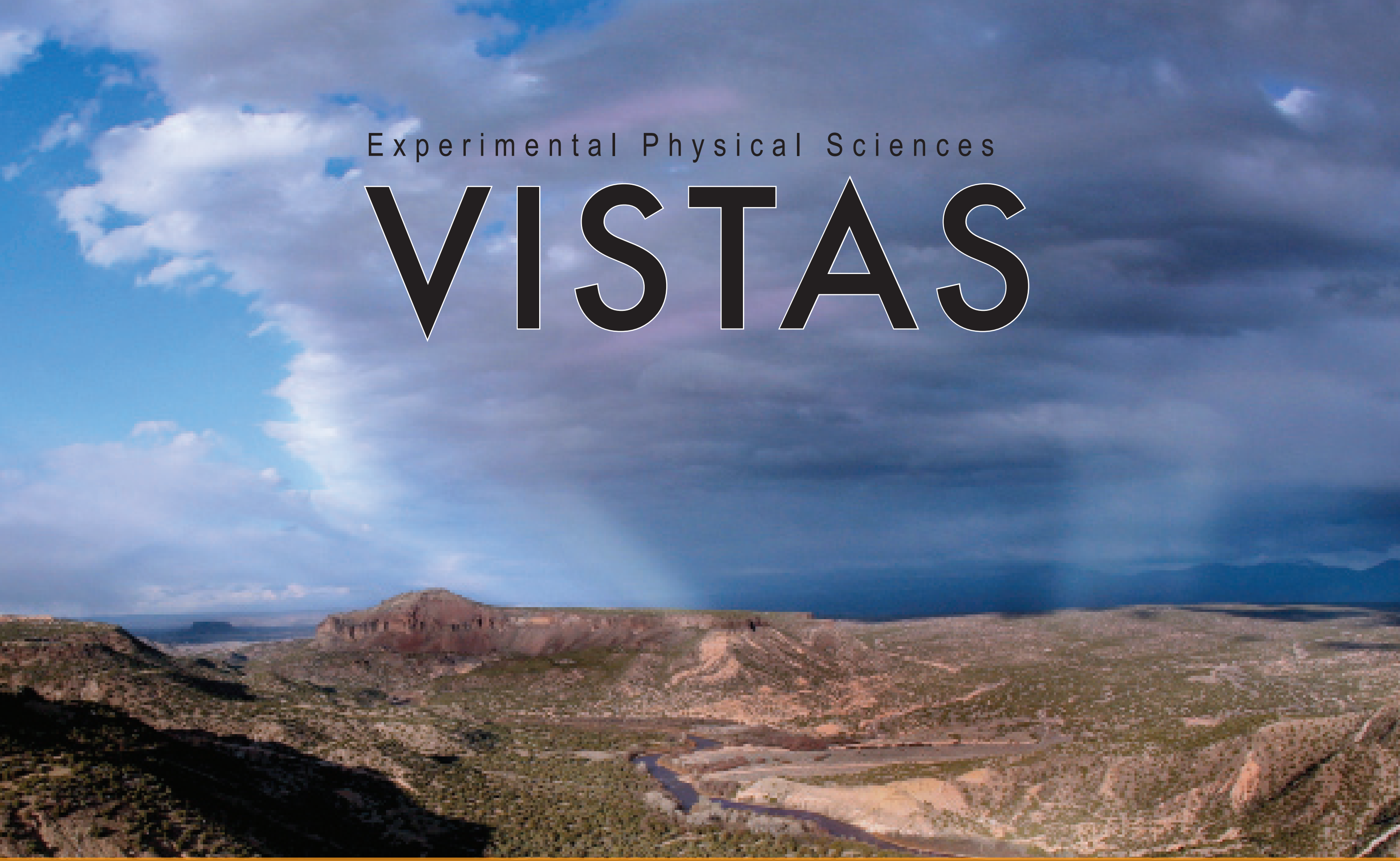
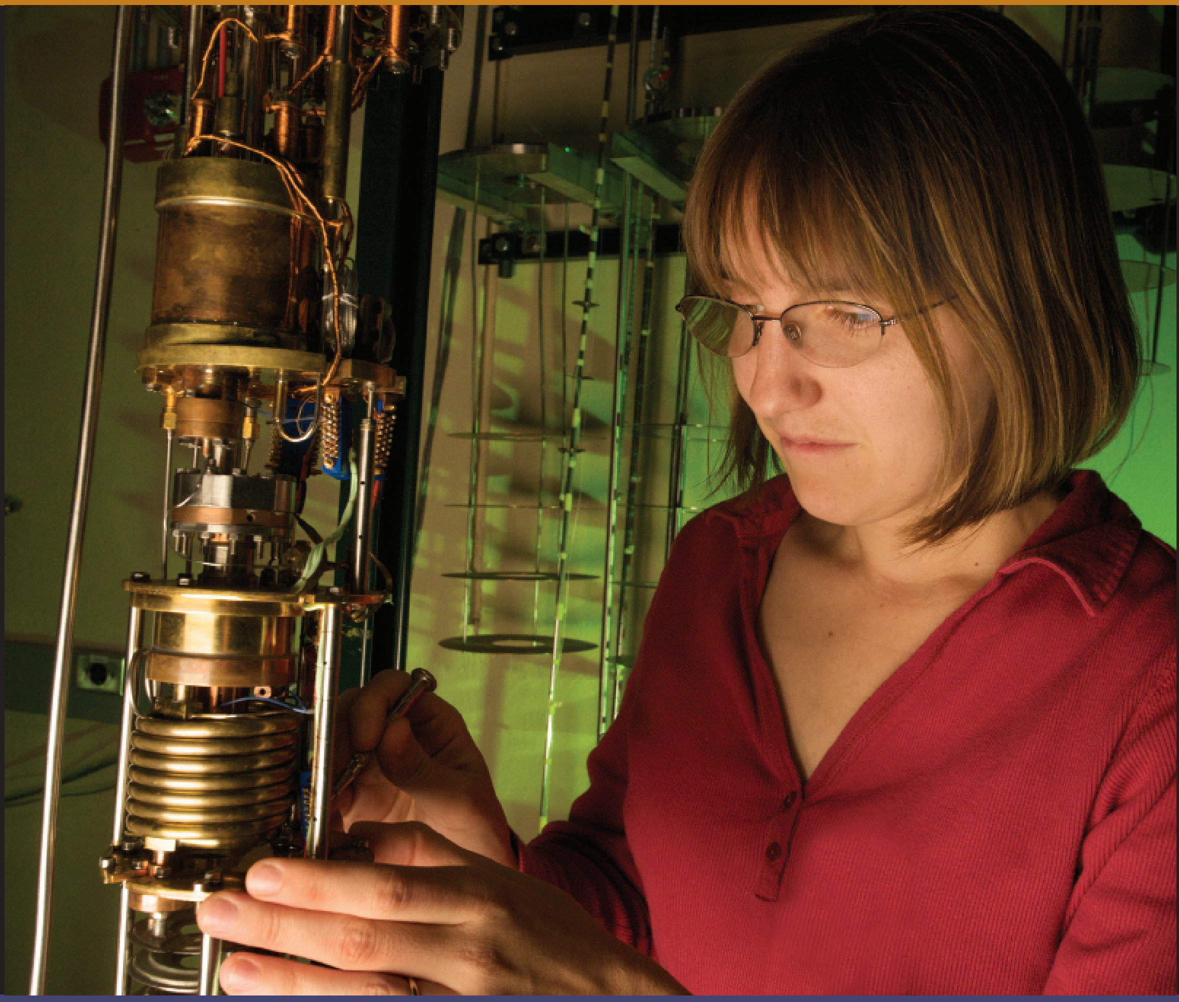
Experimental Physical Sciences

VISTAS



NATIONAL USER FACILITIES



Los Alamos
NATIONAL LABORATORY

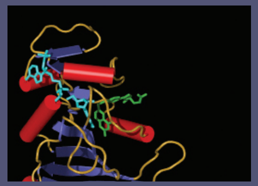
SPRING 2009

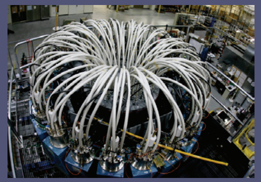
USER **FACILITIES** are a major strength of the Experimental Physical Sciences Directorate at Los Alamos National Laboratory.

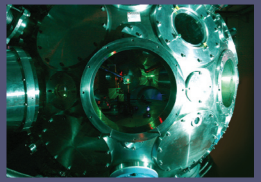
Each facility uniquely contributes to a certain class of scientific experiments, allowing the creation of outstanding **DISCOVERY SCIENCE.**

By applying the capabilities of multiple instruments from more than one Los Alamos facility, we can pursue scientific problems and design experiments under a wider set of conditions and regimes accessible to few other places in the world.

This is the value of **INTEGRATION.**







ON THE COVER
White Rock Canyon and the Rio Grande, with a view of Black Mesa in the distance.

Vivien Zapf, a technical staff member at the National High Magnetic Field Laboratory's Pulsed Field Facility at Los Alamos National Laboratory, studies magnetic field-induced electric polarization in organic magnets.

LEVERAGING multiple user facilities

The grand challenges facing experimental scientists today require the application of deep and broad scientific capabilities using the discovery potential enabled by our unique experimental facilities. Since 1973, when the Los Alamos Meson Physics Facility (LAMPF) received its first experimental proposals, Los Alamos user facilities have attracted students, postdoctoral researchers, users, and staff members from all over the world. I personally came to Los Alamos to perform my doctoral dissertation experiments at LAMPF, which was the first national facility for nuclear physics research. Over time, LAMPF has become the Los Alamos Neutron Science Center (LANSCE), and it remains a unique accelerator with world-class experimental facilities and a crucial element in recruiting the next generation of experimental scientists to Los Alamos National Laboratory.

A major strength of the Experimental Physical Sciences Directorate is our many user facilities. Three of them, the Center for Integrated Nanotechnologies (CINT), the Lujan Neutron Scattering Center at LANSCE, and the National High Magnetic Field Laboratory, are designated national user facilities—the first two by the Department of Energy Office of Science and the last by the National Science Foundation—because of the unique capabilities of the instruments and the broad international interest in using them.

We offer several additional facilities. The Weapons Neutron Research Center at LANSCE is an approved user facility of the National Nuclear Security Administration hosting more than 500 user visits per year and it has the most active industrial user base at the Laboratory. We have recently invested in the Trident Laser Facility and the Proton Radiography Facility to expand experimental capabilities and to develop larger user bases. We also offer the Electron Microscopy Laboratory and the Ion Beam Materials Laboratory to Los Alamos scientists.

This inaugural issue of *Experimental Physical Sciences Vistas* focuses on the unique capabilities of each facility to inspire ideas for potential synergies among them. I believe that if we consider the entirety of our facility capabilities in experiments, we will stimulate creativity and offer new combinations of problem-solving tools. For a number of the grand challenges we face, solutions will only be possible by simultaneously exploiting unique capabilities from multiple facilities. Each instrument within a facility uniquely contributes to a certain type of scientific experiment.

Susan J. Seestrom, Associate Director
Experimental Physical Sciences

By applying the capabilities of multiple instruments and facilities, a scientist can design experiments that could challenge a hypothesis under multiple sets of conditions and regimes. There are advantages to such integration: the commonality or difference of approach to the same problem may provide insight; the diversity of thought that arises from different communities working together could unleash creativity and enable breakthroughs.

Multi-facility integration is an important part of our vision and pursuit of a signature facility called Matter Radiation Interactions in Extreme (MaRIE)

Researchers have discovered that access to world-class instruments and staff, for only the marginal cost of travel, offers tremendous value. With minimal travel and training time, a researcher can execute multiple experiments in one visit, e.g., fabricate a nanostructure sample at CINT; measure its properties at various magnetic fields at NHMFL; and study its crystal structure at Lujan—a unique and powerful opportunity only available at Los Alamos National Laboratory.

Multi-facility integration is an important part of our vision and pursuit of a signature facility called Matter Radiation Interactions in Extreme (MaRIE). We deem MaRIE necessary to realize our Los Alamos vision of materials-centric scientific discovery, which we see as critical to the key national security missions: energy, nuclear weapons, threat reduction, and homeland security. MaRIE will enable us to make the transition from materials observation to materials control—the objective for material sciences in the next decade. More important to the nation will be the ability to apply functionally designed and controlled development of new materials to the grand challenge problems facing national security missions.

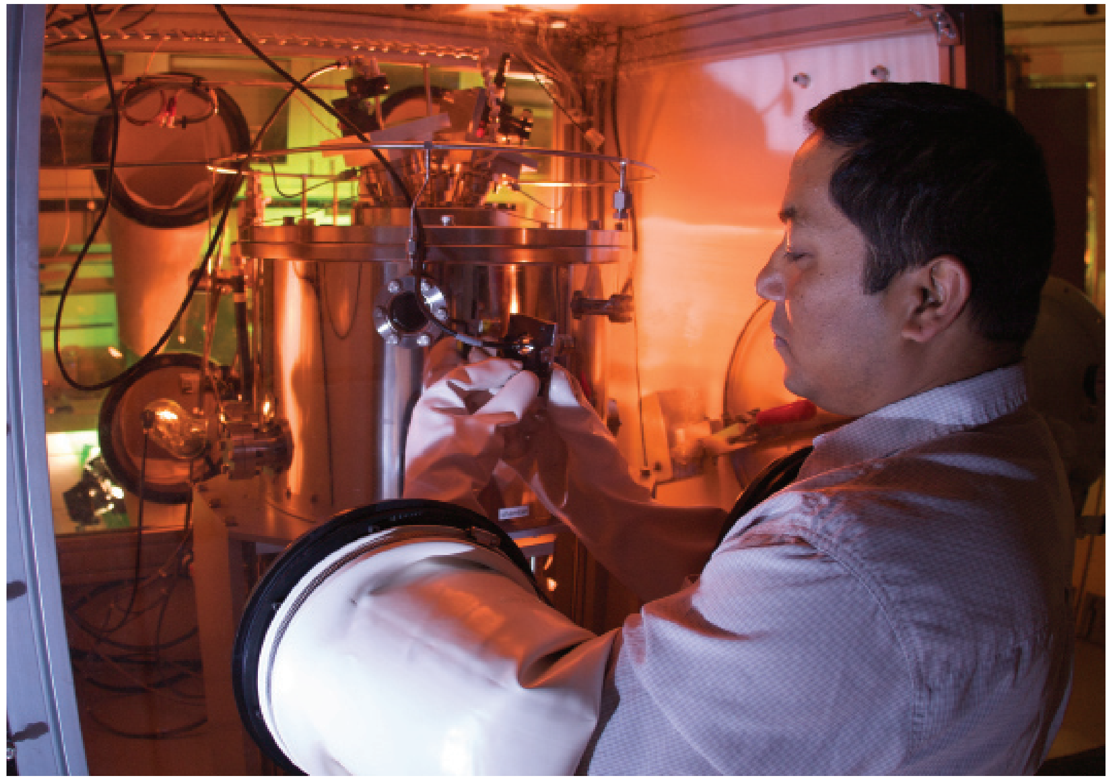
Our efforts to leverage all of our facilities and their associated user communities gives us a unique competitive advantage in attracting and recruiting scientists of international stature to Los Alamos and in pushing the envelope of materials science for national security missions.

