DOE/NA-0129

NNSA National Nuclear Security Administration

Stewardship Science Today

Office of Research, Development, Test, and Evaluation (RDT&E)

VOLUME 4 | NUMBER 1 | MARCH 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 Research, Development, Test, and Evaluation. 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

4/21-22/2022
2nd ZNetUS Workshop, virtual

4/27-29/2022
Omega Laser Users Group (OLUG) Workshop, Rochester, NY

5/8-13/2022
Materials Research Society Spring Meeting, Honolulu, HI

5/15-20/2022
High Temperature Plasma Diagnostic Conference, Rochester, NY

5/15-20/2022
CLEO 2022, San Jose, CA

INSIDE

*National Laboratory Detailee **Contractor Support

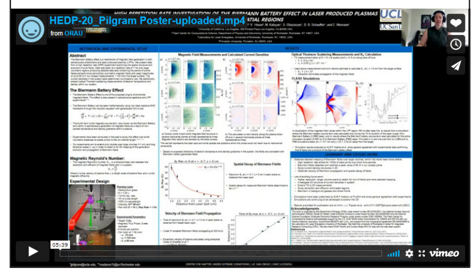
Welcome to the March issue of *Stewardship Science Today*. This issue features recent results using digital holography from experiments conducted at the Special Technologies Laboratory in collaboration with Los Alamos National Laboratory and Sandia National Laboratories. The advances in this diagnostic technique will enhance data capture from subcritical experiments to better understand ejecta particle size and velocity distributions from shocked surfaces. Such results are of great relevance to the nuclear stockpile.

We also feature an interesting multi-platform approach to better understand the response of complex materials under compression. A particularly interesting aspect to this work is the innovative use of multiple experimental facilities both at Sandia National Laboratories and at Argonne National Laboratory to explore the response of materials over a wide variety of conditions to arrive at a more comprehensive equation of state.

In this issue, we highlight investigating the dynamics of helium bubbles in the decay of plutonium. Understanding the behavior of helium formation in plutonium is an area of study with significance to the stockpile, and this study is making use of small-angle X-ray scattering techniques to study larger samples sizes which are statistically more significant.

Outstanding Poster Award Winner

High Repetition Rate Investigation of the Biermann Battery Effect in Laser Produced Plasmas Over Large Spatial Regions



Pictured is one of the nine 2022 SSAP Symposium Outstanding Poster Award winning posters (Jessica Pilgram, University of California, Los Angeles). Click here to view the others.

We also highlight the Outstanding Poster Award winners from the NNSA 2022 Stewardship Science Academic Programs (SSAP) Symposium. Congratulations on your excellent work. The photo above shows one of the award-winning posters. You can view all the winning posters and presentations at www.orau.gov/ssap2022.

As always, keep yourselves and your loved ones safe.

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

2022 Stewardship Science Academic Programs Symposium and Outstanding Poster Awards

The Department of Energy/National Nuclear Security Administration's (DOE/NNSA's) Stewardship Science Academic Programs (SSAP) Symposium was held virtually on February 15-17, 2022. More than 450 registered participants attended.

After the welcome by NNSA's Ann Satsangi, two SSAP Program Managers program overviews were presented by NNSA's David Etim, Program Manager of the Predictive Science Academic Alliance Program, and Dr. Beatriz Cuartas, Federal Program Interim Director for the Minority Serving Institutions Partnership Program. They were followed by Dr. Njema Frazier, Acting Assistant Deputy Administrator for the Office of Strategic Partnership Programs, who delivered a keynote address "Academia, Pipeline, and the Workforce: The Future of the Academic Programs at NNSA."

As in past years, the Symposium featured the research of grantees from the following DOE/NNSA programs:

- Stewardship Science Academic Alliances;
- High Energy Density Laboratory Plasmas; and
- National Laser Users' Facility.

