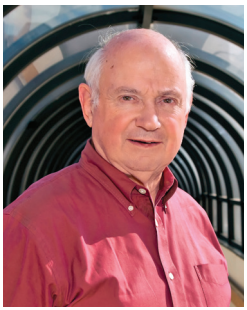
RESEARCH NEWS FROM PPPL
Summer 2014

QUEST

AHA! NEW FACES of DISCOVERY at PPPL

PPPL PRINCETON PLASMA PHYSICS LABORATORY
U.S. DEPARTMENT OF ENERGY
PRINCETON UNIVERSITY

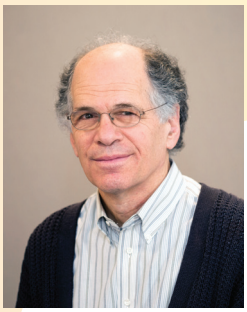


A.J. Stewart Smith
Princeton University
Vice President for PPPL

FROM THE PRINCETON UNIVERSITY VICE PRESIDENT FOR PPPL

Not only is PPPL the country's national laboratory for fusion and plasma science, but it also plays a critical role in graduate education at Princeton University. The Laboratory is home to the Program in Plasma Physics, a division of the Princeton Department of Astrophysical Sciences, and prepares graduate students for leadership in all aspects of fusion and plasma science research. As a veteran professor of physics myself, I take pride in the superb training for young scientists that the Laboratory provides and that is described in this issue.

As the University's dean for research from 2006 to 2013, I oversaw the Laboratory while serving under then-Princeton President Shirley M. Tilghman, who fully supported the scientific and educational mission of PPPL, which Princeton manages for the U.S. Department of Energy (DOE). Now, as University vice president for PPPL, it is my pleasure to oversee the Laboratory and to manage its relations with DOE under Princeton President Christopher L. Eisgruber, a former Princeton undergraduate physics major and also a strong supporter of PPPL. We all look forward with great excitement to the completion of the major new facility at PPPL that is described below, and to the science that it will enable.



Stewart Prager
PPPL Director

FROM THE DIRECTOR OF PPPL

Among the pleasures of directing PPPL is watching our research and the students we train progress side by side. Projects throughout the Laboratory enable students to develop their knowledge and skills under the guidance of scientists who are making fundamental contributions to the research highlighted in this issue.

The past year has set the stage for exciting advances for the Laboratory. The $94 million upgrade of the National Spherical Torus Experiment (NSTX-U), our major fusion experiment, is nearing the completion of three years of construction that will provide a huge boost to its physics capabilities. At the same time, PPPL scientists are developing innovative methods for protecting the interior walls of tokamaks from the scorching heat that fusion reactions produce.

In fundamental plasma physics, work has begun to construct a new experiment to study magnetic reconnection, one of the most common but least understood processes in the universe. This new facility, following on the highly successful Magnetic Reconnection Experiment (MRX), will dovetail nicely with the new Princeton Center for Heliospheric Physics, which the Laboratory has formed with the University to study space weather and other astrophysical phenomena.

PPPL researchers continue to play key roles in collaborations around the world. These range from designing and managing the construction of components for ITER, the huge international fusion experiment being built in France, to scientific collaborations on a new fusion facility in China and on the DIII-D tokamak that General Atomics operates for the U.S. Department of Energy in San Diego.

These are some projects at PPPL that provide opportunities for both graduate study and advanced research. In a very real sense, all of us here at the Lab are learning together.

On the cover: Graduate students in the Princeton Program in Plasma Physics that is substantially located at PPPL.

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BROAD AND DEEP TRAINING FOR LEADERSHIP IN PLASMA SCIENCE AND FUSION RESEARCH

SINCE 1959, MORE THAN 265 STUDENTS HAVE EARNED PRINCETON doctorates through the Program in Plasma Physics that is substantially located at PPPL. Among the graduates are numerous senior executives, project heads and key scientific contributors to major U.S. and international research centers devoted to fusion and plasma science research.

The graduate program, like PPPL itself, reflects the vision of Lyman Spitzer, the Princeton astrophysicist who cofounded the Laboratory in 1951 to develop fusion as a clean and boundless source of energy for generating electricity. Spitzer's pioneering contributions to fusion, plasma physics and astrophysical research helped lay the groundwork for today's program, which is part of the Department of Astrophysical Sciences at Princeton University and was founded by Princeton professor and pioneering plasma physicist Thomas Stix.

This program is both broad and deep. "Students can work on projects in all major areas of research, from developing fusion energy to studying astrophysical plasmas and plasmas used in manufacturing," said Program Director Nat Fisch, a PPPL physicist and Princeton professor.

The program develops insightful modes of thought as well. "Since so many pioneers of fusion and plasma physics have taught here, their intuitions and ways of thinking are passed down to the students," said Greg Hammett, a principal research physicist at PPPL who earned his doctorate from Princeton in 1986 and serves as a lecturer with the rank of professor in the graduate program.

The now-rigorous training was loosely organized at first. "There wasn't really any structure to the program because I was the only student in it," recalled David Montgomery, a professor emeritus at Dartmouth University who wrote his thesis under Spitzer and received the first plasma physics doctorate in 1959.

