Defense Science *Quarterly*

News about the Science Campaign
Winter 2010

Inside This Issue

Message from the Director

Chris Deeney, Defense Science Division

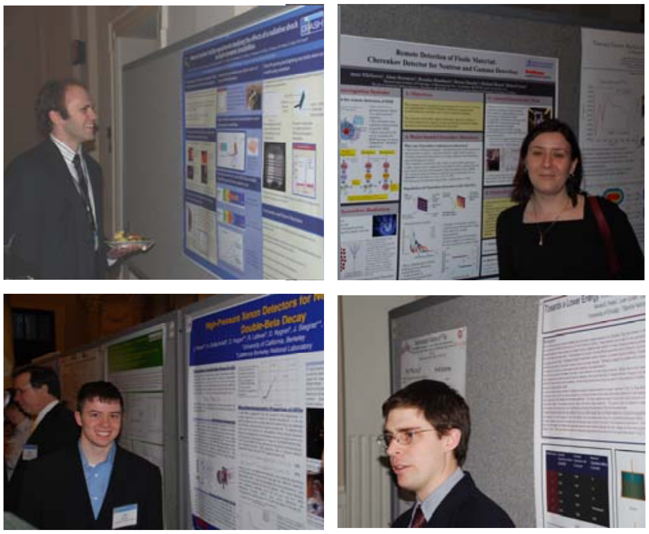
What an amazing time! The National Ignition Facility's (NIF's) progress is extraordinary and the team has completed a major stewardship experiment at the facility. Initial review of the data indicates that earlier promises of NIF's capabilities have been realized.

As we try to bring star power to earth on the NIF, we also demonstrate that we can take our facilities to the stars. Data on astrophysical jet formation was recently published in *Astrophysical Journal* by academic users of the Omega facility. Omega also plays a key role in the pursuit of ignition, and the recent achievement of a 50% increase in the areal density at Omega increases confidence about experiments at NIF. The whole field of high energy density laboratory plasmas (HEDLP) continues to generate excitement, and the upcoming report from the joint NNSA/DOE Office of Fusion Energy Sciences workshop on HEDLP will define some real scientific opportunities.

The Los Alamos Dual Axis Radiographic HydroTest (DARHT) facility has completed its first two-axis shot with a high-explosive driven target. This experiment is discussed in this issue. Subsequently, a full hydrodynamic test has been completed and we are eagerly awaiting full analysis of the results along with the results from the first Advanced Certification experiment. Outstanding work by the DARHT team means the science, technology, and engineering community has delivered a great tool for both Directed Stockpile Work and themselves. With a major life extension planned for the future, this is very timely. Indeed, a key element of our FY 2011 budget request is to use the hydrodynamic tools to understand certification challenges with some of the likely safety and surety improvements in the stockpile.

I would like to take this opportunity to continue to acknowledge the high quality work performed by the science community. It is vitally important to acknowledge others, and this Quarterly includes a few examples. The high-resolution UV holography lens, which received a 2009 R&D 100 Award as one of the most technologically significant products introduced in 2009, clearly demonstrates this high quality. Also, congratulations to Professor Yitzhak Maron on his 2009 Dawson Award of Excellence. Professor Maron and his group received this prestigious award for outstanding plasma spectroscopy. It is certainly well deserved. Please take time to read the papers discussed in the Publication Highlights section. The progress in materials at high pressure is truly remarkable.

Mike Kreisler, Terri Batuyong, and the team from ORISE deserve our thanks for another wonderful Stockpile Stewardship Academic Alliances Symposium at the Carnegie Institution in Washington, D.C. The students and professors found the symposium informative and engaging. Brigadier General Harencak's keynote speech was so rousing that we expect a deluge of employment applications to the laboratories and NNSA! •



University students were on hand to discuss their research during the poster session of the 2010 SSAA Symposium.

Comments

Questions or comments regarding the *Defense Science Quarterly* should be directed to Terri Batuyong, NA-121.1 (Terri.Batuyong@nnsa.doe.gov).

Technical Editor: Christina Coulter

Recent Stockpile Stewardship Relevant Experiments on the National Ignition Facility

by Stephan MacLaren, Peter Young, Amy Cooper, Alastair Moore, Marilyn Schneider, Warren Hsing, Omar Hurricane, Mike Zika, and the Radiation Transport Integrated Experimental Team (Lawrence Livermore National Laboratory)

A key mission driver for the Stockpile Stewardship Program (SSP) is to deliver predictive, physics-based capabilities to enable the assessment of the safety, reliability, and performance of the U.S. nuclear stockpile in an era without nuclear testing. With the recent dedication of a fully operational National Ignition Facility (NIF), the SSP communities now have access to an experimental platform that can reach the extreme temperature and density regimes previously inaccessible without the aid of a nuclear explosive.

Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory, and the U.K.'s Atomic Weapons Establishment have developed experimental campaigns to validate physics-based models relevant to stockpile stewardship. These experimental campaigns are designed to deliver the quantitative data, with high-precision diagnostics, to validate the codes and models and also serve as a tool to develop and train SSP personnel skills, knowledge, and abilities.

In FY 2009, LLNL led the radiation transport Integrated Experimental Team (IET) effort and carried out the first series of SSP-relevant experiments on the NIF. These experiments are designed to study the transport of radiation through a set of targets with different two-dimensional (2-D) and three-dimensional (3-D) features. The two types of targets are designed with the latest 3-D Advanced Simulation and Computing code. The goal is to measure the amount of radiation transported through these 2-D and 3-D features and the subsequent radiation-hydrodynamics.

