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HOTLINE

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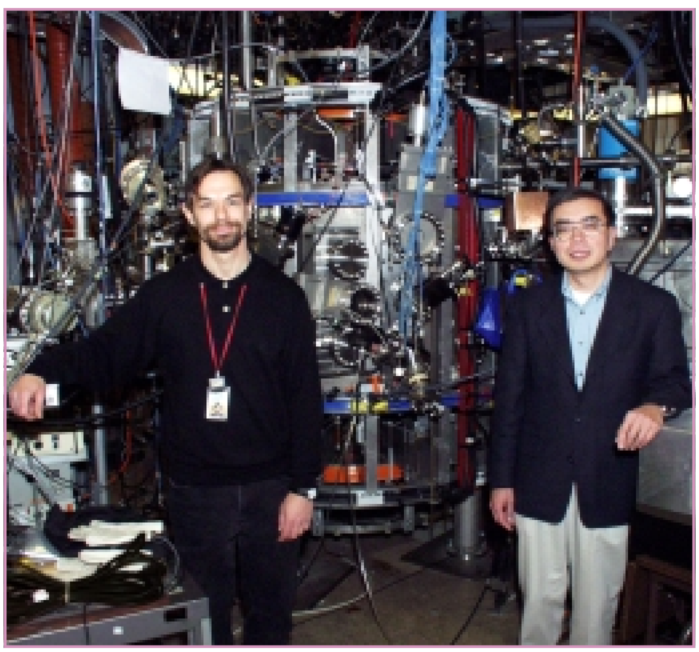
Liquid Lithium Experiments Underway On CDX-U

By Anthony DeMeo

Among the greatest technological challenges in the creation of a practical fusion power reactor is the development of the so-called "first wall." This is the material surface surrounding the hot fusion plasma, which physicists estimate will be subject to power densities in excess of 25 million watts per square meter from fusion neutrons, escaping plasma particles, and radiation. Present designs call for a lithium blanket behind the first wall. Fusion neutrons will react with the lithium to produce tritium that would be extracted and used as fusion fuel. These neutrons will also react with the materials in the first wall itself, producing radioactive isotopes (activation) and causing chemical changes that may lead to its erosion and loss of structural integrity.

Experiments now in progress on the Current Drive Experiment-Upgrade (CDX-U) may eventually yield a revolutionary solution to this materials problem, and, of equal importance, may demonstrate techniques for improved plasma performance in the near term. The work, performed in collaboration with the University of California, San Diego; Oak Ridge National Laboratory; Sandia National Laboratory; and others, involves studies of the interactions between plasma and liquid lithium. A liquid first wall would not be subject to the kind of damage a solid wall can experience, and would be able to handle higher heat loads. While present experiments are focusing on the near-term physics advantages, physicists envision the use of flowing liquid lithium as the first wall in a fusion power reactor.



At the Current Drive Experiment-Upgrade are Dick Majeski (left) and Bob Kaita, who co-head the project.

Bob Kaita, who is leading the effort on CDX-U with Dick Majeski, noted that "the use of a flowing liquid lithium wall can potentially eliminate the erosion problem because the wall is continuously renewed. Furthermore, it may result in a substantial reduction of activation because neutrons will no longer react with materials that stay fixed in a solid first wall structure." Kaita went on to point out that lithium can withstand the onslaught of 25 million watts of power per square meter, and it may be able to soak up the helium that is produced in the deuterium-tritium fusion reactions, which must be removed from the plasma.

As remarkable as these potential benefits seem, they are not the end of the story. Significant physics advantages may also accrue, including control of the plasma oscillations and "kinks"— instabilities that can destroy plasma confinement. Experiments on the former Princeton Beta Experiment-Modification at PPPL and other tokamaks

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Lithium

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demonstrated that a conducting wall inhibits these plasma instabilities. Liquid lithium could also serve as a conducting wall, and if the lithium flows at rates of 10 to 20 meters per second, its ability to stabilize the plasma may actually improve.

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.

