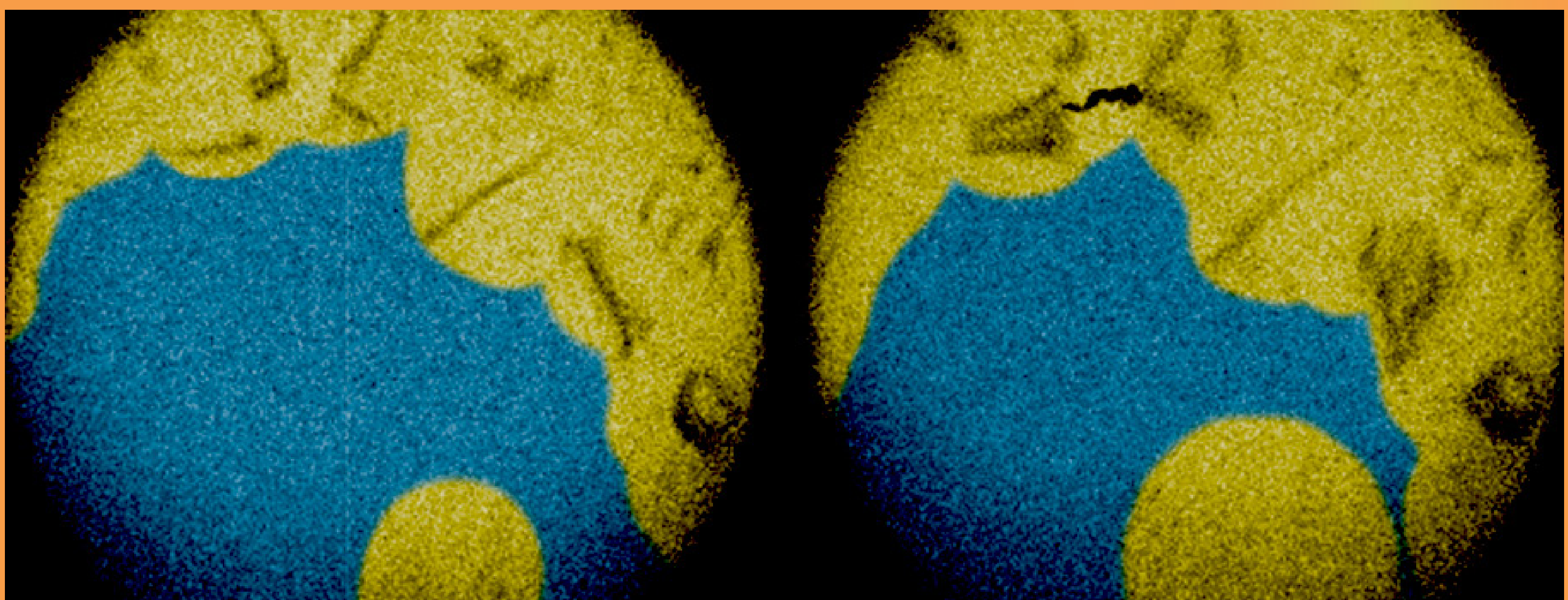
Science and Technology UPDATE

June–August 2013



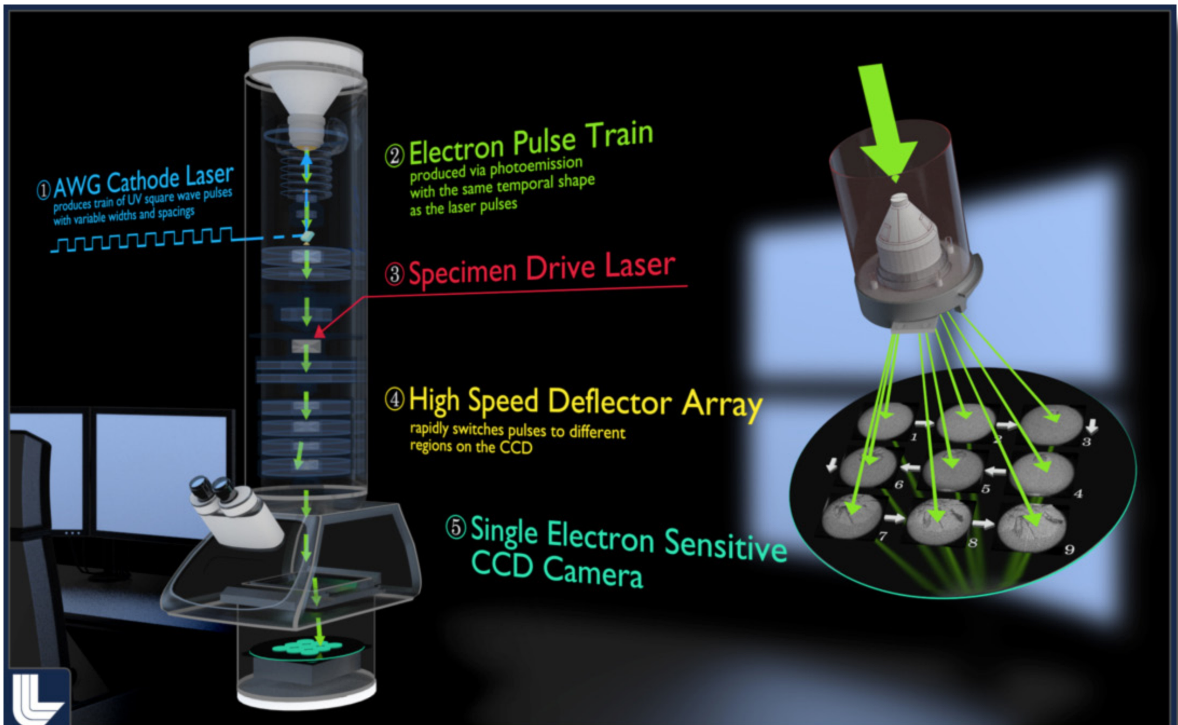
Science on a Mission

LLNL-MI-643293

LIVERMORE WINS FIVE R&D 100 AWARDS

Livermore researchers have received five awards in the latest R&D 100 Awards competition, which selects the world's top 100 innovations with commercial potential. "My sincere congratulations to the winners of this year's R&D 100 Awards," said Secretary of Energy Ernest Moniz. "The scientists and engineers who developed these award-winning technologies at the cutting-edge facilities across our national labs are keeping Americans at the forefront of the innovation community and assuring our nation's economic competitiveness and national security."

The **Movie Mode Dynamic Transmission Electron Microscope** (MM-DTEM) captures billionth-of-a-meter-scale images at frame rates more than 100,000 times faster than those of conventional techniques, enabling the capture of superfast processes as they occur, including microstructural changes, phase transformations, and chemical reactions in nanostructured materials and, potentially, biological organisms. MM-DTEM could even allow direct observation of molecular interactions, such as protein–protein binding and host–pathogen interactions. As in the simplified schematic, MM-DTEM has an arbitrary waveform generation (AWG) laser system that delivers shaped laser pulses and a low-aberration, high-speed deflector array that is precisely synchronized with the AWG laser to deflect each pulse to a different area on the camera.



A Sandia National Laboratories-led team including two LLNL computational scientists developed **Mantevo Suite 1.0**, the first integrated suite of miniapps (small software applications) for high-performance computing. The miniapps help develop new supercomputer systems and the applications that run on them by serving as stripped-down surrogates for complex, full-scale programs. This allows researchers to experiment and optimize quickly, before developing the full-scale application. In a ferociously competitive global market where clock speeds have stalled and future performance gains will come almost exclusively from code improvements, Mantevo Suite will also enable the collaborative, simultaneous development of system components for tomorrow's world-leading supercomputer systems.

About the Cover

Germanium telluride is visually captured as it crystallizes in response to a 17.5-nanosecond electron pulse. (See "DTEM Captures Nanosecond Crystallization," on pg. 15.)

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-7NA27344.

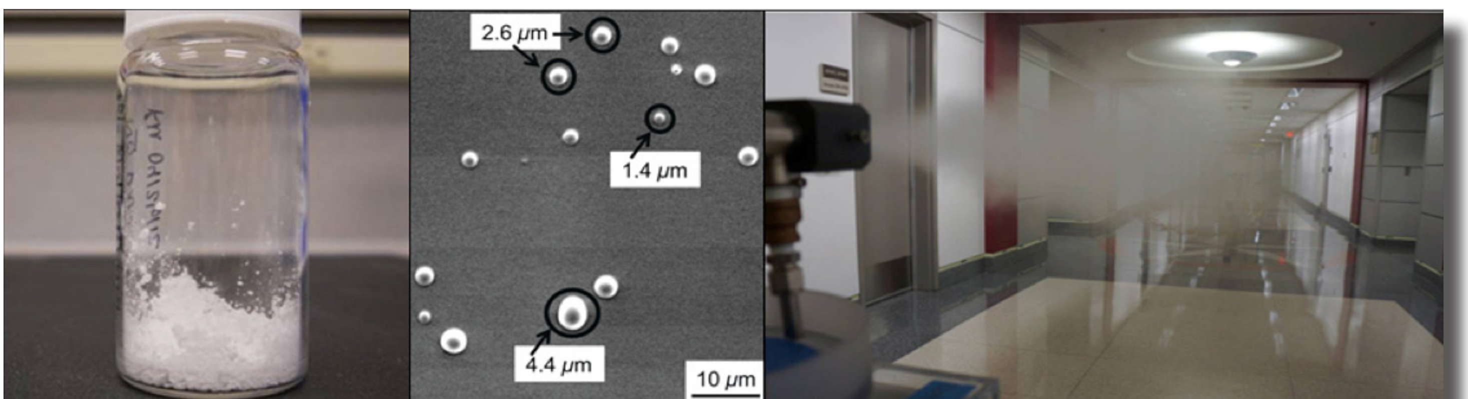
LIVERMORE WINS FIVE R&D 100 AWARDS (CONT'D)

Laser Screening at High-throughput to Identify Energetic Laser Distortion (SHIELD) reduces the time to screen 48 NIF laser checkpoints from 12 hours to less than 1 second. Operated with the push of a button, Laser SHIELD protects the facility's optics by ensuring that the high-energy pulses do not exceed any of their operational limits. Laser SHIELD lets NIF fire more shots in less time and respond flexibly to user requests for wavelength changes in their experiments.

DNA-Tagged Reagents for Aerosol Experiments (DNA TRAX) is a versatile material that can be used to safely, reliably, and rapidly diagnose airflow for assessment of contamination and other scenarios. Stand-ins for dangerous substances, DNA TRAX particles are comprised of sugar and synthetic DNA, which serves as a "bar code" that enables identification. DNA TRAX was successfully tested at the Pentagon last year in a study that enhanced understanding of contaminant spread inside heating, ventilation, and air conditioning systems. Other potential applications include tracking environmental releases and underground fluid flows in fracking operations. The image above shows (left) a vial of DNA TRAX, (center) a scanning electron microscope image of DNA TRAX particles, and (right) DNA TRAX being released in indoor testing.

A technology named **Efficient Mode Converters for High-Power Fiber Amplifiers** overcomes a key limitation of high-power fiber lasers by maintaining beam quality as power is increased. The innovators behind this technology replaced the circular core used in conventional fiber lasers with a rectangular design that accommodates high-energy-output fiber amplifiers by spreading the laser power across the rectangular core's larger area mode, so the modes can be amplified without damaging the fiber. This LLNL technology will increase the power of high-quality fiber lasers from several to potentially 100 kilowatts, for applications in defense and even solid-state lasers for machining, among others.

Two of the winning technologies—MM-DTEM and the Efficient Mode-Converters for High-Power Fiber Amplifiers—received early support from the LDRD Program, which invests in high-risk, potentially high-payoff proposals with a horizon too long for other funding. This year's results bring to 148 the number of R&D 100 Awards the Laboratory has captured since 1978.

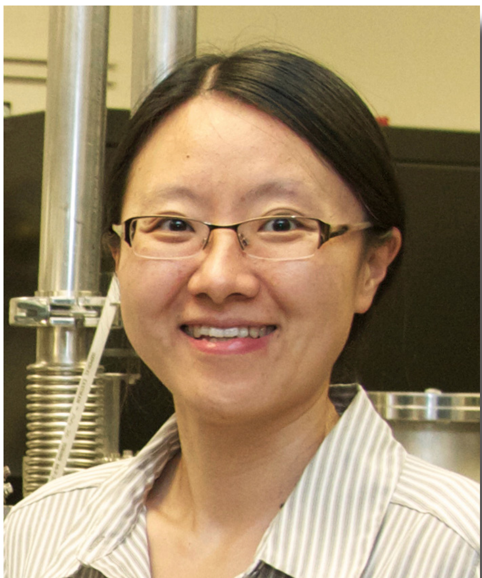


LLNL CITED AS INNOVATION DRIVER IN ADDITIVE MANUFACTURING

Terry Wohlers, considered the "guru" of additive manufacturing, **cited** Lawrence Livermore as one of the drivers of innovation in the field. Wohlers made the remarks in his keynote address at the the Rapid 2013 Conference & Exposition, **held** June 10–13 in Pittsburgh, PA. The president of Fort Collins, Colo.-based Wohlers Associates Inc. also recently published the **18th annual edition of Wohlers Report**, which monitors developments in the sector.

