Lawrence Livermore National Laboratory

Science & Technology REVIEW

September 2011

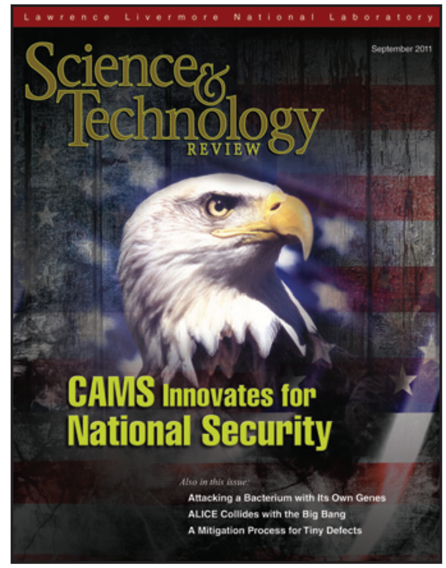
CAMS Innovates for National Security

Also in this issue:

- Attacking a Bacterium with Its Own Genes
- ALICE Collides with the Big Bang
- A Mitigation Process for Tiny Defects

About the Cover

At the Center for Accelerator Mass Spectrometry (CAMS), Livermore researchers can measure extremely low levels of various isotopes to determine with great accuracy the ages of trees, ice, corals, archaeological samples, and human tissues. Less well known is research at CAMS in support of national security. The article beginning on p. 4 describes some of these mission-related efforts, many of which are using the center's new ion beamline. On the cover is a bald eagle (*Haliaeetus leucocephalus*), a North American bird of prey and the national bird and symbol of the U.S.



Cover design: George A. Kitrinos

About *S&TR*

At Lawrence Livermore National Laboratory, we focus on science and technology research to ensure our nation's security. We also apply that expertise to solve other important national problems in energy, bioscience, and the environment. *Science & Technology Review* is published eight times a year to communicate, to a broad audience, the Laboratory's scientific and technological accomplishments in fulfilling its primary missions. The publication's goal is to help readers understand these accomplishments and appreciate their value to the individual citizen, the nation, and the world.

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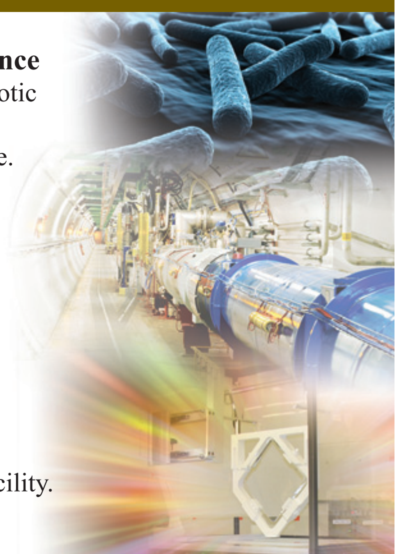

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Two Laboratory Teams Capture R&D 100 Awards

Two technologies developed by Livermore researchers and their collaborators received R&D 100 awards for technologically significant products introduced to the marketplace. *R&D Magazine* presents these awards to the top 100 industrial, high-technology inventions submitted to the magazine's annual competition.

One of the winning technologies is a light deflector called SLIDER (serrated light illumination for deflection-encoded recording). The SLIDER system uses a novel technique to sweep a beam of light at a rate of one resolvable spot per trillionth of a second—faster than ever before. A high-fidelity camera then records the time history of an ultrashort signal with a dynamic range spanning 3,000 levels. This high resolution will allow researchers to examine details of the burning plasma inside a fusion target at the National Ignition Facility.

The Laboratory's second award winner is the stack trace analysis tool (STAT), which is designed to debug computer codes running on systems with 100,000 processor cores or more. Developed in collaboration with researchers from the University of Wisconsin at Madison and the University of New Mexico, STAT detects and groups similar processes at suspicious points in a program's execution. A graphical user interface automatically analyzes the state of the application and pinpoints potential error locations. With STAT, users can focus on a small number of representative processes, quickly identify where in an application an error occurs, and resolve coding problems promptly.

Since 1978, the Laboratory has captured 137 R&D 100 awards. The October/November issue of *S&TR* will highlight these award-winning inventions and the researchers who developed them.

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Sulfur Compound May Affect Earth's Heat Balance

Computer modeling work by Livermore researcher Philip Cameron-Smith and colleagues from Los Alamos and Oak Ridge national laboratories and the New Mexico Institute of Mining and Technology indicate that dimethyl sulfide (DMS) could be more sensitive to global climate change than previously predicted. The team's simulations showed that if fossil-fuel consumption continues at the current pace, the organic compound will increase substantially in the Southern Ocean and decrease in other areas, significantly affecting Earth's heat balance.

Produced by marine plankton, DMS is the largest source of natural sulfur emissions. It also is a major precursor for aerosols and cloud condensation in the marine boundary layer over much of the remote ocean. Once DMS reaches the atmosphere, it is converted into sulfate aerosols, which reflect sunlight and can stimulate cloud formation.

To determine how atmospheric concentrations of carbon dioxide affect DMS in the Southern Hemisphere, the research team ran simulations using a global ocean biogeochemical model. In this study, they compared today's carbon dioxide concentrations of about 355 parts per million with a projected future scenario of about 970 parts per million. The simulations showed that changes in temperature, mixing, nutrients, and light reduced the amount of sea ice and shifted the composition of the ocean ecosystem, which in turn increased DMS levels. As a result, the average DMS emission predicted for the future is 150 percent greater than current levels above the Southern Ocean.

"The melting of the southern sea ice opens up a lot of cold open water in which the DMS-producing plankton thrive," says Cameron-Smith. He adds that because of these findings, future studies may need to consider whether ocean acidification could affect the plankton community and therefore DMS production. The team's results appeared in the April 16, 2011, issue of *Geophysical Research Letters.*

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Searching for Planets Out of This World

Livermore astrophysicist Bruce Macintosh and an international science team have won an 890-hour observing campaign to use the Gemini Planet Imager (GPI) to detect extrasolar planets, or exoplanets. GPI is the next-generation adaptive-optics instrument being built for the 8.1-meter-diameter Gemini telescope, which is located near the summit of Cerro Pachon in central Chile at an altitude of 2,722 meters.

Research teams worldwide have discovered more than 500 exoplanets, primarily by using indirect Doppler techniques that indicate a planet's mass and orbit. GPI is designed to directly detect the light from extrasolar planets orbiting nearby stars, allowing researchers to distinguish a planet from its star's glare. Scientists can also use the GPI data to measure a planet's size, temperature, and gravity and determine the composition of its atmosphere.

Macintosh's team will use GPI to conduct the first-ever robust census of giant planets that are between 5 and 50 astronomical units from their parent stars, or up to 50 times the distance Earth is from the Sun. "We hope to discover about 50 exoplanets, increasing the number of exoplanet images by an order of magnitude," says Macintosh. "By targeting many stars, we will be able to understand how common or unusual our own planetary system may be."

The 890 hours of viewing time is the largest amount allocated to one group at Gemini. It will represent about 10 percent of the telescope time for three years.

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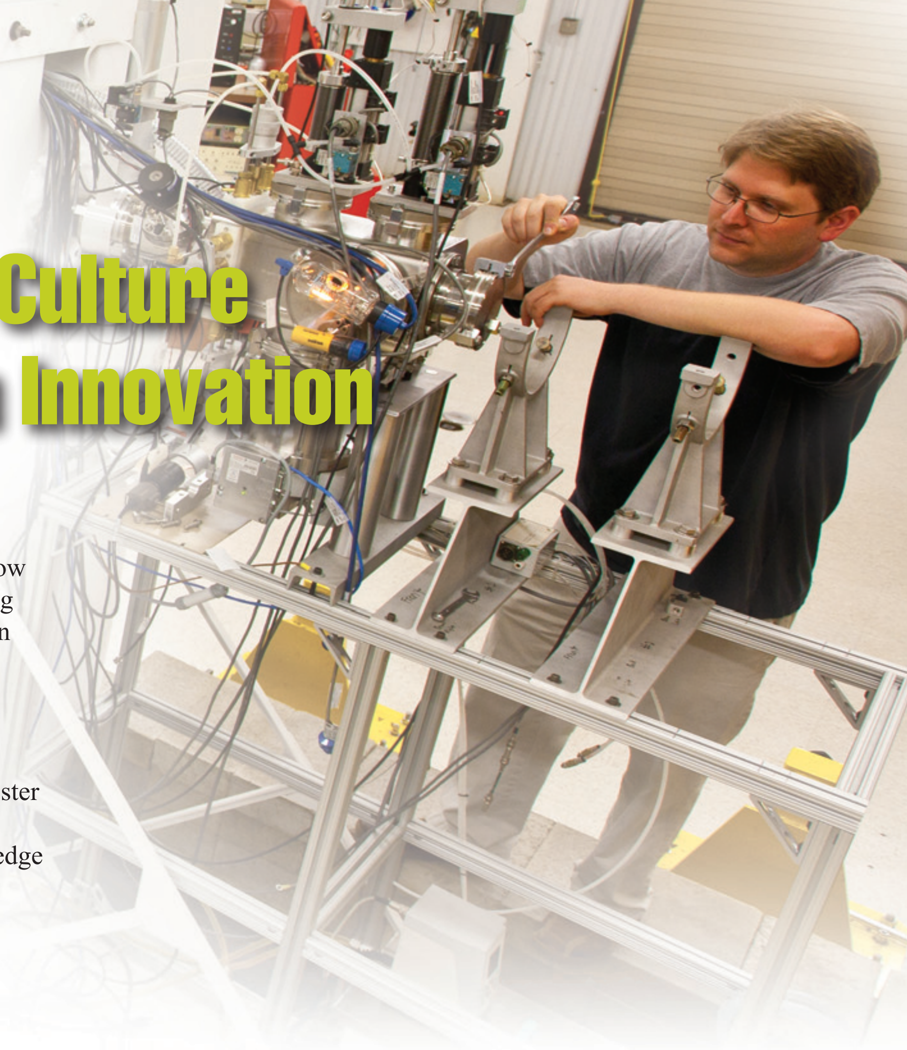
Commentary by William H. Goldstein

Fostering a Culture of Research Innovation



THE charge to keep the nation strong and its people safe from harm poses enormous science and technology challenges. How can we detect the presence of plutonium when someone is trying to hide it? How can we find the cause of the next epidemic of an unknown respiratory disease, and quickly develop a treatment that's safe and effective? How will we know when an aging nuclear stockpile is too old?

The solutions to problems such as these lie beyond what we know today. That is why it is so critical for the Laboratory to foster and incorporate innovation into its national security programs. Innovation—new knowledge and new ways of applying knowledge that address outstanding needs—is the only path to solving the hard problems we face.

