged-particle beam profiler based on cerium-doped silica fibers

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A charged-particle beam profiler called the Universal Beam Monitor (UniBEaM) has been developed by D-Pace Inc. (Canada) and the Albert Einstein Center for Fundamental Physics, Laboratory for High Energy Physics, University of Bern (Switzerland). The device is based on passing 50 to 600 micron cerium-doped optical fibers through a particle beam. Visible scintillation light from the sensor fibers is transmitted to the UniBEaM controller over distances of tens to hundreds of meters with minimal signal loss, and with no susceptibility to electromagnetic fields. Vertical and horizontal beam scans can be obtained independently or simultaneously. The inline device has an insertion length of only 70mm in the beam direction and comes complete with an aluminum vacuum chamber. Accompanying software plots the beam intensity distribution in both the horizontal and vertical planes, and calculates the beam location and integrated profile area, which correlates well with total beam current for radially symmetric beams. UniBEaM is suited to beams with kinetic energies from keV to GeV. Test data is presented for H^- beams at 25keV in the μA to mA current range, and 18MeV in the 50pA to 10μA current range. Maximum absorbed power density of the optical fiber before thermal damage is discussed in relation to dE/dx energy deposition as a function of particle type and kinetic energy, and the thermal radiative emission characteristics of the fibers. Maximum absorbed power density was found to be comparable to conventional tungsten wire scanners, in the range of 0.5 to 1 W/mm^2. These properties, in conjunction with the low cost of the device (~10K USD), make UniBEaM well suited for a wide variety of beamlines including discovery science applications, radio-pharmaceutical

production, hadron therapy, industrial ion beam applications including ion implantation, industrial electron beam applications, ion source testing and many other applications.

Abstract 377 Regular Poster - Poster Sessions

Proton Beam Induced UV Emission Spectroscopy Analysis to Identify Chemical Signatures in Biological Samples

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Particle Induced X-ray Emission Spectroscopy (PIXE) along with Rutherford Backscattering Spectrometry (RBS) have been used to accurately quantify trace elemental concentrations in biological samples. In many cases, it is very helpful to know the specific chemical state of these trace elements. Proton induced UV luminescence spectroscopy (PUVS) used in conjunction with PIXE tool for identifying the chemical compounds, particularly in biological samples. In this presentation, we will be discussing our efforts to develop PUVS utilizing high energy proton beams from a NEC 9SH single-ended 3 MV Pelletron accelerator. The experimental setup of UV spectrometer and collection of the UV signal will be discussed. The test samples will be irradiated in vacuum chamber with proton beams of energies ranging from 2 MeV to 3 MeV and with fluencies ranging from 1×10^{13} to 1×10^{15} atoms/cm^2. The UV emitted by the samples will be focused into a HR2000 Ocean Optics spectrometer located outside by two fused silica plano-convex lenses and fiber optic connected from the vacuum chamber to determine the UV production efficiency of specific chemical compounds. The intensity of specific UV wavelengths will enable the identification of chemical compounds in the sample. It is anticipated that the PUVS combined with PIXE spectroscopy will provide elemental concentrations as well as chemical state information of the elements in the samples. The experimental set-up and preliminary data for production and detection of UV due to irradiation with high energy proton beams towards identification of compounds in the test samples will be presented.

Abstract 87 Regular Poster - Poster Sessions

Electron bremsstrahlung doubly differential cross sections: measurements in Au at the maximum energy transfer point

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Doubly differential cross sections (DDCSs) for electron bremsstrahlung in Au were measured at the maximum energy transfer point, using the low-energy beam line of the São Paulo Microtron. Three HPGe detectors were placed at the angles $\boldsymbol{\theta}$=35°, 90° and 131° with respect to the incident beam direction. Thin-target bremsstrahlung spectra from Au ($(29.9(6)\times10^{15}$ atoms/cm^2) were collected for 11 electron energies $\mathbf{E_0}$ between 20 and 100 keV.

To describe the tip region of the emitted spectrum, we propose an analytical function $\mathbf{B(E_0,\sigma_0;W)}$ which is composed by the product of the well-known dependence with the inverse of the photon energy ($\mathbf{W^{-1}}$) [1,2] and a complementary error function that considers the Gaussian energy spread ($\boldsymbol{\sigma_0}$) of the incident electron beam. The numerical convolution of the response function of each detector, calculated as detailed in [3], with $\mathbf{B(E_0,\sigma_0;W)}$ allows to model the measured spectra in terms of only three amplitude parameters which represent the number of emitted photons at $\boldsymbol{\kappa}$=**W/E**$_0$=1 for each angle. These parameters together with the electron beam average energy $\mathbf{E_0}$ and spread $\boldsymbol{\sigma_0}$ were fitted simultaneusly to the three

collected spectra in each irradiation run by a least-square procedure. The other quantities needed to evaluate absolutely the DDCS were determined as reported in [4].

The obtained DDCSs have relative uncertainties around 3%. These results (a total of 33 values, 11 for each angle) were compared with the theoretical calculations of Seltzer and Berger [1], and Kissel et al. [2]. The ratios experiment/theory are between 0.96 and 1.05 for $\boldsymbol{\theta}=35^o$ and 90^o, which increases the initial precision of ~10% estimated by Seltzer and Berger [1] in their tabulation to 5% according to our data. The ratios corresponding to 131^o lie in the interval 0.90-1.09 and suggest that theory overestimates the DDCS for energies below 30 keV. In 25 of the 33 cases the measured DDCS contains the theoretical value within one standard deviation.

References:

[1] S. M. Seltzer and M. J. Berger, **At. Data Nucl. Data Tables 35** (1986) 345.

[2] L. Kissel, C. A. Quarles and R. H. Pratt, **At. Data Nucl. Data Tables 28** (1983) 381.

[3] J. A. GarcÍa-Alvarez et al., **Radiat. Phys. Chem. 121** (2016) 23.

[4] J. A. GarcÍa-Alvarez et al., **J. Phys. Conf. Ser**. **635** (2015) 052084.

Abstract 93 Regular Poster - Poster Sessions

Multiple ionization of Ar by He^+ and He^{+2} ions at intermediat and high energies

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The multiple ionization is a complex many-electron process where direct ionization and post-collisional electron emission contribute to the final charge state. For certain targets, such as He or Ne, electron-electron correlation and changes in the target potential may be decisive at intermediate energies [1]. For other targets as Kr or Xe it is negligible [2]. In this work we present the intermediate case of multiple ionization of Ar. We used the continuum distorted-wave eikonal initial state [3] and the independent electron model to describe the multiple ionization of Ar by He^{+2} and He^+ in the energy range 0.1-10 Mev/amu, including Auger-like post collisional ionization, which enhance the high energy multiple ionization cross sections via ionization of the inner shells. Our results agree well with the experimental data at high energies where the PCI is the main contribution. At intermediate impact energies the description is also good but it tends to overestimate the triple and quadruple ionization data. We also compare with recent TDDFT calculations [4]. The Ar K and L shell ionization cross sections are also calculated and compared with the experimental data available and with the ECPSSR values [5].

[1] Schenk G and Kirchner T, **Phys. Rev. A 91** 052712 (2015)

[2] Montanari et al, **J. Phys. Conf. Series 388** 012036 (2012)

[3] Fainstein P D, Ponce V H and Rivarola R D, **J. Phys. B: At. Mol. Opt. Phys**. **21** 287 (1988)

[4] Zhang C L, Hong X H, Wang F, Wu Y, and Wang J G, **Phys. Rev. A 87** 032711 (2013)

[5] Lapicki G, **Nucl. Instrum. and Meth. Phys. Res. B 189** 8 (2002)

Abstract 128 Regular Poster - Poster Sessions

Zeeman effect investigations in rare earth ions using Collinear Ion Beam Laser Spectroscopy

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A rare earth ions (e.g. lanthanum, praseodymium and neodymium) have very rich electronic structure with hundreds of even and odd electronic levels what results in very dense spectra. Additionally, the presences of several isotopes with comparable abundances and developed hyperfine structure in some of them makes the picture of the spectra even more complicated. Cases of line overlapping (the so-called blend situation) are very frequent, making spectra interpretation difficult. For such cases, a high resolution technique where transition components are separated sufficiently from each other permitting their clear identification is necessary.

High resolution Zeeman spectra of the hyperfine structure of ionic spectral lines of the rare earth isotopes can be observed using a Collinear Ion Beam Laser Spectroscopy technique (CLIBS). A 19 keV ions are selected by means of a separator electromagnet and overlapped with a counter-propagating laser beam, tuned and stabilized close to the investigated transition. In the interaction region the ions are accelerated step by step (with a step size of 5 MHz) with a scanning voltage in the range 0-3500 V (corresponding to a wave number shift of 0.75 $\mathbf{cm}^{-1}$), allowing the Doppler tuning. The CLIBS technique allows achieve line widths of ca. 50-120 MHz.

