DOE/NA-0133

National Nuclear Security Administration

Stewardship Science Today

Office of Strategic Partnership Programs

Volume 4 | Number 2 | June 2022

Stewardship Science Today (SST) highlights the stewardship science and academic programs supported by the Department of Energy/National Nuclear Security Administration (DOE/NNSA). SST is published quarterly by the NNSA Office of Strategic Partnership Programs. Questions and comments regarding this publication should be directed to Terri Stone via email at terri.stone@nnsa.doe.gov.

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Calendar

7/7-8/2022
International Agreement on Cooperation for Fundamental Science Supporting Stockpile Stewardship, LANL (hybrid); POC: Kreisler

7/17-21/2022
2022 CSGF Annual Program Review, Crystal Gateway Marriott, Arlington, VA

8/2-5/2022
13th Z Fundamental Science with Pulsed Power: Research Opportunities and User Meeting, Albuquerque, NM

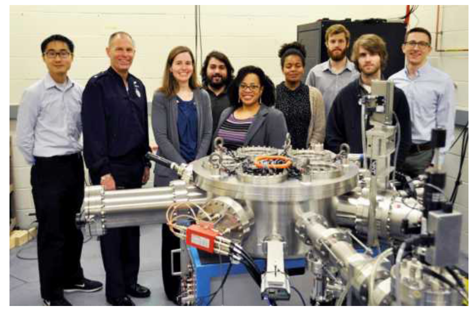
Inside

*National Laboratory Detailee **Contractor Support

For as long as I can remember, I have thoroughly enjoyed engaging with the academic community. Maybe it's because of my background as a scientist, my love for new ideas, or my excitement over the next generation of thought leaders. For whatever reasons, however, I love conversing with and supporting researchers in academia and at the labs.

Dr. Frazier delivers the keynote address for the 2022 SSGF/LRGF Annual Review on June 22.

So imagine my excitement when NNSA Defense Programs (DP) decided to transition Academic Programs from the Office of Research, Development, Test, and Evaluation to the Office of Strategic Partnership Programs (SPP) in the DP Front Office! That decision was made at the beginning of FY 2022. Since then, to ensure continuity of operations, transition of program knowledge, and sufficient headquarters staffing, we have been moving pieces of the program brick-by-brick to SPP. The biggest bricks are the six individual Academic Programs: 1) Stewardship Science Academic Alliances which includes the Stewardship Science Graduate Fellowship (SSGF) and the Laboratory Residency Graduate Fellowship (LRGF), 2) High Energy Density Laboratory Plasmas, 3) Computer Science Graduate Fellowship, 4) Predictive Science Academic Alliance Program, 5) Minority Serving Institution Partnership Program, and 6) Tribal Education Partnership Program.



Dr. Frazier (center) and the former NNSA Principal Assistant Deputy Administrator, Brigadier General Mike Lutton (left), meet with Fellows and students during a tour of the Massachusetts Institute of Technology HED/ICF Division's accelerator facility in January 2017.

A smaller, but no less exciting, brick is this publication: *Stewardship Science Today* (SST). SST highlights stewardship science and academic programs supported by DP. It compiles an array of accomplishments, achievements, breakthroughs, and program news tailored to this community, and I am excited and honored to be in the position to welcome you to this issue of SST.

This issue features ground-breaking plutonium science work that is being conducted at the Sandia National Laboratories Z-Machine in a collaboration with Los Alamos National Laboratory and other nuclear security enterprise and industrial partners. This effort highlights the complex and collaborative nature of our work and is producing vital results that are continuing to allow the NNSA to certify the nuclear weapons stockpile without conducting weapons testing.

Also featured is a significant diagnostic advancement using new and improved scintillator technology to replace diagnostic elements that can no longer be manufactured. To date, the results of this work are providing dramatic and promising improvements in neutron imaging. In addition, this issue includes an update from the Predictive Science Academic Alliance Program III and a highlight about exciting, collaborative research being conducted by Cornell University.

Please enjoy this issue. I am delighted to be here, and I look forward to continuing to engage with the Academic Programs community and to welcoming you to future issues.

