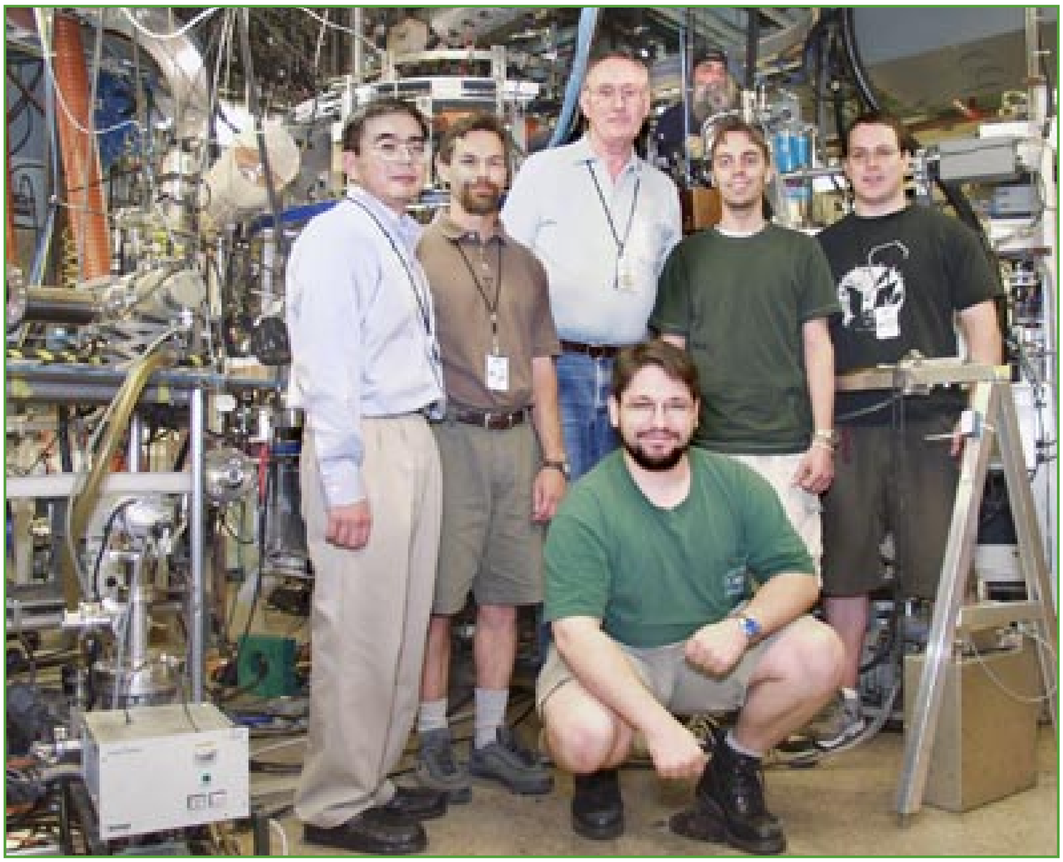
DOI Princeton Plasma Physics Laboratory Vol. 24, No. 10 • July 20, 2003

HOTLINE

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

Successful Liquid-Lithium Experiments Continue on CDX-U

Potential for Fusion Reactors Appears Promising



At CDX-U are members of the team. From left are Project Co-heads Bob Kaita and Dick Majeski, PPPL engineer John Timberlake, Princeton University graduate student Jef Spaleta (kneeling), PPPL technician James Taylor (back in hat), Drexel University student Douglas Rodgers, and Princeton University graduate student Timothy Gray.

Recent experiments on PPPL's Current Drive Experiment-Upgrade (CDX-U) have demonstrated the effectiveness of liquid-lithium limiters for plasma particle and impurity control. Results are a key step toward the use of free-flowing liquid-lithium walls in a fusion power plant, according to Bob Kaita, who co-heads the project with Dick Majeski.