Lawrence Livermore fosters innovation in many ways. The Laboratory Directed Research and Development Program and other internal investment mechanisms provide scientists and engineers with resources to pursue the frontier research and development that generates innovation. Collaborations with the academic and business sectors give them access to innovative ideas from across the science and technology world. Recruitment is another means of priming the Laboratory's innovation engine. By seeking out talented young scientists and engineers, we create a staff with the intellectual curiosity and capacity to push beyond the limitations of today's technology.

New challenges facing the nation in the 21st century are long-term and difficult. They call for innovative thinking and, in many cases, bold solutions at a time when funded programs are increasingly averse to technical risk and targeted at short-term milestones. These conflicting factors make it all the more important for Laboratory managers to encourage a culture of innovation and bold thinking, keeping in mind both identifiable and emerging national needs. Innovation is linked to exploration, and exploration entails blind alleys, frequent improvisation, and a certain luxury of time.

This issue of *S&TR* presents studies in innovation and the application of innovative ideas to the Laboratory's missions. The Center for Accelerator Mass Spectrometry (CAMS) implemented an innovation that grew out of the earliest research using accelerators to study the basic constituents of matter, a field pioneered at the University of California (UC) at Berkeley. In 1987, soon after researchers recognized that accelerator mass spectrometry could be used to detect individual nuclei of specific isotopes, Lawrence Livermore, in collaboration with UC Berkeley and Sandia National Laboratories at Livermore, began construction of CAMS.

Continued innovation since then in areas such as sample preparation, detection methods, and signature development by the experts has ensured that CAMS and Lawrence Livermore remain at the forefront in scientific fields ranging from geophysics to pharmacology. At the same time, the talented staff at CAMS has continually contributed to the Laboratory's national security missions, as described in the article beginning on p. 4. Today, as the facility nears its silver anniversary, researchers there are breaking new ground in drug development, carbon management, and nuclear counterterrorism.

The research highlights in this issue describe other creative developments by Livermore scientists and engineers in their work on a new class of bacteria killers (p. 11), a new state of matter—the quark–gluon plasma (p. 14), and new approaches to ensuring long lifetimes for the fused silica optics used in high-power laser systems (p. 17). Together, these stories provide compelling evidence of the Laboratory's continued efforts to innovate across its mission areas.

■ William H. Goldstein is associate director for Physical and Life Sciences.

A Beamline to National Security

Researchers at the Center for Accelerator Mass Spectrometry continually find new ways to advance Laboratory science.

Livermore researcher Scott Tumey adjusts the controls for a nuclear forensics experiment at the Center for Accelerator Mass Spectrometry (CAMS).

THE Center for Accelerator Mass Spectrometry (CAMS) at Livermore is world renowned for highly accurate dating of trees, ice, corals, archaeological samples, and human tissues. CAMS grew out of the construction in the mid-1980s of a multipurpose tandem accelerator laboratory designed for applications that use ion-beam analytic techniques. Over the years, accelerator mass spectrometry (AMS) became the largest component of the center's work, and today, CAMS is the most heavily used AMS facility in the world.

AMS replaces the older decay-counting methodology, which could take several days to complete, with a precise count of rare isotopes sometimes available within seconds. Although carbon-14 is the most commonly used isotope for dating samples, CAMS can also measure aluminum, beryllium, calcium, chlorine, hydrogen, iodine, plutonium, strontium, tritium, and uranium. The unique sensitivity of CAMS has led to groundbreaking research in earth and environmental sciences; climate change; and human metabolism of chemicals, toxic compounds, and nutrients.

Less well known is research on behalf of the Laboratory's primary mission, national security. "Although our national security work hasn't received a lot of play, the accelerator has been applied to forensics studies since the center was established in 1988," says Graham Bench, director of CAMS, which is part of Livermore's Physical and Life Sciences Directorate.

Forensics to Protect Human Health

In the late 1990s, CAMS scientists helped solve a long-standing controversy about the neutron dose received by survivors of the atomic bomb dropped on Hiroshima in 1945. Health data from survivors of the Hiroshima and Nagasaki bombings are used to calculate the risks of radiation-induced cancers in humans. However, low-energy measurement data at the time indicated that the neutron dose estimate published in a frequently cited 1986 report was too low.

Researchers at CAMS had by then developed a method for detecting trace amounts of radioactive nickel-63 in copper. They applied that technique to copper samples taken from locations ranging from 380 to more than 5,000 meters from the explosion's center, including the Bank of Japan, a soy sauce brewery, an elementary school, and the roof of a Shinto shrine. The team's findings provided the first clear measurements of the neutron dose to survivors in Hiroshima, which essentially agreed with the 1986 estimate.

Anthrax attacks in Washington, DC, and Florida prompted the Federal Bureau of Investigation to call on CAMS in 2001. The bureau needed to determine the age of spores found on envelopes and other contaminated objects. Results from carbon-14 dating experiments indicated the spores had been produced within 12 months of the attacks, information that helped determine possible production sites for the anthrax.

In addition, for more than 10 years, CAMS measurements have helped monitor urine samples from cleanup workers on Rongelap Atoll in the Marshall Islands to ensure that plutonium exposure does not exceed the established safety standards. The Rongelap community had been displaced to a neighboring atoll in 1954 to protect residents from radioactive fallout following an atmospheric nuclear test over nearby Bikini Atoll. The U.S. government resettled the islanders back to Rongelap in 1957. However, in 1985, the community relocated again because of their concerns about lingering contamination. Today, workers at Rongelap are remediating the soil to reduce levels of radioactivity in the atoll's plants. (See *S&TR*, July/August 2010, pp. 18–21.)

Nuclear Forensics Benefits

The nonproliferation community gained a new appreciation for CAMS during a 2009 nuclear forensics exercise. When beryllium-10 testing was requested as part of the exercise, the center was called in to help. CAMS had been using beryllium-10 as a dating tool for the geosciences since the 1990s but had not previously applied the technique for nuclear forensics.

Livermore researcher Scott Tumey leads the center's nuclear forensics and heavy isotope research. He and Tom Brown pioneered many developments in accelerator mass spectrometry and over the years have optimized new uses for the spectrometers.

For example, CAMS was one of the first facilities with the capability to measure strontium-90, which is present in nuclear test fallout. Since then, Tumey and Brown have enhanced the strontium detector, increasing its sensitivity by a factor of almost 100. The improved sensitivity allows researchers to more accurately assess the effectiveness of remediation work in the Marshall Islands. Similarly, for uranium-233, Tumey's modifications to a previous measurement setup increased sensitivity by a factor of 1,000 for more accurate nuclear forensics.

According to Bench, the center now has more projects in support of national security than ever before. "We're developing techniques that will open new frontiers of nuclear science for the Laboratory," he says. "We're also finding more applications for many of our isotope measurements. For example, we are beginning to apply our aluminum-26 capabilities, which we've used for years in geologic studies, to nuclear forensics."

New Beamline at Work

A CAMS project completed this year examined the helium bubbles that form in weapons-grade plutonium as it ages.

Laboratory scientists (from left) William (Skip) Fields, Karis McFarlane, and Scott Tumey prepare for an experiment on the high-energy ion-implantation beamline at CAMS. The new beamline is designed to irradiate highly radioactive elements used in nuclear weapons and to fuel nuclear power plants.

As a nuclear weapon sits in the stockpile, plutonium decays into a uranium atom with the emission of a helium nucleus. The helium nuclei create vacancies in plutonium's solid structure and may coalesce to form voids that could weaken the material. To better examine plutonium aging, researchers used a new high-energy ion beamline to implant helium ions in minute samples and mimic how helium builds up during the natural decay process.

Ion beamlines have been in place at CAMS since the late 1980s when they were used for proton tomography and to initiate nuclear reactions in materials for radiation detector testing and calibration. Ion implantation is a common practice in semiconductor manufacturing, but these industrial applications use relatively low energies such that ions penetrate less than 1 micrometer. The CAMS accelerator can achieve energies up to tens of megaelectronvolts to implant ions hundreds of micrometers deep. The new ion beamline is designed to irradiate actinides, a group of highly radioactive elements, many of which are used in nuclear weapons and to fuel nuclear power plants.

"The helium-ion implantation project ran for five years," Bench says, "and required both the ion beamline and radiation shielding for the target chamber." The shielding, designed to attenuate radiation, is constructed of 5 centimeters of lead surrounded by 70 centimeters of polyethylene. It rides on rails for placement over the target chamber during an experiment. With this heavy shield reducing radiation exposure, higher ion-beam currents can be aimed at a plutonium sample.

Aluminum and bismuth acted as surrogates in experiments to verify that the plutonium samples would not "volatilize" and contaminate other equipment or become an inhalable health hazard. Diagnostic devices along the beamline and at the target chamber include thermal cameras and vacuum gauges. If the temperature inside rises too high or a vacuum failure is indicated, a valve at a bend in the beamline closes to stop the ion beam.

The team conducted several implantation experiments using the beamline. Samples were implanted with 1 atomic percent of helium (equivalent to the amount expected in 250-year-old plutonium). Irradiated material was then analyzed with a transmission electron microscope designed to accommodate actinides. With the Livermore microscope, researchers can examine minute samples and view features less than 1 nanometer across.

Micrographs of the samples showed the helium bubble size was similar to that observed in 40-year-old plutonium. Bubbles continued to grow when samples were annealed in an oven, but no damaging voids formed. "The oldest weapons in the stockpile are approximately 50 years old, but some scientists have wondered if there is a 'cliff' beyond which the pits would suffer deleterious effects," says Bench. "Our research results may be an indication that the answer is no." In fact, stockpile research completed several years ago determined that the credible lifetime for a plutonium nuclear weapon pit would be more than 85 years.

From NIF to the Newest Elements

In a Laboratory Directed Research and Development (LDRD) project, Bench, Brown, and Tumey are working with radiochemist Dawn Shaughnessy to use the ion beamline to produce radioactive gold tracers for analyzing debris collected from laser experiments at the National Ignition Facility (NIF). Debris diagnostics for NIF are conceptually similar to those previously used for forensics investigations following an underground nuclear experiment. The chemical and isotopic analysis techniques are the same.

At the center of the NIF target chamber, a tiny metal cylinder, or hohlraum, holds a spherical fuel capsule on which 192 laser beams are focused. When the fuel capsule explodes, a complex series of nuclear reactions takes place. Small devices inside the target chamber collect debris produced by these reactions. One role of the debris collectors is to record the number of nuclear activations. These data reveal how the capsule fuel mixes, the properties resulting from the fusion reaction, and any exotic nuclear decay processes. Understanding the complex reactions involved is relevant to issues concerning nuclear weapon performance.

