


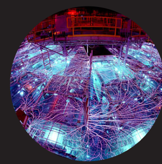


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National Nuclear Security Administration

Office of Research, Development, Test, and Evaluation

Stockpile Stewardship *Quarterly*

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Message from the Assistant Deputy Administrator for Research, Development, Test, and Evaluation, Dr. Kathleen Alexander

Since the last issue of the *Stockpile Stewardship Quarterly* (SSQ), I have attended several conferences where I met researchers that represent the pipeline for staffing future Research, Development, Test, and Evaluation (RDT&E) activities. I attended the Computational Science Graduate Fellowship Annual Program Review and the American Nuclear Society's Plutonium Futures—The Science conference. It was satisfying to see the enthusiasm of the young researchers. Funding Opportunity Announcements, such as the one for the Stewardship Science Academic Alliances program found at the end of this issue, allow us to attract the best and brightest researchers of all ages.

2014 Computational Science Graduate Fellowship Annual Program Review, July 14-17, 2014.

I have also spent considerable time interacting with stockpile stakeholders and refining the message about the critical role of RDT&E in stockpile stewardship. These SSQs are an important means to communicate our accomplishments with a broad audience.

This issue of the SSQ highlights the subprogram Secondary Assessment Technologies (SAT) and associated code validation experiments. The opening article by Kiess et al. provides a high level description of SAT activities at each of the weapon laboratories and the Nevada National Security Site. The second article by Wan et al. summarizes National Ignition Facility (NIF) validation experiments supporting SAT. Experiments at the Omega Laser Facility at the University of Rochester and the Z machine at Sandia National Laboratories have laid the groundwork for many of the NIF experiments. These experiments have helped weapon scientists to improve the fidelity of nuclear weapon performance simulations and reduce uncertainties in weapon assessments.

The article by Beiersdorfer et al. focuses on a collaboration between the Atomic Weapons Establishment (AWE) in the United Kingdom and Lawrence Livermore National Laboratory using AWE's Orion laser. Plans are presented to explore new density and temperature regimes. The article by Hagen et al. describes the dense plasma focus (DPF), which produces a nearly mono-energetic neutron spectrum in short bursts. This is useful for measuring neutron cross-sections. The final article by Abbas Nikroo provides a detailed discussion of what is involved in creating the complicated targets for the SAT subprogram and inertial confinement fusion experiments.

As FY 2014 concludes, I am proud of our accomplishments and productivity. I am also looking to the future and am excited about the efforts we have planned. You will read about them in upcoming issues of the SSQ. If you have suggestions for future articles or comments about the newsletter, please contact Terri Stone at terri.stone@nnsa.doe.gov.

Inside

Comments

The *Stockpile Stewardship Quarterly* is produced by the NNSA Office of Research, Development, Test, and Evaluation. Questions and comments regarding this publication should be directed to Terri Stone at terri.stone@nnsa.doe.gov. | Technical Editor: Dr. Joseph Kindel | Publication Editor: Millicent Mischo

Research and Development of Secondary Assessment Technologies: A Program Secondary to None!

by Thomas E. Kiess (National Nuclear Security Administration), Kimberly C.N. Scott (Los Alamos National Laboratory), Ivan J. Otero and Christopher Werner (Lawrence Livermore National Laboratory), Gregory Rochau (Sandia National Laboratories), and Steven Goldstein (National Security Technologies, LLC)

Introduction

The Secondary Assessment Technologies program within the Office of Research and Development's Science Campaign improves the scientific understanding of the performance of a secondary component of a nuclear weapon. Researchers perform refined analyses of legacy nuclear weapons test data, probe issues of interest by developing physics models, and validate them with new experiments—especially those in regions of high density, temperature, and pressure using the National Ignition Facility (NIF) at the Lawrence Livermore National Laboratory (LLNL), the Omega Laser Facility at the University of Rochester Laboratory for Laser Energetics, and the Z Machine at Sandia National Laboratories (SNL). This overview article identifies program interests and examples of active research activities.

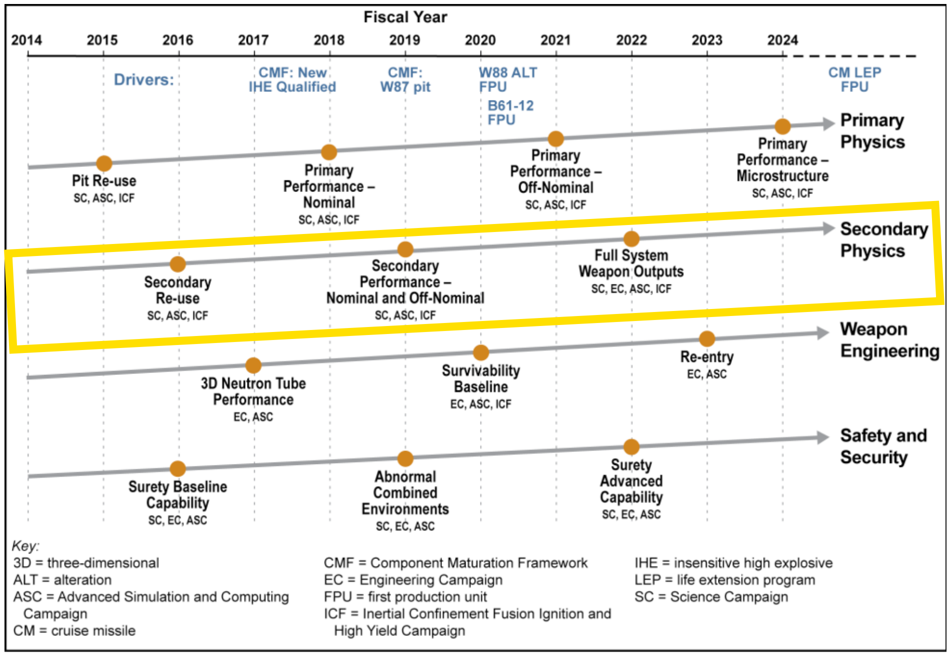

Figure 1. *Figure 3-2 of the SSMP* identifies Secondary Physics as a strand in the PCF.

The Relevance of Secondary Assessment Technologies to NNSA's Stockpile Stewardship Mission

This program's enduring interest is to advance science-based capabilities for assessing and improving the Nation's understanding of secondary performance. The program accomplishes this by sponsoring relevant research, conducted mainly at NNSA laboratories (Los Alamos National Laboratory (LANL), LLNL, and SNL) and the Nevada National Security Site (NNSS), which is operated by National Security Technologies, LLC (NSTec). Such research achieves the following outcomes:

- Replaces phenomenological model calibrations with science-based models validated by experimental data—in direct support of a performance goal of the U.S. Department of Energy Strategic Plan 2014-2018[1];
- Offers advances that increase the range of technical options for stewardship of the evolving stockpile;
- Contributes to other stockpile stewardship activities (e.g., secondary-related issues in Life Extension Programs (LEPs), the Annual Assessment, Significant Finding Investigation resolutions, and/or certifications); and
- Conducts premier science, as part of the Nation's deterrent and capability.

The FY 2015 Stockpile Stewardship and Management Plan[2] identifies these interests in its Predictive Capability Framework (PCF) in the Secondary Physics "strand," which is the program's focus (see Figure 1). Along the strand, program interests are identified as three explicit high-level "pegposts" in the topics of secondary reuse, secondary performance, and full system weapon outputs. To accomplish significant gains in each of those pegposts, the program conducts research typically spanning years to provide technical outcomes that serve as constituent building blocks.

Technical Thrusts of Sponsored Research

What is the physical environment relevant to secondary design and performance? In general, nuclear reactions take place to create a hot dense plasma replete with energetic charged particles, neutral particles, and radiation in a wide range of energies. Various physical effects control dynamics, radiation transport, other forms of energy transfer, behaviors in the plasma, and output signals. This regime is a challenge to study and probe meaningfully.

In the past, diagnostics of legacy nuclear tests provided information used to calibrate weapons codes—computer programs whose constituent data and models contain a representation of secondary performance. Insight into opportunities to improve understanding comes from secondary designers' use of these codes, and their knowledge of the physics contained within them and how it is treated. Some legacy models lack full connectivity to all underlying physics—in such models, some detailed phenomena are treated in simplified terms.

Improved models and/or data come from targeted experiments designed to investigate specific effects. At present, the environmental conditions in the regimes of interest can be studied with the right types of experiments at facilities capable of attaining some of the relevant conditions. Such experiments calibrate new physics models of phenomena selected and controlled for detailed study. Relating these new physics models to those within legacy weapons codes provides a way to improve scientific understanding.

Much of this research is high energy density (HED) physics— exploring the behaviors of matter at extreme pressures, densities, and temperatures, including the study of burning plasma containing thermo-nuclear fuel. Constituent technical issues/topics include the following:

- Material Properties – equations of state, and strength/damage/failure for various elements in extreme conditions of elevated temperature, pressure, and density;
- Radiation Transport – including the opacities of materials to x-rays of various energies;
- Plasma hydrodynamics – energy exchanges among the plasma constituents, non-local equilibrium processes, particle transport (e.g., charged particle behaviors, to include break-up processes and kinetic effects);
- Thermonuclear burn physics – fusion reactions where light atoms combine to form heavier ions plus energy and the effects that they cause; and
- Dense nuclear energetic three-dimensional (3D) radiation/ burn hydrodynamics–putting it all together and attendant complexities.

Other research is conducted in precision experimental measurements of nuclear cross sections—to reduce uncertainties that matter in understanding what reactions take place (e.g., those induced by energetic neutrons) and to what degree.

Still other research is in Latetime Outputs & Effects—which includes calculations of radiation outputs (e.g., neutron fluences and x-ray/gamma-ray spectra) as functions of space, time, and energy. These outputs are important to assess how a weapon discharge will interact with the environment and, subsequently, the nuclear and non-nuclear components of other weapon systems in the local vicinity. This program work is complementary to related work of other U.S. Government sponsors, such as the NNSA Nuclear Survivability program and agencies within the U.S. Department of Defense.

All of this research is challenging to conduct. Experimental work uses specialized facilities that are able to create states of matter never before achievable in the laboratory and diagnostics that are capable of measuring critical aspects of HED matter with unprecedented precision. Research teams at LANL, LLNL, SNL, and NSTec make important contributions as illustrated in the examples below.

