Summer 2015

QUEST

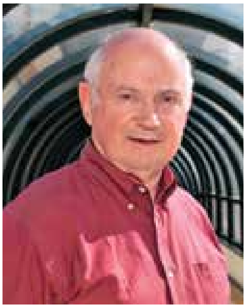
RESEARCH NEWS FROM PPPL

A NEW ERA BEGINS

PPPL PRINCETON PLASMA PHYSICS LABORATORY

U.S. DEPARTMENT OF ENERGY

PRINCETON UNIVERSITY

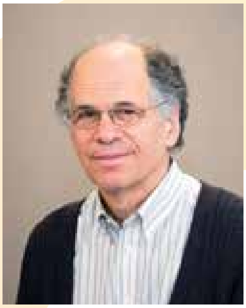


A.J. Stewart Smith
Princeton University
Vice President for PPPL

FROM THE PRINCETON UNIVERSITY VICE PRESIDENT FOR PPPL

Welcome to the new issue of *Quest*, the annual research magazine that highlights major achievements at the Princeton Plasma Physics Laboratory over the past year. These achievements reflect the superb scientific and engineering capabilities of the Laboratory, which Princeton is honored to manage for the U.S. Department of Energy. As this country's national laboratory for fusion and plasma science research, PPPL is one of only 10 national labs supported by the DOE's Office of Science. These institutions have an absolutely luminous history of scientific innovation and discovery in keeping with the goals of DOE.

Research in plasma physics at Princeton began in 1951 when astrophysicist Lyman Spitzer founded what later became PPPL, the first U.S. laboratory dedicated to the development of fusion as a safe, clean and abundant source of power for generating electricity. Today, the lab's coupled missions comprise research that not only paves the way for magnetic fusion energy but also explores the broad frontier of plasma science and technology. The university's scientific and engineering collaborations with the Laboratory have grown apace in recent years, expanding into fields such as plasma astrophysics and materials science in which Princeton and PPPL increasingly benefit from their complementary facilities and expertise. We are delighted at this time to share with you some of PPPL's latest accomplishments.



Stewart Prager
PPPL Director

FROM THE DIRECTOR OF PPPL

This year marks the completion of the $94 million upgrade of the National Spherical Torus Experiment (NSTX-U), our major fusion facility, and the start of a new era for the Laboratory. The NSTX-U is the most advanced spherical tokamak in the world and experiments will reveal whether its design could serve as a model for a major next step in the U.S. fusion program. Our research will narrow or close critical gaps in scientific knowledge on the path to fusion energy and produce valuable findings for ITER, the international facility under construction in France to demonstrate the feasibility of fusion power.

The past year has expanded our prowess in fundamental plasma physics research as well. We recently received funding to increase our study of the role of plasma in the synthesis of nanoparticles — substances prized for their use in consumer goods and computer-chip fabrication. Also notable has been the completion of design work for FLARE, a new and more powerful version of our venerable Magnetic Reconnection Experiment (MRX), which recreates a key astrophysical phenomenon under laboratory conditions. Recent findings on the MRX include a new understanding of how magnetic energy is converted to particle energy during magnetic reconnection, a process that gives rise to the northern lights, solar flares and geomagnetic storms.

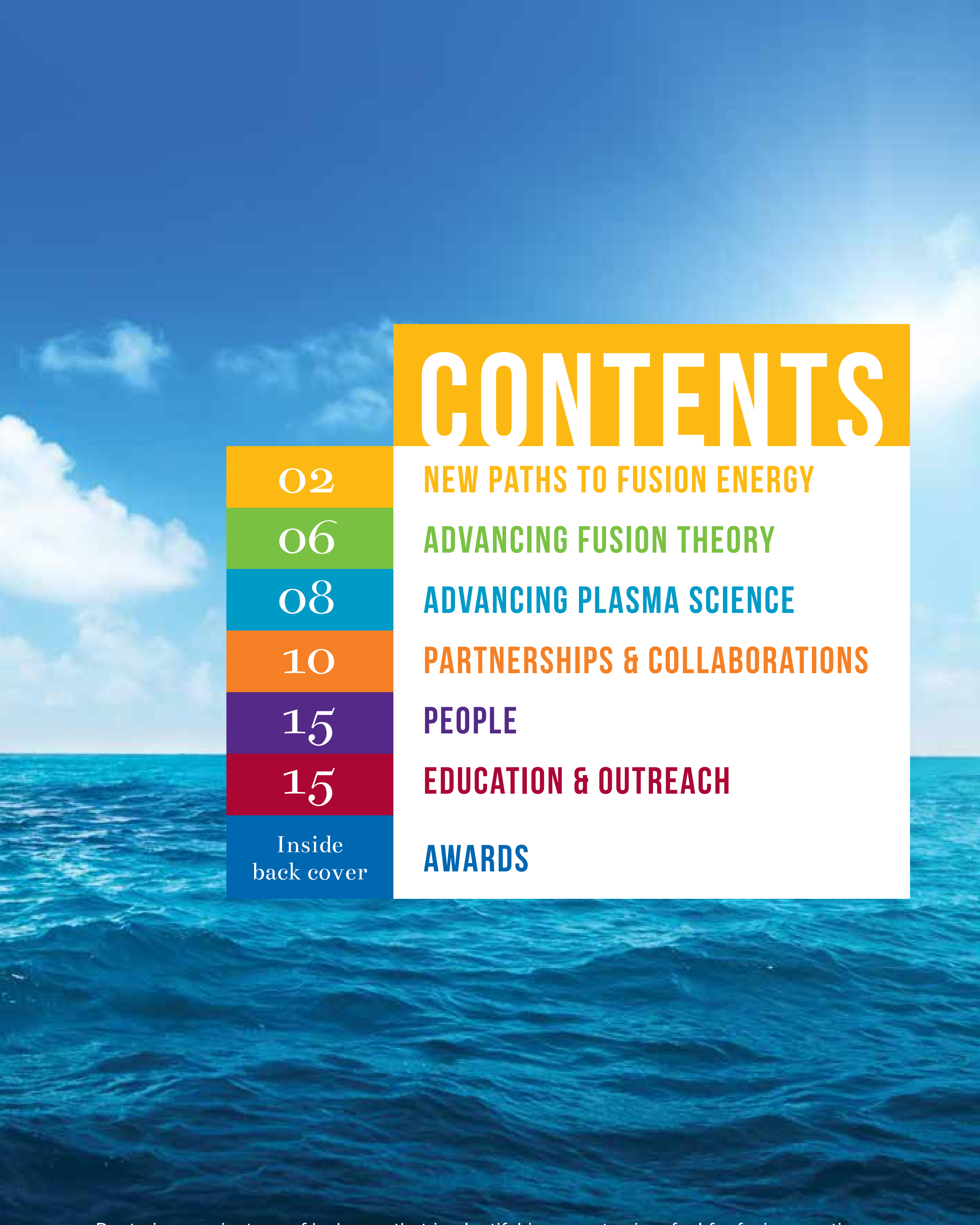
Our wide-ranging collaborations continue to enhance research around the world. Over the year we have built components for the DIII-D tokamak that General Atomics operates for the U.S. Department of Energy in San Diego, and for KSTAR, South Korea's major fusion experiment. These components foster the research that we conduct in these facilities. In Europe, PPPL-designed diagnostic equipment will play a key role in future experiments on ITER, and we have developed components for Germany's newly built Wendelstein 7-X, a twisty fusion facility called a stellarator on which we will also conduct experiments.