PHYSICIST WINS DOE EARLY CAREER RESEARCH PROGRAM AWARD

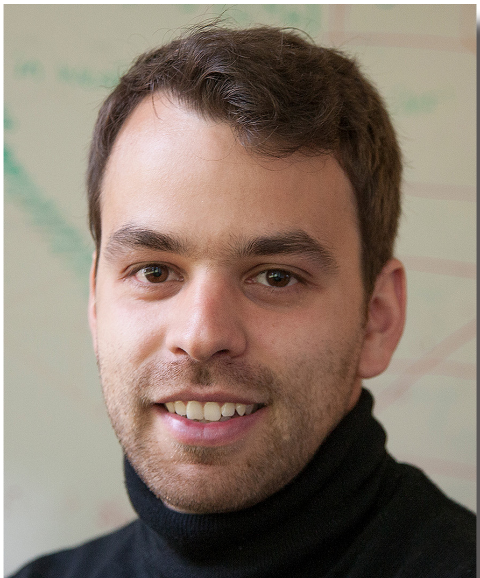
LLNL physicist Yuan Ping has been selected for a DOE Office of Science Early Career Research Program (ECRP) Award. The award provides $2.5 million over 5 years to support the research of outstanding scientists early in their careers and to stimulate research careers in disciplines supported by the Office of Science. "I am very honored and grateful for this great opportunity to do more high-quality work," Yuan said. Her project, selected by the Office of Fusion Research, aims to provide high-quality data on critical energy transport properties of high-energy-density (HED) matter. Transport processes such as thermal and electrical conduction, radiation, viscosity, electron equilibration, and particle stopping determine the mechanisms and rates of energy transfer and redistribution within HED matter. "These energy partition pathways must be properly diagnosed and understood in order to develop and benchmark next-generation advanced models for extreme HED conditions such as those found in inertial confinement fusion," she explained. The data also will impact many other fields where HED science plays a crucial role, such as studies of geophysical phenomena, planetary formation, and astrophysical objects. This year, 61 ECRP awardees were selected from a pool of about 770 applicants from universities and national labs. Yuan is the 10th Livermore recipient since the program's inception in 2010.



LAWRENCE FELLOW WINS COMPUTING CHALLENGE AWARD

A proposal submitted by Lawrence Fellow Frederico Fuiza has been chosen under the 2013 Leadership Computing Challenge program of the Office of Science's Advanced Scientific Computing Research (ASCR) program. This recognition follows on the heels of Frederico winning a European Physical Society award for his Ph.D. thesis.

Frederico's proposal—*Predictive Full-Scale Simulations of Fast Ignition of Fusion Targets*—will receive CPU time on the Argonne Leadership Computing Facility's IBM Blue Gene/Q computer Mira.



TECHNOLOGIES OPTIONED FOR WATER TREATMENT AND ENERGY STORAGE

In June, the Laboratory optioned a metal-doped carbon aerogel technology to Aquas Technologies Corporation. The startup can now negotiate an exclusive license for the technology in water treatment and a nonexclusive license for its use in energy storage. In addition, a six-month option agreement with Global Renewable Energy Engines was signed for an LLNL technology titled "Solar Thermal Technology for 5-kWm Minimum and 10-kWm Maximum Continuous Mechanical Power Output for any Single Cylinder." The company, a startup located in Piedmont, CA, seeks applications in generating and storing power from solar or waste heat.

SUMMER STUDENT WINS SCHOLARSHIP FROM DOE

Crystal Green, who returned to LLNL this year for her third year as a summer student in the Nuclear Criticality Safety Division, has been awarded a $5,000 scholarship from the DOE Nuclear Energy University Programs. Crystal is currently a senior at South Carolina State University, where she majors in nuclear engineering. In her first two summers at LLNL, she won first place at the Laboratory's Summer Student Poster Symposium. This year, Crystal is designing baseline critical experiments to conduct at the National Criticality Experiments Research Center and is also helping perform approach-to-critical experiments using the LLNL Inherently Safe Subcritical Assembly. She was one of 37 recipients of scholarships for the 2013–2014 academic year under DOE's Integrated University Program.

PH.D. THESIS SELECTED FOR SPRINGER SERIES

The 2012 Ph.D. thesis of Michael Kruse, a University of Arizona graduate student working at LLNL with Erich Ormand, Sofia Quaglioni, and Petr Navratil, has been chosen for publication in the Springer Theses series of publications. Michael's **thesis**—*Extensions to the No-Core Shell Model: Importance-Truncation, Regulators and Reactions*—looks at aspects of ab initio quantum mechanical calculations for light nuclei. Michael spent three summers at LLNL and was part of a broader collaboration involving the Laboratory's Nuclear Theory Group. Most of the calculations for his thesis were done on LLNL computers. Every year, **Springer Theses** accepts "best thesis" nominations from research institutions around the globe for publication in this Series. Nominated and endorsed by two recognized specialists, theses are chosen for publication in the series based on their scientific excellence and likely impact on future research.

SUCCESSFUL TEST OF HIGH-SPEED MONORAIL FOR DOD INITIATIVE

An LLNL-led team of U.S. researchers conducted a successful testing of a high-speed monorail sled as part of the Conventional Prompt Global Strike Initiative. The test, conducted at Holloman Air Force Base in New Mexico, achieved supersonic velocities and obtained 100% data return. The Department of Defense initiative seeks to develop the capability to rapidly deliver nonnuclear weapons to a target anywhere in the world. Livermore is the warhead design agent for the initiative and is also building the aeroshell that will simulate a flight vehicle in a test later this year. Because of the extreme speeds that will be attained in the coming experiment, the team tested the material strength, aeroheating, ablation, and aerodynamic flight stability of several components. Project leader Dave Hare stated that all test objectives were met, and an initial look at the results indicated that the data were consistent with predictive simulations.

LDRD SYMPOSIUM SHOWCASES BIG DATA, MATERIALS, AND ENERGY RESEARCH

The 2013 Laboratory Directed Research and Development (LDRD) Program Update was held June

12 in Washington, D.C., attended by representatives of NNSA, Nevada National Security Site, and Sandia, Lawrence Livermore, and Los Alamos National Laboratories. The update is an opportunity for each site and laboratory to present highlights of successful projects and ongoing research. The themes of this year's program update were "Materials in Extremes," "Big Data to Decisions," and "Energy Use Impacts and Mitigation." Livermore's William Craig was one of the three laboratory LDRD program directors to present keynote remarks. In the photo, Livermore's Roger Aines answers questions about his presentation on an LDRD project to develop novel proppants that could mitigate the environmental impact of hydraulic fracturing ("fracking"). (More photos are available **on the NNSA Flickr page**.)

INVITED TALK ON URANIUM MINERALOGY AND CHEMISTRY

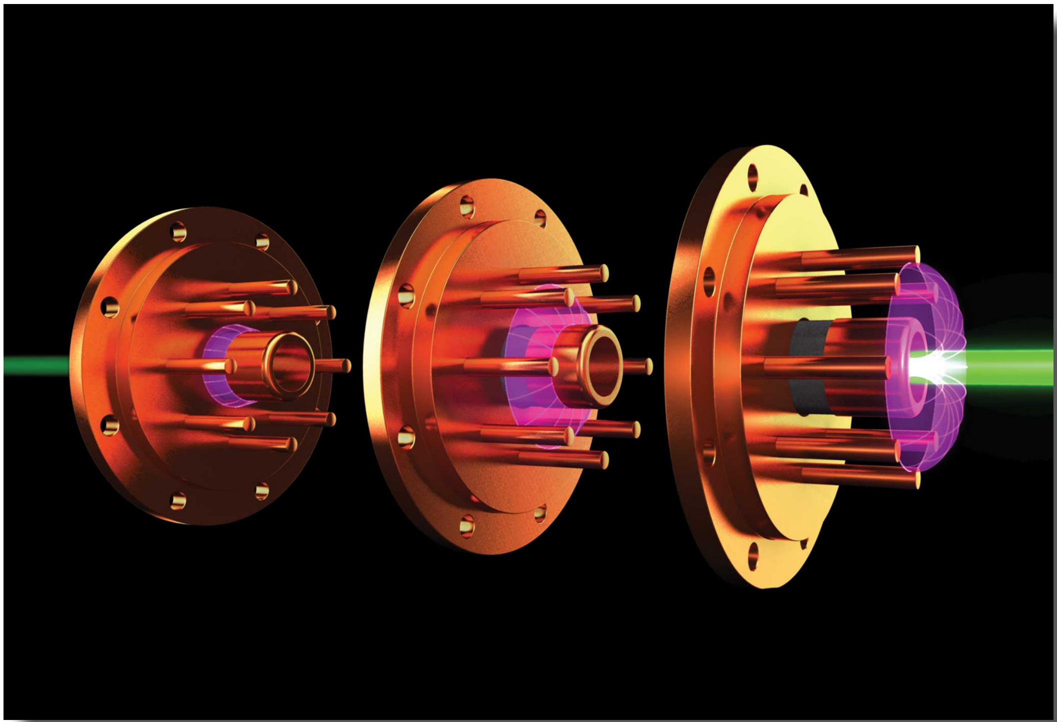
Ian Hutcheon gave an invited talk on nonproliferation nuclear forensics as part of a short course titled "Uranium: Cradle to Grave" that was held on May 20–22 in Winnipeg, Canada, in conjunction with the annual meeting of the Canadian Mineralogical Society. The short course spanned the mineralogy, geochemistry, and ore deposits of uranium, and included nuclear waste challenges and solutions, weapons proliferation, and nuclear forensics for attribution and nuclear security. The short course brought together a panel of international experts focused on educating graduate students, early career scientists, and researchers seeking a deeper involvement in the field.

RESEARCHER ELECTED SOCIETY OF PETROLEUM ENGINEERS PROGRAM CHAIR

Souheil Ezzedine has been elected as the new program chair for the California chapter of the Society of Petroleum Engineers (**SPE**). In this role, he will be responsible for setting and executing objectives for SPE programming, arranging speakers for and publicizing SPE programs, arranging a "distinguished lecturer" series, and assisting SPE International with planning of regional and national meetings and events. Souheil will continue to serve as the scholarship program chair of SPE, a position he has held since 2012. As a constituent society of the American Institute of Mining Engineers, the mission of SPE is to collect, disseminate, and exchange technical knowledge concerning the exploration, development, and production of oil and gas resources and related technologies for the public benefit, and to provide opportunities for professionals to enhance their competence.

$1 MILLION FROM DARPA FOR PLASMA Z-PINCH WORK

The Defense Advanced Research Projects Agency (DARPA) has allocated $1 million to fund groundbreaking work at LLNL in the computational and experimental investigation of the Z-pinch plasma configuration. The work will be conducted by Andrea Schmidt and her plasma research team for DARPA, which is interested in using Z-pinches to make compact neutron sources for applications that require more neutrons than are possible with today's state-of-the-art dense plasma focus experiments. To increase the neutron yield, Andrea and team are optimizing electrode design with a groundbreaking model they developed—the first-ever fully kinetic model of a dense plasma focus that can track physical quantities at the particle level and thereby predict



neutron yields more accurately. (This achievement was **published** in *Physical Review Letters* late last year.) "Modeling these plasmas fully kinetically was a real breakthrough in understanding how they work and predicting their behavior," says Andrea. "DARPA's $1 million award will allow us to apply this new simulation capability to a larger [dense plasma focus] and to push the neutron yield on these devices to even higher levels." In the rendering of a Z-pinch, an umbrella-shaped plasma sheath (purple) is pushed down a cylindrical electrode, then collapses in on itself to create a dense region (white) that "pinches" and thereby accelerates an ion beam (green).

WORKSHOP PRESENTATION ON ENERGY EFFICIENCY IN HIGH-PERFORMANCE COMPUTING

A paper co-authored by Anna Maria Bailey and presented at the annual High-Performance Power-Aware Computing Workshop, **held May 20** in Boston, MA, highlighted LLNL's leadership role in driving energy efficiency measures in supercomputing. The paper—"Recommendations for HPC energy management dashboard displays"—explores how data and metrics should be displayed to provide the "Prius effect" for high-performance computing. The Prius effect refers to the use of dashboards to provide real-time, actionable visual data: by observing the fuel consumption screen, Prius drivers begin to see the direct connection between the way they drive and the rate of fuel consumption, becoming more aware of their behavior and being motivated to drive in a way that keeps fuel consumption low. Anna Maria's paper explores whether there is an equivalent metric that HPC facility managers and others could use. The workshop, held as part of the International Distributed and Parallel Processing Symposium, was co-chaired by LLNL's Bronis de Supinski.

