Abstracts

Office of Nuclear Physics SBIR/STTR Exchange Meeting
September 13-14, 2020

Note: The ordering of the abstracts matches the ordering of the talks.

Day 1: August 13, 2020

Manufacturing and Packaging of Bialkali Photocathodes Grown via Sputtering

Harish Bhandari, RMD Inc., MA
Grant Title: Manufacturing and Packaging of Bialkali Photocathodes Grown via Sputtering
NP SBIR/STTR Topic: **Accelerator**

The Relativistic Heavy Ion Collider (RHIC) at BNL is the nation's premier quantum chromodynamics (QCD) research facility. Its future upgrade calls for the implementation of electron cooling strategies, where ultra-cold electron beams will be generated by photoinjectors. The photocathode, where the electron beam is produced, is required to deliver a significantly high average current (~50 mA) to meet the upgrade requirement. Bialkali cathodes are capable of delivering this high average current, however, based on their lifetimes, they have to be replaced frequently. Hence, there's a need for commercially-available photocathodes that can be produced reliable and supplied in sufficient quantities.
To address this problem, RMD is developing a reliable manufacturing method for bialkali cathodes, where the cathodes can be sealed under vacuum in transportable cartridges. By doing so, these cathodes can be mass produced and stockpiled for their daily use at RHIC. The sealed cathodes can be unsealed at the accelerator and handed off easily to a photoinjector gun to produce the electron beam with the desired emittance and brightness.
The program described in this SBIR integrates a revolutionary cathode growth method proven for its high volume manufacturing with a reliable cathode sealing technology to provide transportable cathodes for the electron cooler. Specifically, RMD will design and build a cathode growth system, which can reliable produce bialkali cathodes, measure the QE and seal them in a transportable cartridge. Later, these cathodes will be unsealed to re-measure their QE and hand off to a DC gun to produce electron beam and measure its lifetime and current.

HOM Absorber Design for eRHIC ERL Cavity

Thomas Schultheiss, TJS Technologies, NY
Grant Title: HOM Absorber Design for eRHIC ERL Cavity
NP SBIR/STTR Topic: **Accelerator**

The Office of Nuclear Physics long range plans include allocation of resources to develop technology for a polarized electron-ion collider. Early BNL effort of their Electron Ion Collider (EIC) included an Energy Recovery Linac design that would provide for significant upgrade in luminosity. One of the components that requires significant development is the high current ERL SRF cavity. To preserve the beam and its characteristics it requires higher order mode absorbers

both in-line and cavity damped. This SBIR focuses on the design and development of an HOM absorber module to be used with a multi-cell cavity and in-line beampipe.

In Phase 1 TJS Technologies provided analysis to show that it has the proper material and geometry to absorb the required HOMs at the expected power level. We then developed an HOM manufacturing plan, design, and cost. BNL also requested a beamline design using a similar core of tile and backer. Phase II is to manufacture both waveguide and beamline prototypes. Though we have been delayed building the waveguide absorber we are presently on schedule to complete both the waveguides and beamline absorber by the end of year 2.

Keynote Presentation

NP Low Energy Facilities and the SBIR/STTR Program

Kelly Chipps, Oak Ridge National Laboratory

Techniques for Energetic Ion Assisted In-Situ Coating of Long, Small Diameter, Beam Pipes with Compacted Thick Crystalline Copper Film

Art Custer, Poole Ventura Inc., CA

Grant Title: Techniques for Energetic Ion Assisted In-Situ Coating of Long, Small Diameter, Beam Pipes with Compacted Thick Crystalline Copper Film

NP SBIR/STTR Topic: **Accelerator**

Techniques for energetic ion assisted in-situ coating of long, small diameter, beam pipes with compacted thick crystalline Copper film.
Electron clouds in accelerators limit machine performance through associated dynamical instabilities and/or vacuum pressure increases. High wall resistivity can cause heating and instabilities in accelerators. Coating accelerator vacuum tubes with compacted thick crystalline copper will mitigate those problems and can enhance luminosity.

To address this challenge our primary goal has been to design, build, and optimize operation of a robotic IAD (Ion Assisted Deposition) device for in-situ coating of long small diameter tubes with defect free Copper films. To date several IAD magnetron iterations have been designed and tested. This process has led to the development of a discharge cleaning process to improve adhesion characteristics of coated tubes. We have also designed and manufactured guide wheel assemblies to drive the magnetron thru accelerator sections with bellows. Designed and fabricated a cryogenic resonator for testing coated samples and also optimized a sputter coating process. We still face challenges in meeting our original goal of IAD deposition in long tube sections but our confident our next generation tool is a step in the right direction. Current studies have us pursuing an IAD magnetron device with self-contained solenoidal magnetic field. This device is currently in the concept phase with promising simulations in process.

