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TECHNICAL MANAGER
Dr. Adam Farrow*

MANAGING EDITOR
Terri Stone

PUBLICATION EDITOR & DESIGN
Millicent Mischo**

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CALENDAR

1/5/2022
DOE/NNSA Stewardship Science Graduate Fellowship applications due

1/12/2022
DOE/NNSA Computational Science Graduate Fellowship applications due

2/15-17/2022
DOE/NNSA Stewardship Science Academic Programs Symposium, virtual

3/7-11/2022
2022 Hardened Electronics and Radiation Technology (HEART) Conference, Tarrytown, NY

3/14-18/2022
APS March Meeting 2022 Chicago, IL

3/16/2022
DOE/NNSA Laboratory Residency Graduate Fellowship applications due

INSIDE

*National Laboratory Detailee **Contractor Support

Welcome to the latest issue of *Stewardship Science Today*. As promised in our last issue, we feature a detailed article on the record-breaking inertial confinement fusion shot that occurred on August 8 at the National Ignition Facility. This is a momentous achievement for the nuclear security enterprise, and we congratulate all of the individuals from across the complex, both past and present, whose work and dedication led to this ground-breaking result. We look forward to continued successes in the quest to achieve laboratory ignition and will keep you all informed of the progress.

This issue also features work performed by the Center of Research Excellence on Dynamically Deformed Solids investigating nanoindentations and how such indentations affect material strength. These exciting new findings at the nano-scale will be used to improve models of material strength, an area of significant importance to stockpile stewardship.

Mark your calendars for the upcoming Stewardship Science Academic Programs Symposium that will be held fully-virtually again this year on February 15-17, 2022. Last year's fully-virtual symposium was a great success, and your participation this year will ensure another banner year for this important event in our community. We look forward to seeing you there online.

Save the Date: 2022 Stewardship Science Academic Programs Symposium. *As shown above, DOE/NNSA's academic partners packed 2021 full of exciting research. Join us at the 2022 SSAP Symposium, to be held virtually, for presentations about featured research, technical posters, and so much more! Read the article below to learn more.*

Please continue to be vigilant in following health and safety protocols. As always, keep yourselves and your loved ones safe.

Dr. Mark C. Anderson
Assistant Deputy Administrator
for Research, Development, Test, and Evaluation

2021 Stewardship Science Academic Programs Symposium

The National Nuclear Security Administration is pleased to announce the 2022 Stewardship Science Academic Programs (SSAP) Symposium will be held on February 15-17, 2022. Due to the uncertainty of the current pandemic situation, and in an effort to safeguard the health of our academic programs community, the 2022 SSAP Symposium will be a fully online, virtual meeting again this year. The symposium agenda will be spread over three days and will have a later start time in the mornings to accommodate the different time zones.

Our goal is to provide you the same opportunities for making important connections, exchanging research information, and interacting with the wide range of scientific communities the SSAP encompasses. As in past years, the symposium will include presentations from grantees on their current research efforts, talks by NNSA and DOE/NNSA national laboratory staff, opportunities to connect with staff from NNSA, the national laboratories, the Krell Institute (who manage our fellowship programs), and multiple opportunities to view the graduate student posters. The symposium will culminate with the Outstanding Poster Awards ceremony.

Important dates include the poster registration deadline of January 10 and symposium registration deadline of February 1. Click here to register. We look forward to seeing you online!

National Ignition Facility Experiment Opens New Doors for Stewardship Science Research *by Charlie Osolin, (Lawrence Livermore National Laboratory)*

On August 8 of this year, the National Nuclear Security Administration's (NNSA's) National Ignition Facility (NIF) at Lawrence Livermore National Laboratory surprised the scientific community by conducting an experiment that produced more than 1.3 megajoules (MJ) of fusion energy. The achievement puts researchers at the threshold of ignition—where a NIF implosion produces more fusion energy than the amount delivered to the target—and opens access to a new experimental regime in high energy density and stewardship science (Figure 1).