In May, PPPL staff and their collaborators at the University of California-San Diego (UCSD) achieved a near complete fill of CDX-U's toroidal-tray limiter by injecting liquid lithium onto the two halves of the tray under an argon atmosphere. "All of the elements were brought together successfully. This is not trivial, because we needed to

Continued on page 2

CDX-U

Continued from page 1

prepare the tray surface correctly and prepare the injectors so the lithium would remain liquefied and flowing. If the surface of the tray is not clean enough, and not at the right temperature, the lithium will bead up," noted Kaita. The argon atmosphere acts as a buffer to prevent the lithium from evaporating rapidly and coating surfaces inside the vacuum vessel. Plasma discharges were initiated within hours after the tray was filled.

Limiters are metal surfaces that are specially designed to protrude from the vacuum vessel wall toward the edge of the plasma. Their job is to prevent the plasma from striking the vacuum chamber and sputtering impurities, especially heavy metals, into the plasma. Metal atoms soak up energy and radiate it away, causing the plasma temperature to drop. Plasma particles (deuterium ions) striking the limiter plates are neutralized and return to the plasma where they again become ionized. This process, called "recycling," tends to cool the plasma edge, and it limits the ability to achieve beneficial plasma confinement modes that require a hot plasma edge. Liquid lithium may be the solution because of its capability for absorbing plasma particles, thereby reducing recycling.

Initial experiments on CDX-U in FY00-01 employed a rail limiter consisting of a cylindrical stainless-steel mesh soaked with liquid lithium. Only 20 cm^2 of the lithium was actually in contact with the plasma. With the toroidal-tray limiter, a 360-degree annular metal belt running below the entire plasma, the area of interaction increases to as much as 1900 $cm.^2$

New Results Are Dramatic

Following pump down in any magnetic fusion device, it is necessary to run a series of conditioning plasma shots, until all of the loosely bound water, oxygen, and carbon in the vacuum vessel walls is removed from the chamber. These materials pollute the plasma, preventing the required energy confinement time needed for experiments. In CDX-U, plasma currents are limited to 20 or 30 kA, until vessel surfaces are cleaned. This can take up to a day of conditioning. However, when CDX-U plasmas are started in the presence of lithium, full plasma currents of 70 to 80 kA can be produced after only a few shots — a dramatic demonstration of the ability of lithium to absorb impurities.

Physicists are never satisfied unless they can measure things, and the CDX-U team is no exception. "It's difficult to quantify these (edge) effects. However, we do have an optical diagnostic that can look for oxygen emission lines typically found at the plasma edge. This spectrometer looks directly at the tray through a port in the vacuum chamber. With no lithium, oxygen emission lines are quite measurable. With lithium in the tray, the measurable level of oxygen goes to zero — a dramatic effect," said Kaita.

The Lithium Tokamak Experiment

Experiments such as Princeton's Tokamak Fusion Test Reactor (TFTR) and the DIII-D at General Atomics, Inc., have demonstrated that even modest recycling reductions can significantly improve plasma performance. These results, and recent experiments with liquid lithium at PPPL, UCSD, and other laboratories, suggest it is time to assemble an experiment in which the entire plasma is surrounded with liquid lithium. Consequently, the CDX-U folks have submitted a proposal for the reincarnation of CDX-U as the Lithium Tokamak Experiment (LTX) in FY06.

The LTX would incorporate a shell, just inside the vacuum chamber walls, onto which a thin layer of liquid lithium, about 1000 Angstroms, would be coated evaporatively. The shell would be maintained at a temperature that would keep the lithium in the liquid state. The coating will be sufficiently thick to absorb and retain plasma particles, preventing recycling, and trapping impurities so that they do not re-enter the plasma from the vacuum vessel walls.

"The idea is to put in a fresh coating of lithium after each shot. Conceptually the process is similar to the gettering done between shots on earlier tokamaks, where titanium was sublimated onto vacuum vessel components to reduce impurities. The difference is that we would make a thin liquid coating instead of a solid one," Kaita said. He envisions that such a system is an important step

Hotline

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The HOTLINE is issued by the 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., C-Site; fax 609-243-2751; telephone 609-243-2757; e-mail pwieser@pppl.gov.

toward a fast flowing, thin liquid-lithium wall in a fusion reactor.