Research at LANL

The LANL High Energy Density ReShock/Shear experiments study extreme hydrodynamic processes on the NIF and Omega laser facilities. The experiments are built with different content and geometries depending on what hydrodynamic phenomena they are used to study. In all cases, the millimeter-scale laser-driven target (see Figure 2, left) is irradiated on both the top and bottom, driving strong shocks into the cylindrical tube body. In the shear experiment configuration, the shocks, separated by a metal plate when they are launched into the tube, pass each other by at the tube center. This creates an intense velocity difference on each side of the plate, allowing researchers to study the Kelvin-Helmholtz shear instability in high-Mach-number, high-density settings. The Kelvin-Helmholtz instability occurs in everyday life when wind blows over water with the resultant unstable water waves. Here, the instability leads to mixing and the initially smooth plate is driven into a rough, irregular shape (see Figure 2, right). The flow speed difference from the left of the tube to the right is in excess of 100 km/sec.[3] The experiments are providing critical validation data for the use of weapons program codes in evolving stockpile scenarios.

Research at LLNL

LLNL researchers are aggressively pursuing three major objectives: (1) improving the fundamental data that feeds into the performance simulations, (2) developing experimental platforms at HED facilities to explore and validate the modeling of the physical processes relevant to secondary modeling, and (3) validating the integrated simulation capabilities by simulating relevant underground tests (UGTs). For the fundamental data, sensitivity studies identify what uncertainties in the data most limit the predictive capability. As an example, the uncertainty in the neutron capture cross section of certain unstable isotopes dominates the uncertainty in the interpretation of some UGT data. It is well known that the neutron capture cross sections are notoriously difficult to compute accurately, and given the short lifetimes of isotopes involved, it is impossible to measure the cross section directly. For the first time, a research team has used an indirect measurement using the surrogate reaction method[4] to infer a neutron capture cross section. The team used yttrium in the demonstration because it has a relatively simple nuclear structure, to infer the cross section for the reaction:

$$^{87}\mathrm{Y} + n \rightarrow {}^{88}Y + \gamma$$

Experimentally, the team created the same compound nucleus (^{88}Y in an excited state) as the capture reaction, by bombarding ^{89}Y with a proton and observing the emitted deuteron:

$$^{89}\mathrm{Y} + \mathrm{p} \rightarrow {}^{88}\mathrm{Y} + \mathrm{d}$$

They measured the emerging gamma rays as the excited ^{88}Y decays to its ground state. These data and a detailed understanding of the nuclear structure of ^{88}Y enable a calculation of the

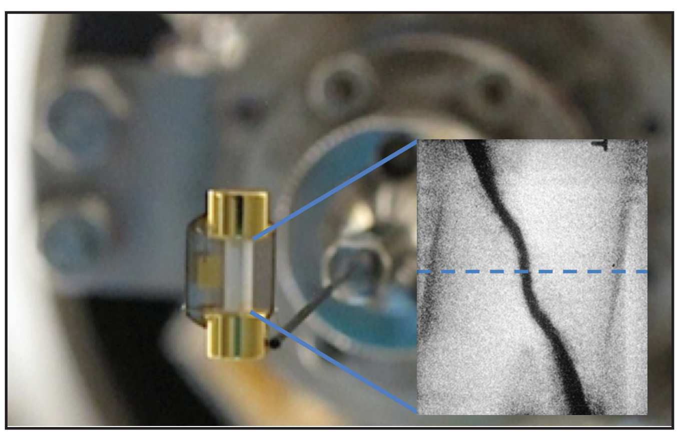

Figure 2. NIF Shear shot N140117 target (left) and radiograph (right) showing the Kelvin-Helmholtz instability driven evolution of the initially smooth target interface.

capture cross section as a function of neutron energy (see Figure 3). The experimentally informed cross section is within the uncertainty band of the previously modeled theoretical evaluation.

Research at SNL

Secondary assessment activities at SNL are focused on addressing specific questions about the way radiation transports through and interacts with matter at extreme temperatures, pressures, and/or radiation intensities. The principle issues under investigation include (1) the measurement of opacity in hot, dense plasmas, (2) the characterization of radiation flow in complex geometries, and (3) the development of intense x-ray sources for applications in radiation effects sciences. Each of these issues is addressed through experiments on the Z facility at SNL that are designed, executed, and analyzed in close collaboration with LANL, LLNL, and academia. In the case of opacity studies, Z experiments measure detailed frequency-dependent opacity with a precision of 10% at electron temperatures and densities up to 200 eV and 4E22 cm^{-3}. This allows for the study of bound-bound and bound-free opacities, including the shape of the associated spectral features from the myriad of excited states that exist at these extreme conditions.[5-6] In the case of x-ray source development, z-pinch implosions on the Z facility produce the world's brightest laboratory x-ray sources in the 1-10 keV spectral range.[7-9] These z-pinches are typically formed by cylindrical arrays of wires that are imploded by a current of over 20 million amps. The high kinetic energy of these implosions is efficiently converted into K-shell x-ray energy as the z-pinch stagnates at the axis. Recent work has extended the spectral range of these sources to photon energies >13 keV utilizing jets of krypton gas as the progenitor for the z-pinch (see Figure 4). Benchmarked models of the supersonic Kr gas flow initiate 3D radiation-hydrodynamic simulations to design z-pinches at simulated implosion velocities exceeding 1,000 kilometers/second that are proven to produce >5 kJ of Kr K-shell radiation at >13 keV. These bright x-ray sources provide a broad range of spectral energies that enable radiation effects testing at fluences previously unattainable in the laboratory.

Research by NSTec

NSTec, the M&O contractor for the NNSS and other facility locations, conducts high-hazard experimentation supporting nuclear weapon stockpile relevant work in assessment, certification, predictive capability, and modernization studies. Core capabilities are in design, engineering, "ruggedization," and other development of HED diagnostics instrumentation and sensor systems that cover a wide spectral range from radio frequency to energetic photons to ionizing radiation, and in providing standards-based calibrations of detectors, sensors, and components in these diagnostics systems to support experiments (see Figure 5). For example, NSTec develops neutron time-of-flight detection systems with specifications tailored to meet HED experimental measurement requirements.

NSTec operates calibration facilities located at LLNL and SNL that include Manson, Henke, and high-energy x-ray laboratories; the Long-Pulse Laser, Short-Pulse Laser and Enhanced Short Pulse Laser laboratories; the Optical Component Calibration Laboratory; and the Electronic Systems Calibration Laboratory. A Manson source and Picoprobe station continue to anchor the microchannel plate (MCP) Assembly and Characterization Laboratory at SNL and provide the necessary characterization and life-cycle maintenance of x-ray framing cameras for imaging and spectroscopic diagnostics. Other ongoing activities include developing MCP and phosphor coating capability, fielding streak cameras and spectrometers, and participating in the design of advanced

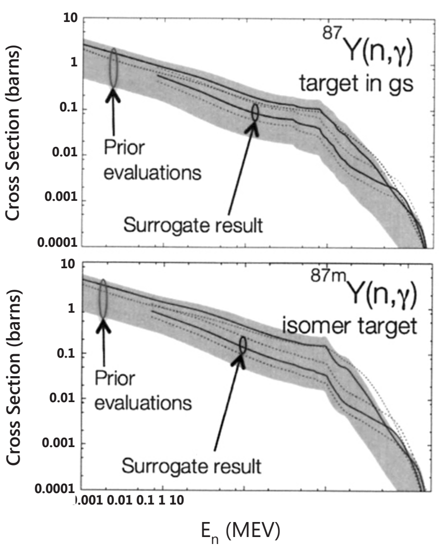

Figure 3. Comparison of the surrogate evaluation of the neutron capture cross sections for yttrium-87 from the ground state (gs) (top), or the isomer state (bottom). The gray band represents the estimated uncertainty in the theoretical cross section, and the dotted lines demark the estimated uncertainty in the surrogate evaluation.

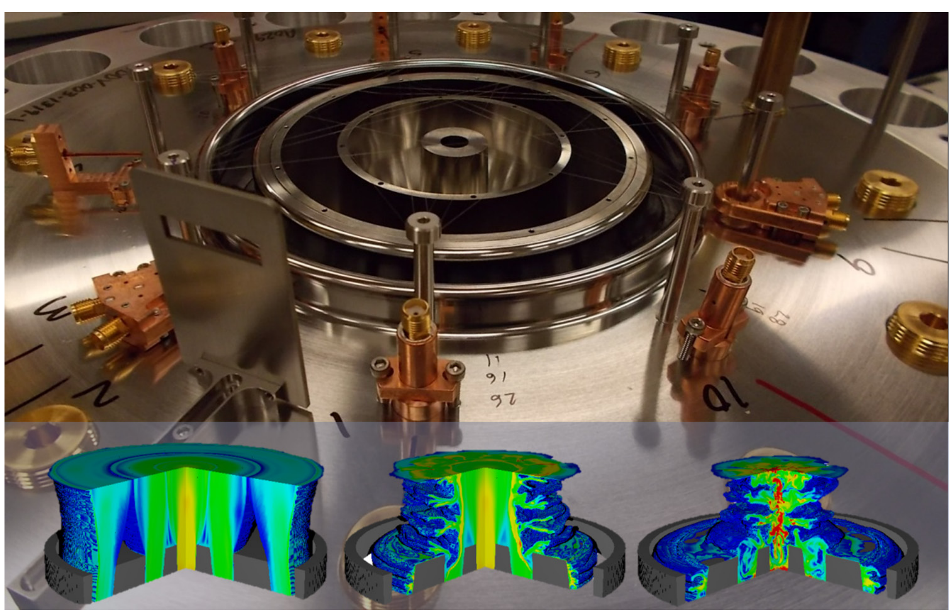

Figure 4. Supersonic gas puff nozzle for a z-pinch experiment on the Z facility that produces >5 kJ of Kr K-shell x-rays at >13 keV photon energy. Three-dimensional simulations are used to optimize the z-pinch design for maximum x-ray yield.