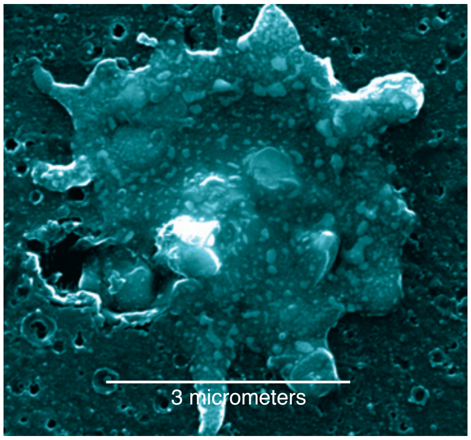
"Debris comes from both the capsule and the hohlraum, but most of it is from the hohlraum," says Shaughnessy. "Once we've acquired good data on the hohlraum debris, our near-term plan is to embed various tracer isotopes in the fuel capsule, so we can differentiate the capsule and hohlraum data."

In collaboration with the Colorado School of Mines and Los Alamos National Laboratory, experimenters are using NIF and smaller Livermore lasers to evaluate collector materials and determine the optimal distances for collector and blast shield placement. After an experiment, chemical processing involving the gold tracers will measure how much debris is generated with different materials and configurations. For example, tests with aluminum as a blast shield material showed it became badly cooked and melted, making it too dirty to use at a site in which cleanliness is a top priority. Debris analysis is currently performed in a radiochemistry laboratory. In the future, however, the highly sensitive measuring capability at CAMS may prove useful for this task.

In another LDRD-funded project, Shaughnessy and the CAMS team are planning to test rapid, automated chemistry systems connected to the ion beamline. The automated system will provide a tool for basic radiochemistry research. Potential applications for the future include providing real-time nuclear forensics capability in the field, producing medical isotopes, analyzing debris collected by NIF diagnostics, and characterizing the chemistry of any radioactive sample.

One application will examine the fundamental properties and chemical behavior of "superheavy" elements. The

Microscopist Mark Wall works with the Laboratory's transmission electron microscope. With this microscope, researchers can examine tiny samples of irradiated material and view features less than 1 nanometer across.



The new high-energy ion beamline at CAMS produces radioactive gold tracers for measuring and analyzing debris collected in experiments at the National Ignition Facility (NIF). In one NIF experiment, a molten droplet of gold condensed quickly on the surface of an aluminum debris shield in the target chamber.

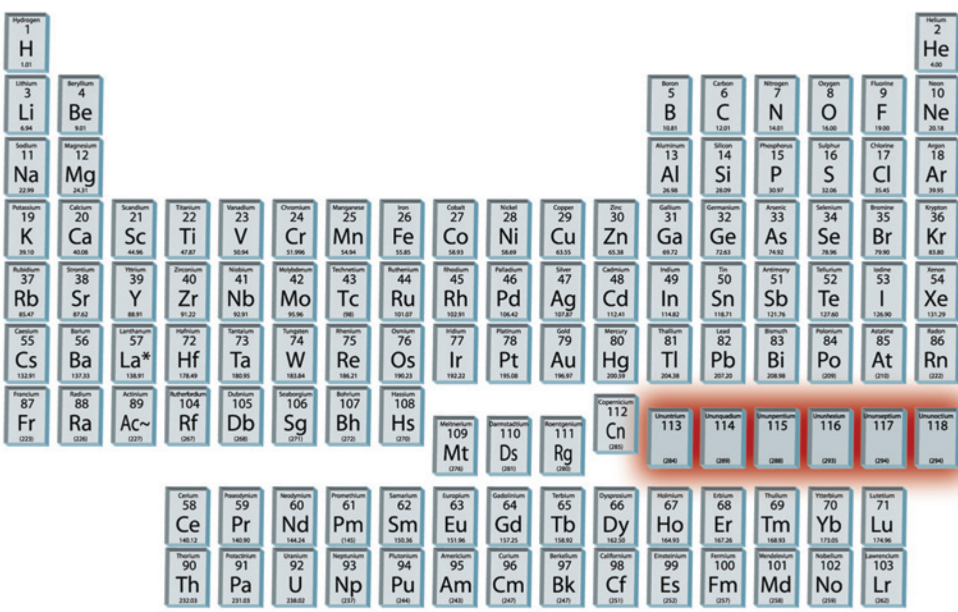
superheavy elements are those at the end of the periodic table and include six that were discovered by Livermore researchers in collaboration with colleagues at the Flerov Laboratory of Nuclear Reactions in Dubna, Russia. (See *S&TR*, October/November 2010, pp. 16–19; January/February 2002, pp. 16–23.)

Little is known about the recently discovered superheavy elements in part because so few atoms are produced before an element begins to decay. For example, researchers have yet to determine whether element 114, one of the Livermore–Dubna discoveries, is tetravalent or divalent, aqueous- or gas-phase. Because of the paucity of atoms, experiments to make these basic discoveries take a very long time. According to Shaughnessy, lighter elements with similar properties are used for chemistry development because they have more atoms available for study. She notes that even with a few more atoms, an automated system is essential because experiments will require rapid chemistry with a high repetition rate performed over several weeks of beam time.

"Most accelerator managers don't want to allocate beam time to time-consuming heavy-element work," says Shaughnessy, "but Graham [Bench] was willing to support our project. And CAMS is the ideal location because it is onsite. We can transport samples between our radiochemistry laboratories and CAMS and modify the automated system as needed to optimize performance. In addition, team members with accelerator experience will perform the final system integration, which is scheduled for 2012."

Developing the system's experimental setup and diagnostic processes is equally challenging because of the exceedingly small sample quantities. Shaughnessy and her colleagues are drawing on prior environmental work that involved tiny amounts of materials against a large background of other substances. They are investigating chemical separation and extraction techniques to remove interfering products and provide information about such properties as chemical bonding.

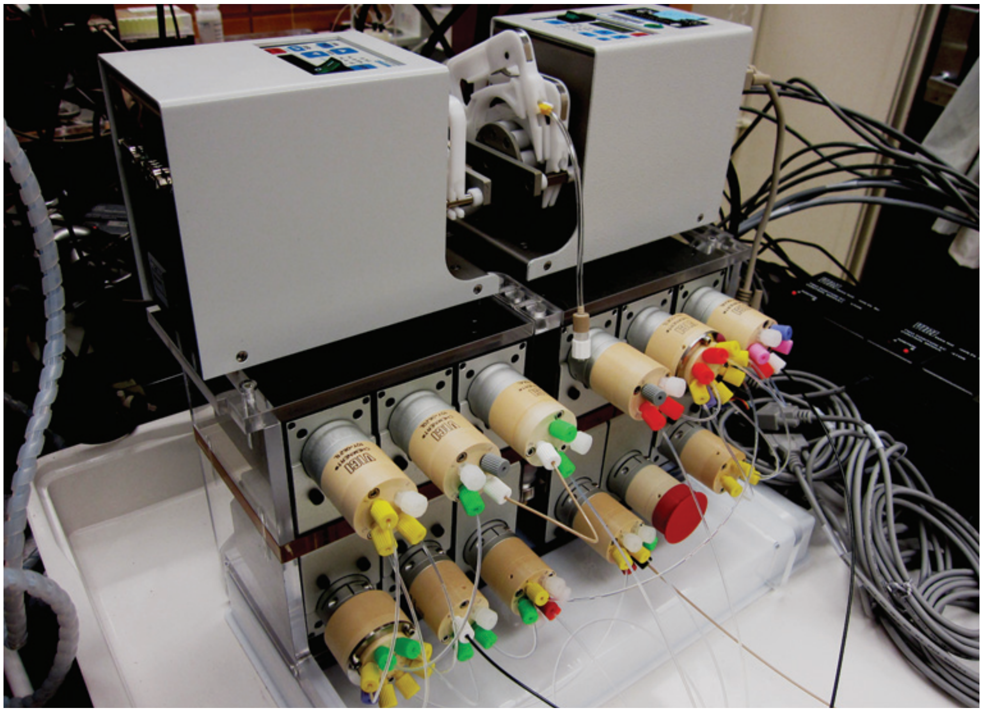
After final testing, the automated system will be shipped either to the Flerov Laboratory in Russia or to GSI Helmholtzzentrum für Schwerionenforschung in Darmstadt, Germany, which operates a large-scale accelerator for heavy ions. Says Shaughnessy, "Collaborators at both sites have committed future beam time to extended heavy-element chemistry experiments."



CAMS researchers are developing a rapid, automated chemistry system to examine the fundamental properties and chemical behavior of superheavy elements, including elements 113 through 118 (red) on the periodic table, which were discovered by a collaboration involving Lawrence Livermore and the Flerov Laboratory of Nuclear Reactions in Dubna, Russia.

For Power Plants of the Future

Innovations at CAMS are also advancing research on the Laser Inertial Fusion Energy (LIFE) concept as a potential fusion power plant for the future. (See *S&TR*, July/August 2011, pp. 4–12.) NIF experiments are serving as a proving ground for LIFE, which



Livermore's automated chemistry system is designed for basic radiochemistry research. In the future, researchers may adapt the system to perform nuclear forensics in the field, produce medical isotopes, analyze debris collected by laser diagnostics, and characterize the chemistry of radioactive samples.

offers the promise of an unlimited supply of clean, sustainable energy. Materials inside a fusion reactor would be exposed to extremely energetic neutrons and temperatures of many hundreds of degrees. Selecting high-performance materials that can withstand this extreme environment is a challenge.

In conventional power plant construction, a system's design generally dictates the materials to be used. For a LIFE reactor, the availability of structural materials will affect the system design. Decisions regarding the allowable operating temperature, coolant, and power conversion system will depend on the performance characteristics of the construction materials.

Tumey and materials scientist Michael Fluss have developed methods for testing potential materials for a LIFE reactor by implanting them with various ions. Says Fluss, "We need radiation-tolerant materials, but they don't have to last for the 40- or 50-year life of the plant. They would be constantly checked and replaced as needed, probably every 4 or 5 years."

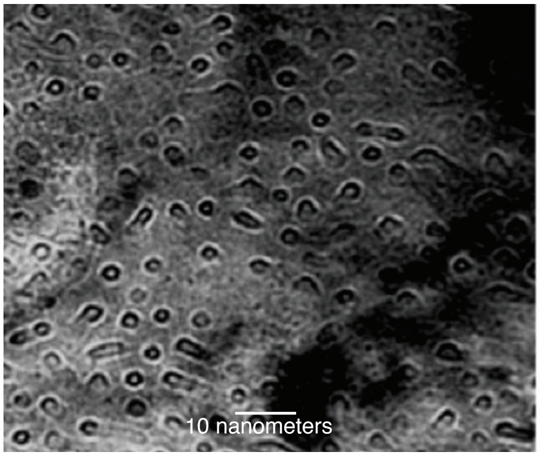
According to Fluss, the optimal choice is a material that is already available and whose properties are well known. One such material is oxide-dispersion-strengthened (ODS) steel. This steel is produced commercially by mechanically alloying the elemental metallic powder with nanoparticles of yttria oxide and consolidating the material by hot extrusion or hot isostatic pressing. Thanks to the nanoparticles, ODS steels are relatively resistant to radiation-induced swelling. They are also stronger than conventional steels and more resistant to oxidation and corrosion at high temperatures.