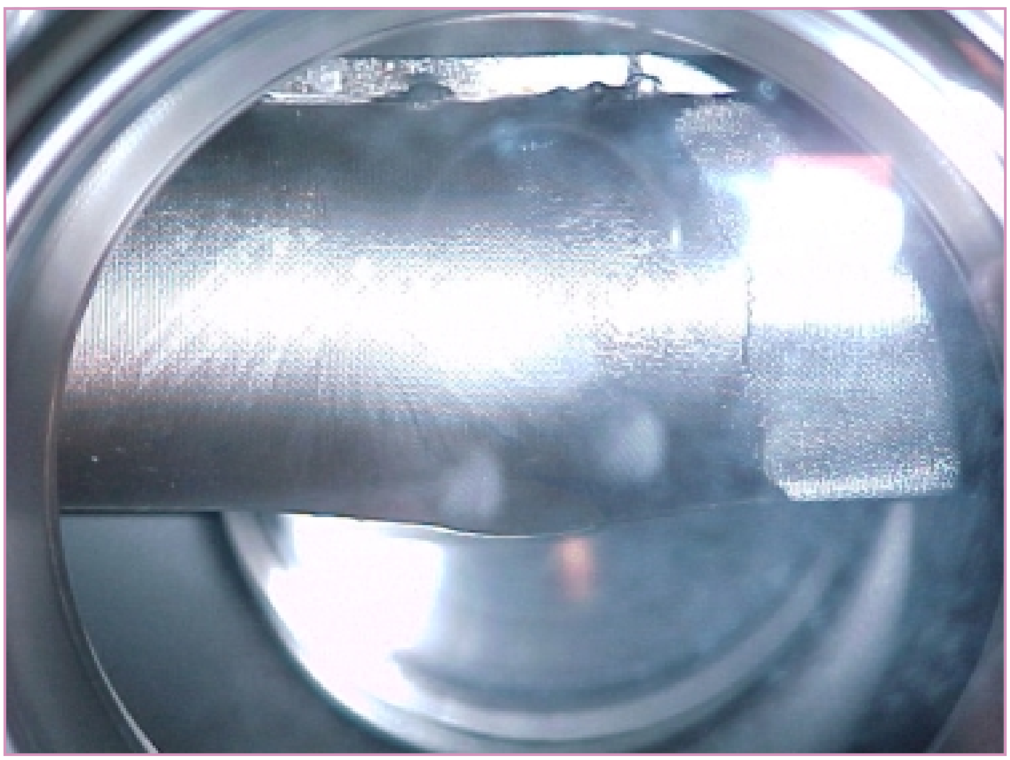
In principle, plasma particles (deuterium ions) striking the limiter plates are neutralized and return to the plasma where they again become ionized. This recycling tends to cool the plasma edge, and it limits the ability to achieve beneficial operational modes that require a hot plasma edge, such as the "H Mode," or high confinement mode. A liquid lithium wall may be the solution because of its capability for absorbing plasma particles. The reduction of the recycling due to the lithium would help establish the hot plasma edge needed for high confinement modes.

"For me the most exciting aspect of these experiments is the chance to investigate the behavior of plasmas with a new and different type of boundary. Experience from TFTR [Tokamak Fusion Test Reactor] and other experiments all over the world tells us that when we change the wall conditions, we change the plasma contained by the wall," said Majeski. CDX-U researchers are hoping that the use of lithium as a wall material will lead to new and improved modes of plasma operation.

Getting Ready

In preparation for lithium experiments which began last fall, a portable handling assembly was designed and built by the University of California, San Diego. The device, which resembles a gun carriage found on a battleship, can be wheeled out of the CDX-U area and taken down the L-Wing freight elevator to a separate lab equipped for fueling and maintenance. The handling assembly contains a unique rail limiter on a retractable probe. The rail limiter consists of a cylindrical surface about 20-cm long and 5-cm wide. Because the limiter is a cylinder, the area in actual contact with the plasma is a strip about a centimeter wide.