Susan J. Seestrom

CINT
Center for Integrated Nanotechnologies

• CINT

Small scale, big science



Postdoctoral researcher Pradeep Manandhar prepares a chemical vapor deposition system for the growth of nanowires.

Nanomaterials—typically on the scale of billionths of a meter or 10,000 times smaller than the diameter of a human hair—offer different chemical and physical properties than bulk materials, as well as the potential to form the basis of new technologies. A nanometer is the scale at which the properties of materials, such as melting temperature, color, and magnetism, are established; it is also the realm where molecular biology operates. Understanding materials at the nanoscale will enable researchers to tailor their physical, chemical, and biological properties.

Nanotechnology's promise is the ability to design nanomaterials and nanosystems with properties tailored to specific needs such as strong lightweight materials, new lubricants, and more efficient solar energy cells. By building structures with architectural control at the level of single atoms, materials may be designed with enhanced mechanical, optical, electrical, or catalytic properties.

Distinguished CINT Postdoctoral Research Fellow Alfred J. Wooten examines luminescent quantum nanodots.

Innovative approaches to nanoscale integration

The Center for Integrated Nanotechnologies (CINT) is a Department of Energy (DOE)/Office of Science Nanoscale Science Research Center (NSRC) operating as a national user facility devoted to establishing the scientific principles that govern the design, performance, and integration of nanoscale materials. CINT is one of five NSRCs throughout the United States. These centers form an integrated national program, affiliated with major facilities at the DOE's national laboratories, to cover the diverse aspects of nanoscience and technology. This complex aspires to become a cornerstone of the nation's nanotechnology revolution, contributing to DOE's principal missions in national defense, energy, and the environment while providing an invaluable resource for universities and industries.

The distinguishing characteristic of CINT, which is jointly operated by Los Alamos and Sandia National Laboratories, is its emphasis on exploring the path from scientific discovery to the integration of nanostructures into the micro and macro worlds. Such integration is key to the exploitation of nanomaterials, and the scientific challenges that it poses are at the heart of CINT's mission. Study of these challenges involves the experimental and theoretical exploration of behavior, the development of a wide variety of synthesis and processing approaches, and an understanding of new performance regimes for nanomaterials.

The CINT community can access dedicated research capabilities in the Core Facility (in Albuquerque, New Mexico) and the CINT Gateway to Los Alamos. Together, these facilities provide laboratory and office space for researchers to synthesize and characterize nanostructured materials, theoretically model and simulate their performance, and integrate nanoscale materials into larger-scale systems in a flexible, cleanroom environment. Joint proposals involving other major research facilities at both locations are encouraged. These resources include the Los Alamos Neutron Science Center (LANSCE) and the National High Magnetic Field Laboratory (NHMFL), both also national user facilities, and the DOE National Laboratory Center for Solid-State Lighting Research and Development at Sandia. LANSCE's capabilities in cold neutrons, neutron reflectometry, and other neutron spectroscopies are essential tools for the study of complexity in nanomaterials. The National Science Foundation NHMFL Pulsed Field Facility, coupled with NHMFL facilities in Tallahassee and Gainesville, Florida, represents a unique nanoscale probe important for exploring nanostructured semiconductors, quantum systems, and complex materials.

Dedicated in 2006, the CINT Gateway to Los Alamos is a cutting-edge nanoscience facility.

A Sandia-Los Alamos collaboration

CINT operates as a national user facility. Access is via peer-reviewed technical proposals for independent or collaborative research, submitted in response to semi-annual calls for user proposals. CINT invites user participation from universities, industry, federal and state laboratories, and the international science community. The majority of the user program is precompetitive research that will be published in the open literature, which allows no-fee access to CINT. Proprietary research may also be conducted in accord with federal regulations for full-cost recovery. Information regarding the next calls for user proposals and instructions for proposal submission are available at the CINT Website at cint.lanl.gov.

The CINT Core Facility at Sandia National Laboratories in Albuquerque contains capabilities and expertise needed to support all CINT scientific thrust areas and provides a highly interactive environment to incubate new cross-disciplinary research teams focused on nanoscience integration challenges. It features low vibration for sensitive characterization, chemical and biological synthesis labs, a cleanroom for device integration, interaction areas and conference rooms, visitor office space, and high-speed communications. Staff at the Core Facility are from both Los Alamos and Sandia National Laboratories. To enhance open access to the user community, the Core Facility is located on DOE property on Eubank Avenue outside of Kirtland Air Force Base.

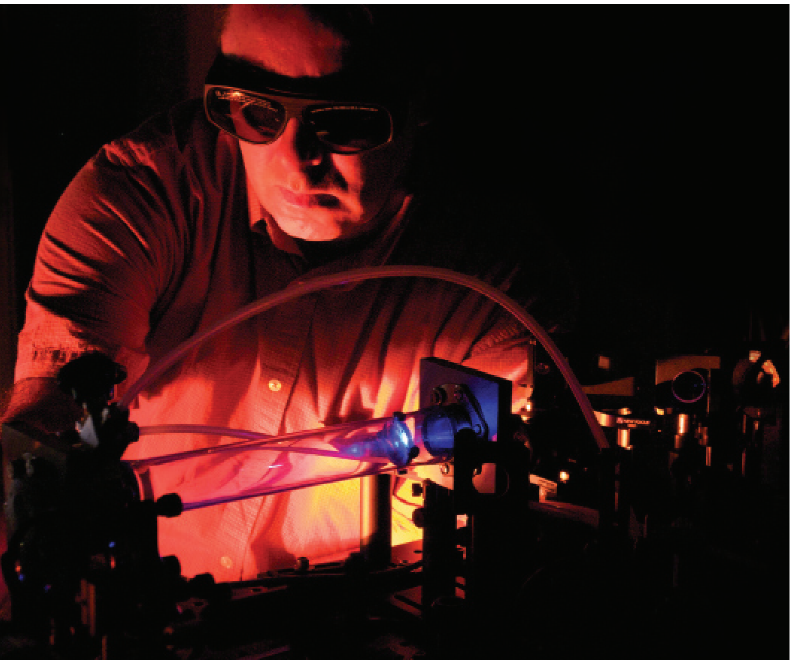
The CINT Gateway to Los Alamos Facility is located in the center of the Los Alamos Materials Science Complex and brings together materials science and bioscience capabilities. The facility features laboratory space dedicated to chemical and biological synthesis and characterization, biomaterials fabrication and characterization, optical microscopy and spectroscopy, physical synthesis, thin film fabrication, spatially resolved scanned probe characterization, advanced computation, and visualization.

CINT scientist and user community

Staffing at CINT consists of Laboratory scientists, postdoctoral researchers, and technical support staff. These researchers provide expertise that supports CINT science thrust areas and also operate specialized equipment within the CINT facilities. They directly interact with users from the external science community. CINT's scientific user community has been growing since CINT became fully operational in fiscal year 2007. During that year, there were 193 active user proposals and in 2008 there were 274 active user proposals. As a result of these proposals, there are currently approximately 400 users that interact with CINT each year, including those who come onsite and those who are involved in sample exchanges. CINT users are drawn from 34 states and 12 foreign countries and our proposal submissions come from U.S. academia (56%), DOE laboratories (23%), foreign academia (10%), U.S. industry (5%), other U.S. government entities (4%), and foreign laboratories (2%).

Thrust areas address nanoscale integration challenges

Building on the strengths of Los Alamos and Sandia National Laboratories to address key challenges in nanoscience integration, CINT has identified four science thrust areas. Through our discussions with CINT users, with our Science Advisory Committee, and within CINT workshops, we have engaged the broader scientific community in developing and refining these thrusts.

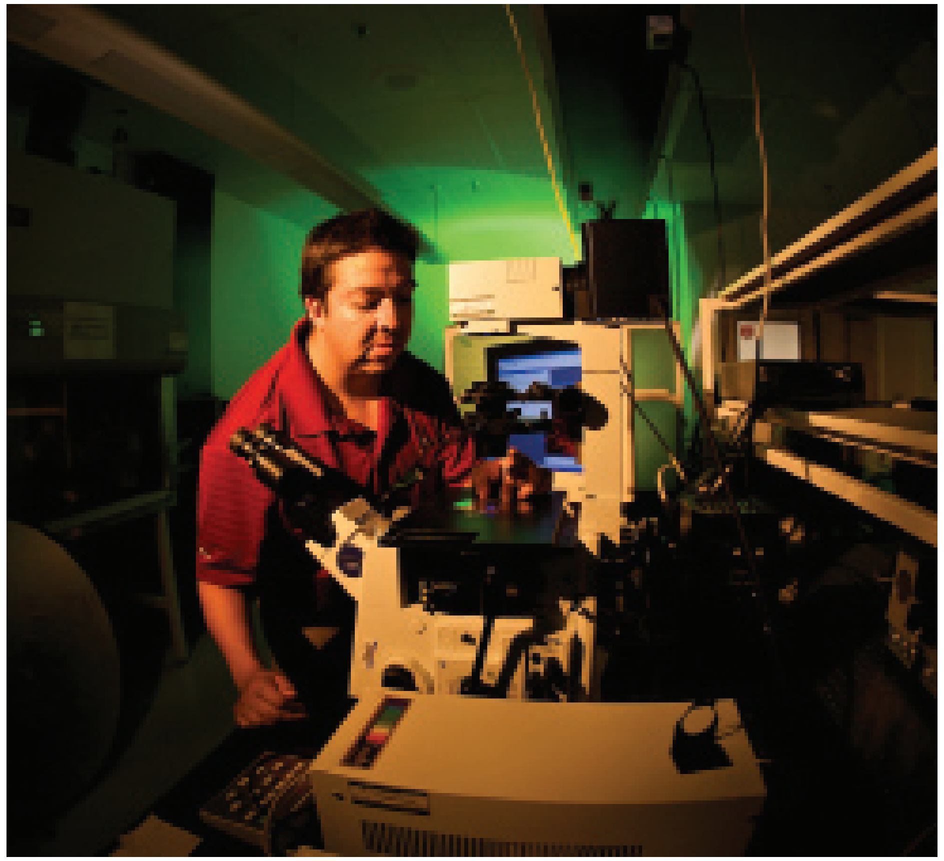


George Rodriguez uses a tabletop laser that promises to revolutionize high-resolution microscopy and spectroscopy in the lab.

Unique to CINT user and science programs are Discovery Platforms—modular, micro-laboratory designed and batch-fabricated chips designed for the purpose of integrating nano- and micro-length scales, studying the physical and chemical properties of nanoscale materials and devices, and directly accessing a wide range of CINT external diagnostic and characterization tools. Born from CINT's goal to provide a user-friendly environment where scientists from a wide range of backgrounds and disciplines can explore the interplay between microfabricated architectures and nanoscale materials and devices, these microlaboratories provide the opportunity to explore issues around the central theme of nanoscience integration. Discovery Platforms play a key role in building a unified CINT user community by allowing researchers to easily compare results and build upon previous advances to address complex, multiple length-scale problems. Current discovery platforms include the Cantilever Array Discovery Platform and the Electrical Transport and Optical Spectroscopy Discovery Platform.

The nanophotonics and optical nanomaterials thrust addresses the overall scientific challenge of understanding and controlling fundamental photonic, electronic, and magnetic interactions in nanostructured optical materials fabricated using both chemical and physical syntheses. Ongoing research includes colloidal synthesis of semiconductor, noble-metal, and magnetic-metal nanostructures; development of bottom-up assembly approaches for photonic materials; use of polymer-assisted thin film growth techniques and pulsed laser deposition to grow synthetically challenging complex metal oxides; application of lithographic methods to the fabrication of two- and three-dimensional photonic crystals; and physical synthesis to fabricate epitaxial quantum dots, quantum well structures, and quantum wires. Challenges in integration science are addressed by exploring new properties stemming from the creation of novel interfaces and hybrid structures and the development of new materials that bring together disparate material types. Capabilities within the thrust include advanced ultrafast and single-nanostructure spectroscopies, including various scan-probe techniques, able to explore energy transformations on the nanoscale from energy and charge transfer to electronic relaxation across multiple length, time, and energy scales.

The nanoscale electronics and mechanics thrust focuses on the scientific challenge of controlling the electronic and mechanical properties of nanoscale materials, as well as issues related to integration of a wide variety of these materials into nanosystems. Ongoing research includes plastic deformation; elastic and fracture properties on the nanoscale; coupled mechanical systems; electrical and thermal transport in low-dimensional systems, including coherent transport and interactions; coupling of mechanical and electronic properties; structural and electronic properties of nanowires; and materials interface properties investigation. This research is strongly supported by an effort in nanofabrication and microscale integration with an emphasis on fabrication of regular nanoscale arrays of electrically active structures, integration of electrical and mechanical systems, and integration with composite nanomaterials and biological systems. Unique tools in this thrust include molecular beam epitaxial growth of semiconductor heterostructures for producing ultraclean low-dimensional electron systems; chemical vapor deposition growth of electrically active heterogeneous nanowires; a high current state-of-the-art ion implanter; new tools for nano-manipulation; in situ scanning tunneling microscopy/transmission electron microscopy (STM/TEM) and specialized growth techniques for films, nanowires, and other nanostructures. This thrust is also developing two Discovery Platforms. The Cantilever Array Discovery Platform provides mechanical tools optimized for nanoscience experiments. The Electrical Transport and Optical Spectroscopy Discovery Platform enables reliable, high throughput electrical and optical measurements compatible with CINT fabrication and characterization equipment.



At CINT, scientists like Gabriel Montaño provide input in the use of integrated nanotechnology solutions to meet global needs in security, energy, and the environment.

The soft, biological and composite nanomaterials thrust focuses facilities and expertise on solution-based, "bottom-up" approaches for development of integrated nanomaterials. Synthesis, assembly, and characterization of soft or biological components and the integration of these components across multiple length scales to form functional architectures are of interest. Ongoing research consists of development of molecular and biomolecular recognition methods for materials assembly, development of transduction strategies for molecular-scale events, chemical and biomolecular functionalization of interfaces to control assembly and interactions of components, passive and active assembly of nanomaterials with complex and emergent behavior, single-particle and single-molecule spectroscopy, interfacial characterization, imaging, and microfluidic platform development. Capabilities and expertise within the thrust include molecular biology, organic and inorganic synthetic chemistry, surface chemistry, spectroscopy, single-molecule detection, scanning probe microscopy, optical imaging, and the design of microfluidic systems and other integrated architectures. Major facilities include laboratories and instrumentation for biochemistry, cell-culturing and biomolecular engineering, self-assembled material and thin film preparation, chemical synthesis, scanning probe microscopies, optical microscopy and spectroscopy, Langmuir-Blodgett troughs, interfacial force measurements, and spectroscopic or imaging ellipsometry.

The theory and simulation of nanoscale phenomena thrust area focuses on the theoretical and simulated understanding of the fundamental nanoscale phenomena that underlie integrated nanomaterials. Classical and quantum methods are applied to determine the emergent properties of nanoscale materials and systems as a basis of assembly of nanomaterials. A key area of interest is the interfacial interactions that are unique to the nanoscale and significant in determining the material properties. Ongoing research topics include passive and active assembly of nanomaterials with complex and emergent behavior, theoretical spectroscopy and nonlinear optical response, energy transfer and charge transport, DNA nanoelectronics, local defects, optical and tunneling probes, and mechanical properties of nanocomposites. Capabilities and expertise within the thrust include molecular theory methods, atomistic and coarse-grained molecular dynamics simulations, static and time dependent density functional theory, and many-body quantum methods. Major facilities include visualization hardware and software and parallel computer clusters.

