# Small Business Innovation Research/ Small Business Technology Transfer (SBIR/SBTT) Exchange

## *2024 Principal Investigators' Meeting*

## August 13-15, 2024

**Gaithersburg Marriott Washingtonian Center**

**Office of Nuclear Physics**

U.S. DEPARTMENT OF ENERGY | Office of Science

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# *Abstracts*

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# Tuesday, August 13 *(Day 1)*

## Material and Design Advances in Silicon-on-Insulator Substrates to Improve Nuclear Physics Sensors and Circuits

**Kevin O'Connor**, Caporus Technologies, Inc.

DE-SC0022480: Novel Insulators in Silicon-on-Insulator Substrates to Improve Nuclear Physics Sensors and Circuits

NP SBIR/STTR Topic: Electronics

Active pixel sensors (APS), including monolithic active pixel sensors (MAPS), have been developed and implemented as detectors in nuclear physics machines including the Relativistic Heavy Ion Collider and the Large Hadron Collider. Requirements to improve these detectors include reduced pixel size for increased resolution and increased radiation hardness to prevent errors and improve device lifetime. Silicon-on-insulator (SOI) substrates enable the isolation of the detector volume from the readout electronics and reduce coupling between adjacent transistors. While SOI thus has the potential to improve MAPS detectors with greater resolution, lower power consumption, faster speed, higher signal-to-noise ratio, and greater design flexibility, the buried oxide layer of the SOI structure is susceptible to generation of trapped charges due to radiation. To offer the advantages of SOI to MAPS detectors in high radiation environments, new materials and designs are needed. Caporus Technologies, Inc. is demonstrating the application of new material structures to provide engineered substrates with improved radiation hardness. In cooperation with Fermilab, the radiation hardness of these engineered substrates is being tested in preparation for MAPS demonstration. This presentation will provide background on SOI technologies, the proposed benefits and challenges for their application in MAPS detectors, and the new materials and designs under evaluation for the Office of Nuclear Physics.

## Gallium Oxide Semiconductor-based Large Volume Ultrafast Radiation Hard Spectroscopic Scintillators

**Amlan Datta**, CapeSym Inc.

DE-SC0021476: High Performance Scintillator for Nuclear Physics Research

NP SBIR/STTR Topic: Instrumentation

We report on the development of the first-ever inorganic radiation hard moisture insensitive large volume spectroscopic semiconductor-based scintillator with less than 2ns decay time and light yields as high as 8000 ph/MeV. Despite extensive research into scintillator materials, the quest for an ideal scintillator combining ultrafast decay times (akin to BaF2 and Yb-doped scintillators such as Lu2O3:Yb), high light yields (exceeding 2000 photons per MeV), spectroscopic capabilities, and exceptional radiation hardness remains unfulfilled. In this study, we demonstrate and report for the first time the viability of large-volume gallium oxide (β-Ga2O3) semiconductor-based scintillators for applications requiring these properties.

## Vertically integrated Timing Readout Chip (VTROC): An advanced, small pitch, low power solution for Nuclear Physics applications

**Sushant Sonde**, EPIR, Inc.

DE-SC0022479: Versatile, high-density, high-yield, low-capacitance 3D integration for nuclear physics detectors

NP SBIR/STTR Topic: Electronics

A finer granularity, required for tracking applications with precision timing requirement, necessitates dedicated efforts of new architectural designs and adoption of more advanced silicon fabrication processes, such as vertical integration (3D integration). EPIR, Inc., in collaboration with Fermilab, is working towards the goal of achieving a new custom 3-tier Application-Specific Integrated Circuit (ASIC) – Vertically integrated Timing Readout Chip (VRTOC) – by developing improved ASIC design and a versatile, high-density, high-yield, low-capacitance 3D integration approach to demonstrate vertically integrated detector and ASIC assembly. In this talk, we will discuss design considerations for each of the 3 tiers of VTROC to achieve 250μm×250μm pixel footprint along with circuit design details for ASIC front end (Tier 1), Time-to-Digital Converter (TDC) array with precision clock distribution (H-tree) (Tier 2) and Readout circuitry (Tier 3). Optimization of vertical integration method, based on EPIR's patented thermomechanical stress aware design will be presented. To validate early demonstration of VRTOC design in 2D, beam test data on single tier integrated devices exhibiting ~45ps timing resolution will be presented.

## Low Noise Fast Switching DC High Voltage Magnetron Power Supplies

**Larry Sadwick**, InnoSys, Inc.

DE-SC0021455: Inexpensive Low Noise Fast Switching DC High Voltage Power Supply

NP SBIR/STTR Topic: Accelerator

There are needs for inexpensive, highly efficient, very low noise power supplies for magnetrons used in scientific experiments and explorations at US national facilities and labs as well as other domestic and global applications and uses. As an example, there is significant need at DOE facilities for a flexible, extremely efficient, modular, low noise family of magnetron power supplies and related electronics that are scalable in output power. These power supplies offer substantial cost reduction and efficiency boost as inexpensive, adaptable, ultra-efficient, compact form factor power supplies for the scientific community as well as numerous commercial, industrial and military applications. There is also a need for upgrades to the power supplies and related electronics for high power magnetron systems. This will also significantly increase the up-time, flexibility, innovation and reliability of the magnetron systems while reducing down time and maintenance costs. To address this need, we are investigating and implementing low noise, fast switching, highly efficient power supplies to replace existing power supplies with these state of the art switching power supplies with additional capabilities, features and functions. These switching power supply replacements must be flexible, intelligent and robust enough to meet current and expected future performance standards at National Labs and elsewhere. Power

consumption and energy use in large national labs and facilities and other such facilities can be extremely high. Properly designed power supplies are needed to more fully take advantage of the capabilities of the magnetrons while dramatically reducing the power consumption, increasing the usable up time and significantly reducing maintenance costs and risks. These power supplies also include a number of safety features, functions, safeguards and protections. To address and meet these needs, we are researching, designing and implementing very low noise switching power supplies that cover the range of 1000s of watts to many hundreds of watts and include filament/heater and additional optional power supplies.

