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MEDIA CONTACTS
Saralyn Stewart
(512) 694-2320
stewart@physics.utexas.edu

Placing Fusion Power on a Pedestal

A team of U.S. scientists produce predictions to enhance the performance of future fusion devices, based on the physics of the plasma boundary.

PROVIDENCE—Using experiments on three tokamak fusion devices, along with state-of-the-art theory and computational physics, plasma scientists now have accurate predictions for the plasma pressure at the boundary of future fusion devices. This work represents a critical step toward projecting the performance of the reactors that will one day generate fusion power for the grid. Such reactors will be considerably larger and more powerful than the best magnetic confinement devices in existence today, but their ability to generate useful power may depend on the physics of a relatively small portion of the fusion plasma, very near the edge, where the temperature is expected to rise by 40 million degrees over a space of 2 inches.

The business of magnetic fusion is, simply put, to use strong magnetic fields to confine plasmas at such high temperature—greater than 100 million degrees—that significant numbers of fusion reactions occur, generating copious amounts of energy. How well these conditions are achieved in the core of a tokamak, a fusion device which has a torus (or donut) shaped vacuum vessel, depends strongly on the happenings at the edge. Because the wall of a tokamak must remain relatively cool, achieving suitably hot and dense conditions in the interior requires a very large differential in temperature and pressure at the boundary, which effectively lifts the core to higher performance. Fusion scientists call this boundary region the edge pedestal.

"You can think of the pedestal as a really fantastic insulator for the core plasma," explains Jerry Hughes, a research scientist at the MIT Plasma Science and Fusion Center. "A fusion plasma is like a house you need to keep warm in the winter. Your cost to heat it depends on the quality of the insulation. Getting the core plasma hotter with less input power gets you more bang for your buck. The pedestal largely sets the efficiency of the whole device."

One of the chief goals of the current research is to predict values of the pedestal on ITER, a one-of-a-kind tokamak being constructed in France by an international coalition that includes the United States. It will be the largest fusion device ever constructed, and will be an important step toward developing a power reactor. The chief mission of ITER is to obtain significant fusion gain, meaning that it will produce more power from fusion than is fed into it by its operators. To achieve this goal, estimates predict ITER will require a pedestal temperature rise of more than 40 million degrees.

Based on their findings from smaller tokamaks, pedestal researchers concluded that this condition is within reach for ITER. Confidence in the ITER estimate is high because key scientific predictions were successfully tested on a wide spectrum of devices.

"No machine can match the conditions on ITER except, one day, ITER," Hughes says. "So having more experiments available for this kind of research is always better, since you can identify the most important physics by looking for commonalities among the machines."

Despite being smaller, some existing devices in the study get close to ITER in terms of other important parameters. For example, the Alcator C-Mod tokamak at MIT confines plasma using magnetic fields of the same strength that will be used on ITER, and despite being nine times smaller in size, achieves a pedestal pressure within a factor of three of that predicted for ITER.

This joint research effort included new data from C-Mod, as well as from the other two U.S. tokamaks: DIII-D at General Atomics and NSTX at Princeton Plasma Physics Laboratory. Experimental physicists worked alongside theorists in planning and completing the research. All told, it involved the direct participation of more than 50 scientists and students from 15 institutions. The project was initiated and supported by the U.S. Department of Energy Office of Fusion Energy Science.

Contact:
J.W. Hughes, MIT Plasma Science and Fusion Center, (617) 252-1797,
jwhughes@psfc.mit.edu

Abstracts:

TI3.00003	**Advancing the predictive capability for pedestal structure through experiment and modeling**
Session	**TI3: Pedestal ELMs and ELM mitigation,** Ballroom BC, Thursday, November 1, 2012, 9:30AM–12:30PM