Dr. Njema J. Frazier
Acting Assistant Deputy Administrator for the Office of Strategic Partnership Programs

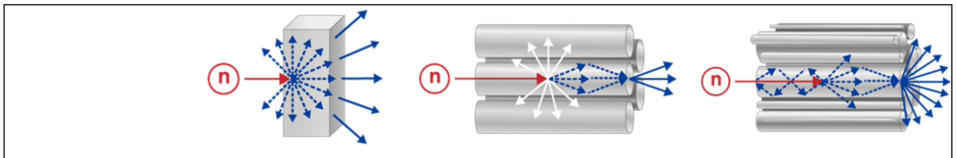
New Scintillating Nanoguide Fiber Bundle Block Brighter Than Legacy Fiber Blocks for Neutron Imaging Missions

by Chris Cooper and Andréa Schmidt (Lawrence Livermore National Laboratory)

The MJOLNIR (MegaJOuLe Neutron Imaging Radiography) team tested a novel nanoguide fiber scintillator block as a possible replacement for a legacy scintillating fiber array bundle that can no longer be manufactured. The new block utilizes Transverse Anderson Localization to propagate nearly all the scintillating light to the edge of the block while maintaining image fidelity. Measurements indicate the nanoguide scintillator has 40× light output compared to the legacy scintillator when coupled to an imaging panel although it is unknown how much the legacy scintillator light may have decreased over time. Neutron radiographs using the nanoguide scintillator are expected to exhibit increased signal and enhanced contrast for the same neutron sources.

Several NNSA missions require neutron radiography to image low-Z materials such as plastic as well as materials obscured by high-Z materials. However, the high penetration of neutrons that makes them critical for radiography missions also makes them difficult to capture and image with scintillators.

Scintillators are exotic materials that interact with radiation to generate visible light emitted in all directions. This causes a problem for neutron scintillator imaging systems because neutrons penetrate several centimeters through scintillators and the imaging light is created over the entire volume of the scintillator. Large monolithic scintillators must be very thin to prevent blurriness and rely on expensive optics to image the entire scintillating volume (~1 cm or 12% of incident DD neutrons). This problem can be avoided using stacks of clad scintillating fiber bundles. These fibers use total internal reflection to relay light produced anywhere along a fiber to the surface without blurring the image. The current MJOLNIR bundle is 5 cm thick and interacts with 50% of DD neutrons but only 4% of the photons make it out due to total internal reflection.



	Monolithic	Fiber Array	Nanoguide
Max. DD neutron Interaction	12% (1 cm) Limit: depth of field	50% (5 cm) Limit: Legacy bundle	75% (10 cm)
Max. Light Capture	50%	4%	100% (with upstream mirror)
Max. end-to-end detection efficiency	**6%**	**2%**	**75%**

Figure 1. Examples of different imaging scintillators and their various efficiencies.

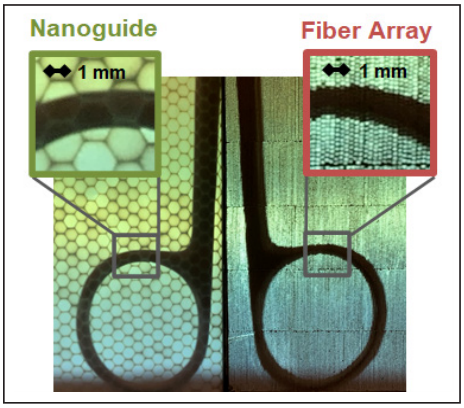


Figure 2. Backlighting test with visible light on (left) the new scintillating nanoguide fiber bundle, each 3 mm "hexagon" contains hundreds of millions of ~100 nm fibers and (right) legacy fiber bundle of stacked 250 micron fibers.

The new nanoguide scintillating fiber block is manufactured by iteratively drawing out stacks of scintillating fibers down to 100-300 nm diameter resulting in a high resolution matrix (Figure 2). The highly disordered bundle scatters the light via transverse Anderson Localization where the light maintains its angle of incidence but is transmitted almost exclusively along the direction of the fibers with almost no loss. Nanoguide blocks have been fabricated up to 10 cm thick, capable of capturing 75% of DD neutrons and up to 7.5 cm × 7.5 cm (possibly larger if requested) in area for neutron imaging of large objects. The higher fill factor and lack of cladding further increase the light output. The combination of these advancements maximize the image quality for neutron radiography of dynamic experiments.