Development of Gen-II LAPPD^{TM} Systems for Nuclear Physics Experiments

Michael Foley, Incom, Inc., MA

Grant Title: Development of Gen-II LAPPD^{TM} Systems for Nuclear Physics Experiments

NP SBIR/STTR Topic: **Instrumentation**

Incom Inc is now producing a capacitively coupled version of the Large Area Picosecond Photo-Detector (LAPPD) – the largest commercially-available planar-geometry photodetector based on microchannel plates (ALD-GCA-MCPs). It features an internal ground plane coupled to a pixelated anode with a stacked chevron pair of "next generation" large area 20um pore MCPs produced by applying resistive and emissive Atomic Layer Deposition (ALD) coatings to glass capillary array (GCA) substrates encapsulated in a ceramic or glass hermetic package. The entry window of the detector is coated with a high sensitivity semitransparent bi-alkali photocathode with 350 cm2 detection area. Signals are read out on pixelated signal boards applied to the bottom of the device. Pixelation can improve detection of photons in high rate environments and of Cherenkov light, and the pixelated pattern can be changed easily by the customer. These devices have demonstrated electron gains of 107, low dark noise rates (15-30 Hz/cm2), single photoelectron timing resolution of 71 picoseconds RMS, single photoelectron spatial resolution of ~2.8 mm RMS with 25 mm pixels, spatially uniform bi-alkali photocathodes with QE ~28%, and low sensitivity to magnetic fields, measured up to 0.8 T. A version with a Fused Silica window featuring an extended UV sensitivity photocathode is also being developed. Performance examples will be shown for a variety of signal board patterns including striplines, and pixels from 25 mm down to 3 mm in size. The challenges of window sealing will also be discussed.

LAPPDs can be employed in particle collider experiments (e.g. SoLID, future EIC), neutrinoless double-beta decay experiments (e.g. THEIA), neutrino experiments (e.g. ANNIE, WATCHMAN, DUNE), medical (PET) and nuclear non-proliferation applications. Production of LAPPDs have increased from one/month in 2018, to four/month in 2020.

Keynote Presentation

Jefferson Lab Medium Energy Physics and S&T Programs

Michael Spata
Thomas Jefferson National Accelerator Facility

Nuclear Physics Gamma-ray Imaging System for Real-Time Rare Isotope Harvesting, Monitoring and Radiochemical Separation – NP Imager

Ethan Hull, PHDs Company, TN

Grant Title: Nuclear Physics Gamma-ray Imaging System for Real-Time Rare Isotope Harvesting, Monitoring and Radiochemical Separation – NP Imager

NP SBIR/STTR Topic: **Instrumentation**

DOE Nuclear Physics missions include the production, harvesting and radiochemical separation (purification) of rare isotopes as part of both Nuclear Physics Research and Radioisotope Production. The two fields have a unique connection in the projectile-fragment harvesting research at the National Superconducting Cyclotron Laboratory (NSCL), where a recirculating

aqueous beam stop captures rare isotopes from the beam and accumulates them in various collection systems including resin columns. As many as 100 different isotopes can be present with an overall activity as high as ~ 1 Ci. Direct gamma-ray imaging of the columns, beam stop, and collection vessels is extremely useful with this large plurality of gamma rays. A new high-purity germanium (HPGe) imaging detector system called the NP-Imager (Nuclear Physics Imager) provides HPGe spectroscopy and gamma-ray imaging at the same time to produce dynamic radiological-location maps of the isotope distributions during these radiochemical processes. The development of the NP Imager and some Phase-II results demonstrate great promise for this technology.

Multi-Scale Modeling for Beam-Beam Depolarization

Ilya Zilberter, Tech-X Corporation, CO

Grant Title: Multi-scale Modeling for Beam-Beam Depolarization

NP SBIR/STTR Topic: **Accelerator**

Accurate simulation of spin precession and orbital dynamics is critical in the design of the next generation of spin-polarized particle accelerators, such as the proposed Electron-Ion Collider. We present a summary of our work to develop efficient modeling tools for spin-polarized particle beams, including an extension to the spin tracking code GPUSpinTrack that allows for the rapid simulation of electron beams on graphics processors.

Accurate Spin Tracking on Modern Computer Architectures for Electron-Ion Colliders

Boaz Nash, RadiaSoft LLC, CO

Grant Title: Accurate Spin Tracking on Modern Computer Architectures for Electron-Ion Colliders

NP SBIR/STTR Topic: **Accelerator**

An electron ion collider (EIC) has been identified by the Nuclear Science Advisory Committee as an important tool to explore the fundamental origins of nuclear spin. High polarization (>80%) is required for both electron and ion beams. Spin tracking studies allow validation of EIC designs and ensure this level of polarization will be achieved. RadiaSoft has worked with Zgoubi, a spin tracking code to modernize the interface and underlying Fortran code, including it in Sirepo, as well as enabling convenient use within Jupyter notebooks. We describe the Sirepo interface to Zgoubi as well as our engagement with the accelerator physics community and how this contributes to the EIC design effort.