WORLD'S DEEPEST ELECTRICAL RESISTANCE TOMOGRAPHY FOR CARBON DIOXIDE SEQUESTRATION

A team led by Livermore's Charles Carrigan has **announced**, in the *International Journal of Greenhouse Gas Control*, the world's deepest electrical resistance tomography (ERT) array and their successful use of ERT to track the movement and concentration of carbon dioxide (CO_2) in a geologic formation. The team obtained time-lapse electrical resistivity images during the injection of more than 1 million tons of CO_2 more than 10,000 feet deep in an oil and gas field in Cranfield, MS—the deepest application of the technique to date. Said Charles, "The images provide information about both the movement of the injected CO_2 within a complex geologic formation and the change with time of the distribution of CO_2 in the porous sandstone reservoir." The photos show (left) the ERT electrode band mounted on nonconductive casing, with the electrodes protected by nonconductive, epoxy-based centralizers; and (right) a closeup of the splitter, which resides above electrode array and combines electrode cables into wireline cables for conduction to surface.

$1.7 MILLION TO DEMO SOLAR POWER SYSTEM WITH LLNL TECHNOLOGY

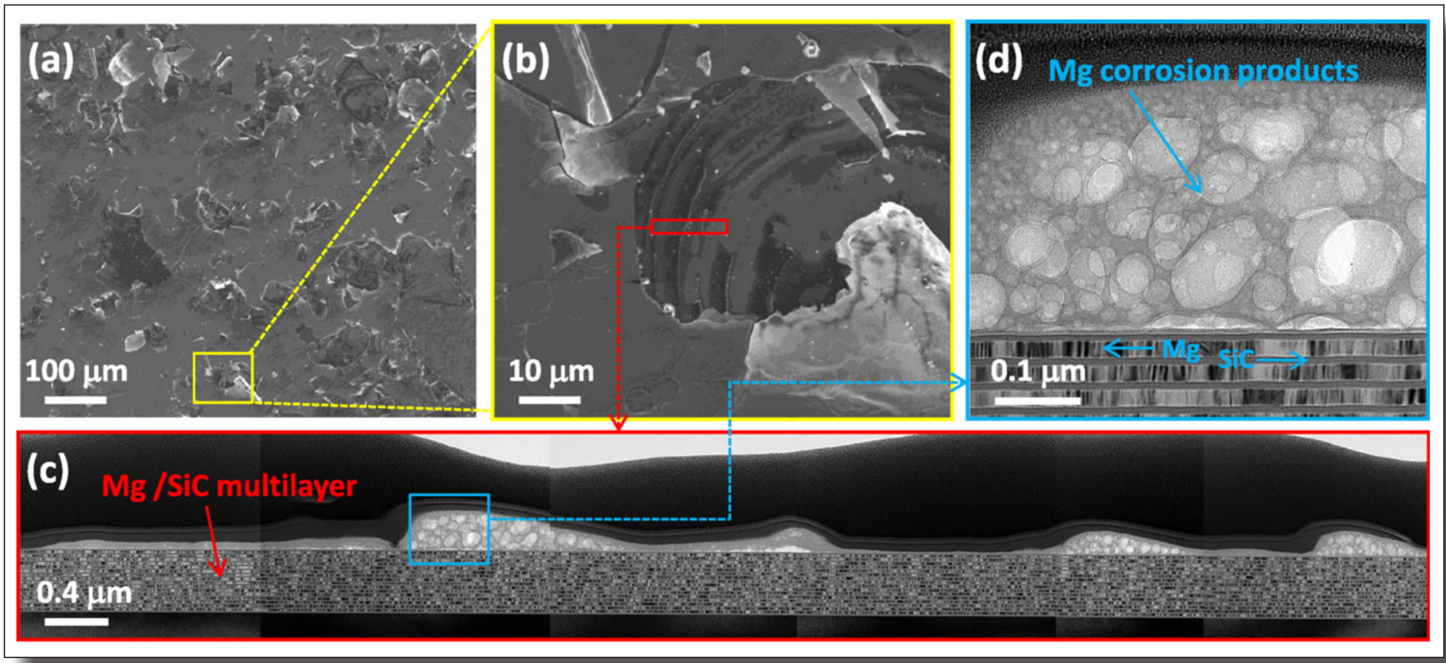
The California Energy Commission has awarded $1.7 million for a project between LLNL and Cool Earth Solar Inc. (**CES**) to demonstrate the community-scale integration of renewable energy. The project, to be conducted at the Livermore Valley Open Campus, will demonstrate a model of how communities can generate solar energy and integrate it into their overall energy system as effectively as possible by, for instance, forecasting solar generation and using energy-management tools to adapt to those forecasts. Livermore-based CES will provide concentrating photovoltaic technology, while LLNL will contribute advanced solar forecasting technology and technology for building energy management, to improve efficiency and reduce peak load. Said LLNL lead Wayne Miller, "We are developing a dynamic cloud-tracking system based on high-resolution sky imagers from CES and public domain satellite data. We can see the clouds as they come at you and can predict their dynamic effect on solar [photovoltaic] power." The photo below shows a field deployment of an actual concentrating photovoltaic system.

PATENT FOR CORROSION-RESISTANT MULTILAYER MIRRORS

Regina Soufli, Monica Fernandez-Perea, and Jeff Robinson were granted a **U.S. patent** for a method for making corrosion-resistant magnesium–silicon carbide (Mg–SiC) multilayer mirrors for extreme ultraviolet applications. The patent describes an efficient and simple-to-implement corrosion barrier for Mg–SiC multilayers, consisting of nanometer-scale Mg and aluminum (Al) layers that intermix spontaneously to form a partially amorphous Al–Mg layer, which maintains the favorable Mg–SiC reflective properties with preventing atmospheric corrosion—an insidious problem that completely degrades reflectance properties and that has hampered use of such multilayers. This achievement, which was funded in part by Livermore's LDRD Program, was published **last year** in *Applied Physics Letters* and **this year** in *Optics Express*. The figure shows (a) a scanning electron micrograph of the surface of a Mg–Sic multilayer aged for 3 years, with a magnified view in (b), a transmission electron micrograph cross-section in (c), and a magnified view of said cross-section in (d).

RESEARCHER RECOGNIZED BY U.S.–EUROPEAN COLLABORATION IN RADIATION DETECTION

On May 31, Samuele Sangiorgio was recognized by the European Union's (EU's) Joint Research Centre Nuclear Security Unit for his efforts on behalf of the Illicit Trafficking Radiological Assessment Program +10 (**ITRAP+10**)—specifically, for helping to strengthen international collaboration to improve standards for radiation detection equipment. Under ITRAP+10, a broad range of radiation detectors, ranging from commercial detectors and small pager systems worn by response personnel to large vehicle portal monitors, are being tested against the standards of the American National Standards Institute and the International Electrotechnical Commission. The large volume of data generated must be quickly analyzed, assessed against standards, and documented for vendor and government reviews. Samuele has provided fast analyses and technical documentation for U.S. effort and assisted the EU with their analysis and reporting. At an EU test site, he worked with test personnel there to provide high-quality data analysis, scripts for additional analyses, and written reports.

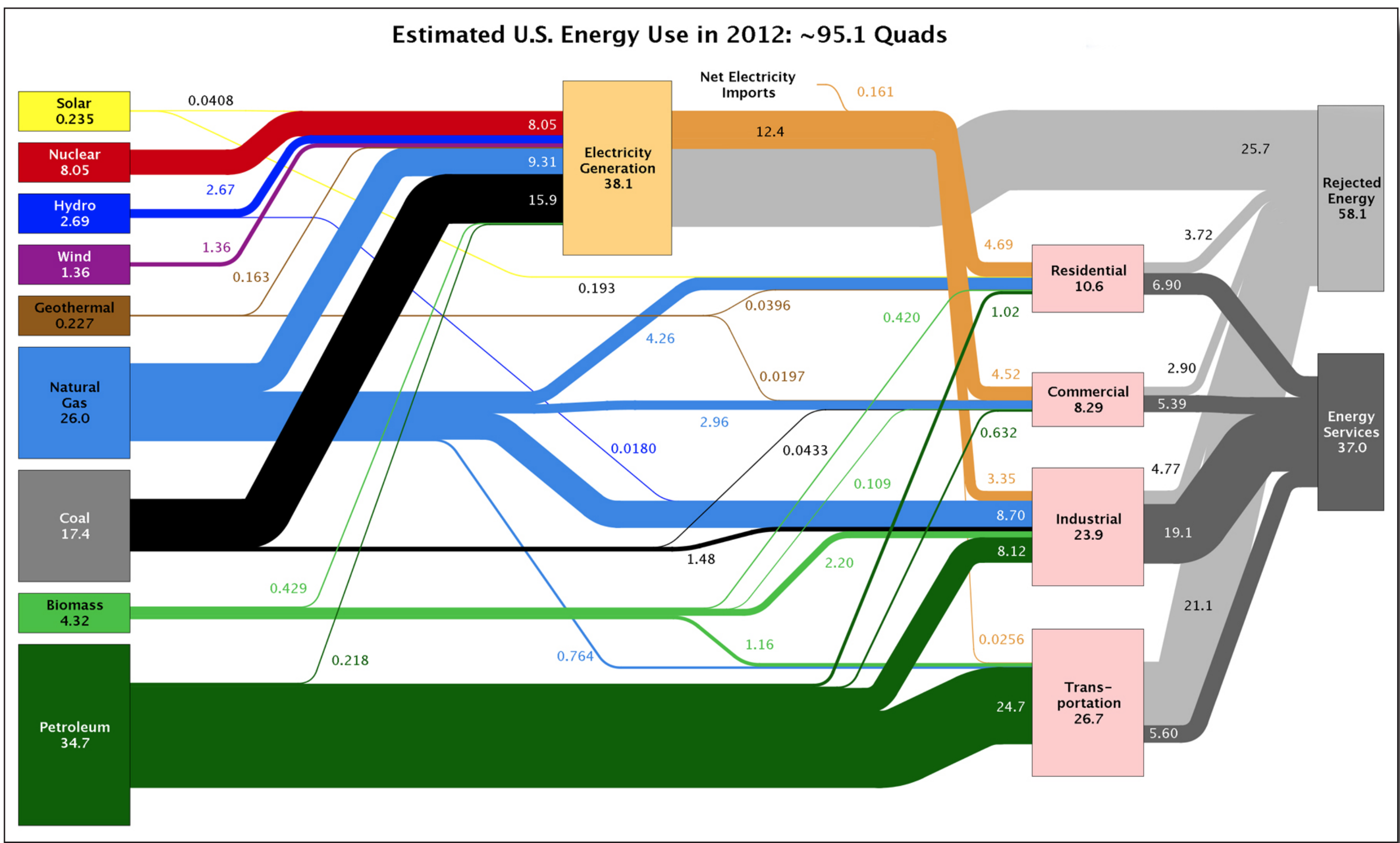


TRIO PARTICIPATES IN TEST BAN TREATY EXERCISE

As part of the Laboratory's ongoing support for the Comprehensive Test Ban Treaty Organization (CTBTO), a three-person team participated in Build-Up Exercise III from May 27 to June 7, 2013, in Hungary. Walter Dekin, Don Felske, and Sean Ford—three of the five U.S. inspectors selected by the CTBTO—underwent training in the five principal methods used for inspecting sites: visual observation, continuation phase techniques, geophysics, radionuclide detection, and seismic monitoring. The three were among the approximately 150 personnel from 40 countries who participated in the exercise, the latest in a series intended to prepare for the CTBTO On-Site Inspection Division's Integrated Field Exercise to be conducted in Jordan during November and December 2014. "The purpose," said Don, "was the practical application of select on-site inspection techniques." Stressing the importance to the nation and the global community of building an infrastructure for the CTBTO, Walter added, "We wouldn't be here if it wasn't in the national interest to do so."

LATEST ENERGY FLOWCHART TRACKS RISE OF RENEWABLES

Americans in 2012 used more energy from natural gas, solar panels, and wind turbines and less energy from coal, according to the Laboratory's most recent **U.S. energy charts**. The widely referenced charts are produced by Livermore's work in **energy informatics**. As overall energy use declined from 97.3 to 95.1 quadrillion BTUs (quads) in 2012, use of renewable forms of energy actually increased. In addition, coal and oil use dropped in 2012 while natural gas use rose, particularly in the electricity generation sector, where it has basically substituted directly for coal, according to LLNL energy systems analyst A. J. Simon, who creates the flowcharts.



APPOINTEE TO NEW EPA PANEL ON FRACKING

Livermore's Steve Bohlen has been appointed to serve on the Environmental Protection Agency's (EPA's) Hydraulic Fracturing Research Advisory Panel, **an independent group of academics and experts** formed to review a Congressionally ordered report on the potential health impacts of hydraulic fracturing ("fracking") on drinking water. Steve's appointment stems from his work over the preceding 16 months to develop a shale gas program at the Laboratory in which advanced technologies developed for other purposes are integrated into standard industry practice through industrial partnerships. "This work has given me a fair amount of visibility in the shale gas arena and insights into advanced technologies that are of interest to companies and have the potential to reduce the environmental footprint of unconventional oil and gas development and production," Steve said. Three years ago, following a request from Congress, the EPA had announced plans to study the impacts of fracking, and the new advisory panel will provide scientific feedback on the draft report, which is due to be released next year.

