PPPL PRINCETON PLASMA PHYSICS LABORATORY
A Collaborative National Center for Fusion & Plasma Research
U.S. DEPARTMENT OF ENERGY
WEEKLY
October 30, 2017

THIS WEEK

TUESDAY, OCT. 31

Happy Halloween!

Photo Clique Nature Walk
12 p.m. ◆ LSB Lobby
See page 7 for details.

WEDNESDAY, NOV. 1

Council Café Lunch
12 p.m. ◆ Cafeteria
David Carle
Head of Facilities & Site Services

PPPL Colloquium
4:15 p.m. ◆ MBG Auditorium
Machine Learning for Controlling Complex Dynamic Systems
Jeffrey Schneider,
Carnegie Mellon University

FRIDAY, NOV. 3

Public Tour
10 a.m.
Go to www.pppl.gov/about/tours to register

UPCOMING

WEDNESDAY, NOV. 15

America Recycles Day
See page 6 for details.

INSIDE

Student Tours 4
Council Café Lunch 4
Open Enrollment Benefits Fair 5
Colloquium 5
Flu Vaccine 5
America Recycles Day 6
Photo Clique Nature Walk 7
Menu 7

PPPL scientists feature their research at the 59th APS-DPP annual meeting

PPPL staffers and graduate students presented more than 100 talks and posters last week during the 59th annual meeting of the American Physical Society-Division of Plasma Physics in Milwaukee, Wisconsin. Topics ranged from theoretical and experimental research on fusion development to laboratory and space plasmas and PPPL collaborations with major tokamak and stellarator facilities around the world.

Among articles highlighted in the virtual press room were PPPL news releases on the use of lithium to prevent or reduce instabilities in tokamaks, and a look at a source of fast reconnection — the process that causes the magnetic field lines in plasma to break apart and forcefully reconnect.

continued on page 2

Team of PPPL scientists wins Edison Award for invention that could be used to produce next generation computer chips

By Jeanne Jackson DeVoe

Three PPPL scientists have won an Edison Patent Award from the New Jersey Research Council for their invention of an imaging apparatus that could be used to produce the next-generation of integrated circuits.

Physicists Manfred Bitter, Kenneth Hill, and Philip Efthimion are among 14 teams to win the 2017 Edison Patent Awards who will be honored at a Nov. 2 ceremony at the Liberty Science Center in Jersey City, New Jersey. It is the second consecutive year PPPL'ers have received the award. Last year, Charles Gentile, George Ascione and Adam Cohen received an Edison Award for their invention of an on-demand method to create a widely-used isotope used in medical imaging devices.

The inventors examine a bust of Thomas Edison at the Edison Library.
Left to right: Kenneth Hill, Philip Efthimion, and Manfred Bitter.
(Screen shot courtesy of the Research & Development Council of New Jersey).

continued on page 3

continued from page 1

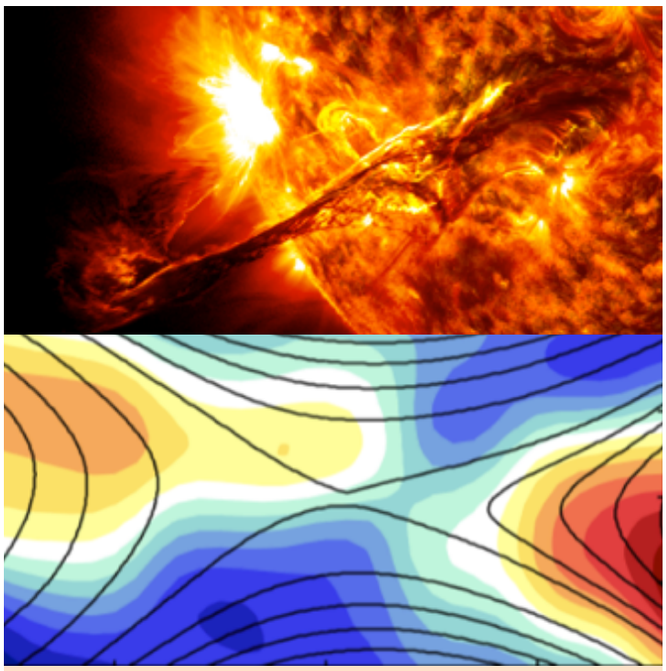
Explosive bursts of energy from plasma happen quite quickly – experiments give indications of why