Figure 1 illustrates the experimental configuration for both types of experiments. DANTE 1 is an X-ray spectral diagnostic used to quantify the X-ray drive, which is generated by 80 beams from the lower side of NIF. For the radiation transport experiments, the key diagnostic is an identical DANTE 2 instrument but with filters designed to measure the expected lower radiation temperature in the calorimeter side of the target package. To diagnose the predicted density wave structure in the targets, researchers have designed and tested a long-duration (8-ns) backlighter that can image the radiation-hydrodynamic evolution, with the images recorded by a streaked x-ray camera located on a DIM at the very apex of the NIF target chamber (Polar DIM).

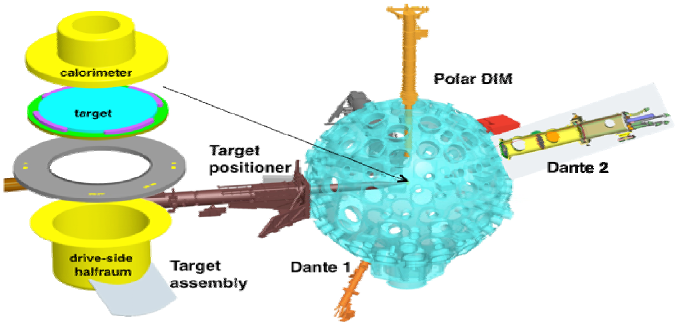


Figure 1: Primary diagnostics and target geometry for the radiation transport experiments on the NIF

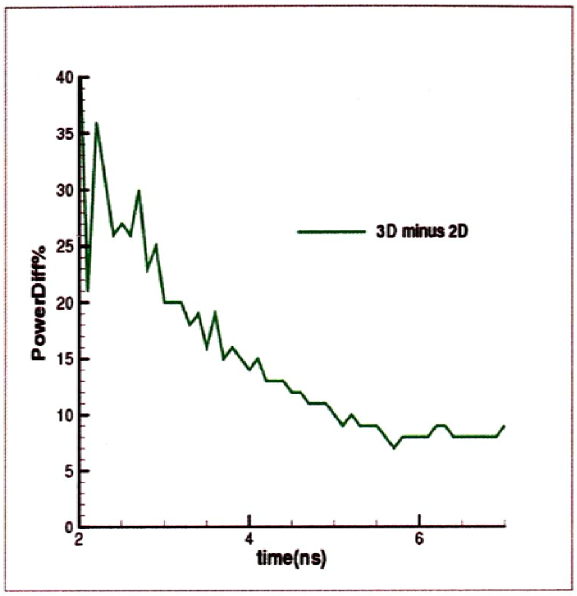


Figure 2: Percentage difference of radiation trans-ported through target as a function of time between a 3-D and 2-D target

The IET has carried out four series of experiments. The team first conducted tests of the 8-ns backlighter, which was previously designed and tested on the OMEGA laser facility in FY 2008. During the fourth quarter (Q4) the IET carried out "qualification" shots to characterize the main drive using DANTE 1 and DANTE 2 in order to confirm sufficient signal-to-noise level using a calorimeter target. Toward the end of Q4, the IET carried out several shots to measure the radiation transported through a variety of 2-D and 3-D features. Figure 2 shows the measured power differential between 2-D and 3-D targets that are designed with the same opening area but geometrically shaped to demonstrate additional radiation transported through a 3-D opening. Data measured is consistent with the predicted range of 10-15% integral differential.

The NIF laser drive has proved to be extraordinarily reproducible, giving the IET high confidence in the results obtained, as well as enabling high-accuracy quantitative comparisons between consecutive target shots with a single controlled design variable. Figure 3 shows the delivered pulse shape and laser energy for 8 shots covering two months of radiation transport experiments.

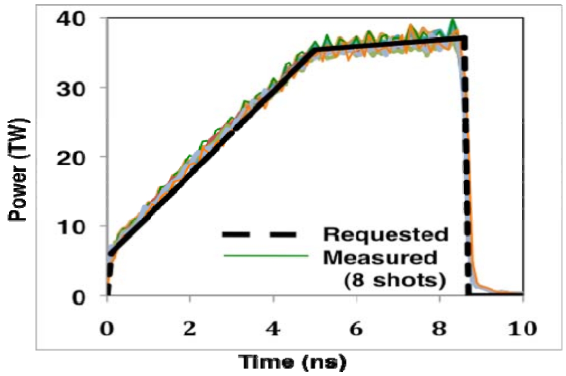


Figure 3: NIF has delivered a very reproducible pulse shape and laser energy for 8 radiation transport shots over a two-month period

The direct energy flux measurements using DANTE 2 have been highly successful due to the better than expected performance of the diagnostics. The good diagnostics performance resulted from both the low level of noise on the measured signals, and high signal-to-noise ratio very early in the process under study. Performance was helped by procedures to inspect component integrity after each shot, and, if needed, replacing, element of all the exposed components of the diagnostics.