Advancing integrated nanotechnology

Nanoscience integration challenges lie at the heart of applying nanomaterials to areas that are directly coupled with Los Alamos National Laboratory's and DOE's national security missions. CINT researchers and the CINT user community provide input in the use of integrated nanotechnology solutions to solar energy utilization, alternative energy technologies, biological imaging techniques, and advanced sensing and diagnostic concepts. These activities contribute to national security missions in the areas of energy research, environmental studies, and threat reduction. In order to further develop CINT's activities in the future, activities are also focused around specific nanoscience integration focal areas, with examples including membrane-based nanocomposite materials, heterogeneous nanowires, nanoplasmonics, and metamaterials. These areas, as they develop, will provide a continuing basis for the contributions of CINT to national and international needs in technology development and lead to a new generation of integrated nanotechnology advances.

Now that CINT is a fully operational user facility, we can focus more on developing connections between CINT and the other Los Alamos user facilities. There are several ways to approach sharing and integration among our facilities. Creating awareness and connecting people from different facilities can stimulate new ideas. To facilitate such recognition, a cross-facility team has been formed that has identified several interesting technical possibilities. For example, postdoctoral researchers jointly hired by user facilities could also be a source of new ideas. We are also exploring the concept of sponsoring a joint CINT-Lujan Center-National High Magnetic Field Laboratory user group meeting that would include workshops on topics of interest to joint scientific communities and enable these user facilities to attract users that would work at multiple facilities.

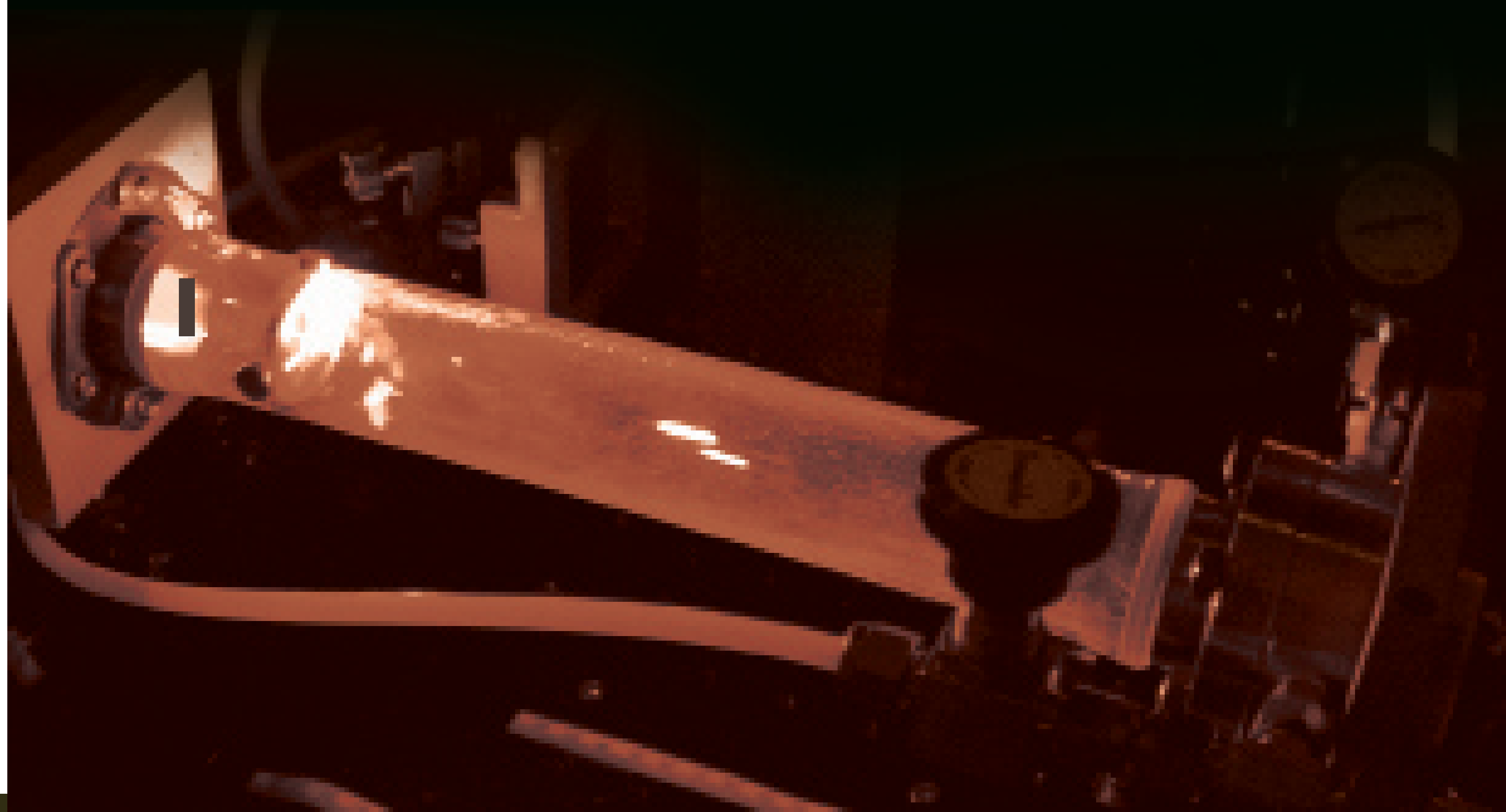
For more information about CINT and about how to become part of its ongoing user and science programs, please visit cint.lanl.gov.

Partnering for nanoscience discovery

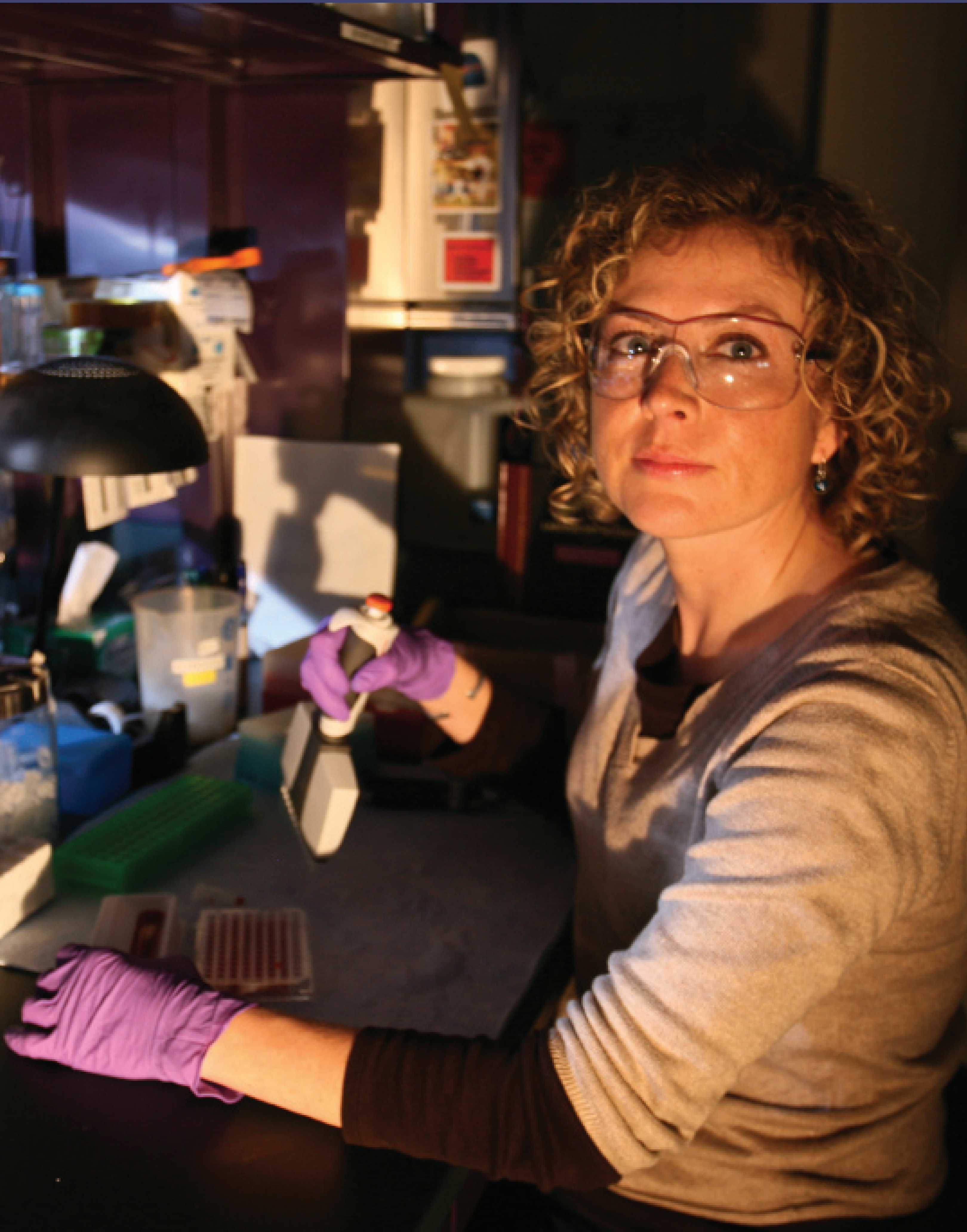
CINT is partnering with Sandia's Microsystems Engineering and Science Applications (MESA) personnel to create CINT Discovery Platforms. These modular, micro-laboratory designed and batch-fabricated chips are developed for the purpose of integrating nano- and micro-length scales and for studying the physical and chemical properties of nanoscale materials and devices. They are designed in a way that enables connections with the appropriate external electrical, optical, and fluidic devices. Examples of the current set of Discovery Platforms are the Cantilever Array Discovery Platform and the Electrical Transport and Optical Spectroscopy Discovery Platform.

The cantilever array platform is a multipurpose chip designed for research in the areas of nanomechanics, novel scanning probe technologies, chemical and biological sensing, magnetization studies, in situ transmission electron microscopy measurements, and physics of coupled mechanical systems. The platform is the same size as typical atomic force microscope (AFM) chips, and can be mounted in most AFMs. However, unlike AFM chips, this platform has multiple cantilevers projecting from all edges and it contains special microelectromechanical systems test structures in the center.

The electrical transport and optical spectroscopy platform is designed to enable fundamental investigations of the optical, electronic, and transport properties of a wide variety of nanomaterials. The platform provides a well-characterized way of interfacing materials with electrical contacts, providing means for considerable versatility in optical and transport measurements. The platform is also compatible with other measurement techniques such as scanning probe and electron microscopies. Fundamental science questions enabled by the platform include electronic transport in molecules, nanowires, and composite nanostructures; transduction of molecular-scale events to produce measurable electronic or optical signals; and control of electrostatic doping of organic thin films and composite nanostructures.



Argon gas pressure inside two-color plasma ionization gas cell.



by Karen E. Kippen

Jennifer Martinez

At home on her family's land in southern Colorado, Jennifer Martinez fixes fences and digs ditches.

At home in her laboratory at the Center for Integrated Nanotechnologies (CINT) at Los Alamos National Laboratory, Martinez designs and characterizes the interface between inorganic and biological systems using biomolecular recognition strategies, with the goal of creating functional nanoscale materials.

A dichotomy perhaps, but not when you consider she grew up in a family of outdoorsmen.

"There's not a scientist in my family, but my dad—and my whole family—are good naturalists," Martinez said. "Perhaps that's where I get my inspiration."

For this as well as other inspired research, Martinez was recently recognized with a prestigious Presidential Early Career Award for Scientists and Engineers. The award is the highest honor bestowed by the U.S. government to outstanding scientists early in their careers. She was one of eight researchers funded by the Department of Energy's Office of Science and the National Nuclear Security Administration to be recognized, and one of 68 researchers supported by nine federal departments and agencies to receive the award.

Martinez said she appreciates the honor, "although I can think of many others here at Los Alamos who are as—or more—deserving," and considers it "a great incentive to do some nice work."

Martinez, a staff scientist in CINT, received a bachelor of science degree in chemistry from the University of Utah and a doctoral degree in bioinorganic chemistry from the University of California, Santa Barbara.

She joined the Laboratory in 2002 as a Director's Postdoctoral Fellow, performing biological sensing research, which has applications in medical diagnostics as well as in the detection of biological threat agents.

She described the work as "an incredible challenge" that allowed her to work with a diverse set of people. "Los Alamos has really great scientists…who are used to collaborating with each other," she said. "People are engaged. They are likely to talk to you about the science and want to get involved in new science."

Martinez finds that spirit of cooperation energizing, and at CINT, she said, a walk down the hall and a knock on a door puts her in touch with people from a range of disciplines—from theorists to biochemists to spectroscopists. "To have so many people with very diverse backgrounds in one building, working in one group, is amazing."

Martinez now splits her time between working with visiting scientists who come to CINT to perform cutting-edge nanoscience and with her Los Alamos colleagues on a range of basic research projects.

"Jennifer's very valuable in terms of bringing in new users from the external scientific community and ensuring they have a good experience while working here at CINT, and being able to move ahead projects that are quite interdisciplinary in nature," said Andrew Shreve, a leader in the soft, biological and composite nanomaterials area of CINT. Shreve works together with Martinez on a project using biological strategies to develop new materials.

Martinez's research on developing high-yield synthesis of metal nanoclusters, in which she collaborates with Shreve, Brian Dyer, Jim Werner, Dung Vu, Sergei Ivanov, and Andrei Piryatinski, has biosensing applications and could eventually lead to better cancer detection techniques. Her research into biocompatible polymers, in which she works with Emily Schmidt, Andrew Bradbury, and Csaba Kiss, could lead to stronger, flexible, highly biocompatible materials of interest to the medical community.

Her work has been published in high-profile journals such as *Science*, *Proceedings of the National Academy of Sciences*, *Journal of the American Chemical Society*, and *Langmuir*.

"Jennifer is one of those people who adds to our capability base tremendously," said Basil Swanson, one of Martinez's former postdoctoral mentors and a Chemistry Division staff member. Much of the research at Los Alamos requires a cross-discipline effort, Swanson said, and "she is able to talk the language of the people—the engineers, who help us develop our (devices and products) and the people in the hard-core sciences."

Jennifer Martinez is a 2009 recipient of a Presidential Early Career Award for Scientists and Engineers.