The strong permanent neodymium magnets generated relatively strong magnetic fields perpendicular to the ion beam inside the interaction chamber. A Hall-effect Gauss-meter measured the field strength and additionally by the Zeeman effect of the ^{138}BaII (5d $^2D_{3/2}$ - 6p $^2P_{3/2}$) transition at 585.368 nm, where the Lande gJ-factors of the combining levels are known with sufficient accuracy. By changing the distance of magnets from the ion-laser interaction region, a uniform magnetic field of 330 Gauss could be achieved. Although, the field is perpendicular to the moving ions, the deflection of the ions having high mass and kinetic energy is minor, and has no influence on the experiment.

Abstract 239 Regular Poster - Poster Sessions

Effect of Electron-Positron Collision Energy on Antihydrogen Synthesis Via Magnetobound States

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Through utilization of classical trajectory simulations, it has been found that antihydrogen may be synthesized via a three body recombination through a magnetobound state of positronium. A magnetobound state of positronium occurs when the interacting positron and electron drift perpendicularly against a strong constant magnetic field and at low temperatures, similar to the conditions in a Penning trap used for producing antihydrogen. The study was conducted to see how the collision energy of an electron-positron pair would affect the production of antihydrogen. This material is based upon work supported by the National Science Foundation under Grant No. PHYS-1500427 and by the Department of Energy under Grant No. DE-FG02-06ER54883.

Abstract 240 Regular Poster - Poster Sessions

Antihydrogen Beam Formation by Transporting an Antiproton Beam Through an Electron-Positron Plasma That Produces Magnetobound Positronium: Effect of Electron-Positron Collision Pitch Angle

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The formation of an antihydrogen beam by transporting an antiproton beam through an electron-positron plasma that produces magnetobound positronium is studied using a classical trajectory simulation. Previous simulations have shown that under certain parameters, an antiproton encountering a magnetobound positronium system leads to antihydrogen formation. This study considers the effect that the electron-positron collision pitch angle has on antihydrogen production via magentobound positronium, in efforts to help improve current methods used for antihydrogen formation at CERN.

This material is based upon work supported by the National Science Foundation under Grant No. PHY-1500427 and by the Department of Energy under Grant No. DE-FG02-06ER54883.

Abstract 21 Regular Poster - Poster Sessions

Changes in the optical properties of Ag and Au implanted Infrasil silica

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We have measured changes in the optical absorption in Infrasil (a type of optically polished quartz silica) due to formation of nanoclusters of gold, due to formation of nanoclusters of silver, as well as due to formation of both nanoclusters of Au and Ag at the same depth in Infrasil coupons. The objective of this research is to study changes in the optical absorption band of these nanoparticles when both exist in close proximity. The implantation energies for Au and Ag were selected using the ion implantation simulation program SRIM in order to produce metallic nanoclusters at the same depth: 2.850MeV Au ions (SRIM calculated implantation depth of 6658A and lateral straggling of 1117A) and Ag ions at 1.452MeV (SRIM calculated implantation depth of 6470A and lateral straggling of 1386A) at fluences from 6 x 10^{16} ions/cm^2 to 3 x 10^{17} ions/cm^2. The optical absorption properties of the implanted Infrasil were measured before and after annealing (900C to 1150C for one hour) for coupons implanted with either Au or Ag to verify the formation of nanoclusters. We then measured the properties of coupons which were first implanted by Ag, subsequently annealed at 1150C, and then implanted by MeV Au, and finally annealed again at 1150C. Initial results indicates spontaneous clustering at high fluence implantation even before annealing, and surface plasma coupling due to formation of Au and Ag nanoclusters in Infrasil.

Abstract 214 Regular Poster - Poster Sessions

Patterned Ion Beam Implantation of Au and Si via Nanoporous Alumina Mask

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Porous anodic alumina (PAA) has attracted significant attention as a versatile nanostructure with diverse applications in nanotechnology[1-3]. The structure consists of a regular array of hexagonal pores arranged in a honeycomb pattern, boasting a high aspect ratio and tuneable dimensions. Currently, anodic alumina has piqued both scientific and technological interest as a dielectric film in electrolytic capacitors and as a method for increasing oxidative and abrasion-wear resistance. PAA may also be a strong candidate for controlling the lateral distribution and size of ion clusters generated via implantation.

Dielectric properties of alumina ensure that PAA is also suitable as a confinement matrix, with the added benefit of reduced requisite processing. In both cases, thickness, pore diameter and wall thickness must be carefully controlled.

Au ions were implanted through the PAA mask into an underlying SiO_2 substrate to visualize and quantify the mask's ability to stop, transmit, and possibly segregate ions. Implantation was performed at a normal incidence with energy of 700 keV and a dose of 1 x 10^{15} ions/cm^2, 10^{-7} Torr, at room temperature in the Tandetron Facility at UWO. The stopping and range of ions in matter (SRIM) analysis indicated that the implantation profile of ions directly into the mask did not exceed the thickness of the oxide layer. An initial investigation of the ability of PAA to act as a confinement matrix for quantum dot synthesis was also performed. Si ions were implanted into the thicker (~1-5 um) PAA film at a 7º angle to the normal with energy of 90 keV and a dose of 1 x 10^{17} ions/cm^2. SEM imaging indicated that Si implantation generated morphological changes that were more significant compared to the Au-implanted mask. Sputtering and amorphization leads to the disappearance of initial hexagonal surface morphology. In order to characterize PAA foil structurally and optically, PL spectra were taken before and after implantation. In comparison to a strong peak at 740nm in SiO_2 matrix due to the Si quantum dots, implanted Al_2O_3 does not have this feature. Photoluminescence of Al_2O_3 shows a broad peak with sharp features at ~ 700nm, that are identical to peaks observed previously for pure g-Al_2O_3 (sapphire). Initial PAA film is likely to be amorphous or may have small grains of γ-Al_2O_3. A broad signal is present from 500-700 nm in the implanted sample that is not seen in the unimplanted Al_2O_3, which can be attributed to various defects and/or Al_2O_3 phases. XRD diffraction identify formation α and δ-Al_2O_3 phases after implantation and anneal to 1100^{o}C.

1. G. D. Sulka, **Nanostructured Materials in Electrochemistry**, Wiley-VCH, Weinheim, 1(2008). 2. H. Masuda, and K. Fukuda, **Science 268**, 1466 (1995). 3. Y. Lei, and W. K. Chim, **Chem. Mater. 17**, 580 (2005).

Abstract 216 — Regular Poster - Poster Sessions

Morphological and hardness changes in silica implanted with MeV heavy ions

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The purpose of this research is to better understand changes in the surface morphology of Infrasil (a type of optical quartz silica) when ion implantation and subsequent annealing are used to induce the formation of metallic nanocrystals beneath the surface, a technique which can be used to create high efficiency thermoelectric devices. The various stresses that are induced by these processes can lead to the formation of complex defects, so an understanding of the defects that are introduced during the different stages, and the role that they play in the overall function and durability of the material can aid in the production of higher quality optoelectronic devices. We have implanted Infrasil coupons with high fluences of MeV gold and silver ions, and verified the implantation profile using Rutherford Backscattering Spectrometry (RBS) and RUMP code simulations. Changes in surface topography were assessed by Atomic Force Microscope (AFM), and changes in hardness using a dynamic ultra micro hardness tester. Obtained results are from various stages of the material (pristine, MeV Ion implanted, and annealing both before and after). Ion implantation significantly increased the surface roughness of the material, but after annealing at elevated temperatures of 900C to 1150C the surfaces were smoother. Changes in the hardness and surface exfoliation were also found to depend on the total implantation fluence. The results of this study will be used to improve the methodology for production of these promising thin film thermoelectric materials.

Abstract 6 — Regular Poster - Poster Sessions

Conducting Low Energy Nuclear Astrophysics Research Using the 1.7 MV 5SDH-2 Pelletron at the Louisiana Accelerator Center

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In 1973, Carl Sagan published **The Cosmic Connection: An Extraterrestrial Perspective** where he wrote "**we are made of star-stuff"**. This famous phrase points out the fact that almost everything (including people) in the universe is synthesized by nuclear reactions in stars. Synthesis of the elements and energy production in stars are at the heart of current research in nuclear astrophysics. One of the original uses for small electrostatic accelerators was to investigate atomic and nuclear structure. However, for most of the last twenty years, research at the Louisiana Accelerator Center (LAC) has concentrated on materials analysis and modification. What research nuclear astrophysics research can be completed using a machine like the 5SDH-2 Pelletron accelerator at LAC? In 2014, S. Cristallo **et al.** looked at the relationship between reaction rates and fluorine production in low mass stars. Many of these reactions involve nitrogen, oxygen, carbon, and fluorine using protons or alpha particles with less than a few MeV of incident energy. R.J. deBoer et al. in early 2015 measured the low energy scattering cross section ratios from 0.9 to 3.75 MeV for ^{14}N and protons. The least efficient reaction in the CNO cycle is $^{14}N(p,g)^{15}O$. This reaction should determine the overall rate for the whole CNO cycle. S. Falahat et al. in 2009 completed similar research where the reaction rates for magnesium and oxygen nuclei were measured when bombarded with alpha particles at the University of Notre Dame. This data will be added to stellar models for future analysis. All of the recently completed nuclear astrophysics mentioned here was completed at incident beam energies similar to what is attainable at LAC. In 2015, the authors received funding from the Louisiana Space Grant Consortium (LaSPACE) to pay an assistantship for an undergraduate student (John Miller) to determine the potential for doing nuclear astrophysics research at LAC. This poster will give the results of the current nuclear astrophysics research at LAC.

