DOE Princeton Plasma Physics Laboratory

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PPPL news

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

$12.5 Million Awarded in NCSX Subcontracts

PPPL Director Rob Goldston (center) signs the subcontracts for the NCSX components fabrication. Joining Goldston at the signing table are NCSX Project Head Hutch Neilson (right) and NCSX Deputy Project Head for Engineering Phil Heitzenroeder.

PPPL has awarded two subcontracts for the fabrication of major components for the National Compact Stellarator Experiment (NCSX), now under construction at the Laboratory. NCSX will explore the physics of an innovative concept for fusion energy production and will advance the understanding of the related basic science. PPPL is building the new experiment in partnership with the USDOE's Oak Ridge National Laboratory (ORNL).

A team led by Energy Industries of Ohio, Inc., of Independence, Ohio, has been selected to manufacture the winding forms upon which unique, modular electromagnetic coils will be mounted. Team members include the C.A. Lawton Company, Pattern Division, of DePerre, Wis.; MetalTek International, Carondelet Division, of Pevely, Mo.; and Major Tool and Machine, Inc., of Indianapolis, Ind. In addition to being part of the winding form team, Major Tool and Machine was awarded a subcontract to manufacture the NCSX vacuum chamber. These components will form the heart of NCSX, which will use a magnetic field to confine a hot ionized gas (plasma) fuel. The modular

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PPPL'ers Celebrate NSTX Operations

Pizza for everyone! On August 6, PPPL'ers consumed more than 100 pizzas in the Lab's Lobby at an Olympics-themed bash to celebrate the successful completion of the National Spherical Torus Experiment (NSTX) operations for Fiscal Year 2004. The machine completed 21.1 weeks of operation on August 5, with myriad accomplishments.

"This party is in honor of the NSTX 21 run-week accomplishment and in honor of all who contributed to making the run a scientific success," said PPPL Director Rob Goldston. "Accomplishing the run-week milestone was an Olympic-class marathon: hurdles were cleared, poles were vaulted, targets were hit (both archery and sharp-shooting), shots were put, hammers were thrown (safely, safely, safely), thrusts were parried, goals were scored, beams were balanced, boats were tacked (!), serves were volleyed, and generally the NSTX plasma was wrestled in every which way (freestyle and Greco-Roman, as well as Taekwondo)."

He congratulated staff and gave a summary of NSTX's achievements, which included producing 2,460 plasma

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Party-goers grab a slice or two. PPPL's John Jenner (far left) leads the line.

NCSX

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electromagnets will help shape the magnetic field confining the NCSX plasma within the vacuum chamber.

"These are the most challenging and critical components of NCSX, and we are delighted to award these contracts to such superbly qualified industrial subcontractors," said PPPL Director Robert J. Goldston. The key innovative feature of NCSX is its complex shape, designed through advanced computer simulations, that is predicted to be able to support a high-efficiency, fully steady-state fusion system. The complex shape makes construction of its components especially challenging.

Energy Industries' contract is valued at approximately $8 million and Major Tool's at approximately $4.5 million. Funded entirely by the USDOE's Office of Science, the construction of NCSX will cost an estimated $86.3 million. It is scheduled to begin operation in 2008.

NCSX's modular coils are among the most complex, innovative electromagnets ever designed. The 18 winding forms will consist of non-magnetic stainless steel castings with the winding surfaces machined to a tolerance of plus or minus 0.020 inch. The largest will be 110 inches tall. Each will weigh approximately 6,000 pounds. The winding forms will provide the backbone of the modular coil system and will be strong enough to support electromagnetic loads in the range of 7,000 pounds per inch. Energy Industries will manufacture six identical sets, each comprised of three types of intricately shaped forms. Delivery of the first winding form is expected in May, 2005. PPPL engineers will then wind layers of insulated copper conductor around the forms to create the modular coils.

The 25,000-pound NCSX vacuum vessel resembles a twisted doughnut. It will be made of Inconel 625, an alloy that is hard to form, but has high electrical resistivity that will suppress electrical currents that might interfere with plasma confinement. The vessel will be press formed with 0.375-inch walls and have an overall profile tolerance of plus or minus 0.188 inch. It will be fabricated in three identical segments, which will be welded together end-to-end at PPPL during final assembly. The subcontract also includes fabrication of the 90 vacuum vessel ports that will provide plasma heating and diagnostic access. Major Tool will deliver the vessel in the fall of 2005.