Other keynote and special sessions were presented by Andrea Kritcher and Alex Zylstra, Lawrence Livermore

(continued on page 4)

Digital Holography Diagnostic for Dynamic Shock Experiments

by Andrew Corredor (Nevada National Security Site)

When a shock wave interacts at a metal-vacuum (gas) interface, metal (liquid) particles (ejecta) are emitted from the surface. Characterizing the size, velocity, and mass distribution of these ejecta particles have been of interest for many decades at Los Alamos National Laboratory (LANL) and Lawrence Livermore National Laboratory (LLNL). A variety of experimental techniques have been implemented to make these measurements. In this article, we report advances to the in-line Fraunhofer holography measurement. This measurement technique records a hologram that is used to reconstruct a three-dimensional volume of particle data in which a direct measurement is made of the particle size and shape. This article reports on new advances that have been made to this diagnostic and presents preliminary results of experiments that were conducted at the Special Technologies Laboratory (STL). The new advances allow not only the particle size and position to be accurately measured, but the particle velocity is measured directly as well. In addition, we are digitally recording the hologram, as opposed to using photographic film.

Five holography experiments were carried out at the Nevada National Security Site (NNSS) STL boom box facility during November 2021. These experiments were carried out as part of a collaboration between NNSS, LANL, and Sandia National Laboratory (SNL).

The experimental campaign produced the first-ever, multi-frame, digital holographic images of micron-scale ejecta in a vacuum environment. Figure 1 shows a schematic of the holography experimental setup. Not shown in the figure is a high-power ultraviolet (355 nm) laser that produces a 20 mJ, 150 ps single laser pulse. The pulse is split into parallel and perpendicular polarizations. One of these pulses is delayed relative to the other pulse by 8.84 ns. The two pulses are recombined on the same axis and proceed to the ejecta region shown in the figure. The two laser pulses pass through an ejecta particle sheet produced by a high-explosively-driven Tin (Sn) target with a single groove. After passing through the ejecta sheet, the scattered and un-scattered wave fronts are relayed through a 5x magnification, high resolution lens system and two separate optical relays with a total magnification of 8.3 at the cameras. The interference between the two wave fronts are captured on the camera sensors. At the right of Figure 1, a polarizing cube is shown that splits each of the two beam pulses to the cameras so the camera records a hologram at the two different times. Figure 2a is a reconstructed image of a particle field. Superimposed on the image are velocity vectors that are produced by overlaying the two images at the two different times and measuring the distance between the particle doublets. The particle size is color-coded as indicated.

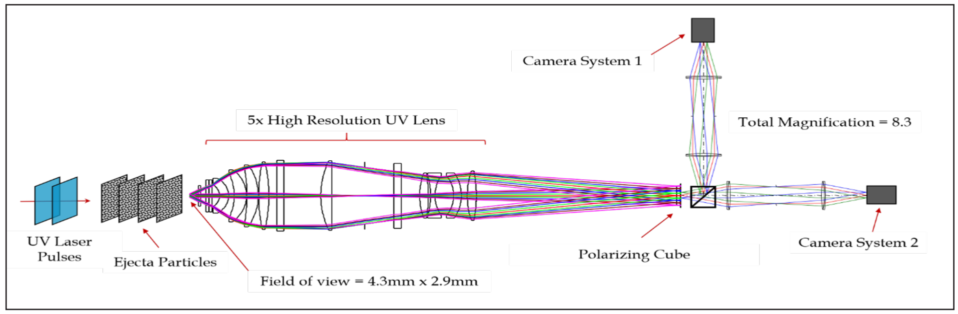


Figure 1. Digital holography diagnostic and experimental layout.

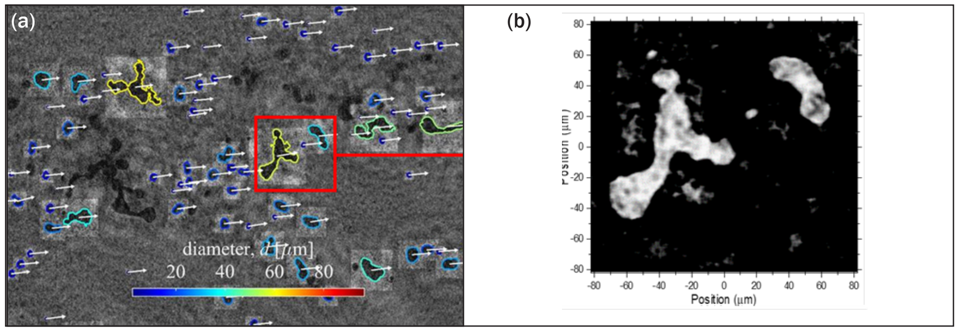


Figure 2. (a). Reconstructed Image. (b) A zoomed-in region of a few particles. Clearly, there are many particles that are non-spherical. From this measurement both particle size and velocity distributions are obtained. Figure 3 shows the particle size distribution.