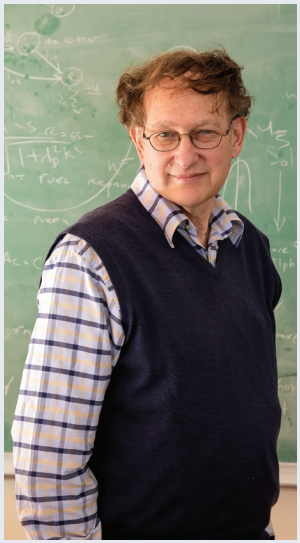
Today's broad curriculum and opportunity to work with leading scientists attract students from around the world. Graduates from more than a dozen countries have earned their doctorates through the program and the current enrollment of 40 students includes 12 who hail from countries such as Russia, China, Canada and Singapore.

The chance to contribute to fusion research motivates many students. "It's cool to work on something that is a grand challenge and would really impact people's lives," said Jeffrey Parker, a sixth-year graduate student who is studying plasma turbulence in magnetic fusion devices.

Students benefit from the program's high ratio of instructors to enrollees. The faculty consists of some 20 PPPL physicists who hold appointments in the Department of Astrophysical Sciences. Many are authors of classic textbooks and research papers in plasma physics.

Newcomers spend their first two years in classroom study at PPPL with full access to laboratory and computer facilities. They then choose dissertation topics, which they can pursue with faculty members, instructors in other Princeton departments or with any of the nearly 100 scientists at PPPL.

Graduates of the program are highly sought. "Our students are trained as specialists in plasma physics, but within the context of a broader training in physics," said Fisch. "Consequently, they are able to find careers on a variety of tracks within industry, academia, and public and private research institutions. Employers see the Princeton degree as a guarantee of a quality physics education."

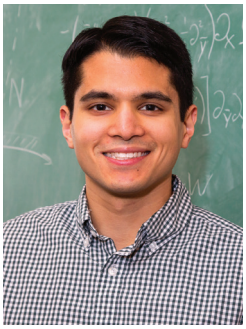


Graduate Program Director Nat Fisch

Opposite page: Graduate student Dennis Boyle works on the Lithium Tokamak Experiment.

MOMENTS OF DISCOVERY

PRINCETON UNIVERSITY GRADUATE STUDENTS PURSUING THEIR doctorates at PPPL explore the behavior of plasma in laboratory experiments, computer models and the natural world. Here eight students describe their Aha! moments of discovery.



Jeffrey Parker

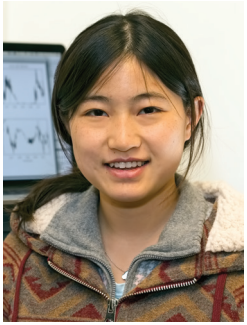
EMERGING INTO THE SUNLIGHT

Theoretical research rarely proceeds smoothly, at least not the way that I have experienced it. At times there is a clear path to follow and the work is straightforward. But most of the time typically gets spent trying to figure out the best way to proceed.

While searching for a better understanding of "zonal flows" — a phenomenon that arises in systems that include tokamaks and the atmosphere of Jupiter — I came across a simple formula that at first seemed unimportant. But when I ran a simulation and plotted the results of this little equation, I immediately knew I had something. This occurred late in the evening, but I grew very excited and spent that night and several nights thereafter burning the midnight oil trying to learn as much as possible about this equation.

My excitement crystallized into certainty as I read papers that made it clear that the exact problem I had been trying to solve was an example of a general class of what are called "pattern formation" systems. Several properties of these systems provided insight into my problem and offered numerical techniques that could be used as well. The feeling of enlightenment that came with these discoveries was incredible. As two years of confusion faded away, it felt like I was emerging from a dark and terrible storm into broad, sunlit uplands.

— Jeffrey Parker, sixth-year graduate student from Brecksville, Ohio



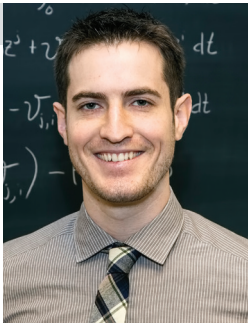
Ge Dong

EVEN THE TINIEST DETAILS COUNT

I was using a computer program with 10,000 lines of code and many complicated algorithms to solve a problem about the transport of plasma particles. But it didn't work, so I tried to find out what was wrong. After several weeks I discovered that I had accidentally left out a very small term on the tail end of some equations. It looked insignificant, but once I implemented the little term everything fell into place. This showed me how important even the tiniest things can be.

— Ge Dong, first-year graduate student from Shanghai, China

THAT'S RIGHT!



Leland Ellison

My research is about developing computer codes that approximate the solution of equations that describe physical systems. We aim to describe the motion of magnetized particles in a plasma and got some funny results when we applied new numerical techniques to the problem. After spending a year building the necessary tools for precisely articulating the nature of this problem, I experienced a breakthrough moment during a trip to my hometown Denver for a belated Christmas celebration.

The day before my trip a collaborator at the Los Alamos National Laboratory sent me some material to spur our discussions. In a sort of perfect storm of planning for our talks, reading a new reference and being forced to consider only big-picture ideas, the lights started to come on while I studied the material on an NJ Transit train to Newark Airport. I must have looked like a madman muttering to myself as I read, "OOOOH, okay… sure, sure. . .but what about? No, that's right — that's right!"

When the cement starts to crack after months of hitting your head against the wall, the feeling is irresistible. And it often takes stepping away from the wall, looking in another direction, and being forced to tell another expert about the problem before one can reasonably expect a different outcome from the persistent string of dead-ends.

