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DOE Princeton Plasma Physics Laboratory

PPPL NEWS

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

Big Displays Come to Life on High-resolution Wall

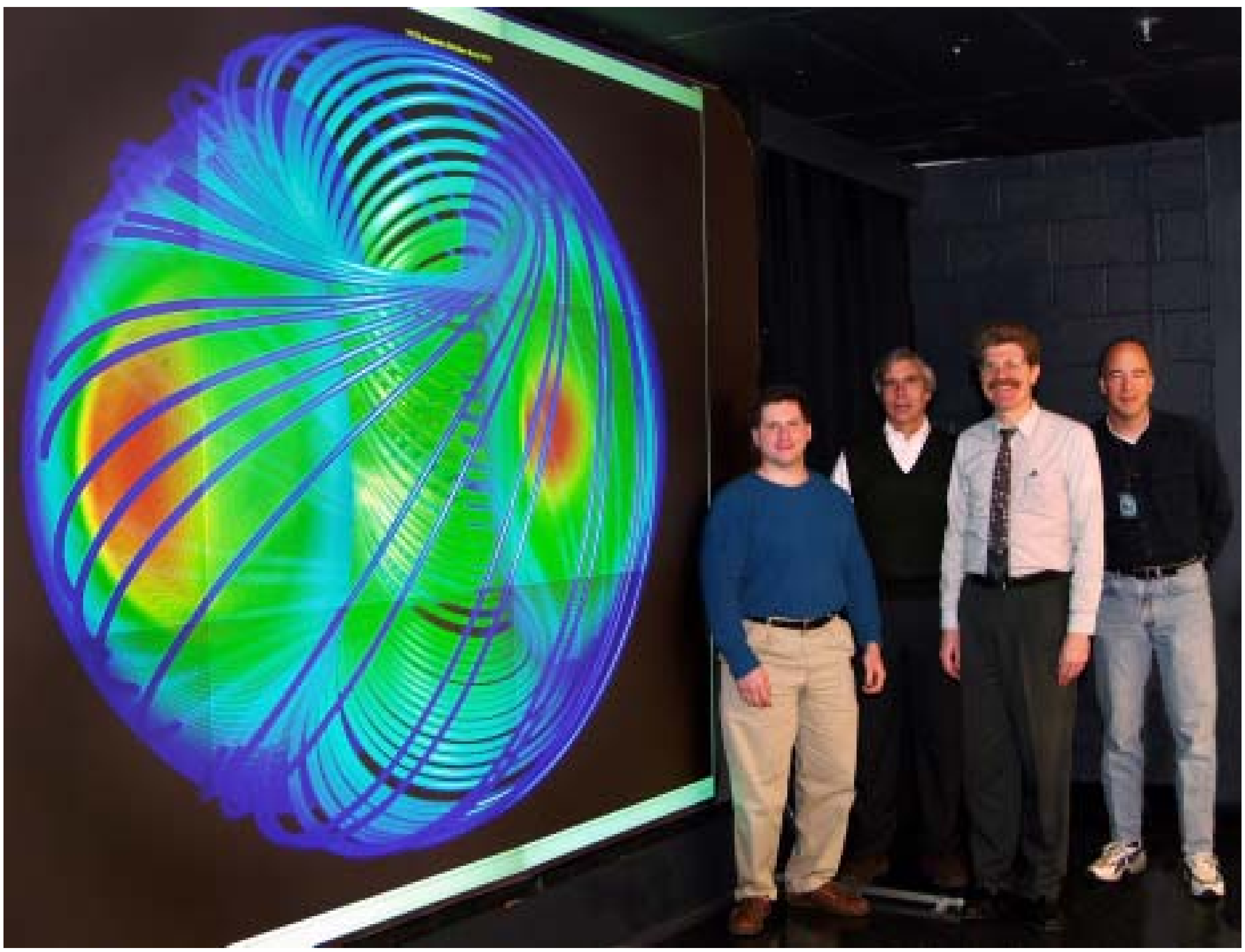

Photo by Elle Starkman

At the High-resolution Wall are, from left, Scott Klasky, Steve Jardin, Irving Zatz, and Doug McCune. The image displayed on the wall is of National Spherical Torus Experiment magnetic field lines.

