Japan Readies Helical Device To Probe Steady-State Plasmas

TOKI, JAPAN—Japan's effort to understand and harness the power that drives the stars will take a big step forward on 31 March when plasma physicist Atsuo Iiyoshi steps up to a panel in a cavernous control room here and pushes a button. Barring last-minute glitches, he will initiate production of the first plasma in a fusion reactor that is the largest of its kind. For Iiyoshi, director-general of Japan's National Institute for Fusion Science (NIFS), the $650 million Large Helical Device (LHD) is the next step in making this type of reactor a contending design for a commercial fusion power plant.

For Japan, the machine marks the newest component in what is arguably the world's most ambitious fusion research program. The LHD is just one element in the country's $250-million-a-year fusion research budget—some $18 million more than the United States is spending. Japan also operates one of the world's most advanced tokamaks, the JT-60, and it's the odds-on favorite to host the planned $10 billion International Thermonuclear Experimental Reactor (ITER). "They're certainly going to give other countries a run for their money [in fusion research]," says Robert Goldston, director of the Princeton Plasma Physics Laboratory in New Jersey.

The design for the LHD was pioneered at Princeton in the 1950s with a device called a stellarator. However, Princeton and most other labs around the world later turned their attention to a competing fusion device, the tokamak. Both approaches rely on heating a plasma of ionized light atoms so that they fuse into heavier atoms, releasing energy in a process that mimics the sun's power plant. To maintain the required temperature of 100 million degrees Celsius, the plasma is confined by a magnetic field that spirals through a doughnut-shaped vessel.

The difference between the two machines lies in how that field is created. In a tokamak, the field is the sum of what is generated by a current sent through the plasma itself and coils that fit like rings around the doughnut. In a helical device, the coils themselves are wound in a helix around the doughnut.

Neither approach is trouble-free. The current running through the plasma in a tokamak can only be applied in short pulses, limiting the duration of the magnetic confinement and, thus, the fusion reaction. Large currents also can cause a phenomenon called disruption, a sudden rapid loss of energy that can damage reactor components. The magnetic field in a helical device is independent of the plasma and can run in a steady state, allowing a continuous fusion reaction. But the plasmas in the early stellarators lost energy at rates an order of magnitude greater than that of the best tokamaks. In addition, their helical coils were hard to build and their magnetic fields were difficult to analyze.


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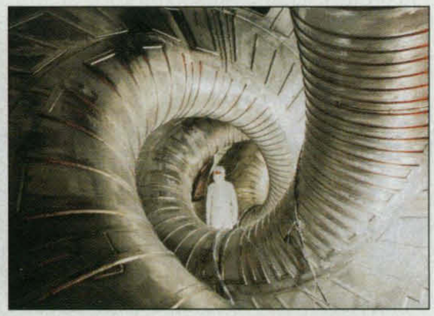
NIFS

Inside story. Iiyoshi with a model of the Large Helical Device, in which helical coils create a powerful magnetic field to confine burning plasma.

While much of the rest of the world abandoned helical devices in the 1960s, a few groups, notably at Kyoto University in Japan and the Max Planck Institute for Plasma Physics in Garching, Germany, continued working on the energy-loss problem. Proponents see the LHD and a German device being built of comparable size but different configuration as opportunities to show that a helical device could be an alternative to the tokamak for commercial power reactors. "There is no unique solution for fusion power yet," Iiyoshi says.

Japan's fervent interest in fusion starts from one simple fact: The nation imports all of its oil. The economic devastation wrought by the oil shocks of the 1970s is still a vivid memory here, fueling the search for alternative energy sources. Policy-makers also believe that fusion research will be a boon to the country's heavy industry. Osamu Motojima, NIFS's director of research operations, points proudly to the LHD's superconducting coils, which required advances in everything from the material of the wires to a new machine to wind them. "Very few countries could build something like this," Motojima says.

The project has also gotten a boost from ongoing competition between rival agencies. "Happily, Japan has two [science] ministries," says Iiyoshi. With JT-60 and Japan's ITER efforts supported by the Science and Technology Agency, NIFS benefited from a willingness of its funding agency, the Ministry of Education, Science, Sports, and Culture (Monbusho), to fund an alternative.

Despite the LHD's domestic importance, Iiyoshi stresses that it will be an international facility and that any scientist can apply for time on the machine. "They are more than just open, they're very eager for people to come here," says John Rice, a research scientist at Massachusetts Institute of Technology now working on diagnostic devices at NIFS.

Iiyoshi says that the parallel efforts on helical devices and tokamaks are complementary and necessary. Tokamaks are far ahead of helical devices in terms of the plasma densities and temperatures achieved. In the last few years, tokamaks have crept closer to break even, where the energy generated by the fusion reaction equals the energy put into heating the plasma (*Science*, 3 October 1997, p. 29). Günter Grieger, director of the new Greifswald branch of the Garching institute, where the new Wendelstein 7X stellarator is being built, adds that their track record makes tokamaks the obvious choice for the next step—investigating the self-sustaining fusion reaction using the deuterium and tritium that would be used in future reactors. "For ITER, it is the right way to go," Grieger says.

But ITER is not the last word in fusion reactors. While ITER plans to operate only in pulses of up to about 1000 seconds, the Japanese and German machines will confine the plasma for hours or even days. "We will be able to investigate parameters of steady-state plasma physics in ways that tokamaks can't," Iiyoshi says. That contribution, says Princeton's Goldston, "makes the LHD an important part of the world fusion research effort."

Helical device proponents hope to make more than just a contribution. Iiyoshi predicts that the performance of the LHD and the Wendelstein 7X will put helical devices back in the running by 2015, when it's time to design a demonstration reactor. "It could be the choice if we have great success with the LHD experiments," he says, a process that starts after he pushes the button.

–Dennis Normile