The MJOLNIR team tested a legacy fiber scintillator block and new nanoguide with the same size, 3" × 3" wide, 2" deep as well as a ZnS monolithic plate 100 mm × 100 mm

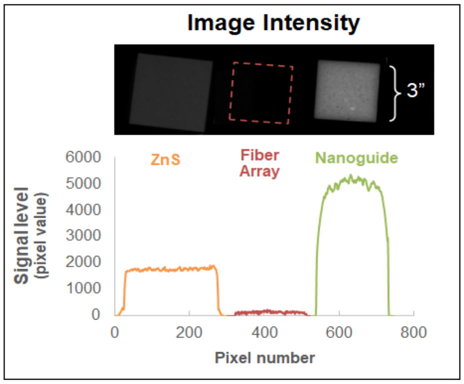


Figure 3. (Top) A side-by-side comparison of a 3-mm-thick monolithic ZnS plate, 2" thick fiber guide, and a 2" thick nanoguide imaged by a silicon panel irradiated with a 5.9x10^{8} n/s Thermo Scientific P 385 DT neutron generator at 50 cm totaling 1.8x10^{11} n/cm^{2}. The nanoguide is 3× brighter than the ZnS and 40× brighter than the fiber bundle. (Bottom) a line out of pixel value for all the panels. The ZnS panel emits a different wavelength with higher detection efficiency on the panel.

× 3 mm deep. The light output was measured by placing them on a 41 cm × 41 cm Varex Imaging XRD 1621 TFT Si digital imaging panel with 400 micron pixel size which measures nearly all the light coming out of the block. However, in high EMF pulsed power applications and high radiatino environments, such as the MJOLNIR experiment, the light is relayed via lens or fiber optic rope to a camera in a shielded box. The MJOLNIR team is currently evaluating the impact of the nanoguide in the current imaging system in MJOLNIR.

The blocks were purchased with C4/ Secondary Assessment Technologies funding.

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Z-Machine Efforts Advance Stockpile Stewardship in Multi-Organization Collaboration

by Maureen Elizabeth Lunn and David A. Fredenburg (Los Alamos National Laboratory); Forward by Adam Farrow (Los Alamos National Laboratory), Detailee to NNSA

Forward

The Office of Experimental Sciences supports flagship facilities across the complex in its efforts to ensure that the scientific underpinnings of the stockpile stay broader than the evolving needs of the stockpile stewardship community. In this newsletter, we often focus on cutting-edge experiments at the facilities themselves. However, without the efforts of the wider National Nuclear Security Administration community, many of their accomplishments would not be possible. Conducting plutonium experiments at Z, as discussed in this article, require efforts across technical organizations throughout Los Alamos National Laboratory, Sandia National Laboratories (SNL), and beyond, from fabricating specimens and shipping them to SNL as well as efforts to ensure that plutonium-bearing waste from these experiments are disposed of properly. We hope pulling back the curtain, even if only a little, on the number of stakeholders engaged in completing these essential experiments shows some of the organizational aspects of high-impact work across the complex.

For the past 15 years, Los Alamos National Laboratory (LANL) employees have played a major role in plutonium experiments using the Z-machine. Located at Sandia National Laboratories (SNL), this device uses high magnetic fields, electrical currents, and X-rays to help scientists understand how materials behave under extreme temperatures and pressures.

High-energy density physics, or the study of matter under extreme conditions, is a key component of certifying the nation's nuclear weapons stockpile.

A Long List of Capabilities

Plutonium experiments are just a fraction of the work done on the Z-machine. LANL has been increasing its utilization of the Z-machine to address weapons physics questions, to enable manufacturing advances, and to inform decision making regarding the U.S. nuclear deterrent. LANL's partnership with SNL on Z experimental platforms is spurring advances in Advanced Simulation and Computing (ASC) codes and is supported by state-of-the-art target fabrication in LANL's Materials Science and Technology (MST)-16, Nuclear Materials Science Division.

One of the most unique aspects of this platform, which makes it ideally suited to support national security science, is its pulse-shaping capability.

"On the Z-machine, it's possible to mimic actual weapons trajectories while simultaneously measuring the response of plutonium along these trajectories with high fidelity," said Anthony Fredenburg of the LANL Office of Experimental Science (OES).

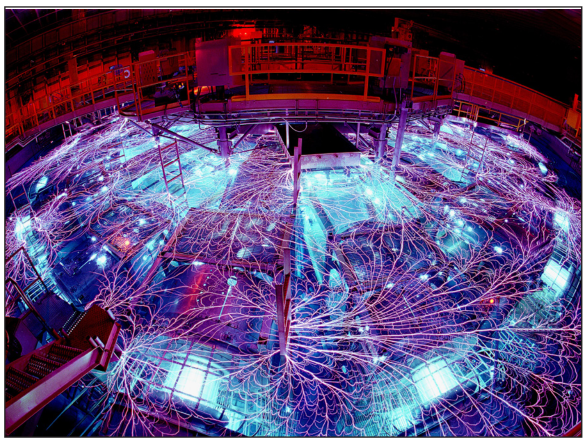


Figure 1. An open-shutter photo showing flashover as electrical energy courses through the transmission line sections of Sandia National Laboratories' Z machine. (Photo by Randy Montoya)

The machine also supports a broad array of academic studies and other scientific programs, including energy and fusion research. With access to the Z-machine for plutonium experiments currently limited to four weeks per calendar year (one experiment takes an entire week to execute) and with the demand for this capability steadily increasing, it is more important than ever to design, build, and execute high-quality experiments.