SCIENTISTS WORK WITH NAVAJO NATION TO PROTECT WATER FROM URANIUM

A team of Laboratory scientists visited Shiprock, NM, in April to help install equipment to help determine whether groundwater is reaching contaminated soil in a uranium mine waste disposal cell. The Lab team was comprised of radiochemists Brad Esser and Theresa Kayzar along with contaminant hydrogeologists Victor Madrid and Michael Taffet. A partnership between LLNL and the Navajo Nation will develop an environmental and hydrological monitoring program for the disposal cell and other sites in northeast Arizona and northwestern New Mexico. Livermore's contributions include providing a soil moisture monitoring system to evaluate waste cell design and developing plans for collecting and analyzing soil, air, and water samples. The photo shows, from left, Brad Esser (LLNL), Gilbert Dayzie, Vic Madrid (LLNL), Michael Taffet (LLNL), Theresa Kayzar (LLNL), and Melvin Yazzie observing a meteorological monitoring system to be installed on a waste cell at the Navajo Nation.

NEW MINERAL NAMED IN HONOR OF LLNL RESEARCHER

A new garnet mineral ($Ca_3Ti_2SiAl_2O_{12}$) recently discovered in a refractory inclusion in the **Allende meteorite** has been named "hutcheonite" in honor of the Lab's Ian Hutcheon, who has made numerous contributions to the study of meteorites and what they can tell us about the evolution of the early solar system. The name was chosen by the mineral's discoverers, Sasha Krot (University of Hawaii) and Chi Ma (Caltech). Both the structure and name of the mineral were recently officially approved by the International Mineralogical Association. The discovery was formally announced at the 76th Annual Meeting of the Meteoritical Society, **which was held** in Edmonton, Canada, July 29–August 2, 2013.

FIRST EXPERIMENTAL DEMONSTRATION OF MULTILAYER REFLECTIVITY ABOVE 500 KEV

In an experiment conducted at the European Synchrotron Radiation Facility (ESRF) in late April, an LLNL team including Marie-Anne Descalle and Regina Soufli have demonstrated, for the first time, that 511-keV and 640-keV x-rays can be reflected by multilayer mirrors. Preliminary analysis indicates good agreement between the data and model predictions. This breakthrough confirms our ability to robustly detect several isotopic decay lines important for nuclear security and paves the way for new astrophysicsal missions such as imaging the electron–positron annihilation emission line in our galaxy. The multilayer mirrors for this experiment were designed and fabricated at LLNL by the research team. The reflectance measurements at ESRF were led by LLNL and involved collaborators from ESRF and the National Space Institute of the Technical University of Denmark. This work was supported by Livermore's LDRD Program.

DNDO RECOGNIZES TWO FOR ASSISTANCE WITH RAD DETECTION EFFORTS

On May 15, the acting director of the Domestic Nuclear Detection Office (DNDO), Dr. Huban Gowadia, recognized LLNL's Brooke Buddemeier and Annmarie Wood-Zika with certificates of appreciation for their efforts in assisting the State of Maryland's Preventive Radiological and Nuclear Detection Program. Over the preceding 8 months, Brooke and Annmarie worked with DNDO to develop its largest, most comprehensive, and highest visibility program-assistance effort to date, with the Laboratory leading efforts to rapidly engage and integrate all key stakeholder agencies, develop major documents, facilitate meetings and workshops, and provide subject-matter expertise. The achievements of this program-assistance effort may ultimately be formalized by the Maryland Governor's Office through an executive order.

CDC ACTS ON LLNL BLUE-RIBBON PANEL'S RECOMMENDATIONS

Two years ago, Tom Slezak co-chaired a blue ribbon panel on bioinformatics—the application of computer technology to the management of biological information—for the Centers for Disease Control and Prevention (CDC). The panel, after examining the state of bioinformatics at the CDC, urged massive changes. The CDC has since implemented several of the panel's recommendations, including establishing a small bioinformatics core activity that provides dedicated staff and computational resources to support 10 innovative public health projects annually. In FY14, a $40M effort in the President's budget request will begin to revolutionize how public health uses modern infectious disease diagnostic technologies. Said Tom, "It's truly gratifying to know that the time spent working with the CDC is leading to such a sweeping modernization of public health bioinformatics and diagnostics capabilities."

LIVERMORE HOSTS FUSION SYMPOSIUM

Livermore hosted **the 25th Symposium on Fusion Engineering** (SOFE), held in San Francisco June 11–14. The meeting was attended by over 300 scientists and engineers working on a wide range of topics related to fusion energy. SOFE, a biennial event organized and sponsored by the Fusion Technology Committee of the IEEE Nuclear and Plasma Sciences Society, covers engineering and scientific advances in both inertial confinement and magnetic confinement fusion, with attendees from major fusion energy research centers worldwide. Livermore's Wayne Meier served as general chair, while personnel from NIF and Physical and Life Sciences served as key members of the symposium's local organizing committee, providing administrative support at the meeting. Over 200 attendees took advantage of the opportunity to tour NIF. Feedback on both the meeting itself and the NIF tour was extremely positive.

LLNL HOSTS U.S.–ISRAELI MEETING ON COMBATING NUCLEAR AND RADIOLOGICAL TERRORISM

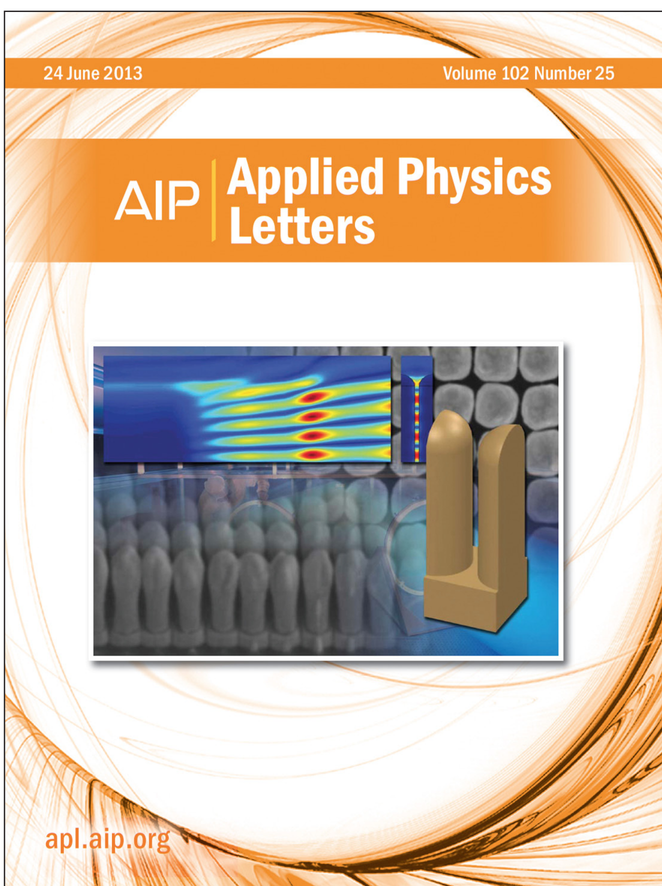
On July 16 and 17, Livermore's National Atmospheric Release Advisory Center hosted the 14th Bilateral Meeting of the Israel and U.S. Cooperating on Combating Nuclear and Radiological Terrorism. This joint meeting, held under the auspices of NNSA's Office of International Emergency Management and Cooperation (IEMC), provides a unique opportunity for the United States and Israel to exchange information on operational capabilities and technical methods for preparing and responding to an attack with a radiation dispersal device. The meeting was attended by representatives of Israel's Atomic Energy Commission, Ministry of Defense, Nuclear Research Center Negev, and Soreq Nuclear Research Center; IEMC Program Manager Vince McClellan; and representatives of Redwood Sciences Laboratory and Argonne, Idaho, Livermore, Oak Ridge, and Sandia National Laboratories.

RESEARCHER REAPPOINTED TO FUSION COMMITTEE

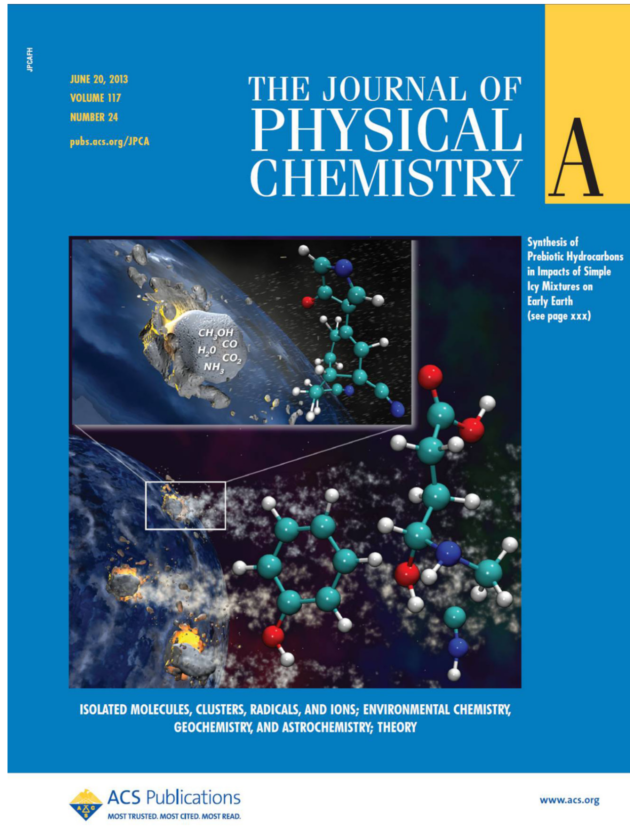
The Acting Director for the DOE Office of Science has requested that Bruce Cohen, LLNL's Associate Program Leader for Magnetic Fusion Theory and Computations, continue to serve as a member of DOE's Fusion Energy Sciences Advisory Committee. Consequently, Bruce's current appointment will be extended by 2 years, for a term ending June 2, 2015. The committee provides independent advice to the Director of the Office of Science on complex scientific and technological issues that arise in planning, implementing, and managing the Fusion Energy Sciences Program. The committee conducts its business in public meetings and submits reports containing its advice and recommendations to the Director of the Office of Science.

NEW PLASMONIC NANORESONATOR ON COVER OF *APL*

In a **paper featured on the cover** of *Applied Physics Letters*, an LLNL team including Mihail Bora and Elaine Behymer describe their creation and demonstration of a plasmonic resonant structure tunable from ultraviolet to near-infrared wavelengths and having a maximum absorbance strength greater than 95% thanks to highly efficient coupling with incident light. Additional harmonics are excited at higher frequencies, extending the absorbance range to multiple wavelengths. Their new concept—a plasmonic black metal nanoresonator—delivers its broadband absorbance characteristics through an increased resonator length, allowing modes to be spaced closer, and through adiabatic plasmonic nanofocusing at the tapered end of the cavity. The cover image shows scanning electron micrographs of the nanowires viewed from the side and top and (bottom right) an illustration of a unit cell of the rectangular array centered on the plasmon nanocavity.

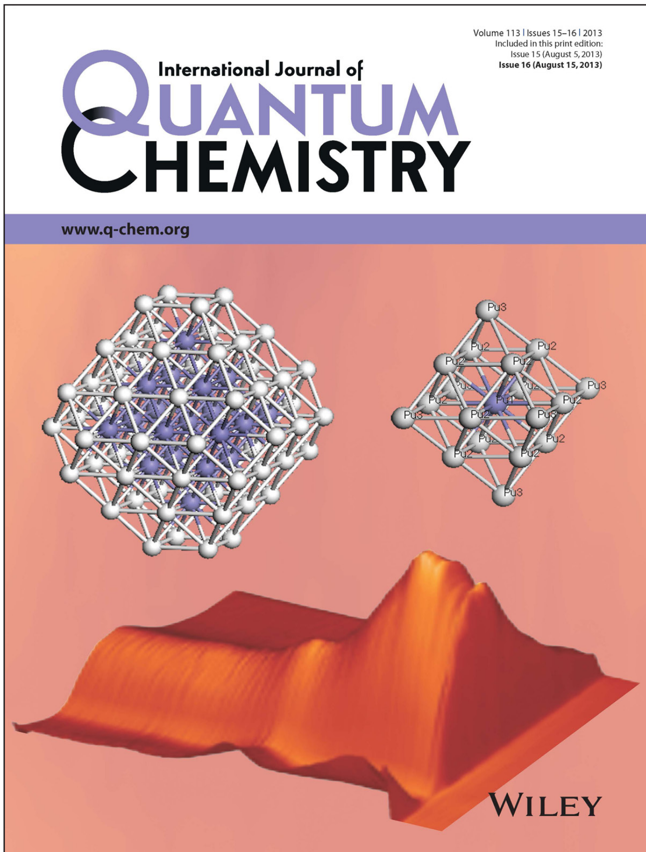


SIMULATIONS BOLSTER THEORY OF COMETARY DELIVERY OF PREBIOTIC COMPOUNDS



Research by Nir Goldman and former LLNL postdoc Isaac Tamblyn **on prebiotic chemistry occurring during shock loading** of a simple mixture of ices—as in the cometary delivery to Earth of the building blocks of life—was featured on the cover of the *Journal of Physical Chemistry*. This work's considerable press coverage includes **an article** by Livermore's David Bradley in *Chemistry Views*. The team's quantum molecular dynamics simulations of shocks in a CO_2-rich ice mixture produced significant quantities of simple carbon–nitrogen compounds, suggesting that cometary impacts could result in the synthesis of prebiotic molecules without the need for other "special" conditions, such as catalysts or ultraviolet radiation. Such knowledge about prebiotic mixtures under extreme thermodynamic conditions also clarifies the role of impact events in the formation of life-building compounds on other planets This research was funded by NASA's Astrobiology: Exobiology and Evolutionary Biology Program.