The next series of experiments will focus on generating imagery using the backlighter and x-ray cameras in the Polar DIM to further quantify the process of interest and provide a complete data set for model validation. This series will begin with the necessary qualification shots for placing new diagnostics into service on the NIF. ●

High-Resolution UV Holography Lens for Particle Size Distribution Measurements

by Robert Malone, Morris Kaufman, Gene Capelle, Mike Grover (National Security Technologies, LLC); and Dan Sorenson, Pete Pazuchanics (Los Alamos National Laboratory)

This work has been selected by an independent judging panel and editors of R&D Magazine as a recipient of a 2009 R&D 100 Award. This award recognizes the 100 most technologically significant products introduced during the past year.

Computer modeling of material damage and fracture during shock conditions is an active research area that utilizes simulations to understand how different materials fatigue. However, experimental data are needed to benchmark the computer modeling parameters.[1]

A high-resolution UV holography relay lens, shown in Figure 1, has been developed for measuring particle size distributions down to 0.5 μm in a 12-mm-diameter by 5-mm-thick volume.[2,3] We measure micro-jet production from grooves that are machined into a metal surface. The material mass and particle velocity distribution within the micro-jets depend on the initial groove depth and angle that is machined into the target material.

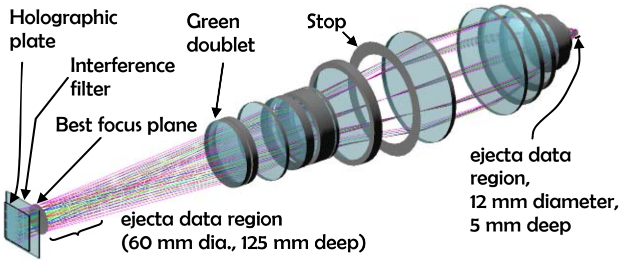


Figure 1: High-resolution lens used to record holograms with tripled Nd:YAG laser. Laser light travels from right to left. The green doublet is used for alignment and removed before the dynamic event.

One benefit of dynamic holography is that by using a short-pulse laser, the motion of the particles ejected from a groove is "frozen" and can be captured in a three-dimensional image. In addition, the in-line Fraunhofer holography technique requires only one laser beam to make the measurement. Greater than 90 percent transmission through the ejecta volume is required, so a slotted mask is used to limit the amount of ejecta in the hologram field of view.

This optical relay system can resolve better than 2000 lp/mm resolution and uses a tripled Nd:YAG laser. To achieve this resolution requires both a low f/# lens and the use of UV light. To get this high resolution, the image plane is allowed to be curved. For particle size distributions, the actual position of the ejecta particles is not critical. However, we will apply image curvature corrections to the positions of the measured ejecta particles.

To achieve the highest resolution, the best location for recording interference fringes onto a holographic film plate would be close to the particles. However, the plate would be destroyed in our energetic environment, so a sophisticated relay lens system transfers the fringes to a safe region for recording. The lens is bolted to a containment vessel using shock-absorbing materials, as shown in Figure 2.

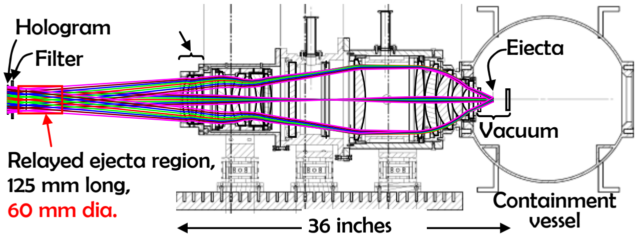


Figure 2: The ejecta are accelerated inside of a small vacuum package, placed inside a containment vessel

The package where ejecta are accelerated is under vacuum. However, the containment vessel is not under vacuum. The portion of the lens where the laser illumination passes through focus is under vacuum to preserve the laser wavefront. Just before the hologram, the ejecta region is magnified by 5X in the *x* and *y* directions, but magnified by 25X along the optical axis. By adding a doublet lens to the system, holograms can be recorded with 1100 lp/mm resolution using a doubled Nd:YAG laser. However, the use of a green laser is used mainly for setup alignment and documentation of resolution performance. The lens resolution at both wavelengths is shown in Figure 3.

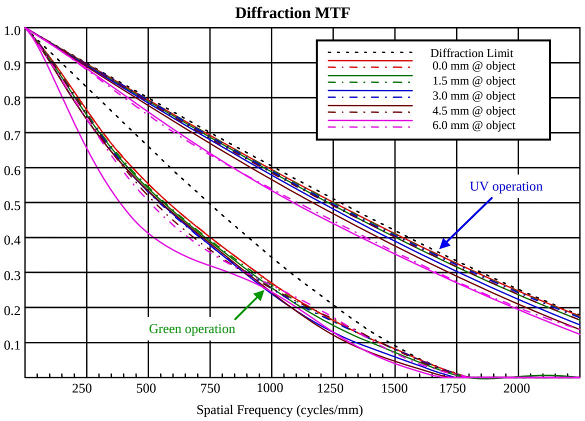


Figure 3: This lens system can be used to record holograms at either doubled or tripled Nd:YAG laser wavelengths

The lens is designed for 5X magnification. All lens elements and window surfaces have a double V-coating at both 354 and 532 nm, except for the detachable doublet lens. The lens housing is made up of five sections that make use of tapered pins for precision assembly. There is built-in compensation that allows for decentering and tilting some of the lenses to achieve the highest possible resolution. Counter-propagating alignment laser beams (one red and one green) are used to align the test package, the lens system, interference filter, and the hologram plate. Careful alignment of these elements is required. If the test package window is tilted by more than 0.10 degrees, then high-resolution holograms will be taken with the green laser instead of the UV laser.