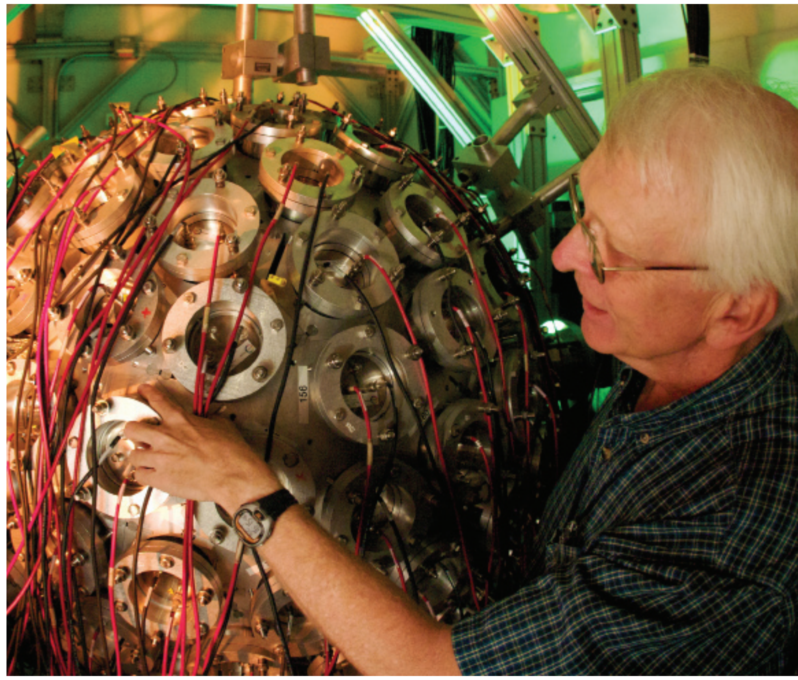
LANSCE

Los Alamos Neutron Scattering Center

The Los Alamos signature science facility

The Los Alamos Neutron Science Center (LANSCE) is the signature experimental science facility at Los Alamos National Laboratory (LANL), underpinning the Laboratory as a world-class scientific institution. LANSCE is a national resource that supports basic and applied research for national security and civilian applications. At the heart of LANSCE is a powerful linear accelerator that accelerates protons (and H^- ions) to 800 million electronvolts (MeV). When these protons strike a tungsten metal target, neutrons are produced by a process called spallation.

Protons and neutrons are used in a wide range of applications that help the nation maintain its leadership in many areas of science and technology. Research conducted at LANSCE helps maintain the nation's nuclear deterrent and counters the spread of weapons of mass destruction. LANSCE also lays the foundation for many products we use in our daily lives by supporting materials science and technology.



John Ullman with the Detector for Advanced Neutron Capture Experiments, a multidisciplinary instrument designed to study neutron capture reactions on small quantities of radioactive or rare stable nuclei.

Although the basic accelerator is more than 30 years old, LANSCE remains a premier accelerator-based user facility for national security and fundamental science because of its strength in technological innovation and its capacity to tailor its intense proton beam and beam delivery modes to changing scientific and programmatic needs.

LANSCE is one of the Laboratory's most important windows into the academic community and a source for many of our brightest early-career scientists. LANSCE can claim no less than 1,200 recruits to the Laboratory's technical staff during the last 30 years and it remains a magnet for the best and the brightest.

Neutron scattering instruments in the Lujan Center beam room.

As a window into the future, LANSCE is crystal clear

The hot cell at the Isotope Production Facility, located at the beginning of the LANSCE proton accelerator.

Five major experimental facilities operate simultaneously at LANSCE using high-energy protons (or negatively charged H-ions) from the accelerator or neutrons generated from spallation targets. These facilities are the following:

- The Lujan Neutron Scattering Center is a major national center annually hosting more than 300 scientists from around the world who perform materials science research and low-energy neutron nuclear physics studies using a variety of uniquely designed instruments.
- The Weapons Neutron Research Facility consists of a high-energy neutron source and a flexible array of neutron flight paths enabling nuclear measurements for the weapons program, civilian applications, and basic nuclear physics research. It is also operated as a user facility used annually by approximately 300 investigators.
- The Proton Radiography Facility provides a unique capability for the study of dynamic processes using 800-MeV protons and a magnetic-lens imaging system. Proton pulse trains allow observation of "movies" of dynamic events on the microsecond timescale.
- The Isotope Production Facility uses 100-MeV protons impinging on specialized targets to produce radioisotopes for both research and nuclear medicine.
- The Ultracold Neutron Source is a facility producing ultracold neutrons moving with speeds of less than 8 meters/second. These neutrons provide an ideal system for high-precision tests of the weak interaction as described in the standard model of particle physics.

LANSCE facilities are available to qualified scientists and engineers through a competitive proposal process. Each year LANSCE receives many more worthy proposals than it can accommodate. The people who conduct experiments at LANSCE represent a cross section of the research community—universities, industry, and other national and federal laboratories—and come from all over the world. Their research ranges from the fundamental, such as investigation of parity-symmetry-breaking in the weak interaction, to the applied, such as assessing neutron-induced single-event upsets in the latest generation of semiconductor devices. One of the great strengths of the LANSCE user program is its ability to attract large numbers of graduate students and postdoctoral researchers. Maintaining a strong component of students, postdoctoral researchers, and early-career scientists is a priority for LANSCE. We are fulfilling a mandate to help train and advance the next generation of scientific leaders—some of whom will join the Laboratory staff.

The following briefly describes the unique capabilities of each LANSCE facility. For more information, please contact the LANSCE user program office via the LANSCE Website at lansce.lanl.gov.

Lujan Neutron Scattering Center

The Lujan Neutron Scattering Center (Lujan Center) is a major international user facility for studying the structure and dynamics of advanced materials and biological macromolecules.

The Lujan Center has 17 flight paths, 12 of which are instrumented for various neutron scattering techniques to study materials. In addition, three flight paths are instrumented for neutron nuclear science; one is instrumented for transmission neutron spectroscopy and two are currently available for future research activities.

The Lujan Center delivers one of the highest-peak neutron fluxes in the world for research in materials science and engineering, magnetic materials, polymers, chemistry, earth science and geology, structural biology, and condensed matter physics. Neutrons have the unique property of high penetrating power, and thus provide a vehicle for true three-dimensional information on atomic and magnetic structure. In addition, the energy of the thermal neutrons can be shifted by interacting with materials, providing fundamental information on atomic lattice vibrations and magnetic excitations. Even though neutron fluxes are low compared to synchrotron-produced x-rays, the unique sensitivity of neutron scattering to light as well as heavy atoms makes this technique indispensable for studying biological materials and other hydrogen-containing systems.

The position and motion of atoms as revealed by neutron scattering affect properties such as strength, compressibility, density, heat capacity, and so forth, thus providing input to one of the grand challenges of materials science, known as the structure–property relationship. Understanding the connection between material structure at the atomic level or the nanoscale and macroscopic material properties promises both better use of existing materials and the ability to design new materials for specific applications ("designer materials"), a capability that will revolutionize manufacturing and technology in the future. Lujan Center users and researchers have discovered the nanoscale structure of high temperature superconductors, determined the role of strain in stabilizing nanometer-scale magnetic layers used in computer disk read heads and in future magnetic random access memory devices, and located specific hydrogen atoms in enzymes and determined the role of those atoms in binding drugs or activating metabolic pathways.

The evolution of materials science means a bright future for LANSCE as plans develop to capitalize on the Lujan Center's high-peak flux of cold neutrons and low pulse-repetition rate. Operating at a pulse repetition rate of 20 hertz, the Lujan Center is unique compared with other existing or planned facilities. For example, the Spallation Neutron Source in Oak Ridge, Tennessee, operates at 60 hertz, and ISIS, the pulsed neutron and muon source in the United Kingdom, currently operates at 50 hertz. Low repetition rate allows for the use of all the cold neutrons in a pulse, and thus leads to efficiency. By fully using the neutron scattering instrumentation, the Lujan Center takes full advantage of its high-peak flux for cold-neutron scattering research. The Lujan cold neutron capability is at the heart of a planned upgrade—the Enhanced Lujan Project—that will lead to full utilization of all Lujan flight paths and a suite of truly world-class instruments.

Neutron/nuclear science capabilities—The WNR Facility

The Weapons Neutron Research (WNR) Facility houses a flexible array of instrumented flight paths enabling nuclear science measurements for the weapons program, civilian applications, and basic nuclear physics research. This facility is the only sufficiently intense broad-spectrum high-energy neutron source for providing the nuclear data necessary for predicting nuclear weapons performance. Developing this science-based predictive capability is crucial to certifying the present and future U.S. nuclear deterrent without testing.

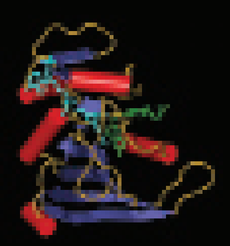
New nuclear data are needed for two major aspects of stockpile stewardship: calculating the energy production of a nuclear weapon and benchmarking predicted nuclear performance against past aboveground or underground test data. The unique research effort at the WNR, coupled with the Laboratory's capabilities for fabricating and handling actinide and radioactive materials, provides an unmatched resource for meeting the requirements of stockpile stewardship. Among these requirements are measuring cross sections on unstable isotopes with short half-lives in order to understand radiochemistry results of past nuclear weapons tests, determining cross sections for neutron-induced reactions on actinide isotopes and weapon materials, and improving our understanding of fission energy production in weapons systems. For example, techniques have recently been demonstrated that enable measuring the fission cross section of samples as small as 10 nanograms and investigating fission cross sections of short-lived isotopes and isomers for defense science applications and nuclear astrophysics.

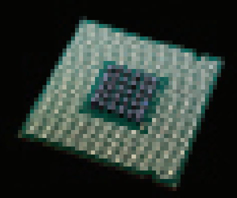
A unique facility at the WNR is the Irradiation of Chips and Electronics (ICE) House. As electronic components continue to decrease in size and operate at lower voltages, their vulnerability to failures caused by single-event upsets (SEUs) by atmospheric neutrons may increase. A few years ago, the WNR began to provide the semiconductor electronics industry with an invaluable capability to irradiate semiconductor components and assemblies and quantify their vulnerability to neutron-induced SEUs. The neutron production spectrum at the WNR closely mimics the naturally occurring neutron energy spectrum seen by aircraft electronics in flight and electronic systems at sea level, but at one million times the intensity. More than 50 different companies have tested semiconductor devices at the WNR facility and the WNR now provides the international standard for testing neutron-induced upsets in electronics.

The Proton Radiography Facility

The Proton Radiography (pRad) Facility provides a unique capability to study dynamic processes using 800-MeV protons and a magnetic-lens imaging system. Because protons interact with materials through both the strong nuclear force and the electromagnetic force, transmission measurements allow simultaneous imaging and determination of material properties.

Los Alamos National Laboratory developed and successfully applied pRad to meet the mission requirements of stockpile stewardship. Proton radiography is a powerful tool for elucidating basic principles of how nuclear weapons work. Because it can take many sequential pictures of an exploding system, it is arguably the most valuable single tool available to interrogate the hydrodynamic phase of a weapon. It is necessary to develop and validate quantitative models of material properties and hydrodynamics for this phase that can be implemented in new computer simulation codes from the Advanced Simulation and Computing Program. These models must capture critical hydrodynamic behaviors with high accuracy, and achieving that goal sets the hydrodynamic data requirements. Although many diagnostic tools have been developed to assess the hydrodynamic behavior of materials, most rely on surface measurements and are unable to interrogate the critical state variables and stress-strain response in the interior of the materials. Modeling depends on accurately capturing the time evolution of the hydrodynamics on a microsecond timescale. Proton radiography, with its ability to penetrate and accurately produce movie images of the interior of highly compressed materials, as well as its highly flexible and precisely recordable pulse format, is uniquely suited to providing these necessary data for weapon certification codes and models.





LANSCE conducts research across a wide range of disciplines. Images above (from left): Using the Protein Crystallography Station to determine the detailed structures of large biological molecules, drugs can be developed that attack disease-causing molecules; concealed nuclear materials in cargo containers and trucks entering the country can be revealed by technologies using neutron science; ways to improve semiconductor technology are explored at the Irradiation of Chips and Electronics House by industry scientists; and magnetic materials research involving thin film magnetic properties promises to improve the performance of computer storage media.

Isotope Production Facility

The new Isotope Production Facility (IPF) continues a 30-year Los Alamos tradition of supplying accelerator-produced radioisotopes for both research and nuclear medicine. Los Alamos and Brookhaven National Laboratories have the only such facilities in the United States. A new proton transport line delivers 100-MeV protons from the existing LANSCE accelerator to the IPF target station. That station is designed specifically for the efficient production of radioisotopes. Targets of different materials are irradiated in a stacked configuration to allow varying the incident neutron energy and thereby optimizing production of the desired radioisotopes. Some of those are distributed through pharmaceutical companies for use in cardiac scans and other medical diagnostics as well as medical treatment and research. Others are used for nuclear data experiments of importance to the weapons program, threat reduction studies related to the dispersal of radioactive materials, and basic nuclear physics research. The IPF was designed to operate with minimal impact on scheduled beam delivery to other experimental areas at LANSCE.

Ultracold Neutron Facility

The Ultracold Neutron (UCN) Source has recently been constructed and commissioned at LANSCE. Ultracold neutrons have millikelvin temperatures and move at speeds of less than 8 meters per second. Because their wave functions are totally reflected from certain materials, they can be stored in a specially designed container, far from background radiation. Thus UCNs provide an ideal system for high-precision tests of the weak interaction as described in the standard model of particle physics. At a planned current of 4 microamperes, preliminary measurements indicate that the UCN source at LANSCE will be the most intense of its kind worldwide. Once the LANSCE source becomes operational at full power, a series of fundamental physics measurements will be conducted, the first of which is a measurement of the β-decay asymmetry resulting from the decay of polarized UCNs. This experiment could detect physics beyond the standard model, thereby changing our ideas of how the fundamental forces in the universe work. A future goal for the UCN Facility is to operate as a fourth national user facility at LANSCE for research delving into the basic structure of matter.

The source uses solid deuterium at 5 kelvin to cool or moderate neutrons from a tungsten spallation target coupled with a set of graphite-beryllium and cold polyethylene moderators. The ultracold neutrons pass through guide tubes to nearby experiments.

LANSCE leverages other Los Alamos capabilities and resources

The success of an institution depends on the facilities, people, and purpose to which it is dedicated. For 30 years, LANSCE has created a unique scientific environment, attracting scientists from around the world to work together on high-stakes issues related to global security, as well as on exciting challenges at the frontiers of knowledge. Today's national and global security imperatives lend extra emphasis and meaning to research that already has high intellectual merit.

The last several years have seen a steady stream of new technologies come online at the LANSCE user facilities: four new world-class instruments for high-precision nuclear physics measurements at the WNR and Lujan Center; high-resolution imaging devices for pRad; the first facility for ultracold neutron research; and seven new instruments for materials science and bioscience on the floor at the Lujan Center. The Lujan Center, in combination with the Center for Integrated Nanotechnologies and the National High Magnetic Field Laboratory Pulsed Field Facility, makes Los Alamos a premier destination for materials scientists interested in materials structure and synthesis, nanoscience, structural biology, and high magnetic fields and pressure. The new LANSCE instruments and Los Alamos facilities were supported through investments by the National Nuclear Security Administration Office of Defense Programs, the Office of Basic Energy Sciences in the Office of Science at the Department of Energy, the National Science Foundation, and the Laboratory-Directed Research and Development Program at Los Alamos.