— Leland Ellison, fifth-year graduate student from Denver

> *"The lights started to come on while I studied the material on an NJ Transit train to Newark Airport."*

FINDING BUGS AND A BIG SURPRISE

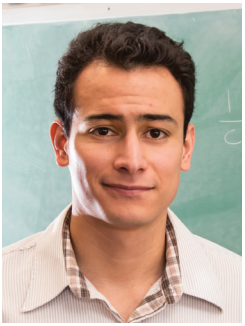
Katy Ghantous

I do programming and there are always little things to solve from day to day. Sometimes things work on first try, but often there are little "bugs" that make the code give funny results. Tracking down these bugs can be very frustrating and finding them can often be an Aha! moment.

At the level of fundamental physics research, once the model I was developing gave results that were off within certain limits. And I said, "Oh wait, you need to depend more on this and less on that within each of the limits." So I made an adjustment to the model to accentuate these dependencies without really expecting the changes to work right away. But they gave me the exact curve that I needed — and that was a big Aha! discovery.

— Katy Ghantous, seventh-year graduate student from Beirut, Lebanon, who received her doctorate in 2013

> *"Tracking down these bugs can be very frustrating and finding them can often be an Aha! moment."*



Daniel Ruiz

SPLITTING THE DIFFERENCE

I like to do research on radiation hydrodynamics, which studies the interaction between materials and the radiation fields that arise when powerful lasers bombard the materials. We model this interaction through transport equations for the radiation and "Navier-Stokes" equations for the material dynamics. Both sets of equations are really hard to solve, even with a computer.

One way to deal with this problem is to model the radiation with a so-called diffusion approximation that is easier to solve than a transport equation but cannot capture the full transport details. So it occurred to me to take a middle path — to treat part of the radiation with a simplified transport equation and the whole bulk of the radiation with a diffusion approximation. We found that this worked well and gave satisfying results.

Now we are working on coupling this simple but accurate description of the radiation fields to the material dynamics part in order to create a complete picture of the interaction between the radiation and the materials.

— Daniel Ruiz, second-year graduate student from Monterrey, Mexico

Clayton Myers

EXPLOSIVE MYSTERY SOLVED

Our laboratory experiment studies "magnetic flux ropes" that are similar to those found in the corona around the sun. We have been searching for mechanisms that can explain why these flux ropes erupt, suddenly and violently, in the form of huge coronal mass ejections that can disrupt satellites and knock out power grids.

Most theoretical studies model these explosive flux ropes as two-dimensional structures. But our experiments produced a huge number of quasi-2D flux ropes without any eruptions in our machine. So just to be sure that I wasn't missing anything, I began to explore some extreme parameters of the experiment when "boom!" an eruption took place, and then another. How come? This was a result that I couldn't understand.

Months later, while I was staring at an image of a solar flux rope, the answer hit me. The extreme conditions in an erupting solar regime create three-dimensional flux ropes shaped like the letter "S"— just as the extreme parameters in our experiment did. And these S-shaped structures, called "sigmoids," produce solar eruptions when 2D flux ropes cannot. So there was the apparent answer to the puzzle of the flux ropes that I had been trying to solve.

"I began to explore some extreme parameters of the experiment when "boom!" an eruption took place, and then another."

— Clayton Myers, seventh-year graduate student from Carey, Ohio

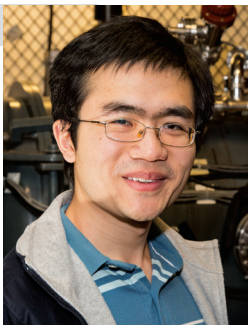
LUCK IS THE RESIDUE OF DESIGN

I'm working on low-temperature plasmas like the ones used in thrusters for spacecraft. We're creating artificial instabilities in these plasmas to find out why natural instabilities sometimes degrade the efficiency of thrusters and sometimes improve it.

The other day I was trying to produce an instability that behaves in a coherent — or constantly rotating — way like a natural instability. Things looked promising the first few times we tried, but when we actually came down to characterizing the instability, things turned out to be messier than we thought.

A few days later, we were searching for the right parameters to produce a coherent instability and just happened to find a regime that was a success. On the one hand, this seemed quite lucky. But on the other hand, it happened because we had the idea that we were going to find the right regime, and we searched for it and did find it.

— Yuan Shi, second-year graduate student from Yunnan, China



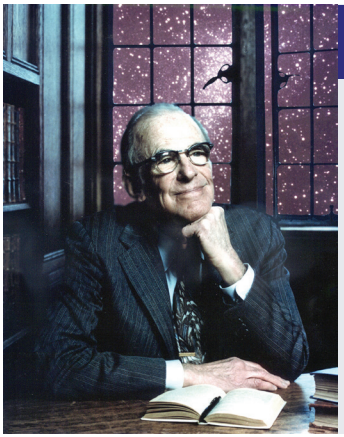
Yuan Shi

DISCOVERING MORE THAN WE EXPECTED TO FIND

Some discoveries are happy accidents. Last year we considered a problem about a spinning and compressing plasma. We began by considering the much simpler problem of a spinning neutral gas. But after we solved it we realized that spinning neutral gas has an interesting and wholly unforeseen property — we could determine the density of the particles in the gas just by taking external measurements. Moreover, we realized that in addition to determining the densities of the known gases inside a container, we could in principle identify the types of gases themselves if they were not known in advance. These discoveries could prove quite useful when we study the contents of a gas container that might be unsafe to open.