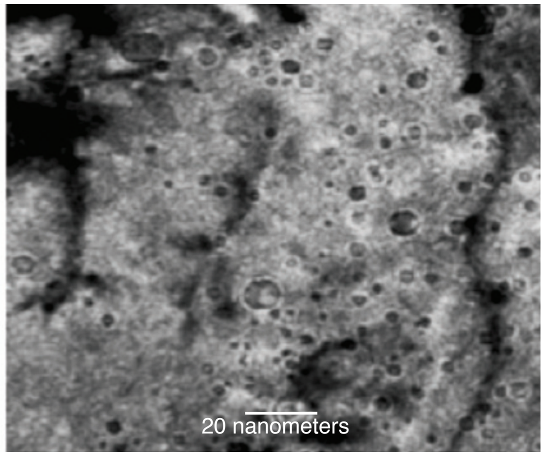
With no existing fusion power plants available for comparison purposes, other experimental platforms are the only route for testing LIFE materials. To mimic the conditions experienced by fusion materials, Fluss wants to simultaneously expose the iron-based steel to ion beams that implant iron, helium, and hydrogen. These experiments are taking place in collaboration with researchers at CEA in Seclay, France, which provides three ion beams operating simultaneously from three electrostatic accelerators.

"The effects of helium are well known because of many years of experience with fission reactors," says Fluss. "Hydrogen is the wild card. Both gases are very light, but they behave differently. Helium is inert and moves slowly through steel's structural lattice. Hydrogen is chemically active and moves quickly through the lattice, interacting with helium and other defects to potentially create complex microstructures. Because a fusion reactor would have four times as much hydrogen as helium, it is imperative that we understand hydrogen's role and any deleterious effects associated with it."

In preparing for the experiments in France, Tumey and Fluss examined the role of the yttria nanoparticles. They investigated two steels, one containing nanoparticles and the other without, and exposed them to both iron and helium ion beams at CAMS. Livermore materials scientist Luke Hsiung then examined the samples using the Laboratory's transmission electron microscope.

High-resolution micrographs revealed that nanoparticles suppress radiation-induced swelling in the ODS steel. Helium-filled cavities tend to be trapped





To better understand how nanoparticles affect radiation-tolerant materials, Livermore researchers irradiated two steel samples with iron and helium ions. The sample with oxide-dispersed nanoparticles (left) formed small bubbles that remained similar in size. The sample without nanoparticles (right) shows a more varied distribution of cavities, some of which have started to grow into potentially damaging voids.

by nanoscale oxide particles and clusters. However, research by scientists in Japan has shown that when ODS steels are exposed to iron, helium, and hydrogen together, material swelling increases by a factor of 10. Says Fluss, "Experiments at CEA will help us better understand this problem with the goal of controlling it."

Customer Community Growing

Livermore researchers led by materials scientist Wayne King are collaborating with Idaho and Argonne national laboratories on a proposal to study changes that occur in metallic fuels, a potential option for future fission power plants. To date, metallic fuels have been subject to less study than the more commonly used oxide fuels. Researchers have found, however, that fission gases released from the fuel could build up pressure and may crack the fuel's cladding. The tri-laboratory team plans to develop a predictive model for this process.

King, Tumey, and coworkers from Livermore and Argonne have found that developing the conditions to study helium bubbles in fuel is a challenge. In combination with an annealing process to mimic the appropriate temperatures to which fuel is subjected, xenon implantation needs very high energies of 80 megaelectronvolts.

Says King, "This project will be unique—if we receive funding, of course. It will combine not only theory, simulation, and experimentation but also uncertainty quantification, or UQ, which has only recently found its way into scientific predictions." (See *S&TR*, July/August 2010, pp. 12–14.) King notes that measuring the degree of uncertainty is the only way to assess the quality of model predictions. If this project proceeds, Tumey's expertise at CAMS will again be put to work.

And the projects just keep coming. Says Bench, "With better tools and an expanding expertise in applying them to the challenges that come our way, CAMS is serving a growing community of customers. Our efforts on behalf of national security show no sign of slowing down."

—Katie Walter

Key Words: accelerator mass spectrometry (AMS), Center for Accelerator Mass Spectrometry (CAMS), heavy-element chemistry, Laser Inertial Fusion Energy (LIFE), National Ignition Facility (NIF), national security, nonproliferation, nuclear forensics.

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Bacterial species impervious to antibiotics, such as *Escherichia coli* (shown here), are a health concern worldwide.

Breaking the Pattern of Antibiotic Resistance

WORLD health organizations have been concerned for the past few decades by the growing problem of antibiotic resistance in developing countries. This discussion grew louder when such bacteria reached the developed world, including the U.S., where for the first time since the discovery of antibiotics, patients have acquired bacterial infections that cannot be treated, putting lives at risk and increasing health-care costs.

The list of bacterial species impervious to antibiotics—*Escherichia coli*, *Salmonella*, *Campylobacter*, and at least 10 others—is growing, presenting significant health concerns worldwide. The rise of rapid, frequent, and relatively cheap international travel allows diseases to leap from continent to continent. Inadequate sanitation, lack of clean drinking water, and misuse of antibiotics contribute to the problem. And zoonotic sources—infectious diseases transmissible under natural conditions between vertebrate animals and human beings—pose more treatment challenges. In the past 20 years, new infectious diseases have appeared, including New Delhi metallo-beta-lactamase-1 and methicillin-resistant *Staphylococcus aureus*. Old ones, such as tuberculosis, are reemerging as serious health threats.

The conventional pharmaceutical response to antibiotic resistance has been to develop new drugs or combine established compounds to knock out multiple metabolic reactions within bacterial cells. Because the specific bacterium causing an infection is difficult to identify, broad-spectrum antibiotics are applied in a shotgun-blast approach to treat a range of disease-causing bacteria. This option, although effective in the short term, gives bacteria an opportunity to develop resistance to several antibiotic compounds.

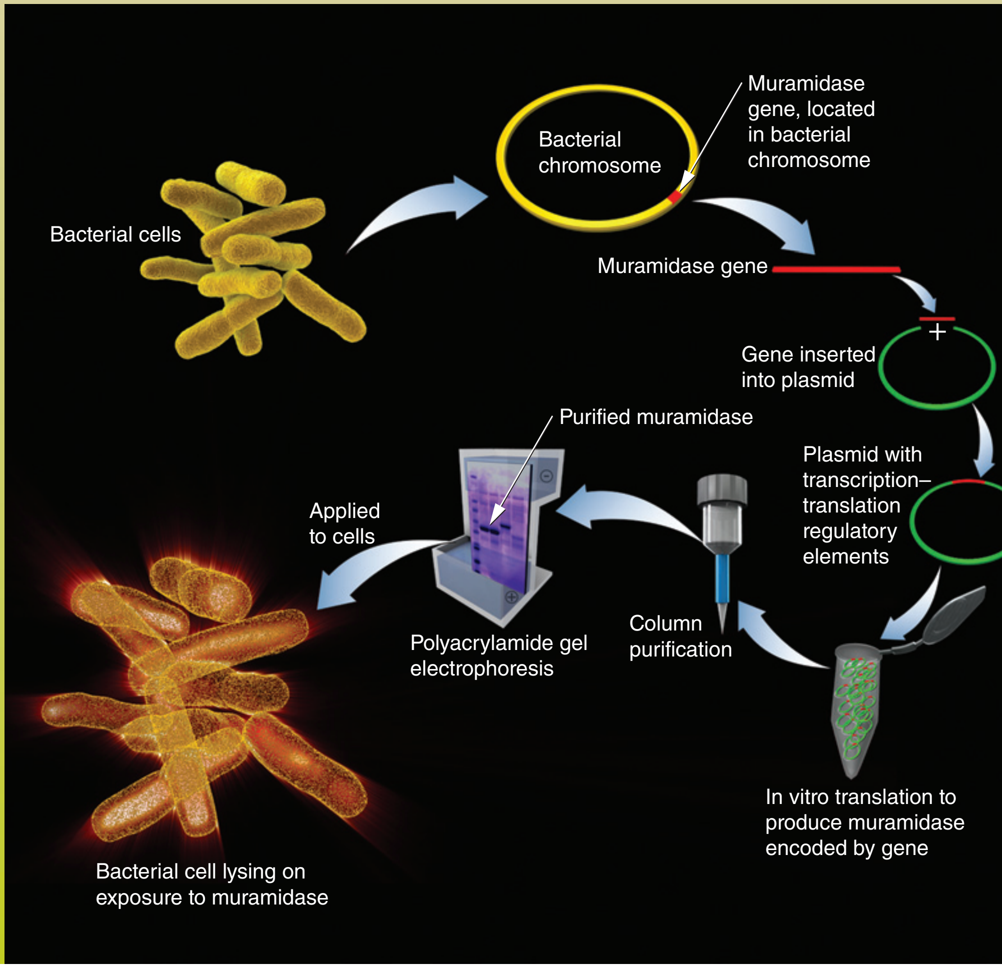
Resistance to antibiotics occurs when a bacterium mutates. "The bacterium modifies itself to prevent the drug from affecting its ability to grow," says Livermore scientist Paul Jackson, who works in the Physical and Life Sciences Directorate. "Microbes are always adapting, so some random mutation eventually protects a small number of them from a particular antibiotic. The protected microbes continue to grow in the presence of the drug."

Jackson is leading a team of Livermore biotechnology researchers who are investigating an alternative method for developing antimicrobial compounds: turning a pathogen's own genes against it. By taking advantage of bacterial genome sequences, the investigators identify which genes encode the proteins that cells require under normal conditions to survive. Then they apply those proteins in a manner not regulated by the cells, which damages the cells and rapidly kills the bacteria. "Because the protein we apply would normally be essential for bacterial

Finding the Right Proteins to Kill Bacteria

To evaluate candidate proteins for use as an antimicrobial treatment, Livermore scientists first select a bacterial pathogen, such as *Escherichia coli*, and from that cell's chromosomes, identify a gene likely involved in cell-wall metabolism or degradation. The selected gene is amplified using polymerase chain reaction, a technique designed to generate up to millions of copies of a particular DNA from a single sequence. The amplified gene is cloned into a plasmid that contains regulatory sequences to help control protein synthesis. DNA sequences encoding chemical (histidine) tags are included in the plasmid at this stage so researchers can rapidly purify the protein after it is synthesized.

Next, the plasmid is cloned into a laboratory strain of *E. coli* and purified to produce the required amount of plasmid for testing. An in vitro transcription–translation system uses the plasmid to direct the synthesis of large amounts of the lytic protein, which are then purified through columns that take advantage of the histidine tag. Finally, the protein is applied to a suspension or plate of cells, and lytic activity is measured.



Rendering by Kwei-Yu Chu.

