

Abstracts

Office of Nuclear Physics SBIR/STTR Exchange Meeting Hilton Washington DC North/Gaithersburg Gaithersburg, Maryland

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

Day 1: August 9, 2016

High-Power Mode-Locked Green Laser Development Based on an All-Fiber Yb-Doped Fiber Laser System

Jihong Geng, AdValue Photonics, Inc.

Grant Title: 100W Mode-locked Green Laser for GaAs Photoemission Guns

NP SBIR/STTR Topic: Accelerator

To address the DoE need for a high-power green laser source used for synchronous photoinjection of GaAs photoemission guns, we have been developing a compact high-power mode-locked green laser source based on an all-fiber Yb-doped fiber laser system, which will be able to be synchronized to an external GHz-rate reference signal. Benefitted from our proprietary high-efficiency rare-earth-doped glass fiber technology, a monolithic high-power Yb-doped mode-locked fiber laser system is enabled, which paves a way to build a robust high-power green laser source for DoE applications. Here, we present the status of our development work for this DoE SBIR Phase II project.

Micro-Channel Thermal Control System Development

Michael Kimble, Reactive Innovations, LLC.

Grant Title: Micro-Channel Thermal Control System Development

NP SBIR/STTR Topic: Electronics

Thermal control systems are a cross-cutting technology that applies to many applications ranging from nuclear physics devices to aerospace and military systems. Of particular interest is the acquisition of heat, especially from high heat flux electronic devices that can approach 1000 W/cm². Power electronics in these systems, as well as with many commercial systems, need improved heat removal technologies that can reject these high heat loads and maintain lower device temperatures in lightweight, compact, and cost-effective thermal management solutions. A new additive-based manufacturing approach for making micro-channel thermal management systems has been developed by Reactive Innovations, LLC where 3-dimensional flow networks are formed that contain varying sized channels and shapes, converging and diverging ducts, integrated venturi nozzles, manifolds, multi-channels, wicks, etc. that fully define the fluid flow regime. Feature sizes less than 1

micron upwards to 6000 microns along with varying sized shapes and 3-dimensional design characteristics have been produced using this method all fashioned into a single continuous flow network. The resulting thermal management systems are thus very lightweight. With this new manufacturing technology, compact and lightweight thermal management systems may be inexpensively produced ranging from single-phase to two-phase flow systems.

Activities Directed Towards HF-Free Electropolishing of Niobium SRF Cavities

E. Jennings Taylor, Faraday Technology, Inc.

Grant Title: Acid-Free Electropolishing of SRF Cavities

NP SBIR/STTR Topic: Accelerator

Under prior and on-going funding from the DOE (SBIR, ARRA, and ORNL P.O.), Faraday Technology has demonstrated the ability to electropolish single-cell niobium SRF cavities in low concentration acid electrolytes (5-10% sulfuric acid) using pulse reverse current electrolysis. In contrast to conventional direct current electropolishing in concentrated sulfuric-hydrofluoric acid electrolytes, the FARADAYIC[®] ElectroPolishing process enables vertically orientated cavity polishing without the need for cavity rotation. This is inherently more scalable and industrially compatible than the oft-used horizontal orientation. The subject DOE SBIR Phase II program is directed towards high rate bulk surface finishing of niobium in near neutral electrolytes. In synergistic activities, the FARADAYIC[®] ElectroPolishing process is being transitioned to three cell stacks simulating nine-cell SRF cavities. This presentation will review the previous work and present the current status of FARADAYIC[®] ElectroPolishing activities.

Keynote Presentation

NP Low Energy Facilities and the SBIR/STTR Program

Georg Bollen

Facility for Rare Isotope Beams/Michigan State University

A High Intensity Positron Source Based on a Superconducting Electron Linac for Nuclear Physics Research

Terry Grimm, Niowave, Inc.

Grant Title: Liquid Metal Bremsstrahlung Converters for High Power Electron Beams

NP SBIR/STTR Topic: Accelerator

Positron sources are essential components of next-generation colliders and have important commercial applications as probes for material stress and fatigue at the microstructure level. Through this DOE SBIR project, Niowave addresses the need for inexpensive, reliable high-intensity positron sources by developing a production target for a high-power superconducting electron accelerator (linac). The liquid metal target converts a 10 MeV, 100 kW electron beam into a high flux positron source. Thin lead-bismuth eutectic targets create positrons as efficiently as conventional solid targets and have superior thermomechanical properties. With a high-power superconducting electron linac providing

continuous beam, these targets will scale positron production to the high power levels needed for next generation lepton accelerators (CLIC, ILC, JLEIC, eRHIC, Super KEK B).