Use of a charge-coupled device (CCD) camera alignment system, shown in Figure 4, reduces the number of holograms that have to be taken before a dynamic event. We are able to document the optical system performance with digitized resolution patterns. Using a CCD camera to set up the optics is more efficient and reduces fielding costs, while using green laser light simplifies overall laser safety issues. The doublet lens is removed before the dynamic event.

The amount of data recorded by the hologram is enormous: recording 2000 lp/mm over a cylinder that measures 12 mm in diameter by 5 mm thick collects 4.5 terabytes of resolvable data. An existing automated reconstruction system can process and store this data.[4]

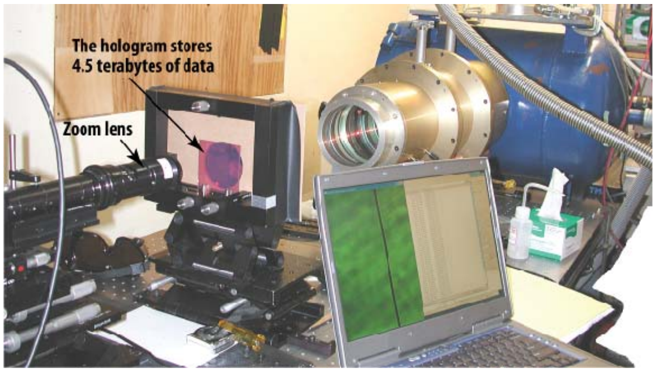


Figure 4: A CCD camera (not shown) uses a zoom lens to view through the hologram plate and to interrogate calibration wires and resolution patterns positioned inside the data region

The lens will help scientists measure the size and velocity of particles ejected off a metal after it is hit by a shock wave. We explore the physics of these particles in order to develop a theoretical model for nonnuclear experiments that safely simulate atomic experiments. Depending on the properties of the metal and the initial shock conditions, the ejecta particle size, velocity, and mass distributions may vary.

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[1] Sorenson, D.S. et al., "Ejecta particle size distributions for shock loaded Sn and Al metals," Journal of Applied Physics, 92, 5830–5836 (2002).

[2] Malone, R.M. et al., "High-resolution UV relay lens for particle size distribution measurements using holography," SPIE Optics & Photonics Conference, Proc. SPIE 7060, 70600A (2008).

[3] Malone, R.M. et al., "Design, assembly, and testing of a high-resolution relay lens used for holography with operation at both doubled and tripled Nd:YAG laser wavelengths," SPIE Optics & Photonics Conference, Proc. SPIE 7433 (2009).

[4] Tunnell, T.W. et al., "Deriving particle distributions from in-line Fraunhofer holographic data," Proc. SPIE 3163, 558–569 (1997). ●

2009 Dawson Award of Excellence

Yitzhak Maron, Weizmann Institute of Science, received the 2009 John Dawson Award for Excellence in Plasma Physics Research during the American Physical Society annual meeting in November. Maron received the annual award, which recognizes a recent outstanding achievement in plasma physics research, for revolutionary, non-invasive spectroscopic techniques to measure magnetic fields in dense plasmas and for resolving in detail in space and time the implosion phase of the Z pinch.

NSTec Livermore Operations Energy Milestone

The Livermore Operations 40,000-square-foot lab/office reduced energy consumption by 18%, eliminated its carbon footprint by 108 tons, and saved energy costs during a time when utility rates increased an average of 16% over three years.

H3837: DARHT'S First Dual-Axis Shot

by Wendy Vogan McNeil, Stephen Balzer, David Bowman, David Funk, James Harsh, Mark Hoverson, Lawrence Hull, Jacob Mendez, Shane Perkins, Scott Watson, and the DARHT operations, diagnostics and support teams (Los Alamos National Laboratory)

Test H3837 was the first explosive shot performed in front of both flash x-ray axes at the Los Alamos Dual Axis Radiographic HydroTest (DARHT) facility. Executed in November 2009, the shot was an explosively-driven metal flyer plate in a series of experiments designed to explore equation-of-state properties of shocked materials.

With high-strength steel walls over half an inch thick, the boombox confined the shot completely without taxing the penetrating capability of the DARHT x-ray beams; in addition, over three inches of tungsten attenuation in the beamlines prevented saturation of the camera systems. The boombox was staged within the DACS (Dual Axis Confinement system[1]), with a source-to-object distance of 1.33 m for each Axis; radiographic magnifications were 4 and 4.5 for Axes I and II, respectively.

The first axis provided a pulse of 60 ns width and dose 450 R @ 1 m, while the second axis provided four pulses of the following widths and doses: 20 ns, 85 R; 45 ns, 169 R; 65 ns, 233 R; and 65 ns, 225 R; beam spot sizes were measured (50% MTF LANL definition) as < 1.7 mm (Axis I) and 1.9 – 2.8 mm (Axis II), with less than 1.5 mm beam motion between Axis II pulses. The Bucky Grid camera system[2] was used for Axis I, while Axis II had a unique four-frame camera developed jointly with MIT Lincoln Laboratory[3].