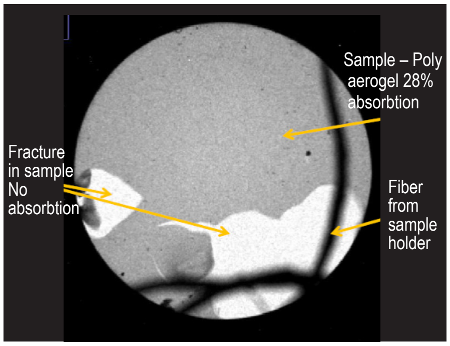

Figure 5. Example of Recent NSTec Diagnostic Development. On the NSTec Manson X-Ray Source, scientists collected the first images of a materials strength target aerogel on a newly developed contact radiography end station. These foams are used in materials strength shots at NIF and are critical to experimental performance. If the capability meets requirements, the materials strength target team will use the contact radiography station for foam characterization on future materials strength and high-Z shots at NIF.

diagnostics such as a compact recoil spectrometer and Thomson parabola.

At the Brookhaven National Laboratory's National Synchrotron Light Source (NSLS), NSTec leads the team composed of LANL, LLNL, and SNL to use x-ray energies that range from 50 eV to 25 keV for critical calibrations of components. With the scheduled closure of NSLS by the end of FY 2014, and the decision to site a replacement x-ray calibration station at the Stanford Synchrotron Radiation Lightsource (SSRL), NSTec will continue to lead the tri-lab team in collaborating with SSRL to develop the required synchrotron-based x-ray beamline endstations. This development effort is underway, scheduled to be completed by the end of 2015 and to be operational by mid-FY 2016 after commissioning.

Summary

The Secondary Assessment Technologies program sponsors scientific research that probes challenging technical issues using specialized facilities and instrumentation. Research outcomes are designed to prepare design laboratories for future LEP options, recertification issues, and stockpile assessment challenges. Advances improve the science basis for current stockpile assessment and provide the foundational understanding needed to assess new stockpile options. This research also maintains the vitality of the workforce and trains the next generation of theoretical, computational, and experimental physicists. Their mission-critical research has an exciting flavor because it pushes the limits of the state-of-the-art in the scientific and technical methods that are used. Accompanying articles within this issue of the *Stockpile Stewardship Quarterly* describe several ongoing research activities in greater depth.

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National Ignition Facility Experiments in Support of the Stockpile Stewardship Program *by Alan Wan (Lawrence Livermore National Laboratory), Kimberly Scott (Los Alamos National Laboratory), and the Los Alamos National Laboratory and Lawrence Livermore National Laboratory High Energy Density Teams*

Experiments on the National Ignition Facility (NIF) at Lawrence Livermore National Laboratory (LLNL) contribute to the enduring U.S. nuclear deterrent in the absence of additional nuclear testing by:

- Elucidating key weapons performance issues left unanswered when testing stopped;
- Validating physics models incorporated in numerical simulation design codes of the Advanced Simulation and Computing program, upon which the Stockpile Stewardship Program (SSP) relies;
- Maintaining aspects of test readiness; and
- Recruiting, training, and retaining weapons program personnel.

The improved numerical simulation codes, which will be benchmarked and validated against underground nuclear test results and experiments at the NIF, will enable nuclear weapon scientists to improve the fidelity of nuclear weapon performance simulations and reduce uncertainties in U.S. and foreign nuclear weapon assessments and U.S. warhead certifications. NIF is unique in its capabilities to provide data needed by the SSP because of its ability to produce extreme energy density conditions over reasonably large volumes combined with high-resolution diagnostics.

NIF has already provided critical data to the SSP. Results from a series of non-ignition experiments on NIF, and precursor experiments on Omega at the University of Rochester Laboratory for Laser Energetics and Z at Sandia National Laboratories, validated a physics-based theory and simulation capability that was a major factor leading to the resolution of a long-standing anomaly left unanswered when underground testing was suspended. Data obtained from NIF showed that the theory and simulation capabilities developed to remove this anomaly were correct. The elimination of this anomaly represents a significant accomplishment for the SSP; eliminating one of the key technical reasons for having to potentially return to underground testing and enabling production decisions in support of stockpile sustainment. The experimental campaign (defined as a series of shots/

experiments to achieve a common objective) on NIF was preceded by many months of platform development, utilizing experimental shot time on Omega and Z to test diagnostics, targets, and data acquisition and reduction. The effort on Omega and Z enabled this experimental platform to be implemented on NIF very rapidly and the experimental series completed to support the closure of the effort.

The acquisition of weapon-physics-relevant data in the high energy density (HED) physics regime to validate these physics-based models is essential to the development of predictive capabilities for stockpile applications. Data generated from both ignition-relevant and non-ignition HED experiments are categorized into four main topics: nuclear, thermonuclear, radiation, and output and effects.

Nuclear

The nuclear area focuses on the physics during the implosion phase of the system. During the implosion phase, the components are driven at high-pressure and high-rate, and are compressed hydrodynamically. The most important physics areas are the material properties at these conditions, the implosion hydrodynamics, and the nuclear properties (such as nuclear cross sections) at the pressure and temperature conditions similar to those at the centers of giant planets and stars. Key HED efforts in this area are the measurement of relevant material properties at the high-pressure and high-rate condition, the study of hydrodynamics of imploding systems, and the measurement of key nuclear physics cross sections, such as fission and fission fragments.

Accurate data about material properties near or at thermonuclear conditions is needed to improve the physics models in weapon performance simulation codes. NIF experiments provide precision data in high pressure (millions to billions of atmospheres) and high temperature (surface of the sun to the interior of massive stars) regimes that are otherwise inaccessible in the absence of nuclear testing. The material properties data broadly fit into three categories: equation-of-state, material strength, and phase structure. Current experiments on NIF focus on obtaining material dynamic data at high pressure and density and at high strain rate. Experiments include the measurements of diffraction data to discern the phase structure and strength data to bound the constitutive properties. Figures 1 (strength) and 2 (phase) show the configurations of these two experimental campaigns.

Scaled experiments on NIF are being used to address complex hydrodynamic phenomena important to predicting nuclear weapon performance. Experiments are "scaled" when physical quantities for the experiment—size, density, and pressure—are selected in a coordinated manner so that the hydrodynamic behavior is the same as the weapons-physics problem, albeit on a different scale—just as scaled airplanes in wind tunnels stand in for yet-to-be-built, full-scale airplanes. They help to "set or eliminate calibration parameters" and provide a means for validating physics codes used to examine issues during the nuclear phase of weapons functioning. They are also vital for development of computational models, helping nuclear weapon scientists develop and choose alternative models and computational methods to solve the stockpile problem of concern. Scaled experiments have begun on the NIF and Figure 3 provides some of the key NIF capabilities required to support this experiment.

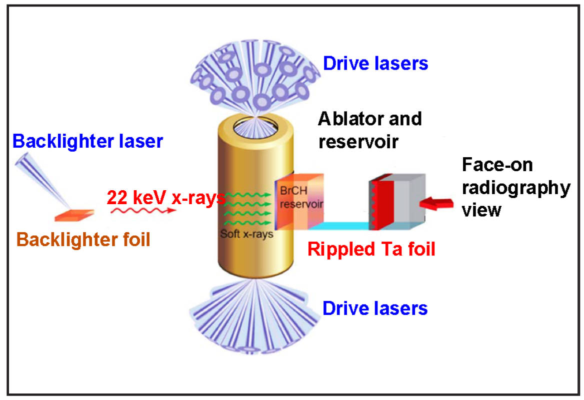

Figure 1. The material strength experimental campaign measures the deformation of solids under high pressure and high rate.

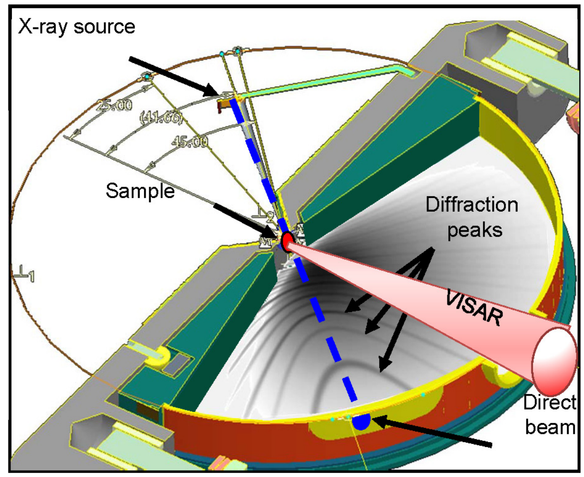

Figure 2. The material diffraction (material phase) experimental campaign measures the diffracted line pattern, which is a unique signature of material phases at various pressures and temperatures.

With recent results that delivered neutron yield in the high 10^{15} range, we have started experimental designs to utilize the high neutron flux to study nuclear physics and measure key fission and radiochemical cross sections. Data will enable us to bound the nuclear cross sections in a regime not accessible by traditional neutron sources.

Thermonuclear

In thermonuclear reactions, the system reaches very high temperatures and densities, similar to those at the center of stars and that of a supernova. At these conditions, the materials turn into hot plasma and are subject to strong dynamic interactions. The dynamic interactions and symmetry have impact on the efficiency of burn performance. Key HED efforts focus on the study of burning plasma performance in the presence of mix, burn, and symmetry issues.