Diamond Sensor for the Neutron Electric Dipole Moment Experiment

Chris Hovde, Southwest Science, Inc.

Grant Title: Same as the presentation title

NP SBIR/STTR Topic: Electronics

Experiments to measure the dipole moment of the neutron (nEDM) require precise knowledge of electric and magnetic fields inside the interaction region. The Phase II research project by Southwest Sciences and the University of Illinois is designed to demonstrate that fiber-optic sensors based on doped diamond make minimal perturbations to the field and can provide a useful check on the performance. Electric field measurement by optically-detected magnetic resonance in a confocal microscope will be described. The experimental measurements can be used to determine vector fields within a small volume in the diamond. Preliminary results also show electric field effects in all-optical measurements averaged over a larger region of the diamond.

Solid-State Neutron Detectors with Integrated Electronics for Nuclear Physics

James Christian, Radiation Monitoring Devices, Inc.

Grant Title: Same as the presentation title

NP SBIR/STTR Topic: Instrumentation

The development of better new neutron detection systems is crucial for the exploration of exotic nuclei systems, in particular with very large neutron excesses. Such experiments often have high background radiation, or are in strong magnetic fields are present. The goal of this SBIR program is to develop a module that can be used to build large detector systems. The Phase-I successfully combined RMDs plastic scintillators with its solid-state optical detectors to develop a spectroscopic neutron detector for nuclear physics research. Detectors were tested in measurements of mixed gamma and neutron fields up to 20 MeV. The Phase II effort is developing a complete module for testing in a relevant environment, such as the Facility for Rare Isotope Beams (FRIB). The proposed detector technology can be used to develop major neutron detection systems at multiple university and national labs. The technology is also promising for nuclear-nonproliferation, other neutron imaging systems, astronomy, and non-destructive testing.

Keynote Presentation

The Relativistic Heavy Ion Collider Facility and the SBIR/STTR Program

Michiko Minty

Brookhaven National Laboratory

Low Z Thin Films for Stripper Foils, Targets and X-Ray Windows

Nalin Kumar, UHV Technologies, Inc.

Grant Title: Same as the presentation title

NP SBIR/STTR Topic: **Instrumentation**

In this presentation, the latest results obtained during the first year of this Phase II SBIR project will be presented. In particular, a fully automated pulse laser deposition system will be described to fabricate nano-layered stacks of sp³ diamond like carbon, sp² graphitic carbon and boron with hundreds of layers. The results of free standing foils made with this system will be described. In addition, the results of silicon nitride, silicon carbide, graphene and nano-crystalline diamond windows will be presented for applications in low energy x-ray detectors and gas ion detectors. Furthermore, UHV's capabilities to R&D and manufacture exotic thin films, vacuum sealing and bonding, x-ray tube manufacturing and thin film manufacturing equipment will be described.

Fabrication of Micro Penning Traps for Continuous Magnetic Field Monitoring in High Radiation Environments

Mark Dugan, Translume, Inc.

Grant Title: Micro Penning Traps for Continuous Magnetic Field Monitoring in High Radiation Environments

NP SBIR/STTR Topic: **Instrumentation**

The next generation of beam facilities requires new instrumentation to deal with the high-radiation environment associated with the interaction of high-power beams with matter. One important piece of instrumentation that is required is a precise, radiation-resistant, magnetic field probe. Translume (Ann Arbor, MI) in collaborating with Michigan State University (MSU) is developing a Penning trap mass spectrometer that will precisely determine magnetic fields by measuring the cyclotron frequency of an ion with known mass and charge. The concept was previously demonstrated at MSU. As part of this program a downscaled micro-trap has been fabricated using precise three-dimensional glass micromachining processes developed by Translume. This Penning microtrap is made out of partially metalized fused silica glass and is believed to be compatible with high-radiation environments. Initial tests are on-going at MSU/FRIB.

Porous Pressed Powders as Solid Catchers of Stopped Rare Isotopes

Uma Sampathkumaran, InnoSense, LLC.