Cross-Complex Collaboration

"The Z-machine is the world's largest pulsed-power machine and provides a truly unique capability to dynamically load macroscopic samples of plutonium to weapon-relevant conditions," said Chris Seagle, the Dynamic Material Properties manager at SNL. "Sandia is proud to partner with LANL. This collaboration has pushed our capabilities in a positive direction and increased the impact of Z-machine experiments on national security and stockpile stewardship."

Providing this world-class capability is no small feat and requires strong coordination across the national security enterprise. In addition to the highly collaborative lab-to-lab partnership between LANL and SNL, successful execution of these experiments requires engagement across all LANL directorates, including Weapons (DDW), Science, Technology and Engineering (DDSTE), and Operations (DDOPS), as well as multiple external stakeholders including the Waste Isolation Pilot Plant (WIPP), Weston Solutions Inc., N3B, and the National Nuclear Security Administration.

"The plutonium measurements on Z provided through this SNL-LANL collaboration are unique and tremendously valuable," said Mark Chadwick, Chief Operating Officer of Weapons Physics (ALDX). "They complement other plutonium data measured by LANL in Nevada subcritical experiments and supporting experiments on-site at Los Alamos that use gas guns and other complex apparatus."

A Boon to National Security

With typical plutonium sample sizes along the order of one square centimeter, recent work on the Z-machine is proof that small-scale plutonium science can have a big impact on national security.

This collaboration and the combination of experiments provides the nuclear weapon design laboratories with confidence in their assessments of weapons materials, helping ensure the safety, reliability, and performance of the nation's stockpile—without testing an actual weapon.

Excellent Start to Year 2 of the NNSA Predictive Science Academic Alliance Program III *by David Etim (National Nuclear Security Administration)*

From January to May 2022, the Predictive Science Academic Alliance Program (PSAAP) III Centers successfully held their Year 2 Trilab Sponsor Team (TST) meetings. The TST meetings typically take place annually about six months before the PSAAP Annual Review. Unlike the Annual Review, the TST meeting is a forum to discuss updates, ideas, and issues surrounding the progress of the research, new developments from the NNSA laboratories, and any challenges from the Center.

The Year 2 PSAAP III Annual Reviews will be held from September to November 2022. The work discussed will reflect accomplishments and awards from the first two years of performance. See the *PSAAP III Year 2 Annual Review Schedule* for details.

PSAAP consists of leading U.S. universities performing development and demonstration of technologies and methodologies through the structure of Multidisciplinary Simulation Centers (MSCs), Single-Disciplinary Centers (SDCs), and Focus Investigatory Centers (FICs) to solve open science and engineering application problems.

MSCs and SDCs focus on scalable application simulations, targeting either large-scale, integrated multidisciplinary problems or a broad single science/engineering discipline, respectively. MSCs and SDCs develop and demonstrate computer science technologies and methodologies that will advance Exascale computing systems and demonstrate integrated, verified, and validated predictive simulation with uncertainty quantification.

FICs are tightly focused on a specific research topic in either a science/engineering discipline or an Exascale enabling technology of interest to the National Nuclear Security Administration's mission.

The primary focus of PSAAP is the emerging field of predictive science, which is the application of verified and validated computational simulations to predict the behavior of complex, multiscale, multi-physics systems with quantified uncertainty. Predictive science is relevant to a variety of applications, including nuclear weapons effects, efficient manufacturing, global economics, high performance computing, and data analytics across multiple disciplines. Each simulation requires integrating a diverse set of disciplines, and the success of each simulation requires using the most powerful computational systems. A key component in PSAAP is computer science research (both software and algorithmic frameworks) that will contribute to the effective use of emerging architectures, systems, and technologies.

Students from the recently established PSAAP III Center at the University at Buffalo.

