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PRINCETON PLASMA PHYSICS LABORATORY
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FACT SHEET
NSTX-U

Sixty Years of Progress Toward *"Putting A Star In A Jar"*

Inside the National Spherical Torus Experiment

For more than half a century scientists have dreamed of harnessing the power that drives the sun and the stars. Mastering this could provide a safe, clean and abundant source of fuel for generating electric power.

Among the pioneers in this quest for a "star in a jar" is the U.S. Department of Energy's Princeton Plasma Physics Laboratory (PPPL) in Plainsboro, N.J. Since opening its doors in 1951, the Laboratory, which is managed by Princeton University, has achieved milestones that include producing more than 10 million watts of fusion power and temperatures of more than 500 million degrees Centigrade, both records in the 1990s. Fusion takes place when two atomic nuclei, such as isotopes–or different forms–of hydrogen, combine at extremely high temperatures and release a burst of energy. Fusion power plants could use this energy to boil water for steam to drive turbines and generate electricity without emitting the greenhouse gases that come from burning fossil fuels. Fusion produces none of the radioactive waste that comes from today's nuclear power plants, which operate by splitting atoms, and carries little or no risk of catastrophic accident. And since hydrogen is found in seawater, the fuel for fusion plants is virtually inexhaustible.

The largest project at PPPL today is an advanced nuclear fusion reactor–or tokamak–called the National Spherical Torus Experiment (NSTX). Researchers from 30 U.S. institutions and 11 other countries are collaborating in this effort. Since this project began in 1999, it has set standards for creating and controlling the superheated and electrically charged gases called plasmas that fuel nuclear fusion and are many times hotter than the 10 million-degree-Centigrade core of the sun. "Our goal is to find the most attractive means of producing fusion in terms of technology and cost," says Masayuki Ono, a principal research physicist who heads the NSTX department at PPPL.

The NSTX is currently undergoing a $94-million upgrade, NSTX-U, that will double its current and heating capacity and the strength of the magnets that confine the plasma inside magnetic fields. This will augment the position of the NSTX as the most powerful reactor of its type in the world when the work is completed in 2015. Discoveries gleaned from the upgrade could make PPPL a candidate to participate in the Fusion Nuclear Science Facility, the proposed next major phase of U.S. fusion research. The upgrade "will provide a huge boost to all NSTX science missions and enhance U.S. fusion research capability," said Stewart Prager, director of PPPL.

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The NSTX-U is part of a worldwide effort to develop a commercially viable fusion power station by the middle of this century. Accomplishing this calls for producing a sustained fusion reaction, or "burning plasma," that puts out more energy than is required to create it. Chief among projects to deliver such output is an experiment called ITER–Latin for "the way"– a fusion reactor being built in Cadarache, France, at an estimated cost of 12.8 billion euros ($18.4 billion), according to ITER. This project is funded by the European Union, the United States and five other countries. NSTX data will help ITER progress toward its target of producing 500 million watts of fusion power for at least 500 seconds by the late 2020s and thereby serving as a bridge to a demonstration fusion power plant.

The compact spherical design of the NSTX-U reactor provides some operating advantages. Most tokamaks, including the major one planned for ITER, confine the plasma inside doughnut-shaped magnetic fields that are costly to produce. But the more streamlined NSTX-U reactor creates a plasma that is shaped like a cored apple and requires less magnetism to confine. The NSTX-U device is in fact the world's highest performance tokamak in terms of a key measure called "beta"–the ratio of the pressure of a plasma to the strength of the field that contains it.

