US DOE Princeton Plasma Physics Laboratory
Vol. 30, No. 12 • September • 2009

HOTLINE

The US DOE Princeton Plasma Physics Laboratory is a United States Department of Energy Facility

Lithium Coatings Advantageous for Fusion

Crucial Experiments are Planned at PPPL in 2010

By Anthony R. DeMeo

In 2005, experiments conducted on PPPL's Current Drive Experiment-Upgrade (CDX-U) provided strong evidence of the remarkable ability of lithium-coated plasma-facing surfaces to result in substantially improved plasma stability, energy confinement, and uniformity of the plasma's temperature profile.

Inspired by these exciting CDX-U results and previous favorable lithium results from the Tokamak Fusion Test Reactor, and to explore theories developed by PPPL's Leonid Zakharov, an extensive series of lithium divertor experiments have been conducted on the National Spherical Torus Experiment (NSTX) at PPPL. The NSTX results not only support the CDX-U findings, but also demonstrate another major benefit from lithium — the elimination of the troublesome plasma instabilities called "Edge Localized Modes" (ELMs). The latter is of particular importance for ITER.

"Lithium is turning out to be a very powerful tool. NSTX's highest plasma confinement, highest stored plasma energy, and longest pulses are now really because of lithium," noted NSTX Project Director Masa Ono.

Why does lithium have such a big effect on plasma performance? There are different reasons, not all of which are fully understood. One explanation involves a phenomenon known as "recycling." When deuterium plasma hits a solid wall in a fusion device, some of the deuterium ions are neutralized and can re-enter the plasma as cold gas, where they are re-ionized, soaking up energy from the plasma, cooling its edge. If the plasma strikes a lithium surface, there is significantly less recycling. The lithium soaks up most of the deuterium at the plasma edge, acting like a pump. By keeping the plasma edge hot, NSTX was able to maintain a more uniform plasma temperature across the plasma, which is beneficial to plasma confinement and stability.

CDX-U used liquid lithium surfaces, whereas NSTX employed divertor surfaces coated with solid lithium. The magnetic field at the periphery of NSTX diverts the plasma away from untreated vacuum chamber walls toward the divertor surface, thus preventing the plasma from touching the wall and sputtering impurities, which migrate into the plasma.

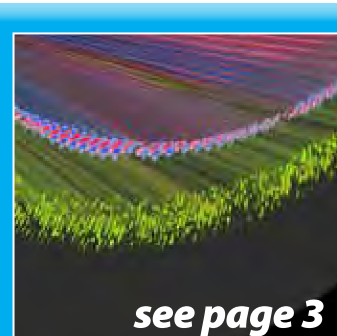
NSTX Program Director Jon Menard (left) and Project Director Masa Ono at the NSTX Test Cell.

Lithium's ability to bind with oxygen and other impurities with low atomic weights also helps keep the plasma more pure and at higher temperature.

continued on page 2

INSIDE

PPPL Plasma Turbulence Simulation Used to Create Award-Winning Movie



see page 3

Lithium Coatings

continued from page 1

An added benefit in NSTX was the production of more reliable, consistently reproducible plasma discharges. "We had been relying on helium glow discharges between plasma shots to clean plasma-facing surfaces of residual deuterium and impurities such as oxygen and carbon. This typically took about twenty minutes between shots. But we found out that with the lithium we don't need to do glow discharge cleaning and so can increase our productivity from 25 shots per day to close to 40," said Ono. "By eliminating glow discharge cleaning, we can produce more consistent, reliable plasmas because, with lithium, conditions are relatively constant on plasma-facing surfaces."

Eliminating ELMs

The quantity Q is the ratio of fusion power produced to the external power used to heat the plasma. To reach record Q values as high as 10, ITER will be required to operate in the so-called high-confinement mode or H-mode, a beneficial plasma configuration in which an energy and particle barrier forms at the plasma edge. With H-mode, there is a fourfold increase in Q compared to low-confinement or L-mode operation.