Abstract 68 Regular Poster - Poster Sessions

Searching for scintillation detector drift through analysis of recoil spectra from neutrons scattered from ^{12}C and γ-rays emitted from radioactive sources ^{137}Cs, ^{60}Co, and ^{241}Am

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The University of Kentucky Accelerator Laboratory is known for fast neutron scattering measurements and g-ray spectroscopy following neutron-induced reactions. The precision of these measurements is possible through well-tested experimental setups and data analysis techniques. C_6D_6 scintillation detectors, known for their efficiency and ability to use pulse shape discrimination to differentiate between γ and neutron interactions, are often used in precise neutron scattering measurements. These detectors are connected to a series of electronics and a data acquisition system, which are monitored visually to ensure there is no sporadic behavior in the detectors or their corresponding electronics. While this method catches some abnormalities, currently no method to evaluate systematically large sporadic or subtle long-term changes in the detector bias exists. The goal of this research was to analyze the nominal energy of neutrons in the recoil spectra and of standard radioactive source γ-rays to see if there was an observed shift in the detector bias or electronics over a three-week experiment. This evaluation was completed by developing a PYTHON program that evaluated all energy spectra. The results of these analyses will be presented.

This research was funded in part by the National Nuclear Security Agency and the Cowen Physical Sciences Institute.

Abstract 116 Regular Poster - Poster Sessions

Study of the $^{28}Si(d,\alpha)^{26}Al$ nuclear reaction at low energies

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Recent techniques and experimental methods have opened up new ways to explore nuclear reactions relevant to nucleosynthesis near to stellar combustion temperatures. A particular case is induced by deuterium which represents a sensitive tool for characterizing low concentrations of elements (isotopes) in materials due to the positive value Q (exothermic) in reactions (d, p) and (d, α). High energy particle emerging from this reaction are then easily identifiable even with simple detection configurations. In this work, we focus on the case of ^{26}Al. Isotope actively associated in the process of nucleosynthesis. It presence in the solar system was unexpected until it was found in the Allende meteorite. It is now understood that cosmic rays induce nuclear reactions to produce materials. On Earth, this process is well known and is based on environmental studies. So ^{26}Al is not just the product of some high-metallicity star collapse. For their study, a protocol is developed to quantify the number of deuterium hitting a target of Si / Al, as a first step to determine the total cross section in the reaction ^{28}Si(d, α)^{26}Al at very low energies of 2.6 MeV to 900 keV. Subsequently, another protocol is developed to determine the ^{26}Al produced using accelerator mass spectrometry (AMS) techniques.

Abstract 135 — Regular Poster - Poster Sessions

Effects of Cold Deformation, Electron Irradiations and Deformed by Extrusion on Deuterium Desorption Temperature Range from Zr-1%Nb Alloy

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The present paper reports the investigation results on the temperature ranges of the ion-implanted deuterium desorption from the zirconium alloy Zr-1%Nb in the cast (initial) state under the action of various treatments: plastic deformation by rolling at a temperature of ~ 300 K to the degree of compression **ε**=3.9, plastic deformation by rolling at a temperature of ~300K to the degree **ε**=3.9 followed by the 10 MeV electron irradiation at ~6×10^{17} cm^{-2} fluence, low-temperature extrusion with the percent reduction of ~15% at extrusion temperature of ~78 K.

The plastic deformation of Zr-1%Nb by rolling at a temperature of ~300 K with **ε**=3.9 gives rise to the nanostructured state with a subgrain average size of 61 nm. A high degree of defect content in the alloy structure is revealed in the deuterium thermodesorption spectrum as an additional deuterium desorption region in the temperature range from 650 to 850 K. Under subsequent electron irradiation of Zr-1%Nb samples, plastically deformed by rolling, the average grain size was decreased to 58 nm and the bulk grain concentration was increased. As a result, in the deuterium thermodesorption spectrum the additional temperature ranges were formed with desorption rate peaks at 700 and 800 K.

In the case of Zr-1%Nb samples, deformed by extrusion at 78 K with reduction of ~15%, a broad set of structure defects is observed in the deuterium thermodesorption spectrum as an additional deuterium desorption region extended on the temperature scale at temperatures ranging from 420 to 850 K.

The structural state behavior is a control factor in the process of deuterium thermodesorption spectrum structure formation with a fixed implanted deuterium dose (hydrogen diagnostics). It appears as additional temperature ranges of deuterium desorption depending on the type, character and defect content.

Abstract 223

Regular Poster - Poster Sessions

Mechanical properties of steel miniature specimens irradiated with high-energy heavy ions

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Heavy ion beam is a useful tool to simulate energetic neutrons to produce cascade damage at high rates in materials, and can thus be used to evaluate the irradiation response of materials candidate to advanced nuclear reactors (Gen IV, fusion). However its range in materials is strictly limited due to strong Coulomb interaction of the incident heavy ions with electrons in materials. Among the miniature specimen technology, small-ball punch test (SP) is capable of obtaining useful information about the deformation and fracture behavior of materials before and after irradiation by using 3-mm disks with a thickness generally between 0.2 to 0.3 mm. In the present work, small-ball punch tests of 3-mm disks of ferritic steels with thickness less than 0.1 mm, specific for irradiation with high-energy heavy ions, were performed. Effects of the variation of specimen thickness (from 40 to 120 micrometers) on the load-displacement character in SP test were studied. A finite-element-method (FEM) model for the thin disks of the Fe-base alloys was developed. A good correlation between the tensile test and the small punch test was established based on the FEM analysis. The position of the maximum shear stress at the periphery of the bulge from FEM calculation matches well with the position of the observed circumference cracks on the SP-tested disks. Data of SP test of specimens of some high-Cr ferritic steels with a thickness around 60 micrometers, before or after irradiation with 122 MeV Ne ions, were analyzed with FEM. The ductility loss of the irradiated specimens was estimated with the equivalent fracture train (e_f), and compared with the results from a classical analysis method.

Abstract 147

Regular Poster - Poster Sessions

Fabrication and design of acceleration system

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The design and fabrication of Quarter Wave Resonator(QWR),Half Wave Resonator(HWR), Single spoke resonator(SSR) cryomodule and cavity are presented. The operation temperature of the cavity for both of the cryomodules is 4.5K and 2K. The cryomodule consists of cavities, tuners, couplers, a vacuum chamber, a magnetic shield and cryogenic pipe line. Fabrication processes are shown for cavities and cryomodules.

Abstract 446

Regular Poster - Poster Sessions

MEDICIS-PROMED: Marie Curie Innovative Training Network on innovative radionuclides for medicine applications

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MEDICIS-PROMED is a network that bridges different disciplines across fundamental research institutions, private companies and hospitals for the production of innovative medical isotopes and radiopharmaceuticals for the imaging and therapy of cancer. Radioisotopes are commonly used for functional imaging and are expected to play an enhanced role in treatment of various types of cancer.

At CERN a new facility is under construction, named MEDICIS, which will provide dedicated medical batches for radiopharmaceuticals and develop new accelerator technologies for medical applications. It will extend the capabilities of the ISOLDE radioactive ion beam facility, operated with a 1.4 GeV proton beam and the on-line mass separator, which allows the production of a spread variety of radioisotopes for different aims.

MEDICIS-PROMED is a Marie Sklodowska-Curie innovative training network of the Horizon 2020 European Commission`s program. Outcome of this network will be a new generation of entrepreneurial scientists, who will take advantage of the different interdisciplinary fields, in order to develop medical systems for new personalized medicine and to develop a network of experts within Europe. The EU support consists of 15 PhD projects based in different partner sites all over the Europe, which are coordinated by CERN. MEDICIS-PROMED is a wide project that covers all aspects from the radioisotope production to the medical application passing through the collection, shipment, safety control and the radiochemical synthesis. The project started in April 2015 and will end in 2019. Together with the completion of the MEDICIS facility (2017), MEDICIS-PROMED will reach its full speed.