By Raphael Rosen

Whether in outer space or in a laboratory, plasma can be volatile. The magnetic field lines that extend through plasma can detach suddenly and snap together again in new orientations, releasing enormous amounts of energy. This process, called magnetic reconnection, happens rapidly and causes eruptions of planet-sized flares from the surface of the sun that can interfere with cell phone service and electric power grids on Earth. Reconnection can also cause disruptions that degrade plasma confinement within doughnut-shaped magnetically confined plasmas like the tokamak.

New experiments by physicists at PPPL have confirmed theoretical models of electron pressure that have long been used to understand reconnection. Specifically, PPPL researchers confirmed that the motion of electrons in plasma creates a pressure that balances the force produced in plasma by parallel electric fields. This balance allows strong electric fields to be sustained, which in turn significantly increases the speed at which reconnection occurs. "These results show how well-controlled and diagnosed laboratory experiments can provide insights into the behavior of plasmas in astrophysics or fusion plasmas, where it is much harder to make such comprehensive measurements," said PPPL physicist Will Fox, who led the experiments.

These findings will enable improved understanding of the explosive events in stars and galaxies, where magnetic reconnection is prevalent, and could enable scientists to more confidently design tokamaks to minimize disruptions created by magnetic connection.



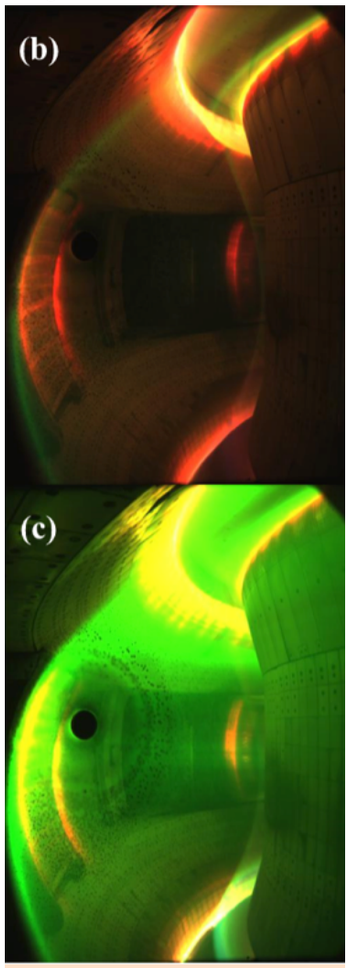
Top: A high-resolution image captured by NASA's Solar Dynamics Observatory shows a long filament of plasma erupting on the solar surface, initiating magnetic reconnection prior to breaking from the sun's surface and being injected into space. Bottom: High (red) and low (blue) pressure structures forming in a region of laboratory plasma undergoing magnetic reconnection.

Plasma acting up? Try a little lithium

By John Greenwald

Lithium, a soft metal known as a source of medicine for a host of human conditions and for its use in rechargeable batteries, can help calm unruly plasma in fusion devices as well. So found an international collaboration led by PPPL physicist Rajesh Maingi. The scientists have shown that intense bursts of heat in plasma, which can shut down a fusion reaction, can be avoided by adding a little bit of the powdered form of the element.

When applied in fusion devices called tokamaks, lithium helps avoid plasma outbursts called "Edge-Localized Modes" (ELMs) that could potentially damage the surrounding walls of the reactor. Lithium also helps keep the plasma hot, with temperatures exceeding 100 million degrees needed to realize this clean and virtually limitless source of energy. The work, done on the Experimental Advanced Superconducting Tokamak (EAST) in China, deployed lithium in three different ways inside the powerful machine, with all three showing excellent progress.



The red color in the top image (b) comes primarily from deuterium that has been allowed to recycle without the use of lithium, while the image below (c) is largely free from recycling as a result of lithium.

The researchers, from PPPL and seven different U.S. institutions, sprinkled a powder of the silvery metal into the EAST fusion device, or tokamak, shot in larger lithium granules, and held a sheet of molten lithium up against the edge of EAST plasmas. Results took a strong step toward optimizing plasma confinement in the long-pulse tokamak, which aims to ultimately produce high-performance plasma for up to 1,000 seconds.