Unfortunately, H-mode plasmas suffer from edge instabilities. Over time, the build-up of plasma energy density at the edge exceeds the capacity of the barrier, resulting in a rapid expulsion of both particles and energy from the plasma. Once this happens, the barrier restores itself and the process is eventually repeated. These repetitive phenomena are referred to as Edge Localized Modes, or ELMs. In present-day tokamaks, ELM events can be tolerated without substantial damage, but in ITER, the heat fluxes associated with ELMs could be so high that melting or ablation of the plasma-facing components is a significant risk with each ELM. Not only could ELMs damage large fusion devices, but could also pollute the plasma with impurities and reduce the fusion power. Thus, in ITER, either the size of ELMs must be significantly reduced, or the ELMs must be eliminated.

But when it comes to ELMs, the latest lithium results from NSTX are extremely exciting. "Not only is recycling reduced and energy confinement increased with solid lithium divertors in NSTX, but ELMs are turned off. That's a really big deal for ITER and future fusion reactors," noted Jon Menard, NSTX Program Director. According to Menard there are competing theories as to how this works. NSTX researchers believe that lithium affects the density and pressure profiles, making them less steep at the edge of the plasma, yet still improving the overall confinement near the edge. While more experimental and theoretical work is needed, adjusting the amount of lithium evaporated onto the divertors between plasma shots clearly affects NSTX's ability to prevent ELMs. Furthermore, NSTX researchers have found that lithium greatly helps the machine access the H-mode initially. Lithium, therefore, is a major control tool.

Future Work

In FY10, both NSTX and PPPL's Lithium Tokamak Experiment (LTX) will employ liquid lithium. CDX-U was recently converted to LTX. NSTX will employ a new lithium divertor system developed in collaboration with Sandia National Laboratories utilizing a thin, solid, but porous molybdenum layer to hold a thin film of liquid lithium — a technology developed initially for LTX. The lithium will be kept in the liquid state by heaters in the divertor. Testing liquid lithium in the divertor of NSTX will provide significant new data. Masa Ono said, "The problem with solid lithium is that the lithium is relatively immobile, so when it absorbs deuterium and impurities, the resulting compounds (oxides and hydroxides) tend to stay on the surface, so the lithium pumping effect becomes degraded as time goes on."

LTX has a conducting shell inside its vacuum vessel. Made of three-eighths-inch thick copper, the shell conforms to the shape of the LTX plasma. The shell has a one-sixteenth-inch thick stainless steel liner explosively bonded to its plasma-facing surface. The copper shell insures uniform heating of the liner. Lithium from an evaporator will coat this surface and the shell will be heated to keep the lithium molten. This will provide nearly complete coverage of the interior walls of LTX with a thin layer of liquid lithium.

"We must acknowledge the contribution of the CDX-U group. They developed the lithium application initially and made it relatively easy for us to adapt. So having this smaller prototype device (CDX-U) is quite useful. If LTX's liquid-lithium wall result is favorable, then NSTX might consider that option in the future. It may mean going to an all lithium wall," said Ono.