Still other collaborations range from a hunt for Big Bang neutrinos that could provide clues to the birth of the universe to a novel method for verifying nuclear warheads that could facilitate new arms control treaties. We are working on both efforts, and others, with colleagues from other Princeton departments.

All these activities, encompassing fusion energy, astrophysics and an assortment of fascinating applications of plasma science, make our Laboratory a hub of vital research that we invite you to read about in the pages that follow.

On the cover: Technicians examine the new center stack that forms the heart of the National Spherical Torus Experiment-Upgrade.

CONTENTS



Deuterium, an isotope of hydrogen that is plentiful in seawater, is a fuel for fusion reactions.

UNVEILING THE MOST POWERFUL SPHERICAL TOKAMAK ON EARTH

THE WORLD-LEADING RESEARCH IS SET TO BEGIN. After nearly three years of construction, the National Spherical Torus Experiment-Upgrade (NSTX-U) is ready to play a critical role in the quest to develop fusion energy as a clean, safe and virtually limitless fuel for generating electricity.

The $94 million overhaul has made the NSTX-U the most powerful spherical tokamak worldwide, doubling its heating power and magnetic fields, and the first major addition to the U.S. fusion program in the 21st century. “The upgrade boosts NSTX-U operating conditions closer to those to be found in a commercial fusion power plant,” said PPPL Director Stewart Prager. “Experiments will push into new physics regimes and assess how well the spherical design can advance research along the path to magnetic fusion energy.”

The key feature of the design is its compact, cored apple-like shape, as compared with the bulkier, donut-like form of conventional tokamaks. The compact shape enables spherical tokamaks to confine highly pressurized plasma gas—the hot, charged fuel for fusion reactions—within comparatively low magnetic fields. This capability makes spherical tokamaks a cost-effective alternative to conventional tokamaks, which require stronger and thus more expensive magnetic fields.

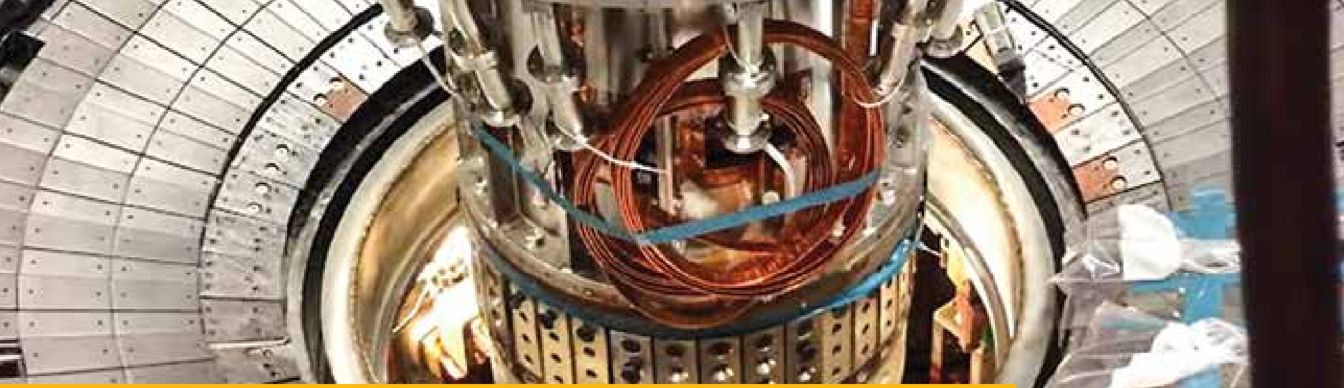
Researchers now plan to test whether the NSTX-U can continue to produce high-pressure plasmas with such low-level fields—a combination known as “high beta”—under the hotter and more powerful conditions that the upgrade allows. Beta is the ratio of the outward plasma pressure to the inward magnetic pressure that confines the plasma. The original NSTX, which ran from 1999 to 2012, produced record beta values. “But before NSTX-U we were smaller and the pressure was considerably less than in conventional tokamaks,” said Masayuki Ono, project director of the NSTX-U. “Now we can get to the highest temperatures, the highest pressure and the highest performance generally for a spherical tokamak.”

A related key question is how effectively the NSTX-U can keep temperatures approaching 100 million degrees centigrade from dissipating away. “You need to reach a certain temperature to get good fusion reactions,” said Jon Menard, program director for the NSTX-U. “If the confinement is not good you never really reach that temperature.”

Further experiments will test the upgrade’s ability to tame the hot plasma particles that escape from confinement and can damage the reactor’s walls—an issue of critical importance to ITER, the international fusion experiment under construction in France. Also under investigation will be new ways to start and sustain the electric current that creates the plasma and completes the magnetic field.