— Vasily Geyko, fifth-year graduate student from Nizhny Novgorod, Russia

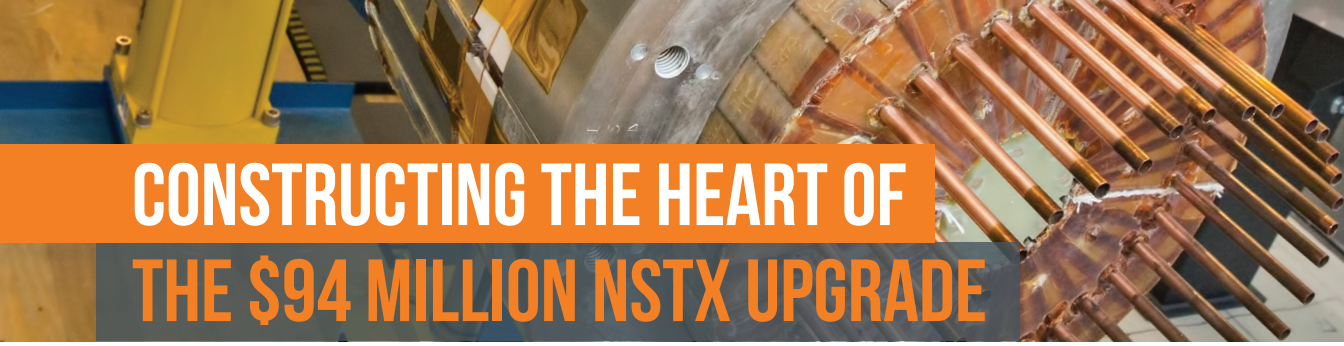
Vasily Geyko



Graduates pass the torch

As the original home of fusion research in the United States, PPPL has passed the torch of scientific learning down through generations of graduates of the Princeton Program in Plasma Physics. More than 50 graduates have joined university faculties around the world, where they prepare future scientists to advance the fields of fusion energy and plasma physics.

Princeton astrophysicist Lyman Spitzer cofounded the Laboratory and inspired generations of teachers.



CONSTRUCTING THE HEART OF THE $94 MILLION NSTX UPGRADE

THE NEW CENTER STACK FOR THE NATIONAL Spherical Torus Experiment (NSTX) forms the heart of a three-year upgrade. This upgrade will make the NSTX the most powerful fusion facility of its kind in the world when the work is completed around the end of the year.

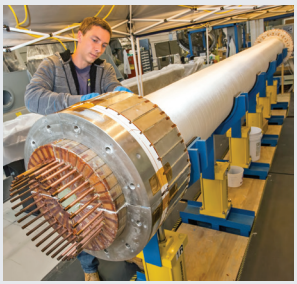
Building the center stack required joining 36 20-foot-long copper conductors into a seamless round column capable of carrying enough power to briefly light a small city. The column consists of four quadrants with nine conductors in each.

This work was part of an effort that saw engineers, technicians and other members of the Laboratory make substantial contributions to the upgrade.

Here is a look at key stages of the center stack construction:

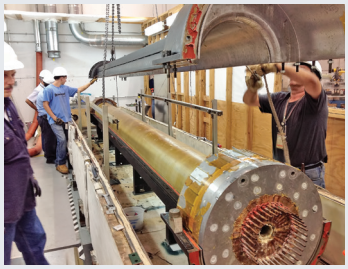
1 ***First quadrant:*** Assembling fiberglass-wrapped conductors for the first of four quadrants that will form the center column.

2 ***Halfway there:*** The first two quadrants are assembled and not yet sealed together.



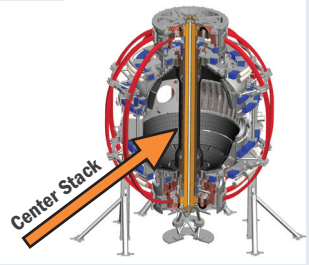
3 ***Four-into-one:*** Adding fiberglass insulation to the round and unsealed column.

4 ***Moving day:*** The column rises from its cradle on the way to the mold to be sealed.



5 ***All together now:*** Opening the mold to reveal the sealed column.

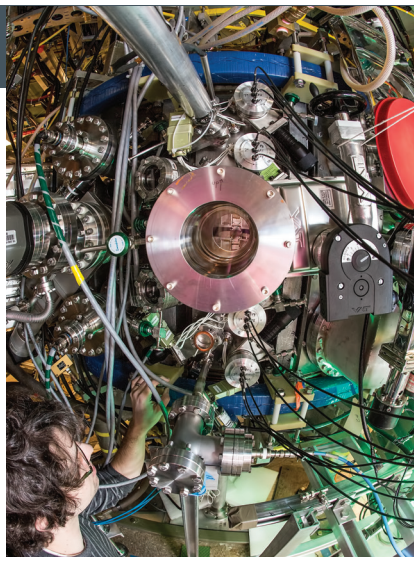
6 ***Wrapping up:*** Winding a heating coil around the column.



7 ***Installed:*** The new stack will form the heart of the fusion facility.

LITHIUM WALLS KEEP PLASMAS INSULATED, CLEAN, AND HOT

FOR MAGNETIC FUSION ENERGY TO FUEL POWER PLANTS, scientists must find highly efficient ways to keep the ionized gas — or plasma — that produces fusion reactions as hot as possible. At PPPL, strides toward meeting this challenge include recent results obtained on the Lithium Tokamak Experiment (LTX). Research on the compact, donut-shaped device, or tokamak, reveals how using liquid lithium to coat the interior walls insulates the plasma from the walls of the container, facilitates the plasma's ability to conduct electric current and extends the lifetime of the ionized gas.



Graduate student Dennis Boyle adjusts a plasma diagnostic on the LTX.

"The material that the walls are made of has a major effect on both the cleanliness of the plasma and how efficiently we can heat it," said physicist Dick Majeski, the principal investigator on the experiment. "LTX tests one approach to improving both."