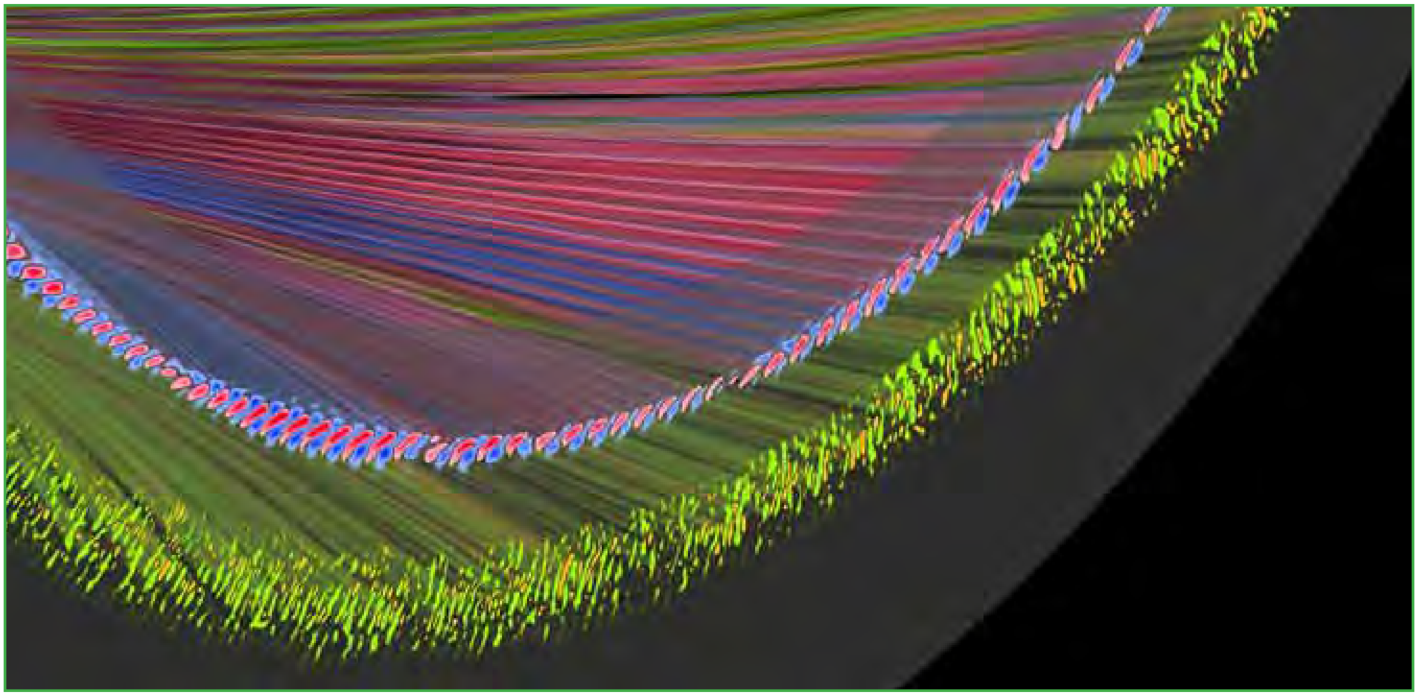
In addition to Henry Kugel, Bob Kaita, Dick Majeski, Dennis Mansfield, Leonid Zakharov, and other staff from PPPL, investigators from Oak Ridge National Laboratory, Lawrence Livermore National Laboratory, Sandia National Laboratory, Purdue University, University of California-San Diego, Johns Hopkins University, and the University of Illinois are also participating in lithium experiments at PPPL. There are also several graduate students in the Program in Plasma Physics in Princeton's Department of Astrophysical Sciences who are doing research on LTX and NSTX. ●

HOTLINE

Editor/Writer: Patti Wieser
Graphics: Greg Czechowicz
Photography: Elle Starkman
Layout Design: Greg Czechowicz

The HOTLINE is issued by the US DOE Princeton Plasma Physics Laboratory, a research facility supported by the United States Department of Energy. It is primarily an internal publication. Correspondence and requests to reprint material should be directed to the Editor, PPPL HOTLINE, P.O. Box 451, Princeton, NJ 08543; Interoffice correspondence should be addressed to MS-38, LSB Bldg.; tel. 609-243-2757; fax 609-243-2751; e-mail pwieser@pppl.gov.

PPPL Plasma Turbulence Simulation Used to Create Award-Winning Movie

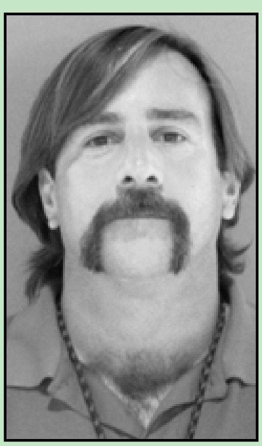


The image is of the electron temperature gradient simulation from the NSTX fusion machine and is part of the movie.