IP Access Gateway

Radu Radulescu, Telluric Labs, NJ

Grant Title: TTDAQ: A Continuous Flow, Timing and Trigger DAQ System

NP SBIR/STTR Topic: **Electronics**

IP Access Gateway (IPAG) is the keystone for a new generation of software driven, continuous acquisition, and in band timing synchronization system, capable to exceed Pbps aggregated bandwidth boundaries for nuclear research labs and other massive data systems. IPAG is a

Backend Electronics board assembly that is configurable as a continuous, piped timestamping engine with pS accuracy, at a sustained, average hit rate of 20-200 million particles hits per second, per channel. Also can be configured as a network node with 64 to 96 ports up to 25Gbps, aggregating up to 1.6Tbps bandwidth, and four 8x PCIe gen4.0 interfaces. In addition, it can accommodate more than 100 low speed 1 to 3.5 Gbps serial digital links, or direct analog signals optically transferred from the detector. IPAG's massive readout bandwidth simplifies FE by reducing or eliminating local buffering. The increased network transport capacity is achieved through radhard optical connectivity direct to the FE ASIC.
IPAG's architecture and the Ultrascale+, High Bandwidth Memory (HBM) FPGA allows an unique integration of functionality. Further, the Generalized Timing Synchronization (GTS) protocol provides deep sub-nS, Ubiquitous Synchronous Time (UST) through Detector's asynchronous network, using the highly accurate timestamps generated by the FPGA. This is essential for eliminating specialized, proprietary, and expensive HW, and eliminates single points of failure for the experiment.
The IPAG provides the lowest cost per channel due to the high number of interfaces and the use of the latest generation, high density FPGAs. Currently we are expanding our technology with DWDM transceivers that can aggregate the entire Tbps traffic on a single fiber for a very low multiplexing cost of inherently radhard, PON technologies. IPAG's modular structure allows configurations that would appeal to several complementary, high volume markets, such as accelerator FPGA boards, or HPC NIC cards for example.
IPAG's architecture addresses high performance data acquisition markets for both real time, physics DAQ, Data Centers, and FPGA based computing acceleration, and low latency data switching.

Current Magnetron Development at Muons, Inc.

Mike Neubauer, Muons Incorporated, IL

Grant Title: A Novel Injection-Locked Amplitude-Modulated Magnetron at 1497 MHz

NP SBIR/STTR Topic: **Accelerator**

The Status of the DOE-NP Phase II is presented along with an additional magnetron development project from DOD-NRL.

Distributed Digital Data Acquisition System with Network Time Synchronization

Wolfgang Hennig, XIA LLC, CA

Grant Title: Distributed Digital Data Acquisition System with Network Time Synchronization

NP SBIR/STTR Topic: **Software**

As radiation detector arrays in nuclear physics applications become larger and physically more separated, the time synchronization and trigger distribution between many channels of detector readout electronics becomes more challenging. Clocks and triggers are traditionally distributed through dedicated cabling, but newer methods such as the IEEE 1588 Precision Time Protocol and White Rabbit allow clock synchronization through the exchange of timing messages over Ethernet.

Consequently, we report here the use of White Rabbit in a new detector readout module, the Pixie-Net XL. The White Rabbit core, data capture from multiple digitizing channels, and subsequent pulse processing for pulse height and constant fraction timing are implemented in a Kintex 7 FPGA. The detector data records include White Rabbit time stamps and are transmitted to storage through the White Rabbit core's gigabit Ethernet data path or a slower diagnostic/control link using an embedded Zynq processor. The performance is characterized by time-of-flight style measurements with radiation from coincident gamma emitters and by time correlation of high energy background events from cosmic showers in detectors separated by longer distances. Software for the Zynq controller implements "software triggering", for example to limit recording of data to events where a minimum number of channels from multiple modules detect radiation at the same time.

Dynamic Friction in Magnetized Electron Coolers for Relativistic Beams

David Bruhwiler, Radiosoft LLC, CO

Grant Title: Dynamic Friction in Magnetized Electron Coolers for Relativistic Beams

NP SBIR/STTR Topic: **Accelerator**

Effective cooling of high-intensity relativistic ion beams is important for achieving the luminosity goals of the proposed BNL electron-ion collider (EIC) design. One approach is to scale magnetized electron cooling techniques from existing nonrelativistic systems to the fundamentally different parameter regime of electron bunches with relativistic gamma factors of order 40. Because the technique would be applied in a previously untested parameter regime, accurate calculations of both magnetized and unmagnetized friction are required. We present new analytic and numerical friction calculations for this new parameter regime, showing areas of agreement and disagreement with previous work. We also present optimized JSPEC simulations of intrabeam scattering (IBS) and electron cooling for the BNL EIC design, indicating that 20 minute cooling times are possible for 25 GeV proton beams (i.e. at injection into the collider ring).

Radiation-Tolerant High-Speed Camera

Matt Engelman, Alphacore Inc., AZ

Grant Title: Radiation Hard High Speed Camera System for Accelerator Beam Diagnostics

NP SBIR/STTR Topic: **Instrumentation**

In response to Department of Energy SBIR topic 24h, Alphacore Inc. has been developing a radiation-tolerant, triggerable, high speed imaging chip and a complete camera system for investigating rapidly occurring phenomena in radiation environments. One of the main applications is beam monitoring in particle accelerator facilities.