LTX researchers have sharply reduced heat losses from the plasma by employing a new technique that uses a high-power electron beam to rapidly evaporate the lithium from a pool in the bottom of the tokamak and create lithium vapor that coats the interior walls. This substantial coating takes just minutes to produce, soaks up any plasma particles that escape and keeps them from bouncing back into the core of the plasma and cooling it off.

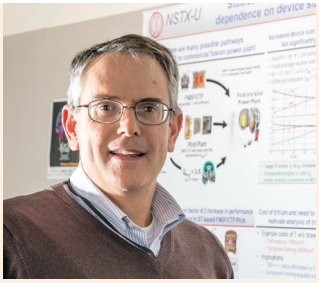
PPPL's Kessel heads study for the projected next step in the U.S. magnetic fusion energy program

The U.S. Department of Energy has named PPPL engineer Charles Kessel to lead a nationwide study that will detail options for a major next step on the country's path to magnetic fusion energy. Kessel's team will define the mission of the proposed Fusion Nuclear Science Facility (FNSF), which would pave the way for a U.S. demonstration fusion power plant and then a commercial plant.

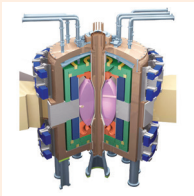
The three-year study will address a broad range of formats for the FNSF — from a compact machine that will test how components interact with the neutrons produced by fusion reactions to a large, fully integrated device that generates electricity. "We're going to look at the whole thing," said Kessel, an expert on fusion power-plant design.

The study will help guide experiments on PPPL's upgraded National Spherical Torus Experiment, whose cored apple-like shape could serve as a model for the FNSF.

Kessel's team will also consider the role of the FNSF in relation to ITER, the large international experiment now under construction in France to demonstrate the feasibility of fusion power. The FNSF could glean lessons from the research done on ITER and serve as a bridge from that international project to a demonstration reactor.



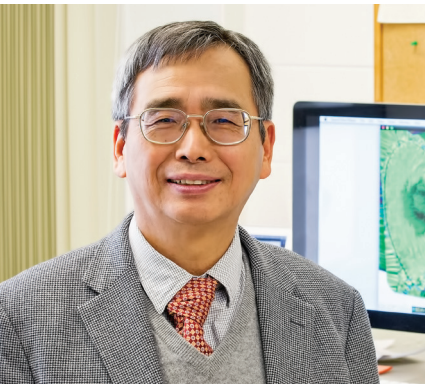
Charles Kessel



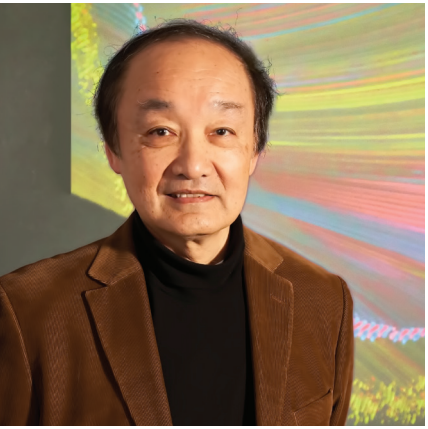
Sketch of a possible FNSF design.

TWO PPPL-LED TEAMS WIN SHARPLY INCREASED SUPERCOMPUTING TIME TO STUDY FUSION PLASMAS

RESEARCHERS LED BY PPPL SCIENTISTS HAVE WON HIGHLY COMPETITIVE allocations of time on two of the world's fastest supercomputers. The increased awards are designed to advance the development of nuclear fusion as a clean and abundant source of energy for generating electricity.



C.S. Chang



William Tang

The allocations marked the second year of three-year grants from a U.S. Department of Energy program to accelerate scientific discovery. The nationwide program, called Innovative and Novel Impact on Computational Theory and Experiment (INCITE), awards millions of computer core — or processor — hours for cutting-edge research on energy projects. Supercomputers have hundreds of thousands of processors that can accomplish in minutes what a desktop computer powered by a single processor would take years to complete.

The PPPL recipients:

- A multi-institutional center led by PPPL physicist C.S. Chang that studies the turbulent edge of the superhot, electrically charged plasma gas that fuels fusion reactions. Chang's team, the Center for Edge Physics Simulation (EPSI), won a total of 229 million core hours — more than double the 100 million core hours the center received in its first year and among the top three allotments in the INCITE program. The new award consists of 129 million core hours on Titan, the Cray XK7 supercomputer at Oak Ridge National Laboratory, and 100 million core hours on the IBM Blue Gene/Q supercomputer at Argonne National Laboratory.

- An international team led by PPPL physicist William Tang that is developing a high-performance code to study the properties of plasma confinement. Such a code will be an essential ingredient for designing an efficient fusion reactor. Tang's team won 50 million core hours on the IBM Blue Gene/Q machine, up from 40 million core hours in the previous year's allotment.

PPPL HEADS GLOBAL EFFORT CRUCIAL TO FUSION DEVELOPMENT

PPPL IS LEADING A WORLDWIDE EFFORT TO ADDRESS a key challenge for fusion energy: Improving ways to predict and mitigate disruptions that can destroy magnetically confined plasmas that are needed for fusion reactions.

Workshop participants: PPPL Director Stewart Prager, Theory Department Head Amitava Bhattacharjee and David Campbell, director of plasma operations at ITER.

Confronting this challenge will be crucial for ITER, the huge international fusion facility that is being built in France. "The future of magnetic fusion research hangs on ITER being successful," said Amitava Bhattacharjee, head of the Theory Department at PPPL, "and ITER will need to avoid disruptions or mitigate them when they occur."