Currently, even the most powerful computers are incapable of calculating high-speed turbulence processes on the smallest scales of interest. As a result, most codes incorporate simplified models for instability growth and turbulence. Different algorithms and models may produce different results. Hence, it is necessary to use experimental data to select the most appropriate model and/or set model parameters. Application of simulations extends to a wider set of problems and leads to results of increasingly uncertain validity, as the problems deviate from

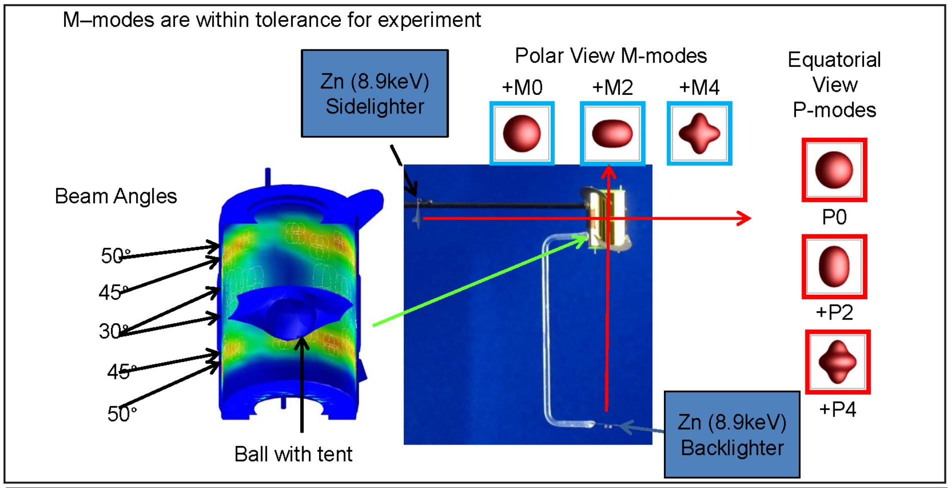

Figure 3. The complex hydrodynamics experimental campaign studies the dynamic evolution of system driven by imposed perturbations.

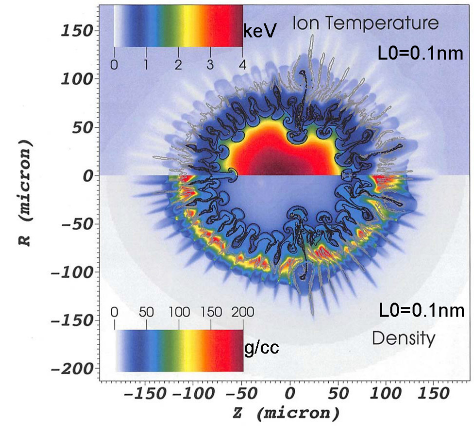

Figure 4. HED experiments on NIF are used to study mix at the fuel-ablator interface and its impact in degrading implosion performance.

the experimental baseline. Figure 4 displays a simulated result on the extent of mix at the fuel-ablator interface of an imploding NIF capsule with a prescribed numerical model. Figure 5 shows a planar experimental platform to study the increasing mix width due to shear instabilities.

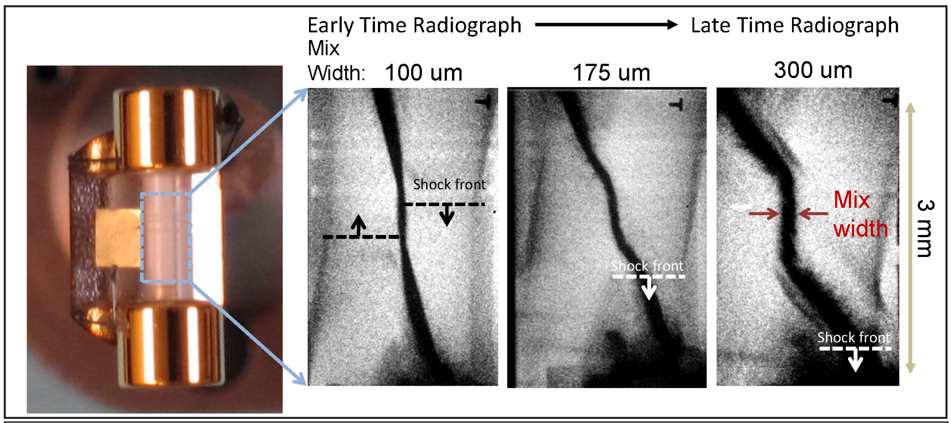

Figure 5. The NIF platform is used to quantify rate of instability growth and benchmark the numerical model parameters.

With the improvement of imploding capsule performance and robustness on NIF, we are beginning to explore the utilization of current and future capsules to study burning plasma and thermonuclear physics. Planned near-term applications include the validation of code and model of capsules with significant self-heating with imposed perturbations. As the capsule performance continues to improve, it will allow the SSP community to expand the application of capsule yield. More detailed applications were delivered in a 90-day study report submitted in 2012 (Classified Appendix to the Application of Ignition 90-day Study, Alan Wan et al., SRD Report, Lawrence Livermore National Laboratory, COPD-2012-0031, February 2012.).

Radiation

The radiation effort focuses on the study of radiation transport in SSP-relevant configurations and the validation of opacity models at relevant temperature and density conditions. Key HED efforts in this area are the measurement of radiation propagation in relevant geometries to validate the radiation flow algorithms incorporated in the design codes and to obtain data to validate first-principle opacity models, which govern the absorption and transmission of x-rays in nuclear devices.

Numerical modeling of radiation transported in a nuclear weapon is complicated by the extremes in conditions encountered and the various geometrical configurations that must be addressed. NIF provides a platform to conduct experiments that allows the validation of numerical algorithms in these relevant regimes.

The opacity of a material governs the absorption and transmission of x-rays in a nuclear explosive device. The opacity of materials is necessary data for codes that simulate the transport of radiation in weapons, a key factor in device performance. First-principles computer models used to calculate opacities are beyond the scope of today's largest supercomputers. Instead, models that generate opacity data use approximate methods and give inexact data with difficult-to-quantify uncertainties as input into the large simulations. Opacity experiments to date have been very important in improving opacity theory and models, but they have been restricted to lower temperatures and densities than those critical to nuclear-phase weapon performance. NIF provides the conditions required to obtain opacity data to significantly advance models in the relevant high temperature regime.

Output and Environment

The output and environment efforts focus on the post-explosion phase where the nuclear weapon releases x-ray, neutron, and gammas on the intended targets. In addition, the study of physics of weapon output and effects allows us to assess the consequence of using the weapons, both intended and unintended, in both the near- and long-terms. Key

HED efforts include developing relevant sources that model weapon output and utilize these sources to study the coupling of radiation for effects assessment and validation.

After the weapon as a whole has functioned, the device emits its energy into the environment through its output as a function of time-, energy-, and spatial-dependent x-ray, neutron, gamma fluxes. These radiation fluxes interact with the environment (e.g., the atmosphere, space) to produce a wide variety of effects, which have far-ranging impacts on overall consequence of execution, forensics, and counter-proliferation. NIF delivers the energetics to develop the needed platforms to validate the models that assess the interaction of radiation with a variety of targets.

Near-term Milestones and Deliverables for SSP Experiments on NIF

Currently, LLNL and Los Alamos National Laboratory are planning to conduct more than 10 experimental campaigns in the FY 2014-2015 timeframe across the four key topics described above. The major near-term deliverables follow.

FY 2014

- Continue to advance the understanding of ignition science.
- Develop the high-Z material experimental platforms at high-pressure and strain rates.
- Complete experimental campaign to validate mix at fuel-ablator interface for imploding capsules at two convergence ratios.

FY 2015

- Complete the readiness to conduct the first SSP-relevant high-Z material dynamic diffraction experiment at high strain rate and high pressure.
- Launch development of new hydroburn HED platform on Omega & NIF for the Marble campaign, including initial decision point on target design feasibility.
- Complete the acquisition of shear low energy density, high energy density, and direct numerical simulation data that will be used to impact the FY 2016 Life Extension Program Level 1 Milestone.
- Start first radiation transport experiment in complex SSP-relevant geometry.

Shining Light on Opacity *by Peter Beiersdorfer (Lawrence Livermore National Laboratory) and David J. Hoarty (Atomic Weapons Establishment)*

Commissioned just over a year ago, the Orion laser at the Atomic Weapons Establishment (AWE) in Aldermaston, England (see Figure 1), has become a key facility for measuring the properties of hot, dense matter. These experiments require the most advanced equipment for measuring the radiation emitted in a burst of x-rays lasting a few picoseconds, i.e., a few trillionths of a second. The experiments are carried out collaboratively between scientists at AWE and Lawrence Livermore National Laboratory (LLNL), who have built on expertise developed at the HELEN laser at AWE and at the Europa and Titan lasers at LLNL.[1,2,3]

Energy flow is a crucial element in understanding weapon performance. This energy flow must be simulated in our weapon codes to assess the performance, safety, and reliability of our nation's nuclear stockpile. Incorporating measured or experimentally validated material properties that impede or facilitate the flow of energy is a requisite to improving these simulations. The experiments at Orion aim at measuring the flow of x-rays through hot, dense material to determine a crucial quantity called the opacity.

Opacity measurements have been performed before at the HELEN laser at AWE, the Nova laser at LLNL, at the Omega laser at the University of Rochester Laboratory for Laser Energetics, and at the Z facility at the Sandia National Laboratories.[4,5] The Orion laser is unique in that it allows us to reach much higher densities and temperatures than have been achieved by the other facilities.

How does it Work?

The Orion laser fires a photon bullet of green light at a dot of sample material smaller than the period at the end of this sentence. This bullet has a duration of 0.5 picoseconds; it has a size less than six thousandths of an inch. This is more than a thousand times shorter than the laser beams produced at LLNL's National Ignition Facility. The shape of this photon bullet is very precisely defined to ensure that all its energy hits the target at once.

The sample material is sandwiched between two layers of carbon in the form of plastic or diamond that prevent it from expanding at these ultrashort time scales (see Figure 2). The result is a sample heated to many million degrees centigrade while maintaining solid density.

The Orion facility also has 10 beams operating at a much larger pulse length. These can be used to shock the target and further increase its density.

Diagnostics Are Key

In order to infer the parameters that determine the flow of light in hot, dense matter, we measure the x-rays produced by the sample itself. These x-rays carry information about the density, temperature, and radiative energy loss of the sample as well as on the sample's state of ionization, i.e., the degree to which the electrons have been peeled off the atoms in the sample.

The ultrashort duration of the laser-matter interaction requires that measurements be carried out with ultrahigh time resolution, stressing the leading edge of the scientific instrumentation.

We use the world's fastest cameras that streak the sample's x-ray emission with sub-picosecond resolution (see Figure 3).[6] These measurements are augmented with absolutely calibrated, time-integrating crystal spectrometers, which provide high spectral resolution. Pin-hole imagers measure the size of the material illuminated by the laser beam.