During the past year, the High-resolution Wall, also known as the Visualization Wall, began operating at the U.S. Department of Energy's Princeton Plasma Physics Laboratory (PPPL). The wall has a resolution quality more than three and a half times better than high-definition TV. Ten clustered computers work together and nine projectors beam pixelated images onto this large display wall, resulting in superior clarity. The PPPL project originated as a result of a conversation between

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Wall

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Professor Kai Li from the Princeton University Computer Science Department and PPPL Chief Scientist Bill Tang. Professor Li's Display Wall on main campus was the model for PPPL's effort. PPPL's Scott Klasky is the driving force behind the assembly of the High-resolution Wall and it's ongoing improvements, and Irving Zatz of PPPL's Engineering and Technical Infrastructure Department, has been a valuable collaborator in the continuing improvement of the facility. Overseeing the project are PPPL's Steve Jardin and Doug McCune. Below, Jardin answers questions about the wall.

Q&A

What is the main purpose for the construction of the PPPL High-resolution Wall?

The main purpose of the Wall is to provide a very powerful, high-resolution, scalable display so that our theoretical researchers can see the fine-scale structure in their output from big supercomputers. The computers we use, particularly at NERSC (the National Energy Research Supercomputer Center at Berkeley) keep getting faster and more powerful, but desktop monitors have not been keeping pace in terms of their resolution capability.

One way of seeing this is in terms of parallelism. The way big supercomputers are getting faster now is that they combine many (up to 4,000 or more) "standard" computers and operate them in parallel. We call that MPP, or massively parallel processing. The display wall is an initial attempt to make a high-resolution display by combining nine "standard" displays in parallel. Its scalability means that even higher resolutions can be readily achieved with the addition of more processors and projectors.

How common is this type of facility at the National Labs?

PPPL is the first U.S. fusion facility to have such a wall, but others are now following. There are several of these walls at the big national laboratories and in computer science departments.

In layperson's terms, what are some of the "gee whiz" statistics pertaining to the assembly of the wall and its operation?

The High-resolution Wall is basically nine standard displays tiled together to make one display with higher resolution. Each of the nine displays has a resolution of about 800 x 1,000 pixels. Thus, the tiled wall has a resolution of about 2,400 x 3,000 pixels or 7.2 million pixels. The highest resolution digital TV formats that are coming out have about 2 million pixels for comparison. The system has nine projectors and one computer to drive each screen, plus a control computer to give directions to the others. It is clearly the Lab's fastest device for displaying visualization. When the computers are not being used to drive the screen, our researchers can use them in parallel to perform modest-scale scientific calculations.

What are some of the most interesting applications that have been tried at PPPL? What is the routine use (if any) of the wall?

We were somewhat surprised by how much people like to use the wall for making presentations. We have had many meetings held there where most of the presentations did not really need the high resolution that the wall provides, but people like the size and crispness of the display. Also, presenters have found that they can include much more information on their slides without it appearing "too busy" because there is so much room to work with.

PPPL NEWS

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We find that more and more, our research groups of six to 12 people are holding working meetings in the High-resolution Wall room and using the wall to show each other the results of their calculations. It is much better than everyone gathering around someone's desktop display, and it does not involve making hard-copy viewgraphs. Also, we are using the wall much more now to view movies of our simulation data. We find that we are noticing details in our simulation data that were not previously apparent.

What are the plans for the visualization facility at PPPL in the near term and the longer term?

We are now preparing proposals in several related areas. One area is that of "virtual meetings" with other laboratories. By using the wall, a collection of cameras, and some microphones and speakers, we can make an excellent virtual meeting room where a group here can see and talk with a group at a similar facility at another laboratory. The size and resolution of the wall make this a much more attractive setup than our present videoconference facilities. Also, we have a proposal to make a similar facility in the NSTX Control Room to show many plasma displays simultaneously at a size in which everyone in the control room can see them.

These two ideas can be combined to have remote control rooms for collaborators where they can see and interact with everyone and view all the data. Presently, projects are underway to develop an automatic alignment system for the projectors and to create a portable and scalable wall that can be moved from place to place.

What about the farther out possibilities, e.g., virtual reality?

Things are really moving in that direction. It is just a matter of when and how much it will cost. We are only a few years away from having the capability to create a 3-D real-time virtual walkthrough of an operating device such as NSTX. I think that in five to 10 years we will have collaboration displays that take up two or more walls in a room, and the displays and audio will be so sharp that it will be just like being in the same room as the people you are remote conferencing with.

As for the virtual reality, it is almost here. Some of our Japanese collaborators already have rudimentary virtual reality displays that use four walls and a ceiling. I think the real push will come when someone uses such a display to discover something really new that they couldn't visualize without it. Then it will really take off everywhere. It helps that the home game market is so strong, as that is providing a commercial incentive for companies to keep improving the display components and is driving the costs down. ●

Proposed Compact Stellarator Reviewed

The Physics Validation Review of the proposed National Compact Stellarator Experiment (NCSX) was held in March at PPPL.