Bhattacharjee kicked off the effort by convening a workshop in 2013 that brought together some 35 physicists from around the world to develop a unified approach to disruption research. A second PPPL-led workshop is scheduled for this summer.

Disruptions take place when there is a sudden drop in heat or electric current during fusion experiments. This drop allows the hot, electrically charged plasma gas that fuels the experiments to dissipate and can release forces that damage fusion facilities.

The PPPL-led workshop produced "a very good degree of analysis from both experimentalists and theorists," said David Campbell, director of plasma operations at ITER. "I hope that we can build on the links developed here."

Theorists and Experimentalists Join Hands

Elena Belova

PPPL theorists use computers to model fusion plasmas and predict their behavior in ways that researchers who conduct experiments can test. In the latest example of this collaboration, physicist Elena Belova is modeling the mysterious tendency of electron heat to leak from the core of the plasma without being driven by differences in electron temperature, as normally is the case. Belova suspects that energetic ion beams that researchers inject into the core of the plasma to heat it may lead to electron heating in the plasma edge instead. This could create much broader electron-energy profiles than otherwise expected, and could prevent disruptions that cause the plasma to collapse.

Awaiting Belova's findings are physicists who plan to test her results on the National Spherical Torus Experiment Upgrade (NSTX-U). Its increased capabilities will create energetic-ion conditions similar to those expected in ITER, the international facility being built in France to produce sustained fusion energy. Discovering the source of the mysterious electron heat transport, and finding ways to control it in NSTX-U plasmas will thus provide valuable lessons for ITER and future fusion research.

Illustration of the solar wind in contact with the Earth's magnetosphere. The streaming wind compresses the magnetosphere on the side of the Earth that is nearest the sun, and stretches the magnetosphere into a long "tail" as the wind blows past the Earth and farther away from the sun.

PRINCETON AND PPPL LAUNCH CENTER TO STUDY VOLATILE SPACE WEATHER

RESEARCHERS AT PPPL AND PRINCETON UNIVERSITY have launched a new center to study the heliosphere, the complex and frequently violent region of space that encompasses the solar system.

This region is carved out by the solar wind — charged plasma particles that constantly stream from the sun — and produces space weather that can disrupt cell phone service, damage satellites and knock out power grids. Such stormy weather results from solar flares and coronal mass ejections — huge solar eruptions that periodically hurl millions of tons of electrically charged plasma particles into the heliosphere.

The Princeton Center for Heliospheric Physics aims to sharpen the capacity to predict solar eruptions and to deepen understanding of the plasma flows and magnetic forces that emanate from the sun. "All this is the domain of heliospheric physics," said Amitava Bhattacharjee, head of the Theory Department at PPPL and co-director of the new center with PPPL physicist Jay Johnson.

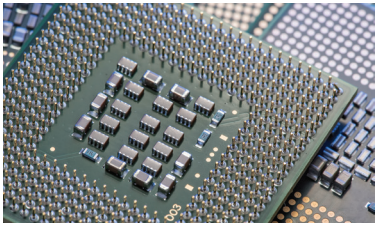
The center combines the resources of Princeton's Department of Astrophysical Sciences and PPPL and facilitates collaboration between them. "Having these complementary efforts within the center provides us with the essential tools for better understanding of space weather," Johnson said.

Key center projects will range from development of a computer code to model as precisely as possible the physics behind the role of magnetic reconnection in geomagnetic storms, to studies of the interaction between the solar wind and the magnetosphere that can whip up disturbances that pose danger to spacecraft and to the human exploration of space.

Bolstering the center's research will be its ability to collaborate with the Magnetic Reconnection Experiment (MRX) at PPPL, which has produced reconnection under laboratory conditions for nearly two decades. Such data will enable researchers to test the power of their codes to model the physics behind reconnection.

SOLUTION TO PUZZLE COULD LEAD TO MORE POWERFUL MICROCHIPS

RESEARCH CONDUCTED BY PPPL PHYSICIST IGOR KAGANOVICH IN collaboration with Dmytro Sydorenko of the University of Alberta provides a key step toward the development of ever-more powerful computer chips. The researchers discovered the physics behind a mysterious process that provides unprecedented control of a recent plasma-based technique for etching transistors on microchips.



A microchip with more than 450 million transistors.

The recent technique utilizes electron beams to reach and harden the surface of the masks that are used for printing microchip circuits. More importantly, the beam creates a population of "suprathermal" electrons that produce the plasma chemistry necessary to protect the mask. While the energy of these electrons is greater than simple thermal heating could produce, how the beam electrons turn into this suprathermal population has been a puzzle.

The PPPL and University of Alberta researchers used a computer simulation to solve the puzzle. The simulation revealed that the electron beam generates intense plasma waves that move through the plasma like ripples in water. And these waves lead to the generation of the crucial suprathermal electrons. This discovery could bring still-greater control of the plasma-surface interactions and further increase the number of transistors on integrated circuits.

STUDYING A KEY ASTROPHYSICAL PROCESS WITH "FLARE"

PPPL is developing a new and more powerful version of its world-leading Magnetic Reconnection Experiment (MRX), which recreates one of the most common but least understood phenomena in the universe. This phenomenon, in which the magnetic field lines in plasma snap apart and violently reconnect, occurs throughout the cosmos and gives rise to the northern lights, solar flares and geomagnetic storms.