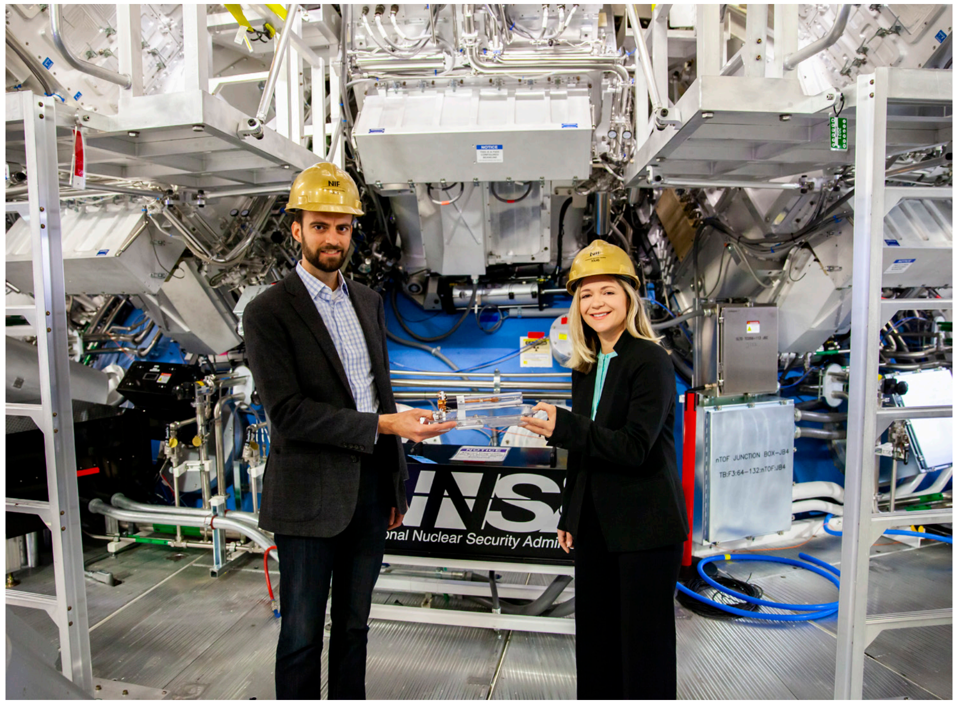

Figure 1. Lead Experimentalist Alex Zylstra and Lead Designer Annie Kritcher with the Hybrid-E target used on the August 8, 2021 experiment.

In the experiment, approximately 1.9 MJ of ultraviolet laser light from NIF's 192 high-energy lasers was focused on a BB-sized target, generating more than 10 quadrillion watts of fusion power for 100 trillionths of a second.

"These results from NIF advance the science that NNSA depends upon to understand and modernize our nuclear weapons and open up new areas of research," said Jill Hruby, the Department of Energy's (DOE's) Under Secretary for Nuclear Security and NNSA Administrator. NIF, the world's largest and highest-energy laser system, is able to produce temperatures of more than 100 million degrees Kelvin and pressures of billions of earth atmospheres—conditions found only in the center of stars, giant planets, and exploding nuclear weapons.

The record-breaking inertial confinement fusion (ICF) shot was one of a series of progressively higher energy-yield experiments on NIF, each building on earlier successful experiments with a variety of previously-demonstrated tactics and new understanding. Key changes included shrinking the aperture of the holes at the ends of the pencil-eraser-sized cylinder (the hohlraum) to curb energy losses; substantially reducing surface and subsurface defects in the capsule; decreasing the size of the tube used to inject fuel into the capsule; and extending the laser pulse to boost the implosion velocity and to concentrate more energy in the capsule's central "hot spot" (Figure 2).

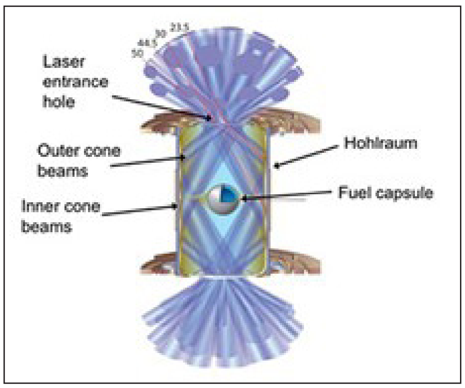

Figure 2. Schematic of a NIF ignition target. The fuel capsule is suspended inside a gold or other high-Z cylinder, the hohlraum. The laser beams enter the target at the ends of the cylinder through laser entrance holes and strike the inside of the hohlraum to generate x rays, which ablate the surface of the capsule and cause a rocket-like, high-velocity implosion. The extreme pressures and temperatures cause deuterium and tritium atoms to fuse, releasing enormous amounts of energy.