Of overall interest is whether the spherical design can be a strong candidate for a Fusion Nuclear Science Facility, a proposed next step in the U.S. fusion program, which would provide an integrated test of a fusion energy system in preparation for a demonstration fusion power plant. “The bottom line for all this is that we’ve never really looked at this combination of plasma conditions in a spherical tokamak before,” said Menard, “and we don’t know how it will all turn out. That’s the exciting part.”

“Now we can get to the highest temperatures, the highest pressure and the highest performance generally for a spherical tokamak.”



BUILDING THE MOST POWERFUL SPHERICAL TOKAMAK

CONSTRUCTING THE NATIONAL SPHERICAL TORUS EXPERIMENT—Upgrade (NSTX-U) posed novel challenges for engineers and technicians throughout the Laboratory. Tasks ranged from flying a 70-ton neutral beam machine over a 22-foot wall to building a 29,000 pound center-stack magnet. These huge components had to fit into an existing facility—the original NSTX—with hair-thin precision, requiring an effort that one engineer likened to rebuilding a ship in a bottle.

Above: The center stack enters the NSTX-U vacuum vessel.
Below: The center stack arrives in the NSTX-U test cell.

"This project was more complex than building the NSTX in the first place," said Mike Williams, head of engineering and infrastructure and associate director of the Laboratory. "We had to figure out how to reinforce the existing facility to withstand the increased electromagnetic forces produced by the upgrade."

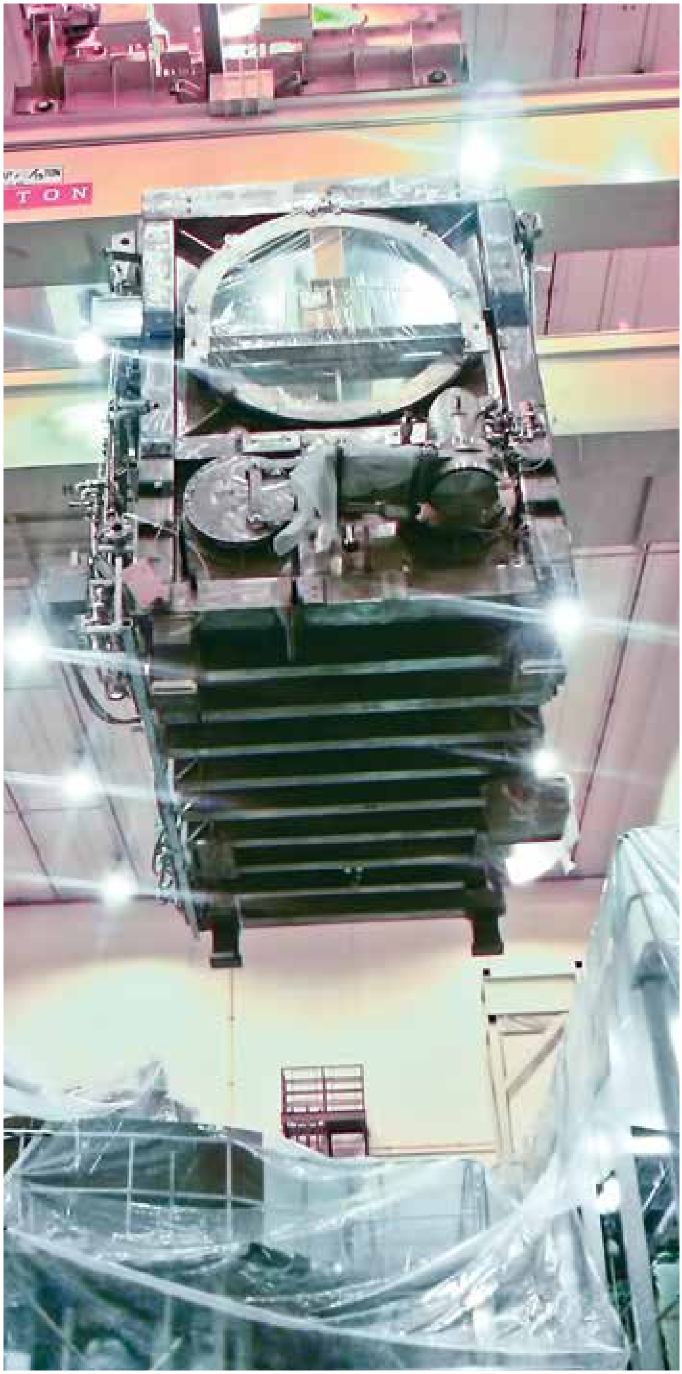
The NSTX-U has twice the heating and magnetic field strength, plus twice the plasma current and up to five times the electrical pulse length, of the original facility. The new components work hand-in-glove together: The new center stack delivers the higher current and strengthened magnetic field that controls the charged plasma gas that fuels fusion reactions; the new beam box doubles the heat that excites the atomic nuclei—or ions—inside the gas, causing them to fuse together.

Creating the new stack meant sanding, brazing, welding and applying insulation tape to each of the 36 copper conductors that make up the 21-foot-long magnet. Technicians next bound the conductors together through repeated applications of vacuum pressure impregnation—a potentially volatile process. They then fabricated a coil that winds around the bundle to induce current into the plasma.

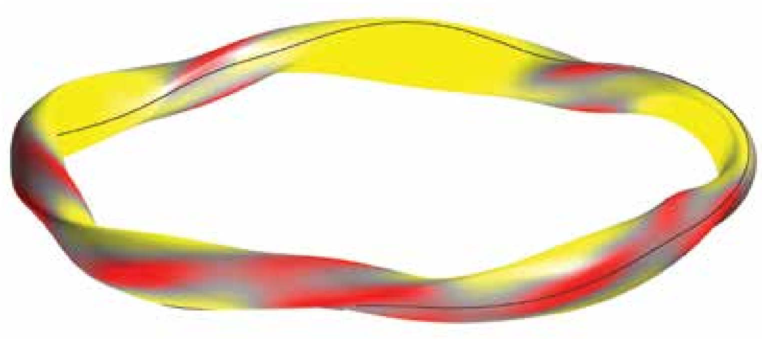
The final step called for using an overhead crane to lift the magnet over a 22-foot shield wall, which the bundle cleared by inches, and carefully lower it into the center of the fusion facility. “This was really a watershed moment,” Williams said of the installation, which completed the center stack construction.