Not surprisingly, this burst of creativity and investment has been accompanied by a steady and dramatic increase in the number of experiments, users, and individual user visits, as well as in the level of user satisfaction every year since 2001. The demographics are also impressive. At the Lujan Center, almost half the users are students and postdoctoral researchers conducting publishable research of a more fundamental nature, and nearly two-thirds are early-career scientists. A contributing factor to these healthy demographics is the LANSCE Neutron Scattering School, a topical school started in 2004 that hosts 30 students for nine days of hands-on experimentation as well as instruction by a dozen world-class lecturers. Thus, LANSCE continues to be a magnet facility for scientific talent. The Laboratory can point to well over 1,200 people who have joined the Laboratory permanently after having been at LANSCE, and many of them have contributed significantly to the Laboratory's core mission.

Future plans—LANSCE-R

Future national missions will require enhanced LANSCE capabilities to support a spectrum of national security and basic science missions. Proposed LANSCE performance enhancements are focused to address specific mission requirements for multiple sponsors over the next 20-plus years. Our strategy is to start with enhancements to LANSCE facilities that fully exploit existing capabilities using 800-MeV protons and then to proceed with upgrades to accelerator energy and power that enable new and significant upgrades to facility performance. The enhancements will result in major benefits.

The LANSCE facility serves as a cornerstone in our national security and defense missions through its scientific excellence in research critical to those missions. Future LANSCE enhancements will ensure that this important role in national defense is maintained over the next two decades.

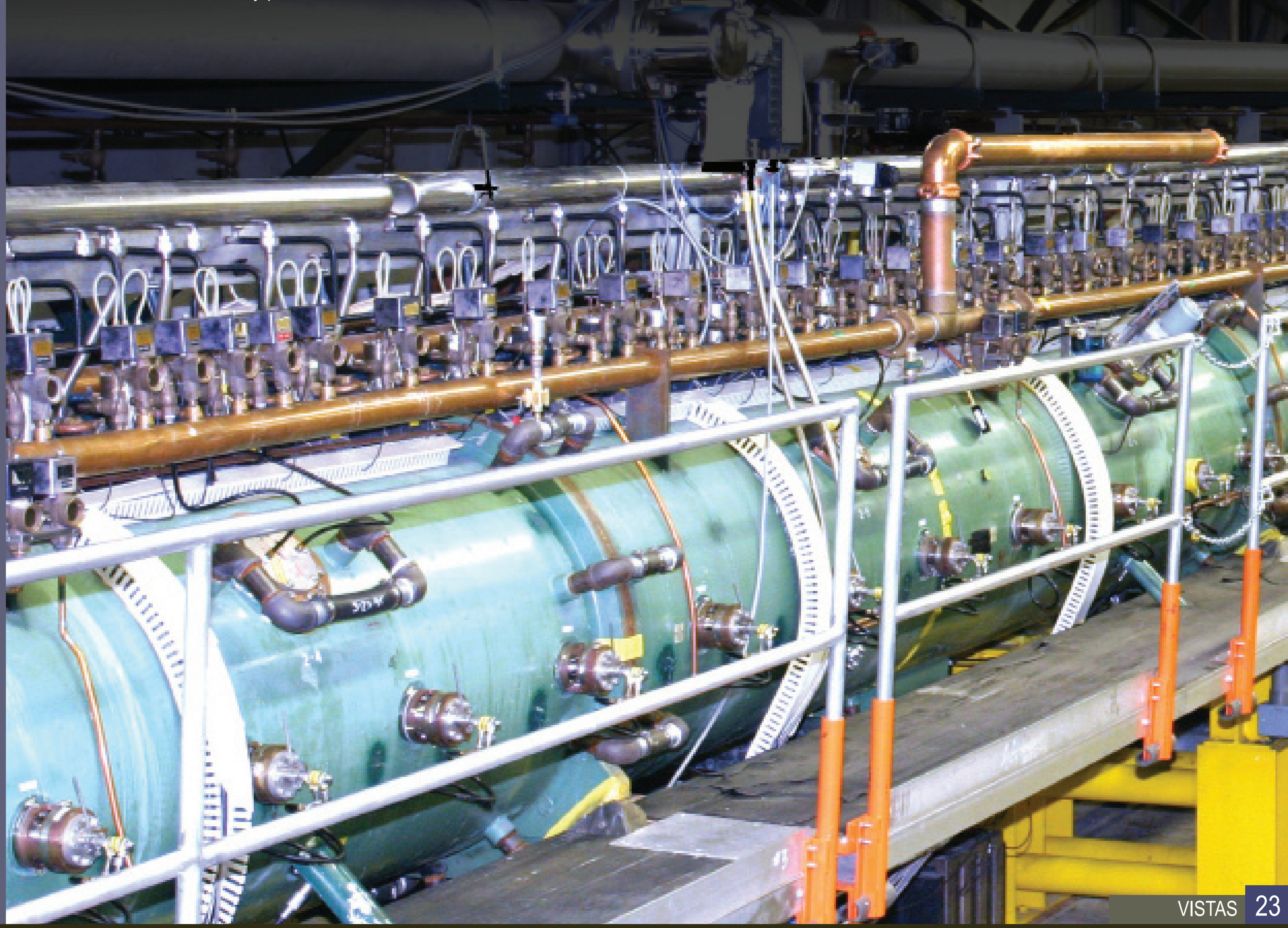
Plans to refurbish the facility and extend its role are underway. The LANSCE refurbishment (LANSCE-R) project is designed to sustain reliable facility operations well into the next decade for defense research and applications. A Materials Test Station, delivering an intense fast neutron flux, has been designed for exploring advanced nuclear energy options. A newly commissioned ultracold neutron source user facility will make high-precision tests of the standard model of elementary particle physics. Upgrades at the Proton Radiography Facility will enable high-resolution high-speed imaging of hydrodynamic instabilities and detonation physics of importance to stockpile stewardship. Enhancements to the existing Lujan Neutron Scattering Center will ensure its preeminence in cold, long-wavelength neutron scattering for the foreseeable future. These and other plans promise that LANSCE will support the nation's nuclear deterrent, energy security, health and welfare, and leadership in science for many decades to come.

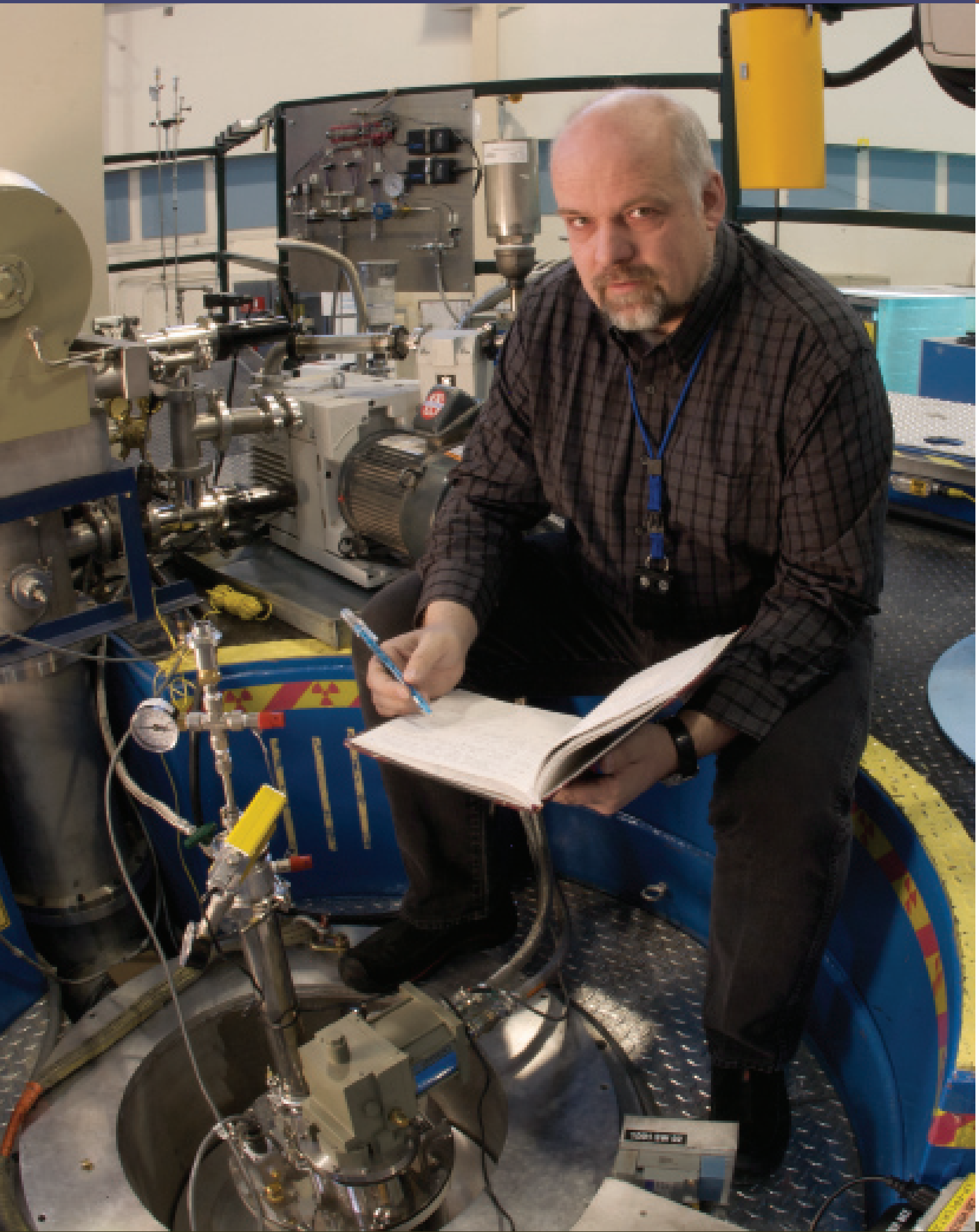
Jarek Majewski, instrument scientist for the Surface Profile Analysis Reflectometer, a state-of-the-art neutron reflectometer used to study chemical density profiles of ultrathin layers in a variety of environments.

The second stage of the LANSCE proton accelerator. Here, protons are traveling at 64% the speed of light.

Faster than a speeding bullet

The heart of the Los Alamos Neutron Science Center is a highly flexible linear accelerator (linac) system, one of the most powerful in the world, that can accelerate up to 1 milliampere of protons to an energy of 800 million electronvolts (MeV) (84% the speed of light), and then deliver the protons to multiple experimental areas. The linac can also accelerate simultaneously negative hydrogen ions to 800 MeV. Protons at 100 MeV are used at the Isotope Production Facility for making medical and other short-lived radioisotopes. Pulses of 800-MeV negative hydrogen ions are used at the Proton Radiography Facility for imaging dynamic events related to nuclear weapons performance and are also sent to heavy-metal targets at the Weapons Neutron Research (WNR) Facility. At the WNR, proton–nucleus collisions in the targets generate large numbers of neutrons (approximately 20 neutrons per proton) through a process called nuclear spallation. The neutron pulses, in turn, are used for materials irradiation and basic and applied nuclear science research. The negative hydrogen ions are also injected into a 30-meter-diameter Proton Storage Ring, which compresses the 625-microsecond pulses into a 125-nanosecond (half-width at half-maximum) intense burst. Those intense proton bursts produce, through nuclear spallation, bursts of neutrons for neutron scattering studies of material properties at the Lujan Center and for nuclear physics research at the WNR. In addition, a newly commissioned ultracold neutron research facility is beginning the exploration of fundamental nuclear physics with experiments designed to test the standard model of elementary particles.





Thomas Proffen

With a gentle grin, Thomas Proffen likes to say that he has three children. His largest child is the size of a Greyhound bus and weighs 40 tons.

Proffen did indeed conceive the Neutron Pair Distribution Diffractometer, an instrument housed at the Lujan Neutron Scattering Center that uses neutrons to reveal the atomic structure of matter. The Lujan Center scientist was hired in 2001 to design and construct the instrument's upgrade.

With the diffractometer fully functional in 2003, Proffen is, as instrument scientist, solely responsible for its operation and care, 24 hours a day. The valuable instrument is used around the clock. Do visiting scientists really call him in the middle of the night? "They are entitled to," he said with pride.

The diffractometer is colossal in size. Scientists don't manipulate the instrument so much as climb aboard. "We move equipment in and out with a big, overhead industrial bridge crane," Proffen said. He possesses a special crane driver's license, required for lifting and moving objects of 15-tons or heavier.

Proffen received his doctorate degree in crystallography from Ludwig Maximilians University in Munich, Germany. With a smile, he said that despite what some may imagine, crystallography has "nothing to do with healing crystals." Then with a bigger smile, he said, "If I opened up a little healing crystal business maybe I could make more money.

"Crystallography is actually closely related to material science and condensed metaphysics," Proffen said, explaining crystallography's relation to neutrons. In Germany, Proffen studied the structure of artificial diamonds, called cubic stabilized zirconia. This clear, sparkling crystal is used as an oxygen sensor in automobiles and is more commonly known for its use in jewelry. Zirconia are interesting to scientists, who study deviations in their orderly crystal structure.

While completing his degree Proffen studied large single zirconia crystals. He now performs diffuse scattering experiments on powders. Some materials can't be made into a single large crystal, so powder analysis is an important advancement. Lujan Neutron Scattering Center Director Alan Hurd said that scientists like Proffen use a stream of neutrons like a flashlight to explore the atomic structure of powdered materials.

With doctorate in hand, Proffen and his wife decided they wanted to live in Australia. According to Proffen, his thesis advisor pointed out that a competing laboratory was in Canberra, Australia. Proffen jokingly recalled the two labs were "arch-enemies," each favoring different models to describe diffuse scattering in stabilized zirconia. His former competitor jumped at the chance to hire Proffen because of his diffuse scattering experience.

Proffen, working with Richard Welberry, a chemistry professor at the Australian National University, eventually devised a new model to understand zirconia. In doing so, they settled the conflict that had divided Munich and Canberra.

After Australia, Proffen said he learned about "the powder side of things" during his postdoctoral work at Michigan State University. This experience led to his position at Los Alamos doing powder diffractometry.

The Neutron Pair Distribution Diffractometer is part of the Los Alamos Neutron Science Center, which generates neutrons for research. There, protons are slammed into a chunk of tungsten to break loose neutrons. Neutrons, like x-rays, are used to see inside things and neutrons are used to measure distances as small as 0.1 nanometer. To visualize how small this is, imagine enlarging a grain of sand to the size of Mount Everest. At that magnification, 0.1 nanometer would still be thin as paper.

Can Proffen really measure the distance between single atoms? "Yup," he said.

Proffen is unsure how to describe his experimental method. Orderly? Efficient? German? After some thought, he admitted all apply. James Rhyne, Lujan Neutron Scattering Center deputy director for science, is more direct: "Thomas is not afraid to work hard if it will produce results."

Thomas Proffen is the instrument scientist for the Neutron Pair Distribution Diffractometer, used to determine local structure in amorphous and crystalline nanomaterials.

Aaron Couture

The chance to make an impact, perform hands-on work, and pursue a variety of research opportunities all drew Aaron Couture to Los Alamos National Laboratory.

Couture, a nuclear physicist with the Neutron and Nuclear Science group of the Los Alamos Neutron Science Center (LANSCE), balances his time between experiments in nuclear astrophysics, nuclear energy, and for the Laboratory's isotope program. He uses the Detector for Advanced Neutron Capture Experiments (DANCE), a one-of-a-kind multidisciplinary instrument designed to study neutron capture reactions on small quantities of radioactive or rare stable nuclei, to perform tests that can be done nowhere else.