This diagnostic development work is aimed at future subcritical experiments that require measurements of ejecta particle size and velocity distributions emitted from shocked surfaces. The diagnostic development efforts are aimed primarily at the following areas:

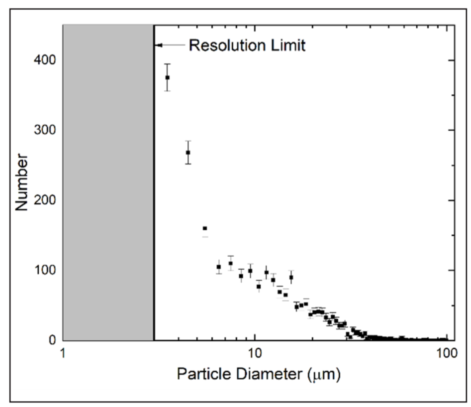


Figure 3. Particle size distribution.

1. Multi-frame digital holography,
2. Recording the hologram digitally (currently the holograms are recorded on film), and
3. Developing and testing phase conjugate holography to allow holography measurements in a gas environment.

Digital Holography Team

Andrew Corredor, Dan Sorenson, Robert Malone, David Phillips, Jason Mance, Ben Valencia, Matt Staska (NNSS); Dana Duke (Principal Investigator), Jeremy Danielson, Emma Rudziensky, Kevin Lamb (LANL); Daniel Guildenbecher, Anthony McMaster (SNL).

Sandia Puts into Action a Broad-Range, Multi-Platform Approach for Material Physics

by Patricia Kalita (Sandia National Laboratories)

Multi-platform research on complex materials and the utilization of multiple length- and time-scales advances the science that the National Nuclear Security Administration (NNSA) depends on to understand and modernize our nuclear weapons. Stewardship science research focuses on all stages of material compression: static cold compression on the timescale of minutes which maps the isotherm; the sub-nanosecond shock compression where each experiment is an end-point location on the Hugoniot curve; and, in between those two, a range of isentropic ramp compression paths over tens to hundreds of nanoseconds.

In this project, we laid out a systematic plan to exploit the shock, ramp, and static compression capabilities at NNSA facilities, with diagnostics spanning from the continuum scale to the atomic scale complemented by simulations, to probe the response of a complex, heavy metal oxide to dynamic compression. The material is gallium oxide, an important functional material with rich physicochemical properties and an emerging candidate for applications in different fields (high power electronics, optoelectronics, and more). It has an ultra-large band gap (>>3 eV), is a transparent semiconducting oxide, and belongs to the family of strong oxides (materials possessing covalent bonds with a strength of a few electron-volts). Its phase diagram has only been partially mapped thus far and displays multiple phase transitions.

For this project, we chose gallium oxide because of its rich crystal structure and its potential for exotic behavior under dynamic loading, including time dependence of phase transitions.