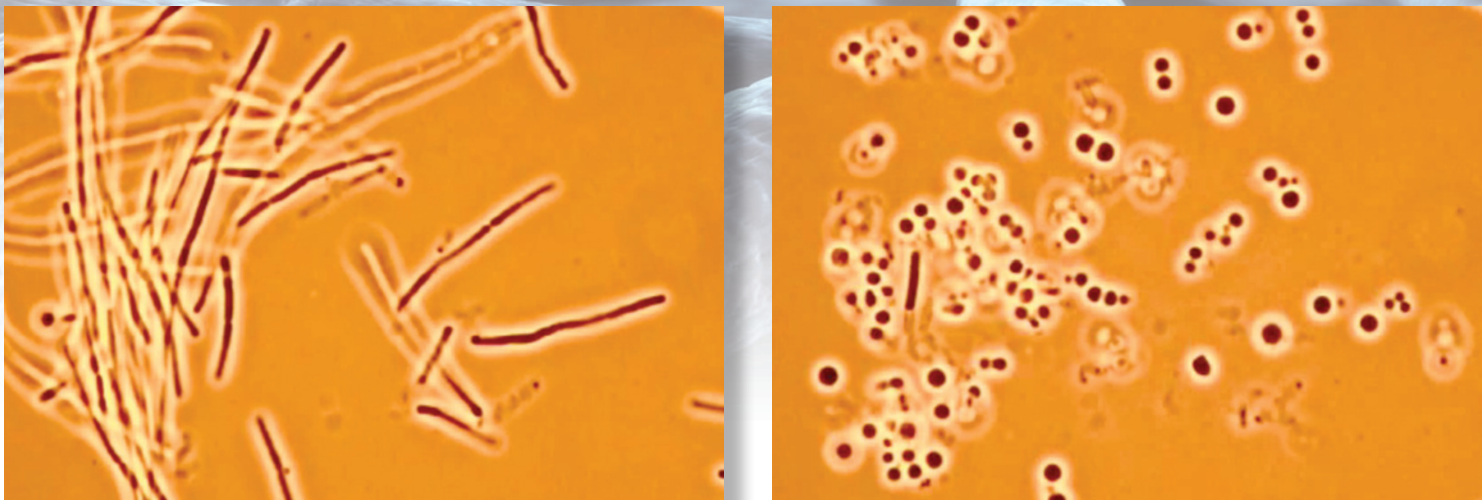
survival, we don't think the microbes can adapt to fend off the compound," says Jackson.

Beating Back the Bugs

With funding from the Laboratory Directed Research and Development Program, the research team, which includes Livermore scientists Feliza Bourguet, Matt Coleman, and Brian Souza, investigated endolysins, a family of lytic enzymes that cells produce in a controlled manner. Normally, lytic enzymes introduce nicks in cell walls that permit cells to divide and propagate. However, in high concentrations, endolysins cause rapid cell-wall degradation and cell rupture, a process termed cell lysis.

To determine which genes encode these proteins, the Livermore scientists used computational tools to search DNA databases of bacterial genomes. (See the box above.) For example, they identified several such genes in *Bacillus anthracis*, the bacterium that causes anthrax. Then they produced a large amount of the protein, purified it, and introduced it to the exterior of the cells. Experimental results showed total destruction of the pathogen's cell wall and, most importantly, rapid cell death. "When applied to the outside, the protein completely destroyed the integrity of the cell wall, quickly killing the bacterium," Jackson says.

Current technologies allow investigators to sequence genomes within a few weeks, providing information on newly identified pathogens, unknown bacterial species, or even species that have yet to be sequenced. With that information, the Livermore team can determine which genes encode lytic proteins in the new sequences and then produce those proteins in the quantities needed



Before the antimicrobial treatment process (left), bacterial cells on the slide are whole and complete, as indicated by the long strands. Seconds after the purified form of the bacteria's own protein is introduced to its exterior, the cell walls are destroyed (right). The fragments on the slide appear as mere dots.

to destroy the identified pathogens. For help with this sequencing effort, the team works with molecular biologist Crystal Jaing and bioinformatics experts Adam Zemla, Kevin Mcloughlin, and Tom Slezak.

Jackson acknowledges that the team's work would be extremely difficult without all of the Laboratory's resources. "We benefit not only from the multidisciplinary expertise but also from the different way each person thinks," he says. "The simple idea we started with really grew through this collaboration."

From the Lab to the World

In tests by the Centers for Disease Control and Prevention (CDC), Livermore's lytic protein killed 100 percent of *B. anthracis* cells, meeting the CDC's strict assay standard for rapid and complete lysis. Experiments with large batches produced at the center's core production facility showed that the protein is fully functional and stable after freeze-drying, and it has a long shelf life. Because of this success, CDC is including the protein in a new assay—a procedure to determine which bacteria resist a particular antibiotic—for use by the center's Laboratory Response Network, which was established to respond to biological and chemical terrorism and other public health emergencies. Livermore investigators are also providing the lytic protein to colleagues at the U.S. Army Medical Research Institute for Infectious Diseases.

The class of lytic proteins identified by the Livermore team shows promise for a number of topical treatments: to disinfect surfaces, which may be effective in combating hospital-acquired infections; to sanitize a patient's skin or wounds; and to reduce biofilms, an aggregate of microorganisms in which cells adhere to each other on a surface. Future tests will determine whether the proteins can be used for intravenous therapy.

The *B. anthracis* lytic protein may also prove effective in combination with procedures that force anthrax spores to germinate, allowing remediation teams to clean spore-contaminated equipment and facilities without using toxic or caustic materials. This class of protein may even be applied to foods to remove listeria—bacteria responsible for listeriosis, a rare but potentially lethal food-borne infection—and other food pathogens such as *E. coli* serotypes O157 and O104. "The Food and Drug Administration has already approved a cocktail of six different bacteriophage to spray on meat to reduce or eliminate all listeria," says Jackson. "The targeted proteins we're developing could provide a more effective approach for that purpose and for removing other harmful bacteria."

The team continues to test its technique on additional pathogens. According to Jackson, technological advances will eventually lead to quick identification of specific bacteria, and treatments for bacterial infections will become more focused. Because the Livermore process identifies a lytic protein unique to each bacterial species, the purified protein will target that specific species plus a few other closely related ones, leaving beneficial bacteria unharmed. Different lytic proteins could then be combined when a more broad-spectrum treatment is needed.

—*Kris Fury*

Key Words: antibiotic resistance, gene, lytic protein, pathogen.

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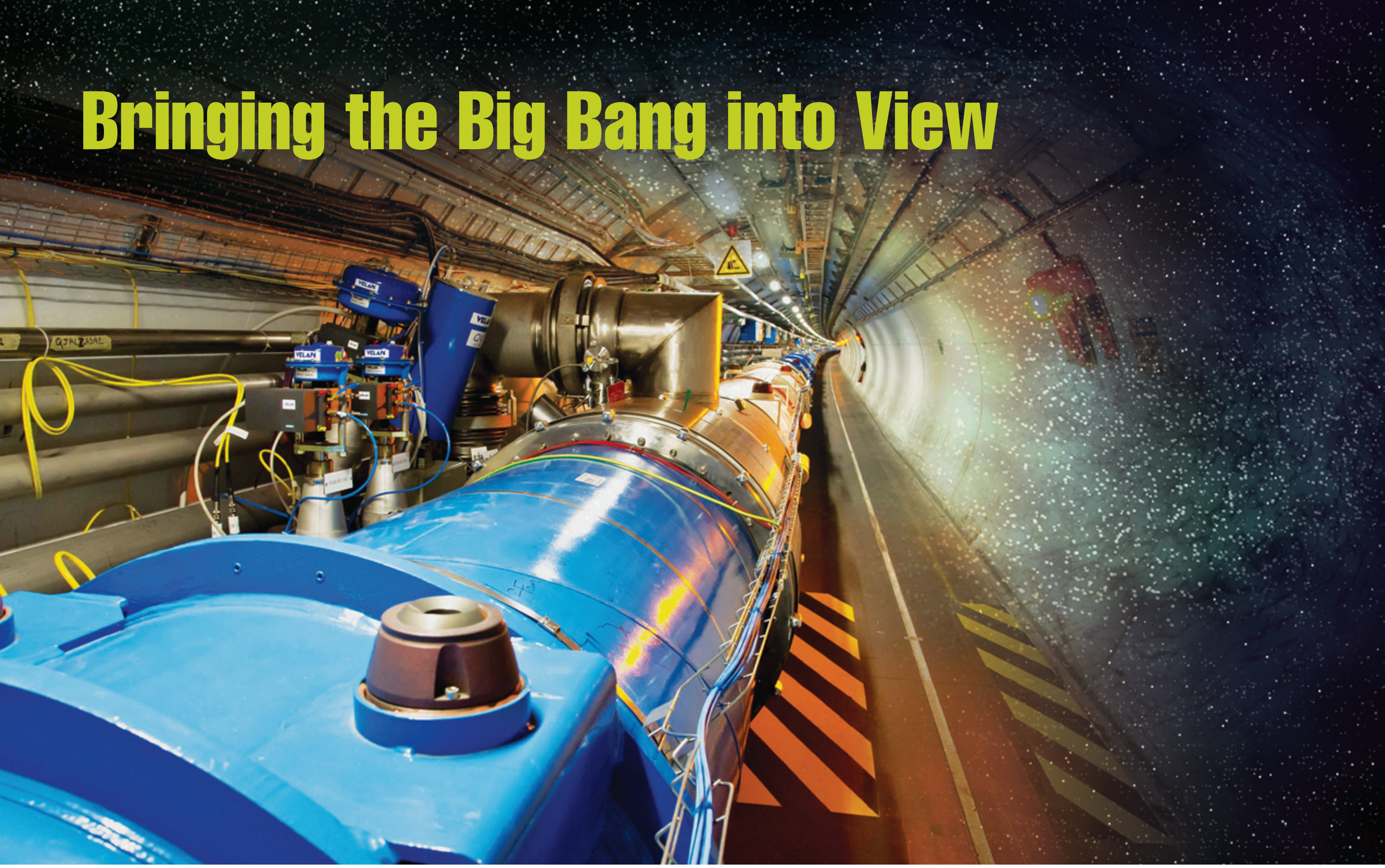
Bringing the Big Bang into View



In a large underground tunnel that straddles the French–Swiss border, the Large Hadron Collider smashes particles together at almost the speed of light and at unheard-of energies to examine their basic properties. (Courtesy of CERN, the European Organization for Nuclear Research.)

DURING the first milliseconds after the big bang, quarks, the most elementary of all known particles, roamed free in the universe. But their lifetimes were vanishingly brief. As the universe began to cool, quarks and the gluons that hold them together coalesced into protons and neutrons, two basic constituents of atoms. Efforts to re-create the high-energy and high-density conditions of the big bang—and thereby examine the fundamental physics of matter as it existed then—have been exceedingly difficult.