A team of PPPL collaborators from California used a plasma turbulence simulation created by PPPL scientists to generate an award-winning movie. During the annual Scientific Discovery through Advanced Computing (SciDAC) meeting this summer, the Department of Energy chose the movie, "Visualization of Electron-Scale Turbulence in Strongly Shaped Fusion Plasma," as one of 2009's ten best scientific visualizations. The featured simulation code developed by PPPL accurately models global turbulent transport of plasma using the full geometry of the tokamak device. The large-scale simulation is of microturbulence driven by changes in the electron temperature across the plasma in PPPL's National Spherical Torus Experiment (NSTX). "The simulation uses the real experimental profiles of a specific NSTX shot, or discharge," says PPPL computational physicist Stephane Ethier. Ethier works on a team led by PPPL physicist Weixing Wang, who created the code. Ethier's visualization colleagues Kwan-Liu Ma, Chris Ho and Chad Jones from the University of California, Davis, used the simulation data to generate the movie. "The movie explores the structure of the electrostatic potential at a certain time during the simulation by 'flying' around the torus," Ethier explains. Ethier and the UC Davis team received the award.

The movie is available on the web at: **http://vis.cs.ucdavis.edu/~jonesc/SciDAC/IUSV_Plasma_1080p.mov**. ●

IN MEMORY



Mike Widdis

PPPL colleagues and friends remembered Mike Widdis as a unique individual with a large and varied skill set, strong work ethic, and sense of humor. Widdis, a 17-year employee of PPPL who worked in the Facilities group, died in July. "Mike possessed a skill set that was very large," said PPPL Facilities Division Head Shawn Connolly. "He could operate any piece of heavy equipment or crane. He was a hazardous waste and radioactive waste technician, and could do any mechanical work that needed to be done."

Rob Sheneman, Head of PPPL's Materiel & Environmental Services Division, recalled working with Widdis in the former ER/WM Division. "Mike's experience in environmental cleanup and waste management was multiplied by his construction background," Sheneman said. "He skillfully handled a wide variety of projects, from asbestos and waste packaging to field sampling, excavation, and remediation. Mike worked hard to ensure that a job was done well and always kept his sense of humor."

Staff members described Widdis as easy going and always ready with a joke, a good friend, an avid motorcyclist, and a person who was close to his family, which includes his mother, two brothers, a sister, and a longtime girlfriend. "Mike lived with his mom who is about 80. We would routinely talk about her and how full of life and energy she was. He was very proud of his mom and all his family," said Connolly, noting that he also had the privilege of knowing Mike as a friend. "PPPL lost an excellent employee, and even better friend," Connolly said. Family and friends celebrated Mike's life at a gathering and eulogy in Rockaway on July 31. ●

What's Happening @ PPPL?

PPPL's Nat Fisch gave a presentation, "Hall Thrusters and Plasma-based Lasers," during the Federal Laboratory Consortium for Technology Transfer's Northeast Regional meeting September 15-16 at PPPL. The meeting, which drew more than 50, featured presentations on technology projects at regional federal laboratories and New Jersey universities, as well as on New Jersey State economic development activities.Topics included PPPL technologies, Princeton University's Office of Technology Licensing and the University's Energy and Environmental Center, as well as activities at the University's Engineering Department. PPPL Tech Transfer Head Lewis Meixler was appointed the new FLC Northeast Regional Coordinator during the meeting.

The GFDL-PPPL volleyball team made it to the playoffs in this year's competition with other Forrestal-area businesses and institutions in the league. Team members from left are PPPL's Nikolai Gorelenkov, PPPL's Gretchen Zimmer, GFDL's Steve Garner, PPPL's Yevgeny Raitses, Dow Jones's Roman Nadtochy, and PPPL's Cassandra Pugh. Team members not in the photo are GFDL's Serguei Nikonov and Gabriel Vecchi, and PPPL's Lu Wang. The season began in June and concluded in August, with the playoffs presently in progress. GFDL is the Geophysical Fluid Dynamics Laboratory. GO TEAM!

Employees enjoy the food and conversation during the PPPL Picnic September 9 on the front lawn.

PPPL's John Lacenere (left) and Bill Gervasi grill the burgers. Erik Perry is in the background.