The new $4.3 million device will probe facets of magnetic reconnection never before accessible to laboratory experiments, said Hantao Ji, a PPPL physicist and Princeton professor of astrophysical sciences who will serve as principal investigator for research on the new machine. Ji headed a Princeton-led consortium that won a $3 million National Science Foundation (NSF) construction grant in a nationwide competition with entries from all areas of science. The University will contribute an additional $1.3 million of funds for construction of the device, to be called the Facility for Laboratory Reconnection Experiment (FLARE).

When completed in 2016, the new device will form the heart of a broad study of reconnection involving 40 participants from nearly two dozen institutions in the United States, Europe and Asia. The increased size and power of the new machine — its diameter will be twice that of the sports utility vehicle-sized MRX — will enable scientists to better replicate reconnection in nature, said PPPL physicist Masaaki Yamada, principal investigator for the MRX and a senior researcher on the new machine.

Joining Princeton and PPPL on the team launching the project are UCLA, the University of California-Berkeley, the universities of Maryland and Wisconsin-Madison, and Los Alamos National Laboratory.

PPPL TEAMS WITH USDA TO PASTEURIZE EGGS

Researchers at PPPL and the U.S. Department of Agriculture (USDA) have developed a novel technique and device for rapidly pasteurizing eggs in the shell without damaging the delicate egg white. The process could lead to a sharp reduction in illnesses caused by egg-borne salmonella bacteria, a widespread public health concern.

The new method uses radio frequency (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 white. Researchers then bathe the egg in hot water to pasteurize the white and finish pasteurizing the yolk.

The aim is to produce a pasteurized egg that is "hardly discernible from a fresh, non-pasteurized egg," said David Geveke, lead scientist, at the USDA Agricultural Research Service in Wyndmoor, Pa. His laboratory teamed up with PPPL engineer Christopher Brunkhorst, an expert in RF heating, to develop the device.

Christopher Brunkhorst displays an egg while a computer image simulates the levels of RF power that different parts of an egg absorbed during an experiment.

Lab supports the world's largest fusion experiment with leading-edge ideas and design

PPPL is a key contributor to ITER, a huge international fusion facility under construction in Cadarache, France. ITER is designed to demonstrate the scientific and technological feasibility of fusion power by the late 2020s.

PPPL provides hardware, fabrication, and research and development for ITER under contract to US ITER, a DOE Office of Science project managed by Oak Ridge National Laboratory. The United States participates in ITER together with China, the European Union, India, Japan, South Korea and Russia.

The PPPL tools will provide essential data during experiments on the donut-shaped, 10-story ITER fusion facility, or tokamak. PPPL also is procuring the bulk of the electrical network that will deliver steady-state, or constant, power across the sprawling 445-acre ITER site, and is conducting experimental and theoretical research relevant to ITER as well.

PPPL scientists, engineers, technicians and other members of the Laboratory contribute to the ITER project.

A unique system for verifying nuclear warheads

PPPL and Princeton scientists are developing a unique process to verify that nuclear weapons to be dismantled or removed from deployment contain true warheads. The system would do so without revealing classified information that could lead to nuclear proliferation if the data were to be leaked.

The research calls for firing high-energy neutrons at a test object containing non-nuclear materials. This target will be used to test the validity of the novel approach to verification.

"The goal is to prove with as high confidence as required that an inspected object is a true nuclear warhead while learning nothing about the materials and design of the warhead itself," said PPPL physicist and former Laboratory Director Robert Goldston, a co-principal investigator for the project and a professor of astrophysical sciences at Princeton.

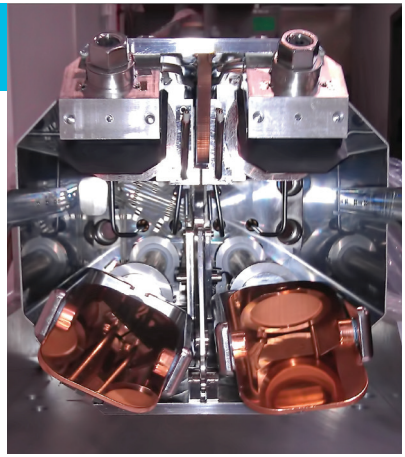
Goldston is working with Princeton physicist Alexander Glaser and PPPL engineer Charles Gentile to develop the process, which the two physicists thought up with Boaz Barak, a former Princeton associate professor of computer science and now a senior researcher at Microsoft Research New England.

Hands across the country

PPPL's collaboration on the DIII-D tokamak that General Atomics operates for the U.S. Department of Energy in San Diego has yielded numerous advances in fusion research and technology. Recent achievements include the development of a fast and powerful system for suppressing instabilities that could degrade the performance of a fusion plasma. Such suppression will be vital for future fusion facilities such as ITER, the international project under construction in France.

The system developed on DIII-D aims high-power microwave beams at instabilities called "islands" and generates electrical current that eliminates the islands. The process links software-controlled mirrors to detection equipment, creating a system that can respond to instabilities and suppress them within milliseconds. "It works like a scalpel that removes the island," said PPPL physicist Raffi Nazikian, the head of the Laboratory's collaboration with DIII-D.

PPPL physicists and engineers worked closely on the project together with their counterparts at General Atomics. PPPL engineer Robert Ellis designed the system of mirrors used for directing the high-power microwaves into the plasma. PPPL Physicist Egemen Kolemen, an expert in plasma control, created much of the software that automatically steers the mirrors and directs the microwave beams to their target. PPPL engineer Alexander Nagy also shared responsibility for the system, providing onsite support in San Diego.



A look into the microwave launcher showing the steering mirrors that guide the beam.

KRISTEN FISCHER, New Chief Financial Officer

Kristen Fischer, PPPL's new chief financial officer, has taken on the challenging job of overseeing a budget of approximately $85 million and managing all financial operations.