A Multi-Channel Radiation-Tolerant, Low Power, High-Speed, and Resolution Analog-to-Digital Converter for Nuclear Physics Detectors

Ping Gui, TallannQuest LLC, TX

Grant Title: A Multi-Channel Radiation-Tolerant, Low Power, High-Speed, and Resolution Analog-to-Digital Converter for Nuclear Physics Detectors

NP SBIR/STTR Topic: **Electronics**

Nuclear physics experiments require the detection of the arrival and the interaction points of particles or photons with high timing resolution and accuracy. High-resolution timing detectors require the precise extraction of information from the sensor signals and need to withstand high levels of radiation. The purpose of this project is to develop an analog-to-digital converter that would serve for the waveform analysis on the detector and would be able to tolerate a TID up to 10Mrad, as well as single-event effects. An initial 12-bit ADC design, implemented in a 65nm CMOS process, shows promising results, with a sampling rate up to 2.56GHz. A more recent design in the more advanced 28nm has also been fabricated, and several test-chips that incorporate basic building blocks in this 28nm process are being tested for radiation performance. Ultimately, based on this technology, a 16-channel system-on-chip (SoC) ADC, having a high-speed interface for real-time reading, will be targeted in an extension of this project.

This presentation also includes the company's other radiation-resilient offerings, such as a rad-hard 180nm CMOS process design kit (PDK) developed in collaboration with TSI Semiconductors, and a family of rad-hard ICs based that was designed based on it.

Software-Driven Network Architecture for Synchronous Data Acquisition

Gary McMillian, Crossfield Technology LLC, TX

Grant Title: Software-Driven Network Architecture for Synchronous Data Acquisition

NP SBIR/STTR Topic: **Software**

Crossfield's Instrumentation Gateways provide data acquisition, precision timing and network communications. The gateways include FMC+ slots for multi-GSPS ADCs, a 100G Ethernet optical network interface and a high-performance FPGA to implement instrumentation and signal processing functions. Remote Direct Memory Access (RDMA) protocol over Converged Ethernet (RoCE) provides an industry-standard interface to a high-performance computer (HPC). Crossfield ported the software implementation of RoCE to a quad-core ARM processor in the FPGA, providing compatibility with industry-standard network adapters. Raw or processed data can be streamed directly to the HPC at low latency and high throughput using a RoCE hardware accelerator in the FPGA fabric. With RoCE, the sensor data can be transported directly into the HPC processor or coprocessor memory (e.g. NVIDIA Tesla) for processing and event building, or into storage using NVMe over RoCE.

Automated Preparation of 211AT for Targeted Alpha Therapy Applications

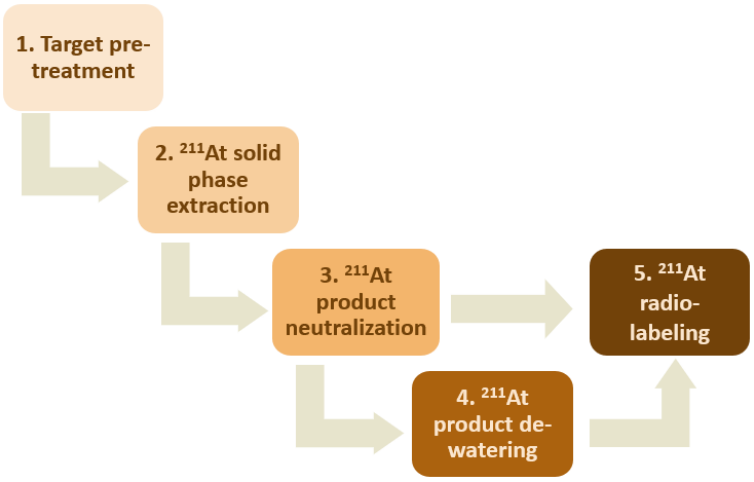
Graham Marshall, Global FIA, Inc. WA

Grant Title: Automated Preparation of 211AT for Targeted Alpha Therapy Applications

NP SBIR/STTR Topic: **Isotope**

Astatine-211 has been identified as a leading contender for future targeted alpha therapeutics (TAT). Its short half-life and absence of toxic daughter products make it ideally suited for precision treatment of various malignancies. Its low natural abundance, poorly understood

chemistry, and multi-step purification processing has hampered its wide-spread acceptance. Researchers at PNNL and Global FIA with funding from the Isotope Program Office has undertaken the development of an automated fluid handling system for the isolation of ^{211}At to address this shortcoming.
In this presentation, progress to date in the design and optimization of five unit-operations that are required for product isolation will be presented.



Low Cost Data Acquisition Synchronization for Nuclear Physics Applications
Wojtek Skulski, SkuTek Instrumentation, NY
Grant Title: Low Cost Data Acquisition Synchronization for Nuclear Physics Applications
NP SBIR/STTR Topic: **Software**

I will describe our prototype of digital pulse processors with 32 channels digitizing at 14 bits @ 100 MHz, equipped with front panel gigabit Ethernet readout, as well as the back panel ten gigabit Ethernet and the link to ATLAS Time and Trigger Control Link (TTCL). In Phase I, we performed measurements with high purity germanium Gammasphere detectors. In the first year of Phase II we developed and tested the hardware boards. These developments provide a foundation for designing the digital pulse processors for ATLAS, FRIB, and other Nuclear Physics facilities.