Grant Title: Thermo-Mechanically Stable Tungsten Powders as Solid Catchers for the Fast Release of Stopped Rare Isotopes

NP SBIR/STTR Topic: **Accelerator**

Porous solid catchers of rare isotopes produced at high energies via in-flight reactions will play an important role in high power heavy ion accelerator facilities such as FRIB. Such catchers are complementary to helium gas catchers especially for parasitic harvesting of rare isotopes in the in-flight separators. Here InnoSense LLC (ISL) is optimizing doped

tungsten (W) and tungsten carbide powders for long-term use in high temperature beam environments while enabling the stopping and fast release of desired reactive molecular or single elemental rare isotopes. Lightly pressed disks of undoped tungsten did undergo some particle coalescence (Ostwald ripening) and grain growth when vacuum heated to 1400 °C for 12 hours while the doped tungsten powders showed significant grain growth suppression. On-line characterization of the samples is being carried out at with the residual gas analyzer (RGA) apparatus installed at Florida State University with beams from their Tandem (e.g., ^4He , ^7Li , ^{13}C , and ^{18}O). Beams at NSCL (e.g., primary beam of ^{16}O together with their A1900 fragment separator intense secondary beams of ^6He , ^{15}O , and ^{10}C are available for on-line tests of release efficiency, delay times, and sideband formation). We will report on ongoing work.

Development of a Nanomaterial Anode for a Low Voltage Proportional Counter for Neutron Detection

Matthew Craps, NanoTechLabs, Inc.

Grant Title: Same as presentation title

NP SBIR/STTR Topic: Instrumentation

NanoTechLabs Inc. in collaboration with Savannah River National Laboratory and Clemson University have been developing of a next generation proportional counter for neutron detection utilizing robust, inexpensive nanostructured anodes while maximizing neutron capture. The concept is based on a controlled parallel plate array of nanoscale anodes to detect the reaction products produced by the interaction of a neutron with boron-10. Typical PCs operate with high bias potentials that create electronic noise. Incorporating nanomaterials into the anode of PCs can theoretically operate at low voltages (eg. 10-100V) due to an increase in the electric field associated with a smaller diameter nano-scale pillars on the anode. In addition to the lower operating voltage, typical high PC voltages (~1200V) could be used to generate a larger electric field resulting in more electrons being collected, thus increasing the sensitivity of the PC.

Nb-on-Cu Cavities for 700-1500 MHz SRF Accelerators

Katherine Velas, Alameda Applied Sciences Co.

Grant Title: Same as the presentation title

NP SBIR/STTR Topic: Accelerator

Alameda Applied Sciences Corporation (AASC) grows superconducting Nb films via Coaxial Energetic Deposition (CED) from a cathodic arc plasma. AASC is coating 1.3 GHz SRF cavities manufactured at Thomas Jefferson National Accelerator Facility (JLab) and continues to improve the technology and coating procedure with the goal of achieving $Q_0 > 10^{10}$. In Year 1 of the NP SBIR Phase II grant, AASC set out to improve the CED triggering system, upgrade the vacuum chamber system, optimize thickness control, coat and cryotest multiple SRF cavities. The first cavity coated after implementing improvements reached a Q_0 of 10^9 , the highest Q measured on a cavity coated using CED. Further improvements are needed to

reach $Q_0 > 10^{10}$. Plans include making additional improvements to the vacuum chamber, exploring variations in coating parameters, and working with JLab to assemble all coating hardware inside JLab cleanroom facilities.

Development of a Multicell Superconducting Cavity with a Photonic-Bandgap Coupling Cell

Chase Boulware, Niowave, Inc.

Grant Title: Development of a Superconducting RF Harmonic Cavity for eRHIC

NP SBIR/STTR Topic: Accelerator

Next generation light sources and colliders require continuous electron beams with currents up to the ampere level. One example is the proposed collider eRHIC, where hadrons from one of the RHIC storage rings will interact with electrons accelerated in a six-pass energy recovery linac. A possible enhancement to the design involves compensating nonlinearities from the main linac by extra accelerating sections operating at a harmonic of the main frequency. Photonic band gap cells have been recently suggested for use as the harmonic linac cavities to reduce beam distortion from higher-order modes. This Phase II SBIR project built and tested the first-ever multi-cell superconducting accelerating cavity with a photonic bandgap coupling cell. In addition to building the new cavity design, novel vacuum and RF seals were developed for the waveguide ports. The cavity was tested at cryogenic temperature in its helium vessel, demonstrating high cavity quality factor at a significant fraction of the design fields.