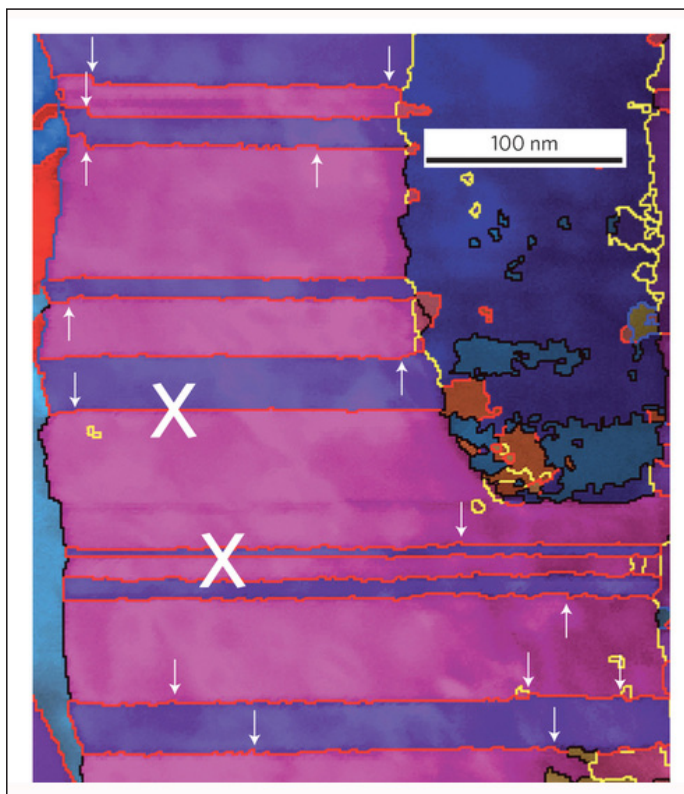
PLUTONIUM CALCULATION APPROACH VALIDATED



Progress in understanding the electronic structure of actinide-containing solids as a function of system size has been hampered by the highly radioactive, chemically toxic, and pyrolytic nature of these materials and by the theoretical difficulties associated with ab initio treatments of correlated electron systems in high-atomic-number elements. In a **paper** featured on the cover of the *International Journal of Quantum Chemistry*, LLNL researchers Sung-Woo Yu, Brandon Chung, and James Tobin, together with Russian colleagues, describe the results of applying to plutonium a new approach of calculating the electronic structure of atomic clusters. The researchers compare the theoretical results to available spectroscopic data, confirming the validity of their approach. In addition to the intrinsic scientific interest in how the electronic structure changes as a function of the number of atoms in the cluster, this work is also relevant to the transport of nuclear contaminants in environmental systems, which often occurs in colloids.

DEFECTS IN TWIN BOUNDARIES STRENGTHEN MATERIALS

Coherent twin boundaries (CTBs)—planar defects in crystals that separate domains of different crystallographic orientation—are known to play a significant role in determining the strength, ductility, and other properties of many materials. Using a combination of experiments and simulations, a team of Lab researchers led by Morris Wang have now shown that CTBs in nanotwinned copper are not, contrary to previous belief, perfect planar interfaces but instead are inherently defective—**a discovery reported in *Nature Materials***. The team has also shown that these defects play a crucial role in the deformation mechanisms and mechanical behavior of the nanotwinned copper. The figure is an edge-on high-resolution inverse pole figure orientation mapping image of CTBs in nanotwinned copper. Each "X" marks a perfect CTB without defects, while arrows indicate growth direction.

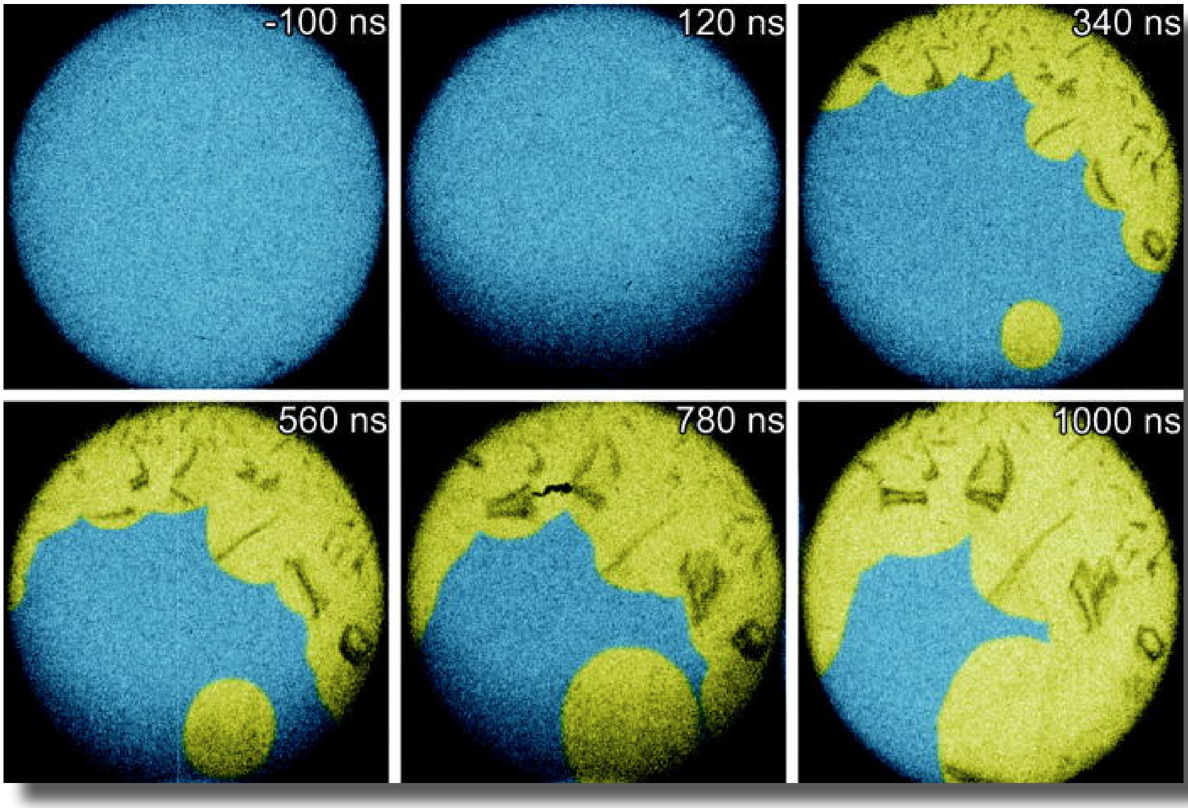


DTEM Captures Nanosecond Crystallization

Laboratory researchers have, for the first time, produced movies of reactions that occur too rapidly to capture with conventional electron microscopy. **Publishing** in *Applied Physics Letters*, Melissa Santala, her LLNL colleagues, and colleagues from IBM describe how they used the multiframe, nanosecond-scale imaging capabilities of LLNL's dynamic transmission electron microscope (DTEM)—which subsequently won an R&D 100 Award; see page 1)—to create movies of the crystallization of phase-change materials used in optical and resistive memory. (A phase-change material is a substance that can be switched between an amorphous and a crystalline state with rapid heating.) For these applications, laser- or current-induced crystallization happens orders of magnitude too quickly to visually capture with other microscopic imaging techniques. This work paves the way for studying crystallization kinetics of phase-change materials over the whole range of technologically relevant temperatures. The figure shows the amorphous germanium telluride (blue) crystallizing (yellow) in response to a series of 17.5-nanosecond electron pulses of a 4.7-microjoule laser shot.

Evidence of Brain's Neurogenesis into Adulthood

A **paper published** in *Cell* announces a surprising finding about the human brain—that a small area involved in memory makes new neurons well into adulthood. At LLNL's Center for Accelerator Mass Spectrometry, the team measured the age of neurons in mice and human hippocampus tissue by determining the prevalence in their DNA of carbon-14, which spiked during the Cold War era of nuclear bomb testing and which has been declining at a known rate since the ban on such testing. Based on this data, the researchers conclude that one-third of all human hippocampal neurons are subject to renewal, with 1.75% turning over each year. This implies that hippocampal neurogenesis may contribute to human brain function into adulthood and is also extensive enough to play a significant role in human behavior.



NIF EXPERIMENTS AND MODELS IN *PHYSICS OF PLASMAS*

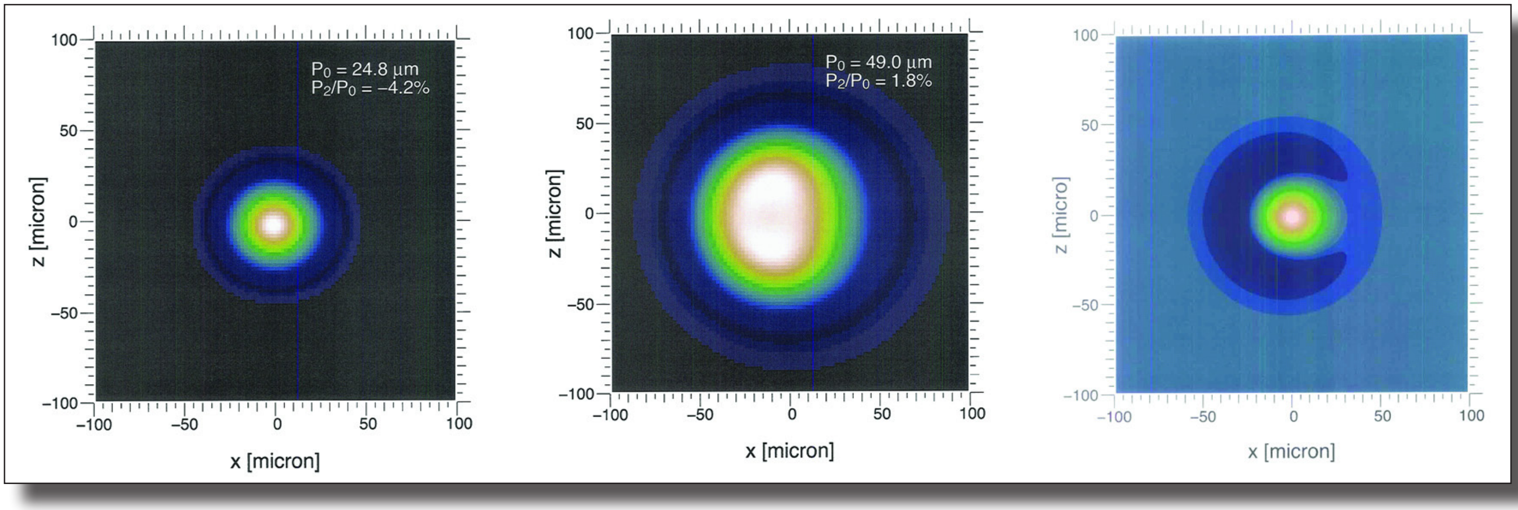
The May issue of *Physics of Plasmas* highlights recent NIF experiments and simulations. "The effect of laser pulse shape variations on the adiabat of NIF capsule implosions," by Harry Robey and colleagues, **describes** how variations in the shape of a NIF laser pulse affect the in-flight adiabat (internal compressibility) of fuel during implosion. Achieving ignition requires the assembly of a fuel layer with sufficient areal density to inertially confine the burning fuel long enough to sustain a self-propagating burn wave, and high areal density requires that the fuel remain highly compressible. Harry et al. compared the measured shot-to-shot variations in the fuel capsule's areal density from a large number of layered deuterium–tritium ignition target implosions on NIF spanning a 2-year period, discovering a strong sensitivity to variations in the initial low-power "foot" of the laser pulse.

A **second paper**—"Detailed implosion modeling of deuterium–tritium layered experiments on the National Ignition Facility," by Dan Clark and colleagues—discusses the use of post-shot simulations of some layered deuterium–tritium implosions to understand discrepancies in neutron yield and ion temperature between two-dimensional radiation-hydrodynamics simulations and experimental results.

Finally, Charles Cerjan and colleagues **report the development** of a conceptual model for the conditions of inertial confinement fusion implosions that integrates available diagnostic information to determine the stagnation properties of the interior capsule fill and surrounding shell. The researchers' analysis of NIF capsule performance suggests that poor kinetic energy coupling to the hot core because of non-spherical implosion may be the primary cause of the observed low thermonuclear burn yields compared to simulations. The figure below, from the third paper, shows, from left to right, two fit neutron images, in the energy ranges of 13–15 MeV and 6–12 MeV, and the overlaid image.