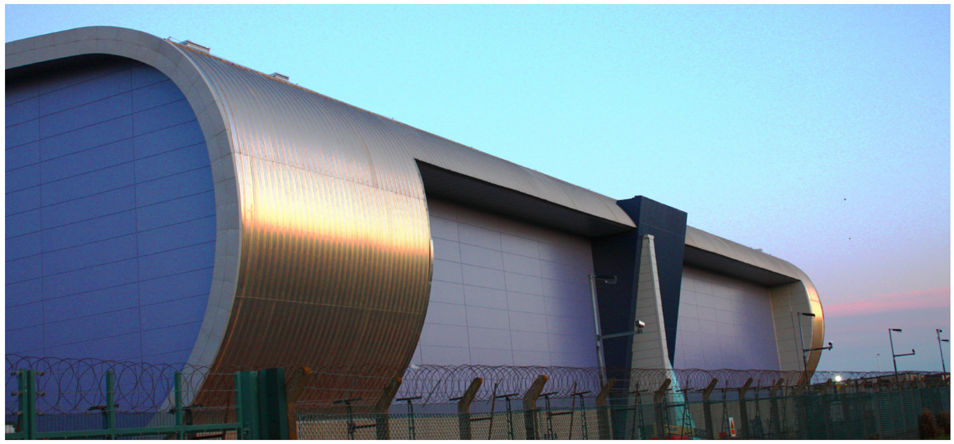

Figure 1. The Orion laser facility.

Material Properties at the Quantum Edge

The high density and temperatures in the sample bring out quantum mechanical effects that change the material properties and are challenging to quantify theoretically from first principles. Having precise handles on the density and temperature in our experiments, we can watch as a given atom loses its ability to hold on to its electron through a process called ionization potential depression (IPD). IPD is an effect in which the atom has fewer quantum mechanical states as the density is increased, thus reducing its ability to keep its electrons.

IPD models are crucial inputs for our ability to predict material properties. Recent experiments at the Linac Coherent Light Source (LCLS) facility at Stanford University have called into question the validity of the most widely used IPD model.[7] We conducted experiments on the Orion facility to explore IPD in the hot, dense matter regime not accessible by the LCLS measurements (see Figure 4). We found that the standard model gives the best description of IPD in this regime.[8] However, the predictions do not perfectly match our data, which indicates that improvements in the model and new measurements on an even finer density scale are warranted.

Opacity Measurements

If all relevant parameters in the sample have thermalized, i.e., they can be described by a single temperature, the sample is said to be in local thermodynamic equilibrium (LTE). Materials in LTE are much easier to model than those that are not in LTE, because a statistical approach can be used. If the sample deviates from LTE by only a small amount, the absolute x-ray emissivity can still be compared with LTE spectral predictions invoking an equivalent ionization temperature for a particular density as given by scaling relations developed by Busquet.[9] LTE models are a subset of the more general non-LTE models, which calculate the processes in the sample in detail without resorting to statistical averages. Non-LTE models are being developed at AWE and LLNL and are also being benchmarked against the Orion data. In addition to temperature and density, the sample thickness, emission duration, and emission area together with the response function of the detectors must be known to make a meaningful comparison. Fulfilling all of these criteria simultaneously is a grand challenge of opacity measurements.

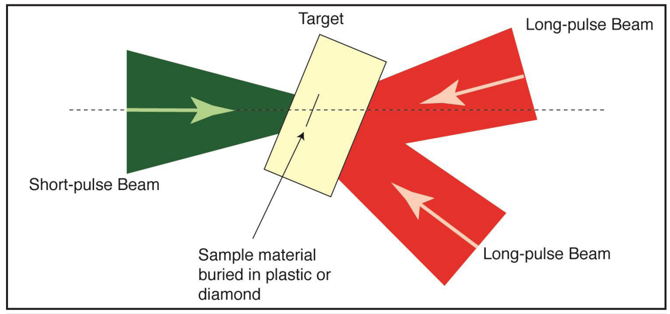

Figure 2. Target arrangement for opacity measurements on Orion. Two long-pulse laser beams of red light irradiate the backside of the target, inducing a shock wave that compresses the sample. One short-pulse laser beam of green light irradiates the front of the target and heats the sample. The diameter of sample is two thousands of an inch, its thickness is less than 10 millionth of an inch. The plastic or diamond that surrounds the sample is twenty times (front) to fifty times (back) thicker than the sample.

Our initial measurements showed that Orion heated the sample more than expected so that the sample was too far from the required LTE conditions. Achieving higher temperatures than planned is a better situation than finding that temperatures are too low. We have now redesigned our targets to lower the temperature to the desired values.

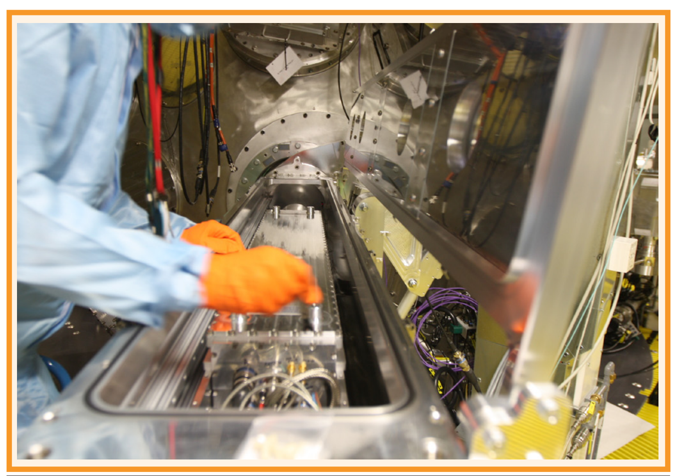

Figure 3. U.S.-built, time-resolved x-ray spectrometer installation on Orion.

On Orion, we have another knob to approach near-LTE conditions: We can use the aforementioned sample compression to increase its density. At sufficiently high densities, collisions overwhelm radiative processes and thereby bring the statistical occupation of the available quantum mechanical states to near LTE. We have now started to implement long-pulse compression in our opacity experiments.

The Future

The Orion laser facility is still evolving. Expected upgrades to the facility in the coming year will double the available energy of the green laser light, allowing us to investigate larger samples with more homogeneous conditions and to obtain more signal in our time-resolved measurements. AWE is planning additional major upgrades of the laser within a five-year horizon that will push the accessible parameter range to new regimes of interest to stockpile stewardship.

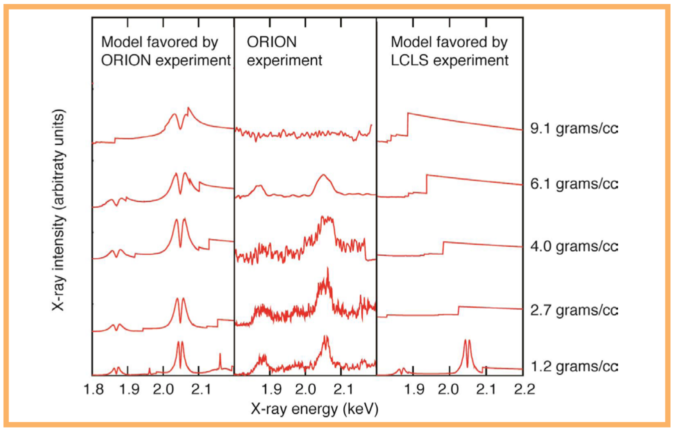

Figure 4. Comparison of ORION experimental data of aluminum (shown in the center panel) with two IPD model predictions (shown in the right and left panels). The density increases from bottom to top (from 1.2 to 9.1 grams per cubic centimeter) for each of the red curves. Our experimental data rule out the model favored by the recent LCLS experiment. Instead, the experimental data favor the predictions in the leftmost panel, but the agreement is not perfect.

Concurrently, our instrumentation is evolving to match the signal produced by the Orion laser. We are in the process of building a second sub-picosecond streak camera. A time-resolved pin-hole imager, a radiation thermometer, and a focusing x-ray spectrometer with very high spectral resolution are expected to join the existing suite of leading edge diagnostics in the coming year.

Together, our collaboration will explore new density and temperature regimes needed to refine our predictive understanding of nuclear weapons.

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Pulsed Neutron Capabilities Developed for Experiments at Nevada National Security Site

by Chris Hagen, Daniel Lowe, Frank Cverna, Steve Goldstein, and David Pacheco, National Security Technologies, LLC (Nevada National Security Site)

After the declassification of fusion research in the late 1950s, a series of ideas and papers emerged on ways to produce fusion using z-pinches. In 1965, J.W. Mather and a team at Los Alamos National Laboratory (LANL) published results showing remarkable neutron yields from a relatively compact, low-current generator: a dense plasma focus (DPF). Data did show that this laboratory-scale device was a powerful neutron source but, alas, the neutrons were created by instability mechanisms rather than a bulk thermal process. Work over the next 25 years showed that these DPF devices could scale to about 1 x 10^{12} neutrons in pure deuterium (D) experiments but that was the limit. Now in 2014, with the two DPF research and development facilities in Nevada, the U.S. Department of Energy(DOE)/National Nuclear Security Administration (NNSA) now has the highest current DPF capability in America and is using it to further several DOE missions.

During the period of designing sources to meet mission requirements and building laboratory capability, National Security Technologies, LLC (NSTec)-designed and -built DPFs have grown from storing less than 100 kilojoules to having the capacity of storing up to 2 million joules. Yields have increased over three decades of development effort. Operational flexibility has greatly increased. Over 6,000 DPF shots have been executed so far. This program has established a world-class DPF performance capability within DOE/NNSA.

What is a DPF Machine and How Does It Work?

While DPFs were invented and optimized over five decades ago,[1] the operative plasma physics processes are yet to be fully understood. The DPF system that produces fusion is simple in concept while also being a product of a rich combination of scientific and engineering disciplines. Shown in Figure 1 is the Gemini DPF source. Inside a dense plasma focus machine, light gases are heated and magnetically compressed to conditions similar to those inside the sun.