Abstract 184 Regular Poster - Poster Sessions

Ion-Beam Analysis of Artificial Turf

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There has been considerable concern in recent years that artificial turf, used in many playing fields throughout the world, may be unsafe. While the presence of heavy metals and carcinogenic chemicals have been reported in a number of studies, more data and research is needed to determine if there is a real link between artificial turf and adverse health effects. We are performing PIXE and PIGE analysis of artificial turf leaf and in-fill samples to search for heavy metals and other possibly toxic substances. The samples are bombarded with proton beams from the 1.1-MV Pelletron tandem accelerator in the Union College Ion-Beam Analysis Laboratory and the emitted X-rays and gamma-rays are measured with Si drift and CdTe detectors, respectively. Some preliminary work on this project was performed using an external beam facility that we constructed from a beam pipe with an aluminum end cap supporting a ¼" diameter window made of 7.5-micron Kapton foil which allows us to analyze samples that cannot be put into the vacuum chamber. We will describe the development of the external beam facility and the analysis of the artificial turf samples, and present preliminary results.

Abstract 262 Regular Poster - Poster Sessions

RBS Study of a Dilute Alloy of Ga(99.8% at.):Bi(0.2% at.)

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Dilute alloys of bismuth in gallium (98-99% at.) are known from theoretical calculations and x-ray scattering to display a strong segregation of bismuth atoms at the surface, a monatomic layer of bismuth appearing because of the lower surface tension of the Bi compared to the Ga. Rutherford backscattering (RBS) spectra from 2 MeV He^+ and 2 MeV C^+ on a dilute alloy of Ga(99.8% at.):Bi(0.2% at.) have been measured. A distinct peak in the bismuth RBS spectra, corresponding to scattering from the surface of the alloy is consistent with a monatomic layer of bismuth on the alloy over a range of temperatures for which the alloy is a liquid. The peak is not observed when the alloy is cooled to a solid state and this observation is thought to be due to the irregular surface structure of the alloy. Bismuth is also observed to be uniformly distributed throughout the gallium host for the depths studied at these beam energies. Some oxide may be present due to the 10^{-7} Torr vacuum and the long spectral integration times.

Abstract 34 Regular Poster - Poster Sessions

Effects of Ar sputtering and UV-Ozone radiation on the physico-chemical surface properties of ITO

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Indium Tin Oxides (ITOs), are widely used in many device applications requiring transparent conducting oxides (TCOs). They are known to have Sn-rich surfaces. The excess Sn at the surface of ITOs, mostly in the form of SnO_4 is responsible for enhanced work function relative to the stoichiometric ITO beneath the surface. The enhanced work function is a desirable property in ITOs that leads to optimal and efficient devices applications such as OPVs and OLEDs. Most, if not all, OPVs and OLEDs devices fabrications are done ex-situ. The surface of these ITOs are covered with hydrocarbon contamination that is responsible for lowering the work function leading to poor performance of the fabricated devices. Many surface cleaning methodologies (chemical etching, oxygen plasma, surface ion etching or sputtering) have been developed and used to remove hydrocarbon contaminations prior to devices fabrication. Ar sputtering is of the surface cleaning methods that is very efficient at removing the hydrocarbon contamination on ITO surface. In this study, we used X-ray photoelectron spectroscopy (XPS) and Ultraviolet photoelectron spectroscopy to evaluate the effects of 1 KeV Ar^+ irradiation (sputtering) on the chemistry of ITO surface, the change in surface atomic composition and change in its the work function. A comparative study between Ar sputtering and UV ozone treatment of ITO is presented. Although Ar+ sputtering removes hydrocarbon contaminants, it minimizes the Sn rich surface of ITO and leads to a reduction of the oxidation state of Sn from Sn^{4+} to Sn^{2+}. The optimal and highest work function of the ITO is directly correlated to both the lowest level of hydrocarbon contaminant and highest SnO_2/SnO atomic ratio in the top surface region.

Abstract 448 Regular Poster - Poster Sessions

Layout of a portable, Compact, Quadrilateral Electrostatic Storage Ring

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Electrostatic ion-storage rings (ESRs) are flexible tools in atomic and molecular physics due to their capability for mass-independent storage of positive or negative ions [1]. Using solely electrostatic ion-optics, they allow for the storage of ions with arbitrary mass, and thereby permit the internal relaxation of large macromolecular or cluster ions. A number of ESRs have been constructed in recent years [2]. In most cases, the rings follow the optical concept and layout of the pioneering electrostatic ion-storage ring in Aarhus - ELISA [1]. The ELISA design typifies linear ion-optics of cylindrical or parallel-plate deflectors to bend the beam, and quadrupole lenses to focus it, within a racetrack-shaped closed-orbit of ~7 m perimeter. New designs relying on quadrupole-based ion-optics make use of four-way 90° electrostatic turning quadrupoles instead of the cylindrical and parallel-plate deflectors. In this optical concept, the closed-orbit thereby consists of an array of four 90° quadrupole benders. SAPHIRA, the Storage Ring in Aarhus for PHoton-Ion Reaction Analysis [3] is the first operating ring built under such concept. It features a square-shaped, medium-sized ring of ~4 m perimeter, the lattice of

which relies on quadrupole triplets to focus and shape the ion-beam. Here, we present the layout of a so-called Q-Ring [4] that features a compact, quadrilateral-shaped ring of four turning quadrupoles (hence the name). Unlike SAPHIRA, the design of the Q-ring makes use of quadrupole doublets to focus the ion-beam. The purpose of this design for a transportable quadrilateral ring has been outlined elsewhere [5]. This design makes possible the study of the interaction of internally-cold macromolecular ions with polarized synchrotron light from (**e.g**.) the SOLEIL Facility in Paris [6].

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[1] S. P. MØller 1997 **Nucl. Instrum. Meth. A 394,** 281-286.

[2] M. O. A. El Ghazaly **et al.** 2016 **Nucl. Instrum. Meth. 806,** 36-42.

[3] H. B. Pedersen, **et al.** 2015 **Rev. Sci. Instrum. 86,** 063107.

[4] M. O. A. El Ghazaly, "A Compact Electrostatic Ion Storage Ring for Molecular Ions, and Investigations in Highly-Charged Atomic Ions of Astrophysical Interest" proposal, NASA Postdoctoral Program (NPP), November, 2013.

[5] M. O. A. El Ghazaly, "Perspective for a Compact Electrostatic Storage Ring"
Proc. XXVIII International Conference on Photonic, Electronic and Atomic Collisions (ICPEAC 2013), 24-30 July, 2013, Lanzhou, China, [Abstract ID: 22691, T14 Related Topics].
http://icpeac2013.impcas.ac.cn/absbook/abstracts/T14%20Related%20Topics/

[6] M. O. A. El Ghazaly, Technical Design Report of a Compact Electrostatic Storage Ring, through a proposal submitted to KACST, July 2013. Saudi Arabia

Abstract 117 Regular Poster - Poster Sessions

In-air ion beam extraction set-up for the external micro - PIXE analysis and local implantation

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A measuring system for local elemental analysis is constructed on the basis of the ion accelerator AN-2500. It comprises the device of an in-air ion beam extraction through the tapered glass capillary and PIXE spectrometer. The angular dependence of the proton beam possessing the energy of 150-250 keV transmission through the tapered capillary with the output diameters 5 and 10μm has been determined. The transit of protons through the capillary was found to have threshold character and to be determined by the charging rate of its internal surface. The characteristics of current and energy of the ion beam extracted into the atmosphere were analyzed. It was found that the value of output current may vary from 0.5 to 3 nA, while the ion energy is almost equal to the initial beam energy. PIXE energy spectra from various materials were measured under atmospheric pressure. It was found that the output beam intensity is enough for accurate determination of the elemental composition of the samples under analysis.

Abstract 138 Regular Poster - Poster Sessions

Study the distribution of elements in ODS steel in external beam protons

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Uniformity of distribution of oxide particles is one of the main criteria when creating oxide dispersion strengthened (ODS) steels.Samples of austenitic 08Cr18Ni10T steel that dispersion strengthened by nanopowders of Y_2O_3- ZrO_2 system were prepared by mechanical alloying [1]. The grain's size of steel was about 1.5-2µ, the medium size of oxide precipitations - 10 nm. The samples were investigated after rolling and fallowing electropolishing. Studied the distribution of elements in the sample of external beam PIXE with the energy of 1700 keV. X-rays are recorded Si (PiN) and HpGe detectors positioned at an angle of the 135°, at a distance of 20 to 40 mm from that target. A filter of Al foil 200 and 500 microns thick was placed in front of the detectors. The spectra were measured before charging a set of 200 µKl, with a beam current of 100 nA.

The influence of proton beam size on the result of the analysis it was determined. Preliminary has been studied in beam particle distribution uniformity. And then without changing the geometry of the radiation beam size on the target changed from 200 µm to 1500 µm.

The experiments lead to the following conclusions that it is possible to analyzing the distribution of elements in the target by varying the size of the proton beam; electropolishing operation leads to a change in concentration of the elements.