## High-Density Glass with Tuned Scintillation/Cherenkov Response to improve hadron energy resolution in nuclear physics experiments

**Tanja Horn**, Scintilex

DE-SC0021459: High-Density Glass with Tuned Scintillation/Cherenkov Response to improve hadron energy resolution in nuclear physics experiments

NP SBIR/STTR Topic: Instrumentation

Achieving high-quality science at nuclear physics facilities requires the measurement of particle energy with excellent calorimeter energy resolution. Particles that produce electromagnetic showers can be detected with high precision. However, there is a need to improve the energy resolution of hadron calorimetry. This Phase I/II project addresses this need through the development of high-density scintillating glass for calorimeters based on dual readout, one of the most promising methods to achieve better performance for hadronic calorimeters, which consists of the simultaneous measurement of signals produced by Scintillation light (S) and Cherenkov light (C) in the same detector. This method is particularly effective in homogenous calorimeters. Phase I established the fabrication techniques for lab scale production (5-10 blocks) of high-density scintillating glass (CSGlass) with favorable C/S signal ratio, reproducible optical properties and dimensions up to ~10 radiation lengths. Initial measurements with R&D prototypes along with simulations indicate that CSGlass produces measurable Cherenkov and Scintillation light of sufficient intensity that can be separated for physics. The glass samples have excellent optical properties and radiation resistance (no damage up to 1000 Gy electromagnetic and 1015 n/cm2 hadron irradiation, the highest doses tested to date). The present samples have densities up to 5.4 g/cm3, X0=2.2-2.8 cm, and a Moliere radius of 2-3 cm. The feasibility for scaling up the size was demonstrated with the production of 2 x 2 x 40 cm3 blocks. Phase II will establish that the new CSGlass developed in Phase I coupled to state-of-the-art light sensors can meet the experimental specifications at GeV scale. Detailed studies of the performance of the high-density CSGlass will be performed using particle beams. The main objective is to show that signals can be separated into Scintillation and Cherenkov components that are measured simultaneously, e.g., through discrimination by timing and/or waveform. Production capability for larger numbers of uniform CSGlass will be developed to meet the need of large-volume nuclear physics

electromagnetic calorimeters. A second objective of Phase II is to demonstrate the production of different CSGlass shapes. The Phase II program is aligned to make CSGlass blocks available to meet the needs of key nuclear physics experiments, e.g., the large-volume calorimeters for the Electron-Ion Collider (EIC), JLab, or future LHC upgrades, that require high performance scintillator material in large quantities on specific schedules.

## A Multichannel DSP ASIC for Streaming Readout

**Anton Karnitski**, Pacific Microchip

DE-SC0022495: A Multichannel DSP ASIC for Streaming Readout

NP SBIR/STTR Topic: Electronics

NP detectors are undergoing a paradigm shift towards streaming readout technologies to replace the triggered readout. These detectors employ thousands of readout channels working at increasingly high event rate. If based on of-the-shelf components, the electronics occupy large volume, dissipate excessive heat and cannot tolerate high TID levels. Pacific Microchip Corp. proposes to develop a TID tolerant ASIC to support high-speed streaming readout for multichannel detectors. The ASIC includes a continuously sampling 32-channel 12-bit 1GS/s ADC IP block and a high-performance DSP block with an event building back-end. The ADC will digitize while the DSP block will shape the event related pulses, restore the baseline, detect the pulse peak, analyze its amplitude, timing, add the channel address information, compress the data and ship it out. This ASIC will facilitate the detector systems to support streaming readout while increasing the readout speed, TID tolerance, cost effectiveness, robustness and will lower power consumption. In Phase I, the ASIC's architecture will be developed, the TID immunity of the ADC IP block will be tested, the critical circuits will be designed, and the proof of feasibility will be provided. Phase II will result in the fabricated and tested ASIC's prototype. Examples of commercial applications for the proposed ASIC include radiography instruments in medicine, imaging systems for airport security, border/customs control, industrial radiography systems for non-destructive defect detection. Currently, there is no TID tolerant ASIC that can perform the DSP function simultaneously in 32 channels on event produced pulses digitized at 1GS/s. The ASIC will be provided as a component, and as an IP block. According to "Research and Markets", the global smart sensor technology market is growing annually at a CAGR of 10.4% and is expected to reach $242B by 2025. This projection confirms the great commercial potential for the proposed ASIC.

## A Watt Meter to Identify Poorly Performing SRF Accelerating Cavities

**George Biallas**, Hyperboloid LLC

DE-SC0022380: Helium Flow Meter

NP SBIR/STTR Topic: Accelerator

Hyperboloid LLC developed a practical, robust, sub-atmospheric, gaseous Helium Flow Meter for use at 3 K and 1/30 atm. The unique meter is placed in the return helium gas flow stream from a long Dewar, called a Cryomodule. The Cryomodule contains Superconducting Radio Frequency (SRF) Accelerating Cavities that are bathed in 2 K liquid helium. Needed by the operators for 35 years, the Flow Meter, calibrated in watts of equivalent helium evaporation, acts as a power meter, finding poorly performing Cavities that evaporate excess helium from the 2 K helium bath at resolution of 1 Watt. The meter uses a wire/element made of a superconductor (SC), made cold enough to "switch" to the superconducting state from the flowing, cold gas. An adjacent heater wire bucks the cooling, turning the SC "normal conducting" at heater currents that increase with higher flows. Status of the 14 positions at JLab and their use by operations is presented. Also presented is the status of the first commercialization of the meter with a sale to Oak Ridge National Laboratory at the half-way point of the SBIR II award.