The 13-member peer review committee addressed a Department of Energy charge that had several elements, including scientific merit, soundness of the NCSX physics basis, and relevance to fusion program goals. Committee members were also asked whether the level of experimental flexibility and robustness satisfies the Fusion Energy Science Advisory Committee (FESAC) requirements for the compact stellarator to attain proof-of-principle status. The review committee gave a strong affirmation on these questions and commended the preconceptual engineering design concept. Professor Gerald Navratil of Columbia University served as the Scientific Chair of the review.

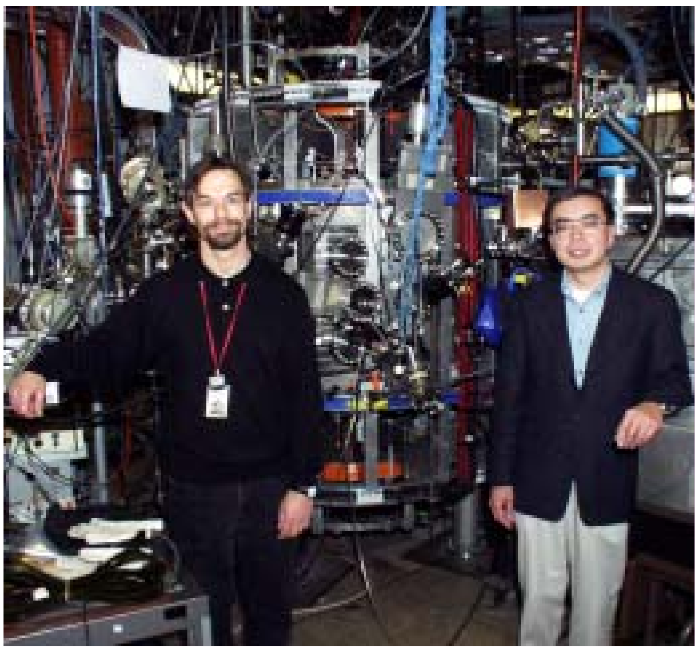
Prior to the meeting, the project team prepared a document "NCSX Physics Validation Report" to assist in the review process. This report documents the motivation and goals for NCSX, its physics and engineering design characteristics, its physics basis, and plans. It is posted on the NCSX web site at http://www.pppl.gov/ncsx. ●

PPPL's Michael Zarnstorff (standing, left) and Jeffrey Freidberg of the Massachusetts Institute of Technology (standing, right) discuss the proposed National Compact Stellarator Experiment (NCSX) during a recent NCSX Physics Validation Review meeting at PPPL.

Liquid Lithium Experiments are Underway on CDX-U Machine

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.



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

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 Laboratories; 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.

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 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.

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.

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 demonstrated 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."

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.

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.

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.

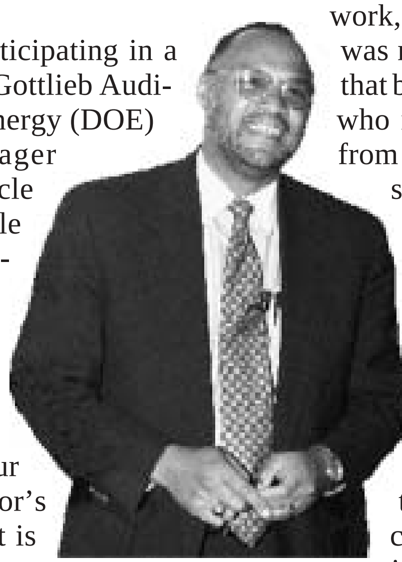
In the next series of CDX-U lithium experiments, the area of the plasma-lithium interaction will be increased from the modest 20 cm^2 to 1,900 cm^2. Researchers will employ a "belt" or "tray" limiter that will rest all the way around the bottom of the vacuum vessel, below the entire plasma. Using this setup, CDX-U 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. ●

DOE's Gunn Stresses Value of Diversity

To one woman, it was a person swimming in the middle of a pool. To another, it was a donut with a tiny center hole. One fellow thought it was a speck in the universe, while someone else said it was a snake looking up from a hole in the ground.

So who was right? All of them.

Those offering answers were participating in a simple exercise at PPPL's Melvin B. Gottlieb Auditorium on March 1. Department of Energy (DOE) Chicago Operations Office Manager Marvin Gunn had drawn a large circle with a dot in the center and asked people around the room what it was. The drawing conjured up images as individual as, well, each individual.