Informal Discussion on Challenges and Best Practices for Commercialization

Michelle Shinn, DOE, Office of Nuclear Physics

I will facilitate a discussion amongst the participants on what does or doesn't work when attempting to make the leap from a NP-funded SBIR/STTR grant to a product or service.

Day 2 – August 10, 2016

The Design and Application of Harmonic Rf Cavities

Brock Roberts, Electrodynamic

Grant Title: Non-Invasive Bunch Length Monitor, Fast Kicker, Bunch Shaper and Photogun

NP SBIR/STTR Topic: Accelerator

RF cavities have been designed and constructed that simultaneously and exclusively resonate many harmonic TM_{0n0} modes. These modes are axially symmetric and have their electric field maximum along the cavities bore. A periodic beam passing through a harmonic cavity's bore excites these modes whose superposition can be measured at the cavities antenna with a sampling oscilloscope. Processing the detected waveform with the harmonic cavities transfer function yields the Fourier series of the beam, and a near real-time, non-invasive measurement

of the beams longitudinal bunch shape and duration. Experiments have been performed on the 130 kV injector at the Thomas Jefferson National Accelerator Facility's Continuous Electron Beam Accelerator Facility. The harmonic cavities sensitivity was near 1 mV/ μ A and measured beam bunches ranging in width from 45 to 150 picoseconds (FWHM). These measurements were in close agreement with measurements made using an invasive bunch measurement system as well as predictions by a particle tracking simulations. Harmonic cavities also have potential applications when actively driven. Demonstrating fast bunch kicking and bunch shaping using harmonic cavities is the current focus of our research.

Radiation Resistant Magnetic Field Sensor

Vladimir Kochergin, Microxact, Inc.

Grant Title: Radiation Resistant Magnetic Field Sensor

NP SBIR/STTR Topic: Instrumentation

All high power target facilities and accelerators, especially the Facility for Rare Isotope Beams (FRIB), require magnetic field sensors to measure magnetic fields in various magnets employed at these facilities as well as in cyclotrons. The currently used and/or commercially available sensors show only limited radiation resistance. MicroXact is developing a new type of fiber optic magnetic field sensor and instrumentation that will be small, sensitive, inexpensive and radiation resistant. Sensors and instrumentation will work for years without the need for frequent replacement and/or recalibration. The results of the sensor and instrumentation development and qualification will be presented. Wide dynamic range, stable, accurate operation of the sensor will be demonstrated.

Low Cost, High-Density Digital Electronics for Nuclear Physics

Wojciech Skulski, Skutek Instrumentation

Grant Title: Same as the presentation title

NP SBIR/STTR Topic: Electronics

In this talk I will present the progress concerning our Phase II SBIR project titled "Low Cost, High-Density Digital Electronics for Nuclear Physics".

Digital Silicon Photomultiplier Array Readout Integrated Circuits

Adam Lee, Voxel, Inc.

Grant Title: Same as the presentation title

NP SBIR/STTR Topic: Instrumentation

Voxel is currently developing a photon integrating and time-of-flight (ToF) sensor with single photon sensitivity. The sensor design is based upon a custom readout integrated circuit (ROIC) and an array of single photon avalanche detectors (SPAD) where the SPAD arrays is monolithically integrated within the ROIC pixel design. We will present the sensor architecture, ROIC and sensor specifications, simulation/modeling results, as well as a review of the latest SPAD developments and device characterization.