Ã€.N. Velikodnyi et al. PAST, 4, 94 (2014)

Abstract 156 Regular Poster - Poster Sessions

Identification of the phase transition in zinc oxynitride layers by ERDA-TOF

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Zinc nitride (Zn_3N_2) is a metastable material that reacts with air in normal ambient conditions, suffering a progressive oxidation that leads to a zinc oxide (ZnO) layer [1]. This characteristic can limit the performance of electronic devices based on this material, such as thin film transistors [2]. One way to avoid this effect is the growth of stable $Zn_xO_yN_z$ compounds [3], but the different ionic radius for O^{2-} and N^{3-} difficult the formation of such ternaries for all the desired compositions.

In this work we study the phase transition between Zn_3N_2 to ZnO by growing different ternary compounds. The layers were grown by RF magnetron sputtering of a pure Zn target (99.995 %) with reactive nitrogen and oxygen plasma at room temperature and 10^{-2} mbar. The N2/O2 flux ratio was varied in the whole range obtaining different stoichiometries. The structural transformation from a polycrystalline cubic nitride lattice of Zn_3N_2 towards a polycrystalline hexagonal ZnO lattice was analyzed by X-ray diffraction, and the morphology studied by scanning electron microscopy. The optical properties of the ternary layers were determined by spectroscopic ellipsometry and absorption, confirming the band gap variation from 1.5 eV (for Zn_3N_2) to 3.3 eV (for ZnO).

In order to understand this phase transition, a detailed compositional analysis of the films was carried out by elastic recoil detection analysis with time-of-flight (ERDA-TOF). The experiments were performed with 30 MeV I^{5+} ion beam produced with the 5 MV Cockcroft-Walton accelerator of the Centre of Micro-Analysis of Materials. Our results demonstrate that O atoms replace N even for very low flux ratios (N2/O2=29:1), resulting in a poorly doped compound with a high band gap. Nevertheless, thanks to sensitivity and mass separation of the ERDA-TOF technique, we were able to identify the conditions for a highly doped oxynitride film (with 11% nitrogen incorporation) coinciding with an "X-ray amorphous" phase and intermediate band gap (2.1 eV). Overall, this confirms the higher stability of the Zn-O bonds and the abrupt transition from the nitride phase to the fully oxidized phase.

[1] C. GarcÍa Núñez, J.L. Pau, M.J. HernÁndez, M. Cervera, E. RuÍz, J. Piqueras, Thin Solid Films 522, 208 (2012).

[2] C. GarcÍa Núñez, J.L. Pau, E. RuÍz, J. Piqueras, Appl. Phys. Lett. 101, 253501 (2012).

[3] X.Cao, A. Sato, Y. Ninomiya, N.Yamada et al., J. Phys. Chem. C 119, 5327 (2015)

Abstract 178 Regular Poster - Poster Sessions

Triassico: A Sphere Positioning System for Surface Studies with IBA Techniques

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We propose here a novel technique to microscopically study the whole surface of millimeter sized spheres. The sphere dimensions can be from 1 mm; the upper limit is defined only by the power and by the mechanical characteristics of the motors used. Three motorized driving rods are arranged so an equilateral triangle is formed by the rod's axes, on such triangle the sphere sits. Movement is achieved by rotating the axes with precise relative speeds and by exploiting the friction between the sphere and the axes surfaces. The sphere can be held in place it her by gravity or by an opposing trio of axes. By rotating the rods with specific relative angular velocities, a net torque can be exercised on the sphere that will rotate. No repositioning of the sphere or of the motors is needed to cover the full surface with the investigating tools. There are no fixed positions on the sphere so a continuous movement with no blind spots can be achieved. An algorithm, that takes into account the kinematics constraints, was developed. The algorithm minimizes the number of rotations needed by the rods, in order to efficiently select a particular position on the sphere surface. The Triassico was initially developed for the National Ignition Facility, of the Lawrence Livermore National Laboratory (Livermore, California, USA), as a sphere manipulation apparatus for R&D of the DT inertial confinement fusion fuel spheres. Other applications span from samples orientation, ball bearing manufacturing, or jewelry.

Abstract 221 Regular Poster - Poster Sessions

Geochemical Characterisation of Soil and Sediment Samples from Gold Mining Areas using Particle Induced X-ray Emission Technique

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Non regular mining activities result in low quantity and grade of the target mineral, loss of other economic recoverable ones and toxic indicator elements contamination of various environmental media. The trace-level determination of the indicator or pathfinder elements, needed to ensure the occurrence of the mineral, require a robust analytical procedure and statistical treatment of the resulting data. Particle induced x-ray emission (PIXE) analysis technique was used to characterise the soil and sediment samples from two gold mining sites for 29 major, minor and trace elements used to obtain the mineralogical information. Though not large, the geochemical data served as input into the statistical analyses to identify the pathfinder elements of gold for fingerprinting and toxicity potential purposes. A number of mineralogical phases for the gold occurrence have been confirmed and the pathfinder elements for the two sites identified. The high level of the determined

pathfinder elements implies a relatively high heavy metal contamination risk to the miners and the ecosystem. The major hazard index is represented by the abandoned waste, pits and ponds already serving as fish ponds.

Abstract 222 — Regular Poster - Poster Sessions

PIXE Characterisation of Mineral-Hosted Soil Samples: A Radiometric and Potential Toxicity Assessment

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The soil and ore samples from two mine sites have been characterised to determine the concentration of 33 major, minor and trace elements including the radionuclides (^{40}K, ^{232}Th and ^{238}U) and toxic metals (V, Cd, Ba and Pb). This is based on the particle induced x-ray emission (PIXE) analytical technique free of most of the peak resolution, interference, self-absorption, geometrical and density correction problems inherent in gamma spectrometry. The calculated activity concentrations of the radionuclides ranged from 415 to 15520, 1 to 3, and 4 to 10 kBq/kg for ^{40}K, ^{232}Th and ^{238}U, respectively with an average exceeding the world limit and suggesting possible radiological consequences. The toxic metals levels, with an average value of 330 ± 82, 785 ± 9, 6990 ± 150 and 394 ± 92 µg/g, respectively, are higher than the world average recommended value for each of the elements. This suggests a potential health risk to the miners and other vulnerable groups.

Abstract 288 — Regular Poster - Poster Sessions

RBS analysis of down-conversion layers comprising two rare-earth elements

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Rutherford Backscattering Spectroscopy (RBS) of samples containing two rare-earth elements is difficult owing to the small mass separation of even the lightest and heaviest of the group. In studies of the growth of silicon nitride down-conversion layers compatible with silicon photovoltaic technology, 2-3 MeV RBS has been combined with RBS at 5 MeV and alpha PIXE to determine the composition of samples grown with different amounts of cerium and ytterbium. The films were produced using reactive magnetron co-sputtering. Conventional RBS at 2.2 MeV is used to determine the nitrogen and oxygen and silicon content of the films. At this energy elements from carbon upwards have scattering cross-sections determined by the Coulomb potential. However, the cerium and ytterbium peaks at this energy merge into one and make it very difficult to determine the ratio of these elements or the absolute amount of each element. At 5.0 MeV sufficient separation was achieved between the cerium and ytterbium peaks that their ratio and absolute amount could be measured. At this energy the scattering from these elements is still determined by the Coulomb potential. For all the other elements in the sample the Coulomb barrier has been exceeded such that data from them is unusable. Care needs to be taken to ensure no interference with the rare-earth scattering peaks in the spectrum and products of nuclear reactions from the lower Z-elements.

Abstract 335 — Regular Poster - Poster Sessions

TXRF Yield Formed by PXWR in Conditions of Ion Beam Excitation

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X-ray fluorescence analysis of materials in conditions of the total external reflection of X-ray exciting flux on the studied surface (TXRF analysis) is commonly used in research and industrial laboratories, today [1]. TXRF method is characterized by X-ray fluorescence excitation of the material surface layer with thickness 3-5 nm. In the result, the method is featured by very small background intensity and has not need in the matrix correction introduction. Moreover, fluorescence lines intensities are connected with atomic concentration in the surface layer, linearly, and method can be used as the effective quantitative procedure for the concentration analysis of superlow pollutions concentration. But TXRF analysis is characterized by very low efficiency of light elements determination in materials. This methodical disadvantage can be compensated by application of ion beam excitation of X-ray fluorescence (PIXE-method) [2].

In our work we elaborated the experimental scheme for TXRF measurements in conditions of characteristical fluorescence excitation by high energy proton beams. The scheme is build on base of the planar X-ray waveguide-resonator (PXWR) [3] with specific design. PXWR in this scheme is formed by Be polished reflector with hole in its centre and surface of studied target. Slit clearance between Be reflector and target surface (s=0.15 mm) selects characteristic fluorescence yield from the surface target layer with thickness 3-5 nm. So, we realized new method for surface material diagnostic characterized by high efficiency for the light element determination. Its features in conditions of Sokol-3 ion beam analytical complex [4] application are discussed.