The strength and diversity of the Laboratory's researchers, with whom he frequently collaborates, "only enhances the experience," Couture said. Los Alamos "is a really fantastic place to be."

Couture discovered a taste for "coming up with new ways of doing things," he said, when, as an undergraduate student at the University of Notre Dame, he signed up to help construct an accelerator to be used in low energy nuclear astrophysics research. Although much of it was grunt work, "it was a really good experience," he said. "I got to touch everything. There aren't many programs like that." In 2006 he earned his doctorate degree in physics from the Indiana university.

When considering where to perform his postdoctoral research, Couture chose Los Alamos, because "the attractive equipment was here," he said. "And from my point of view that was a big advantage."

There was also, "a lot of opportunity to make an immediate impact… (At Los Alamos) you are encouraged to be independent, to build things like a research program," he said, and unlike at universities, "there doesn't feel like there is a hierarchical structure." As well, the possibility of a two- or three-year appointment turning "into a permanent position is incredibly rare at a university."

In his astrophysics research, Couture uses DANCE to better understand the origins of elements and develop stellar models. Using the instrument's unique neutron flux, efficiency, and segmentation capabilities, Couture said, "we can do things in nuclear astrophysics here we can't do anywhere else."

Aaron Couture is the instrument scientist for flight path 12 at LANSCE, which is used for basic nuclear physics experiments.

For his work in support of the Advanced Fuel Cycle Initiative (AFCI), Couture uses DANCE to capture cross-section measurements to better predict how materials to be used in fast nuclear reactors behave and how leftover nuclear materials should be treated. The result could mean a new generation of more cost-efficient nuclear reactors.

"It's the uncertainties that drive the economics, especially when you're talking about the next fleet of nuclear reactors," said Tony Hill, chairperson of the nuclear physics working group for AFCI at Los Alamos. Couture, Hill said, is one of the scientists providing "measurements to this program at a rate of two isotopes per year with really unprecedented precision."

Couture uses a similar technique to aid in the development of bulk isotopes for the Laboratory's isotope program. Isotopes are produced for applications ranging from medical research to basic science.

When the Laboratory recently reestablished the capability to measure proton cross sections—a capability unique in the country—Couture was "instrumental in setting up our (data collection system) to make the experiment successful," said Donna Smith, isotope program manager at Los Alamos. "He was one of our go-to guys."

Couture, who Smith described as "good at brainstorming… enthusiastic," is also playing a role in moving the program forward by looking for connections between nuclear physics and isotope production.

He is also the instrument scientist on flight path 12 at LANSCE, in the last year responsible for coordinating five unique experiments from 16 different institutions with 30 individual researchers. Couture not only serves as a liaison between the Laboratory and the users for safety and security issues, but also provides technical assistance during experiments.

At the heart of all these pursuits is nuclear physics. Working on such diverse projects "is challenging, interesting, exciting, and sometimes frustrating," Couture said. "It can be difficult to find a balance."

Admitting he likes to get at the underlying challenges, Couture said things start to get interesting "when a new set of thinking has to be learned, where the problems have (to be discovered), and where the impact can be made." In the end, he said, "I like to try to solve things."

NHMFL

National High Magnetic Field Laboratory

Jonathan Betts assembles the cryostat top of the 60-tesla Long-pulse Magnet.

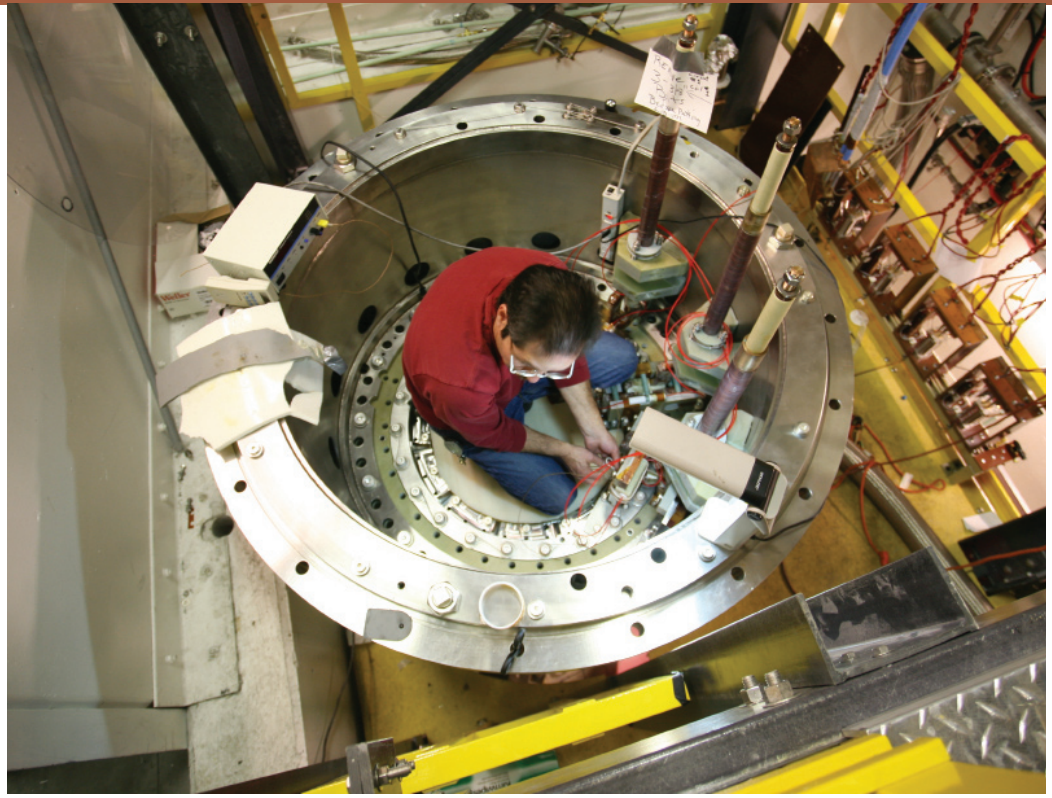
In extreme conditions

The Single-turn Magnet, capable of producing field in excess of 300 tesla, is proven to leave the sample probe intact in fields up to 240 tesla.

Powerful magnets—some of the most powerful in the world—are available to researchers visiting the National High Magnetic Field Laboratory's Pulsed Field Facility (NHMFL-PFF). Located high on a mesa on the campus of Los Alamos National Laboratory, the NHMFL-PFF is the only pulsed high field user facility in the country as well as the center of exceptional condensed matter physics research.

At the Pulsed Field Facility, scientists use high magnetic fields as a basic tool to predictably manipulate an electron's trajectory and its spins in a reversible and nondestructive manner, exploring and characterizing the thermodynamic properties of new materials in order to understand the basic underpinning of their behavior and to discover new states of matter.

By studying materials under extreme magnetic field conditions scientists develop a better understanding of quantum mechanical principles—from the mechanisms that



The 100-tesla Multi-shot Magnet, being assembled by Mike Pacheco, is the flagship of the National High Magnetic Field Laboratory Pulsed Field Facility.

drive superconductivity at high temperatures, thus leading to potential advances in energy storage and transmission—to fundamental magnetic, electrical, and structural properties that open the way to functional materials by design.

Pulsed Field Facility at Los Alamos, part of a unique national resource

The Pulsed Field Facility is one of three campuses of the NHMFL. The magnet lab's general headquarters are located at Florida State University in Tallahassee, Florida. The 370,000-square-foot complex boasts capabilities focusing on continuous fields and magnetic resonance. At the University of Florida in Gainesville, Florida, capabilities center on ultralow temperatures at high magnetic fields and magnetic resonance imaging. Together, these facilities comprise a unique resource for researchers to explore the extremes of magnetic field, pressure, and temperature.

Established by the National Science Foundation in 1990 and sponsored primarily by its Division of Materials Research, with additional support from the U.S. Department of Energy and the State of Florida, the NHMFL provides a user facility open to all qualified researchers, develops magnet technology in association with the private sector, and advances science and technology opportunities using high magnetic fields.

The Pulsed Field Facility not only allows researchers access to a wide variety of experimental capabilities in pulsed magnetic fields, but also gives researchers access to assistance from some of the world's leading experts in condensed matter physics and pulsed magnet science. All user support scientists are active researchers and collaborate with multiple users per year.

Magnet lab users have the opportunity to reap the benefits of access to a unique range of capabilities at Los Alamos National Laboratory. The Laboratory's materials capability includes expertise in nanotechnology and microfabrication, superconductivity science and technology, condensed matter, materials chemistry, metallurgy, structure-property relations, sensor and electrochemical devices, polymers and coatings, and nuclear materials science.

Users can also take advantage of the Laboratory's two other national user facilities, the Los Alamos Neutron Science Center (LANSCE) and the Center for Integrated Nanotechnologies (CINT), and the Laboratory's theory talent in the Theoretical Division. For example, at LANSCE users can investigate a material's magnetic structure and correlations. At CINT, users can synthesize and characterize nanostructured materials. In collaboration with experts in the Theoretical Division, users can model and predict a material's behavior.

The NHMFL Pulsed Field Facility has a history of developing connections with the Lujan Center in the area of condensed matter physics. In this regard, the two facilities have pursued joint scientific projects and shared postdoctoral researchers and students. Connections with the CINT facility are being explored and developed through a newly formed cross-facility team that has identified several different scientific possibilities that would make both facilities more attractive to the user community.

Magnet facts

The NHMFL Pulsed Field Facility features both destructive and nondestructive magnets and is the only place in the world where researchers can design experiments using the highest magnetic fields ever nondestructively produced on a repetitive basis.

Nondestructive pulsed magnet designers must solve the problem of the exceedingly high stresses generated in the magnet during pulsing. These stresses typically reach 200,000 pounds per square inch, which is greater than the strength of most materials. As such, pulsed magnet technology relies on state-of-the-art materials research. The most flexible pulsed magnets, from the point of view of the experimentalist, are "shaped-pulse" magnets in which the magnetic field shape can be specified to meet the

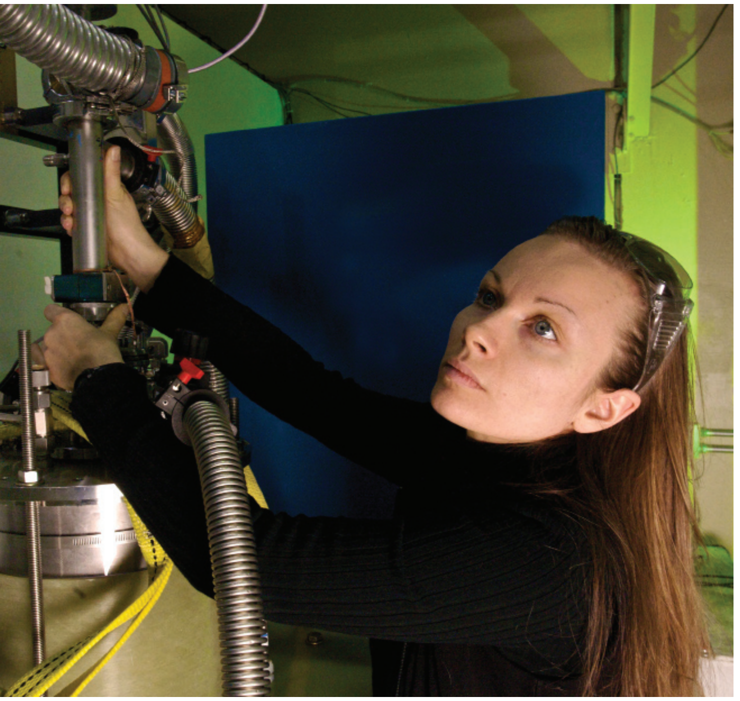
Users at the National High Magnetic Field Laboratory Pulsed Field Facility benefit from the knowledge of pulsed magnet science experts such as Dwight Rickel (left) and Mike Pacheco.

particular needs of a given experiment.

Destructive pulsed magnets sidestep the strength of materials problem and are designed to self-destroy with every pulse. Since the intense magnetic field exists only as long as it takes a shockwave to propagate through the magnet, the pulse duration is limited to a few microseconds.

Ten years in the making, the 100-tesla Multi-shot Magnet is the NHMFL's flagship, with a 15.5-millimeter bore and 5-millisecond rise time from 40-89.6 tesla, and marks a major milestone in magnet design and materials engineering as the world's most powerful, pulsed nondestructive magnet.

A tesla is a unit of magnetic field strength, and at 100 tesla, the magnet's field is approximately 2,000,000 times stronger than Earth's magnetic field on the surface.



Postdoctoral research associate Sonia Francoual uses the magnet lab's unique instruments to explore the unknown territory of heavy fermions.

Funded by the Department of Energy Office of Basic Energy Sciences and the National Science Foundation, the magnet allows researchers the ability to explore uncharted regimes of low temperature and high magnetic field, central to understanding the mechanism of superconductivity, magnetic-field-induced phase transitions, and so-called quantum critical points, in which small changes in materials properties at very low temperature have dramatic effects on physical behavior.

The 100-tesla magnet recently set the world record for the highest nondestructive, reproducible pulsed magnetic field intensity at 89.6 tesla. Plans are underway for reaching the ultimate field of 100 tesla within the next couple years.

The 100-tesla magnet is just one available to users. Other available magnets include the following.

The 50-tesla Mid-pulse Magnet, with a 300-millisecond, extended field decay, is well suited for high conductivity materials that undergo heating during routine pulses and materials that experience magnetocaloric effects.

The 50-tesla Short-pulse Magnet, with a 24-millimeter bore, offers an exceptional platform for experiments requiring an angle-dependent rotation stage.

The 65-tesla Short-pulse Magnet provides the highest nondestructive magnetic fields offered to users on a routine basis (with the exception of the 100-tesla magnet), with a 10-millisecond rise time and 14-millimeter bore.

The 300-tesla Single-turn Magnet, with rise times at 2.4 microseconds, provides a challenging experimental environment by offering the highest nondestructive-to-the-sample fields at the NHMFL. The single-turn magnet destroys the magnet coil for each high field pulse while preserving the sample. Routine shots are to 170 tesla at temperatures as low as 2.5 kelvin.

The 60-tesla Long-pulse Magnet features a unique magnetic field system with the ability to control the pulse shape with a 32-millimeter bore and a 100-millisecond flat-top at 60 tesla, well suited for samples that undergo heating during millisecond-duration pulses. The 60-tesla Long-pulse Magnet is unique in the world for field volume and pulse shape.

As well, the magnet lab provides various superconducting magnets up to 20 tesla for staging experiments and special configurations.

At the heart of pulsed field activities at the NHMFL-PFF is a fully multiplexed and computer controlled, six position, 16-kilovolt, 4-megajoule capacitor bank system. This capacitor bank provides the electrical energy for all the millisecond-duration pulsed magnets for the user program. Some 4,000 shots per year are fired for the user's program, which accommodates approximately 120 individual user groups.

The largest magnets at the NHMFL-PFF are powered by a 1.4-gigawatt generator system that requires about 5 megawatts of continuous power for 4-5 minutes to deliver a 2-second long pulse to 60 tesla, which in the case of the 100-tesla magnet is supplemented by a dedicated capacitor bank to reach 89.6 tesla.