## Radiation Hardened Magnetometer

**Daniel Engelhart**, Hedgefog Research Inc.

DE-SC0018586: Radiation Hardened Opto-Atomic Magnetometer

NP SBIR/STTR Topic: Instrumentation

In the high-radiation environments of high-power target facilities and accelerators, precise electromagnetic manipulation of reaction products is needed to deliver intense beams with good ion optical quality and desired timing/energy characteristics. Therefore, magnetic-field probing is one of the essential diagnostic tools needed in the routine operation of RIB facilities. The major technical issue with current magnetic-field probes used in high-power target facilities is the limited operation lifetime of these probes in high-radiation environments. Nuclear magnetic resonance (NMR) probes commonly used in these applications tend to have lifetime of less than several weeks, significantly increasing operational cost and efficiency of the facilities. Addressing the DOE need, Hedgefog Research Inc. (HFR) is developing a Radiation Hardened Opto-atomic Magnetometer (RHOM) for applications in high-radiation environments (up to 10 MGy per year), offering high precision ($\Delta B/B < 4\times10\text{-}5$, $0.2\ T < B < 2.5\ T$), high sampling rate (> 1 Hz), and prolonged operation lifetime (> 1 year, projected).

## High Radiation Durable Seals for Cryomodules Gate Valves

**Maggie Bump**, NanoSonic

DE-SC0022482: 3D Printed Bimetallic Structures for Radio Frequency Devices

NP SBIR/STTR Topic: Accelerator

New high radiation durable composites shall be used as replacements for Viton within gate valves for the cryomodules in Jefferson Laboratory's CEBAF. New radiation durable composites are being produced via new techniques at NanoSonic and Virginia Tech for use as gate valves within the cryomodules in RF systems. These new gate valves and materials shall double the service life over current materials and advance the DOE's goals for nuclear physics experiments. A broader market can be addressed with the solvent and void-free, non-outgassing radiation durable extruded filaments and pellets for 3D printed materials and injection molded structures. NanoSonic addressed two opportunities identified by the Office of Nuclear Physics community regarding advanced materials for superconducting radio frequency components within particle accelerators. Specifically, NanoSonic developed new cost-effective bimetallic structure forming techniques as well as void-free, non-offgassing, additively manufacturable radiation durable polymers. The major commercial and national laboratory opportunity that presented itself was the VAT seal systems. NanoSonic demonstrated that our low glass temperature (Tg), cryogenically resilient, yet high temperature durable polymers could be compounded with radiation resistant constituents in our twin-screw extruder using zero solvent – as films, filaments for 3D printing, or pellets for molding.

## High Performance Glass Scintillators for Nuclear Physics Experiments

**Tanja Horn**, Scintilex

DE-SC0020619: High Performance Glass Scintillators for Nuclear Physics Experiments

NP SBIR/STTR Topic: Instrumentation

High performance scintillator materials are needed for particle identification and measurements of energy and momentum of electromagnetic particles in modern nuclear physics experiments. Achieving high-quality science at nuclear physics facilities requires the measurement of particle energy with excellent calorimeter energy resolution in the momentum range 0.1 – (10-20) GeV/c. Crystals such as lead tungstate (PbWO4) have been used in precision calorimeters, but their production is slow and expensive. This Phase I/II/IIA project addresses the need for alternative high performance scintillator materials by developing the basis to replace such crystals with scintillating glass that is simpler and faster to produce in large quantities while meeting the desired specifications. The reduced time and complexity of manufacturing results in significant cost reduction compared to crystals and increased flexibility in shape and size for the final detector. Phase I established the formulation and fabrication techniques for producing small batches of SciGlass blocks. During Phase II, considerable progress was made on improvement of glass properties and the manufacturing process for blocks of ~15 radiation lengths (X0). Beam tests with a small detector prototype indicate, along with Geant4 simulations, that SciGlass has an energy

resolution comparable to PbWO4 for block sizes of a comparable number of radiation lengths. The glass samples have excellent radiation resistance (no damage up to 1000 Gy electromagnetic and 1015 n/cm2 hadron irradiation, the highest doses tested to date), response time of 20-50 ns, and near-UV transmittance (78% at 440 nm). Sufficient 2 x 2 x 40 cm3 SciGlass bars have now been produced to meet the objective of building and testing a larger 5x5 detector prototype. This objective is supported by characterization results, simulations, and community feedback, and additional information that has become available on the EIC detectors. In addition, the block size will be optimized relative to the Moliere radius and the objective of demonstrating the ability to produce bars of various shapes will be completed. The Phase IIA program is aligned to make SciGlass blocks available to meet the needs of key nuclear physics experiments, e.g., the large-volume calorimeters for the Electron-Ion Collider or JLab, that require high performance scintillator material in large quantities on specific schedules.