A stainless steel mesh covers the limiter. Lithium melts at about 181 degrees Celsius and is liquified in a reservior above the stainless steel mesh. As lithium is dripped on the mesh, it is automatically soaked up and spreads across the surface of the mesh. This is because liquid lithium resembles mercury, and like mercury, it has a high-surface tension. The rail limiter can be heated up to 300 degrees Celsius to insure that the lithium continues to flow evenly over the mesh surface.



Shown is the limiter head prior to plasma exposure. The view is through the side port of the probe drive assembly when the head is in its retracted position. The primary plasma contact position is the region on the bottom and toward the left of the head. The stainless steel mesh surrounding the head can be seen in the section without a lithium coating toward the right of head.

Lithium, like other alkali metals, reacts vigorously with water, including moisture in the air. Consequently, limiter fueling is performed in a glovebox containing argon, an inert gas. The limiter is then brought to the CDX-U area and inserted in the vacuum vessel via a double gate valve airlock system. When the rail limiter is in position, it forms the upper limiting surface for the plasma.

During the fall of 2000, CDX-U staff successfully dem-

Above is the head in the CDX-U vacuum chamber during argon glow-discharge cleaning. The center of the head, where the interaction with the plasma was the strongest, still shows a coating. The surface near each end is cleaner. The previously bare region toward the right of the head has become "wetted" with lithium.

onstrated the safe and efficient handling of lithium. Experiments underway during the latter part of 2000 were conducted with solid and liquid lithium limiters. During these preliminary tests there was evidence that the lithium was interacting with the plasma. Bands of very bright light around the limiter indicated that lithium was being driven off its surface.

Data from Spectrometers

Data from spectrometers showed that there was an influx of lithium into the core of the plasma. This caused energy to be radiated out of the plasma, not at a level detrimental to confinement. After each experiment, when the lithium was cooled, a coating was found on the limiter. CDX-U scientists believe that this was lithium hydroxide, which was formed when the hot lithium interacted with the small amount of water vapor that was inside the vacuum chamber. They were able to remove the coating by bombarding the limiter with argon ions in a process called "glow discharge cleaning."

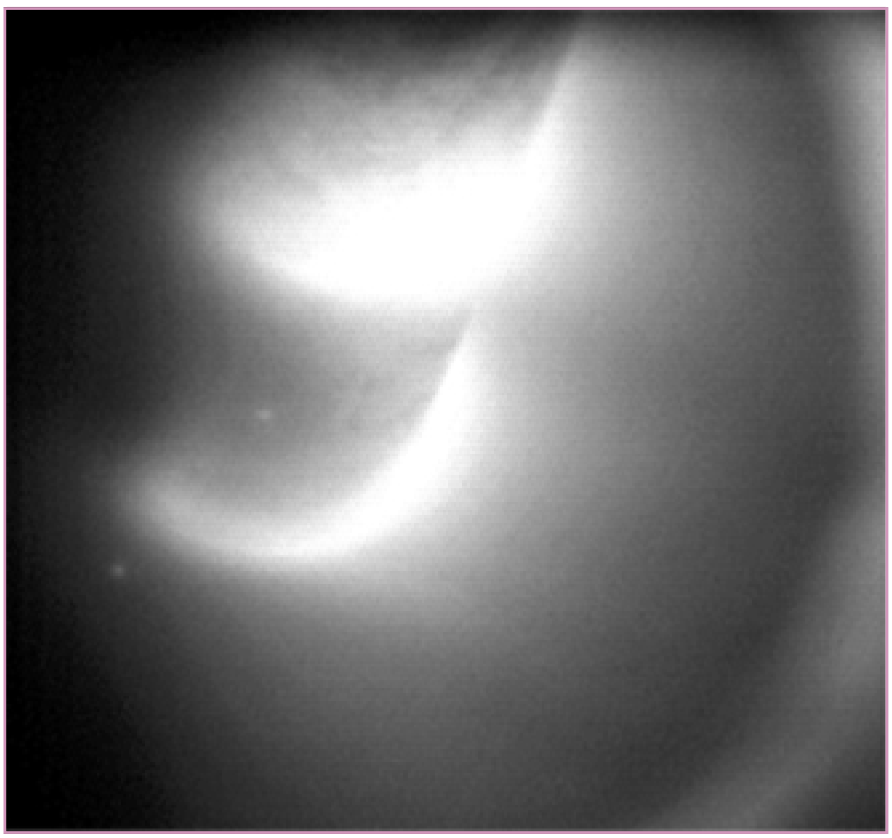
Measurements were made of the light from the deuterium atoms near the limiter, and the "pumpout rate" of the deuterium after a plasma was formed. They showed that while recycling was reduced, it was not completely eliminated.