In the sun, Z machine, National Ignition Facility (NIF), and DPF, gas atoms fuse to form heavier products. Fusion releases energy, both in the form of high-energy particles and photons. DPF operation is roughly analogous to the familiar stroboscopic flash used in a camera: the flash slowly transfers energy from a direct current power source (the battery) to charge a capacitor storing this energy with the ability to discharge it almost instantly. To cause the flash, the capacitors are discharged through a gas-filled tube, ionizing the gas causing it to emit a very short, very bright flash of light and the picture is taken. In a DPF, the physics used allows the slow capacitor discharge (many microseconds) to be converted into a rapid energy compression (less than 100 ns). In the Z facility and in NIF, in contrast, the pulsed power or laser systems are designed to produce an energy pulse of 100 ns or less.

In the Nevada DPF machines, up to 1 million Joules of energy is stored in large capacitors at voltages of up to 70,000 volts, awaiting the command to generate neutron-producing fusion. The currents create intense magnetic fields and the high voltage causes high electrical fields in the gas-containing source tube. DPF machines use many gases, including D and tritium (T). The insulating gas becomes ionized, transforming into current-carrying plasma. The plasma is pushed to the reaction point in the tube at the end of the anode, as shown in Figure 2. There the intense magnetic fields compress the plasma into a very small volume, making it dense and hot; hence the name "dense plasma focus." The final compression process is called a z-pinch. Temperatures and pressures of the plasma reach extreme conditions like those on the outer parts of stars. The DPF is not hot or dense enough to produce fusion like in a star, but plasma instabilities do produce some very local heating and some very energetic beams of deuterons. These cause neutrons to be emitted. The neutrons are measured with various experimental diagnostics, and data are acquired. From start-to-finish, the whole process lasts but a few millionths of a second; the fusion processes last for less than a millionth of a second. Neutrons are emitted in a tiny volume about the size and shape of a short piece of pencil lead, a cylinder roughly 1 mm in radius and 10 mm long. Neutrons are emitted at rates up to 10^{20} per second.

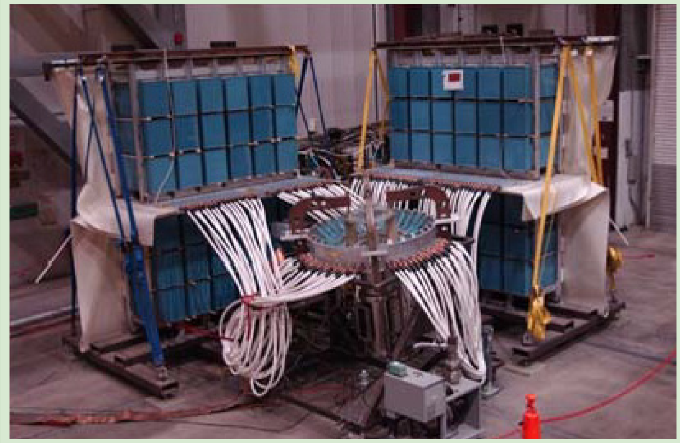

Figure 1. The "Gemini" megajoule DPF source. The blue assemblies are capacitor banks that store energy; the white coaxial cables transmit current to the central DPF tube assembly.

Unlike nuclear reactors that emit neutrons over a broad range of energies, DPF fusion devices are fairly mono-energetic. This characteristic is beneficial for many types of physics experiments, for instance, measuring nuclear cross-sections. Also, the DPF emits neutrons in very short bursts, allowing for fast time resolution. Furthermore, DPF machines are quite compact in comparison to large accelerators that are used as neutron sources; this makes them ideal for applications where space is at a premium or where transportability is required. These defining characteristics provide a research and application niche in which the DPF excels as a tool to accomplish high quality research quickly and efficiently.

The DPF machines at the Nevada National Security Site (NNSS) are producing intense (up to 10^{13}) 14.1 MeV neutrons per burst, and short (less than 100 ns) pulses of either 2.45 or 14 MeV neutrons from nuclear fusion using D or DT gases.

Mather in the United States and Filippov[2] in the Union of Soviet Socialist Republics independently discovered the process of neutron production with DPF machines. Using deuterium, both Mather and Filippov succeeded in reaching neutron yields of greater than 10^{12} neutrons per burst. Today, there is a rich community of laboratories using DPF machines for a wide variety of purposes, ranging from lithography to plasma physics to nuclear physics.[3] There has been a recent resurgence in the use of these machines facilitated by much better theoretical tools that are leading to improved understanding of the complex z-pinch process.

The Road to a World-Class DPF Capability

A legacy 1.5 kJ DPF source was supplied to NSTec and, with the knowledge gained from operating it, a series of sequentially larger sources were assembled and tested (see Figure 3). Based on NSTec's operation of the legacy DPF source, around the year 2000, LANL requested that NSTec design and fabricate a specialized DPF for a proposed downhole subcritical experiment named Unicorn at the NNSS. NSTec designed and built the 133 kJ OneSys machine as the result of this effort. It produced over 10^{10} 2.45 neutrons per pulse using deuterium, and subsequently over 10^{12} 14 MeV neutrons when using DT gas mix as fuel.

LANL subsequently requested the fabrication of a more powerful DPF source that would burn DT gas and make over 10^{13} 14.1 MeV neutrons per pulse, in a single burst that is very narrow in time. Furthermore, the source is required to be compact in order to fit into the U1a tunnel complex at the NNSS as part of a future experiment series.

Under development, a 350 kJ Sodium source has produced pulses of over 10^{13} 14.1 MeV neutrons per pulse (see Figure 4); present efforts are focused on achieving narrow-in-time pulses.

Improvements to performance, repeatability, and reliability that NSTec has achieved are due to iteration and characterization of tube design, source/drive tailoring, and characterization; sophisticated timing; firing and control

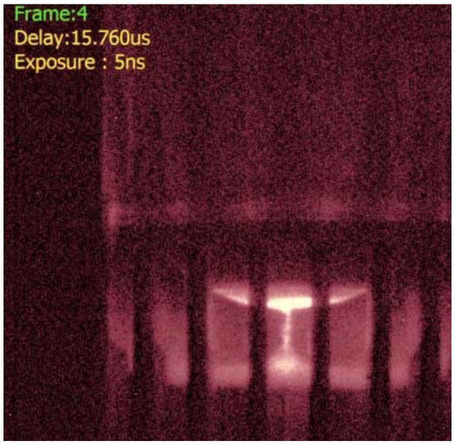

Figure 2. A high speed framing camera photo of the z-pinch at maximum compression. The exposure time is 5 nano-seconds. The pinch is estimated to last between 20 and 50 nano-seconds.

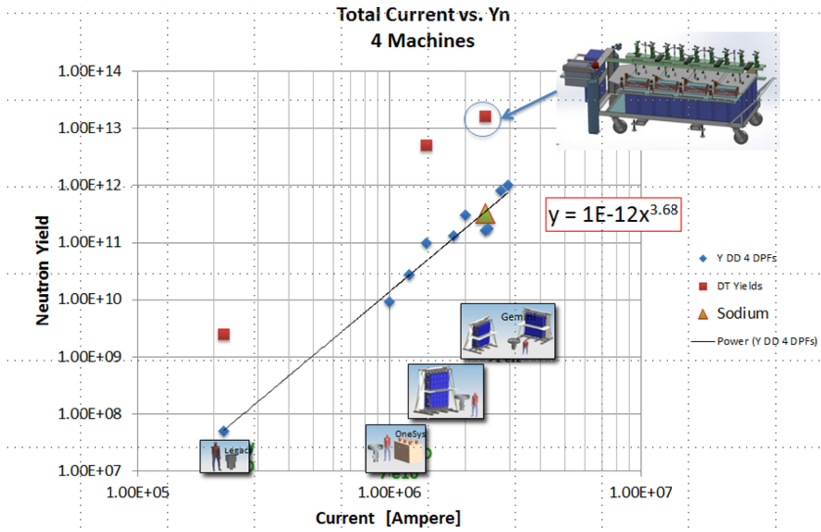

Figure 3. Growth of the DD and DT neutron sources. The “Legacy” source was supplied to NSTec; using knowledge gained from it, the OneSys (133 kJ), TallBoy (500 kJ), Gemini (1 MJ) and Sodium (350 kJ) sources were developed.

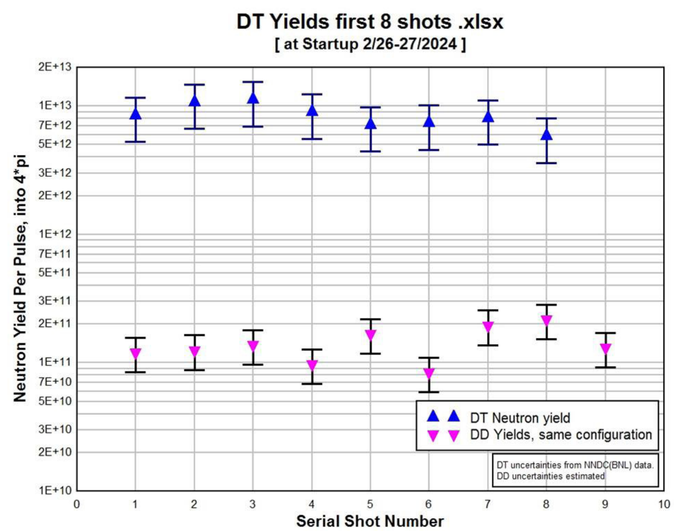

Figure 4. First day data from the startup of the 350 kJ “Sodium” source. Note the small shot-to-shot variation in yield, and the increase in yield resulting from use of DT mix versus pure deuterium.

systems; and concurrent modeling of all processes from current flow to plasma production.

Some examples of the increased experimental capacity developed by the DPF team are the ability to vary the yield of a single DPF machine over five orders of magnitude, the re-entrant chamber that allows very high neutron doses to be supplied to targets, the capability of producing narrow, intense single pulses of neutrons, and the ability to reliably, repeatedly, operate at high voltage and current levels.

The NSTec DPF laboratories have been used by LANL, Lawrence Livermore National Laboratory, Sandia National Laboratories, the Atomic Weapons Establishment (United Kingdom), research and development programs, and universities. For example, the DPFs have been used for a wide variety of physics experiments, including stockpile stewardship instrumentation development, Teller Light experiments,[4] and the measurement of physical quantities such as material properties, nuclear cross-sections, and for quantifying the performance of specialized systems, ranging from homeland security (e.g., radiochemistry activation experiments) to national defense issues (e.g., improvised nuclear devices).