## High ESP and QE Spin Polarized Photocathode for EICs

**Kannan Vasudevan**, Structured Materials Industries, Inc.

DE-SC0022416: High Performance High Current CW Polarized Photocathodes for Electron Ion Colliders

NP SBIR/STTR Topic: Accelerator

The Department of Energy's Office of Nuclear Physics has chosen Structured Materials Industries, Inc. (SMI) to participate in a Phase II Small Business Technology Transfer (STTR) project to develop spin polarized photocathodes for electron ion colliders (EIC). In this work, SMI is partnered with Brookhaven National Laboratory (BNL) and Stanford Research Institute (SRI) International to develop spin polarized electron emitting photocathodes. The work continues a successful Phase I effort and focuses on optimizing quantum efficiency (QE) and electron spin polarization (ESP) utilizing Super Lattice (SL)-Double Bragg’s Reflector (DBR) GaAs/GaAsP structure. In Phase I of this two-phase effort, SMI along with BNL and SRI have already achieved a spin polarized photocathode QE >5% and ESP >80% at 780 nm with SL-DBR GaAs/GaAsP structure. The device structures are grown using Metal Organic Chemical Vapor Deposition (MOCVD) process.

# Wednesday, August 14 *(Day 2)*

## Data Management for High Speed, Distributed Data Acquisition

**Jeff Maggio**, SkuTek Instrumentation

DE-SC0021502: Data Management for High Speed, Distributed Data Acquisition

NP SBIR/STTR Topic: Software

SkuTek Instrumentation is developing technologies to record and transfer next-generation scientific data operating in the 100+ Gbps range. SkuTek will present our work on streaming digitizers, collection computers, and data transfer node computers meant to operate on high performance scientific networks.

## An ASIC with a low power multichannel ADC for energy and timing measurements

**Anton Karnitski**, Pacific Microchip

DE-SC0018566: An ASIC with a low power multichannel ADC for energy and timing measurements

NP SBIR/STTR Topic: Electronics

Pacific Microchip Corp. is developing an ASIC targeted for streaming (triggerless) readout of multichannel X-ray and gamma-ray detectors. The ASIC is digitizing and digitally processing signals from 32 detectors performing automatic triggering and event building by extracting the event related information (time of arrival, peak value, time of peak, time over threshold and channel address). Further, the data is wrapped into frames and shipped out through a high-speed serial interface.

## Advanced HOM Absorber Design Project Update

**Victor Arrieta**, Ultramet

DE-SC0021487: Development and Testing of an Advanced HOM Absorber Design for SRF Accelerators Using Dielectric-Coated Cores

NP SBIR/STTR Topic: Accelerator

Effective methods are needed to dampen and extract power from higher order modes (HOM) in superconducting radio frequency (SRF) particle accelerators. Innovative manufacturing and material processing technologies are needed to fabricate robust broadband HOM absorber structures capable of effective operation through the entire ambient-to-cryogenic operating

environment of superconducting particle accelerators. Ultramet has teamed with Cornell University's SRF Group and researchers at Pennsylvania State University to develop an advanced HOM absorber design for use in superconducting accelerator systems. Building upon previous research in HOM absorber development by Cornell and others in the accelerator community, the experience and expertise of Ultramet and Penn State researchers in advanced materials and process technologies are being applied to identify appropriate materials and develop fabrication methods to meet the critical HOM design criteria specified by Cornell. A review of the Phase I results and an update of the ongoing Phase II project will be presented including RF test results and the planned path forward.

## High Output Pulsed Power Source

**Alexander Smirnov**, RadiaBeam Technologies, LLC

DE-SC0021548: High Output Pulsed Power Source

NP SBIR/STTR Topic: Accelerator

Brookhaven National Laboratory has recently been selected as the site for the Electron-Ion Collider (EIC). The EIC will consist of two intersecting accelerators, one producing an intense beam of electrons, the other a high-energy beam of protons or heavier atomic nuclei, which are steered into head-on collisions. One of the sections of the EIC beamline will require a hadron injection kicker system. The injection kicker system for EIC will be required to support single bunch transfers with a bunching frequency of 24.6 MHz. As a result, this kicker system must provide rise, flat-top and fall times which cumulatively add to no more than 40.7 ns. The entire system will consist of 20 kicker units. The requirements on the driving pulse for EIC injection kickers are challenging from both perspectives: high amplitude of 50 kV (corresponding to current amplitude of 1000 A into a 50 Ohm kicker input impedance), +/-5% tolerance of flatness and stability; rise and fall times that must be less than 10 ns each. RadiaBeam is developing such dual-channel pulse generator (pulser) based on Gallium Nitride technology (GaN); and the summary of our findings and progress is reported.

## Boron Nitride Nanotube Vibration Damping for SRF Structures

**Roy Whitney**, BNNT LLC

DE-SC0018489_MOD No._0003: Boron Nitride Nanotube Vibration Damping for SRF Structures

NP SBIR/STTR Topic: Accelerator

Pellets of boron nitride nanotubes (BNNTs) developed by BNNT LLC demonstrate viscoelastic behavior that can be used for passive vibration attenuation and damping. With DOE Office of Science Nuclear Physics SBIR funding, working in collaboration with Jefferson Lab under a CRADA, measurements demonstrate that this behavior exists beyond the temperatures of traditional viscoelastic materials with BNNT pellets going down to 2 K and likely below, and

beyond 400 °C. The target application of the SBIR work developed passive vibration damping for superconducting radio frequency (SRF) cryomodules to mitigate costly microphonics. The Jefferson Lab CEBAF cryomodule with BNNT vibration damping installed, demonstrates the lowest level of microphonic trips of all CEBAF C100 cryomodules.