The NCSX vacuum vessel.

Fusion is the energy source of the stars. It involves the joining, or fusing, of the atoms of light elements, such as hydrogen, to produce heavier elements, such as helium. In the process, mass is converted into energy according to the Einstein formula $E = mc^2$.

To produce useful amounts of energy from fusion on earth, scientists must produce a plasma with the required temperature, density, and heat retention. To achieve this, fusion researchers must find the best shape for the hot reacting plasma and the magnetic fields that keep it in place. Dramatic advances in magnetic confinement physics and computational capabilities have yielded a promising new configuration — the compact stellarator. NCSX will be the first device in this class anywhere in the world. Currently the most developed plasma configuration is produced in the doughnut-shaped tokamak. Record levels of fusion power have been achieved in large tokamak devices, such as the Tokamak Fusion Test Reactor, which operated at PPPL between 1983 and 1997. The cross section of a tokamak is circular and remains the same all around the doughnut. The cross section of a stellarator varies, depending on where the doughnut is sliced. This additional degree of freedom allows physicists to select the best plasma cross section for optimal performance.

The first magnetic fusion devices explored at Princeton were stellarators, or "star generators," a term coined by Princeton Professor Lyman Spitzer, who initiated fusion research in the U.S. The NCSX will create a plasma that is more compact than traditional stellarators, including those now operational in Europe and Japan. NCSX will combine the best features of the traditional stellarator with those of the tokamak. The smaller size may lead to a more economical fusion power plant.

The Helically Symmetric eXperiment (HSX) at the University of Wisconsin, Madison, is the only existing stellarator in the U.S. Foreign experiments include the Large Helical Device in Japan and the Wendelstein 7-AS in Germany. The Wendelstein 7X is now under construction in Germany as well. ●

Party

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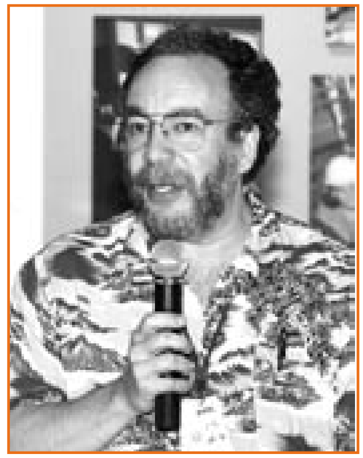
discharges with some of the best characteristics ever made in NSTX.

The Director noted that many experimental hurdles were jumped on the machine. During the run, experiments required by the NSTX 2004 milestones were successfully completed, enabling further analyses. By using new research tools, a wider range of plasma operating conditions was obtained.

Ed Synakowski, NSTX Deputy Program Director, characterized the FY 2004 operations as "wonderfully run experiments that produced wonderful data."

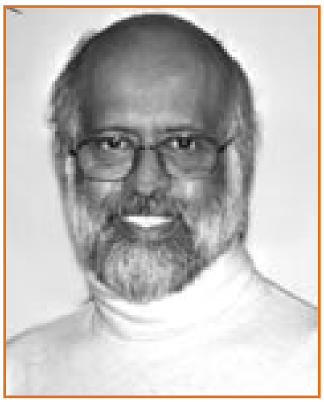
The machine is in a maintenance period until early 2005. "Our achievements set us up for what needs to be done for the next NSTX run," said Goldston. ●



At right, PPPL Director Rob Goldston delivers congratulatory remarks to staff at the celebration.

Manickam Named New Theory Head

Physicist Janardhan Manickam has been named Head of PPPL's Theory Department. He replaces William Tang, PPPL Chief Scientist, who is engaged in advancing scientific computing initiatives and strategies in collaboration with other plasma science institutions, Princeton University departments, and the DOE Office of Science.



Janardhan Manickam

A leader in the fusion theory community, Manickam also has contributed strongly to the experimental program, most recently as national coordinator for spherical torus theory. A spherical torus is a type of experimental fusion device. His principal interest focuses on magnetohydrodynamics, which is the study of the interaction between electrical fields and conducting fluids.