When sprinkled as a powder, lithium prevented ELMs entirely. When injected in larger granules, the element gave researchers fine control over how often the ELMs occurred.

Researchers went on to observe improved phases of energy confinement when using the flowing liquid lithium system. The molten substance reduced the amount of deuterium—the main plasma fuel—at the edge of the plasma that bounced back and cooled the core of the plasma, a process that can halt fusion reactions. Fast-camera images showed potentially damaging deuterium recycling without lithium, compared with lithium in place.

Hosting these experiments was the Institute for Plasma Physics, Chinese Academy of Science, with strong collaboration between the U.S. participants and Chinese colleagues.

Edison Award

continued from page 1

This year's winners created an X-ray imaging apparatus that can be used for extreme ultraviolet light (EUV) lithography. "We are very grateful to have been selected for this award," Bitter said. "It's nice to come up with a new idea, if it is useful to somebody."

The three scientists recently went to the library at the inventor's home and laboratory at the Thomas Edison National Historic Park in West Orange, New Jersey, to film a short video segment on their research that will soon be available on the New Jersey Research Council website. "It's humbling and gratifying to do work that we enjoy and to do work that we hope will eventually help mankind and society," Hill said.

The technique of using extreme ultraviolet lithography to make computer chips will be "revolutionary."

Ethimion, head of the Plasma Science & Technology Department, agreed with that sentiment. "It's quite humbling to be mentioned in the same breath as Thomas Edison," he said.

Efthimion said the technique of using extreme ultraviolet (EUV) lithography to make computer chips will be "revolutionary." This technique is considered the next generation of computer chip manufacturing because the EUV light, called soft X-rays, are just 10 to 15 nanometers long. The current technology uses ultraviolet light, which is 200 nanometers long. That means "you should be able to place 100 times more components, like transistors, in the same area" of tiny computer chips, Efthimion explained. The linear distance between components is also 10 times shorter, he said, which means the speed of the chip could be 10 times faster.

EUV lithography uses reflectors to diffract EUV light off a mask that has an image of the information that will be imprinted on the chip. The EUV beam demagnifies the image to the size of the chip and imprints it onto the chip. But current EUV lithography technology, which is still being developed, can only do this by scanning a tiny piece of the image onto the chip at once. This is because only a small area of the reflector focuses the EUV beam to preserve the image – a fact known as the Bragg condition.

The inventors' device uses a multi-layered structure to reflect the EUV beams to produce a wider beam of light. This fulfills the Bragg condition on every point of the reflector and captures all the information on the mask and imprints it onto the computer chip without the need for scanning. Funding the invention was a Laboratory Directed Research and Development (LDRD) grant through the U.S. Department of Energy.

Decades of experience

Bitter and Hill have decades of experience with manipulating X-rays in X-ray crystal spectrometers, which measure the temperature and other parameters of the plasma in fusion experiments. The two were the lead inventors on a 2012 patented invention that uses matched pairs of spherically-bent mirrors to eliminate astigmatic imaging errors in X-ray and EUV images.

Bitter and Hill began building such devices in the 1970s for the Princeton Large Torus (PLT). They built similar devices, as well as other diagnostics, for the Tokamak Fusion Test Reactor (TFTR) and the National Spherical Torus Experiment (NSTX) at PPPL.

The most recent spectrometer is used to diagnose high-energy density plasmas, which are only a tenth of a millimeter wide. The spectra of the X-ray radiation emitted from these plasmas provides information on the temperature of the ions and other key data. A version of the device was recently used on laser-produced plasmas at the Omega EP Laser Facility at the University of Rochester in New York and was recently installed on the National Ignition Facility at the Lawrence Livermore National Laboratory in Livermore, California.

Bitter and Hill spectrometers are also being used worldwide on doughnut-shaped tokamaks and twisty stellarators; the latter include the Large Helical Device in Japan and the Wendelstein 7-X stellarator in Germany. The two physicists are also working with a team of scientists at PPPL on the design of crystal spectrometers for ITER, the international fusion experiment being built in Cadarache, France. "These two gentlemen are renowned experts in X-ray technology and they've made many contributions to plasma technology," Efthimion said.