## Organic Glass Scintillators for Nuclear Physics Experiments

**Edgar van Loef**, Radiation Monitoring Devices, Inc.

DE-SC0021545: Organic Glass Scintillators for Nuclear Physics Experiments

NP SBIR/STTR Topic: Instrumentation

In this project, Radiation Monitoring Devices, Inc. (RMD) in collaboration with Sandia National Laboratories (SNL) have researched and developed Organic Glass Scintillators (OGS) for Nuclear Physics Experiments. In particular, polymer-blended OGS compositions were fabricate in large sizes to replace the plastic scintillators currently in use in the Low-Energy Neutron Detector Array (LENDA) located at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU).It will be shown that polymer-blended OGS has much better properties than plastic scintillators, enabling neutron gamma pulse shape discrimination (PSD) with an energy threshold less than 50 keV. Additionally, metal-loaded OGS can provide gamma-ray spectroscopy capabilities as well.

## Sheet Electron Probe for Beam Tomography

**Mary Anne Cummings**, Muons, Inc.

**Vadim Dudnikov**, Muons, Inc.

DE-SC0021581: Sheet Electron Probe for Beam Tomography

NP SBIR/STTR Topic: Accelerator

An electron beam probe has been successfully used for the determination of accelerated particle density distributions. However, the apparatus used for this diagnostic had a large size and complex design, which limit the broad use of this diagnostic for tomography of accelerated bunches. We propose a new approach to electron beam tomography: we will generate a pulsed sheet of electrons. As the ion beam bunches pass through the sheet, they cause distortions in the distribution of sheet electrons arriving at luminescent screen with CCD device on the other side of the beam that are interpreted to give a continuous measurement of the beam profile. The apparatus to generate the sheet beam is a strip cathode, which, compared to the scanning electron beam probe, is smaller, has simpler design and less expensive manufacturing, has better magnetic shielding, has higher sensitivity, higher resolution, has better accuracy of measurement and better time resolution. With this device it is possible to develop almost ideal tomography diagnostics of bunches in linear accelerators and in circular accelerators and storage rings. Design of electron gun for sheet electron probe production for ion beam tomography will be discussed.

## Large volume Ring-Contact HPGe Detectors (RCD) for low-background counting arrays and radiopurity-assay

**Ethan Hull**, PHDS Co.

DE-SC0020624: Large volume Ring-Contact HPGe Detectors (RCD) for low-background counting arrays and radiopurity-assay

NP SBIR/STTR Topic: Instrumentation

DOE Nuclear Physics missions include the ongoing search for rare processes including neutrinoless double-beta decay. Arrays of high-purity germanium detectors are being used to pursue this research. A new Ring Contact Detector (RCD) design is being investigated as a complement to the successful point contact and inverted point-contact detector designs. RCDs will provide the largest overall volume of depleted germanium per volt of applied bias voltage. The RCD detector design is being experimentally researched through novel germanium detector processing and high-purity germanium crystal growth.

## Compact, low-cost higher order mode absorbers formed by cold spray of metal matrix composites

**Paul Carriere**, Radiabeam

DE-SC0020562: Compact, low-cost higher order mode absorbers formed by cold spray of metal matrix composites

NP SBIR/STTR Topic: Accelerator

Radiabeam is developing lossy coating and characterization techniques for beamline absorbers used for accelerator applications. The coatings are based on cold spray technology which enables multi-material coatings on the inside diameter of copper beam pipes. Both Al/SiC and NiCr coatings have been tested, including vacuum outgassing, low power RF and metallurgical evaluation. Updates on high power RF testing at Radiabeam as well as comparative studies on conventional graphite loaded SiC will also be given.

## A Scintillator-based Beam Monitor (SBM) for Real-Time Imaging & Analysis of Ion Beams from Single-Particles to High-Intensity Beams for Nuclear Physics & FLASH Radiotherapy

**Peter Friedman**, Integrated Sensors, LLC

DE-SC0019597: High Performance Scintillator and Beam Monitoring System

NP SBIR/STTR Topic: Instrumentation

We have developed a high-performance, Scintillator-based Beam Monitor (SBM) that provides real-time beam analysis across a wide range of isotopes, ion energies, and intensities. It has attracted attention at facilities where single-particle and fast beam imaging and tuning are at a

premium. The SBM uses a low-noise machine-vision camera and thin scintillator targets that can be moved into or out of the beam without breaking vacuum. Two types of proprietary scintillators are used: 1) A semicrystalline polymer material (PM) tested over a thickness range of ~1 to 200 μm. It produces much stronger signals per unit thickness than common PVT based plastic scintillators, and can be transmissive for some fast beams; 2) An opaque hybrid material (HM) of thickness 100-400 μm consisting of inorganic crystal grains in a polymer matrix. It generates an order-of-magnitude larger signal per unit thickness than a single crystal CsI(Tl) reference. Importantly, it produces a sharp beam image, with minimal secondary reflections and little to no observable halo. Both scintillator types are non-hygroscopic with the HM type being especially radiation damage resistant. In Phase-II, the SBM prototype was staged at FRIB (Facility for Rare Isotope Beams, Michigan State University) using a 86Kr+26 reaccelerated 2.75 MeV/u ion-beam, demonstrating real-time beam profiles and rate analysis spanning more than 5 orders-of-magnitude including visualization of single-ion signals with ~20 μm spatial resolution. In Phase-IIB, we delivered, installed and tested/qualified our first SBM commercial product on the ReA3-SECAR beamline at FRIB using a 4.5 MeV/u ion-beam of both mixed and "pure" 35Cl+15 and 14N+6 particles over a range of 7 orders-of-magnitude from single-particles to 107 pps. The SBM is also a development platform for a transmissive and ultrafast 20 kHz real-time beam monitor (updated every 50 μs) for FLASH-radiotherapy. For FLASH-radiotherapy the monitor was also staged in an 8 MeV electron-beam at the Notre Dame Radiation Laboratory at FLASH compatible dose rates of ~2 Gy per 2 ns pulse at 30 Hz. This work is funded by the DOE-SC and DOE-NP, and the NIH National Cancer Institute, the latter under a three-year "Direct-to-Phase-II" SBIR.