PUMA-V: Polyhedral User Mapping Assistant and Visualizer Tool, CPS Code Enhancements, Extending R-Stream with LLVM for Mapping C++ and QDP++ Codes, and Faster Linear Solvers and Preconditioners

M. Harper Langston, Reservoir Labs, Inc.

Grant Title: Polyhedral User Mapping Assistant and Visualizer (PUMA-V)

NP SBIR/STTR Topic: **Software**

Calculations undertaken by physicists for solving fundamental problems such as Lattice Quantum Chromo Dynamics (LQCD) are prohibitively demanding without expertly optimized software. Such software is very complex and costly to write and maintain without automated tools, especially for advanced heterogeneous architectures. The goal of the Polyhedral User Mapping Assistant and Visualizer (PUMA-V) project was to address this problem starting from existing high-level technology for automatic, mixed static/dynamic, mapping of dense multi-linear algebra algorithms. The PUMA-V project focused on automated tools, an optimization and visualization toolchain, source-to-source compilers, and advanced linear solvers meet this complexity challenge and increase user productivity. Four areas of engagement made great strides in addressing the needs of the LQCD community specifically and the scientific community in general: 1. Columbia Physics System Code Enhancements, 2. PUMA-V Visualizer Tool, 3. Extending R-Stream with LLVM for Mapping C++ and QDP++ Codes, and 4. Faster Linear Solvers and Preconditioners. More generally, the four original primary goals of this project were focused on (1) the implementation of translation tools interfacing heavily templated LQCD libraries to polyhedral mapping, (2) application of the tools to current theoretical physics simulations related to testing Standard Model (SM) theories, (3) development of new optimized solver algorithms for LQCD, and (4) development and quality improvements. The four engagements listed above address all of these targets, and work continues to develop the capability for fully automating the optimization of complex software. Heterogeneous hardware can provide orders of magnitude improvements in computational rates but presents significantly more complex code development and porting challenges. PUMA-V has begun to address this need in significant ways that will have lasting impact in the near future as well as years to come.

Keynote Presentation

Jefferson Lab and its SBIR/STTR Program

Drew Weisenberger

Thomas Jefferson National Accelerator Facility

Low-Latency Ultra-High Capacity Holographic Data Storage Archive Library

Ken Anderson, Akonia Holographics

Grant Title: Same as the presentation title

NP SBIR/STTR Topic: **Software**

In the last 3 to 4 years, the growth of disk areal density has decreased from its 20 year average of 40% down to under 20% per year. This new growth rate is expected to continue or even decrease in the years to come causing serious cost issues when data growth is expected to

continue rising at about 45% a year. As these relative costs begin to rise, data storage budgets will begin to dominate overall IT budgets. As 2D data storage technologies like magnetic disk, tape, and flash memory attempt to stack data in 3D, they inherently fail at realizing the scaling potential of a truly 3D storage technology enjoys. Holographic Data Storage is one of the only inherently 3D data storage technologies that can continue to scale as the world's needs scale. The other cost benefit is that the information is stored in plastic and not some rare materials that are too expensive to harvest.

Development of High Quantum Efficiency and High Polarization Electron Source at Svta / GaAsSb/AlGaAsP Superlattice High-Polarization Electron Source

Yiqiao Chen, SVT Associates, Inc.

Grant Title: GaAsSb/AlGaAsP Superlattice High-Polarization Electron Source

NP SBIR/STTR Topic: **Accelerator**

Spin-polarized electron sources are of great interest to DoE for applications in high-precision high-energy nuclear physics experiments at beam energy up to several GeV. Polarized electrons are essential for parity-violating experiments and measurements of nucleon spin structure. SVT Associates has been working on polarized photocathode materials and devices for 15 years to meet DoE's polarized electron source needs. Remarkable improvement including high quantum efficiency (QE) and high polarization has been achieved with DoE SBIR programs. Very recently, with very high QE and 85% polarization were measured from a photocathode grown on GaAs substrate. SVT and JLab are continuing working on improvement of QE and polarization for GaAs/GaAsP and GaAsSb/AlGaAsP SL photocathodes.

Modular Planar Germanium (MPGe) Detector Systems for High Resolution Gamma-ray Spectroscopy and Tracking Arrays

Ethan Hull, PHDs Co.

Grant Title: Same as the presentation title

NP SBIR/STTR Topic: **Instrumentation**

Modular Planar Germanium (MPGe) detector systems are being developed for nuclear-physics detector arrays. These detector systems provide excellent spatial and energy resolution with reasonably high % solid-angle coverage in a compact overall forward footprint. Enabled by new larger-diameter germanium crystals, the MPGe systems will provide the basis for the next generation heavy-ion detector arrays. The lower detector operating temperature and electronic trap correction techniques will allow these detectors to survive the extreme radiation-damage in next generation heavy-ion detector arrays. Prototype MPGe detector systems have now been fabricated and demonstrated. Side by side gamma-ray imaging comparisons with other commercial detectors shows that MPGe will also have an extremely positive impact on global nuclear security.