PSAAP III

Year 2 Annual Review Schedule

Predictive Science Academic Alliance Program III

9/26-27: Center for Micromorphic Multiphysics Porous and Particulate Materials Simulations with Exascale Computing Workflows, University of Colorado (Boulder, CO)

9/29-30: Center for Understandable, Performant Exascale Communication, University of New Mexico (Albuquerque, NM) - Meeting will be held in Chattanooga, TN

10/6-7: Center for Exascale Monte Carlo Neutron Transport, Oregon State University (Corvallis, OR)

10/13-14: Integrated Simulations using Exascale Multi-physics Ensembles, Stanford University (Palo Alto, CA)

10/17-18: Center for the Exascale Simulation of Material Interfaces in Extreme Environments, Massachusetts Institute of Technology (Cambridge, MA)

10/20-21: Solution-Verification, Grid-Adaption and Uncertainty Quantification for Chaotic Turbulent Flow Problems, University of Maryland (College Park, MD)

10/24-25: Center for Exascale Simulation of Hybrid Rocket Motors, University at Buffalo (Buffalo, NY)

10/27-28: Center for Exascale-Enabled Scramjet Design, University of Illinois (Urbana-Champaign, IL)

11/3-4: Exascale Predictive Simulation of Inductively Coupled Plasma Torches, University of Texas (Austin, TX)

Peculiarities of Planar Shockwave Interaction with Air-Water Interface and Solid Target

by [1]D. Maler, [1]S. Efimov, [2]S. Theocharous, [3]J. Strucka, [3]Y. Yao, [3]W. Proud, [4]A Rack, [4]B. Lukic, [3]S.N. Bland, and [1]Ya. E. Krasik

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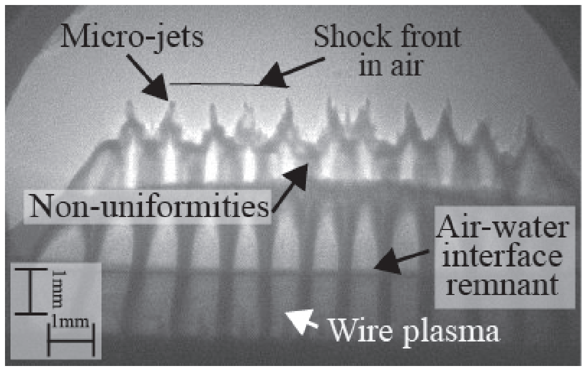
[2]Engineering Mechanics Department, Royal Institute of Technology
[3]Plasma Physics Group, Imperial College London
[4]European Synchrotron Radiation Facility

This highlight summarizes an article that is an Editor's Pick in the Physics of Plasmas journal.

In research partly supported by NNSA's Multi-University Center of Excellence for Pulsed-Power-Driven High-Energy Density Science, students from Imperial College and Technion led efforts to study the explosion of metallic wires embedded in insulators. High resolution radiography enabled some of the first direct measurements of wire density as the wires transitioned into the warm dense regime, and probed the complex behaviour of shocks launched from the wires into the insulator and at an insulator/air interface. A highly compact, pulsed power generator (~30 kA, ~1 µs rise time) was utilised to ohmically heat planar arrays of copper wire with the diameter, length, and number of wires tuned to provide critical damping of the energy in the generator. To provide insulation, the wires were submerged in a water bath several millimeters in depth. The explosion of the wires and the shockwaves passing through the water were imaged using the ID19 phase contrast imaging beamline at the European Synchrotron Radiations Facility synchrotron. Each experiment generated up to 256 frames of high resolution X-ray radiography with an interframe time 176 ns or 704 ns.

Comparison of current and voltage measurements with radiographs taken at different stages of the experiment enabled plasma parameters, including the coupling coefficient, electron density, and conductivity to be estimated as the wires underwent phase changes forming a dense, highly resistive plasma that then expanded against the water.



Radiograph captured when an air-water interface was present above the submerged array (wires into the page, at the bottom of the image).

When a simple air-water interface was left above the position of the expanding wires, radiography showed that multiple shockwave interactions in the water produced micro-jetting phenomena in the air. With a large, solid target used instead of the air, shock reflection and rarefaction waves were observed in the water, and cavitation seen between the wires and the target. Two-dimensional (2D) simulations achieved good agreement with experimental results in both configurations, and the results help explain previous measurements of the motion of flyer plates driven by wire array explosions—a potential new drive for impact equation of state experiments.

The experiments demonstrate the versatility of coupling pulsed power driven experiments to the exemplary diagnostic capabilities of 3rd generation synchrotrons. Future experiments will explore convergence onto warm dense matter targets in 2D and 3D and a higher current, ~150 kA, driver is being prepared for use.

Reference

D. Maler et al., Physics of Plasmas 29, 063502 (2022); https://doi.org/10.1063/5.0095506

In the next issue...

CELEBRATING 20 YEARS STEWARDSHIP SCIENCE ACADEMIC ALLIANCES

Happy 20th Anniversary to the NNSA Stewardship Science Academic Alliances Program!