Design, Construction, and Testing of a Magnetized Electron Source
Karl Smolenski, Xelera Research LLC, NY
Grant Title: A Magnetized Injector for Electron Cooling Applications
NP SBIR/STTR Topic: **Accelerator**

In Phase I of this SBIR project, Xelera Research LLC performed simulations and calculations to develop a prototype design for a magnetized electron injector that can be used as a source for cooling an ion beam. We developed general design methodologies and techniques that are applicable not only to specific machine designs but to other applications requiring magnetized injectors as well. In this Phase II SBIR project, Xelera Research LLC, in collaboration with a team

at JLab, designed, built, and tested a thermionic electron source for driving a magnetized electron cooler in a future electron-ion collider project. This device was delivered to JLab in July 2019 and achieved first beam in December 2019.

Simulating Plasma Formation in SRF Cavities

Jarrod Leddy, Tech-X Corporation, CO

Grant Title: Modeling Plasma Discharge Cleaning of SRF Cavities

NP SBIR/STTR Topic: **Accelerator**

Superconducting radio frequency (SRF) cavities are utilized for acceleration in particle accelerators, and therefore must sustain large electromagnetic fields. Impurities on the surface of the cavity can cause arcing and therefore lower the maximum obtainable fields inside the cavity. One method being pursued for removing these impurities is to treat the cavity surface with a plasma for both mechanical and chemical removal, but the formation of this plasma is not well understood.

We have performed electromagnetic particle-in-cell simulations using VSim to investigate the plasma formation via ionization cascade using a Monte Carlo collision framework. The energy to sustain this ionization is provided via electromagnetic modes excited within the cavity; these modes are well described in vacuum via pure EM simulation (*i.e.*, without particles). To model plasma formation, a background gas is included along with impact ionization, electron scattering, and recombination. With this full set of physics requirements, we have explored the EM power threshold for plasma ignition at experimentally relevant background gas pressures and compared them with experimental data.

In addition to plasma formation, the behavior of the plasma at long time scales is also of interest since it is the steady state plasma properties that determine the plasma's ability to remove impurities from surfaces. PIC simulations are too expensive for any time scale longer than hundreds of nanoseconds, so a hybrid model has been implemented in VSim for this purpose. Such a model treats the ions as kinetic species and approximates the electrons as a fluid with source terms determined by the previously conducted PIC simulations of the plasma formation. We will describe the hybrid model implementation and show preliminary benchmarks for this implementation.

Day 2, August 14, 2020

A Scalable Additive Manufacturing Technology for Large Area Printed Circuit Boards

Nalin Kumar, UHV Technologies, Inc., KY

Grant Title: A Scalable Additive Manufacturing Technology for Large Area Printed Circuit Boards

NP SBIR/STTR Topic: **Electronics**

The goal of this phase II SBIR project is to develop an innovative 3D printing technology called confined electro-deposition (CED) that can fabricate pure metal features at room temperature with bulk metal conductivity. In this presentation, we will provide an update on the latest results as well as our efforts to develop a 3D printer that can fabricate both plastic and metal parts in the same 3D printer.

Scintillating Bolometer Crystal Growth and Purification for Neutrinoless Double Beta Decay Experiments

Michael Squillante, Radiation Monitoring Devices, Inc., MA

Grant Title: Scintillating Bolometer Crystal Growth and Purification for Neutrinoless Double Beta Decay Experiments

NP SBIR/STT Topic: **Instrumentation**

In the search to better understand the fundamental physics of our universe, a crucial goal is elucidating the nature of the neutrino. Although our understanding of the physics of the neutrino is improving, many questions remain.

Research at the frontier of nuclear physics is often limited by the capabilities of available detectors. More sensitive detectors are required to detect and characterize very rare nuclear events. This SBIR project will lead to the production of such high sensitivity detectors needed for elucidating the nature of the neutrino.

The objective of the program is to develop the capability to produce Li2MoO4 (LMO) crystals suitable for neutrinoless double-beta decay experiments. A major component of the project is to improve crystal purity for reduced radioactive background, and for optimizing bolometric and scintillation performance at cryogenic temperatures. Another key aspect of the project is the optimization and scale-up of the crystal growth process.

This project is being performed in collaboration with MIT and the CUPID Interest Group. Cryo-test runs have been made by the MIT team using RMD LMO and performance and radio-background data have been generated. Purity and scintillation performance of the RMD crystals have been commensurate with other sources of LMO being investigated by the CUPID Interest Group.