PPPL Director Rob Goldston, who made the announcement last week, said, "Janardhan 'Manny' Manickam has the scientific and personal respect of everyone who knows him. He has a history of leadership in the fusion theory community, and his theoretical work has contributed strongly to the experimental program. I have great confidence that Manny's leadership style, which involves both holding up the highest scientific standards and also working closely with people as individuals, will be extremely effective in our challenging research environment, which requires the best from everyone."

Manickam joined PPPL in 1975 and has been a principal research physicist since 1986. He has been a visiting scientist at several research institutions, including the Max Planck Institute for Plasma Physics in Garching, Germany, and the Japan Atomic Energy Research Institute in Tokai, Japan. He received a bachelor's degree in physics from Osmania University in India, a master's degree in nuclear physics from Andhra University in India, and a Ph.D. in plasma physics from the Stevens Institute of Technology in Hoboken, New Jersey. He is a Fellow of the American Physical Society, a member of numerous professional organizations, and a co-author on more than 150 papers in scientific journals. Manickam lives in Lawrenceville and serves on the School Board of the Lawrence Township Schools. ●

PPPL NEWS

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PPPL's Fisch Named E.O. Lawrence Award Recipient

PPPL's Nathaniel Fisch is among seven winners of the 2004 E.O. Lawrence Award. Each winner received a gold medal, a citation, and $50,000. The award is given in categories for outstanding contributions in the field of atomic energy, broadly defined.

"We are all enriched by the contributions these researchers have made ranging from engines with no moving parts to better ways to see the stars," said Energy Secretary Spencer Abraham. "These awards, and the research for which they are given, show that DOE could easily be called the Department of Science and Energy." Secretary Abraham announced the recipients in September. The Lawrence Awards were presented at a ceremony in Washington, D.C., on November 8.

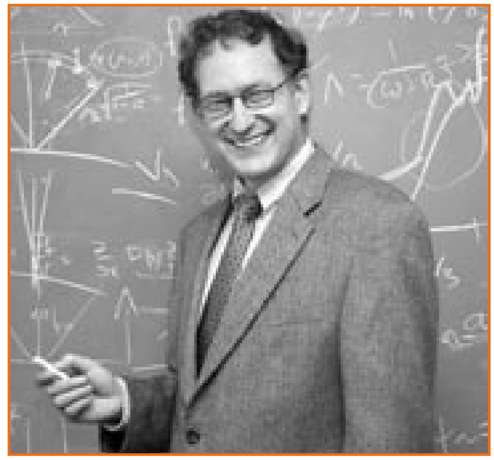
Fisch received the award in the nuclear technology category for his discovery of ways to use plasma waves to produce electric current. These wave-induced currents can enable tokamaks to operate continuously, which is necessary for an economical and practical fusion reactor.

Fisch specializes in theoretical plasma physics with applications to controlled nuclear fusion, plasma devices, lasers, and astrophysics. At Princeton University, Fisch is Professor of Astrophysical Sciences and Director of the Program in Plasma Physics. He also is an Associated Faculty member in the Department of Mechanical and Aerospace Engineering. At PPPL, he is Associate Director for Academic Affairs and Head of the Laboratory's Hall Thruster Experiment.

Impact of Fisch's Ideas

Pointing to the continuing impact of Fisch's ideas, PPPL Director Rob Goldston said, "Professor Fisch's analyses of techniques to use radio waves to drive electrical currents in plasmas are as elegant and insightful as they are practical. His theoretical work, and close collaboration with the experimental team on the Princeton Large Torus, opened the way for a wide range of experiments and further analyses, and led to a substantial field of research on current-drive in toroidal plasmas. Indeed, sustainment of currents using radio waves may prove to be an essential ingredient in the steady-state operation of fusion power systems." The Princeton Large Torus was an experimental fusion device at PPPL.

Scott Tremaine, Chair of Princeton University's Astrophysical Sciences Department, praised Fisch for his influential role in shaping graduate education in plasma physics.