[1] **R. Klockenkamper, A. Von Bohlen. Total reflection fluorescence analysis and related methods (second edition). - Wiley: New York. 2015.**

[2] **S.A.E. Johanson, J.L. Campbell, K.G. Malquist. Particle induced X-ray emission spectrometry (PIXE). - Wiley: New York. 1995.**

[3] **V.K. Egorov, E.V. Egorov**, Planar waveguide-resonator a new device for X-ray optics // X-ray Spectrometry, 2004, v33, P. 360-371.

[4] **V.K. Egorov, A.P. Zuev, E.V. Egorov**, Scintillation response of monocrystal $PbWO_4$ to random and channeled ions // NIM, 1996, B119, P. 418-424.

Abstract 340 Regular Poster - Poster Sessions

Investigation of thickness and composition on aging of Polyimide thin films at high temperature using RBS Technique

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The need for faster devices with high voltage and high switching frequency capabilities, operating at higher than 150 °C junction temperature is growing or up to 400°C in environmental temperature. However, such devices able to work under such conditions need appropriate packaging to sustain operation throughout their entire planned life cycle. Therefore, particular attention has to be paid to material selection when designing high temperature packaging. Polyimides (PIs) have received considerable attention due to their high thermal stability, mechanical and electrical insulating properties.

A series of 12 PI thin films was spin-coated onto Silicon substrate and then cured at 400°C for one hour in an oven under N_2 atmosphere. The final film thickness of 1.5 µm was obtained and measured before aging using a KLA Tencor profilometer. The obtained sample was divided into two parts. The first consist of six samples of PI deposited onto Silicon substrate. The second six samples were covered with a gold (Au) thin film with an approximated thickness of 180 nm by thermal evaporation. Each sample is aged at 300°C in open air at different times from 0h to 1500h.

RBS technique was employed to monitor the composition and the thickness of PI material versus aging times. The RBS measurement was done by using accelerated alpha-particle beams of energy 2 MeV. It was found that as the aging time increases the PI thickness in PI/Si samples decreases following an exponential decay, while that in Au/PI/Si it almost stable. This decrease in thickness is suggested to the surface degradation mechanism. It is argued that the presence of Au layer upon the PI/Si led to protection of PI against aging effects.

Moreover, a peak related to Silicon (Si) was observed on the top of the samples with increasing aging time. The reason of the appearance of this layer is assumed to be due to the impurity inside the oven.

Abstract 341 Regular Poster - Poster Sessions

Characterization of archeological pottery from Tyre historical site using PIXE technique and cluster analysis

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It is proposed to study the excavated ceramics from Tyre, the prestigious city of antiquity (locally named Sour and located at 85 km south of Beirut, Lebanon). The originality of Tyre in this context is its long permanence of prosperity as a great center of pottery production and maritime trade through the centuries without interruptions, which were experienced by neighboring cities and rivals. In this work, several series of excavated pottery are analyzed in order to characterize the Tyre production, based on the elemental composition, and thus to be distinguished from those of other neighboring workshops (Serapta, Sidon or Acre), possible sites of ceramic production at this period. Particle induced X-ray emission technique PIXE is used to determine the elemental composition of about 107 excavated shards. The elemental composition provided by PIXE and based on 12 most abundant elements, ranging from Mg to Zr, was used in a multivariate statistical program, were two well defined groups were identified.

Abstract 342 Regular Poster - Poster Sessions

Characterization of atmospheric particulate matter PM2.5 in Beirut suburb using PIXE technique

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In this work, it is investigated the elemental composition of fine and coarse air particulate matter $PM_{2.5}$ and $PM_{10-2.5}$ collected in 2014-2015 in a suburb area of Beirut, using the ISAP®1050e sampler having a combined inlet. The collection of fine particles was carried out on thin Teflon filters while the coarse ones were collected by impaction using a custom made polypropylene ring foil. The characterization of the elemental content of the two fraction mode, fine and coarse particles, were analyzed using proton induced X-ray emission technique PIXE. It will be more focused on the elemental composition of the fine fraction $PM_{2.5}$, using PIXE in two runs. Proton beam of energy 1 MeV irradiated the samples in order to determine low Z elements, while 3 MeV protons, with 75 µm Kapton filter used as X-ray absorber, were used to determine the high Z elements. This allows the determination of elemental concentration (in ng/cm^2) of Na, Mg, Al, Si, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn and Pb. For each sample, there was a clear dependence of the elemental content, as well as the mass of total PM2.5, with potential pollution sources such as car traffic and meteorological conditions.

Abstract 32 Regular Poster - Poster Sessions

Neutron imager with Micro Channel Plates (MCP) in electrostatic mirror configuration: first experimental test

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The idea of a new high transparency device based on Micro Channel Plate (MCP) has been recently presented for monitoring the flux and spatial profile of neutron beams [1]. It consists of the assembly of a very thin carbon (C) foil with 6Li deposit placed in the beam and a MCP equipped with a phosphor screen readout viewed by a CCD camera outside. A peculiar feature of this device is that it uses an electrostatic mirror to minimizing the perturbation of the neutron beam, i.e. absorption and scattering. It can be used at existing time-of-flight facilities, in particular at the n_TOF facility at CERN, for monitoring the flux and spatial profile of neutron beams in the thermal and epithermal region. In this contribution the first experimental test carried out by using radioactive sources will be presented and the related results discussed.

[1] V. Variale, Physics Procedia 66 (2015) 242-248

Abstract 89 Regular Poster - Poster Sessions

Neutron Scattering Differential Cross Sections for ^{12}C from 5.58 to 6.04 MeV

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Using the neutron production and detection capabilities at the University of Kentucky Accelerator Lab (UKAL) in Lexington, KY, measurements were made of ^{12}C elastic (n,n) and inelastic (n, n') neutron scattering angular distributions for incident neutron energies of 5.58, 5.83, and 6.04 MeV. The quasi-monoenergetic neutrons collided with a ^{12}C sample isotopically enriched to 99.999% and were scattered. The scattered neutrons were detected in a C_6D_6 detector using neutron time-of-flight (TOF) techniques for angles between 20 and 153 degrees. The neutron scattering angular distributions were used to deduce the elastic and inelastic differential cross sections. The results were compared to the existing data from the National Nuclear Data Center which currently show discrepancies of nearly 40%. The research aids in both the development of future nuclear reactors using graphite as a neutron moderator and the overall understanding of the ^{12}C nucleus.

This research was funded in part by the National Nuclear Security Agency and the Cowan Physical Sciences Institute at the University of Dallas.

Abstract 209 Regular Poster - Poster Sessions

A Preliminary Study of Toxic Elements in Cotton Seeds with Instrumental Neutron Activation Analysis (INAA)

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Cotton has been an important cash crop in the Palmetto State since revolutionary times to current day. Throughout the growing season, cotton assimilates numerous trace elements from the soil, including the toxic ones. Some of these trace elements are accumulated or enriched in cotton seeds. Therefore, cotton seeds can serve as an indicator of heavy metal contamination of local soil. South Carolina, like other states, is subject to the environmental impact of human behaviors. Dozens of heavily-polluted superfund sites are scattered in the state, and most of which are close to cotton plantations. It is conceivable that cotton may be under contamination impact of these sites through ground water movement or other migration paths.

This study is an initial stage of a long term project. Several cotton seeds and corresponding local soil samples from the Midlands Region of South Carolina were studied with instrumental neutron activation analysis (INAA). After irradiation of the samples with thermal and epithermal neutrons in the PULSTAR Reactor, all of short-lived, medium-lived and long-lived isotopes spectra were collected with HpGe spectrometers. The preliminary results indicate that: (1) INAA can determine the level of elements in soil and cotton seeds with high accuracy and extreme sensitivity. It is an appropriate tool for conducting multi-element analysis in agricultural products, especially cash crops; (2) as a life form, cotton can work like a refining factory: it has the ability to not only increase the concentration of curial elements in cotton seeds but also block some elements which it does not need.

Abstract 48 Regular Poster - Poster Sessions

Measurements of the effective atomic numbers of alloys using thick-target bremsstrahlung intensities

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The accuracy with which the effective atomic number (Z_{eff}) of an alloy can be measured using the intensity of the thick-target bremsstrahlung produced by low-energy electrons incident on the alloy target has been investigated. The experiments involved 4.25 keV and 5.00 keV electron beams incident on thick bismuth-indium-lead-tin, brass, nickel-iron-molybdenum, nickel-molybdenum-chromium, and stainless steel targets. By comparing the data obtained using alloy targets to the data obtained using a high-purity aluminum target and those of a previous study performed by our group (in which the Z-dependence of thick-target bremsstrahlung was studied), the Z_{eff} values of the alloy targets were measured.

Abstract 104 Regular Poster - Poster Sessions

Positron Annihilation Spectroscopy Study of Minerals Commonly Found in Shale

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Positron Annihilation Lifetime and Doppler Broadening spectroscopies are used to investigate twenty-three different rock-forming minerals that are commonly found in shale. Doppler Broadening provides information about the positron and positronium (Ps) trapping sites for comparison among the various minerals. Correlations of positron lifetime and Doppler broadening are observed for different groups of minerals. Finally, Ps formation, or lack thereof, in the various minerals has been determined.