Future Work

In the lithium rail limiter experiments, the plasma interacted mostly with parts of the machine not containing lithium, including limiters made of boron carbide on the center column and on the bottom of the vacuum vessel.

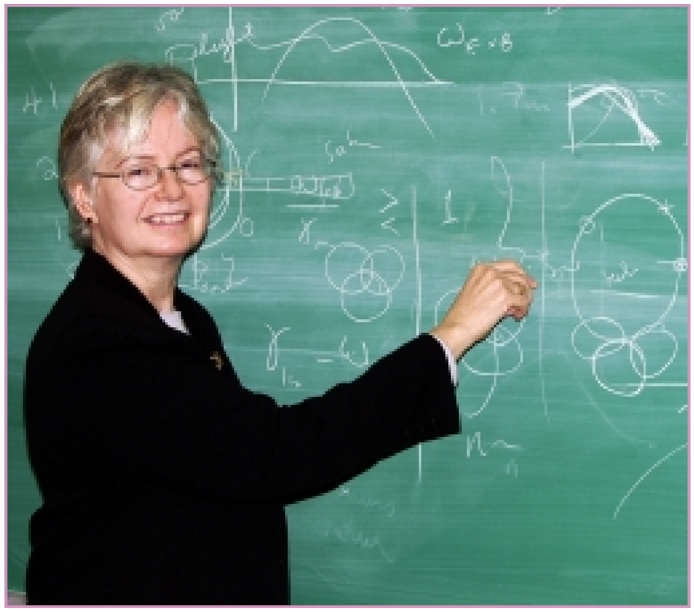
In the next series of CDX-U lithium experiments, the area of the plasma-lithium interaction will be increased from the modest 20 $cm,^2$ to 1900 $cm.^2$ Researchers will employ a "belt" or "tray" limiter that will rest all the way around the bottom of the vacuum vessel, below the entire plasma.

Using this setup, Current Drive Experiment-Upgrade researchers will investigate plasmas which will indeed interact primarily with a lithium surface. Scientists hope that the operational experience and knowledge gained from these and subsequent lithium experiments on CDX-U will greatly advance the physics and technology base for liquid metal first walls, a potentially critical element for the realization of practical fusion power plants later this century. ●



Above is the head during a CDX-U discharge. The underside of the head, which faces the plasma, is viewed through a filter that only passes deuterium light. Part of the cylindrical form of the head is outlined by the emission. While the main contact point is near its center, there is also emission near the end of the head.

Redi Chairs APS-DPP Committee for Women



Martha Redi

PPPL physicist Martha Redi was recently appointed Chair of the American Physical Society-Division of Plasma Physics (APS-DPP) Committee for Women in Plasma Physics (CWPP). The new committee was formed last year.

"Plasma physics is a field in which women have not found much success compared to other fields of physics. APS-DPP became aware of this last year and formed the committee in an effort to improve the environment for women and to work for equitable opportunities for them in the field," said Redi, who has been active in speaking for the women of the Division to the APS-DPP Executive Committee and has organized get-togethers for the women at the Annual Meeting for several years.

An APS-DPP ad hoc committee, reporting to the Executive Committee last year, recommended the creation of the standing committee after compiling statistics about the number of women members and Fellows involved in the Division. The ad hoc committee was appointed in response to a letter to DPP leadership written by Redi and signed by 20 percent of the women in the Division. In it, they expressed concern about the low number of women entering and remaining in the field of plasma physics, and the difficulty women found in gaining recognition for their work — through invited talks, by appointments to committees, and by attaining leadership positions and funding. The ad hoc committee found that few women were entering the field, and even fewer were remaining and attaining Fellowship status. In 1999, there were 111 female members of the DPP out of a total of 2,500 members, or about 4 percent. The APS has 8 percent women on average in all the divisions.