Installing the new neutral beam box required even heavier lifting. Technicians first spent months taking apart, decontaminating and refurbishing the truck-sized device, which had been used with the Lab’s now-dismantled Tokamak Fusion Test Reactor. They then towed the box into NSTX-U test cell, attached it to the overhead crane and hoisted it over the shield wall.

Workers next had to hook up the box and its power supplies, cables, cooling-water pipes and other equipment in the already crowded test cell. Last came the task of cutting a window into the NSTX-U vacuum vessel and aligning the beam to within 80 thousands of an inch of a target inside the vessel. “The whole thing was fraught with challenges and difficulties,” said engineer Tim Stevenson, who headed the beam box project. “It was a monumental team effort that took a great deal of preparation. And when it was show-time, everyone showed up.”



The new neutral beam box arrives in the NSTX-U test cell.



Magnetic field strength in a turbulence-optimized stellarator design. Regions with the highest strength are shown in yellow.

SCIENTISTS USE PLASMA SHAPING TO CONTROL TURBULENCE IN STELLARATORS

RESEARCHERS AT PPPL AND THE MAX PLANCK INSTITUTE OF PLASMA PHYSICS in Germany have devised a new method for minimizing turbulence in bumpy donut-shaped experimental fusion facilities called stellarators. This method could help physicists overcome a major barrier to the production of fusion energy in such devices and could also apply to their more widely used symmetrical donut-shaped cousins called tokamaks.

Turbulence allows the hot, charged plasma gas that fuels fusion reactions to escape from the magnetic fields that confine the gas in stellarators and tokamaks. This turbulent transport occurs at comparable levels in both devices, and has long been recognized as a challenge for both in producing fusion power economically.

This method could help physicists overcome a major barrier to the production of fusion energy.

"Confinement bears directly on the cost of fusion energy," said physicist Harry Mynick, a PPPL coauthor of the paper, "and we're finding how to reshape the plasma to enhance confinement."

The new method uses two types of advanced computer codes that have only recently become available. The authors modified these codes to address turbulent transport, evolving the starting design of a fusion device into one with reduced levels of turbulence. The current paper applies the new method to the world's largest and most advanced stellarator, the Wendelstein 7-X, whose construction was recently completed in Greifswald, Germany.

PROVIDING GOLD-STANDARD SOFTWARE TO ITER

PPPL contributions to the international ITER experiment include the Laboratory's TRANSP code—the worldwide gold standard for interpreting and predicting the results of fusion experiments. TRANSP will join a suite of codes from the United States and other countries that researchers will use to model and predict the behavior of plasma in the ITER tokamak that is under construction in France.

Different codes can produce different results for the same conditions, said physicist Francesca Poli, who is helping to integrate TRANSP into the software suite. Her task calls for comparing—or benchmarking—results produced by TRANSP with those developed by CORSICA, a code from Lawrence Berkeley National Laboratory that is part of the suite of ITER codes. Such benchmarking aims to identify similarities and differences between the codes and establish guidelines for improving physics models and quantifying and reducing uncertainties in predictive capabilities.

Those working on the integration project include Rob Andre, a computational scientist who is installing TRANSP in the software suite. Supervising PPPL's role in the project are physicists Stan Kaye, deputy program director of the National Spherical Torus Experiment-Upgrade, and Stephen Jardin, head of the Laboratory's Computational Plasma Physics Group.

Francesca Poli

NEW SUPERCOMPUTER TIME TO STUDY TURBULENCE IN FUSION PLASMAS

Researchers led by physicist C.S. Chang have won a whopping 270 million core hours on two of the world's most powerful supercomputers to study turbulence at the volatile edge of fusion plasmas. The award marks the team's third straight annual allotment from the U.S. Department of Energy's Innovative and Novel Computational Impact on Theory and Experiment (INCITE) program—and nearly triples the 100 million hours the team received in its first year of operation.

A core hour represents an hour of time on a computer processor core, making the new allotment equal to roughly 31,000 years on a desktop computer powered by a single core. Since supercomputers have hundreds of thousands of cores, all 270 million hours could be utilized in roughly three weeks if the researchers were to use, say, 500,000 cores continuously.

Chang's team, the Center for Edge Physics Simulation (EPSI), will use its time to model how charged particles behave at the plasma edge. Such behavior leads to "blobby" turbulence in which the particles bunch together and carry away heat and energy, cooling the core of the plasma and halting fusion reactions. "We are studying how [the bunched particles] are born, how they move around and die and how they carry mass and energy away from the plasma to the material wall," Chang said.

The INCITE award includes 170 million core hours on Titan, the Cray XK7 supercomputer at Oak Ridge National Laboratory that can perform more than 20 quadrillion—or million billion—calculations per second, and 100 million core hours on Mira, an IBM Blue Gene/Q computer at Argonne National Laboratory that can perform 10 quadrillion calculations per second.

C.S. Chang

EXPANDING THE ROLE OF PLASMA IN SYNTHESIZING NANOPARTICLES

THE U.S. DEPARTMENT OF ENERGY HAS AWARDED PPPL some $4.3 million over three years to develop an increased understanding of the role of plasma in the synthesis of nanoparticles. Such particles can be found in golf clubs, microchips, pharmaceutical goods and a variety of other products and have potentially wide-ranging applications in the development of new energy technologies.

"Plasma is widely used as a tool for producing nanoparticles, but there is no deep understanding of the role that plasma plays in this process," said physicist Yevgeny Raitses, the principal investigator for the project. "Our goal is to develop an understanding that can lead to improved synthesis of these particles."

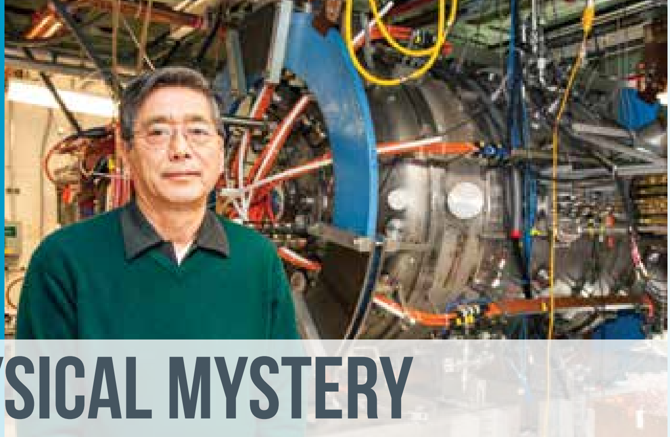
Graduate students Jonathan Ng, left, and James Mitrani with physicist Yevgeny Raitses in the nanolaboratory.