In the experiment, alpha particles (helium nuclei) produced by fusion reactions in the hot spot deposited their energy in the surrounding cold deuterium-tritium fuel. Alpha heating became the dominant source of heating, igniting additional fusion reactions that spread through the fuel in a self-sustaining thermonuclear burn wave called a propagating burn. About 2 percent of the fuel was consumed in the burn wave.

The shot produced an unprecedented 4.8×10^{17} (480 quadrillion) neutrons. The 1.35 megajoules of fusion energy yield was eight times NIF's previous energy record, set by an experiment in February of this year, and 25 times the record set in 2018. The fusion energy yield was about 70 percent of the energy needed to meet the formal definition of ignition established by the National Academy of Science in 1997.

Supporting the Stockpile

The experiment was a milestone for NIF's role in NNSA's science-based Stockpile Stewardship Program. Mark Herrmann, Livermore's deputy director for fundamental weapons physics, said that access to this new experimental regime will help weapons scientists test and refine the computer models they use to better understand and assess the performance of the stockpile's aging nuclear weapons. The higher yields also can contribute to near-term applications supporting NNSA's nuclear modernization program and studies of nuclear survivability, improve understanding of the thermonuclear burn process, and increase confidence in the development of a future high-yield facility to support stewardship.

"This is a regime that we've been working toward for a very long time," Herrmann said. "It's a massive change for not just our program but for the national [stewardship] program. It's really a testament to this lab and our partnerships with many external partners—General Atomics, Los Alamos and Sandia national labs, the University of Rochester, and many others."

LLNL Director Kim Budil said the result "opens the door to exciting new NIF applications to support stockpile stewardship, enables us to study robustly burning plasmas for the first time since underground testing ended, and creates new possibilities to get to much higher fusion yields on NIF."

"There's a lot more to learn, a lot more to think about, a lot more experiments to do," added Herrmann. "It's hard to imagine a more exciting time for this program."

This work was performed by Lawrence Livermore National Laboratory, operated by Lawrence Livermore National Security, LLC, for the U.S. Department of Energy/ National Nuclear Security Administration. The NNSA Office of Experimental Sciences supported this work through its Inertial Confinement Fusion Program.

Looking Beneath the Surface of Nano-scale Indentation Response

by Michael Demkowicz (Texas A&M University)

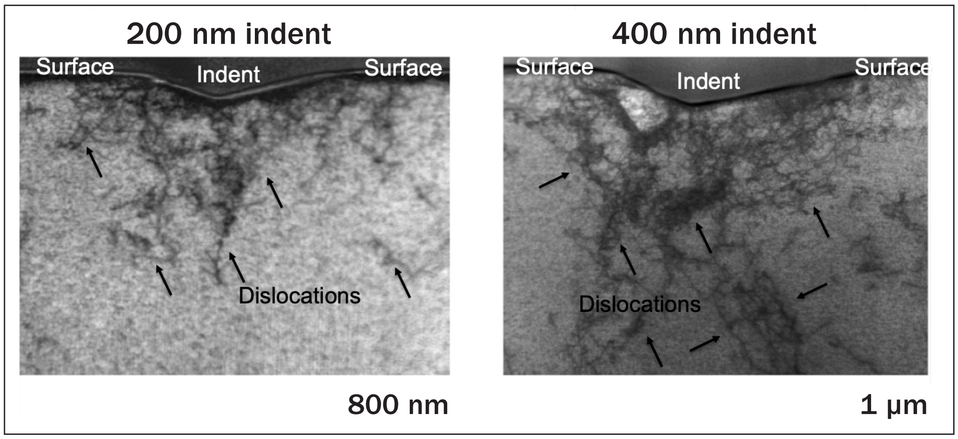

Figure 1. These cross-section views through material beneath surface indents show that dislocations (visible as dark tangles) are present in much lower numbers under shallow indents (left) than under deeper ones (right).