James Drake, Chair of the APS-DPP Executive Committee in 2000, said in a message posted on the DPP's web site, "What I found to be most alarming were the statistics on the number of women Fellows in our field. There are a total of seven women Fellows in the DPP compared with 450 male Fellows. Even more alarming is that among the female Fellows in the DPP, only one is actually active in plasma physics at the present time (as opposed to space and astrophysics). It seems clear then that a number of our most outstanding female members are moving out of the field. Thus, we find ourselves in a situation where we are not only not attracting significant numbers of women to our field, but we are also not able to retain female scientists."

When the APS-DPP Executive Committee created the CWPP, it passed a resolution, stating, in part, "The DPP must promote the recruitment, participation, and advancement of women in plasma physics, and ensure that women are fairly represented, both scientifically through invited talks, and in activities and leadership positions as officers, executive committee members, and committee chairs."

In addition to Redi, the other Committee for Women in Plasma Physics members are Gail Glendinning, Lawrence Livermore National Laboratory; Professor Noah Hershkowitz, University of Wisconsin; Professor Mary K. Hudson, Dartmouth College; Professor David Newman, University of Alaska; Mary Ann Sweeney, Sandia National Laboratories; Cha-Mei Tang, Creatv Micro Tech, Inc.; Professor Linda Vahala, Old Dominion University; and Professor Ellen Zweibel, University of Colorado, Boulder.

"We are asked to keep track of how APS-DPP is doing with respect to representation of women members on the Annual Meeting Program Committee, invited speakers, and other committees. We also are asked to submit names of women for Fellowship nomination," said Redi, who also has been asked to work with the APS Committee on the Status of Women in Physics. "For example, this year a woman plasma physicist who is a member of the National Academy of Sciences may become an APS-DPP Fellow. APS-DPP has shown real concern and we are hopeful that the next generation of women will find plasma physics fascinating, challenging, and with opportunities for success." ●

Former PPPL Physicist Thomas Stix Dies

Thomas Howard Stix, one of the most original thinkers and leading developers of the field of plasma physics, died April 16 in Princeton. He was 76 and a professor emeritus in astrophysical sciences at Princeton University. The cause of death was leukemia.

Professor Stix will be remembered not only as an outstanding scientist, educator, innovator, and inventor, but also for his warmth, humor, and genuine concern for people.

Born on July 12, 1924, in St. Louis, he served in the United States Army from 1942 to 1945. After receiving a bachelor's degree from the California Institute of Technology in 1948 and a Ph.D. from Princeton University in 1953, he joined Project Matterhorn, then a small, classified project on Princeton's Forrestal Campus. The project's aim was to harness fusion energy for peacetime use. Project Matterhorn grew quickly and, in 1961, when Stix headed the Experimental Division, its name was changed to the Princeton Plasma Physics Laboratory (PPPL).

Stix's work revolutionized research in plasma physics by showing how waves could heat plasma. This early work was presented at the Second International Atoms for Peace Conference in Geneva in 1958, held soon after the major nations working on controlled thermonuclear fusion research had agreed to declassify their work.

Stix published his classic text, "The Theory of Plasma Waves," in 1962, the same year he was appointed Professor of Astrophysical Sciences at Princeton University. Enormously influential, this textbook explored and formalized the growing subject of waves in plasma, both for laboratory and astrophysical applications. The book educated and inspired several generations of plasma physicists.

Stix showed how microwaves, injected from antennas or waveguides, could heat plasma to thermonuclear temperatures — tens of millions of degrees Fahrenheit — while confining it within powerful magnetic fields. Among his inventions is a coil structure in which sections of coil were alternately wound around the device clockwise and counterclockwise. Later known as a Stix coil, this structure coupled radio-frequency waves at ion cyclotron frequencies into the plasma. Stix also contributed importantly to the theory of stochastic and chaotic behavior of particles and magnetic fields in plasmas.