## Update on design, measurements and applications for HDSoC: High Density digitizer System-on-Chip

**Isar Mostafanezhad**, Nalu Scientific, LLC

DE-SC0020457: Design and fabrication of the HDSoC- High Density digitizer System-on-Chip

NP SBIR/STTR Topic: Electronics

Nalu Scientific will develop the "HDSoC," a fast integrated circuit to readout several (up to 64) high-speed signals generated by particles in nuclear and high energy physics experiments. Detection of individual charged particles and photons and estimation of their properties is the basis for a wide range of scientific and commercial applications from high-energy, nuclear, and astrophysics to medical imaging and diagnosis and LiDAR. We are targeting the data acquisition market for medium to large scientific experiments in the energy or intensity frontiers. These complex experiments require hundreds to thousands of recording channels at high samplings speed and high rates capable of fast data acquisition and signal processing. The HDSoC allows for timing resolutions on the order of 100s of picoseconds, translating to highly accurate estimates of charged particles and their tracks. Low cost, low power designs are especially attractive for experiments with thousands of recording channels.

## A Novel and Efficient Design for Short Superconducting Magnets

**Ramesh Gupta**, Brookhaven National Laboratory

DE-SC0021578: A new medium field superconducting magnet for the EIC

NP SBIR/STTR Topic: Accelerator

We are developing and demonstrating a novel optimum integral design for the Electron Ion Collider (EIC). The optimum integral design provides a unique solution for building short magnets, with dipole coil lengths less than their coil diameter, quadrupole coil length less than their coil radius and sextupole coil length 2/3 of their coil radius, etc. Such short superconducting magnets are otherwise not possible with a comparable integral field for the same coil length and coil thickness. The optimum integral design can be used in other accelerators, medical and fusion energy application magnets as well. The status and the latest plan and test results will be provided. Beyond Phase II, we will also discuss the possibility of collaborating with others for developing magnets based on this technology for Electron Ion Collier (EIC) and other applications.

## Large area single crystal diamond detector for position and energy determination

**Valeriy Konovalov**, Applied Diamond

DE-SC00201452: Fast, Large-Area Detector for Position and Energy Determination

NP SBIR/STTR Topic: Instrumentation

Diamond radiation detectors have an excellent radiation tolerance and have been found to withstand irradiation doses many times exceeding the common Si detectors. Large size detector grade polycrystalline diamond (PCD) material is currently available, providing a fast response and position determination, but PCD detectors are not suitable for energy determination, e.g. product identification. Single crystal diamond (SCD) detectors provide an energy resolution close to Si detectors, but the size of today's commercially available detector-grade SCD material is limited to about 4.5 mm, which is smaller than the beam size. Applied Diamond Inc. proposed to make the large area SCD mosaic material suitable for fabrication of radiation detectors used for energy and position determination and having a fast time response. Providing beam position measurement quality similar to large PCD detectors (while providing more sensitivity), they will also allow the spectroscopic measurements for heavy ion identification in environments where high beam intensity and good detector spectral resolution will be needed. Two types of large size mosaic SCD detectors have been developed. The first type represents an array of individual SCD plates bonded together by foreign material. As the first prototype, a 9×9 mm SCD detector was made from four individual 4.5×4.5 mm plates having the identical thickness of 52 ± 1 μm. The width of a "dead zone" between the individual plates was reduced to 100 μm, which completely satisfies the current needs of several customers. The prototype was successfully tested and the spectra from a combined alpha source demonstrated an excellent ~50 keV spectral resolution, identical across the whole detector area. The second type of mosaic SCD material, which is currently under development,

represents “all diamond” material when individual SCD plates are bonded together by overgrown CVD diamond. This is much more challenging technological process which includes three important tasks: CVD process development for effective CVD bonding of diamond plates avoiding growth defects and cracks, and for the growth of detector grade SCD material. New CVD reactor suitable for the growth of electronic-grade SCD was developed and constructed. Electronic grade SCD CVD material was further improved.

## Advanced Electronic Packaging of Multi Chip Microsystems Enabled by 3D Interconnections

**Reza Abbaspour**, DUJUD

DE-SC0021477: Scalable Micron-Sized Flexible Interconnects Enabled by Dielectric-Metal 3D Printing Technology for the Packaging of Large and Segmented Nuclear Physics Detectors

NP SBIR/STTR Topic: Electronics

The semiconductor industry continues to push the boundaries of microfabrication technologies to meet the increasing demand for more advanced microsystems. Currently, 3D microelectronics is considered the next solution to address the ever-growing need for higher density of integration, hence higher performance metrics. However, state-of-the-art microelectronic manufacturing techniques are designed for building 2D microdevices, making it challenging, if not impossible, to microfabricate 3D microsystems. To address these shortcomings, we have developed a new class of heterogeneously integrated microelectronic systems based on DUJUD’s proprietary micron-scale 3D flexible interconnects (3FIs) technology. The core enabling technology is DUJUD’s patented microfabrication process, specifically developed to build 3D electronic microsystems. In the first phase of technology adoption, 3FIs are employed to circumvent conventional off-chip interconnections such as wire bonds, tape bonding, and flip-chip bonding. These interconnections, used in nearly all microelectronics, are permanent and not designed for upgradability. Many large-scale microelectronic systems, such as pixel detector modules in particle accelerators, require upgrades during their lifecycle. Since these high-precision detectors are permanently interconnected to supporting electronics, upgrading them with newly developed semiconductors is extremely challenging. This lack of upgradability has become more pronounced as the semiconductor industry continuously rolls out denser and smaller transistor nodes every two years, limiting the performance of these particle accelerators to older generations of electronics. DUJUD’s 3FI technology facilitates frequent upgrades of these particle detector modules by applying the latest electronic chips to the detectors' front-end modules. Moreover, multi-chip modules (MCM) seen in particle detectors, which consist of multiple electronic chips, are now upgradable at the silicon chip level using 3FIs. The technology adoption under this Phase II SBIR project presents a unique opportunity to bring critical improvements to the next generation of particle accelerators.