Nanoindentation is a powerful technique for investigating the mechanical properties of solids. Usually, it involves measuring the force needed to press the sharp corner of a diamond into a solid surface. However, until now what happens beneath the surface has eluded scientists. In a paper published in the *Proceedings of the National Academy of Science*, a team of researchers from Texas A&M University reports direct experimental measurements of the density of dislocations—the crystal imperfections that govern strength in most metals—in material directly underneath the impression made by a diamond indenter.[1] The team was led by Kelvin Y. Xie and included Center of Research Excellence on Dynamically Deformed Solids (CREDDS) members, George M. Pharr and PhD student Wesley Higgins.

The study relies on an advanced transmission electron microscopy technique known as precession electron diffraction (PED). Using it, the authors found that for indents smaller than one micrometer, the dislocation density is much lower than expected. In contrast to the prevailing Nix-Gao model, which assumes there should be a significant increase in dislocation density as the size of the indent decreases, the new observations show that strength at small indent depths is more likely controlled by dislocation source starvation. On the other hand, at larger depths, the dislocations increase in number, become heavily intertwined, and eventually self-arrange to form complex, entangled structures in better agreement with the Nix–Gao model.

These findings stand to improve models of mechanical strength of solids at the nano-scale. They provide fundamental understanding needed to interpret high-strain-rate nanoindentation experiments currently underway at CREDDS. Specifically, they will aid in distinguishing size-dependent deformation from strain-rate-dependent response.

Indentation strain rate may be expressed as $\dot{\varepsilon} = \dot{d} / d$, where d is indentation depth and $\dot{d}$—the time derivative of d—is indentation velocity. Because d appears in the denominator, low indentation depths tend to yield high strain rates. Additionally, in some experiments, $\dot{d}$ is greatest when the indenter impacts the sample surface, i.e., when $d = 0$. Thus, investigating high strain rate material response using indentation requires the ability to distinguish the influence of strain rate from the indentation size effect.

Reference

[1]Xiaolong Ma, Wesley Higgins, Zhiyuan Liang, Dexin Zhao, George M. Pharr, and Kelvin Y. Xie, "Exploring the Origins of the Indentation Size Effect at Submicron Scales," Proceedings of the National Academy of Science 118, e2025657118 (2021).

Highlights

During the week of November 7, three Los Alamos Neutron Science Center pRad Medusa series experiments were successfully executed to investigate the initiation and corner turning performance of the newly-developed high explosive PBX 9701. PBX 9701 is a DAAF (3,3'-diamino-4,4'-azoxyfurazan)-based explosive with similar mechanical safety characteristics to PBX 9502 but with increased detonation performance. The experiments were performed at cold, ambient, and hot temperatures, and a preliminary analysis shows consistent behavior across the temperature range. Another unique feature of these experiments was that DAAF was the only explosive molecule in these experiments (the detonators used a DAAF pellet and there were no separate boosters). The cold and hot experiments were the first all-DAAF/PBX 9701 initiation experiments performed at those temperatures.

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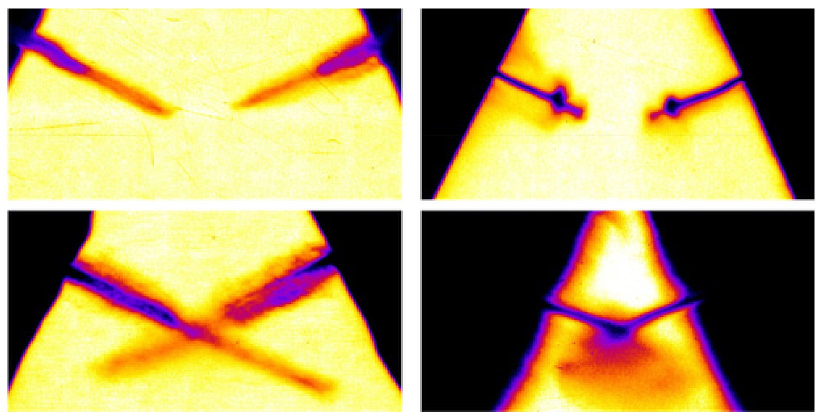
During the week of September 20, Los Alamos National Laboratory performed X-ray diffraction experiments at the Advanced Photon Source's 1ID beamline to characterize the effects of defects on phase stability in a plutonium-gallium alloy. The experiments on multiple bulk PuGa alloy samples, at temperatures from 10 K to room temperature, required triple containment radiation shields. The high X-ray energy (95 keV) beam penetrated the environment vacuum chamber and PuGa samples to provide bulk diffraction characterization of the sample microstructure. High resolution (~1 micron) computed tomography, diffraction, and small angle scattering measurements were completed.