Imaging the initial shock wave traveling through the flyer plate, DARHT Axis II captured the range of motion from the shock front emergence in the flyer to breakout at the free surface; the Axis I pulse provided a perpendicular perspective of the shot at a time coinciding with the third pulse of Axis II. Shock speed in the material and other time-dependent properties such as material damage progression are measured using the time-evolved data from Axis II, while density reconstructions are made from the views of Axes I and II. The radiographs from Axis I and Axis II pulse 3 are compared in order to generate a three-dimensional image of the shocked material, enabling determination of the degree of symmetry of the shock drive and the material damage.

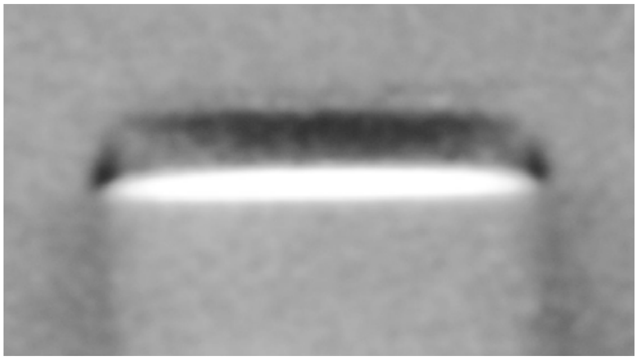

Figure 1: DARHT Axis I radiograph, obtained at 8.225 μs with respect to Load Ring. The shock front has progressed about two-thirds the way through the flyer.

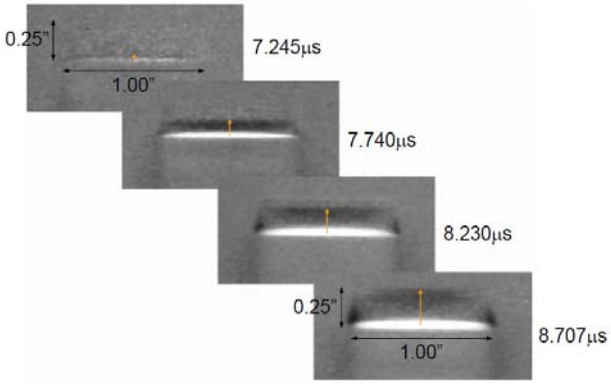

Figure 2: DARHT Axis II radiographs; times with respect to Load Ring are noted. The dynamic images were divided by the pre-shot static images; hence the outline of the one-inch-diameter explosive charge can be seen below the target material. The progression of the shock front is indicated by the orange arrows; its planarity is reduced by edge effects by the time of surface breakout.

Since the days of the Manhattan Project, penetrating radiography with multiple frames from different viewing angles has remained a high-profile goal at the Laboratory. H3837 is merely the beginning of a bright future for two-axis penetrating radiography.

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[1] Rodriguez, E. et al., DynEx Program: Confinement Vessel Design Philosophy, Los Alamos National Laboratory, DX-ER-0008, 2000.

[2] Watson, S. et al., Design, Fabrication and Testing of a Large, Anti-Scatter Grid for Megavolt X-ray Imaging, Nuclear Science Symposium, 2005.

[3] Watson, S., The DARHT Camera. Los Alamos Science, 2003. •

National Laser User's Facility (NLUF) Experiment Published in Astrophysical Journal

A multi-institutional team, led by Professor P. Hartigan (Rice University), studied the evolution of astrophysical jets by directly comparing new telescope observations with experiments performed on the OMEGA laser system at the University of Rochester's Laboratory for Laser Energetics. The results were reported in Volume 705, No. 1 of the Astrophysical Journal (November 1, 2009). This research effort represents the first time that new astrophysical images were obtained for the express purpose of comparing to experimental data. The OMEGA experiments were part of the NLUF Program funded by NNSA. NLUF is a peer-reviewed program that provides access to OMEGA facility time for University/Industry users.

Publication Highlights by Douglas Drake

This section highlights recent publications in high-impact scientific journals of research supported by the NNSA Science Campaigns.

Shock Compression of Quartz to 1.6 TPa: Redefining a Pressure Standard, M.D. Knudson and M.P. Desjarlais, Sandia National Laboratories, Physical Review Letters, November 6, 2009

Shock wave experiments are often used to investigate the equation of state (EOS) of materials at ultra-high pressures, providing critical data in areas of physics such as geophysics, planetary astrophysics, and inertial confinement fusion. In so-called impedance matching experiments carried out on Sandia's Z machine, for example, small metal plates are accelerated to speeds up to 40 km/s. The speed of the shocks created when they strike another material can be measured to very high accuracy using velocity interferometer diagnostics, which measure the Doppler shift of an accelerating surface.

If the EOS of one material is accurately known over the range of conditions of interest, so that it can serve as a standard, information on the speeds at which shocks propagate in that material and another can be used to infer particle velocities in the materials. This shock and particle velocity data can then be used to determine the other material's EOS.

The authors of this paper report that, in a series of such experiments carried out on Z, they discovered very significant discrepancies between the accepted and measured particle velocities for quartz. As quartz is often used as a standard in the several 100 GPa pressure regime, this implies that measurements based on its use in experiments such as those described above may be seriously in error. For example, the authors note that measured densities in less compressible materials such as carbon may be off by around 4%, over the pressure range of 0.6 to 2.0 TPa. Even larger errors of as much as 23% can result in more compressible materials such as helium. They suggest that these results indicate the need for reanalysis of several recently published data sets, which have immediate ramifications for the modeling of gas giant planets and other high energy density conditions.