Recipient of numerous awards, including a Guggenheim Fellowship in 1969, Stix was awarded the 1980 James Clerk Maxwell Prize, the American Physical Society's highest award in the field of plasma physics.

Thomas Stix with a tokamak model.

This award recognized his pioneering role in developing and formalizing the theory of wave propagation and wave heating in plasmas. In 1999, he was awarded the Distinguished Career Award by Fusion Power Associates. In 1991, Princeton University recognized Stix's contributions as a teacher and educator by awarding him its first "University Award for Distinguished Teaching."

Stix was Chair of the Division of Plasma Physics of the American Physical Society in 1962. In 1978, he was appointed Associate Director for Academic Affairs at PPPL, and for many years he was Director of the Program in Plasma Physics at Princeton University. He spent three sabbaticals at the Weizmann Institute of Science in Israel.

Stix also embraced civic responsibility. He was Chair of the American Physical Society Committee on International Freedom of Scientists, working tirelessly on behalf of human rights and the political freedom of scientists worldwide. He also served on the American Physical Society Panel on Public Affairs, chaired the Princeton United Jewish Appeal in 1954-55 and in 1963-64, and was Chair of the Princeton Hillel Foundation from 1972 to 1976 and Acting Director for the newly founded Princeton University Center for Jewish Life in 1994.

Stix is survived by his wife, Hazel Sherwin Stix; two brothers, Ernest, a sculptor in St. Louis; and John, of Nyack, N.Y., a stage director and longtime faculty member of The Juilliard School; a son, Dr. Michael Sherwin Stix of Lexington, Mass.; a daughter, Susan Sherwin Fisher of New York City; and four grandchildren.

Earth Day Event at PPPL Draws 150 Students

More than 150 area students who participated in the Lab's pollution prevention poster contest attended the Fifth Annual Earth Week Poster Contest and Pollution Prevention Awareness Day at PPPL on Thursday, April 19. The event featured an awards program for poster contest winners, as well as hands-on science demonstrations, guest speakers, and pollution prevention displays.

Margaret King and Thomas McGeachen co-organized the event. Said King, "PPPL's Fifth Annual Earth Week Poster Contest celebration was brilliant. The posters created by the children showed their understanding of the 3 R's — recycling, reducing, and reusing — and of buying recycled materials. The poster contest is an educational and exciting project for the children, and some of the children were graded for this project. As we gathered for the presentations, it was impressive hearing the children's views about recycling."

PPPL and external exhibitors had displays and demonstrations in the Lab's Lobby and along the entrance. The fourth through sixth grade visitors collected recycled promotional items from various exhibitors and toured PPPL's and FMC's emergency response units. In the Auditorium, Marcal Paper Mills Vice President Peter Marcalus gave a presentation, "Closing the Recycling Loop with Marcal," and PPPL Director Rob Goldston delivered a talk, "Fusion in the New Century." Goldston concluded the event by handing out awards and prizes to the poster contest winners.

Twenty winners were selected by PPPL judges among more than 380 poster entries from students from eight area schools. Entries were posted around PPPL. The participating schools were the Antheil Elementary School in Ewing; Corpus Christi School in Willingboro; Grace N. Rogers School in East Windsor; Thomas Grover Middle School in West Windsor; Parkway Elementary School in Ewing; Toll Gate Grammar School in Pennington; Timberlane Middle School in Pennington; and Terrill Middle School in Scotch Plains. The Lab also sponsored a poster contest for the children of staff.

"The 2001 Earth Day event encourages us to continue to be environmental stewards by supporting companies that utilize recycled items in their manufacturing pro-

The poster contest winners who attended the Fifth Annual Earth Week Poster Contest and Pollution Prevention Awareness Day at PPPL on April 19 are above with PPPL Director Rob Goldston (far right), who presented awards to the winners, and Peter Marcalus (far left), a speaker at the event.

cesses. As we strive to educate the area middle schools on various environmental issues, we are also learning how we can better serve the earth. Recycling, reducing, and reusing can only be completed when we purchase products made out of recycled items. When you get down to the nitty-gritty, educating our children about the environment is extremely important because in our children lies our future," McGeachen said.