In parallel with the proposed operation of LTX will be a series of prototype studies on the National Spherical Torus Experiment (NSTX) beginning in FY04. The first experiments will involve a small area coated with liquid lithium. The longer-term goal for NSTX would be the design, installation, and operation of a flowing liquid-lithium divertor in FY08. In FY05-06, CDX-U would be used for preliminary tests of lithium coating technology in preparation for its conversion to LTX.

Divertor coils, located inside the vacuum chamber, modify the magnetic field at the plasma edge to divert plasma particles and impurities to a region within the vacuum chamber, where they collide with a specially coated surface, are absorbed, and are prevented from entering the plasma. Divertors eliminate the need for limiters, greatly reducing recycling, resulting in a hotter plasma edge and better confinement. Kaita asked, "If divertors are more effective than limiters for particle control, why not go ahead and use lithium-coated surfaces in them as well?" The divertor envisaged for NSTX would employ a static thin film of liquid lithium first, and then a flowing lithium system.

Long-term Possibilities

The jury is still out on the role of divertors and/or limiters in a commercial fusion reactor. This depends on the practicality and effectiveness of the flowing liquid-lithium wall in controlling recycling and impurities. If successful, can such a wall also be used to remove the excess tritium that gets embedded in a fusion reactor wall?

Deuterium and tritium, both isotopes of hydrogen, will be used as fuel in a fusion power plant. During its operation, a substantial quantity of tritium, which is radioactive, can accumulate in the power plant walls. Depending on how long the tritium is retained in the lithium, a flowing liquid-lithium wall could avoid this by moving the tritium out of the vacuum vessel — a major advantage over solid reactor walls.

The pool of liquid lithium is shown in the toroidal tray that encircles the bottom of the CDX-U vacuum vessel. The tip of the liquid-lithium injector, which is removed before plasma operations, is reflected on the shiny surface of the liquid lithium.

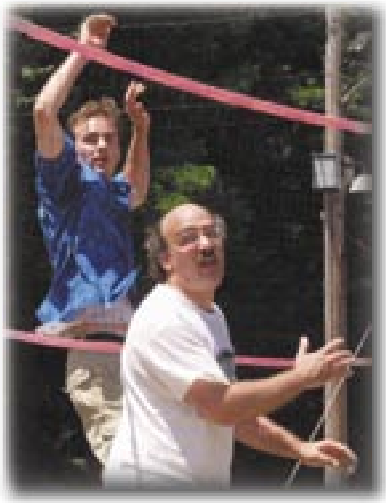
With the exciting, innovative liquid-lithium experiments planned for the next several years on CDX-U, NSTX and LTX, Princeton is positioned to make vital contributions to technological developments that are essential for practical fusion power in the 21st Century. ●

— By Anthony DeMeo

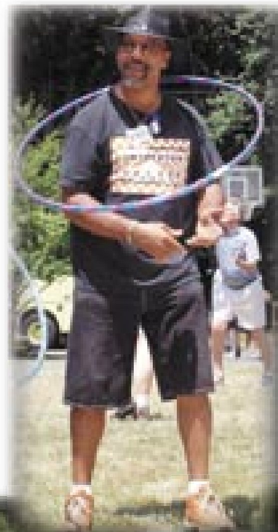
Local Officials Join Goldston for Breakfast Meeting

PPPL Director Rob Goldston hosted a breakfast briefing for 16 state, county, municipal, and school representatives from the area on June 27. Goldston gave a presentation about fusion (at left), which was followed with a guided tour of the experimental areas by PPPL Deputy Director Rich Hawryluk. ●

Fun Dominates PPPL Staff Picnic








A single word could be used to describe this year's PPPL Picnic for staff: "fun." The picnic, "Lunch on the Lawn," drew nearly everyone at the Lab to the front lawn outside the Lyman Spitzer Building on Thursday, July 17. Festivities included a barbeque and a host of games, from a Hula-Hoop contest to pling (Bingo) to horseshoes and volleyball. ●