Expertise enhances user experience

To allow users to make the most of their NHMFL-PFF experience, 10 user support scientists specializing in pulsed magnetic field research are on hand as well as technicians providing the necessary research and development support.

NHMFL-PFF researchers are experts in electrical transport, resonant ultrasound, optics, magnetization, heat capacity, gigahertz/radio frequency and torque magnetometry, resonant ultrasound, pulse echo ultrasound, magnetization, pulsed magnet design, thermodynamics, dielectrics, and the electronics necessary for data acquisition in an electromagnetically noisy environment.

NHMFL-PFF technicians specialize in cryogenic systems design and fabrication; high-power electrical circuits design, operation, and fabrication; pulsed power systems troubleshooting, operation, and repair; as well as design and fabrication of probes for materials characterization in transient magnetic fields.

The NHMFL-PFF also offers expertise in pulsed magnet design and development with dedicated scientific staff for design and development of pulsed magnet systems.

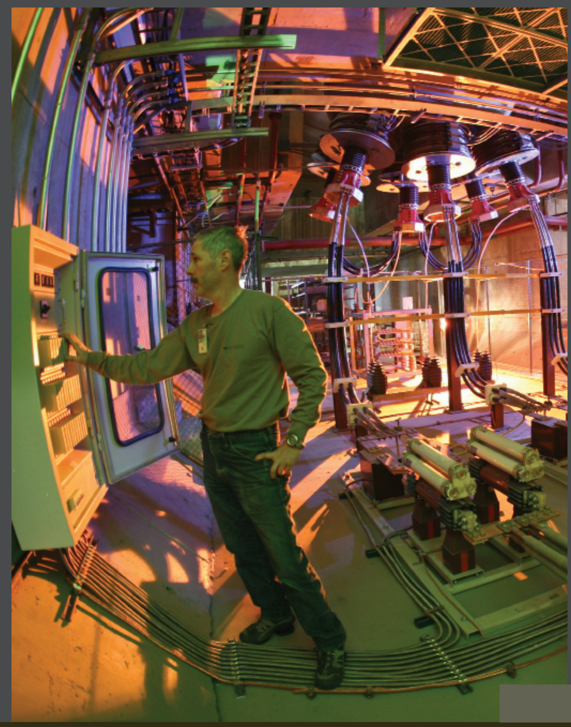
The NHMFL user program is designed to provide researchers with a balance of the highest research magnetic fields and robust scientific diagnostics. The connection with the DC (direct current) Field Facility in Florida is strong and complementary in expertise. The facility's main purpose is to create the best research environment, providing users with assistance from world-class experts in science conducted in the highest pulsed magnets.

For more information about the NHMFL-PFF and its user program, please visit www.lanl.gov/orgs/mpa/nhmfl.

Supporting the nation's security needs

The NHMFL-PFF supports the national security mission of Los Alamos National Laboratory with an active program in actinide materials research, including special nuclear materials, in an effort to understand electronic structure and its connection to fundamental material properties. The unique influence that actinides have on compounds and the unique facilities that the NHMFL-PFF offer are merged in a scientific exchange that has mutually benefited each institution.

The behavior of electrons in metals, while in a magnetic field, reveals many basic properties of the material. In pure actinides, the response to extremes in a magnetic field is still largely unexplored. In metals such as plutonium, multiple structural phases are observed as temperature increases. The exact mechanism for the structure change is unknown, but thought to originate in the exotic highly anisotropic 5*f*-electron orbitals. Magnetic fields couple to the electron system in metals and can exert forces on the electrons. As the magnetic field can be adjusted and controlled from an external source, it is thought that it can be used to influence the structural properties of plutonium. This would be a remarkable discovery because the energy scale of this perturbation would be exactly known, hence the experiments would determine the energy scale and mechanism for the multiple structures.



Mike Gordon makes adjustments to the 600-megajoule AC generator, which powers many of the facility's magnets.

Research on the frontier of high magnetic fields

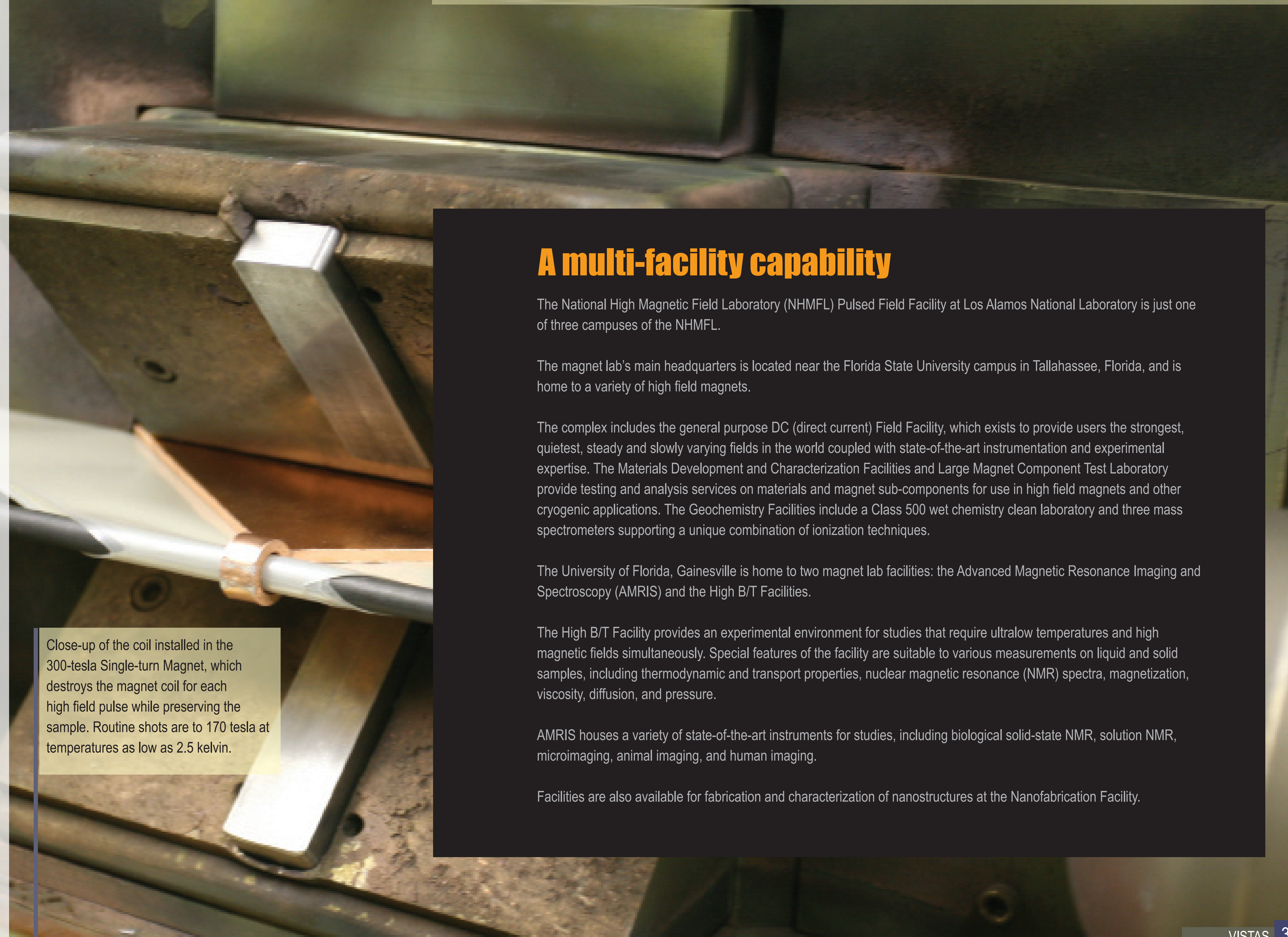
Some of the most challenging intellectual puzzles for solid state physicists remain unsolved because materials attractive for applications and devices are complex and unexplainable by traditional paradigms. Without a deep understanding and the ability to predict responses, technologists lack the means to optimize material response.

Research at extreme magnetic fields helps reveal properties in zones of the materials phase-space where behavior is governed by one—just one—external parameter, i.e., the external fields, creating a playground for testing models and novel theory approaches.

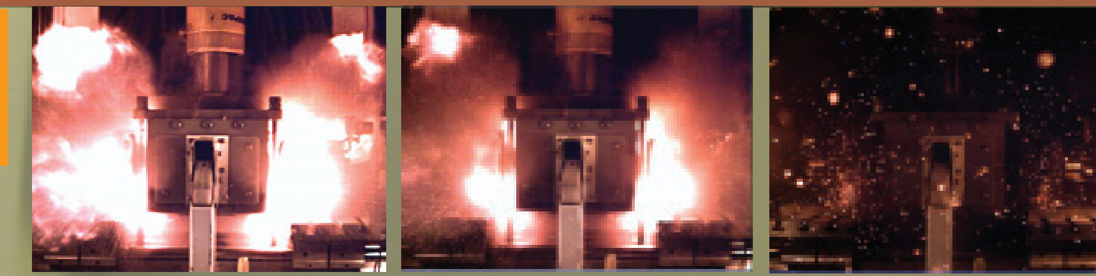
In this spirit, both Los Alamos and visiting world-class scientists use state-of-the-art experimental tools to open new frontiers in areas as diverse as high temperature superconductors, which are our best promise for future energy solutions; low-dimensional magnets, where magnetic correlations and geometric magnetic frustration can be designed to provide functionality; organic multiferroics, which provide a way to control electrical properties with magnetic fields, and conversely magnetic properties with electric fields; magnetic semiconductors, where spin-coherent transport of electrons opens the window to so-called spintronics or electronics based on both charge and spin of carriers; and nanomaterials, where intense magnetic fields confine electrons to the realm of nanostructures.

100-tesla flagship open to users

In 2008, the first call for user proposals for the100-tesla Multi-shot Magnet was announced, receiving more than twice the number of requests than what could be accommodated in the projected available magnet time. The proposals recently selected—in a process that focused on the quality of the science, the perceived chances of success, and the qualifications and diversity of the investigators involved—spanned several of the most topical areas of research in modern condensed matter physics, bringing the NHMFL-PFF, Los Alamos National Laboratory, and scientists from around the world to the experimental battlefields at the frontiers of condensed matter physics.



Close-up of the coil installed in the 300-tesla Single-turn Magnet, which destroys the magnet coil for each high field pulse while preserving the sample. Routine shots are to 170 tesla at temperatures as low as 2.5 kelvin.



Inset, frame captures of high-speed video of a 170-tesla shot.

A multi-facility capability

The National High Magnetic Field Laboratory (NHMFL) Pulsed Field Facility at Los Alamos National Laboratory is just one of three campuses of the NHMFL.

The magnet lab's main headquarters is located near the Florida State University campus in Tallahassee, Florida, and is home to a variety of high field magnets.

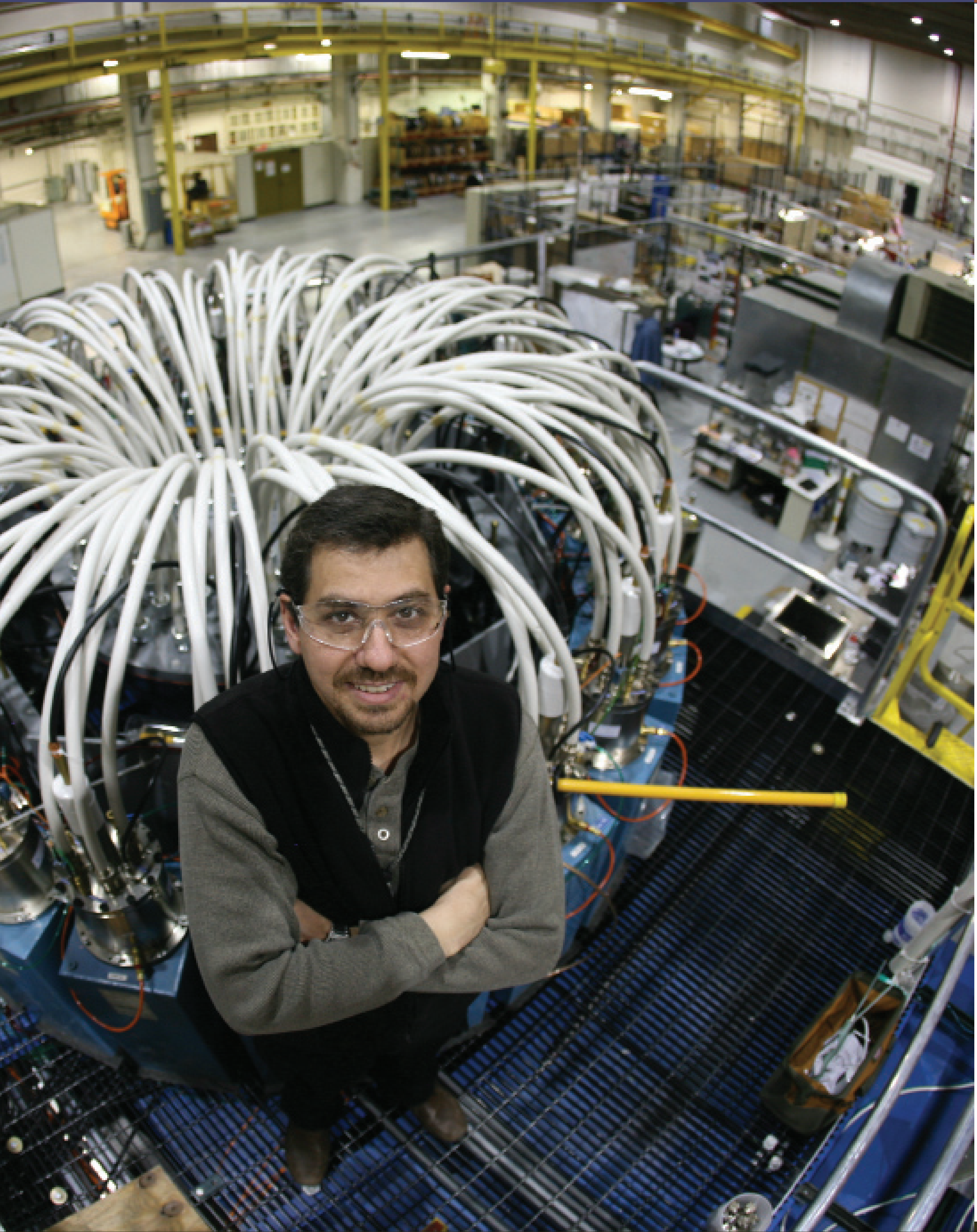
The complex includes the general purpose DC (direct current) Field Facility, which exists to provide users the strongest, quietest, steady and slowly varying fields in the world coupled with state-of-the-art instrumentation and experimental expertise. The Materials Development and Characterization Facilities and Large Magnet Component Test Laboratory provide testing and analysis services on materials and magnet sub-components for use in high field magnets and other cryogenic applications. The Geochemistry Facilities include a Class 500 wet chemistry clean laboratory and three mass spectrometers supporting a unique combination of ionization techniques.