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Abstract 122 Regular Poster - Poster Sessions

Rotational Behavior in ^{179,180}W

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High spin states of ^{179,180}W were produced via the 4n and 5n channels respectively in the ^{14}C + ^{170}Er reaction at beam energies of 68 MeV and 75 MeV. This experiment was performed at Florida State's John D. Fox Laboratory with three escape-suppressed germanium clovers and seven escape- suppressed single crystal germanium detectors in order to deteect gamma rays.

The experiment produced 852 million γ-γ coincidences and 82 million γ-γ-γ coincidences at 75 MeV beam energy. Additionally, at 68 MeV, there were 119 million γ-γ coincidences and 9.6 million γ-γ-γ coincidences. Analysis of this data is in progress using the Radware analysis package [1] using both double (matrix) and triple (cube) formats. Preliminary analysis is already revealing extensions to previously known structures [2,3] as well as new bands being observed. These results will be presented and discussed.

[1] D. C. Radford, Nucl. Instrum. Methods Phys. Res. A 361, 297 (1995).

[2] P. M. Walker et al., Phys. Rev. Lett. 67, 4 (1991).

[3] P. M. Walker et al., Phys. Lett. B 309, 17 (1993).

Abstract 4 Regular Poster - Poster Sessions

Improving the Reliability of Cyclotrons

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The TR19 cyclotron installed at CCR, IFIN-HH, is a versatile and complex machine used for obtaining new radioisotopes and for nuclear physics research . A maximum current of 2.8 mA of H^- ions can be produced using an external Ion Source and injecting it in the middle of the accelerator using it's unique Injection System. After accelerating to energies between 14 Mev and 19 MeV the ions collide the extraction carbon foil and a maximum 300 μA current of proton beam is obtained. Using different types of targets a wide range of radioisotopes including PET radioisotopes such as: ^{18}F, ^{11}C, ^{15}O,^{13}N, ^{124}I, ^{64}Cu can be obtained. The most important feature of TR19 cyclotron is the possibility of extracting two proton beams in the same time at 180^0 angle. All the installed equipments need to be cooled to ~20^0 C using deionized water. For that we propose an improved method to reduce the power consumption on water pumps- part of the Water Package system. Also an extension line is installed on one side of our cyclotron and it consists of a 6 meters beam line (with a powerful vacuum system) and three magnetic lenses for beam focusing. The quadrupoles are very sensitive to any electrical power supply variations so the proposed technique is used to protect the equipment from high voltage spikes during operation and power on- power off cycles. If we want the beam at the end of the 6 m beam line to have a perfect shape (not to focused) and to have the proper intensity it is very important to have a very stable power supplies of all three quadrupoles. Targets helium cooling system is an very important constituent that needs lot of attention- no water should enter the system, unless....Performance of our accelerator and operating emerging problems will be discussed.

Abstract 30 Regular Poster - Poster Sessions

Characterization of Inductive Loop Coupling in a Cyclotron Dee Structure

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Many of today's low to medium-energy cyclotrons apply RF power to the resonator structure (the 'dees') by inductive loop coupling through a feed-line driven by an RF transmitter incorporating a triode or tetrode power tube. The dee system acts as a high-Q (in the thousands) capacitively-loaded quarter-wave resonator.

Near resonance, the impedance -- normalized with respect to Z_0 and measured directly at the loop's input terminal, is given by a compact formula: $z_{in} = jx_{L1} + (k^2 Q_0 x_{L1}) / (1 + j\psi)$. x_{L1} is the normalized self-reactance of the loop; k is the inductive coupling coefficient; Q_0 is the un-coupled Q of the resonator; and ψ is a generalized frequency variable.

Less studied is the effect of the reverse-impedance looking back toward the transmitter. The transmitter's output network transforms the the tube's optimum load line -- typically a few thousand ohms -- to Z_0, typically 50 ohms. However, since the load-line is not a physical resistance, one would not expect to see 50 ohms when looking back toward the transmitter. If both the the resonator's input and the transmitter's output are matched to Z_0, then the coupled Q of the resonator is reduced to half that of the uncoupled Q, implying that half the power is being dissipated in the transmitter's output resistance -- an inefficient and expensive solution for a high power RF application.

More power is available if the transmitter's reverse-impedance is not matched to Z_0, but this may result in misalignment between the frequency for correct forward match at the loop, versus the frequency for maximum power in the resonator. The misalignment can be eliminated, and the working Q maximized, by choosing the appropriate length of feed-line between the (non-matched) transmitter output and the (matched) loop input.

The appropriate length -- expressed in electrical degrees -- is arctangent ($1 / x_{L1}$), plus an additional length -- as required to make the physical connection -- comprising an even number (0,2, 4...) of 1/4 waves for a low output resistance, or an odd number (1,3,5...) of 1/4 waves for a high output resistance. A wrong choice of feed-line length, in particular, adding an even number of 1/4 waves for a high output resistance or vice-versa -- results in a curious 'degenerate' condition, where the working Q appears to collapse. Resonator bandwidth expands by an order of magnitude, and the potential for transmitter overload increases substantially -- a condition to be avoided!

The rationale for these results is revealed by transforming z_{in} to the complex reflection coefficient $\Gamma = (z_{in} - 1) / (z_{in} + 1)$ and plotting the result on a Smith Chart over a frequency sweep centered at the matched resonant frequency. The locus of Γ -- measured at the transmitter-end of the feed-line -- is described by a geometric construct called a 'Q circle'. Correct alignment of frequency (and/or the degenerate condition cited above) is governed by symmetry of the Q circle relative to the horizontal axis of the Smith Chart.

Abstract 203 Regular Poster - Poster Sessions

Design of Magnet of Non-Scaling Fixed Field Alternating Gradient Accelerator with Asymmetric Current

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The type of magnets that makes the required magnetic field for the Fixed Field Alternating Gradient (FFAG) accelerator is "iron pole shape". The design of "iron pole shape" is more complicated than the conventional multipole magnet. To solve the problem, the Non-Scaling Fixed Field Alternating Gradient (NS-FFAG) accelerator which is able to be built using conventional multipole magnets is suggested. Currently, the quadrupole was employed for the constructed NS-FFAG accelerator. The focusing strength of magnetic field in quadrupole can vary with orbit radius differently the "iron pole shape". Therefore, if the beam was added energy in the accelerator, the beam could be unstable. Also, the way of alignment of quadrupoles for the NS-FFAG accelerator induces that the beam is placed at the end of poles of magnets. It is known that the beam at the end of poles is unstable.

To overcome instability of beam, the study makes difference of current flew in each coil of the quadrupole for the constructed NS-FFAG accelerator. Consequently, the center of beam is fixed at the center of the quadrupole. Also, the magnetic field with the asymmetric current is more similar the required magnetic field for FFAG accelerator than the constructed NS-FFAG accelerator. The suggested magnetic field was simulated by the OPERA-3D program. Field indexes were obtained by fitting to the simulated magnetic field in order to compare distributions of magnetic fields which were the suggested magnetic field, the constructed NS-FFAG accelerator and the FFAG accelerator.

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An Examination of the Application and Benefits of a Fully Digital Acquisition System for High Count Rate Radiation Detection and Spectroscopy

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An ideal progression for a modern ion beam analysis laboratory lies in the potential of a fully digital acquisition system (DAS) that combines pulse processing for energy and timing analysis with ion beam control (synchronized scanning, start and stop) in a single system. The true strength of digital acquisition systems lies in the potential for individually optimized digital filter response (DFR) via specific parameters that could be used across multiple ion beam analysis setups (i.e. PIXE, RBS, STIM). Use of an infinite impulse response (IIR) filter allows for this flexibility and an achievable realization of an optimum DFR for any given input signal across multiple detector characteristics. The acquisition system is set up for two four-channel digitizers with onboard FPGA for pulse processing. All timing characteristics for IIR filters are user controlled. Each channel has baseline restoration, pulse pile-up rejection, and individual channel-energy calibration. The system was tested with a precision pulser and a wave function generator to simulate active transistor reset and resistive reset preamplifier signals. The performance was then tested using X-ray detector with a FE-55 source and a particle detector with an AM-241 source. Other tests included the integral and differential linearity of the system as well as the response and efficacy of digital baseline restoration and pulse pile-up rejection.