An Important New Application

Important new applications such as Neutron Diagnosed Subcritical Experiments (NDSE), which dynamically measure reactivity, are currently being explored. The purpose of this class of experiment is to quantify the neutron multiplication (“chain reaction”) that is the fundamental mechanism that generates energy in nuclear weapons. Neutron multiplication is extremely sensitive to compressibility of materials, and understanding compressibility under the conditions encountered in a nuclear weapon primary will be a key factor in the NNSA developing Life Extension Program options (including pit reuse), guarding against problematic aging effects, and establishing the safety/security characteristics for the future stockpile. This class of experiment is similar to a Reaction History measurement on prior underground nuclear tests, except in NDSE the fissions are initiated by a short, intense pulse of neutrons injected around peak compression time, and the implosion is designed to remain below critical.

To be successful as one of several candidate pulsed neutron sources for these experiments, the DPF will need to generate a neutron pulse of the desired profile and a width of 50 nanoseconds (at 2 meters flight path), have a trigger jitter less than ±100 nanoseconds, and produce a single neutron burst of at least $5x10^{12}$. The DPF is an existing candidate source for achieving these requirements and will be employed in static proof-of-principle experiments over the next several years.

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[4]“Teller Light” is generated when radiation interacts with air. At the dawn of the nuclear era, Edward Teller used it to measure the performance of the first atomic weapons. In a ground or low altitude detonation the fluorescence (also known as Teller Light) occurs promptly in the first few microseconds. Teller Light is proposed as a nuclear forensic technique.

General Atomics’ Target Fabrication Support for NNSA’s Secondary Assessment Technology Experiments on NNSA’s High Energy Density Facilities *by Abbas Nikroo (General Atomics)*

Target fabrication is essential to the success of the experiments at the National Nuclear Security Administration’s (NNSA’s) high energy density (HED) facilities. Understanding nuclear weapon performance relies on having models of HED experiments with the goal of adequately describing the behavior of materials under extreme conditions. The targets are at the heart of these HED experiments. They enable development of models to understand material response and testing of those models in the regime of HED, essential to the Stockpile Stewardship Program (SSP). The unique collection of HED experimental facilities, supported by General Atomics (GA) target fabrication, is available within NNSA to fill in the gaps in the theoretical modeling of materials under extreme conditions. These HED facilities include Omega, Z, and the National Ignition Facility (NIF). The Omega laser at the University of Rochester Laboratory for Laser Energetics provides well over 1,000 shots per year to allow various experiments to be carried out in this regard while training future stewards in the process. The Z facility at Sandia National Laboratories provides the capability to study unique dynamic material properties, radiation effects, and fusion experiments for relevant materials ranging the entire periodic table. NIF allows access to extreme physical conditions relevant to an operating nuclear weapon. Targets are provided for the collective set of experiments performed at these facilities along with the concomitant modeling and simulations which refine the above mentioned models.

Targets are carefully designed based on the goals of the experiments through simulations utilizing models that are subject to validation. The target is an assembly of specific components, each geared towards realizing various parts of the intended design in the laboratory experiment. Among these are components designed to provide the drive (e.g., x-ray or magnetic), the materials under study, various backlighters used as flash x-ray sources, and tracer diagnostic elements to assist in deciphering the material under extreme conditions. Components also enable data to verify that the desired test conditions were indeed achieved. The target assembly process has to bring these components together with high precision (usually within several micrometers) for proper fielding at the facility and alignment with diagnostics. Hence, production and characterization of the assembled target and its components that are faithful to the intended design within the allowed tolerances is paramount to ensuring that the intended initial conditions were indeed present in the experiment. Given the fragility of the assembled targets and logistics of fielding them on the facilities, final assembly is usually performed onsite at the laboratory that houses the facility.

As is the case with most targets, realization involves close collaboration in development and production between the GA target team and those at the NNSA national laboratories as well as the end users. GA has developed over time through NNSA and internal investments a large suite of capabilities, including coatings, precision machining, shell fabrication and characterization, and introduced new techniques such as laser machining and robotics, all dedicated and focused on producing high precision components and target assemblies for the NNSA SSP mission (see Figure 1). While the range of targets developed for the broader set of experiments is too large to describe in this article, below we present some examples of recent target platforms developed and produced with major involvement by the GA team in support of the Secondary Assessment Technology subprogram and inertial confinement fusion (ICF) experiments, in particular.

A major recent campaign at NIF has examined deuterium-tritium (DT) implosions, which are on a higher adiabat than the ignition point design, the so-called “high foot” campaign. The rapid fielding of the high foot experiments was only possible by highly leveraging the infrastructure developed for indirect drive implosions on NIF, including cryogenic target fabrication. These implosions are high-performance implosions that are more robust against ablation-front Rayleigh-Taylor instability, have less convergence, and are generally less sensitive to modeling uncertainties. The goal of these experiments has been to validate the codes in these lower convergence implosions where hydrodynamic mix is reduced, hence possibly isolating mix as a cause for the lower than expected performance of point design targets. This campaign has been highly successful, with simulations

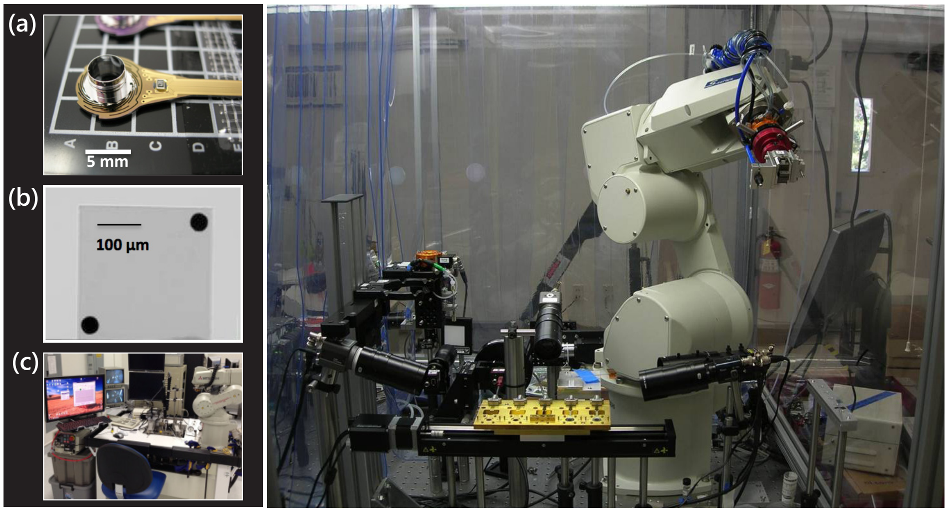

Figure 1. In addition to traditional fabrication techniques, GA has implemented new processes such as laser machining and robotics to increase throughput while maintaining the precision required. The robotic arm shown above is used on a routine basis in several different operations currently that involved much manual labor previously. (a) Thermomechanical Package subassembly for NIF cryogenic targets. (b) 50-µm gold dot gluing to diamond windows, a tedious manual assembly job previously, (c) Atomic force microscopy, with throughput increasing from ~ 20 shells per day to over 1,000 in an overnight automated operation with the robot.

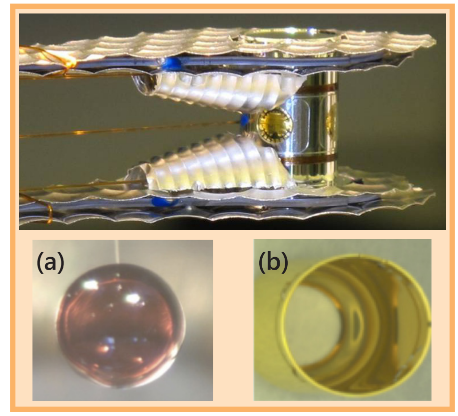

Figure 2. High foot campaign has used the NIF cryogenic target fabrication infrastructure to allow fielding of targets rapidly for this campaign. A capsule with a fill tube (a) is suspended with tents inside a gold lined DU hohlraum (b), which is cooled using the Thermomechanical Package cryogenic refrigerator hardware in the final assembled target shown above. The capsule is laser- and tumble-polished to remove isolated features to meet NIF specifications and has a 10-µm-diameter fill tube.

correctly predicting many of the implosion performance parameters, including neutron yield. For target fabrication in these experiments, some of the techniques included fabricating various components of the targets, such as ultra-smooth plastic capsules of varying thicknesses, polished to “ignition” specifications using tumble and laser polishing developed jointly by Lawrence Livermore National Laboratory (LLNL) and GA, and containing 10-µm-diameter fill tubes attached to the capsule with only 5 ng of glue to allow delivery of DT fuel. Another technique included gold-lined depleted uranium (DU) hohlraums developed for these and other experiments. Finally, target fabrication for the campaign included precision assembly techniques to allow support of centering of the capsule inside the hohlraum to less than 20 µm tolerance, and finally cryogenic layering of the DT fuel was utilized to allow availability of the proper targets for this campaign (see Figure 2). The suite of experiments for this campaign also included the keyhole targets developed for shock timing experiments and the convergent ablator targets that image the ablator trajectory both in one and two dimensions.

The Toto campaign is investigating implosion of experimental capsules in a hohlraum platform for the complex hydrodynamics effort. This platform includes low density copper (Cu) foam (~ 0.9 g/cc) as part of a capsule under study. Development of this experiment, as has become the case for many others, involves determining proper shock timing in a keyhole target prior to the integrated implosion experiments. In addition, the development of targets that allow observation and hence timing of shocks in multiple directions allow examining the symmetry of drive in these major directions. To allow viewing of shock break-out inside the spherical ablator in the required directions, the multiple axis keyhole targets have been developed jointly by LLNL and GA. These have become a workhorse for the ICF experiments, but this platform has been extended to provide the needed variation for the Toto campaign. This target design required the addition of a special spherical aluminum reflector to utilize the three axis keyhole ICF target platform to perform shock break-out experiments in the material of choice, the low density Cu foam. In this configuration, the VISAR diagnostic captures the shock breakout on the interior spherical reflective surface, which provides information on shock speeds through the ablator and the reflector materials. Using the coating and shell fabrication capabilities at GA, a 25-micron-thick aluminum hemispherical shell was developed to serve as the reflector. Again, the spherical shape is important so that the VISAR diagnostic can observe all three axes simultaneously, while the uniformity of the 25-micron wall (and its characterization) is important to ensure shock transit times are not affected by undesired thickness variations in the spherical reflector. An optical test of the assembly at LLNL has demonstrated that the spherical shape of the hemi shell was met (see Figure 3). GA has also been pursuing development of low density Cu foam itself using an aerogel technique, in an attempt to improve on the current slip casting technique used at LLNL that has a low fabrication yield of approximately a few percent. Early results are quite encouraging with Cu aerogel that is machinable and has the desired <1-µm pore size (see Figure 4). Experiments on NIF utilizing this platform are planned for late FY 2014 and beyond.