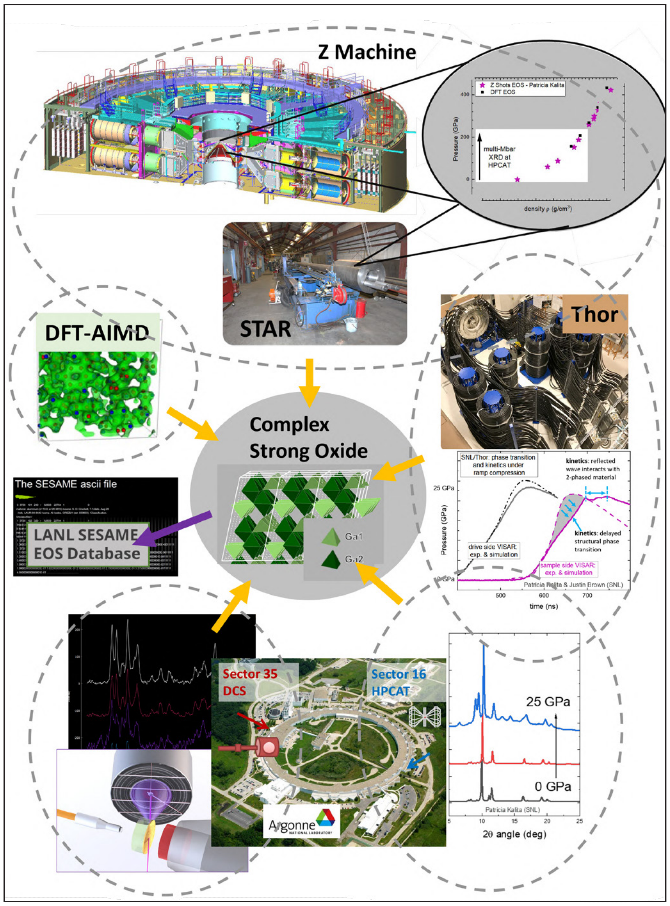


Figure 1. Multi-platform, multi length- and time-scales experimental and theoretical project to probe the response of a complex, heavy metal oxide to dynamic compression.

The material was also chosen because its multiple low-symmetry (i.e. not cubic) crystal structures and thermal anisotropy make experiments, density-functional theory (DFT) simulations, and equation of state (EOS) design much more challenging, which motivates us to push boundaries of both experimental and modelling methods.

This multi-platform project—illustrated in Figure 1—combines the Z machine, STAR, and Thor at Sandia National Laboratories (SNL), and the Dynamic Compression Sector (DCS) and the High Pressure Collaborative Access Team (HPCAT) at the Advanced Photon Source (APS), Argonne National Laboratory (ANL). Shock compression on SNL's Z machine up to 1.5 Terapascal is complemented with the SNL STAR facility's 2-stage gas gun shots to map out the unknown Hugoniot EOS. Shock experiments are paired with Ab Initio Molecular Dynamics calculations at SNL. Structural phase transitions are being mapped at the atomic scale with X-ray diffraction and diamond anvil cells at HPCAT at the APS. Dynamic response at the continuum scale is probed at SNL's Thor pulsed power facility, while structural studies of dynamic response are carried out at DCS. Experimental results and simulations are being compiled into a multi-phase, broad range EOS at Los Alamos National Laboratory (LANL).

The lead experimentalist of the series is SNL physicist Patricia Kalita, and the SNL team includes Scott Alexander, Dave Bliss, Justin Brown, Kyle Cochrane, Bernardo Farfan, Paul Specht, Josh Townsend, and the Dynamic Material Properties manager Chris Seagle. Additional team members are LANL's Scott Crockett, Advanced Simulation and Computing Physics and Engineering Models EOS Project Leader (design of a multiphase, broad-range EOS), and NNSA's DCS and HPCAT beamlines at the Advanced Photon Source. We are also mentoring students from University of Alabama Professor Yogesh Vohra's laboratory.

Successful capture of quality crystal structure changes and their kinetics under dynamic compression on a low symmetry and high Z material is very challenging. Obtaining high quality density functional theory calculations requires delicate geometry relaxations to produce reliable equilibrium data. Many of the standard EOS models currently in use are geared to simple elemental metals. Gallium oxide pushes the modeling beyond basic physics assumptions. The complex nature of the crystalline structures leads to anisotropy or directional dependency. These dependencies make various quantities like thermal expansion and the compression response change according to crystalline orientation. We are currently modelling an EOS for four of the solid phases and the liquid.

Helium Bubble Dynamics in Aging Plutonium *by Hector E. Lorenzana and Joshua A. Hammons (Lawrence Livermore National Laboratory)*

Helium bubbles in plutonium are a product of radioactive decay and play a key role in changing bulk properties such as density and strength as helium accumulates with age. As part of the National Plutonium Aging Strategy, we aim to advance our understanding of helium bubble dynamics in aging plutonium. Helium bubble properties under transient conditions have typically been diagnosed with various microscopies which have the drawback of having a limited field-of-view, small sampling numbers, and difficulty resolving bubbles at high temperatures. To observe a statistically large number of bubbles under transient conditions, we have developed an experimental approach based on small-angle X-ray scattering (SAXS) to study the dynamics of ~10^{12} helium bubbles at elevated temperatures with a time resolution of ≈ 5 minutes. We have demonstrated the power of this approach on several helium-implanted, non-hazardous metals using intense synchrotron x-rays at the 9-I-DC beamline at the Advanced Photon Source at Argonne National Laboratory. These scoping experiments have uncovered new