Melting Temperature of Diamond at Ultrahigh Pressure, J.H. Eggert, D.G. Hicks, P.M. Celliers, D.K. Bradley, R.S. McWilliams, R. Jeanloz, J.E. Miller, T.R. Boehly and G.W. Collins, Nature Physics, Nov. 8, 2009

Diamond is a material of great interest to planetary scientists because of speculation about the presence of significant amounts of pure carbon in the cores of giant planets such as Uranus and Neptune. If so, the authors point out, accurate information about its high temperature, high pressure behavior would be "essential to predicting the evolution and structure of such planets." As diamond has also been considered as an ablator material for inertial confinement fusion targets, its thermal properties under extreme conditions are a matter of significant interest to the Office of Defense Science as well.

One of the most important of such properties, its melting temperature, has been very difficult to measure accurately because, at atmospheric pressure, diamond converts to graphite before melting, and it is one of the most tightly bonded of all materials.

This paper reports accurate measurements of the melting temperature of diamond at ultrahigh pressures of 6 to 40 Mbar carried out at the University of Rochester's OMEGA laser facility. By launching shocks into diamond and observing the results with a combination of velocity interferometer and streaked optical pyrometer diagnostics, the authors were able to demonstrate that its melting temperature was in good agreement with first-principles calculations. Their data also indicated that diamond melts to a denser, metallic fluid between 6 and 10.5 Mbar, and appears to melt to a complex fluid state at still higher pressures, which dissociates at shock pressures between 11 and 25 Mbar as the temperatures increase above 50,000 K. The data open the possibility that carbon could exist on the planets Neptune and Uranus in the liquid metallic state, forming a fluid core that helps to sustain the planetary magnetic fields.

DARHT 2 kA Cathode Development, E. Henestroza et. al., Lawrence Berkeley National Laboratory, eScholarship.org, March 25, 2009

In a paper published on the University of California's eScholarship website (http://www.escholarship.org/uc/item/72x1t1w4), the authors document the development process that enabled them to successfully achieve the milestone of 2 kA of electron beam current on DARHT. This was a very significant achievement, as beams produced in cathodes of similar dimensions (6.5" diameter) had previously been limited to about 1.3 kA. At those levels, cathode operating temperatures reached levels of 1140 degrees Celsius, and heat loss was dominated by radiation. As radiation energy scales as temperature to the fourth power, it was deemed impractical to limit the overheating damage to the cathode components that was limiting increases in beam current beyond these levels by simply designing components that could run at higher temperatures.

To meet this challenge, a novel cathode design that avoided the high temperature barrier by enabling operation at a lower work function was proposed. This extensive review of the steps in the building and successful demonstration of the new cathode documents many of the technological hurdles that were encountered and successfully overcome along the way. It includes numerous highly detailed graphics that should be of interest to anyone wishing to acquire a better understanding of DARHT components and operation.

2010 Stewardship Science Academic Alliance (SSAA) Symposium by Mike Kreisler

More than 200 individuals from the science community attended the 2010 Stewardship Science Academic Alliance (SSAA) Symposium, held at the Carnegie Institution of Washington in Washington, DC from January 20 - 22, 2010. Attendees included students, research staff, and faculty members involved with the grants and Centers of Excellence supported by the SSAA program, officials from the NNSA and the DOE Office of Science, and representatives from the NNSA national laboratories. The purpose of the symposium is to bring together researchers from the various academic institutions in the SSAA program to discuss research progress and to establish connections within the community and with the NNSA laboratories and offices.

Dr. Richard Meserve, President of the Carnegie Institution of Washington, kicked off the symposium with a welcome. He was followed by Dr. Chris Deeney, Director of the Office of Inertial Confinement Fusion and the National Ignition Facility Project and Acting Director of the Division of Defense Science, who discussed the scientific challenges facing the NNSA in the coming years, plans for NNSA investments in science, and the array of scientific tools and facilities that are now available to address those challenges.

The reports from the grants and centers were presented in random order rather than by discipline to reflect the fact that NNSA laboratories are multi-disciplinary. Laboratory staffs are expected to be knowledgeable about all fields of science and technology in addition to being an expert in one area. To help attendees who may have been unfamiliar with research in some areas, several introductory talks were then presented, each with the title: “What is the field of XXX and why does the NNSA care about it?” Dennis McNabb, the Nuclear Physics Section Leader at Lawrence Livermore National Laboratory (LLNL), spoke about Low Energy Nuclear Science. Robert Hanrahan, the NNSA Program Manager for the SSAA Program, spoke about Materials Under Extreme Conditions. Kim Budil from LLNL, currently serving as Senior Advisor to the DOE Under Secretary for Science, discussed High Energy Density Physics-Hydrodynamics and John Apruzese, a staff scientist at the Naval Research Laboratory, discussed High Energy Density Physics-Radiation Science. After the introduction, more than 45 presentations, one from each of the centers and grants, were given during the three-day meeting.

At the end of the first day, Brigadier General Garrett Harencak, the Principal Assistant Deputy Administrator for Military Application in the Office of Defense Programs, thanked everyone for the important contributions they are making to the nation and gave an inspirational talk about the future. He also encouraged scientists in the audience to consider a career with the NNSA.

The poster session, held the evening of the first day, afforded attendees the opportunity to interact and discuss ongoing research. Many senior NNSA officials attended and met members of the research teams.