GA also provides the majority of targets used on the Z facility. One class of targets used for radiation flow experiments is called “Cibola.” These targets support

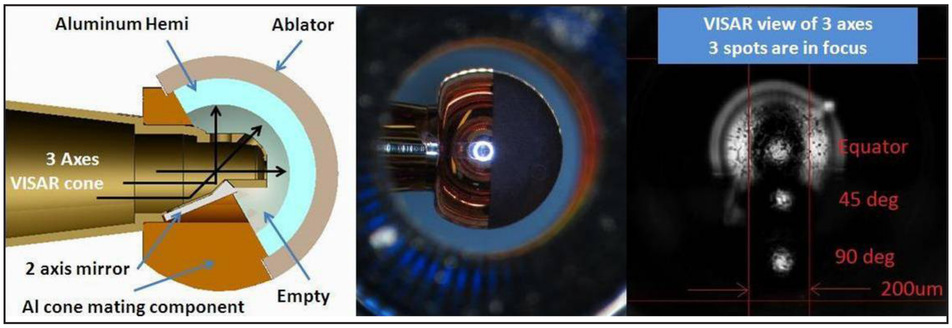

Figure 3. Two views of an aluminum spherical hemi shell fabricated as a reflector for complex hydrodynamic shock breakout experiments. Image: Three axes target design concept, and assembly test results for reflectivity and focus. Assembly performed at LLNL.

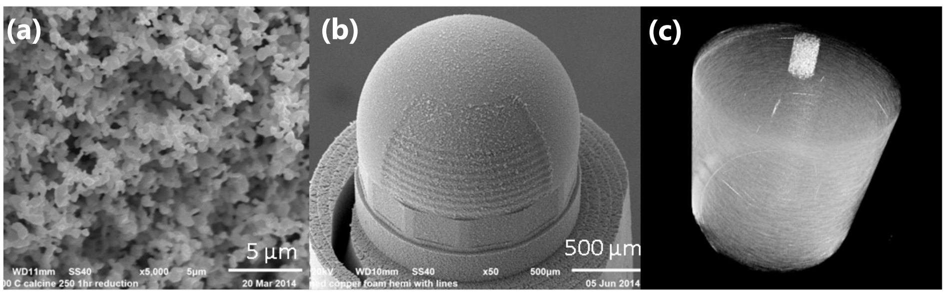

Figure 4. Low density Cu foam (~ 0.9 g/cc) is used in a number of experiments, including the so-called Toto platform used in the complex hydro effort by LLNL. GA has pursued an alternate development route for low density Cu foam using an aerogel technique as opposed to the slip casting technique that currently has a low fabrication yield of approximately a few percent. The Cu aerogel has <1 µm pore size (a), can be diamond turned to shape (b), and does not have major voids as examined in x-ray tomography (c). Current effort to produce samples large enough appropriate for the experiments at ~ 5 mm scale.

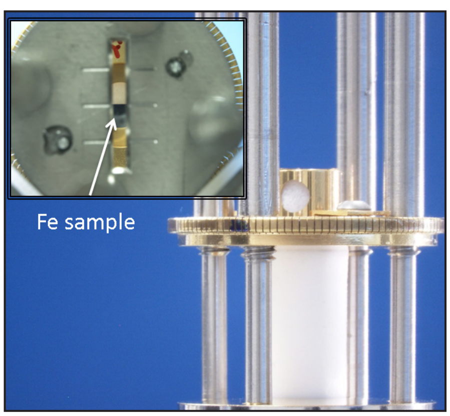

Figure 5. Assembled target for opacity shot on Z. The white central cylinder ~ 14 mg/cc CH foam inside the wire array assembly that is in turn supported by the top plate. A secondary hohlraum is mounted in this configuration above the wire array assembly to characterize axial radiation from wire array. Inset: Typical opacity configuration where an iron sample under study is mounted to the top plate receiving the radiation from the wire array implosion.

LLNL's Radiation Flow experiments on the Z facility. These targets are another examples of collaboration between GA and LLNL target fabrication teams to jointly produce these complicated targets. LLNL provides the portion of the secondary hohlraum that holds the radiation flow experiment, and GA produces the rest of the target and performs the final target assembly of all components onsite at SNL. These are among some of the most complex components that are machined for the Z program using precision machining facilities at GA. "Cibola" platform supports LLNL experiments on Z at a level of about two weeks of experiments per year.

SNL devotes several weeks of experiments per year to the Opacity campaign. This campaign uses the "dynamic hohlraum" platform, which is a nested pair of tungsten wire arrays imploding onto a foam annulus, which creates a collapsing hohlraum inside the foam volume that reaches remarkably high temperatures and emits copious radiation. These radiation sources can be used to drive experiments, including opacity experiments for both fundamental science research (e.g., Fe) and for stockpile stewardship research (other high-Z materials). These targets involve efforts by both the GA and LANL target teams. GA scientists develop and fabricate the foam annuli that are nested inside the dynamic hohlraum itself to provide pulse shaping for the radiation from imploding wire array. Depending on the type of material involved, the opacity samples may be provided by LANL, but again the onsite GA team performs the target assembly at SNL, including mounting the opacity samples to the foams (see Figure 5). The concept of using an on-axis secondary hohlraum has been resurrected in some recent experiments with the secondary hohlraum placed above the wire array load to characterize the axial radiation energy.

The above touches on the breadth of areas where target fabrication, particularly the effort at GA, has become a key enabling technology in support of Secondary Assessment Technology and ICF. One of the key functions GA performs is the iteration with the physics end users to simplify as much as possible very complex targets, and then make them possible through scientific development of materials needed and engineering of target assemblies to required specifications and functionality. Collaboration among target fabrication teams at GA and other labs, and target fabrication and physics have been an essential component of this highly successful effort. •

Contact Us

Please send your comments about this issue of the *Stockpile Stewardship Quarterly* and suggestions for future issues to Terri Stone at terri.stone@nnsa.doe.gov. To subscribe to our mailing list, submit your full name, email address, and organization.

In Memorium
Heino Nitsche, 1949-2014

It is with great sadness that we learned of the passing of Professor Heino Nitsche of the University of California, Berkeley (UC Berkeley) in mid-July. Professor Nitsche was an outstanding scientist, leading efforts in radiochemistry, heavy element research and a host of other scientific pursuits in chemistry and nuclear physics. He was one of the first principal investigators funded when the Stewardship Science Academic Alliances program began—first in low energy nuclear science and more recently in radiochemistry.

Professor Nitsche attracted and inspired exceptional graduate students. Quite often, one of his team won an award for the best poster at the annual SSAA Symposium. Conversations with his students revealed that he was an excellent mentor effectively encouraging his students to achieve excellence in their careers.

Professor Nitsche was born July 1949 in Munich, Germany. He earned his Ph.D. in 1980 in chemistry at the Freie Universität Berlin. He studied nuclear chemistry and electrochemistry and did experiments on the conductivity of uranium. He then joined the University of California, Berkeley as a Lawrence Berkeley National Laboratory staff scientist. He worked there for 13 years and in 1993 returned to the newly reunified Germany to direct a radiochemistry research institute in Dresden. In 1998, he returned to the University of California, Berkeley and became a full professor in the Department of Chemistry and the founding director of the Glenn T. Seaborg Center. He was a world-renowned and accomplished scientist in actinides whose most recent achievement was being part of the team that confirmed the existence of element 117, also known as ununseptium (Uus). He will be missed.

Highlights

Funding Opportunity Announcement

The National Nuclear Security Administration's (NNSA's) Office of Research, Development, Test, and Evaluation recently released the latest funding opportunity annoucement (FOA) of the Stewardship Science Academic Alliances Program. This FOA, Funding Opportunity Number DE-FOA-0001067, requests new and renewal proposals for grants in the research areas of Properties of Materials Under Extreme Conditions and/or Hydrodynamics; Low Energy Nuclear Science; and Radiochemistry. The full posting is available at GRANTS.GOV. The application due date is October 27, 2014. •

Stewardship Science Academic Alliances Program Grantee News

Stewardship Science Academic Alliances Program grantee Witek Nazarewicz has been appointed Chief Scientist at the Facility for Rare Isotope Beams (FRIB).

The FRIB is a new national user facility for nuclear science, funded by the Department of Energy Office of Science, Michigan State University (MSU), and the State of Michigan.

Located on campus and operated by MSU, FRIB will provide intense beams of rare isotopes (that is, short-lived nuclei not normally found on Earth). FRIB will enable scientists to make discoveries about the properties of these rare isotopes in order to better understand the physics of nuclei, nuclear astrophysics, fundamental interactions, and applications for society. Nazarewicz has been a central figure in developing the scientific vision for rare isotope science and has served on many international advisory committees, including the most recent National Research Council Decadal Study in Nuclear Science.

Nazarewicz is excited about the challenge and looks forward to leading the establishment of a vibrant FRIB Theory Center and helping the FRIB users realize the full scientific potential of FRIB. His role will be to articulate the scientific opportunities with FRIB, advise the laboratory director and project director on issues related to science, and to represent FRIB capabilities to the broader scientific community. •

Leda Experiment a Success

Deep in the U1a tunnel at the Nevada National Security Site on August 12, 2014, a device named Leda imploded in the thick metal vessel shown above. Leda was a scaled, hydrodynamic experiment using plutonium surrogate material and high explosives the scientists had been building for more than a year. Scientists studied her data and proclaimed the Leda experiment a 100 percent success. Congratulations to the Leda Team!