The University of Florida, Gainesville is home to two magnet lab facilities: the Advanced Magnetic Resonance Imaging and Spectroscopy (AMRIS) and the High B/T Facilities.

The High B/T Facility provides an experimental environment for studies that require ultralow temperatures and high magnetic fields simultaneously. Special features of the facility are suitable to various measurements on liquid and solid samples, including thermodynamic and transport properties, nuclear magnetic resonance (NMR) spectra, magnetization, viscosity, diffusion, and pressure.

AMRIS houses a variety of state-of-the-art instruments for studies, including biological solid-state NMR, solution NMR, microimaging, animal imaging, and human imaging.

Facilities are also available for fabrication and characterization of nanostructures at the Nanofabrication Facility.



by Clay Dillingham

Chuck Mielke

Meet Chuck Mielke.

Mielke is head of the user program of the National High Magnetic Field Laboratory Pulsed Field Facility (NHMFL-PFF) at Los Alamos National Laboratory (LANL). He came to Los Alamos in 1994 as a graduate student from Clark University before becoming a postdoctoral fellow in the Condensed Matter and Thermal Physics group in 1996.

Hooked on physics through a college course on Einstein's General Theory of Relativity, Mielke then became interested in materials physics experiments in the most extreme magnetic fields. "Max Fowler, a pioneer in the field of extremely high magnetic fields, was … at LANL," he said. "Combined with having the Pulsed Field Facility here, LANL was a wonderful place to come for my postdoc."

"Chuck was my first postdoc at the Pulsed Field Facility and he came fully prepared for the job," said Alex Lacerda, director of the NHMFL-PFF. "Chuck is one of the most talented experimentalists I have ever met—and I have been to a lot of places around the globe."

The Pulsed Field Facility is one of three campuses of the NHMFL; the others are in Florida. Sponsored primarily by the National Science Foundation, with additional support from the State of Florida and the U.S. Department of Energy, the NHMFL operates a user program open on a competitive basis to all qualified users. Los Alamos not only supplies the infrastructure to support the operation of the Pulsed Field Facility, it also provides scientific resources such as theorists, complementary scientists, and technicians.

"My relationship with my colleagues is one of the most important things that keeps me here," Mielke said. "For example, the scientists who work on weapons programs are some of the brightest in the world. I have learned so much from them and I greatly value their accomplishments. And of course, the Laboratory provides a nurturing overall atmosphere to make researchers comfortable and to enjoy their time here.

"I tell prospective students and postdocs that coming to LANL is a wonderful opportunity," he said. "They should come here and work very hard and it will be what they make of it … Come here and work hard, you'll reap the benefits."

Colleague Jason Cooley, of the Materials Technology: Metallurgy group said, "Chuck's technical work is driven by the same kind of optimism and work ethic. He will set out to do very difficult things and achieve them by enthusiastic hard work."

"For me," Mielke said, "the most rewarding thing about heading up the user program is having a student or postdoc come into the program and leave a couple of years later being converted into a 'disciple' of high magnetic field experimentation."

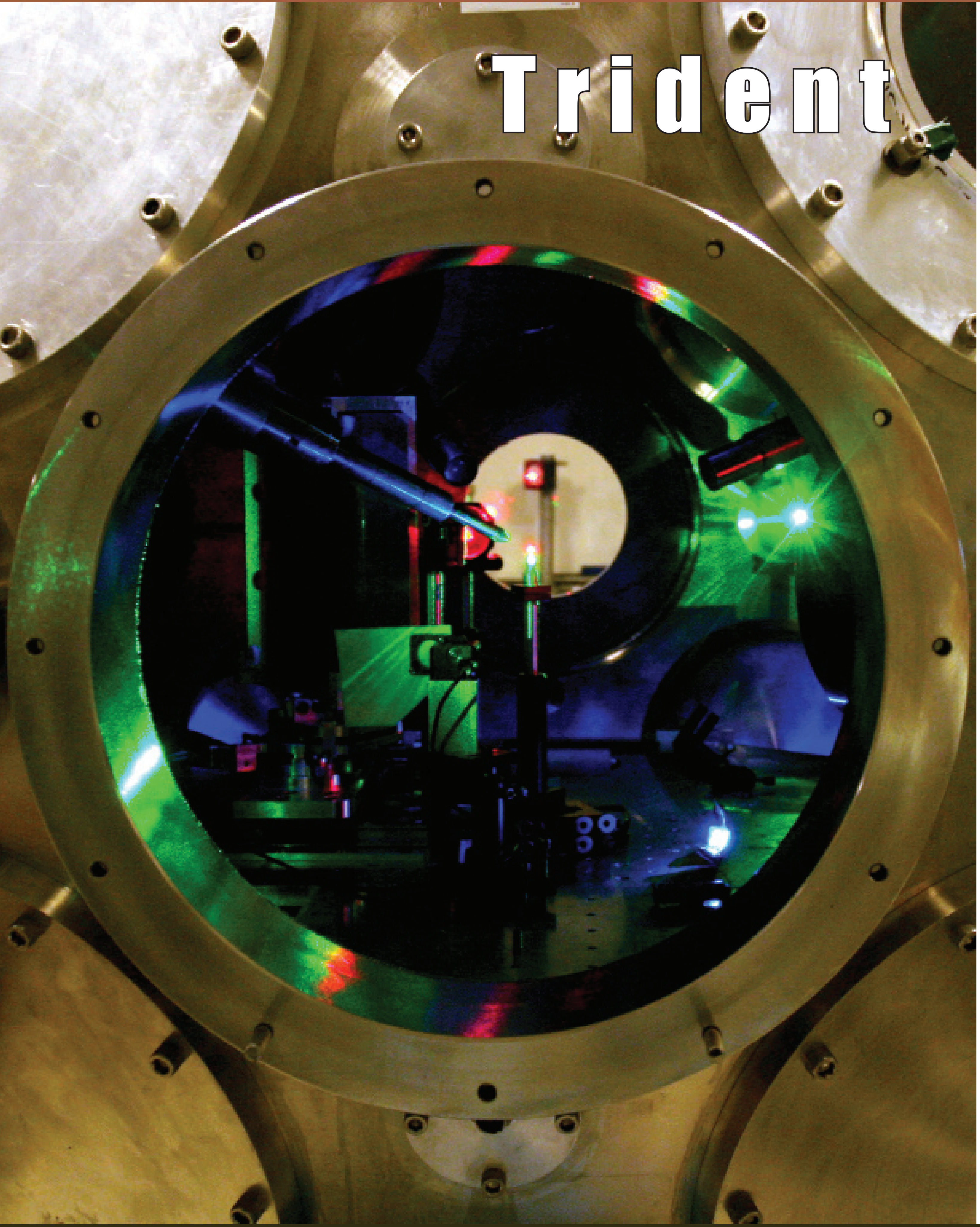
Mielke is a disciple of the single-turn magnet, an instrument he helped design and build after taking part in the Dirac series, an international collaboration in ultrahigh magnetic fields at Los Alamos in 1996 and 1997. Working with fellow Laboratory scientists and distinguished Russian, Japanese, Australian, and German physicists, Mielke was granted three high explosive, 145-tesla shots of his own.

"Back then, these shots were highly complex to set up. They were very different from the condensed matter physics experiments we do today, and not only destroyed the samples, but had a high probability of not giving us much in the way of usable data," Mielke said. "I had this 'aha!' moment after the shots and during analysis of the data, when I realized that I needed to build the single-turn magnet if we were to really advance the firing-point techniques and get to the physics that I crave."

Mielke's single-turn magnet delivers a whopping 240-tesla pulse without destroying the sample probe. A routine shot is 170 tesla—almost 3.5 million times the Earth's magnetic field—and the system is capable of exceeding 5 million times the Earth's magnetic field. The current pulse is routinely 2.5 million amperes. The system is capable of a 4-mega-amp pulse.

"Currently my collaborators and I are using the single-turn magnet's ultrahigh magnetic fields and working hard to reveal the condensed matter properties of plutonium," Mielke said. "And in 10 years I hope to be running a 1,000-tesla electromagnetic flux compression system for our users. I hope that this research can make an impact on the energy security of the nation."

Chuck Mielke, atop the single-turn coil cage, is head of the National High Magnetic Field Laboratory Pulsed Field Facility User Program.



Light at many scales for many users

The Trident Laser Facility at Los Alamos National Laboratory is an extremely versatile neodymium-glass laser system dedicated to high-energy-density physics research and fundamental laser-matter interactions. Trident's unique laser capabilities and diagnostics provide an ideal platform for many experiments. The laser system consists of three high energy beams which can be delivered into two (and soon to be three) nearly independent target experimental areas. The target areas are equipped with an extensive suite of diagnostics for research in ultra-intense laser-matter interactions, dynamic material properties, and laser-plasma instabilities.

Several important discoveries and first observations have been made at Trident, including laser-accelerated million electronvolts (MeV) monoenergetic ions, nonlinear kinetic plasma waves, the transition between kinetic and fluid nonlinear behavior, as well as other fundamental laser-matter interaction processes. Trident's unique long-pulse capabilities have enabled state-of-the-art innovations in laser-launched flyer plates and other unique loading techniques for material dynamics research, including studies of incipient spall and effects of microstructure on shocks.

The Trident 200-terawatt laser is capable of generating electric fields in excess of a tera-electronvolt per meter. Ten thousand times stronger than advanced conventional accelerators, these fields can be used to accelerate ions and electrons to tens of MeV energies in microns. Currently, Trident is the world-record holder for maximum proton and carbon ion acceleration per irradiance energy. With 80 joule (J) laser energy, Trident has been shown to accelerate ions to more than 50 MeV, nearly the same maximum energies as observed from lasers with 4-5 times the energy, namely the Livermore Nova petawatt (500 J, 58 MeV) and the Rutherford Appleton Laboratory Vulcan petawatt (400 J, 58 MeV) laser systems. We are at the forefront of laser-particle acceleration, with several active experimental programs attempting to boost the energy of laser-accelerated ions toward a giga-electronvolt and beyond. Techniques like novel target designs (flat-top cones and structured targets), underdense and near critical density wakefields, and new acceleration mechanisms like radiation pressure acceleration or the breakout laser afterburner (BOA) are used. BOA was discovered at Los Alamos through super-massive three-dimensional particle-in-cell simulations done on the world's fastest computer, Roadrunner. In particular, Los Alamos is the world leader in ion-based fast ignition concepts, theory, and experiments. The Trident optical parametric chipped pulse amplified front-end was recently upgraded with a second-order short-pulse optical parametric amplification cleaning technique (dubbed SPOPA), which has successfully cleaned the 200-terawatt laser to an unprecedented contrast of better than 10^{-9}, and probably closer to 10^{-10}, making Trident the world's cleanest high-power ultra-intense laser system, capable of shooting targets as thin as 5 nanometers.

The Trident Laser Facility is now operated in support of a national user program, enabling world-class science in high-energy-density physics. All run-time on the facility must be proposed to the Trident facility coordinator and all proposals go through rigorous external scientific merit review. For the first half of the fiscal year 2009 run on Trident, 27 proposals representing 21 unique institutions and more than 60 different users requesting 100 weeks of run-time were received. We welcome new proposals as we work to expand the user community in high-energy-density laboratory plasmas.

For more information, please visit trident.lanl.gov.

A view into an open port of the Trident Laser Facility north target chamber.

David Montgomery

Ever since he was in elementary school, David Montgomery said, he has known he "wanted to do something technical." In college he dropped his pre-med studies for physics after becoming fascinated by the subject during a calculus-based physics class.

Director of the Trident Laser Facility and team leader for laser-matter interactions in the Plasma Physics group of Physics Division, Montgomery joined Los Alamos National Laboratory (LANL) in 1996 because he enjoyed collaborating with Los Alamos researchers and liked the broad opportunities available for research in his field.

"The colleagues that I work with at LANL are really some of the best scientists in our field," said Montgomery, a Fellow of the American Physical Society. "I tell students and postdocs that coming to LANL will expose them to a large group of scientists working in a very broad range of disciplines, as well as some pretty cool scientific facilities and capabilities, both experimental and computational.

"The coolest thing I've ever done at the Lab was when I realized that we could do single hot-spot experiments on Trident," Montgomery said. "This would give us a sort of microscope to look into the fundamental aspects of laser-plasma instabilities. This kind of experiment isn't possible on the larger lasers. It would require a laser with greater flexibility and plenty of shot access. With Trident, the scientific community has access to what is probably the most flexible, high-power laser in the world to explore high-energy-density physics."

Montgomery originally developed and utilized the idea for single hot-spot experiments in 1998, with some initial successes, but he confessed he had a limited vision of the potential value of this concept at that time. It wasn't until about 2001 that he realized he could actually detect individual plasma waves, each coupled with one another by nonlinear effects and separated slightly in frequency from each other.

When his group obtained its first results, the plasma wavelengths and frequencies all corresponded nicely to what was expected from the nonlinear theory. "I couldn't wait to show this to our LANL colleagues. We brought the theorists over to the experiment at Trident and showed them raw data on the computer screen," he said. "Now, we make a routine of this theorists' tour for many of our experiments."

"David is a uniquely important physicist because he understands what's possible and has achieved what was not thought experimentally possible," said Harvey Rose of the Physics of Condensed Matter and Complex Systems group. "This helps keep theorists and other experimentalists honest."

"He is a born collaborator," said Physics Deputy Division Leader Cris Barnes. "Everyone who meets him likes him, gets impressed by his friendly competence, wants to work with him, and they end up pleased at having done something really good with him."

Montgomery is developing imaging x-ray Thomson scattering to take a snapshot (space and time resolved) of the density, temperature, and ionization state behind a strong shock in a dense plasma, with 20-micrometer resolution, and time resolution of 10–100 picoseconds. With this capability, future experiments can be conducted to study warm dense matter (conditions similar to the inside of giant gas planets) and energy transport in dense materials, the effects of coalescing and colliding shocks, and the coupling of energetic particle beams to dense matter. "These are important to scientists working on inertial confinement fusion, scientists trying to understand planetary formation and planetary interiors, and to those working on aspects of weapons physics," he said.

In the future, Montgomery said he hopes to grapple with nonlinear optics in plasmas. "The field of nonlinear optics in high-energy-density plasmas has a lot of exciting opportunities to create and manipulate dense, hot states of matter to do some exotic things," he said. "There are great frontier scientific opportunities to have laser-plasmas be the next advanced accelerator. Think about shrinking the mile-size particle accelerators down to a few meters using laser-plasmas. It would be incredibly exciting to make it happen in the laboratory."

David Montgomery is director of the Trident Laser Facility.

Experimental Physical Sciences mission

We develop and apply a broad set of capabilities in materials science and experimental physics to programs and problems of national importance. The success of our science requires world-class research and processing facilities, including our Los Alamos-based national user facilities—the Los Alamos Neutron Science Center, the Center for Integrated Nanotechnologies, and the National High Magnetic Field Laboratory.

Experimental Physical Sciences vision

We cultivate a responsive, high-performance staff that conducts innovative, cross-disciplinary research and development that produces breakthrough solutions to the most pressing national security challenges.

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ON THE BACK
An artist's drawing of an array of vertical germanium nanowires with gold catalyst at the tips growing in a germane vapor from an s-layer protein biotemplate.

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Experimental Physical Sciences

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