Publication in *Physical Review Letters* Highlights Innovative Work Studying Ejecta Interactions

A paper recently selected as a *Physical Review Letters* Editor's Suggestion describes results from a new platform on OMEGA EP designed to study metal ejecta interactions. The work is the first to show time sequences of radiography images of colliding tin ejecta microjets. Two tin shock pressures (before release) were explored, showing two regimes of interaction behavior; jets emerging from tin shocked to 11.7 GPa pass through each other unattenuated, whereas jets emerging from tin shocked at 116.0 GPa interact strongly and form a corona of material around the interaction region. The results of the interactions are compared to hard-sphere collision simulations performed in the radiation hydrodynamics code Ares. The simulations and experimental data suggest that many factors (such as jet density, particle size distributions, elasticity of collisions, and material phase) contribute to the difference in interaction behavior observed. This work offers ideas to further probe the physics dominating ejecta microjet interactions and opens new avenues of research in the field of particle collision dynamics and ejecta physics through its novel explorations collisional behavior. Abstract ◆ Paper



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Assessed Self-Similar Scaling of Magneto-Rayleigh-Taylor Instability with Drive Current on Z

Sandia National Laboratories conducted the first dedicated Z experiment to study scaling of magneto-Rayleigh-Taylor instability (MRTI) growth with current. The team scaled down a 19-MA peak current MRTI target [D.B. Sinars, S.A. Slutz, M.C. Herrmann et al., Phys. Rev. Lett. 105, 185001 (2010)] to 14 MA. The preliminary analysis indicates the MRTI growth is conserved, as predicted by magnetohydrodynamic simulations and theory, for appropriately modified amplitude and wavelength of the pre-seeded perturbations on a scaled liner (Figure 1). These results provide confidence in paradigms considered to scale ICF to a future pulsed power generator capability.

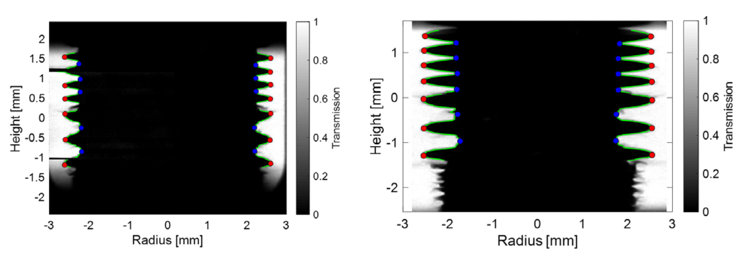

Figure 1. Radiographs using time-gated backlighting capability of ultrafast X-ray imager camera on Shot Z3614 with MRT growth of 338 μm (left) and 600 μm (right) wavelength perturbations.

The Department of Energy National Nuclear Security Administration Stewardship Science Graduate Fellowship **(DOE NNSA SSGF)** provides outstanding benefits and opportunities to students pursuing degrees in stewardship science areas, such as **properties of materials under extreme conditions and hydrodynamics, nuclear science, or high energy density physics.**

The fellowship includes a 12-week research practicum at Lawrence Livermore National Laboratory, Los Alamos National Laboratory or Sandia National Laboratories.

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The Department of Energy National Nuclear Security Administration Laboratory Residency Graduate Fellowship **(DOE NNSA LRGF)** gives students the opportunity to work at DOE NNSA facilities while pursuing degrees in fields relevant to nuclear stockpile stewardship: **engineering and applied sciences, physics, materials, or mathematics and computational science.**

Fellowships include at least two 12-week research residencies at Lawrence Livermore, Los Alamos or Sandia national laboratories, or the Nevada National Security Site.

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The Department of Energy Computational Science Graduate Fellowship (DOE CSGF) provides up to four years of financial support for students pursuing doctoral degrees in fields that use high-performance computing to solve complex problems in science and engineering.
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