COLLECTIVE FUEL VELOCITIES IN DEUTERIUM–TRITIUM IMPLOSIONS

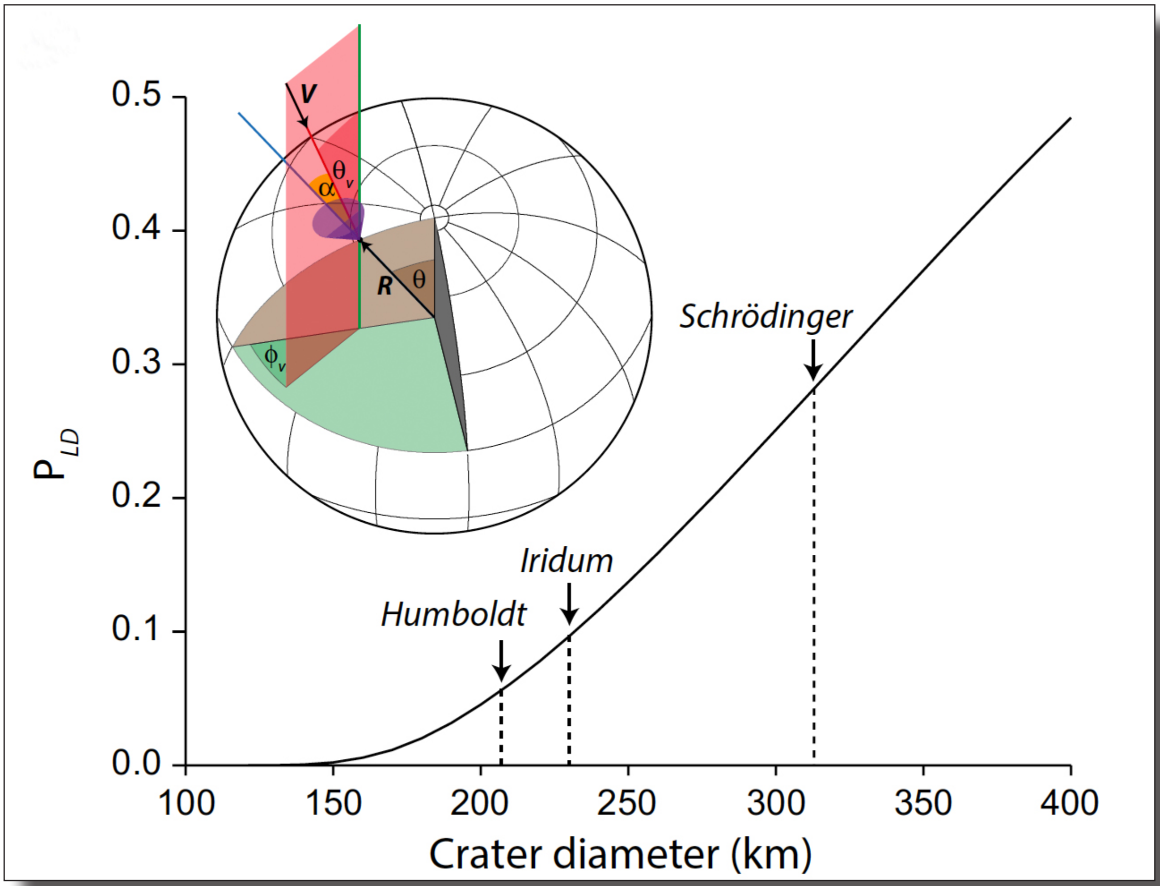
The first quantitative measurements of collective fuel velocities in NIF inertial confinement fusion implosions using the magnetic recoil neutron spectrometer were **reported** in a *Physics of Plasmas* paper by Maria Gatu Johnson of MIT and collaborators at LLNL and elsewhere. Ignition on NIF requires effective conversion of the laser energy to fuel shell kinetic energy and to hot-spot thermal energy. If the implosion is set into collective, directional motion known as "jets," the fuel shell kinetic energy corresponding to this motion is lost in the implosion process, resulting in less efficient conversion of kinetic energy to hot-spot thermal energy. The researchers said recent NIF experiments indicate the presence of systematic low-mode areal density asymmetries, most likely caused by drive asymmetry.



Integrated analysis of x-ray and neutron data from a large number of cryogenically layered deuterium–tritium implosions on NIF also has identified a deficit in achieved hot-spot internal energy of about three kilojoules, possibly connected to these drive asymmetries. The reason for this energy deficit is not clear at this point, the researchers said, but if the missing hot-spot energy instead took the form of kinetic energy manifested as collective fuel motion ("jets") along the hohlraum axis, a collective, directional velocity of about 190 kilometers per second is expected for these implosions.

RESEARCH UPDATES LIFESPAN—AND FORMATION MECHANISM—OF MOON'S ACTIVE CORE

Research published in the *Proceedings of the National Academy of Sciences* concludes that the moon's dynamo—a molten, convecting core of liquid metal that generated a strong magnetic field—lasted 160 million years longer than originally estimated, remaining continuously active until well after the final large impacts that pock its surface today. LLNL scientist William Cassata and an international group of collaborators base their conclusion of an analysis of two rocks gathered during the Apollo 11 mission, finding that the rocks had been magnetized in a stable and surprisingly intense magnetic field. "The important implication of this discovery," says William, "is that the moon possessed a magnetic field much later than would be expected for a body of its size." The team's data also point to a mechanism of dynamo formation in which the moon's magnetic-field-generating dynamo was generated by continuous stirring of the liquid metal core by the overlying rocky mantle due to Earth's gravitational pull—a finding that has implications for the magnetic fields of other planetary bodies. The figure graphs the probability of libration dynamo induction as a function of crater diameter, with the craters Humboldt, Iridum, and Schrödinger shown.

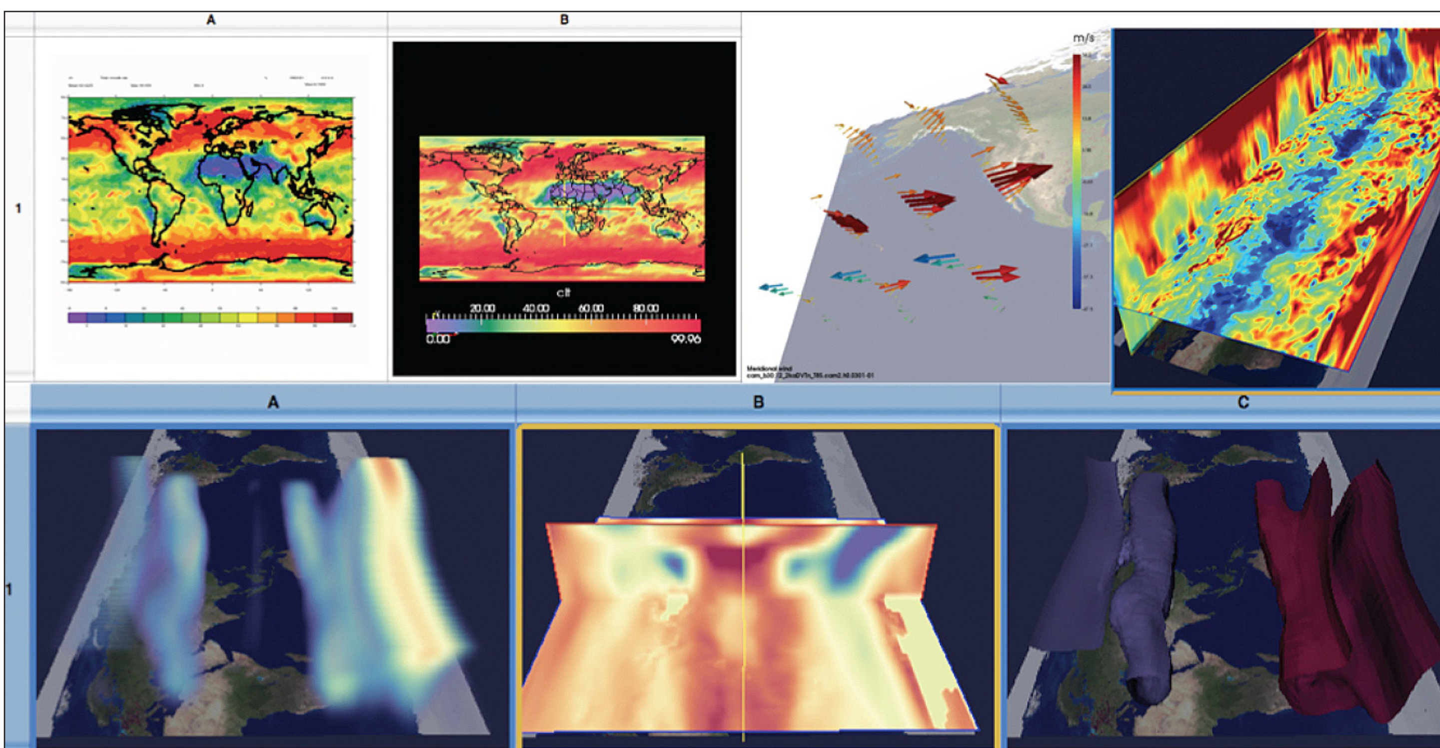


CLIMATE DATA ANALYSIS TOOL FEATURED IN *COMPUTER* ISSUE ON VISUALIZATION

LLNL computation scientists were major contributors to an **article** on LLNL's Ultrascale Visualization Climate Data Analysis Tools (**UV-CDAT**) in the May 2013 issue of *Computer*. This special issue of the IEEE publication was dedicated to cutting-edge research in visualization. UV-CDAT integrates a powerful set of scientific computing libraries and applications to foster more efficient knowledge discovery in support of interactive visualization and analysis of complex, large-scale climate datasets. Connected through a provenance framework, the UV-CDAT components can be loosely coupled for fast integration or tightly coupled for greater functionality and communication with other components. This framework addresses many challenges in the interactive visual analysis of distributed large-scale data for the climate community. The figure below is a collage showing how UV-CDAT supports many two- and three-dimensional visualization techniques.

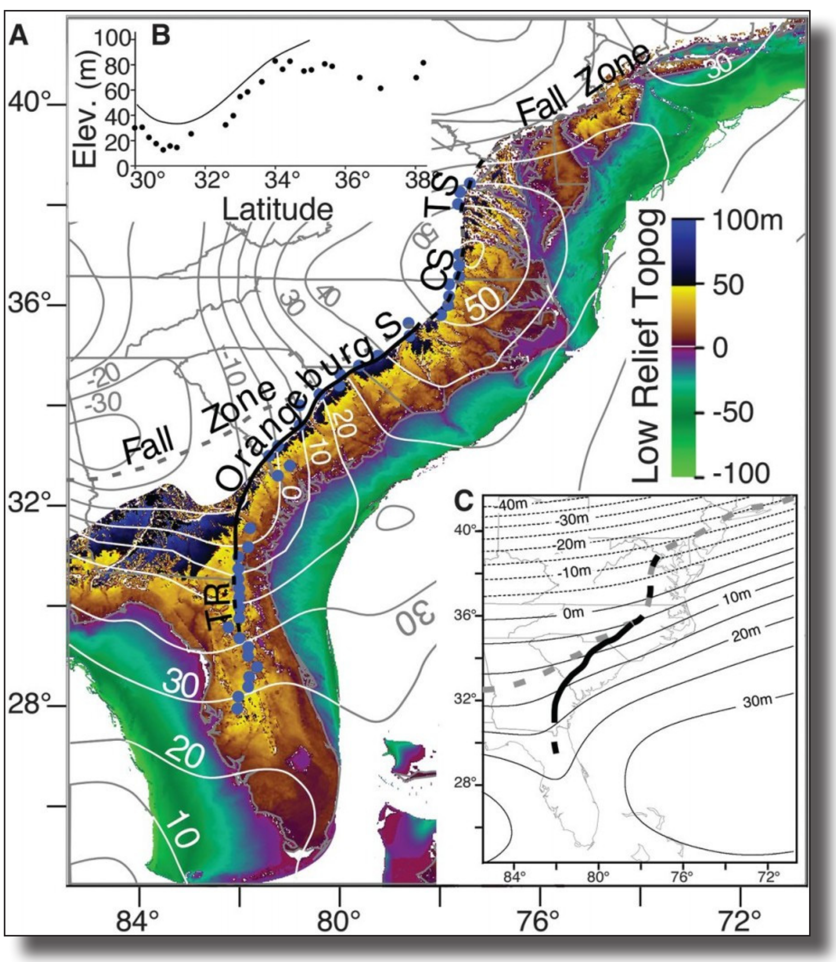
SEQUOIA SIMULATIONS SHOW HOW MATTER RESPONDS TO INTENSE X-RAY IRRADIATION

In a paper in *Physical Review E*, physicist Stefan Hau-Riege **reports new simulations**—some of which were the first science runs on Sequoia—of the electron–electron equilibration processes that take place after a solid is heated by short-pulses x-rays, such as those produced by the Linac Coherent Light Source. This hard x-ray free-electron laser (XFEL) can produce x-ray pulses as short as 10–40 fs in duration. When such short pulses impinge on matter, the electrons in that matter are driven far from equilibrium. Using the molecular dynamics code ddcMD, Stefan calculated the evolution of the electron system in solid-density matter irradiated by high-intensity x-ray pulses, showing that for pulses shorter than 40 fs, the kinetic energy distribution of the electrons is highly nonthermal during and right after the pulse. These nonequilibrium electron distributions cannot be adequately described by a single temperature, which has important implications for the behavior and description of XFEL-generated plasmas.