# Thursday, August 15 *(Day 3)*

## Novel High Voltage Cryogenic Breaks

**Christopher Rey**, Energy to Power Solutions (e2P)

DE-SC0021608: Novel High Voltage Cryogenic Breaks

NP SBIR/STTR Topic: Accelerator

The US Department of Energy (DOE), Office of Nuclear Science, is actively seeking new and novel technologies for Cryogenic High Voltage Cryogenic Breaks (CHVB) operating at liquid nitrogen and liquid helium temperatures of 4.2 K and 1.9 K in order to supply helium to ECR ion sources. CHVB's are used in nearly every superconducting application involving a superconducting device operating at high potential and a grounded cryogenic refrigeration system. Some example applications include: ECR ion sources, fusion energy devices, and superconducting power equipment such as transformers, motors, generators, and cable. Existing metal-ceramic and glass-metal CHVB's have several limitations in cryocooled based applications including their magnetic nature and tendency to crack and leak over the lifetime of the machine. Energy to Power Solutions (e2P) in collaboration with Argonne National Laboratory (ANL) has designed, fabricated, and tested a thermally insulating CHVB. Results show a < 5 K temperature decrease on the exterior surface with flowing LN2 on its interior at applied voltages up to 150 kV to ground.

## Defect Free, Conformal and Stable Coatings of Bellows and Waveguides for Accelerators Using Ultra-Fast HiPIMS Through Controlling Ion Energy

**Robert Stubbers**, Starfire Industries

DE-SC0020481: High-Quality Conductive Bellows Coatings Using
Conformal Ionized PVD To Replace Unreliable Electroplating Processes

NP SBIR/STTR Topic: Accelerator

To maintain sufficient energy supply for Continuous Electron Beam Accelerator Facility (CEBAF) operation, cryomodules and components are refurbished nearly every year. Copper plated fundamental power coupler waveguides are important components of the cryomodules. The integrity and quality of copper coating is very crucial to reduce the heat load from the waveguides into the He bath at 2.07 K. In fact, there has been a continuous search for replacing traditional wet-chemical processes to get high-quality copper plating or re-plating of bellows and CEBAF-style waveguides. This SBIR work demonstrated an ionized physical vapor deposition (iPVD) process that results in a conformal metal film, capable of coating complex, convoluted parts that are common in modern particle accelerators (e.g., bellows, RF waveguides). Results are presented for a process utilizing the combined deposition and etching that are achieved using ultra-fast high-power impulse magnetron sputtering (HiPIMS) coupled with precision control of the ion energy

using a positive voltage reversal. The resulting Cu films are 5-10 μm in thickness, exhibit excellent adhesion, can tolerate extreme temperatures ranging from 77 K to a 400 C vacuum bakeout, and can sustain extreme plastic deformation of the substrate without buckling, cracking, or delamination. Present development efforts are largely focused on achieving a conformal deposition over the extreme aspect ratio presented by the CEBAF waveguide assemblies identical to those used in the LCLS-II.

## High Performance FPGA‐based Embedded System for Decision Making in Scientific Environments

**Yu Sun**, Sunrise Technology Inc.

DE-SC0019518: High Performance FPGA‐based Embedded System for Decision Making in Scientific Environments

NP SBIR/STTR Topic: Software

In March 2024, the sPHENIX experiment commenced data collection at the BNL Relativistic Heavy Ion Collider. The high-rate detectors analyze high-energy heavy ions and produce vast amounts of unprocessed information that surpasses the available DAQ and data storage capability. To meet this challenge, we proposed to develop a state-of-the-art AI-based trigger system to select events in real time. This will allow us to effectively sample the full high-energy collision events delivered by the accelerators while maintaining the final data throughput for offline storage at a manageable level within the available DAQ bandwidth, storage, and computing capacity. This project designs real-time AI-based algorithms operating on high-rate data streams, allowing the identification of important rare physics events from abundant backgrounds in the sPHENIX's p+p and p+Au collisions. We collaborated on creating physics-aware high-speed Graph Neural Networks that can complete complex tasks such as identifying collision event hits, reconstructing tracks, and detecting triggers in real time. Successfully integrating this system would be the initial stage in implementing autonomous control loops for large-scale, multifaceted high-energy nuclear physics experiments using powerful online AI algorithms.

## Making Detector Gain Structures Quickly and Cheaply

**Jerome Moore**, Robot Nose

DE-SC0019535: Additively Manufactured Z-Channel Detectors for Heavy Ion Accelerator Diagnostics

NP SBIR/STTR Topic: Accelerator

Additive manufacturing (AM) to create microchannel plate gain structures has been established through a partnership between Robot Nose and Argonne National Lab. We have explored novel materials, structures and coating methods to create 1 cm size in-line detectors for tuning heavy-ion accelerators and developed systems with embedded computers and time-to-digital converters for readout. Results from these efforts will be presented, along with follow-on research on a new,

much faster additive manufacturing tool and applications to larger area detectors for nuclear physics.