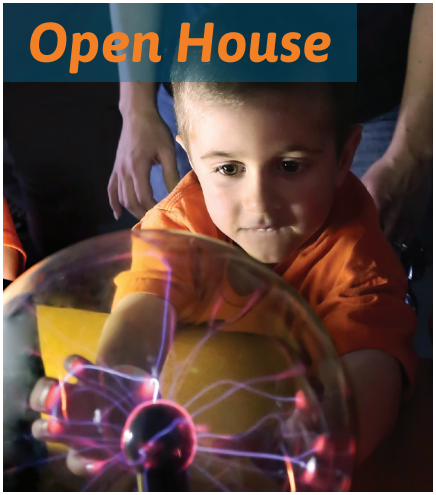
Fischer comes to the Laboratory after working 16 years at the New Jersey State Office of the Attorney General where she was the budget director for six years, overseeing a $1 billion budget as director of budget and grant operations.

Kristen Fischer

PAULETTE GANGEMI, New Director of Human Resources

Paulette Gangemi, PPPL's new director for human resources, arrived with more than a decade of experience as a human resources expert for the pharmaceutical industry. At PPPL, Gangemi (pronounced Gan-jem-ee) manages a staff of seven people, a departmental budget, and the numerous functions of the HR Department. She also oversees the development of environment, safety and technical training; ensures that PPPL complies with U.S. Department of Energy and Princeton University policies; and manages the Lab's Occupational Medical Office and the Furth Plasma Physics Library.

Paulette Gangemi



Open House

More than 3,000 people learned about "hot plasma and cool science" during PPPL's Laboratory-wide Open House. Visitors saw virtually every corner of the Laboratory — from the machine shops to the National Spherical Torus Experiment Upgrade and other plasma physics experiments. Also on display were science-education demonstrations, computer games, NASA moon rocks and a Hall of Machines.

PPPL premiered its "Star Power" video, a colorful 10-minute look at the Laboratory that includes animations, interviews with PPPL scientists, engineers and technicians and an original score. The video can be viewed and downloaded from PPPL's homepage: http://www.pppl.gov/star%20power

PPPL brings a 50,000 degree plasma experiment into your living room

A unique hands-on experiment at PPPL enables users to study and control a plasma in the Laboratory from anywhere in the world. The system, developed by physicist Arturo Dominguez of the Science Education Department, lets users operate the experiment with a set of online controls and watch the effect on the apparatus at PPPL via a live webstream video. This online link connects to the experiment: https://pppl.princeton.edu/ww.pppl.gov-RGDX

A sample screen with the apparatus shown at top and the adjustable controls below it.

Science Bowl

An emotional moment during the high school competition.

The New Jersey Regional Science Bowl was a mental Olympics for teams from 32 high schools and 16 middle schools that met in the annual competition held at PPPL. The students in the DOE-sponsored event fielded tough questions in physics, energy, earth science and math, with the winners moving on to the National Science Bowl® in Washington D.C.

Fusion Technology Award

Phil Heitzenroeder, who leads the Mechanical Engineering Division at PPPL and whose advice is sought by engineers around the world, won the 2013 Fusion Technology Award. The high honor from the IEEE Nuclear and Plasma Sciences Society recognizes outstanding contributions to research and development in the field of fusion technology.

Early Career Research Grant

PPPL physicist Ahmed Diallo won a highly competitive Early Career Research Program grant sponsored by the U.S. Department of Energy's Office of Science. His $500,000 per year award, which can be renewed for up to five years, will fund research into understanding and controlling the volatile edge of the superhot, charged plasma gas that fuels fusion reactions inside tokamaks.

Environmental Honors

PPPL staffers clean up the grounds to celebrate Earth Week. The Laboratory's composting and recycling efforts were among the practices cited by the New Jersey environmental stewardship award.

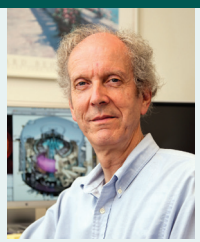
PPPL won state and U.S. honors for its environmental practices. The New Jersey Department of Environmental Protection named PPPL the state's top facility for environmental stewardship based on the Laboratory's performance in areas ranging from reducing greenhouse gas emissions to purchasing environmentally friendly goods and services. PPPL also received a 2013 U.S. Department of Energy Sustainability Award for outstanding sustainability performance, and the U.S. Environmental Protection Agency named PPPL its 2012 EPA WasteWise Program's Federal Partner of the Year for reducing the amount of waste it disposed of from 147,000 tons to 140,000 tons.

Hawryluk honored for service to ITER

The U.S. Department of Energy honored PPPL physicist Rich Hawryluk with a Secretary's Appreciation Award for his service to ITER, the international fusion experiment under construction in France. Hawryluk served as deputy director-general for the Administration Department at ITER from April 2011 to April 2013. The award, signed by former Energy Secretary Steven Chu, was presented by Energy Secretary Ernest Moniz, shown here at left with Hawryluk.

New APS Fellows

David Gates



Charles Skinner

The American Physical Society (APS) named PPPL physicists David Gates and Charles Skinner APS fellows — an honor given to one-half of 1 percent of the APS's nearly 50,000 members last year. Gates is a principal research physicist and stellarator physics lead. Skinner is a principal research physicist whose work has focused on spectroscopy and plasma-wall interactions. The two new fellows bring to 51 the total number of APS fellows at PPPL.

QUEST | RESEARCH NEWS FROM PPPL
Summer 2014

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