Nathaniel Fisch

"For over a decade, Nat has headed the Program in Plasma Physics at Princeton University, which is widely recognized as one of the world's premier graduate programs in plasma physics. Under Nat's guidance, Princeton has trained the generation of extremely talented young researchers who may transform the dream of controlled fusion energy to reality. Nat is committed to the concept that both universities and national laboratories benefit from close cooperation in research and education in plasma physics," said Tremaine.

Fisch studied electrical engineering and computer science at the Massachusetts Institute of Technology, receiving a B.S. in 1972, an M.S. in 1975, and a Ph.D. in 1978. Fisch is a Fellow of the American Physical Society (APS). He received a Guggenheim Fellowship in 1985, the 1992 APS Award for Excellence in Plasma Physics, and a Department of Energy Bronze Medal for Outstanding Mentor 2002. Fisch is the author or co-author of more than 200 research papers and has been granted nine U.S. patents.

A list of the other winners of this year's Lawrence Award and additional information about each of the recipients is available on the web at www.sc.doe.gov.

The Lawrence Award was established in 1959 to honor the memory of the late Dr. Ernest Orlando Lawrence, who invented the cyclotron (a particle accelerator) and after whom two major Energy Department laboratories in Berkeley and Livermore, Calif., are named. The Energy Secretary makes the final selection of honorees each year. ●

Maintenance Group Celebrates Safety Record

In October, the Lab's Maintenance and Operations Division celebrated 100,000 consecutive hours without a recordable injury. The 100,000 work-hours cover from May of 2003 to October of 2004.

"I'm very impressed by the manner in which the maintenance staff members have been incorporating safety considerations into their day-to-day jobs. It's very challenging, especially with the diverse type of work and workplaces that they deal with. But the staff does take this very seriously everyday, and it pays off in the long run. The 100,000 hours and 17 months are a pretty remarkable milestone," said Jack Anderson, Head of ES&H and Infrastructure Support.

The Division's 40 employees are composed of maintenance technicians, supervisors, clerical support staff, janitors, system and project engineers, and administrators. To celebrate the milestone, Maintenance and Operations Division Head Carl Potensky and Manager Shawn Connolly treated the staff to a pizza-and-soda party at the Facilities Building on October 29. The group is at left, with a banner to mark the occasion. Holding the banner, created by PPPL's Greg Czechowicz, are Anderson at left and Potensky at right. ●

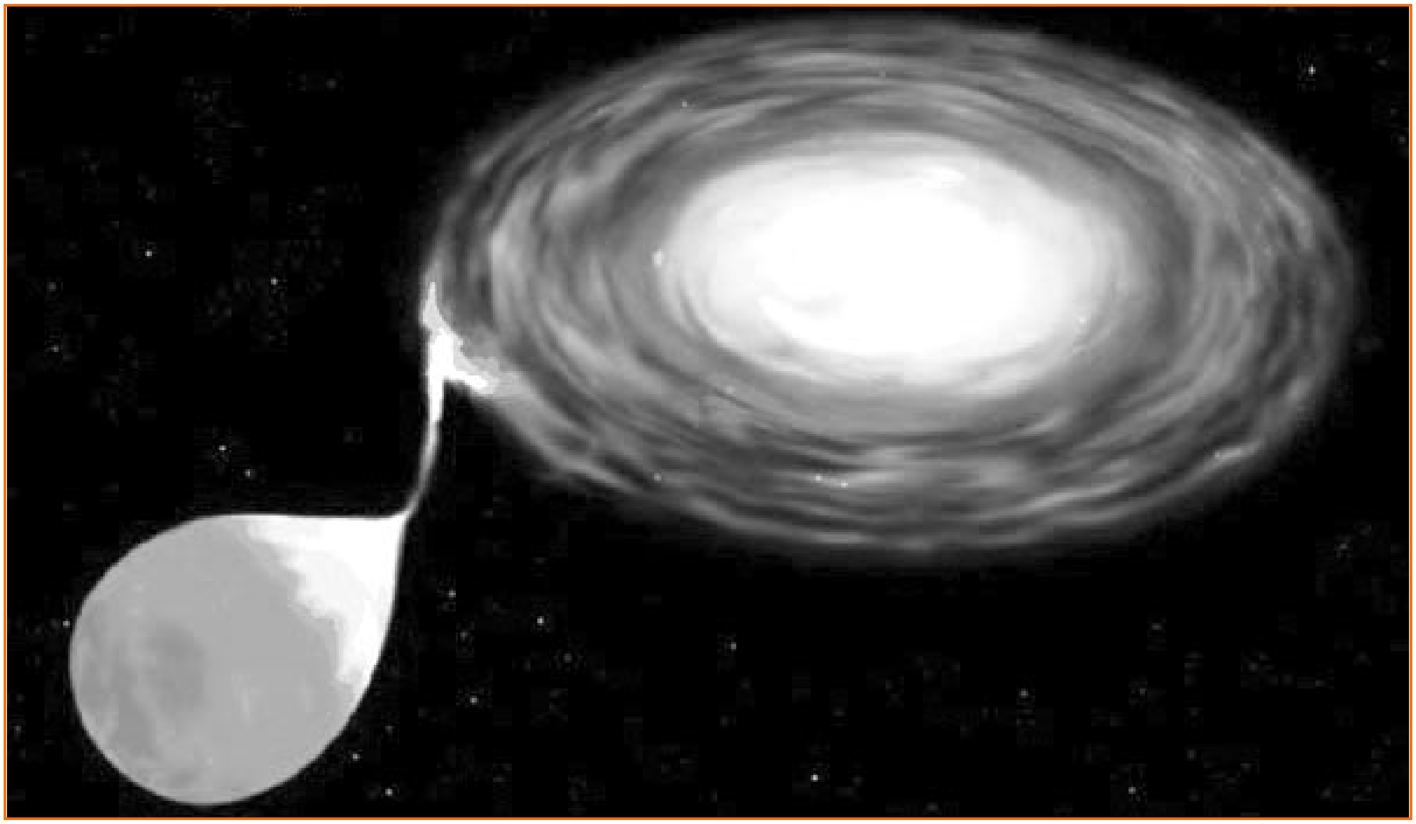
PPPL's von Halle Takes Fusion Show to Trenton