Boron Nitride Nanotube Vibration Damping for SRF Structures

Roy Whitney, BNNT, LLC, VA

Grant Title: Boron Nitride Nanotube Vibration Damping for SRF Structures

NP SBIR/STTR Topic: **Accelerator**

Boron nitride nanotubes (BNNTs) demonstrate viscoelastic behavior that can be utilized for passive vibration damping over a temperature range from 2 K to 700 K. We have demonstrated that BNNT pellets demonstrate effective damping of a Jefferson Lab CEBAF C100 Superconducting Radio Frequency (SRF) cavity at room temperature, and we are preparing for testing at 2 K. Additionally, we are exploring BNNT vibration damping at 2 K for cavities in an LCLS cryomodule.

Long-Term Radiation Rugged Rotary Vacuum and Water Seals in Heavy-Ion Accelerators

Jennifer Lalli NanoSonic, Inc., VA

Grant Title: Long-Term Radiation Rugged Rotary Vacuum and Water Seals in Heavy-Ion Accelerators

NP SBIR/STTR Topic: **Instrumentation**

The Department of Energy's Office of Nuclear Physics has identified a need for materials that will survive high radiation environments to support next generation rare isotope beam facilities such as Michigan State University's Facility for Rare Isotope Beams. The goal of this program is to develop a long-lifetime, rotary vacuum and water seal that can survive 0.5 – 1.5 MGy/month for up to a year to minimize maintenance within this radioactive environment. Current gaskets and seals do not offer the combined mechanical and radiation survivability needed for multiple years of service. The approach for new seals involves the synthesis of innovative polymers compounded and extruded with radiation tolerant materials such as BN as composites that offer combined low air and water permeability with extreme radiation durability. Advanced polyorganosiloxanes were developed and exposed to harsh irradiation at the Brookhaven National Laboratory (BNL) NASA Space Radiation Laboratory (NSRL) for a durability study to reach a Technology Readiness Level 4-5. Mechanical and thermomechanical testing of the new materials were conducted pre- and post- irradiation alongside current commercial off-the-shelf (COTS) seal materials. Permeation, rotational abrasion, and sealing experiments post representative rare isotope high radiation environment exposure are ongoing and high dose exposure is scheduled to be conducted at Brookhaven's Linac Isotope Producer. Radiation durable rotary vacuum and water seals shall be manufactured for use with rare isotope beam facilities for the stable production of new and rare isotopes. These isotopes shall also benefit medical accelerators, advanced imaging needs within the medical community, and military and space applications.

Keynote Speaker

The Relativistic Heavy Ion Collider Facility and its SBIR/STTR Opportunities

Michiko Minty, Brookhaven National Laboratory

12-bit 32 Channel 500MSps Low Latency ADC

Dalius Baranauskas, Pacific Microchip, CA

Grant Title: 12-bit 32 Channel 500MSps Low Latency ADC

NP SBIR/STTR Topic: **Accelerator**

Pacific Microchip Corp. is developing a 12-bit 32 independent channel 500MSps low latency ADC ASIC. Its targeted applications include particle beam control systems, multichannel gamma-ray and other types of detectors. Within the Phase II project, the prototype chip was designed, fabricated and assembled on a custom chip carrier. Currently the chip is being tested and characterized.

Radiation Hardened Opto-atomic Magnetometer

Jae Choi, Hedgefog Research Inc., CA

Grant Title: Radiation Hardened Opto-atomic Magnetometer

NP SBIR/STTR Topic: **Instrumentation**

Hedgefog Research Inc. (HFR) is developing a Radiation Hardened Opto-atomic Magnetometer (RHOM) for magnetic-field sensing applications in high-radiation environments. RHOM is a new approach to magnetometry that offers intrinsic radiation hardening by design. The RHOM probe modules will enable long, uninterrupted magnetic field sensing operation.

Multi-Channel Readout IC for Nuclear Physics Experiments

Esko Mikkola, Alphacore, Inc. AZ

Grant Title: Multi-Channel Readout IC for Nuclear Physics Experiments

NP SBIR/STTR Topic: **Instrumentation**

Alphacore will present results from a 2-year DOE Phase II STTR program for the development of versatile, low-cost readout integrated circuit (IC) solutions for nuclear physics experiments. We will discuss a few different preamplifier and analog-to-digital converter (ADC) ICs that are tailored to NP applications. We will also introduce our advanced digitizer IP library comprised of silicon-proven low-power digitizers from 300 megasamples per second (MS/s) to as high as 20 gigasamples per second (GS/s).

Long Length Welded NbTi CIC Superconducting Cable for Accelerator Applications

Michael Tomsic, Hyper Tech Research, Inc., OH

Grant Title: Long Length Welded NbTi CIC Superconducting Cable for Accelerator Applications

NP SBIR/STTR Topic: **Accelerator**

Reporting on NP SBIR Phase II on development of small diameter superconducting cables for fabricating of either 3 T or 6T dipole magnets. Discuss the fabrication of small diameter superconducting cables and forming the cables into coils. Discussion of using these cables designs for NbTi, MgB2, and Nb3Sn superconducting strands. Also discussions of other applications for the cables such as stator coils for superconducting motors, and transmission cables for connecting power supplies to superconducting magnets for accelerator applications.