The new funds will expand research in a nanotechnology laboratory that PPPL launched in 2012. The facility studies the complex interactions that occur when hot, electrically charged plasma gas is used as a synthesizing agent to produce material such as carbon nanon-tubes—items that are tens of thousands of times thinner than a human hair, yet stronger than steel on an ounce-per-ounce basis. These interactions must be precisely controlled to ensure the quality and purity of such material.

In discussing the new research, PPPL Director Stewart Prager noted that, "The synthesis of nanoparticles is a challenging and exciting field with wide-ranging applications. This project combines our expertise in plasma science with the material science capabilities of Princeton University and other institutions."

The expanded research "fits right into our core competency," said Adam Cohen, PPPL deputy director for operations. "We've gained knowledge of plasma from our fusion research and this enables us to grow into a whole new research opportunity."

"Our goal is to develop an understanding that can lead to improved synthesis of these particles."



PPPL SCIENTISTS TAKE KEY STEP TOWARD SOLVING A MAJOR ASTROPHYSICAL MYSTERY

Magnetic reconnection can trigger geomagnetic storms that disrupt cell phone service, damage satellites and blackout power grids. But how reconnection, in which the magnetic field lines in plasma snap apart and violently reconnect, transforms magnetic energy into explosive particle energy remains a major unsolved problem in plasma astrophysics.

Now scientists at PPPL have taken a key step toward a solution. In research conducted on the Magnetic Reconnection Experiment (MRX) at PPPL, the scientists not only identified how the mysterious transformation takes place, but measured experimentally the amount of magnetic energy that turns into particle energy.

The investigation showed that reconnection converts about 50 percent of the magnetic energy, with one-third of the conversion heating the electrons and two-thirds accelerating the ions—or atomic nuclei—in the plasma. In large bodies like the sun, such converted energy can equal the power of millions of tons of TNT.

"This is a major milestone for our research… We can now see the entire picture."

"This is a major milestone for our research," said Masaaki Yamada, the principal investigator for the MRX. "We can now see the entire picture of how much of the energy goes to the electrons and how much to the ions in a proto-typical reconnection layer."

The findings also suggested the process by which the energy conversion occurs. "Reconnection first propels and energizes the electrons, and this creates an electrically charged field that becomes the primary energy source for the ions," said Jongsoo Yoo, an associate research physicist at PPPL.

If confirmed by data from space explorations, the PPPL results could help resolve decades-long questions and create practical benefits. These could include a better understanding of geomagnetic storms that could lead to advanced warning of the disturbances and an improved ability to cope with them. Researchers could shut down sensitive instruments on communications satellites, for example, to protect the instruments from harm.

The PPPL team will eagerly watch the four-satellite mission that NASA launched this year to study reconnection in the magnetosphere—the magnetic field that surrounds the Earth. The team plans to collaborate with the venture, called the Magnetospheric Multiscale (MMS) Mission, by providing MRX data to it. The MMS probes could in turn help to confirm the Laboratory's findings.

Above: Masaaki Yamada with the MRX.

PPPL PLAYS LEADING ROLE IN U.S.- GERMAN COLLABORATION

Hutch Neilson at the W7-X construction site in Germany.

PPPL leads U.S. participation in Germany's new Wendelstein 7-X (W7-X), the world's most advanced stellarator, which the Max Planck Institute for Plasma Physics (IPP) has built and will begin operating this year. Stellarators confine plasma in twisty—or 3D—magnetic fields, compared with the symmetrical—or 2D—fields that tokamaks produce. Experiments on the W7-X will investigate the predicted benefits of 3D fields and the resulting 3D plasma shapes as solutions for fusion power plants.

Hutch Neilson

PPPL collaborates on the facility in many ways. The Laboratory designed and delivered five barn-door size trim coils, together with power supplies, that will help shape the plasma during W7-X experiments. And PPPL is preparing diagnostics and other tools for U.S. researchers to operate as collaborators in the scientific exploitation of W7-X. Other Laboratories joining PPPL as collaborators on experiments are Oak Ridge National Laboratory and Los Alamos National Laboratory. Also joining are MIT, Auburn University, the University of Wisconsin and Xantho Technologies.

PPPL aims to work with all the U.S. partners to conduct a coherent program on W7-X. "We're in this for the science that we'll get from the research and will make available to ourselves and the world," said physicist Hutch Neilson, the head of Advanced Projects at PPPL, who recently spent nine months at the W7-X site in Greifswald, Germany, to pave the way for U.S. researchers.

Participants from PPPL include physicists Sam Lazerson, Novimir Pablant, and David Gates. Lazerson, who will be stationed in Greifswald for 11 months, will model the behavior of W7-X plasmas and take part in experiments. Pablant, an expert in the design of diagnostic instruments called x-ray crystal spectrometers, has developed such an instrument for W7-X; he will help to install it and will use the measurements in understanding the plasma's behavior. Gates oversees PPPL's stellarator physics research, of which the W7-X collaboration is now the largest element.

BOB ELLIS DESIGNS A PPPL FIRST: A 3D PRINTED MIRROR FOR MICROWAVE LAUNCHERS

WHEN SCIENTISTS AT THE KOREA SUPERCOMPUTING TOKAMAK ADVANCED RESEARCH (KSTAR) FACILITY needed a crucial new component, they turned to PPPL engineer Bob Ellis. His task: Design a water-cooled fixed mirror that can withstand high heat loads for up to 300 seconds while directing microwaves beamed from launchers to heat the plasma that fuels fusion reactions.

Ellis, who had designed mirrors without coolant for shorter experiments, decided to try a novel manufacturing process called 3D printing that produces components as unified wholes with minimal need for further processing. 3D printing would enable the mirror to be built for less cost than a non-water-cooled mirror produced by conventional manufacturing, Ellis said, "and that was a very nice thing to find out about."