On September 30, PPPL engineer Al von Halle introduced the topic of fusion and plasmas to a total of about 50 students at Trenton High School. Above is von Halle with a group of the students following the classroom presentation.

The U.S. Department of Energy's (DOE's) National Laboratories house world-class facilities where more than 30,000 scientists and engineers perform cutting-edge research spanning DOE's science, energy, national security, and environmental quality missions. Interested in the latest achievements of the National Laboratories? Then visit the DOE Pulse at: http://www.ornl.gov/news/pulse/.

November Marked the Start of MRI Experiment at PPPL

May Shed Light on Star and Planet Formation



Accretion occurs in a binary star system when one star is paired with a sufficiently compact star such as a white dwarf, a neutron star, or a black hole. An accretion disk may form as the stellar envelop of the first star is captured by the denser star. (Space Telescope Science Institute, NASA)

by Anthony DeMeo

The formation process of stars and planets remains one of the big questions in astrophysical science. Presently, scientists do not understand the required conditions and the accretion, or matter collection process, involved in this formation. The Magnetorotational Instability (MRI) experiment at PPPL, however, may shed light on this mystery.

"The Earth must have sufficient angular momentum so that it does not fall into the Sun under the influence of gravity," said PPPL physicist Hantao Ji, who is the project's Principal Investigator. Angular momentum is the impetus of a body to keep rotating. "We also know that galaxies and solar systems have a preferred direction of rotation. Consequently, matter forming these systems must also have had net angular momentum, which must have been overcome by gravity for the matter to coalesce."

Ji explained that the angular momentum prevents matter from falling into the star directly, so an accretion disk is formed, which consists of matter losing its angular momentum and swirling into the core of the star. "For example, when our Sun was formed, the accretion process was very efficient in casting off angular momentum because most of the material comprising our solar system ended up in the Sun," he said.

Since angular momentum must be conserved, the lost amounts must be efficiently transported elsewhere. But how does this happen, and where does the angular momentum go?

Star formation occurs in deep space and therefore is not directly observable, so the accretion process has been described only in theoretical models and in their resulting computer simulations. The unique PPPL apparatus will be the first anywhere to attempt a direct test of this widely postulated physical process in accretion disks.