A questionnaire, completed by many of the attendees, provided suggestions on how to improve future symposia. Interactions among the attendees continued during breaks from the formal talks and during lunch. The general consensus was that the symposium was a success.

The arrangements for the symposium were handled by an able team from ORISE, led by Tim Ledford. The SSAA Program, of course, owes a debt of thanks to Terri Batuyong of the NNSA not only for her efforts in ensuring the success of the symposium but for her work on the program throughout the year. •

Brig. General Garrett Harencak and Dr. Chris Deeney discuss ongoing research with Alla Safronova, UN-Reno.

David Ceperley, UI-Urbana-Champaign (right) with Miguel Morales, Rice University, his former graduate student and first graduate of the Stockpile Stewardship Graduate Fellowship Program (see page 9).

Jim Coronez, President of Krell Institute, talks with Kim Budil, Senior Advisor to the DOE Under Secretary for Science, and Dr. Jolie Cizewski, Professor of Physics, Rutgers.

Stewardship Science Graduate Fellowship Program

Krystle Catalli, a doctoral candidate at the Massachusetts Institute of Technology, uses the pressures produced in a diamond anvil cell to synthesize materials and emulate conditions found deep in the earth. Her goal is to understand how high pressures affect mineral physics, especially in magnesium-silicate perovskite.

Although it's the most abundant silicate mineral in the earth, perovskite's structure is stable only under pressures found at depths of approximately 660 km to 2,700 km. Using the bright X-ray beams at the Advanced Photon Source at Argonne National Laboratory (ANL), Catalli and her colleagues probed how pressure affects the spin state of ferric iron (Fe^{3+}) in perovskite and how that, in turn, influences the mineral's elastic properties.

Catalli is lead author of a paper describing the research.[1] Co-authors are her adviser, Sang-Heon Shim of MIT; Vitali B. Prakapenka of the University of Chicago and ANL; Jiyong Zhao, Wolfgang Sturhahn, Paul Chow, Yuming Xiao and Haozhe Liu of ANL; and Hyunchae Cynn and William J. Evans of Lawrence Livermore National Laboratory (LLNL). The researchers synthesized magnesium silicate perovskite containing all ferric iron and subjected it to pressures of more than 100 gigapascals (GPa) in a laser-heated diamond anvil cell.

The materials were measured with synchrotron Mossbauer spectroscopy (SMS), X-ray emission spectroscopy (XES) and X-ray diffraction (XRD). In perovskite synthesized at pressures above about 50 GPa, Fe^{3+} atoms appear to enter into dodecahedral (A) and octahedral (B) crystal sites approximately equally, the team reports. SMS and XES measurements indicate that below 50 GPa high-spin Fe^{3+} is present in both the A and B sites but low-spin Fe^{3+} is found only in the B site.

The group's data show that ferric iron in the B site undergoes a gradual spin transition, starting at ambient pressures, until at mid-lower mantle pressures—between approximately 50 and 60 GPa—all ferric iron in the B site is low-spin. Ferric iron in the A site, meanwhile, remains solely high spin. The data suggest that perovskite is more compressible during the spin transition but less compressible when it's complete. The transition, the researchers say, likely affects seismic velocities in the lower mantle. "The elasticity change found at the completion of the…spin transition can be a useful probe for seismic investigations of the valence state of iron and compositional heterogeneities in the lower mantle," the paper concludes. Catalli did the XES measurements during her LLNL practicum under Cynn from September 2008 through early January 2009. She plans to incorporate the results into her thesis.

DOE NNSA Stewardship Science Graduate Fellowship recipient **Matthew Gomez** is helping test new, Russian-made technology that could trigger Z-pinch reactions more efficiently and rapidly. The third-year fellow at the University of Michigan (UM), is working with MAIZE, the Michigan Accelerator for Inductive Z-pinch Experiments. At MAIZE's heart is a fast linear transformer driver (LTD), a compact supplier of short, high-current pulses.

Designed and built at the Institute of High Current Electronics in Tomsk, Russia in collaboration with Sandia National Laboratories (SNL) and UM, LTDs are touted for their repetitive-pulsing capability, high current, fast risetime, compactness, ability to "stack" for inductive voltage addition and improved energy efficiency over conventional Marx/water line technology. LTDs could be components in a next-generation Z pinch device at SNL.

With advisor Ronald Gilgenbach, Gomez is testing an LTD designed to deliver 1 mega-ampere (MA) at 100 kilovolts (kV) with a risetime of 100 nanoseconds into a matched resistive load. It's one of 11 such units in the United States. The LTD is comprised of a ring 3 meters in diameter holding 80 capacitors and 40 spark gap switches arranged in 40 "bricks." It's designed to store 16 kilojoules (kJ) of energy and to deliver 11.5 kJ. In the MAIZE, a coaxial line followed by a radial transmission line transports the current to a chosen load. Initial tests show this configuration sends nearly all of the current to the load with little effect on pulse shape, as predicted in computer models.

The researchers are working on two MAIZE experiments: magneto-Rayleigh-Taylor (MRT) instability studies with foil loads and current loss due to plasma formation in post-hole convolutes. MRT instabilities can cause bubbles and spikes when foils ablate in magnetized inertial confinement fusion implosions, destroying the symmetry. The experiments will examine instability growth rates and modes and test whether patterning foils can seed a particular mode.