Keynote Presentation

DOE Isotope Program and Facilities and the SBIR/STTR Program

Cathy Cutler

Brookhaven National Laboratory

Radionuclides play a major role in research applications, in environmental studies and in industrial applications as sources as well as in nuclear medicine imaging and therapy. The DOE isotope program has a long history of utilizing its unique national laboratory facilities and expertise to develop and supply radionuclides that are in high demand and commercially unavailable. DOE is actively supporting novel production and purification methods for radioisotopes for use in a variety of applications. Current efforts have focused on developing methods to produce therapeutic radioisotopes with high purity and thus minimal to no impurities as well as high specific activity radioisotopes which can be attached to biomolecules or targeting vectors that selectively distribute within diseased tissues, thus delivering toxic radioactivity to diseased tissue while minimizing or sparing damage to healthy or normal cells. Furthermore, the DOE Isotope Program has increased its production facilities and capabilities to meet increased demand and to allow for assessment of novel production methods. While simultaneously increasing its testing facilities and quality programs to meet the regulations required for radioisotopes of use in clinical trials and in approved drug formulations. This presentation will present an overview of the program and its facilities and programmatic growth areas that have potential for SBIR/STTR funding.

Ferroelectric Based High Power Tuner

Alexei Kanareykin, Euclid Techlabs LLC

Grant Title: Ferroelectric Based High Power Components for L-Band Accelerator Applications

NP SBIR/STTR Topic: Accelerator

A fast controllable phase shifter would allow microphonics compensation for CW SRF accelerators. Nonlinear ferroelectric microwave components can control the tuning or the input power coupling for RF cavities. Applying a bias voltage across a nonlinear ferroelectric changes its permittivity. This effect is used to control a phase change of a RF signal or change the resonant frequency of a cavity. In Phase II of the project, 2014-2016, two designs for the new frequency 400 MHz proposed by BNL for the power test. RF power losses and temperature control were studied. Operating temperature in the range of 40 C has been chosen to optimize the tuning range. Ferroelectric elements were fabricated and characterized. The engineering design of the ferroelectric based tuner was completed. All tuner components have been manufactured. The BST tuner was assembled and tested with wide range 300 RF phase tunability by 30 C thermo control and fine fast tuning 100 phase over kV/mm bias field.

Digital SQUID Magnetometers for Read-out of Detectors and Magnetic Particles

Masoud Radparvar, Hypres, Inc.

Grant Title: Same as the presentation title

NP SBIR/STTR Topic: **Accelerator**

We have devised a Time-Division Multiplexing (TDM) scheme for minimizing the circuit complexity required for an array of sensors. As a proof-of-concept, we have designed, fabricated, and tested a 4-channel TDM read-out circuit. The proposed scheme can be generalized for a larger number of channels. The read-out circuit comprises an array of ADCs (Analog to Digital Converters) to digitize sensor outputs, a multiplexing unit, a clock controller, and a counter with parallel-to-serial output interface. For demonstration purposes, we employed low-pass phase modulation-demodulation (LP PMD) ADCs running in a synchronous mode of operation. To facilitate independent verification of circuit operation we also placed an on-chip pattern generator to apply a unique pattern to each channel. The multiplexing unit is based on an array of sequentially triggered switches, each controlling the flow of data from a single ADC to a common output bus. In our scheme, the switches are realized using RS-flip-flops with non-destructive readout (RSN) cells with only one RSN cell turned on at a time. Multiplexed output data were stored in rippled counter based on T-flip-flops and read out to room temperature electronics using a serial interface. The chip was extensively evaluated at sampling frequencies up to 12 GHz. By means of embedded pattern generators we proved the correct operation of each channel and of all 4 channels combined. We also were able to perform reconstruction of signal applied to individual ADC. The chip was fabricated using Hypres' 4.5 kA/cm² process with 4 Nb metal layers.

Keynote Presentation

Update on the Department of Energy SBIR/STTR Program

Chris O'Gwin

DOE SBIR/STTR Office

I will provide a brief overview and update of any recent changes within the last year impacting the DOE SBIR/STTR programs.