The project's primary mission is to test the plausibility of a 1991 theory that indicates magnetorotational instability (MRI), a disruptive plasma process, plays a major role in accretion. Unlike most PPPL experiments, MRI will not use an actual plasma. Ji and Princeton University Professor Jeremy Goodman, the principal collaborator for theory and astrophysics on the project, came up with a way to physically simulate an accretion disk with material "standing in" for the plasma, dust, and other materials.

The system they are building consists of two concentric cylinders, each 28 centimeters in length, free to rotate independently about a common axis. The inner cylinder has a radius of 7 centimeters and is made of steel, and the outer cylinder has a radius of 20.3 centimeters and is made of plastic to allow visual inspection.

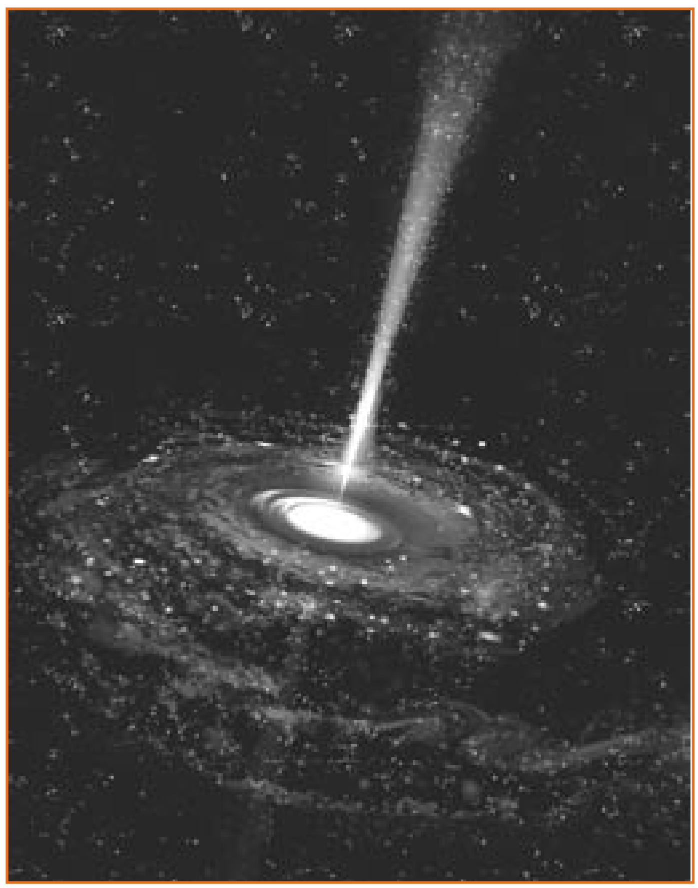
During a typical experiment, the space between the cylinders will be filled with a liquid metal, chosen because it is easy to maintain and interacts with the magnetic field in ways similar to plasma. The researchers have chosen a mixture of 67 percent gallium, 20.5 percent indium and 12.5 percent tin. The inner and outer cylinders will rotate independently in the same direction, but at significantly different speeds, 4,000 rpm and 533 rpm, respectively. The project is a significant engineering challenge since it requires two rotating disks at each end of the cylinders. The disks must be driven at different speeds by separate motors through six concentric pipes.

Experiments will be conducted with and without a magnetic field parallel to the axis of the cylinders. Researchers will measure the differences in the torque on the cylinders between both conditions. The magnetorotational instability, when it occurs in the liquid metal, will cause angular momentum to be transferred from the inner cylinder toward the outer cylinder, resulting in an increase in torque couplings between cylinders. This is equivalent to the transfer of angular momentum outward in an accretion disk, allowing matter to fall toward its center, forming a star. This result would support the hypothesis that MRI is responsible for the transport of angular momentum.

Accretion disks also form around massive black holes in the center of many galaxies and in binary star systems. Results from the PPPL experiments will help astrophysicists better understand these phenomena. Understanding transport phenomena in plasmas is important for basic plasma physics in general, and also for fusion plasmas in particular.