Post-hole convolutes combine current from several magnetically insulated transmission lines near the load, but the complex geometry also can lead to current losses. Initial MAIZE tests have found plasma formation at the location of a magnetic null, matching computer simulations. The researchers also are developing diagnostics to measure current upstream and downstream of the convolute.

The convolute research ties in well with Gomez's work during a fall 2009 SNL practicum that has been extended through December. He's helping develop a visible spectroscopic device to measure plasma that forms in the post-hole convolute on the lab's Z machine. •

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[1] Catalli, K., et al., Spin state of ferric iron in $MgSiO_3$ perovskite and its effect on elastic properties, Earth Planet. Sci. Lett. (2009) doi:10.1016/j.epsl.2009.10.029.

Highlights

Morales First Graduate of Stewardship Science Graduate Fellowship Program

Miguel Morales is the first graduate of the SSGF Program. He was selected in 2006 to be one of the first generation Stewardship Science Graduate Fellows. At the time he was a second year graduate student at the University of Illinois at Urbana-Champaign, working with Dr. David Ceperley on the study of light elements at high pressures using Quantum Monte Carlo (QMC) methods.

In the summer of 2008, Morales did a 12-week research practicum at Lawrence Livermore National Laboratory (LLNL), working with Dr. Erick Schwegler, director of the Quantum Simulations Group. At LLNL, Morales worked on several projects related to the application of first principles simulation methods to complex mixtures at high pressures.

According to Dr. Morales, the SSGF program was instrumental to his graduate work. "The research practicum is one of the strongest points of the SSGF program." While at LLNL, he had access to a creative environment, strong collaborations with the group and a unique computational resource. Consequently, he produced high quality work which furthered his dissertation research.

Dr. Morales is now a post doc with Dr. Gustavo Scuseria in the Chemistry Department at Rice University.

Director of SSAA Center Reviews Physics Programs at Kuwait University, Kuwait

Jolie Cizewski, Professor of Physics at Rutgers University and Director of the SSAA Center for Radioactive Ion Beam Studies for Stewardship Science, was invited to review the Masters of Physics program at Kuwait University (KU), Kuwait City in November 2009. The KU Physics Department has approximately 25 faculty members doing research in experimental and theoretical physics, spanning both basic science and applications, such as remote sensing. Although there are few graduate students in physics, Dr. Cizewski was impressed with the high level of research funding available from the Kuwaiti government and local industries and the opportunities the faculty have to travel abroad for international conferences and research collaborations. Her recommendations will include suggestions for increasing the physics graduate student population.

Left to right: Professor Mansour Al Zonedi, Vice Dean, Faculty of Science; Professor Nabeel Al-Loughani, Dean, Graduate College; and Professor Jolie Cizewski at the closing session in the office of the Dean of the Graduate College, Kuwait University.

Areal Density of 0.3 g/cm^2 Demonstrated with Cryogenic DT Target Implosion on OMEGA

During the November 2009 meeting of the American Physical Society, scientists from the University of Rochester's Laboratory for Laser Energetics (LLE) announced the highest compression of a cryogenic deuterium-tritium (DT) capsule ever reported. Cryogenic capsules are an essential part of most inertial confinement fusion ignition designs, including those that will be used for the first ignition experiments on the National Ignition Facility (NIF). The compression is characterized by the areal density of the capsule, the product of the density and the radius of the compressed fuel. In collaboration with scientists from the Massachusetts Institute of Technology, LLE scientists measured a compressed areal density of ~0.3 grams per square centimeter on the OMEGA laser system that is in agreement with theoretical predictions. These results demonstrate that compression of cryogenic DT is well understood, increasing confidence in demonstration of ignition on the NIF. This areal density is the minimum required to initiate fusion burn, at temperatures higher than possible with OMEGA's laser energy.

Fiducial Laser System Shipped to NIF/LLNL

LLE designed and built the NIF fourth harmonic fiducial laser system in response to a LLNL request in May 2008. The requirements were agreed upon during the first quarter of FY 2009, and the project was added to LLE's activities. The hardware costs approximately $200,000 and the design, construction, and demonstration effort is estimated to have taken more than two person-years of LLE staff effort.

NSTec Remote Goniometer Positioning System

The NSTec fielding team delivered a remote goniometer positioning system to the LANL proton radiography team at TA-53 for use in the remote manipulation of target positions.

National Ignition Facility (NIF) Activity

Before scheduled shutdown, NIF completed a major shot series and began the Ignition Preparation Project (IPP). *Diagnostics Shots* – On December 3, NIF fired a neopentane-filled gaspipe target with Q36B to cross-calibrate the Full Aperture Backscatter/Near Backscatter Imager diagnostic. This was followed by an optics performance shot on Beam 342 equivalent to 1.8MJ. NIF also fired three Integrated Signal Programmer (ISP) rod shots to conduct the IPS pulse-shaping loop for a 1-MJ shot. *Hohlraum Shot* – On December 5, NIF fired a 1.2-MJ cryogenic Hohlraum shot with 191 beams, and all diagnostics acquired data. This shot concluded a successful start-up period of Energetics Campaign experiments as part of the first National Ignition Campaign. *IPP* – The IPP, began by NSTec, will prepare NIF for layered target ignition experiments later in FY 2010. It will enable routine, high-energy operation of the laser; cryogenic layering of DT targets; the capability to handle tritium and depleted uranium; and the execution of high neutron-yield shots.