Bitter and Hill received PPPL's Kaul Prize for Excellence in Plasma Physics Research and Technology Development in 2012. All three inventors have been at the Laboratory for nearly four decades.

Bitter is a Princeton, New Jersey, resident who retired from PPPL in 2012 but continues to come into work three or four days a week. He received his undergraduate degree and Ph.D. from the Universities of Munich and Aachen. He was a staff member of the European Space Research Institute in Frascati, Italy, from 1969 to 1973 and a visiting scientist at the Centre de Recherches en Physique des Plasmas in Lausanne, Switzerland from 1973 to 1977 before joining PPPL in 1977. He was named a fellow of the American Physical Society in 1987 and received the Alexander von Humboldt Physics Prize in 1996, which allowed him to do research at the Forschungszentrum Jülich in Germany for one year.

Hill, who lives in Plainsboro, New Jersey, is the author of more than 300 publications. He received a Ph.D. in atomic physics from the University of North Carolina at Chapel Hill in 1974. Before joining PPPL in 1978, he worked in ion-atom collision physics at the U.S. Naval Research Laboratory and in spectroscopic plasma diagnostics at the Oak Ridge National Laboratory. He has collaborated with research institutes around the world and is a member of the American Physical Society.

Efthimion, who lives in Bedminster, New Jersey, joined PPPL after receiving his bachelor's degree from Columbia University in 1970 and his Ph.D. from Columbia in 1977. He first worked on the Princeton Large Torus making measurements to support Bitter's experiments in X-ray spectroscopy. He led a group of scientists on TFTR and has been head of the Plasma Science & Technology Department at PPPL since 2001. Efthimion is a fellow of the American Physical Society.

Hill said he and Bitter complement each other. "Manfred is excellent at spatial visualization, at seeing special geometries and understanding how particular geometries can be useful for our X-ray work," Hill said. "I am better at taking that analysis and using computer programs to visualize it and apply it to real situations.

Efthimion is also a prolific inventor who has a total of six patents, including two others in the field of spectroscopy. He has encouraged his two colleagues to branch out into other areas in which their X-ray technology would be useful.

Efthimion said he has been pairing early career scientists with Hill and Bitter so that the veteran scientists can pass along their knowledge. Hill has been at the Laboratory for 39 years and Bitter for 40 years. Bitter says he enjoys working with the young physicists. "We work together to tackle new subjects," he said.

Bitter and Hill say they hope their technology will someday be put to good use. "It is relevant and it's a good idea," Hill said. "It's an idea that potentially may be used for some other aspect of lithography."

Youngsters from the Stone Hill Learning Center and the Princeton Area Home School Network tour PPPL

Ray Camp speaks to students from the Stone Hill Learning Center, Princeton, in the NSTX-U Control Room on an Oct. 26 tour. *(Photo by Raphael Rosen)*

Kevin Lamb talks to students from the Princeton Area Home School Network on another Oct. 26 tour. *(Photo by Raphael Rosen)*

Stone Hill Learning Center students in the NSTX-U test cell. *(Photo by Raphael Rosen)*

Kevin Lamb with Home School Network students in the NSTX-U test cell. *(Photo by Raphael Rosen)*

Council Café Lunch

This Week:

David Carle, Head of Facilities & Site Services

Wednesday, Nov. 1
12 p.m., PPPL Café

Next Week: Marc Cohen

PPPL'ers learn about benefits at Open Enrollment Benefits Fair

PPPL staff learned about their health and work life benefits at an Open Enrollment Benefits Fair on Oct. 26 in the Lyman Spitzer Building lobby. Open Enrollment ends Friday, Nov. 10.

Richard Owusu talks to representatives from Lynda.com. *(Photo by Raphael Rosen)*

Robert Kaita, left, and William Bryan at one of the tables. *(Photo by Raphael Rosen)*

Leanna Meyer Sullivan, right, talks to one of the vendors. *(Photo by Raphael Rosen)*

COLLOQUIUM

Machine Learning for Controlling Complex Dynamic Systems

Jeffrey Schneider,
Carnegie Mellon University

Wednesday, Nov. 1
4:15 p.m., M.B.G. Auditorium, Lyman Spitzer Building

Make an appointment for your flu shot

Protect yourself from influenza and avoid spreading the illness to others by getting a flu shot.