MANTLE CONVECTION FINDINGS: IMPLICATIONS FOR COASTAL EVOLUTION AND CLIMATE CHANGE

Nathan Simmons of LLNL and colleagues from American and Canadian universities modeled the active topography of the U.S. Atlantic coastal plain using mantle convection simulations that predict the amplitude and broad spatial distribution of this distortion, achieving results implying that dynamic topography and, to a lesser extent, glacial adjustment account for the current architecture of the coastal plain and nearby shelf. The **results were published** in *Science* and featured in *Science Express*. Says Nathan: "Our simulations of dynamic topography of the Eastern Seaboard have implications for inferences of global long-term sea-level change." In short, the new results provide another powerful piece of evidence that mantle flow is intimately involved in shaping the Earth's surface and must be considered when attempting to unravel numerous long-term Earth processes such as sea-level variations over millions of years. The figure shows present-day topography based on the **ETOPO1** global relief model, emphasizing the incised, low-relief, mid-Pliocene flooding surface and highlighting the Orangeburg, Chippenham (CS), and Thornburg (TS) wave-cut scarps.

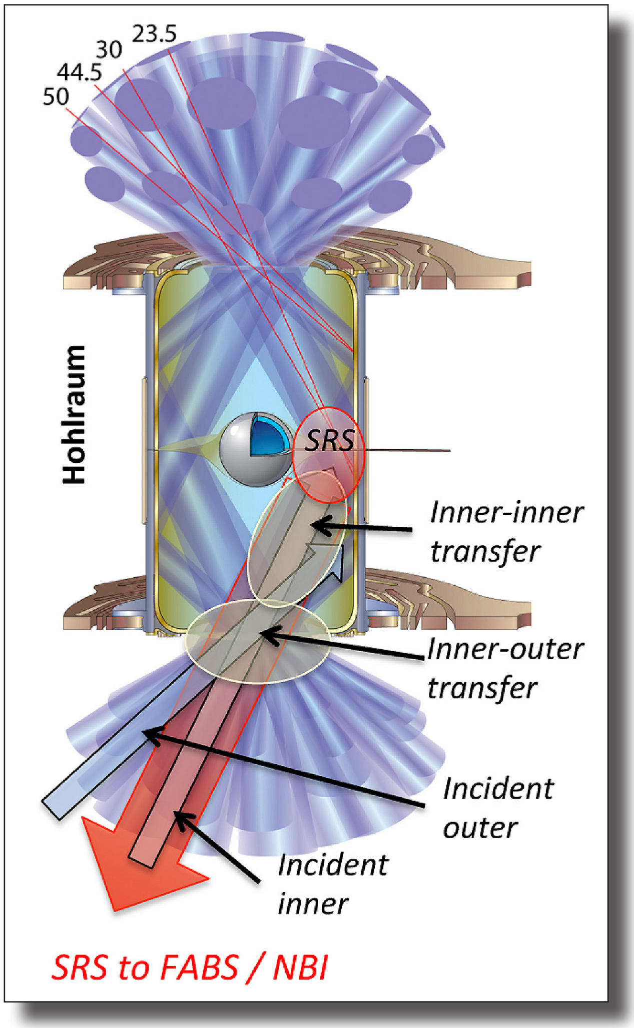


RADIATIVE SHOCKS FROM SPHERICAL CRYOGENIC NIF IMPLOSIONS

In a *Physics of Plasmas* paper, lead author Arthur Pak and his LLNL colleagues, along with collaborators around the world, **report on experiments** that created a spherically expanding radiative shock wave produced by a NIF inertial confinement fusion (ICF) experiment. The researchers said measurements of the temporal evolution of the expansion of the shock and luminosity from the shock-heated matter were in good agreement with radiation hydrodynamic simulations that used similar amounts of laser energy and were initialized to match the inferred stagnation pressure. "By modifying the [ICF] capsule composition and dimensions, as well as by changing the laser drive conditions," the researchers concluded, "the shock velocity and radiative properties could be tailored to study various regimes related to supernova remnants. In these experiments, the absolute luminosity of x-ray emission from the forward and reserve shock waves can be measured and used to test hypotheses to better understand the observed x-ray emission from supernovae." Arthur was joined by LLNL colleagues and collaborators from Oxford University in the United Kingdom, the MIT Plasma Science and Fusion Center, Los Alamos and Sandia National Laboratories, General Atomics, and France's Alternative Energies and Atomic Energy Commission.

REMOTE SENSOR TO MEASURE CROSSBEAM ENERGY TRANSFER

A new, nondisruptive technique for **measuring the amount of laser power transferred during crossbeam energy transfer** in NIF hohlraums was described in *Physical Review Letters* by lead author Ken Moody and team. Probe access holes sometimes cut into a hohlraum to observe the processes inside can alter the local plasma conditions and affect the measurements. To develop an nonintrusive alternative, the researchers employed stimulated Raman scattering as a remote sensor to quantify the instantaneous laser power after transfer from outer to inner cones that cross in a gas-filled hohlraum plasma. Using this remote sensor, the team conducted the first-ever nondisruptive measure of power transfer in an indirect-drive NIF experiment using optical measurements. The drawing depicts the hohlraum target used for the measurements, showing the different beam cones and the stimulated Raman scattering (SRS) backscatter. The power and spectrum of the SRS backscatter are measured with a time-resolved near backscatter imager (NBI) and a full-aperture backscatter system (FABS), respectively.



PHYSICS OF PLASMAS PAPER ON ION HEATING'S EFFECTS ON CROSSBEAM ENERGY TRANSFER

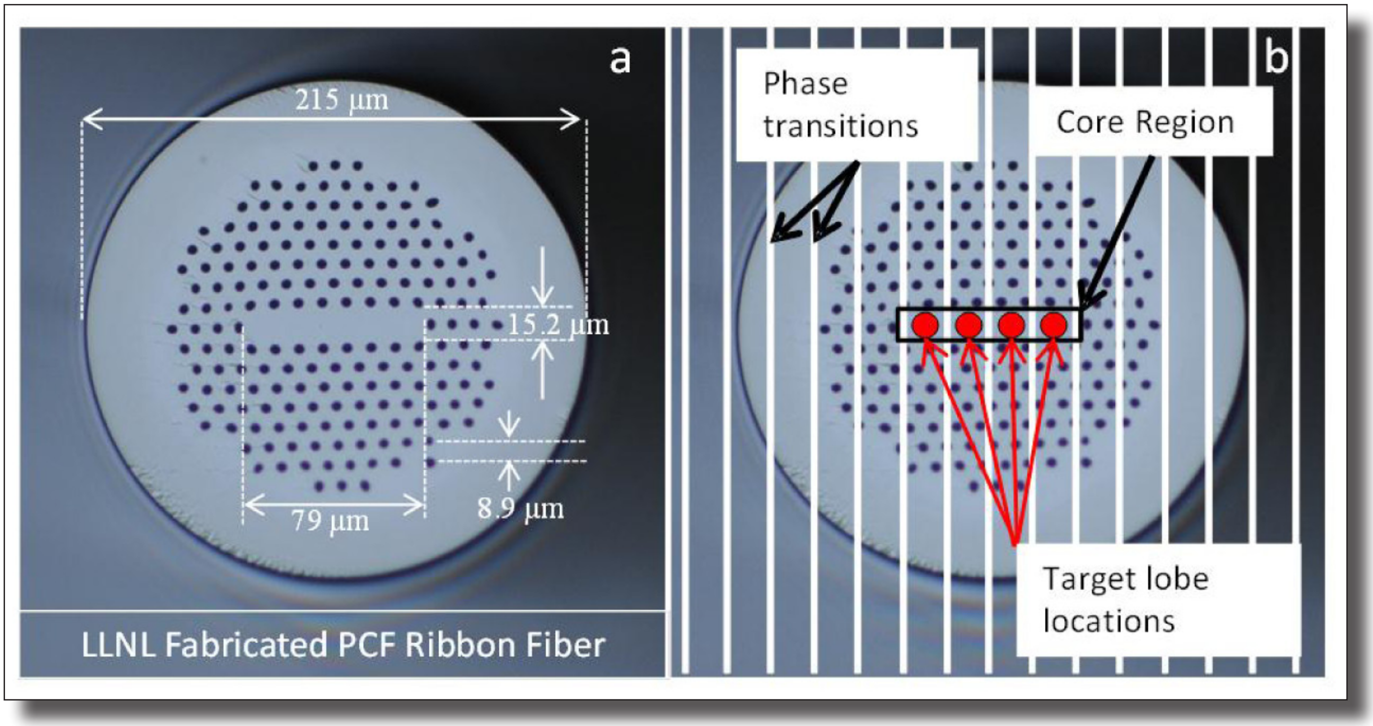
Crossbeam energy transfer (CBET) has been used as a tool on NIF since the first energetics experiments in 2009 to control energy deposition in ignition hohlraums and tune the implosion symmetry. As large amounts of power are transferred between laser beams at the laser entrance holes (LEH) of NIF hohlraums, the presence of many overlapping beat waves can lead to stochastic (random) ion heating in the regions where laser beams overlap, reducing the efficiency of CBET. **In a *Physics of Plasmas* paper**, LLNL researcher Pierre Michel and colleagues report that stochastic ion heating from many beat waves created by multiple crossing laser beams can be an efficient saturation mechanism for CBET. "Strong ion heating rates are expected in a cubic-millimeter-scale volume at the LEH of NIF hohlraums," the researchers reported. "The plasma flow should also be modified from momentum deposition: in the case of power transfer from 'outer' to 'inner' beams, as is currently the case for NIF experiments, the flow near the LEH should be accelerated; on the other hand, for experiments where power transfer would be required to occur in the opposite direction, i.e., from the outer beams to the inner beams, the flow would be decelerated near the LEH. A self-consistent hydrodynamics package including a ray-based CBET model together with the associated ion heating and momentum deposition is currently being tested in the HYDRA and LASNEX codes."

SELECTIVE MODE AMPLIFICATION IN RIBBON-CORE OPTICAL FIBERS

Ribbon fiber lasers—those with a rectangular cross section—and amplifiers show promise of sidestepping the power limits of their conventional circular-core counterparts. Because a ribbon core has a larger surface area than a circular one for the same enclosed volume, it radiates heat more efficiently. In an *Optics Express* **paper** lead authored by Reggie Drachenberg, LLNL researchers describe a novel method for scaling the power of single emitters beyond their current limits. Their technique excites a single high-order mode that, in a passive fiber, achieved 90 percent mode purity. Configured as an amplifier, an active fiber achieved 10.5 W of output power and more than 24 dB of gain. "Ribbon core fibers may ultimately provide the capability to produce laser amplifiers with 100 kW of diffraction-limited [ideal] output power by mitigating the nonlinear effects that currently limit circular core fibers," the researchers said. The figure shows (left) a photonic crystal ribbon fiber with a rectangular core cross-section and (right) an image of a ribbon fiber end face with overlaid illustrated binary phase plate transitions and target mode profile.

LATTICE CALCULATIONS SUGGEST DARK MATTER CANDIDATE

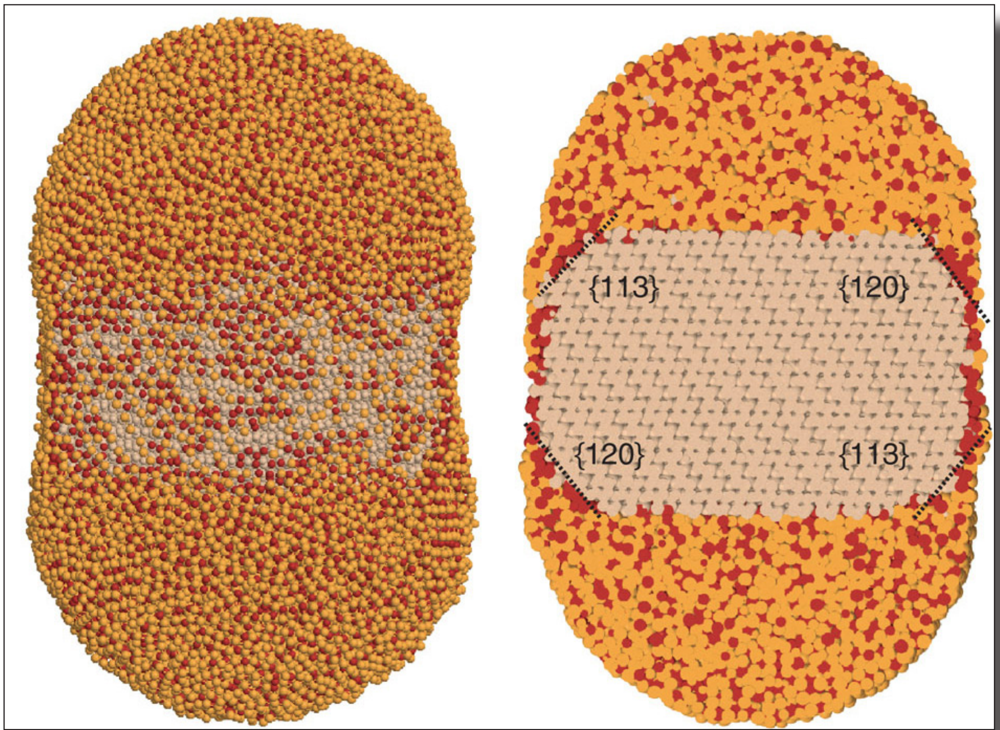
A **paper** in *Physical Review D* attempts to demystify one of the grandest mysteries in science today—dark matter. Although comprising over 80% of the entire mass of the Universe, dark matter is essentially invisible, not interacting directly with either the electromagnetic or the strong nuclear force. Although it does not reflect light and travels through ordinary matter with only the feeblest of interactions, dark matter does interact with gravity to produce striking effects on the movement of galaxies and galactic clusters, leaving little doubt of its existence. In the paper, members of the Lattice Strong Dynamics Collaboration—including LLNL researchers Michael Buchoff, Christopher Schroeder, Pavlos Vranas, and Joseph Wasem—examine the possibility that dark matter is a composite, made up of constituents strongly bound by an as-yet-unknown force of nature, much as the proton and neutron in nuclear physics are made of strongly bound quarks and gluons. The papers' authors used numerical (lattice) simulations run on LLNL's BlueGene/L supercomputer to study the feeble interaction of a particular type of theoretical dark matter with the electromag-



netic force. Based on that result, they then calculated the effect of such dark matter on the **XENON100 dark matter detector** operating in Gran Sasso, Italy. Because this detector has not yet observed any dark matter, such composite dark matter candidates must, they conclude, have masses greater than 10 TeV (10,000 times that of the proton). Work at Livermore was supported by the LDRD Program.