The project marked a first for PPPL, which had previously used 3D printers to build plastic models but had not employed the process for creating metal parts. "Metal came into 3D printing about five years ago and was sort of exotic then," said Phil Heitzenroeder, head of the Mechanical Engineering Division at PPPL. "Now 3D is beginning to drift down into real-world metal products."

Ellis created a CAD-CAM model of the shoe-box-size mirror system and delivered it to Imperial Machine & Tool Co. to produce the stainless steel and copper component through metal 3D printing. The process puts down hair-thin layers of stainless steel powder and fuses the powder in each layer with lasers. The parts are thus built from the bottom up layer by layer and follow every twist and turn of the CAD-CAM design. "3D printing allows you to produce components in a single piece," Ellis said, "and that's a huge advantage."

The stainless steel granules have the consistency of talcum powder before they are fused, said Christian M. Joest, president of Imperial Machine & Tool, which fabricated the component. The 3D process took about 20 hours to complete, Joest said.

Ellis now is designing a steerable mirror for KSTAR that can be controlled by computer to direct microwaves into different parts of the plasma. Ellis dubs this mirror, to be delivered this year, "Generation 2.0," since it will have flat cooling channels rather than the round ones on the fixed mirror. The flat channels will increase the efficiency of the coolant, he said, which will be important for shedding heat from the constantly moving steerable mirror.

Bob Ellis with a 3D-printed plastic prototype for a non-mirror part of the launcher.

PPPL, PRINCETON LAUNCH HUNT FOR BIG BANG PARTICLES OFFERING CLUES TO THE ORIGIN OF THE UNIVERSE

Chris Tully adjusts the PTOLEMY prototype.

Billions upon billions of neutrinos speed harmlessly through everyone's body every moment of the day, according to cosmologists. The bulk of these subatomic particles are believed to come straight from the Big Bang, rather than from the sun or other sources. Experimental confirmation of this belief could yield seminal insights into the early universe and the physics of neutrinos. But how do you interrogate something so elusive that it could zip through a barrier of iron a light-year thick as if it were empty space?

At PPPL, researchers led by Princeton University physicist Chris Tully are set to hunt for these nearly massless Big Bang relics by exploiting a curious fact: Neutrinos can be captured by tritium, a radioactive isotope of hydrogen, and provide a tiny boost of energy to the electrons—or beta particles—that are emitted in tritium decay.

Tully has created a prototype lab at PPPL to detect Big Bang neutrinos by measuring the extra energy they impart to the electrons—and to achieve this with greater precision than has ever been done before. Spotting these neutrinos is akin to "detecting a faint heartbeat in a sports arena filled to the brim" said Charles Gentile, who heads engineering for the project, which Tully has dubbed PTOLEMY for "Princeton Tritium Observatory for Light, Early Universe Massive Neutrino Yield." Ptolemy was an ancient Greek astronomer who lived in Egypt during the first century.

The task calls for measuring the energy of an electron with a precision comparable to detecting the mass of a neutrino, which until recently was thought to have no mass at all. Such measurements require the darkest, coldest conditions achievable in a laboratory and the use of quantum electronics—a discipline that deals with the effect of quantum mechanics on the behavior of electrons in matter—to detect the minute extra energy that a Big Bang neutrino would impart. Quantum mechanics describes the motion and direction of subatomic particles.

Tully aims to show that the prototype for PTOLEMY, which is housed in a basement site at PPPL, can indeed achieve the precision needed to detect Big Bang neutrinos. The cutting-edge technology could then become the basis for a major experiment at PPPL to test long-held assumptions about the density of Big Bang neutrinos throughout the universe.

Hong Qin promoted to executive dean at the University of Science and Technology of China

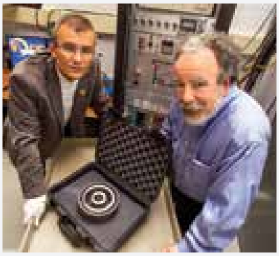
Hong Qin

The past year brought twin honors to physicist Hong Qin. In recent years he has shuttled between PPPL and a teaching post at the University of Science and Technology of China (USTC), which named him executive dean of its School of Nuclear Science and Technology in October. He takes up the position while maintaining his agenda as a principal research physicist in the PPPL Theory Department and a teacher in the Program in Plasma Physics at Princeton University.

Hong's promotion coincides with another form of recognition that he received in October: The American Physical Society (APS) named him an APS Fellow—an honor given annually to one-half of 1 percent of the society's nearly 50,000 members.

His new role at USTC "is a win-win for everyone—PPPL, USTC and Princeton University," said Nat Fisch, director of the Program in Plasma Physics. "The Chinese fusion program is advancing rapidly," Fisch said, "and Hong has played a pivotal role in our collaboration with it. With his new role, Hong will be even more valuable to us in pursuing collaborative research and teaching initiatives with the expanding and vibrant Chinese program. Lucky for us that Hong can manage so much on his plate."

PPPL-PRINCETON PROJECT TO VERIFY NUCLEAR WARHEADS WINS WORLDWIDE ATTENTION



Alex Glaser, left, and Rob Goldston with non-nuclear test object.

When news of a novel PPPL-Princeton project to verify nuclear warheads broke last year, it quickly went viral. A paper describing the project in the journal *Nature* succeeded in "setting the arms control community abuzz," wrote rival journal *Science*. Editors of *Foreign Policy* magazine named authors of the paper to its list of "100 Leading Global Thinkers of 2014" for research aimed at "verifying that which can't be seen."

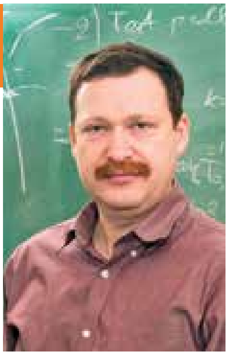
Recognized for their work were fusion physicist Rob Goldston, a Princeton University professor of astrophysical sciences and former director of PPPL; Alex Glaser, an assistant professor in Princeton's Mechanical and Aerospace Engineering Department, and Boaz Barak of Microsoft Research New England.