In addition to PPPL, exhibitors included Eurest Dining Services, Executive Business Products, FMC Corporation's Environmental Control Department and Environmental Response Unit, Marcal Paper Mills, Inc., Mercer County Improvement Authority, and Waste Management, Inc.

Dozens of prizes donated by area businesses were awarded to the winners. Prizes were donated by Barnes & Noble Booksellers, Big K-mart, John Bennevich, Borders Books & Music, Circle Line Cruise, COMPUSA, FMC Corporation, Jenkinson's Aquarium, Liberty Science Center, Michaels Arts & Crafts, the PPPL Director's Advisory Committee on Women, Ripley's Believe It or Not, Robert J. Novins Planetarium at Ocean County College, Sam's Club, Seastreak Atlantic Highlands, Target, Wal-Mart, and Wegmans. Thanks to everyone who made this event a success! ●

A young visitor dons emergency gear while checking out the emergency response units set up for PPPL's Earth Week event.

Science Fair Winners Exhibit Projects at PPPL

At left, PPPL's Raffi Nazikian (right), Head of International Collaborations, talks to Cameron Sadegh about the latter's project, "Quantitative Spectroscopic Analysis of Sulfur-oxy Anions using Ellmans Reagent," during the Science Fair at the Lab. At far left, Laboratory staff talk to the exhibitors about their science projects, which were displayed in the Lobby on April 18. Second to left is Engineering Head Michael Williams.

Fourteen area students exhibited their science projects on Wednesday, April 18, during PPPL's annual Science Fair Day. The Science Fair honored the 12 winners of PPPL's Corporate Awards, who were chosen among student exhibitors last month at the North Jersey Regional Science Fair at the County College of Morris in Randolph and at the Mercer Science and Engineering Fair at Rider College in Lawrenceville. Also honored were two special visitors. PPPL's Science Fair winners and the special visitors displayed their projects in the Laboratory's Lobby and were on hand to discuss their exhibits. The featured young scientists and their guests also toured the National Spherical Torus Experiment and had lunch with PPPL Deputy Director Rich Hawryluk, who presented the winners with awards. PPPL's Mary Ann Brown organized the event. ●

Fusion in a Beer Can is Topic of University Speaker

Richard Siemon, Head of the Fusion Energy Research Program at the Los Alamos National Laboratory, is scheduled to discuss, "Fusion in a Beer Can — a Solution to Our Growing Energy Problem?" at the Plasma Science and Technology Distinguished Speaker Lecture Series on Tuesday, April 24, at 8 p.m. at Princeton University. The talk will take place in the Small Auditorium (room 105) of the Computer Science Building, at 35 Olden Ave.

Five years ago, Russian and U.S. scientists initiated a startling collaborative endeavor to meld two fusion approaches, magnetic and inertial, into one with the potential for developing a more affordable and practical fusion power plant. Dr. Siemon leads the U.S. effort, based on a Los Alamos technology called Magnetized Target Fusion.

The hybrid method begins with threading a magnetic field through a small tenuous plasma — a dilute gas with a temperature of about 1 million °C. This plasma is then quickly inserted into a metal tube the size of a beer can. Strong magnetic fields are then applied to the can, compressing it and the plasma by a factor of 100. The plasma is heated to temperatures over 100 million C, high enough for fusion to occur. If the initial gas consists of a mixture of deuterium and tritium (isotopes of hydrogen), or deuterium and helium-3, copious amounts of energy would be released in an intense explosion. Converting this energy into a useful form poses great technical challenges.


Richard Siemon

Dr. Siemon recently served on the advisory committee to the Fusion Energy Program and the Energy Directorate at Lawrence Livermore National Laboratory. He was appointed by the Secretary of Energy to serve on the Magnetic Fusion Advisory Committee and the Fusion Energy Advisory Committee. Dr. Siemon is a Fellow of the American Physical Society and a Los Alamos Industrial Fellow.

The seminar series is sponsored by the Princeton Plasma Physics Laboratory and the School of Engineering and Applied Science. The talk is open to the public. ●

Happy Spring!

HOTLINE

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