ATOMISTIC SIMULATIONS SHED LIGHT ON NANOWIRE GROWTH

Variations of the vapour–liquid–solid method are commonly used to make semiconducting nanowires, but the fundamental mechanisms involved in the growth process are poorly understood. In a **paper published** in *Nature Communications*, Luis Zepeda-Ruiz and George H. Gilmer (retired) report on atomistic molecular dynamics simulations that elucidate the mechanisms involved in the growth and stability of gold-catalyzed silicon nanowires. The study highlights the key interfacial characteristics relevant to controlling the morphology and composition of semiconducting nanowire arrays. The figure shows (left) the atomic configuration of a nanowire capped with droplets of gold–silicon catalyst particles and (right) a cross-section the droplet–nanowire system revealing the shape of the droplets and the faceted nature of the solid nanowire.



PRL PAPER IS ONE STEP FURTHER TO SOLVING XENON "PARADOX"

In *Physical Review Letters*, LLNL researcher Stanimir Bonev and colleagues from France and the U.K. describe their discovery, using **a combination of experiment and theory**, that xenon reacts with water to form the stable metallic compound $Xe_4O_{12}H_x$ at high temperatures (1,500 K) and pressures (> 50 GPa)—conditions present in the interiors of large planets such as Uranus and Neptune. These results predict that xenon should be depleted in the atmospheres of the giant planets as a result of sequestration at depth. It has long been recognized that Earth's atmosphere is depleted in xenon relative to the other noble gases, and that both Mars and Jupiter also similarly lack xenon in their atmospheres, the assumption being that the missing xenon is sequestered in some hidden reservoir in the planets' interiors. The results of Stanimir et al., although not explaining the terrestrial or Martian xenon deficiencies, may be applicable to Jupiter and the other giant planets and thus taking planetary scientists one step closer to solving the missing xenon paradox.

Deep Metagenomic Technique Described in *Bioinformatics*

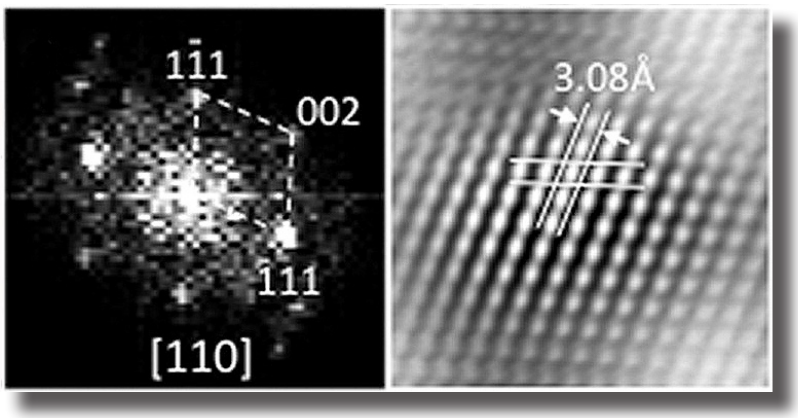
Jonathan Allen and Shea Gardner **published a paper** in *Bioinformatics* on an LLNL advancement in deep metagenomic sequencing, a technique with the potential to recover from biological samples otherwise difficult-to-detect microorganisms and to characterize biological samples accurately even when prior knowledge of the sample is limited. Existing algorithms for metagenomic taxonomic classification, however, do not scale well to analyze very large metagenomic datasets, presenting the fundamental challenge of balancing classification accuracy with computational efficiency. As Jonathan et al. describe, the **Livermore Metagenomic Analysis Toolkit** shifts computational costs to offline computation by creating a taxonomy–genome index that supports scalable metagenomic classification. They demonstrated scalable performance on real and simulated data to show accurate classification in the presence of novel organisms in samples including viruses, prokaryotes, fungi, and protists. Taxonomic classification of 150 billion base pairs of genomic data on the **Tyrolean Iceman** took less than 20 hours on a single-node, 40-core, large-memory machine and provided new insights on the metagenomic contents of the Iceman's genome. Work at LLNL received support from the LDRD Program.

PRL Paper Announces Highest Energy Results with Multilayer Mirrors

In the July 12 issue of *Physical Review Letters*, a team of LLNL researchers and colleagues from Oak Ridge National Laboratory, the European Synchrotron Radiation Facility, and the Danish Technical University **describe their groundbreaking experiments** that conclusively demonstrate that multilayer-coated grazing-incidence mirrors can work at up to 400 keV. The first paper to document the performance of a multilayer mirror at gamma-ray energies, these results push the operational range of multilayers from 180 keV into the soft gamma-ray band, opening the possibility of using gamma-ray multilayer mirrors for the nondestructive assay of spent nuclear fuel. This work, sponsored by the NNSA Nonproliferation R&D Program, was carried out under a joint project between co-principal investigators at Livermore (Michael Pivovaroff) and Oak Ridge (Klaus Ziock). Since the paper's publication, this LLNL team has already beaten the aforementioned results and shown that good reflectivity can be obtained from a multilayer at 640 keV. Those more recent results, obtained with LDRD support, have not yet been published.

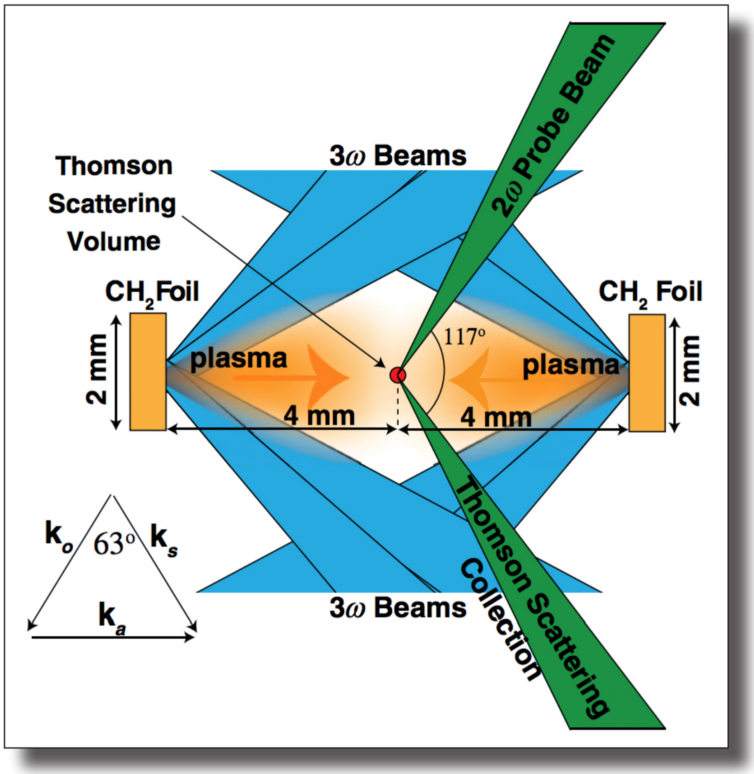
Plutonium Transport Properties Reviewed in Special Issue of *Inorganic Chemistry*

A special issue of *Inorganic Chemistry* on the inorganic chemistry of nuclear energy **contains a review paper** by Annie Kersting, director of Livermore's Glenn T. Seaborg Institute, that summarizes our current understanding of the conditions and processes that control the chemical and transport behavior of plutonium in the environment, identifies important gaps in our knowledge, and recommends high-priority areas for future research. The figure is (left) a fast Fourier transform of a plutonium nanocolloid, showing the PuO_2 face-centered-cubic structure, and (right) a filtered high-resolution transmission electron microscopy image of a plutonium colloid, showing the lattice of the nanocolloids.



COLLISIONLESS COUPLING OF ION AND ELECTRON TEMPERATURES

High-energy particle generation and acceleration at the front of a collisionless shock following a supernova explosion is a possible source of cosmic rays, and astrophysics experiments present a unique opportunity to directly measure these phenomena. In experiments at the OMEGA Laser Facility, LLNL researchers have discovered a novel mechanism that causes rapid electron and ion heating in high-velocity, collisionless counter-streaming plasma flows. In a *Physical Review Letters* paper, lead author Steven Ross, principal investigator Hye-Sook Park, and their colleagues said **significant increases in electron and ion temperatures were observed** using Thomson scattering in the counter-streaming plasmas as compared to a single plasma stream. They attributed the heating to a combination of collisional electron heating via electron–ion drag and collisionless ion heating via an ion two-stream instability, and report that only particle-in-cell simulations including both collisional and collisionless effects accurately reproduce the measured heating. This work was supported in part by the LDRD Program. The figure shows the experimental setup at OMEGA: two methylene (CH_2) foils were irradiated with ten 3ω (ultraviolet) laser beams using one-nanosecond square pulses. A 2ω (green light) probe beam was focused at the target chamber center. Thomson scattered light was collected 117 degrees relative to the probe.



X-RAY SCATTERING MEASUREMENTS IN *PRL*

Warm dense matter (WDM), a complex state of matter that occurs during inertial confinement fusion (ICF) experiments, is characterized by temperatures usually associated with plasmas but at densities similar to solids. In addition to shedding light on the implosion phase of ICF experiments, the study of WDM also represents laboratory analogues of astrophysical environments found in the interior of planets and the crusts of old stars. In a *Physical Review Letters* paper, LLNL researchers and colleagues in the U.S. and the U.K. **report the first observations** of the strong ion–ion correlation peak characteristic of WDM. Experiments at the OMEGA Laser Facility demonstrated the ability of simultaneous angularly, temporally, and spectrally resolved x-ray Thomson scattering in laser-driven shock-compressed aluminum to resolve the ion–ion correlation in WDM and obtain an accurate measurement of compression. They said the results show that theoretical models for the ion structure must take the complex interactions in WDM into account in order to agree with the data. The results also demonstrate a new accurate diagnostic to measure the state of compression of WDM. LLNL researchers Tammy Ma, Tilo Döppner, Otto Landen, Arthur Pak, and Siegfried Glenzer were joined on the paper by collaborators from UC Berkeley, UCLA, the Stanford Linear Accelerator Center, and the U.K.'s Centre for Fusion, Space, and Astrophysics.

IMPLOSIONS AT IGNITION-RELEVANT VELOCITIES DESCRIBED IN *PHYSICS OF PLASMAS*

To achieve hot-spot temperature high enough to initiate ignition on NIF, the imploding deuterium–tritium fuel must reach a velocity of about 350 km/s. During the implosion's acceleration phase, the ablation front of the imploding capsule shell is susceptible to Rayleigh-Taylor hydrodynamic instability, which can interfere with ignition if it reaches the hot spot. Simulations indicate that at least 0.25 micrograms of capsule ablator material must remain between the fuel layer and the ablation front to separate the hot spot from Rayleigh-Taylor instability growth. Increasing the capsule ablator mass to achieve that level of remaining material, however, increases the laser energy and power needed to drive the fuel pusher to the required velocity. In a *Physics of Plasmas* paper, LLNL researchers and collaborators **report the results of recent "convergent ablator"** and symmetry capsule (symcap) experiments testing the use of a capsule 20 micrometers thicker than the nominal 195-micrometer-thick ignition capsule. When driven by a 520-terawatt, 1.86-megajoule laser pulse, the thicker capsule "appears to have achieved an implosion trajectory equivalent to the ignition [mass and velocity] goal," the researchers reported. The equivalent of fuel velocity greater than or equal to 350 km/s "has been demonstrated with high confidence," they said. Lead author Nathan Meezan was joined on the paper by LLNL colleagues and collaborators from Sandia and Los Alamos National Laboratories, the Atomic Weapons Establishment in the United Kingdom, and General Atomics in San Diego.

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