Brief discussion of two NP SBIR Phase I's, MgB2 magnetic shield tubes for electron beams, and impact forming of Nb superconducting RF cavities with no electron beam welding.

Resonant Polarimetry and Magnetometry
Brock Roberts, Electrodynamic, NM
Grant Title: Resonant Polarimetry and Magnetometry
NP SBIR/STTR Topic: **Accelerator**

Electrodynamic has teamed with the Thomas Jefferson National Laboratory (JLab), and Cornell's Laboratory of Elementary-Particle Physics (LEPP) to create and evaluate non-invasive resonant polarimeters and magnetometers.

Prototype resonant polarimeters and magnetometers and a high sensitivity receivers have been designed and constructed for the polarized beam line at JLab's Upgrade Injector Test Stand and the magnetized beamline on JLab's Gun test stand (GTS). Progress toward beamline evaluation of these technologies will be reported.

Keynote Speaker
Update on the Department of Energy SBIR/STTR Program
Manny Oliver, DOE SBIR/STTR Office

High Power Extremely Narrow Linewidth Diode Laser for Polarizing 3He Target
Steven Lu, Raytum Photonics, VA
Grant Title: High Power Extremely Narrow Linewidth Diode Laser for Polarizing 3He Target
NP SBIR/STTR Topic: **Instrumentation**

Polarizing high intensity 3He gas is an extremely important task since polarized 3He is an effective neutron target for a broad nuclear physics programs such as some conducted in Jefferson Lab's Continuous Electron Beam Accelerator facility (CEBAF) and Spallation Neutron Source (SNS) in Oakridge National Lab. The polarized 3He gas has also been used in medical imaging to detect the lung disease. The polarization of 3He strongly relies on the power, linewidth, wavelength stability, and polarization of the pumping laser.

In the Phase II, we develop a fiber coupled diode laser system with output power of more than 200W, linewidth close to 0.1 nm and the lasing wavelength automatically locked to the Rb absorption line.

Low RF Loss DC Conductive Ceramic for High Power Input Coupler Windows for SRF Cavities
Ben Freemire, Euclid Techlabs LLC, OH
Grant Title: Low RF Loss DC Conductive Ceramic for High Power Input Coupler Windows for SRF Cavities
NP SBIR/STTR Topic: **Accelerator**

Ceramic RF windows used in power couplers for superconducting cavities are prone to accumulate volume and surface charges. The electric field generated by charging builds up until it discharges, with the resultant arc damaging or destroying the window. Euclid Techlabs has developed a new ceramic composition that exhibits low losses at high frequencies and is conductive at DC. This allows the charge to drain off rather than being accumulated in the material, which was confirmed via a beam charging test of both conductive and non-conductive versions of the ceramic. Windows made of this conductive ceramic were fabricated for use in 1.5 GHz and 650 MHz RF couplers at JLab and FNAL. Fabrication of four RF couplers (two for JLab and two for FNAL) has commenced. Construction of high power test stands at both labs is nearing completion, to be followed by high power tests of multiple windows at each lab to determine the maximum safe operating conditions. The window production and coupler brazing process is being formalized, leveraging Euclid's furnace commissioned during Phase II. Prototypes of RF coupler windows for the EIC and LHC will also be designed, produced and tested. Finally, this technology will be applied to normal conducting cavity couplers for wider use in industry.

Design and Fabrication of the ASoC: Analog to Digital Converter System on Chip

Isar Mostafanezhad, Nalu Scientific, LLC, HI

Grant Title: Design and Fabrication of the ASoC: A System-on-Chip Data Acquisition System

NP SBIR/STTR Topic: **Electronics**

Readout electronics for modern particle imaging based identification detectors must be compact, low power, deliver acceptable timing resolution and be robust to pile-ups. The solution is to integrate full waveform sampling, analog buffering and feature extraction and digital signal processing into one single Application Specific Integrated Circuit (ASoC in the following). ASoC can be used as a building block for such readout devices. The prototype fabricated ASoC has 4 channels, operates at 3 GSa/s and has on-chip trigger timestamping, calibration and signal processing capabilities. ASoC also provides 32k storage samples per channel which makes it suitable for large experiments. In this summary, measurements of analog and digital performance of the asic together with the next steps will be reported.

Graphene Backing for Radioisotope Targets

Richard Fink, Applied Nanotech, Inc., TX

Grant Title: Graphene Backing for Radioisotope Targets

NP SBIR/STTR Topic: **Instrumentation**

The overall goal of this project is to develop isotope targets using graphene-based, low-Z thin film material used as a backing material or matrix for holding isotope particles. The targets will have superior thermal and mechanical stability needed in charge particle induced experiments. This approach allows fabrication of thin targets using materials or isotopes that are difficult to roll into a thin foil. Target areal densities from 0.5 – 10 mg/cm^2 are demonstrated with using boron, iridium, tungsten, hafnium, rhenium, chromium and others in the form of natural elements, enriched isotopes and compounds (oxides, carbides, etc).