It takes an enormous and extraordinarily expensive particle collider to create the environment in which quarks and gluons might again be free of their confinement as constituents of larger particles. Because such colliders are few and far between, hundreds of partner institutions collaborate on the experiments. For the past decade, a team of Livermore researchers, led by particle physicist Ron Soltz in the Physical and Life Sciences Directorate, has worked at one such facility—the Relativistic Heavy Ion Collider (RHIC) operated by Brookhaven National Laboratory. Inside this particle accelerator, two beams of gold ions travel in opposite directions around the 3.8-kilometer ring at nearly the speed of light. When the two beams smash into each other, they briefly produce a quark–gluon plasma similar to the one generated in the big bang. (See *S&TR,* January/February 2003, pp. 4–9.)

While Soltz and his many collaborators continue to make substantial discoveries at RHIC, they also have a new, far more powerful collider at their disposal. The Large Hadron Collider (LHC) is a ring 27 kilometers in circumference in a tunnel under the French–Swiss border near Geneva, Switzerland. Approximately 10,000 scientists, engineers, and technicians collaborate at LHC, which was built and is operated by the European Organization for Nuclear Research, known by its French acronym, CERN.

LHC came on line briefly in 2008 before equipment problems forced CERN to shut it down for several months. In 2009, LHC began powering up and will eventually generate energies approximately 28 times higher than those at RHIC. Current LHC operational energies are about half that amount, or 2.7 trillion electronvolts per nucleon, still many times higher than the 200 billion electronvolts per nucleon typically produced by RHIC.

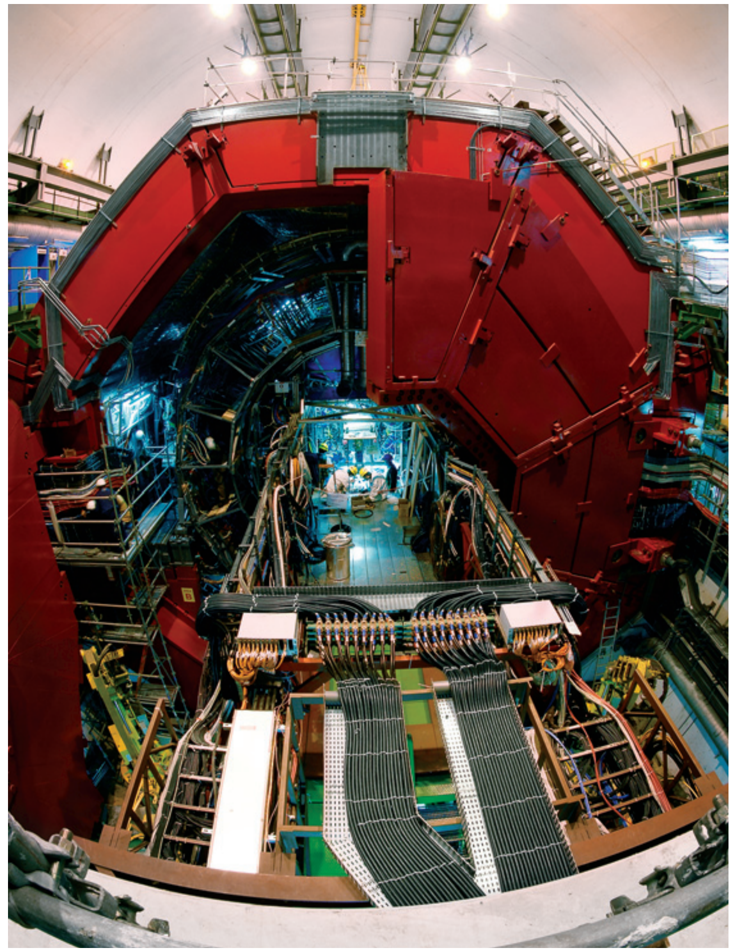
"About 80 percent of experimental time at LHC is used to study proton collisions," says Soltz. "One of the many goals for LHC researchers is to pin down the existence of a particle known as the Higgs boson, which is thought to give mass to matter. In fact, Livermore scientists Doug Wright, David Lange, and Jeff Gronberg are working toward that goal as part of another LHC effort called the Compact Muon Solenoid experiment."

CERN also allocates about a month of collider time each year for experiments designed to free quarks inside protons and neutrons. Soltz and his partners are studying results produced by both types of LHC experiments to discern how collision by-products behave.

Down the Rabbit Hole with ALICE

LHC experiments smash lead nuclei together, rather than gold. With this heavier element and LHC's longer circumference, nuclear collisions are 40 times more energetic than those generated at RHIC, resulting in plasmas with unprecedented temperatures and energy densities. Livermore researchers and their partners are conducting research on LHC's A Large Ion Collider Experiment, or ALICE. This experiment is designed to measure the properties of lead ions as they collide in the cylindrical belly of ALICE and create the "quark soup" of the big bang. A calorimeter provided by U.S. collaborators measures and records the very high energies dissipated by the particle collisions within the plasma.

The primary focus for the U.S. scientists working on ALICE is to further examine a surprising finding from their RHIC research. In those experiments, the collision of highly charged heavy ions generated high-energy, asymmetric "jets" in the surrounding plasma. Each jet—a spray of by-products from the reaction—interacts with the plasma, where it deposits some or all of its energy. "In a vacuum, colliding particles such as protons routinely create jets," says Soltz, "but those jets are symmetric. A central question in this area of physics is to understand why jets behave so differently in plasma. Through further experiments and modeling, we can begin to measure the phenomenon and what, if any, effect it might have had on the big bang's quark–gluon plasma."



A Large Ion Collider Experiment (ALICE) is a giant cylindrical device used by Livermore researchers and their partners to measure the collisions of lead ions and examine the conditions existing in the universe a few seconds after the big bang. (Courtesy of CERN.)

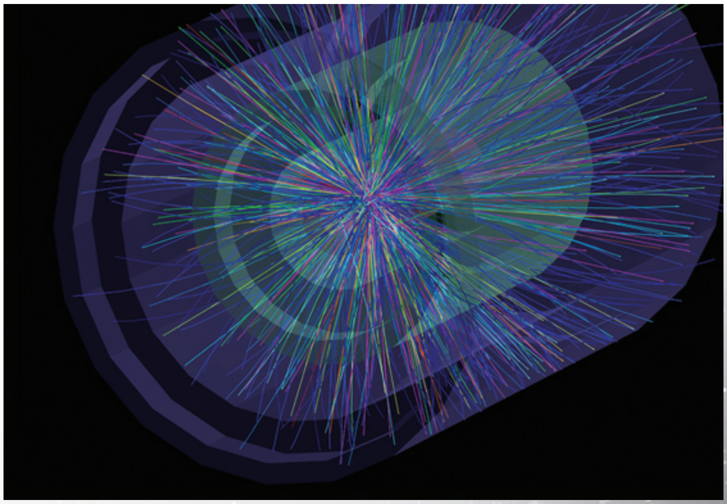
Sorting Out the Data

LHC experiments such as ALICE generate about 10 trillion bytes (terabytes) of data per day. Storing and processing so much information in one place is impossible. To get around this problem, CERN funnels data to a grid of computing centers located around the world.

Lawrence Livermore and Lawrence Berkeley national laboratories have jointly developed one such receiving point at Berkeley's National Energy Research Scientific Computing Center. Together, the two laboratories, with funding from the Nuclear Physics Program in the Department of Energy's Office of Science, are providing the primary computing and storage resources for ALICE collaborators in North and South America. The 1,000-plus collaborators worldwide can access those data using the ALICE Grid. Ten percent of all data from ALICE is transmitted from Switzerland to Berkeley and Livermore over ESnet, the Department of Energy's Energy Science Network.

"Making sense of experimental results at ALICE is difficult," notes Soltz, who serves as the computing coordinator for the Office of Science. "Experiments produce giant sprays of particles. Sorting them all out and determining what they mean requires a lot of high-performance computing power."

Livermore scientists (from left) Teresa Kamakea, Jeff Cunningham, and Ron Soltz view a map showing the member sites of the international ALICE collaboration that link to the Laboratory's Green Linux Compute Cluster.



Lead ion collisions recorded by ALICE reveal a spray of particles. Data produced in these experiments are processed on a giant international grid of high-performance computers, including Livermore's Green Linux Compute Cluster. (Courtesy of CERN.)

Livermore's ALICE cluster is called the Green Linux Compute Cluster. Installed in September 2010, it is the third largest ALICE cluster as measured by jobs completed per 24-hour period, and the associated 650-terabyte storage element for processed data is among the most heavily used. The cluster, which processed a series of simulations in preparation for the first heavy-ion experiments last November, is Livermore's first grid computing project involving an international collaboration.

Postdoctoral researchers Irakli Garishvili and Betty Abelev are working with Soltz on a Laboratory Directed Research and Development project to interpret ALICE data. In particular, they are searching for telltale signs of jets and the dissipated energy absorbed by the surrounding plasma. Soltz admits that at this point, researchers are unsure what the collider study of jet–plasma interactions will teach them about the big bang plasma. Jets may not have been present in this same form in the early universe, but says Soltz, "At a minimum, they serve as indispensable probes for examining the plasmas in our experiments."

He notes that the physics of big bang and LHC plasmas are identical, but they began in different ways. "The big bang plasma was born extremely hot and highly uniform except for the tiny clumps that eventually coalesced into galaxies, solar systems, planets, and us," says Soltz. "At LHC, nuclear collisions rapidly heat up to produce the plasma. In studying these events, we hope to learn what role jets play in the process."

—Katie Walter

Key Words: A Large Ion Collider Experiment (ALICE), big bang, European Organization for Nuclear Research (CERN), Green Linux Compute Cluster, Large Hadron Collider (LHC), quark–gluon plasma, Relativistic Heavy Ion Collider (RHIC).