Marvin Gunn

"The point of the exercise is to see the value of diversity," said Gunn, who addressed all PPPL staff during a visit to the Lab that also included a tour of PPPL and a meeting with the Director's Minority Advisory Committee. "That is what gives us the strength we need to accomplish great things."

Gunn opened the talk by giving a personal overview of his lifelong interest in technology and concluded by discussing the importance of differences among individuals and teamwork. The DOE manager recalled how his interest in science was sparked after receiving a tool kit for Christmas as a child. "I took an old clock radio apart and put it back together without using half of its original parts," he said. His interest in technology and science followed him throughout his high school and college years, when he realized the need for collaboration. Building a model of an atom required teamwork, and his college group involved in the project was melded by their shared interest. "The thing that brought us together was science," said Gunn, who received a mechanical engineering degree from Howard University before going into public service. His philosophy about teamwork continued to guide his career at the Chicago Operations Office, where he said he realized he could not do his job alone — nor could anyone.

The Department of Energy Head emphasized the importance of celebrating individual differences, discussing a staff Unity Day Celebration at his office. "We talked about the differences in how we process information," said Gunn, who has been in his current position since December. He added that individuals must be valued for their unique capabilities and their contributions to a team's success. "Look at all the inventions, new ideas, and projects — all were done by a systematic assemblage of genius ...We are all geniuses in our own right. Organizing geniuses is a challenge, but a successful team gets it done," said Gunn. ●

In Remembrance

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. 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. 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. Stix's work revolutionized research in plasma physics by showing how waves could heat plasma. Stix (above, with a tokamak model) was also the author of a classic text, "The Theory of Plasma Waves," published in 1962, and the recipient of numerous awards. ●

PPPL Outreach ...

This year's Science-on-Saturday series at PPPL concluded on March 17 with a talk, "Keeping the Flame Alive — Flames of the Sydney 2000 Olympic Games," by Richard Kelso. Kelso (seen lighting the Olympic Torch at the lecture) described how a team of Adelaide engineers in Australia designed the fuel and combustion systems for the Olympic torch and the stadium cauldron for the Sydney Olympics. He was the Chief Design Coordinator of the Torch Development Team and Joint Leader of the Stadium Cauldron Design Team for the Sydney 2000 Olympics.

Science on Saturday is a wintertime series of free lectures geared toward high school students, but open to everyone. Started 17 years ago at PPPL, it attracts about 300 people each Saturday. This year's series included eight talks and was organized by PPPL's Ronald Hatcher, Janardhan Manickam, and James Morgan. ●

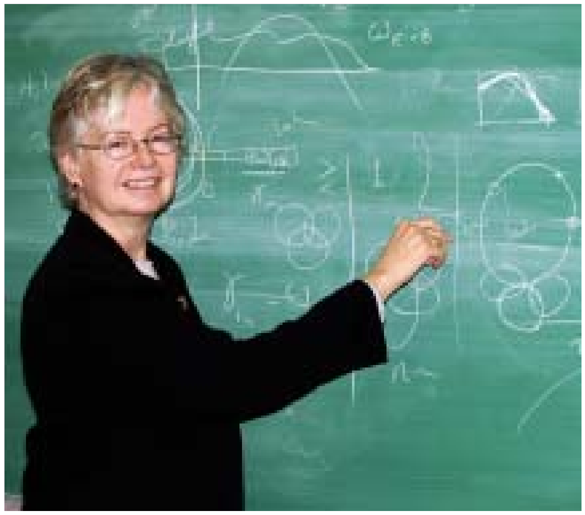
Photo by John Bennevich

On April 28, PPPL participated in Communiversity, the annual town-gown festival in downtown Princeton. Lab staff volunteered at the PPPL exhibit, which included fusion and PPPL handouts, as well as hands-on science demonstrations. More than 1,000 visitors saw the Lab's exhibit. Above, PPPL engineer Henry Carnevale fields questions about fusion. ●

More than 160 seventh through 12th grade female students from area schools came to PPPL on March 16 to participate in the "Expand Your Horizons Mini-Conference for Young Women in Science, Mathematics, and Technology." The conference included talks by various women in the sciences, a panel discussion, exhibits, and lunch. Above, mini-conference participants listen to a presentation about the NASA Goddard Space Flight Center. ●

Fourteen area students exhibited their science projects on 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 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 in March. Also honored were two special visitors,who displayed their science projects. PPPL Engineering and Technical Infrastructure Head Michael Williams talks to an exhibitor about her science project. ●

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." Besides 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." ●