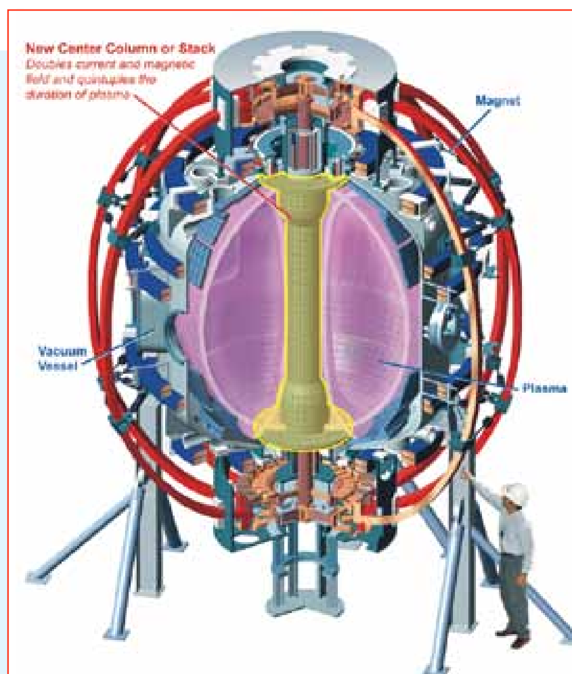
NSTX-U researchers seek to maintain this high beta following the upgrade while controlling the impact of the superhot plasma particles that escape from the confinement and strike the tokamak wall. "Particles will always leak out of the plasma. It's just the nature of the beast," says Michael Williams, associate director for engineering and infrastructure at PPPL. Such contact kicks up impurities that cool and degrade the plasma and prevent fusion from taking place.

Solving this problem is one of the major challenges of fusion research. "What you want is a high-performance plasma that's not changing," says Jonathan Menard, a principal research physicist and program director for the NSTX-U. "It stays the way you want it for as long as you can run the magnets" that keep the plasma in place. PPPL engineers have applied an ultrathin layer of lithium to the floor and walls of the reactor to improve plasma performance. The lithium turns liquid when stray particles strike the layer and sponges up the impurities to keep them from cooling the rest of the plasma. "To show that we can sustain the plasma for as long as we want without impurities building up would be quite significant," says Steven Sabbagh, a senior research scientist at Columbia University who is on long-term assignment at PPPL.

Further insight into lithium's ability to act as a sponge will come from another PPPL project called the Lithium Tokamak Experiment (LTX) — the first fusion reactor to have the light, silvery metal coated on all of its walls. This small doughnut-shaped machine made its first plasma in 2008 and began operating with a full lithium jacket in 2010.

For more information, please go to:
www.pppl.gov/nationalsphericaltorus.cfm

NSTX-U AT A GLANCE



- **The $94 million upgrade will make the NSTX reactor the most powerful spherical torus, or tokamak, in the world when the work is completed in 2015. The spherical design confines superheated plasmas in the shape of a cored apple, compared with the donut-shaped plasmas that bulkier conventional tokamaks create. The spherical geometry requires less high-cost magnetism to maintain.**
- **The NSTX reactor has already set world records for creating and controlling plasmas under laboratory conditions. This achievement is measured by a value called "beta," which gives the ratio of the pressure of a plasma to the strength of the magnetic field that confines it. The NSTX beta has been found to be some three times higher than the best ratio for conventional tokamaks. The higher the beta, the more cost-effective the reactor.**
- **The enhancements will double the temperature range at the core of the plasma to at least 20-60 million degrees Celsius, as compared with the 10 million degree temperature at the core of the sun.**
- **The upgrade will double the strength of the reactor's magnetic field to 1 tesla, or 20,000 times the strength of the Earth's magnetic field and more than 200 times the strength of a refrigerator magnet.**
- **The NSTX reactor's current will double to 2 million amperes as a result of the upgrade. A 100-watt light bulb draws 1 amp of current.**
- **Strategies developed for taming the intensely hot plasma particles that strike the wall of the upgrade could serve as a model for the international experiment ITER, a major conventional tokamak that is under construction in the south of France.**
- **Scientists will use the upgrade to determine the suitability of the NSTX design for a "U.S. fusion nuclear science facility" that would develop components for a commercial fusion power plant.**
- **Planners hope to have a commercial fusion reactor in operation by 2050. It would use the heat produced by fusion to generate electricity.**

The Princeton Plasma Physics Laboratory is operated by Princeton University under contract to the U.S. Department of Energy. For additional information, please contact: Office of Communications, Princeton Plasma Physics Laboratory, P.O. Box 451, Princeton, NJ 08543; Tel. (609) 243-2750; e-mail: pppl_info@pppl.gov or visit our web site at: www.pppl.gov.