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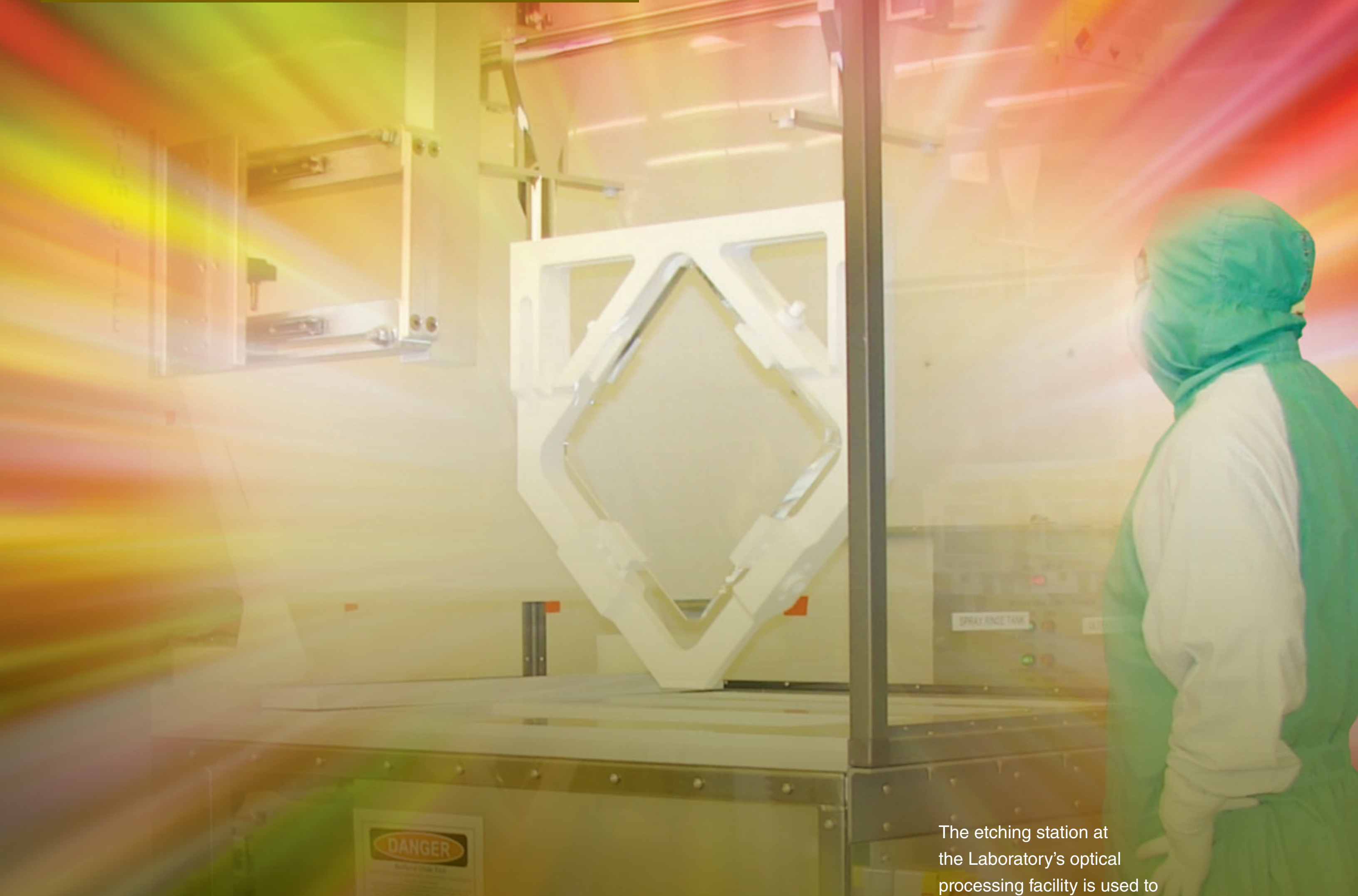


The etching station at the Laboratory's optical processing facility is used to treat fused silica optics with the advanced mitigation process. The white-framed, wedge-shaped final focusing lens is visible through the enclosure.

Enhanced Damage Resistance for NIF Optics

IN addition to being the world's largest and most energetic laser, the National Ignition Facility (NIF) is the largest optical instrument ever built. The giant laser has 7,500 large optics, ranging from 60 to 100 centimeters in diameter, and 30,000 smaller ones that guide, reflect, amplify, and focus 192 laser beams onto a fusion target about the size of a BB.

Many NIF optics are made of fused silica (noncrystalline silicon dioxide) because this material exhibits excellent optical properties. In particular, it transmits laser light over a wide spectral range. The manufacturing processes for fused silica optics can, however, produce microscopic defects, or damage precursors, on the glass surface, especially when optics are polished near the end of fabrication. When NIF construction began in 1997, even the best manufacturers produced high-quality optics with thousands of tiny defects. To lessen the potential for damage, Livermore researchers worked closely with their industrial partners to improve optics fabrication by developing more stringent finishing and quality assurance procedures.

That effort paid off: By 2007, improvements in surface finishing had reduced the number of defects in the final focusing lenses, which must withstand the highest fluences, from about 30,000 per lens to about 200. Livermore scientists also developed procedures to remove and mitigate the laser-induced damage on fused silica optics. These mitigation techniques are effective but time-consuming. In addition, lenses with a large number of defects must be treated more frequently, which can increase the cost for an experiment.

To further extend lens lifetimes, the NIF optics science and technology group conducted an exhaustive study to improve the damage resistance of fused silica surfaces. In a multiyear project funded by the Laboratory Directed Research and Development Program, the group first examined the nature of damage precursors that develop when the optics are polished and then worked to develop a cost-effective method that can prevent or significantly reduce the number of precursor sites.

Led by scientists Tayyab Suratwala and Jeff Bude of the Laboratory's Physical and Life Sciences Directorate, the researchers discovered an extremely thin defect layer on the surface of fine fractures that form on optic surfaces. This layer hosts damage precursors that limit a beam's fluence, or the energy passing it. A procedure developed by the Livermore team, called the advanced mitigation process (AMP), removes the problem layer. As a result, the process reduces expected damage sites in the final focusing lenses to less than 10 defects per optic over the course of 50 laser ignition shots.

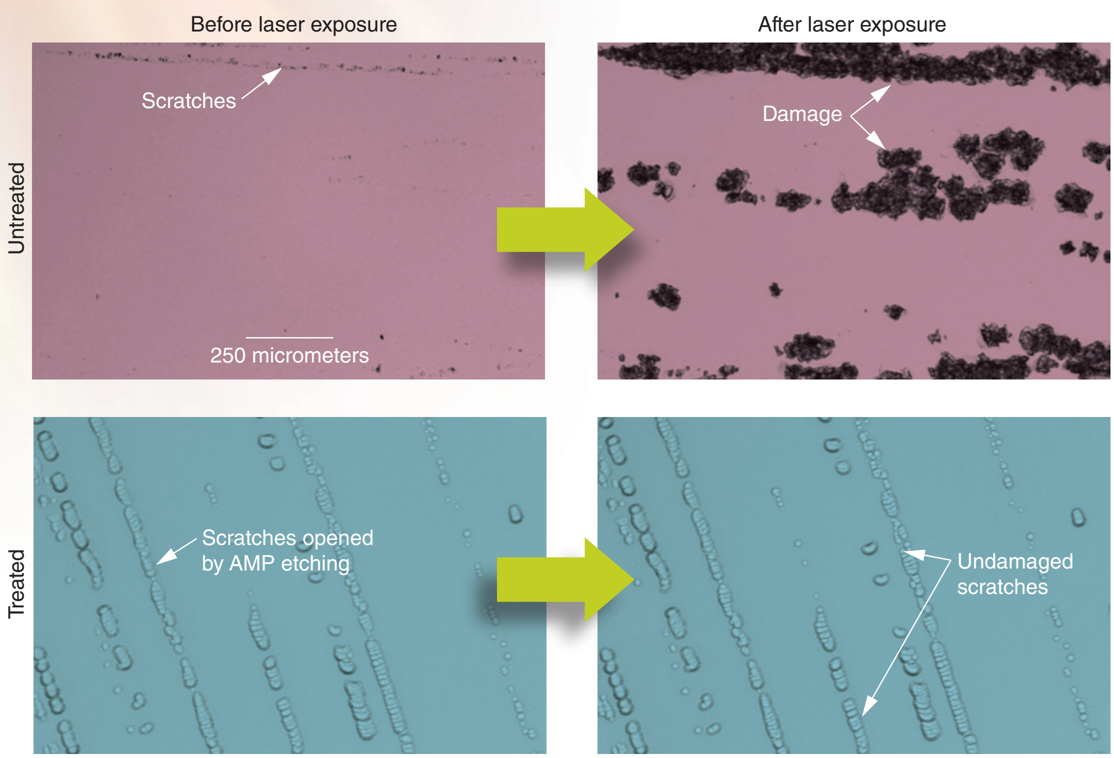
Bude attributed the success of this project to the wide range of talents on the AMP team. Phil Miller, William Steele, Nan Shen, Michael Feit, Ted Laurence, and Lana Wong worked with Bude and Suratwala to isolate the precursors and develop the process for laboratory testing. Laser physicists Mary Norton and Wren Carr performed large-area damage testing of the protocol, and chemical engineer Marcus Monticelli helped implement the production process for full-size lenses.

A Process to Remove Manufacturing Defects

Bude notes that throughout the history of laser research and development, important advances have been made in glass manufacturing and finishing, many of them developed by Livermore researchers working on the Laboratory's ever-larger lasers. Nevertheless, high-quality optics still contain minute scratches, fractures, deformations, or impurities. These defects, often measuring only about 100 nanometers in diameter, absorb laser energy and in less than a nanosecond, can cause an optic's surface temperature to reach up to 10,000 kelvins, hotter than the surface of the Sun.

Such extreme heat can trigger an explosive ejection of material, leaving a surface crater measuring tens of micrometers in diameter. If the initial sites remained small, they would not pose a serious problem. However, they tend to grow exponentially with each laser shot. Repeated exposure to the photon energy densities, or fluences, of a NIF-size laser can adversely affect a component's performance and limit its useful lifetime. Eventually, a damaged optic must be removed and either replaced or recycled.

In developing AMP, researchers concentrated on the fused silica lenses used in the 48 final optics assemblies that connect NIF's 192 beamlines to the target chamber. These assemblies convert the wavelength of laser light from 1,053 nanometers in the infrared portion of the electromagnetic spectrum (which scientists designate



Micrographs of fused silica samples illustrate how well Livermore's advanced mitigation process (AMP) works to reduce the number of damage precursors on optic surfaces. The top left image shows a scratched, untreated sample. The bottom left image shows a scratched sample treated with AMP. Both optics were exposed to three shots of three-omega (ultraviolet) light, each with a photon energy density of 12 joules per square centimeter and lasting for 3 nanoseconds. The untreated sample (top right) had extensive damage, while the treated sample (lower right) shows no damage.

as 1-omega light) to 355 nanometers in the ultraviolet portion (called 3-omega light). As a result, lenses in these assemblies must withstand the highest ultraviolet fluence generated by the laser—9 joules per square centimeter.

Each final optics assembly is composed of a disposable debris shield and vacuum window, a fused silica grating debris shield, crystals that convert light from infrared to ultraviolet, and the aspheric fused silica lenses that precisely focus the ultraviolet light onto the target. Because of the intense fluences generated in the final optics assemblies, microscopic defects near the surface of the final focusing lenses have the potential to absorb enough energy to initiate small points of damage. Although a damage site may initially be only about 20 micrometers in diameter, it can grow quickly with repeated exposure to energetic laser light. "Three-omega photons are much more energetic than 1-omega photons," says Bude, "so the damage risk for lenses in the final optics assemblies is much higher."

Defect Layer 200 Nanometers Thick

In probing the nature of defects and damage precursors, the team found that defect layers less than 200 nanometers thick form on the surface of fine scratches made during the polishing operation. "For our high-quality finished lenses, this defect layer is the dominant source of laser damage initiation at nominal NIF fluences," says Bude.