Staffing the MRI project are Ji, postdoc Michael Burin, and graduate students Ethan Schartman and Wei Liu, with technical and engineering support from Robert Cutler, Steve Raftopoulos, Phil Heitzenroeder, Chang Jun, and Lew Morris. The team is working in collaboration with Professor Goodman of the Princeton University Observatory. DOE, NSF, and NASA jointly fund the work. ●

At the MRI experiment are, from left, Bob Cutler, Michael Burin, Ethan Schartman, and Hantao Ji. The apparatus includes elaborate driving mechanisms for the concentric cylinders.

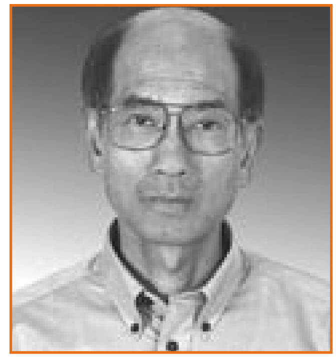


Above is a rendering of an accretion disk around a massive black hole often thought to exist in the center of many galaxies. (NASA)

PPPL's Cheng, Ji, and Wong Receive American Physical Society Honors

Frank Cheng

Hantao Ji



King-Lap Wong

The American Physical Society (APS) recently honored three scientists at PPPL. PPPL's Chio Z. "Frank" Cheng and King-Lap Wong received the APS 2004 Award for Excellence in Plasma Physics Research and Hantao Ji was named an APS Fellow. The awards were announced in November at the APS Division of Plasma Physics meeting.

Award for Excellence in Plasma Physics Research

Cheng and Wong were among five scientists to receive the Excellence in Plasma Physics Research Award in recognition for work related to the confinement of energetic alpha particles, which is important to fusion energy research. (More information about the award and all of the recipients is available on the APS web site at http://www.aps.org/praw/plasma/index.cfm.)

PPPL Director Rob Goldston congratulated Cheng and Wong on their ground-breaking research of fundamental importance for the ITER project, a major international fusion experiment that is the next large step for the development of fusion.

Cheng is the Head of the Energetic Particle Physics Group and of the Space Plasma Physics Division in PPPL's Theory Department. He is a 1996 PPPL Distinguished Research Fellow and an APS Fellow. Cheng's area of expertise is in theoretical and computational plasma physics with applications in fusion research and space physics. He has more than 200 publications on laboratory and space plasma physics, and has presented more than 40 invited talks at major conferences. Cheng received a bachelor's degree in physics from the National Cheng-Kung University, Taiwan, in 1969, and a Ph.D. in physics from the University of Iowa in 1975. He joined the research staff at PPPL in 1975. He is a resident of Belle Mead.

Wong received a bachelor's degree in physics from The Chinese University of Hong Kong in 1968 and a Ph.D. from the University of Wisconsin-Madison in 1975. He worked for Columbia University for one year as a research associate, joining PPPL's research staff in 1976. Wong is on long-term assignment at General Atomics in San Diego, working on electron cyclotron wave heating and current drive experiments on the DIII-D fusion machine. He is an APS Fellow. He presently resides in Carmel Valley, San Diego.

APS Fellow

Ji received the lifetime appointment of Fellow in recognition of his contributions to the field of plasma physics. The APS rules limit the maximum number of Fellows selected each year to be no more than half of one percent of the Division membership. "Dr. Ji's work on fundamental plasma physics forms a key bridge between laboratory plasma science and plasma problems of high importance in astrophysics," said Goldston.

Ji received a bachelor's degree in physics from Ehime University in Japan in 1985 and a doctor of science degree in physics from the University of Tokyo in 1990. He conducted plasma physics research at the National Institution for Fusion Sciences in Japan and at the University of Wisconsin-Madison before coming to PPPL in 1995. He has been conducting experiments to study the physics of magnetic reconnection, magnetorotational instability (MRI), and other basic physical processes. (Information about magnetic reconnection is available on the web at: http://www.pppl.gov/projects/pages/magnetic_reconnect.html and about MRI at: http://www.pppl.gov/publications/pages/pppl_digests.html.) Ji has published many papers on laboratory studies of these subjects. Ji shared the 2003 Kaul Foundation Prize for Excellence in Plasma Physics Research and Technology Development given by Princeton University and the APS-DPP 2002 Award for Excellence in Plasma Physics Research. He is a resident of Plainsboro Township. ●