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The Cryogenic Current Comparator, a SQUID based diagnostics for non-intercepting intensity measurements in the nA range

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The cryogenic current comparator (CCC) for ion beam current measurements was shown to be a unique device to measure the beam intensity of slow extracted beams down to nano-Ampere precision non-destructively. After successful beam measurements at the GSI accelerator beam line, a new advanced CCC system with improved current sensitivity is under development, six units of which are foreseen to be installed in the upcoming FAIR accelerator facility at GSI. The new CCC system will be first installed in the Cryring@ESR storage ring for further optimizations, as a commissioning tool and as an additional instrument for atomic physics experiments. It is designed to satisfy various geometrical and cryogenics boundary conditions at FAIR along with optimized sensor parameters. The beam tests results with the existing GSI-CCC prototype as well as the results of FEM simulation for magnetic shield optimization will be presented together with the overall design of the new FAIR CCC.

Abstract 370 Regular Poster - Poster Sessions

Laser Plasma Acceleration: Moving Towards External Injection with CO2 Lasers

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It can be shown that the conditions for laser wakefield acceleration (LWFA) scale favorably with near-IR lasers due to the higher ponderomotive potential that is provided relative to lasers operating with wavelengths near 1µm - a two order of magnitude effect. The 10 µm, high-power, CO_2 laser at the Brookhaven National Lab. Accelerator Test Facility (ATF) is an excellent candidate for external electron beam injection in the so-called "blowout" regime.

We outline the case for near-IR lasers as drivers for laser plasma acceleration and detail the ongoing efforts at the ATF.

Abstract 383 Regular Poster - Poster Sessions

S-Band Thermionic RF Source with Improved Back-Bombardment Suppression

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The push to higher power electron beams for industrial practices requires electron sources that are capable of producing currents that are greater than 1 ampere. The ideal source would have little, or no, damaging electron back-bombardment. FAR-TECH, Inc. is developing an electrons source directed toward the suppression of electron back-bombardment and an increase in electron capture efficiency. This source combines a short first cell and an independently driven second cell in close proximity to the first. The effects of the coupling mitigation scheme and simulation results will be presented.The push to higher power electron beams for industrial practices requires electron sources that are capable of producing currents that are greater than 1 ampere. The ideal source would have little, or no, damaging electron back-bombardment. FAR-TECH, Inc. is developing an electrons source directed toward the suppression of electron back-bombardment and an increase in electron capture efficiency. This source combines a short first cell and an independently driven second cell in close proximity to the first. The effects of the coupling mitigation scheme and simulation results will be presented.

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Gas Field-Ionization Emission from Frozen Taylor Cone of Liquid Metal Ion Source

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We present preliminary work on the examination of gas phase field emission from the frozen Taylor cone of a liquid metal ion source (LMIS). This project probes an unexplored aspect of field emission sources, and may potentially lead to a cost- and time-efficient method of producing multiple ion species from a high-brightness source.

The effects on a conducting, liquid surface due to the presence of an electric field are well-established. From Sir Geoffrey Taylor's mathematical analysis, the shape of the liquid surface under static high field conditions is a cone with exterior half angle of 130.7^o. The LMIS is not static, though, and the apex of the cone undergoes changes associated with increasing field strength. Namely, the apex elongates at larger currents (larger fields) and is drawn out into a thin cusp.

Gas field-ionization sources (GFISs) operate by electrons tunneling into a surface from atoms outside the surface because of the presence of a large electric field. Gas atoms are attracted to the high-field emitter apex region through polarization, and ionize in this manner at a critical distance from the emitter surface.

We have designed and built a LMIS, including the additional capability of introducing gas for gas phase field emission. Here we will discuss our source design, present initial measurements of output current vs. extraction voltage, and finally present measurements of current vs. time for a 'quenching' experiment. This 'quenching' is where we cool the LMIS while in operation, freezing the Taylor cone in place.

This project will ultimately evaluate the various emission properties of a frozen LMIS (FMIS). From these results we will be able to provide insight on the possibility of a GFIS whose emitter is the Taylor cone of a FMIS.

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Ion Cyclotron Resonance Heating Transmitter Opening Switch Upgrade

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Diversified Technologies Inc. (DTI) is currently installing a high-power solid-state opening switch upgrade package to replace the current mercury ignitron crowbars in the Ion Cyclotron Resonance Heating (ICRH) Transmitters operating at MIT Plasma Fusion Science Center's (PFSC) Alcator C-Mod, a Tokamak-type fusion experimental device. The speed of the series opening switch avoids the large fault currents on the transformer and power feed inherent with a crowbar. This improvement enables re-optimization of the Transformer/Rectifier (T/R) set, ultimately allowing increased power output and increased tetrode reliability.

A key concern is the possibility of ignitron explosion. Such explosions have occurred in the past, leading to the release of mercury into the cabinet and possibly the laboratory. This risk was unavoidable until improved protection switches, such as the solid-state opening switch, became practical. A second key concern is transmitter output power. The ratings of the existing high voltage power supply in the transmitter are a compromise between high output power (lower impedance required from the T/R set) and crowbar reliability (higher impedance required from the power supply to limit fault current). The opening switch upgrade safely allows the use of significantly reduced transformer impedance and lower droop, giving increased power as well as improved tube protection.

The hardware developed was specifically optimized for the legacy FMIT (Fusion Materials Irradiation Test) transmitters (manufactured by Continental Electronics) in use at several laboratories. The FMIT transmitters started out as "classic" 600 kW 80 MHz continuous wave units intended to power a linear accelerator for deuterons. The original systems have a triode low power amplifier, a tetrode driver stage and a high-power tetrode final amplifier. The DOE fusion community has upgraded these systems extensively over the past 25 years . DTI's opening switch kit can readily be adapted to any similar transmitters (such as the ABB transmitters at General Atomics) as an upgrade from a crowbar. The kit applies DTI's proven high voltage solid-state switching technology to the plate and screen grid supplies of both the Final Power Amplifier and Driver Cavity Amplifiers (four switches and controls).

The work applies directly to transmitters used for ITER component development testing and is also applicable to newly built transmitters. The upgrade is designed as a kit which can be installed into existing transmitters with minimal disruption and downtime for the fusion experiments.

Abstract 402 — Regular Poster - Poster Sessions

Accuracy of a mechanical alignment strategy for integrated metallization patterns on optical fibers.

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We have described, in a companion paper, a simple process for fabricating 4-channel neural probes on fine optical fibers for optogenetic interrogation of neural circuits. The extension of this technology to probes with the large number (>40) of micrometer-scale contacts that are needed to map laminar circuits in the brain requires a significant advance in alignment technology. As with the 4-channel probes, integrated wiring patterns are printed by ion beam proximity lithography on 4-sides of an optical fiber substrate using a conformal, plasma deposited resist [Parikh et al. J. Microelectromechanical Systems 17, pp. 735-740, 2008]. Fibers are held in anisotropically-etched V-grooves that terminate on an integral stencil mask. The width of the groove determines the distance between the fiber and the mask. When the stencil mask is illuminated by a broad beam of 50 keV helium ions, transmitted beamlets transfer the mask pattern to resist on the fiber. The current exposure jig enables ten fibers to be exposed at the same time-potentially there could be many more.

The near-atomic straightness of fiber holder and accurate registration of the mask pattern with the V-grooves ensures that the printed pattern will be centered on the bottom of the fiber. Two patterns on the fiber will lay one over the other if and only if a) corresponding features on the two patterns are the same distance from the probe tip and b) they have the same rotation relative to a common reference. Longitudinal alignment (a) is achieved using a fiber-stop, while rotational alignment (b) uses a high precision cubic bead glued to the end of the fiber as the reference. The fiber stops are high precision ball bearings which are glued to lithographically defined pits at the tip-end of each V-groove. The variation in diameter and sphericity of the balls is 0.25 micrometers. A manual process has been developed for gluing the balls at the end of the pit. An experiment has been carried out to assess the longitudinal errors in gluing 12 balls in 12 different pits. The measured (SEM) errors show a tight clustering below 0.25 micrometers with few outliers in the 1-5 micrometer ranges. The errors seem to be due to etching defects. Rotational errors are expected to be in the sub-micron regime.

The results of 2-mask overlay experiments will be presented at the conference.

Abstract 86 — Regular Poster - Poster Sessions

PIXE analysis of commercial breakfast cereals

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X-ray spectrometric methods like Particle Induced X-ray Emission (PIXE) or X-Ray Fluorescence (XRF) have been applied in the determination of the contents of certain elements in food, like tomato puree [1] or dried chili [2]. In the present work, PIXE is applied to measure elemental concentrations in breakfast cereal (corn, rice, oat meal and/or wheat) samples. The specimens were obtained from market packages, freeze dried, ground in an agate mortar and pressed into pellets. A 2 MeV proton beam was used to carry out PIXE analysis. The detection system calibration was done with NIST certified reference materials of tomato and orchid leaves, while the analytical accuracy was verified with NIST 3233 reference material (fortified cereal). The elements found and their concentrations did not exceed intake standards.

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References

[1] E. Romero-DÁvila and J. Miranda, J. Radioanal. Nucl. Chem. 262 (2004) 355-362.

[2] E. Romero-DÁvila, J. Miranda and J. C. Pineda, AIP Conf. Proc. 1671 (2015) 020006.

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