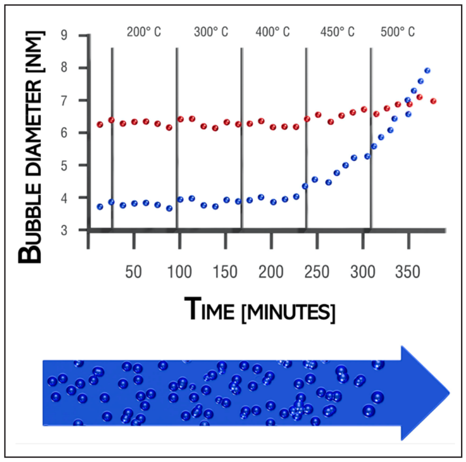


Figure 1. Techniques for in situ measurement of helium bubble dynamics point to new connections with other aging effects. Helium-bubble growth in two distinct aluminum samples with the same helium loading but different implantation and damage characteristics. Our combined experiments and simulations suggest that bubble growth is highly dependent on the type of damage present, as shown above.

insights into the central processes controlling helium-bubble evolution and have paved the way for comparable studies in plutonium. For the first time, two different bubble growth mechanisms are identified that promote large bubble growth at two distinct temperatures depending on radiation damage characteristics. Specifically, variations in lattice defects incurred during implantation result in a distinctly different bubble growth mechanism and change the temperature at which bubble growth is activated by 100 °C, as illustrated Figure 1. Near-term experiments aim to apply the same approach to materials in our nuclear stockpile to investigate the effects of aging on helium bubble dynamics and the resulting changes to bulk properties. Understanding the annealing of helium may also point to a way to mitigate aging effects.

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

2022 Stewardship Science Academic Programs Symposium and Outstanding Poster Awards *(continued from page 1)*

National Laboratory, "Achieving the Lawson Criterion and 1.35 MJ on the NIF"; Olivier Vacus, Scientific Director of Commissariat à l'Energie Atomique et aux énergies alternatives Military Applications Division (CEA/DAM), "Post Doctoral Opportunities in France"; A. Viahos and R. Burns, DOE Counter Intelligence Officers, "Protecting Scientific Research and U.S. Technologies"; Kristee Hall, NNSA Grants Officer, "Financial Assistance at a Glance"; and fellowship and internship opportunities for Stewardship Science Graduate Fellowship, Laboratory Residency Graduate Fellowship, Computational Science Graduate Fellowship, NNSA Graduate Fellowship Program, and the Minority Serving Institution Internship Program. There were also sessions focused on opportunities at the DOE/NNSA national laboratories and Sites, a User's Facility panel discussion, and networking with the national labs for graduate students.

More than 130 graduate students submitted posters this year, and we extend our thanks to the many judges. The winners this year are:

Patricia Cho
University of Texas at Austin
Testing Astrophysical Accretion Disk Models with Photoionized Iron Plasma Experiments

Raul Melean
University of Michigan
Pulsed-Power Magnetized Shocks under an External Magnetic Field

Rachel Shaffer
Louisiana State University
Studying Low-Lying States of 9B with Split-Pole Spectograph and SABRE

Yenuel Jones-Alberty
Ohio University
Studying the 11B Proton Structure via the 10Be(p,n)10B Reaction: A Preliminary Investigation

Wyatt Witzen
University of California, Santa Barbara
GND Mapping and Analysis in Shock Loaded Ta using 3D EBSD

Lauren Poole
University of California, Santa Barbara
Quasi-static and Dynamic Mechanical Behavior of Co-continuous Composites

Jessica Pilgram
University of California, Los Angeles
High Repetition Rate Investigation of the Biermann Battery Effect in Laser Produced Plasmas Over Large Spatial Regions

Rebecca Toomey
Rutgers University
ODeSA and the 18O(alpha,n)21Ne Cross Section

Hannah Bausch
Northwestern University
Shock-ramp Compression of Iron-rich (Mg,Fe)O: Preliminary Theory and Application to Earth's Ultra-low Velocity Zones

Congratulations to all!