Research showed that chemical etching with hydrofluoric acid can mitigate all types of defects, including impurities and scratches. A buffered solution of hydrofluoric acid is widely used by industries for cleaning glass and processing silicon wafers. "Hydrofluoric acid is one of the few chemicals that can attack silica, which is chemically quite inert," says Bude. "We invested a lot of effort to make sure we knew how to work safely with this potent acid."

To mimic real defects caused by polishing, the team rubbed silica beads across the surface of small-scale fused silica samples. The purposely scratched samples were submerged in various concentrations of hydrofluoric acid solutions under different process conditions. Although the solutions readily opened the fractures and removed the defect layer associated with them, by-products from the etching process precipitated in the open fractures. As with the original precursor sites, the precipitates could absorb light and initiate damage, frustrating attempts to improve damage resistance. With further research, the team found that details of the etching process, including acid composition, amount of agitation, and optic cleanliness, affect the amount of precipitation and, hence, damage resistance to 3-omega light.

To optimize AMP, the Livermore researchers combined extensive experiments with mass-transport simulations. They identified the concentrations of hydrofluoric acid and ammonium fluoride that best mitigate precursor sites. They also determined the correct amount and intensity of high-frequency acoustic waves to apply for shaking by-products loose from the surface and help transport them away. In the final step, lenses are rinsed in a series of deionized water baths that remove any remaining etch by-products.

The team characterized the effectiveness of AMP by using high-fluence laser light and imaging the treated optics with time-resolved photoluminescence. The results showed that AMP could open fractures, remove the defect layer, and leave a surface free of absorbing precursors. When a fused silica optic is treated with AMP, the optic is much more resistant to damage, with measured improvements over 10 times greater than before the treatment. With the defect layer eliminated, the average threshold at which damage is initiated in a 30-micrometer-wide scratch increased from 7 to 41 joules of applied laser energy per square centimeter.

Applying AMP to 192 Lenses

Having demonstrated the technique's effectiveness, the team developed a production process for AMP and oversaw its application to all 192 final focusing lenses. The procedure, performed at NIF's optical processing facility, involves lowering the optic into a 30-gallon (0.12-cubic-meter) tank for 14 hours, followed by treatment with high-frequency sound waves and a final series of rinses. Technicians monitor the operation to ensure that etching steps are performed uniformly and do not alter an optic's exact shape, which is critical for precise focusing. With this approach, the facility can treat two optics per day.

Bude estimates that in 1997, a final focusing lens exposed to 50 NIF-scale shots would have had more than 30,000 damage precursors. By 2007, advancements made in manufacturing processes had reduced that number to about 250. Now, thanks to AMP, the estimated number of defects per final focusing lens is less than 10. With such dramatic improvements, NIF operators can achieve more shots with each fused silica optic before it must be refurbished, and they can increase the laser's fluence with less concern for increased damage to critical components.

The Livermore team is now applying AMP to the fused silica grating debris shield, another critical optic in the final optics assembly. The researchers are also evaluating approaches to further reduce the number of defects produced during manufacturing and investigating new etch processes with even higher damage resistance. Says Bude, "We still have much more to learn about the fundamental nature of optics damage and effective mitigation techniques."

—Arnie Heller

Key Words: advanced mitigation process (AMP), final optics assembly, focusing lens, fused silica optics, hydrofluoric acid, National Ignition Facility (NIF), 3-omega light.

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Patents and Awards

In this section, we list recent patents issued to and awards received by Laboratory employees. Our goal is to showcase the distinguished scientific and technical achievements of our employees as well as to indicate the scale and scope of the work done at the Laboratory.

Patents

Chemical Analysis Kit for the Presence of Explosives

Joel Del Eckels, Peter J. Nunes, Armando Alcaraz, Richard E. Whipple
U.S. Patent 7,939,029 B2
May 10, 2011
This chemical analysis kit can be used to test a location for explosives. The kit uses two explosives-detecting reagents, each in a reagent holder, and a sample collection unit with a heating unit attached. Samples acquired at a test location are exposed first to one reagent and then the other and are heated to determine whether explosives are present.

Hyperspectral Microscope for In Vivo Imaging of Microstructures and Cells in Tissues

Stavros G. Demos
U.S. Patent 7,945,077 B2
May 17, 2011
An optical hyperspectral–multimodal imaging system provides high signal sensitivity for implementing various optical imaging approaches. The system uses long-working-distance microscope objectives that enable offaxis illumination of predetermined tissue and thus allow for excitation at any optical wavelength. The system has a simplified design that reduces the number of required optical elements as well as the spectral noise produced by those elements and can quickly acquire high-quality images in vivo. This technology provides a means of detecting disease at the single-cell level, such as cancer or precancer; ischemic, traumatic, or other types of injury; infection; and other diseases or conditions that alter cells and tissue microstructures.

Nano-Laminate-Based Ignitors

Troy W. Barbee, Jr., Randall L. Simpson, Alexander E. Gash, Joe H. Satcher, Jr.
U.S. Patent 7,951,247 B2
May 31, 2011
Solgel chemistry is used to prepare igniters comprising energetic multilayer structures coated with energetic booster materials. These igniters can be tailored to remain stable when exposed to extreme environmental conditions, such as temperatures from –30°C to 150°C and relative humidity from 0 to 100 percent.

Flow Cytometric Detection Method for DNA Samples

Shanavaz Nasarabadi, Richard G. Langlois, Kodumudi S. Venkateswaran
U.S. Patent 7,972,818 B2
July 5, 2011
Two methods for rapid multiplex analysis can be used to determine the presence and identity of target DNA sequences within a DNA sample. Both methods use reporting DNA sequences, such as modified conventional Taqman® probes, to combine multiplex polymerase chain reaction (PCR) amplification with microsphere-based hybridization using flow cytometry means of detection. Real-time PCR detection can also be incorporated. The first method uses a cyanine dye, such as Cy3™, as the reporter linked to the 5´ end of a reporting DNA sequence. The second method positions a reporter dye, such as FAM™ on the 3´ end of the reporting DNA sequence and a quencher dye, such as TAMRA™, on the 5´ end.

Awards

The Heavy Vehicle Aerodynamic Drag Project, a collaboration led by Livermore scientist **Kambiz Salari**, received the **High-Performance Computing Innovation Excellence Award** from **International Data Corporation**. The project was honored for its use of modeling and simulation to find practical ways to reduce aerodynamic drag and improve the fuel efficiency of tractor-trailers on the nation's highways.

The project team used a virtual testing approach to design devices that can easily be attached to a tractor-trailer to reduce its aerodynamic drag. Tests showed the devices could improve fuel efficiency up to 17 percent, annually reducing diesel fuel consumption by about 6.2 billion gallons and preventing about 63 million tons of carbon dioxide from being released into the atmosphere.

The **American Physical Society's Division of Plasma Physics** honored Laboratory researcher **Yuan Ping** with the **2011 Katherine E. Weimer Award**. Established in 2001, the award recognizes the contribution and potential of women in plasma science and is given every three years to a female physicist in the first 10 years of her career. Ping was chosen for her "pioneering experiments to explore the interaction of high-intensity laser light with matter."

Laboratory physicist **Lin Yang** was named a **fellow** of the **Institute of Physics** in recognition of his "personal contribution to the advancement of physics as a discipline and a profession" and for his work in dual areas of multidisciplinary physics. Yang's primary research interest is classical and quantum molecular-dynamics simulations of materials under extreme conditions. Since joining the Laboratory in 1991, he has developed the plane-wave pseudopotential quantum molecular-dynamics simulation code and the Green's function molecular-dynamics method on petascale computers.

Livermore geochemist **Kim Knight** received the **best poster award** at the **National Nuclear Security Administration**'s annual symposium for **Laboratory Directed Research and Development** projects. The winning poster, "Resonance Ionization Mass Spectrometry (RIMS) for Nuclear Forensics Applications with Rapid Response," describes a technique developed by Knight and her colleagues Ian Hutcheon from Livermore, Michael Savina from Argonne National Laboratory, and Stan Prussin from the University of California at Berkeley. RIMS is a nuclear forensics tool that can directly image raw materials and determine the fallout from a nuclear event.

Abstract

A Beamline to National Security

The Center for Accelerator Mass Spectrometry (CAMS) at Livermore is world renowned for highly accurate dating of trees, ice, corals, archaeological samples, and human tissues. Less well known is research at CAMS on behalf of the Laboratory's primary mission, national security. An ability to measure extremely low levels of various isotopes is key to CAMS support for environmental health, nuclear forensics, and intelligence gathering. Several isotopes serve as markers for evaluating human health. Analyses of uranium isotopes can help the intelligence community determine the provenance of highly enriched uranium used in nuclear weapons. A recent project in support of stockpile stewardship used a new high-energy beamline to examine the formation of helium bubbles in weapons-grade plutonium. Designed to implant actinide ions, the beamline is also providing novel diagnostics for experiments at the National Ignition Facility and helping to characterize the short-lived superheavy elements. In addition, scientists are using the beamline as a test bed for experiments on materials that can withstand the extreme conditions inside reactors being proposed for next-generation fission and fusion power plants.

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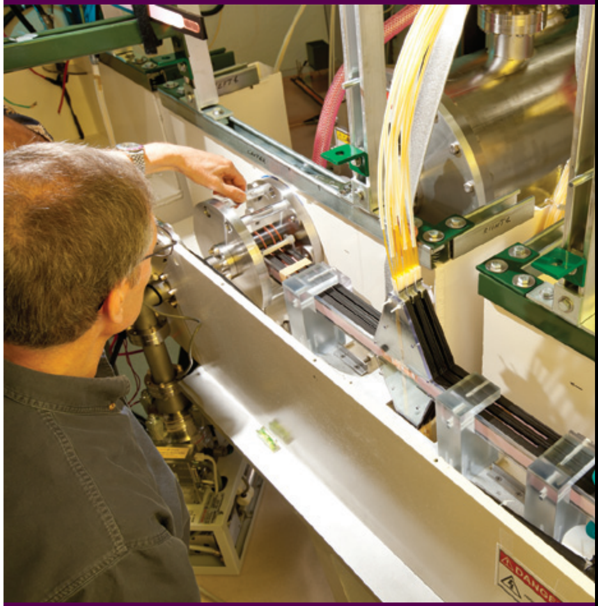
Coming Next Issue

Revolutionary Proton Therapy



A Livermore particle accelerator technology is becoming a tool to save the lives of cancer patients.

Also in October/November

- *A lightweight, scalable tool that quickly identifies a supercomputer's code errors garners an R&D 100 Award.*

- *A light deflector, which also won an R&D 100 Award, will capture details of burning plasma in fusion reactions with unprecedented performance metrics.*

- *Livermore researchers are examining the geochemical processes that control plutonium's underground migration behavior.*

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