The scientists have designed a process called a "zero-knowledge protocol" for verifying that nuclear weapons to be dismantled or removed from deployment contain true warheads. The process would verify this without collecting any classified information that could lead to nuclear proliferation. Goldston and Glaser are developing a prototype of the system at PPPL that will test their idea by beaming neutrons at a non-nuclear test object.

The project was launched with a seed grant from the Simons Foundation of Vancouver, Canada, that came to Princeton through Global Zero, a nonprofit organization. Support also was provided by the U.S. Department of State, the U.S. Department of Energy and most recently, a total of $3.5 million over five years from the National Nuclear Security Administration.

Goldston said he hoped the recognition for an approach to arms control that carries no risk of spreading classified information "would help to encourage policy makers to keep pushing this agenda." Glaser expressed a similar sentiment. "It is fantastic to see that new ideas in the area of nuclear arms control can get the attention of the broader policy community," he said. While "real progress" has been made in reducing the global stockpile of nuclear weapons since the Cold War, he added, "much more needs to and can be done."

PPPL LENDS GENERAL ELECTRIC A HELPING HAND



Igor Kaganovich

Researchers at General Electric have turned to PPPL for help in designing a plasma-based power switch. The proposed switch, which GE is developing under contract with the DOE's Advanced Research Projects Agency-Energy, could contribute to a more advanced and reliable electric grid and help lower utility bills.

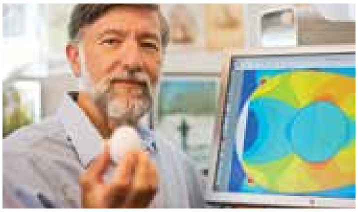
The switch would consist of a plasma-filled tube that turns current on and off in systems that convert the direct current coming from long-distance power lines to the alternating current that lights homes and businesses; such systems are used to reverse the process as well. The tube would serve as a compact, less costly alternative to the bulky assemblies of semiconductor switches now installed in power-conversion systems throughout the grid.

To assist GE, researchers led by physicist Igor Kaganovich used a pair of computer codes to model the properties of plasma under different magnetic field configurations and gas pressures.

GE also consulted with PPPL about developing a method for protecting the liquid-metal cathode—the negative terminal inside the tube—from damage from the ions carrying the current flowing through the plasma. The company has been studying PPPL's use of liquid lithium, which the laboratory employs to prevent damage to the divertor that exhausts heat in a fusion facility. The lithium forms a wet, self-healing barrier that could serve as a model for the GE cathode.

PPPL AND USDA ENGINEERS RECEIVE A PATENT FOR PASTEURIZING EGGS IN THE SHELL

THE U.S. PATENT AND TRADEMARK OFFICE HAS GRANTED a patent to a novel technique and device for pasteurizing eggs developed by engineers at PPPL and the U.S. Department of Agriculture (USDA). The award marks the 27th patent granted to PPPL inventors since 1994.



Chris Brunkhorst

"This is a unique experience for me," said Chris Brunkhorst, an expert in radio frequency (RF) heating at PPPL. "It's the first time I've had a patent awarded." Brunkhorst holds the patent with David Geveke, research chemical engineer and lead scientist at the USDA Agricultural Research Service in Wyndmoor, Pa., and Andrew Bigley, an engineering technician recently retired from the USDA.

The three inventors will share in any revenue that comes from licensing the invention. Princeton University holds joint rights to the technology with the USDA, which is in talks to license it to an industrial user.

The invention uses RF energy to transmit heat through the shell and into the yolk while the egg rotates. Streams of cool water simultaneously flow over the egg to protect the delicate white. Researchers then bathe the egg in hot water to complete the pasteurization process.

The invention can pasteurize shell eggs in one-third the time that current methods require, according to Geveke. And unlike such methods, which heat the eggs in water for about an hour, the invention doesn't affect the appearance of the egg white, he said. The aim is to produce a pasteurized egg "that is hardly discernible from a fresh, nonpasteurized egg," he noted.

PPPL COLLABORATES WITH GENERAL ATOMICS ON MITIGATING INSTABILITIES ON DIII-D

Close-up view of the high-speed propeller inside the injector.

PPPL has developed an innovative device to diminish the size of instabilities known as "edge localized modes (ELMs)" that can damage the interior of fusion facilities. The device, tested in a joint effort with staff members of General Atomics, has proven highly successful on the DIII-D tokamak that General Atomics operates for the U.S. Department of Energy in San Diego.

The system, developed by physicist Dennis Mansfield and engineer Lane Roquemore, injects granular lithium particles into tokamak plasmas to increase the frequency of the ELMs. The aim is to make the ELMs smaller and reduce the amount of heat that strikes the divertor that exhausts heat in fusion facilities.

Tests of the system called for close collaboration between PPPL and General Atomics researchers. On the PPPL side, physicists Rajesh Maingi and Alessandro Bortolon, together with technician Alex Nagy, worked with General Atomics physicists Gary Jackson and Tom Osborne to demonstrate successful operation of the lithium injector.

The PPPL system could serve as a possible model for mitigating ELMs on ITER, the fusion facility under construction in France to demonstrate the feasibility of fusion energy. "ELMs are a big issue for ITER," said Mickey Wade, director of the DIII-D fusion program. Large-scale ELMs, he noted, could melt plasma-facing components inside the ITER tokamak.

Another PPPL system has proven successful in mitigating ELMs on the EAST tokamak in Hefei, China. A system is also planned for PPPL's major fusion facility, the National Spherical Torus Experiment-Upgrade.

CAPECE AND TRESEMER APPEAR IN DOE VIDEOS

Physicist Angela Capece and engineer Kelsey Tresemer have prominent roles in new DOE videos about the Laboratory. Capece, an expert in material science, urges young women to pursue their passion in science and technology in a video titled "Women in Stem: A Physicist Focuses on Scientific Advancement." Her research investigates the use of lithium coatings on metal surfaces in support of the National Spherical Torus Experiment-Upgrade (NSTX-U). "It's exciting," Capece says in the video, "because you get to play with things and see right in front of your eyes how things work."

Angela Capece

Tresemer, a mechanical design engineer, appears in the video "A Star on Earth" together with PPPL Director Stewart Prager and Laboratory physicists. Tresemer oversaw the design of protective tiles for the new NSTX-U center stack and is working on plasma facing components for ITER. In the video, she explains that the upgrade has enlarged the NSTX-U center stack and notes that the successful production of fusion energy "would basically change societies around the globe."