## HOM Absorber Design for eRHIC ERL Cavity (Now EIC)

**Thomas Schultheiss**, TJS Technologies

DE-SC0018466: HOM Absorber Design for eRHIC (EIC) 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 HOM absorbers to be used with a multi-cell cavities, in-line beampipes and crab cavities. 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. In Phase II we manufactured a waveguide and a beamline prototype assembly. Both are at BNL and are planned to be tested when they have available funds and personnel. In Phase IIA TJS Technologies fabricated a crab cavity absorber with light weight tile/backer assemblies. RF low power tests of the B-shaped waveguide assembly and the crab cavity assembly were performed and compared to analysis using test data provided by DOE Labs. BNL has provided equipment, personnel and performed high power absorption tests of 2, 3 and 4 tile assemblies.

## High Channel Density Digital Data Acquisition System

**Wojciech Skulski**, SkuTek Instrumentation

DE-SC0023557: High Channel Density Digital Data Acquisition System

NP SBIR/STTR Topic: Instrumentation

We are working on a High Density digital data acquisition system. The system will be composed of ADC cards, with several price/performance options selected with different ADC speed grades and bit ranges. Trigger, clock, and time stamp will be handled by Logic Manager boards, serving up to ten ADC cards per manager. The managers will be cascadable, extending the numbers of served channels into thousands with only two layers of manager boards.

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

**Jennifer Lalli**, NanoSonic

DE-SC0017107: Long-Term Radiation Rugged Rotary Vacuum and Water Seals in Heavy-Ion Accelerators

NP SBIR/STTR Topic: Accelerator

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 (MSU) Facility for Rare Isotope Beams (FRIB). The goal of this Phase IIA program is to expand upon the results achieved in the Phase II program through down-selection of materials and higher dose irradiation studies 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 lip seals do not offer the combined mechanical and radiation survivability needed for multiple years of service. The approach for the new seals involves the development of high-performance polymers compounded with radiation tolerant materials as composites that offer combined low air and water permeability with extreme radiation durability. NanoSonic's films have been introduced within a special housing for seal testing. Mechanical and thermomechanical testing of the new materials have been conducted pre- and post- irradiation alongside current commercial off-the-shelf (COTS) seal materials. Currently, we are working towards a Technology Readiness Level of 7 via permeation, rotational abrasion, and sealing experiments post representative rare isotope high radiation environment exposure at MSU. 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.

## Design and fabrication of the "AODS": All-in-One Digital System-on-Chip

**Isar Mostafanezhad**, Nalu Scientific, LLC

DE-SC0019527: Design and fabrication of the "AODS": All-in-One Digital System-on-Chip

NP SBIR/STTR Topic: Electronics

In this project Nalu Scientific will design, develop, and make commercially available the "AODS", a fast measurement tool to readout high speed signals generated by particles in particle and high energy physics experiments. Detection of individual charged particles and photons and estimation of their properties, momentum, and direction of arrival is the basis for a wide range of scientific and commercial applications from high-energy, nuclear and astro- physics to medical imaging and diagnosis and LIDAR. We are targeting the data acquisition market for medium to large scientific experiments in the energy or intensity frontiers. These complex experiments require hundreds to thousands of recording channels capable of fast data acquisition and signal processing. The AODS allows for timing resolutions on the order of 100s of picoseconds, which will translate to highly

accurate estimates of charged particles and their tracks. This requires design and development of custom electronic equipment to highly integrate functionality and performance and bring the cost per channel down. Low cost, low power designs are especially attractive for experiments with thousands of recording channels.

## Non-Invasive Polarimetry and Magnetometry

**Brock Roberts**, Electrodynamic

DE-SC0017120: Resonant Polarimetry and Magnetometry

NP SBIR/STTR Topic: Accelerator

This talk will describe how this collaborative SBIR effort successfully measured longitudinal spin polarization and beam magnetization, non-invasively, using beamline hardware and RF techniques. Measurements of longitudinal spin polarization of electron beams are currently being made at the Thomas Jefferson National Laboratory (JLAB) at the Upgraded Injector Test Facility (UITF).

## An RF Beam Sweeper for Purifying In-Flight Produced Rare Isotope Beams

**Alexander Smirnov**, RadiaBeam Technologies, LLC

DE-SC 0019719: An RF beam Sweeper for Purifying In-Flight Produced Rare Isotope Beams

NP SBIR/STTR Topic: Accelerator

RadiaBeam is developing an RF beam sweeper for purifying in-flight produced rare isotope beams at the ATLAS facility of Argonne National Laboratory. The device will operate in two frequency regimes – 6 MHz and 12 MHz – each providing a 150 kV deflecting voltage, which doubles the capabilities of the existing ATLAS sweeper. Here, we present the new version of a high-voltage RF sweeper and discuss beam dynamics along with electromagnetic and engineering design solutions.

## High Granularity Low-Gain Avalanche Detectors

**Rafiqul Islam**, Cactus Materials, Inc

DE-SC0020572: A New Approach to Achieving High Granularity in Low-Gain Avalanche Detectors

NP SBIR/STTR Topic: Electronics

The Low Gain Avalanche Detector (LGAD), a new type of solid-state detector, has achieved a timing resolution of better than 20 psec., enabling the development of fast timing layers for the ATLAS and CMS detectors. The high speed of LGAD signals have also drawn the attention of the

nuclear, low energy x-ray, and photon science communities. This company is fabricating the first-ever prototype of a proprietary new approach to the production of high-granularity LGADs that employs silicon diode pixilation, effectively removing the granularity limit suffered by current state-of-the-art LGAD sensors. The dynamic range of our LGAD is limited only by space-charge saturation of the bias field and is tunable by up to two orders of magnitude via the externally-applied bias voltage. We are seeking relationship with defense and commercial customers in particle detectors, photodetector space, and medical imaging applications.

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