An ASIC with a Low Power Multichannel ADC for Energy and Timing Measurements

Anton Karnitski, Pacific Microchip Corporation, CA

Grant Title: An ASIC with a Low Power Multichannel ADC for Energy and Timing Measurements

NP SBIR/STTR Topic: **Instrumentation**

Pacific Microchip Corp. is developing an ASIC with a low power multichannel ADC for energy and timing measurements. It includes 32 independent 12-bit 200Ms/s ADCs with integrated digital backend for event detection and recording. Within the Phase II project, the prototype chip was designed and being fabricated.

Neutron Radiation Hardened Infrared Focal Plane Arrays

Yong Chang, Epir, Inc., IL

Grant Title: Radiation Hardened Infrared Focal Plane Arrays

NP SBIR/STTR Topic: **Instrumentation**

We will present our work on the design and fabrication of mid-wavelength-infrared (MWIR) HgCdTe-based focal plane arrays (FPAs) and on assembling the neutron radiation-tolerant infrared cameras to be used in nuclear reactors and the next-generation rare isotope beam facilities. The material system (HgCdTe) that we chose for FPA fabrication is relatively insensitive to radiation effects. Additionally, we optimized the device processes to mitigate expected changes in material properties under irradiation. High sensitivity HgCdTe FPAs can be tailored for response across the entire infrared spectrum and are commonly utilized at EPIR for the fabrication of infrared cameras. During this project, we demonstrated in collaboration with Fermilab, material, device, and camera stability under 10^8 neutrons/cm2/s irradiation flux, which is three orders of magnitude higher than the typical fluxes encountered in the isotope beam facilities. We also demonstrated material and device-level stability under 100 krad(Si) and 63 MeV proton irradiation We will present our current progress in the material growth and device processing technique development. We optimized the design of the camera architecture and shielding so that the detectors and electronics are exposed only to a small fraction of the total neutron flux. Our designed camera will be capable of operating at standard frame rates with video graphics array sensor resolutions, with a radiation tolerance for prolonged operation in the presence of neutron fluxes higher than 10^5 neutron/cm2/s and a total absorbed dose of ~ 1MRad/yr.

Precise and Ultra-Stable Laser Polarization Control for Polarized Electron Beam Generation

Bo Guo, Raytum Photonics, LLC, VA

Grant Title: Precise and Ultra-Stable Laser Polarization Control for Polarized Electron Beam Generation

NP SBIR/STTR Topic: **Instrumentation**

In this presentation, an innovative high precision, ultra-stable and fast switching circular laser beam polarization flipping system will be presented. This system is designed for generation of precisely controlled polarized electron beams for next generation Parity Violating Electron Scattering (PVES) experiments. It consists of three parts: modulator subsystem, laser table test

bed subsystem and central control software. We report the design and evaluation of modulator subsystem and laser table test bed subsystem, including the latest evaluation results of a dual DKDP EO modulator and a bi-level digital high voltage driver.

Low Cost, High-Density Digital Electronics for Nuclear Physics

Wojtek Skulski, Sku Tek Instrumentation, NY

Grant Title: Low Cost, High-Density Digital Electronics for Nuclear Physics

NP SBIR/STTR Topic: **Electronics**

Low Cost, High-Density Digital Electronics for Nuclear Physics Wojciech Skulski, SkuTek Instrumentation Grant Title: Low Cost, High-Density Digital Electronics for Nuclear Physics NP SBIR/STTR Topic: Electronics

I will describe our prototypes of digital pulse processors from two up to forty channels digitizing at 14 bits @ 100 MHz. We developed hardware, firmware, and Linux software running on embedded ARM processors. We also developed a remote GUI running in a web browser. We performed several measurements with different kinds of detectors, including high purity germanium. These developments provide a foundation for designing the digital pulse processors for ATLAS, FRIB, and other Nuclear Physics facilities.

A Novel Ionizing Particle Beam Fluence and Position Detector Array using the Micromegas Technology with Multi-Coordinate Readout

Evgeny Galyaev, Radiation Detection and Imaging Technologies, LLC, AZ

Grant Title: A Novel Ionizing Particle Beam Fluence and Position Detector Array using the Micromegas Technology with Multi-Coordinate Readout

NP SBIR/STTR Topic: **Instrumentation**

Upon completing Phase I and Phase IIA of the DOE SBIR program, Dr. Evgeny Galyaev of Radiation Detection and Imaging (RDI) talks about the current state of the "Ionizing particle beam fluence and position micro-pattern detector array with multi-coordinate readout" deliverables, the status, and the outlook beyond the completed DOE Phase II funding and the original project scope. Continued and expanding collaboration with the Texas A&M Cyclotron Institute is explored upon successful delivery of the micromegas detector array products made by the RDI team. Experimental applications of the RDI micromegas and readout technologies, as well as collaboration in using RDI methods and expertise in designing new resistive micromegas array and a GEM combination for the upgraded TexAT detector.
The continued collaboration with Mayo Clinic Arizona proton radiotherapy team is nearing the release of the RDI first unique3 commercial product, a proton fluence and position detector array for pencil-beam and continued beam scanning treatment modalities.