Please call the OMO at ext. 3200 to schedule an appointment.

PPPL celebrates America Recycles Day

Mark your calendar for America Recycles Day events the week of Nov. 13 and on America Recycles Day Nov. 15.

Events include:

- A recycling art contest
- Clothing drive
- Unicor electronics collection
- Get caught green-handed

Recycling Art contest

Enter the 2017 Recycling Art contest! Winners will receive a prize and entries will be on display in the LSB lobby Nov. 13–15. Contact Margaret Kevin-King, ext. 3652, or Leanna Sullivan, ext. 2599, for more information.

Clothing Drive

Please donate your gently used clothing to the Trenton Rescue Mission through Nov. 21. Bins are located in the LSB lobby and lower parking lot entrance.

Unicor electronics recycling collection

On Nov. 15, please bring your home electronics for recycling to the Warehouse by the roll-up door across from the firehouse 7:30–10 a.m.

Photo Clique Nature Walk

Please join us Tuesday, Oct. 31, at noon in the LSB lobby for a nature photo walk. We will be going into the woods around the Laboratory with our devices (cell phones, cameras) so dress appropriately.

Questions? Contact Elle Starkman at x2090 or estarkma@pppl.gov.

BROCK

NICK PETTI
Chef Manager

Café at PPPL

BREAKFAST ..... 7 a.m. • 10 a.m.
CONTINENTAL BREAKFAST ..... 10 a.m. • 11:30 a.m.
LUNCH ..... 11:30 a.m. • 1:30 p.m.
SNACK SERVICE ..... until 2:30 p.m.

	Monday Oct. 30	Tuesday Oct. 31	Wednesday Nov. 1	Thursday Nov. 2	Friday Nov. 3
COMMAND PERFORMANCE Chef's Feature	**Roast Pork** with Barley Wild Rice Pilaf and Vegetable	**Pasta Bowl** with Garlic Breadstick	**Caprese Chicken** with Orzo Pilaf	**Buffalo Chicken Meatloaf** with Roasted Potatoes and Carrots	**Fish and Chips**
Early Riser	**Bacon, Egg and Cheese English Muffin**	**Mexican Breakfast Burrito**	**Scrapple and Eggs**	**Cinnamon-Raisin Pancakes** with Homemade Apple Compote	**French Toast Sticks**
Country Kettle	**Manhattan Clam Chowder**	**Vegetable**	**Chicken Noodle**	**Tomato Soup**	**Chili Bean**
Deli Special	**Autumn Chicken Salad Wrap**	**Caribbean Ham Hoagie**	**California BLT** with Avocado	**Turkey Sloppy Joe**	**Spicy Crab Wrap**
Grill Special	**Grilled Vegetable Quesadilla**	**Chipotle BBQ Pulled Pork Sandwich** with Fries and Slaw	**Burgerlicious Old Macdonald Burger**	**Ham and Cheese Pizza Roll**	**Greek Chicken Cheesesteak**
Panini	**Prosciutto and Spinach Melt**	**Fried Flounder Hero** with Cajun Remoulade	**Pastrami and Swiss** on Marble Rye	**Chipotle Roast Beef Melt**	**Breaded Chicken Cutlet** with Ham, Swiss Cheese, Lettuce & Honey Mustard Ciabatta

MENU SUBJECT TO CHANGE WITHOUT NOTICE

HEART HEALTHY | VEGETARIAN OPTION

WEEKLY

Editor: **Jeanne Jackson DeVoe** ◆ Layout and graphic design: **Kyle Palmer** ◆ Photography: **Elle Starkman** ◆ Science Editor: **John Greenwald** ◆ Science Writer: **Raphael Rosen** ◆ Webmaster: **Chris Cane** ◆ Communications Director: **Larry Bernard**

The **PPPL WEEKLY** is published by the PPPL Office of Communications on Mondays throughout most of the year and biweekly during the summer, except for holidays.
DEADLINE for calendar item submissions is noon on WEDNESDAY. Other stories should be submitted no later than noon on TUESDAY.
Comments: commteam@pppl.gov ◆ **PPPL WEEKLY** is archived on the web at: http://w3.pppl.gov/communications/weekly/.