Kelsey Tresemer

PhD Comics comes to PPPL

Anyone curious about fusion can quickly learn the basics from a new animated video that features interviews and cartoon characters based on PPPL physicists. The eight-minute video developed by PhD Comics' creator Jorge Cham can be viewed by Googling "PhD Comics: Fusion energy explained."

In the video, cartoon versions of Andrew Zwicker, head of Science Education at PPPL, and Arturo Dominguez, a postdoctoral fellow, explain some of the basics of magnetic fusion. Stefan Gerhardt, a principal research physicist at PPPL, gives a tour of the National Spherical Torus Experiment-Upgrade, the Laboratory's major fusion facility, in a live video and as a cartoon character.

Cham, who holds a doctorate in mechanical engineering from Stanford University, created PhD Comics—the letters stand for "Piled Higher and Deeper"—in 1997 as a light-hearted look at life in graduate school. His website gave rise to a live-action adaptation of PhD Comics in 2011 and gets about 6.5 million unique visitors a year.

A scene from PhD Comics video "Fusion Energy Explained."

SCOUTS GET A HANDS-ON FEEL FOR SCIENCE, TECHNOLOGY AND MATH

GIRL SCOUTS AND BOY SCOUTS ENJOYED DAYLONG EVENTS filled with hands-on activities at PPPL during the past year. Some 240 Girl Scouts in grades three through twelve from throughout New Jersey took part in the Girl Scout STEM Fair, working with scientists and engineers to build robots and solar cars, do chemistry experiments, study circuits and learn what it's like to be inventors.

The Scouts came away with a newfound taste for scientific enterprise. "I like science a lot," said Khushi Varshney, 12, of Princeton Junction. But not all girls her age feel the same way. "Many girls don't like science," she said. "But once they learn about it, they find it's very interesting."

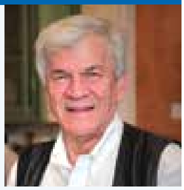
Boy Scouts could choose from more than 15 different merit badges during the Central New Jersey Council's Science and Technology Merit Badge Fair. Popular activities ranged from building robots to soldering electronic circuit boards. Included in the day were Laboratory tours led by PPPL physicists and engineers.

"They were all interested and engaged," said engineer Steve Raftopoulos, who was the technical expert for the engineering classes. "They wanted to be here and they behaved like they wanted to be here."

Engineer Steve Raftopoulos leads a tour for Boy Scouts.

Engineer Atiba Brereton coaches a Girl Scouts project.

Ronald Davidson receives FPA Distinguished Career Award


Ronald Davidson

Ronald Davidson, PPPL director from 1991 to 1996 and a leading contributor to fusion and plasma science research, was honored with a 2014 Distinguished Career Award from Fusion Power Associates (FPA), which promotes the development of fusion energy.

In citing Davidson's achievements, FPA directors noted his "decades of outstanding career contributions as a scientist, educator, manager and advisor in the areas of both magnetic and inertial confinement fusion."

"Ron Davidson's accomplishments that underlie this award are astounding," said PPPL Director Stewart Prager. "They begin first and foremost with his prodigious output of seminal contributions to theoretical plasma physics and include his long mentorship of students, authorship of textbooks, leadership of major community activities, and directorships of major institutions. An amazing record of achievement."

Ilya Dodin wins first Stix Award

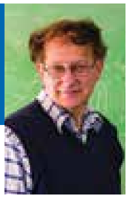

Ilya Dodin

Physicist Ilya Dodin has won the first Thomas H. Stix Award for Outstanding Early Career Contributions to Plasma Physics Research. The honor, presented by the American Physical Society, recognized Dodin for his modeling of waves in plasmas.

The award is named for the late Thomas H. Stix, founding director of the Princeton Program in Plasma Physics, a division of the Department of Astrophysical Sciences at Princeton University. Stix's achievements include a leading textbook about plasma waves, a key issue in fusion research.

Dodin, who uses the text in a graduate course that he teaches, has developed a theoretical approach to describing the behavior of waves in simplified but robust forms. This mathematical treatment is hard-wired to elucidate and accurately treat the most critical aspects of wave dynamics when plasma parameters change. As a result, the new theory brings out the wave dynamics in ways that would not otherwise be seen.

Nat Fisch honored with Europe's Alfvén Prize


Nat Fisch

The European Physical Society has named physicist Nat Fisch winner of the 2015 Hannes Alfvén Prize. The prize, named for 1970 Nobel Laureate Hannes Alfvén, goes each year to a person who has contributed greatly to the advancement of plasma physics or shows promise of doing so in the future.

Fisch, director of the Princeton Program in Plasma Physics and professor and associate chair of astrophysical sciences at Princeton University, was honored for fundamental studies of wave-particle interactions and for predicting new plasma phenomena, including new ways of creating electrical currents in tokamaks by using radio-frequency waves. One notable prediction, borne out by experiment, showed that huge electrical currents could be produced with relatively little power consumption.

"I am very grateful that the European Physical Society reached across the ocean to recognize my contributions to plasma physics research," said Fisch. "My efforts would not have been successful without the support and vibrant intellectual environment provided by my colleagues at PPPL over many years."

Brian Grierson wins DOE Early Career Grant


Brian Grierson

Physicist Brian Grierson of PPPL won an Early Career Research Program award sponsored by the DOE's Office of Science. The five-year grant will total some $2.5 million and fund exploration of the mechanisms that govern the formation and maintenance of the hot edge of fusion plasmas. The work will be carried out on the DIII-D National Fusion Facility that General Atomics operates for the DOE in San Diego.

Understanding and controlling the edge of a hot fusion plasma is crucial for achieving high performance in devices like the ITER tokamak, the world's largest fusion experiment, now under construction in France.

The award for Grierson marks the second Early Career Grant in as many years to physicists at PPPL. Ahmed Diallo, leader of the pedestal structure and control topical science group for the NSTX-U, won a five-year award for research on the plasma edge last year.

QUEST | RESEARCH NEWS FROM PPPL
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