Fusion makes major step forward at MIT through studies of the plasma edge

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Researchers at MIT have taken steps toward practical fusion energy through better understanding of the physics that governs the interaction between plasmas and the material walls of the vessels that contain them.

The best developed approach for practical fusion energy employs magnetic bottles to hold and isolate extremely hot plasmas inside a vacuum vessel. Using magnetic fields for thermal insulation has proven quite effective, allowing plasma temperatures in excess of 100 million C to be attained - conditions under which the nuclei fuse and release energy.

The tokamak device, a torus or donut-shaped magnetic bottle, has been found to perform particularly well and is the basis for ITER, a full-scale international fusion experiment presently under construction in France with U.S. participation. Projections from current experiments to ITER, and beyond to energy producing reactors, presents a number of scientific and technical challenges. Prominent among these is handling the very large heat loads which occur at the interface between the plasma and the materials from which the reactor is constructed.

Plasma channels as it streams along magnetic field lines in adjoining boundary layers. This produces narrow footprints on wall surfaces. The smaller the footprint, the more intense the heat flux becomes. In fact, the intensity can easily exceed the power handling ability of present technologies. Even worse, certain naturally occurring plasma oscillations can create transient heat loads which are larger still. Recent experiments on the Alcator C-Mod tokamak are aimed at understanding and overcoming this challenge by reducing the steady-state power conducted to the wall, by characterizing the physics which sets the area over which this power is distributed, and by investigating a confinement regime that eliminates transient heat loads.

One set of recent experiments in Alcator C-Mod used ultra-violet radiation from injected impurities to decrease power reaching the divertor, a portion of the wall with the highest heat flux footprint. These results are significant for ITER as well as future fusion reactors that will provide commercial electricity, and show that redistributing the exhaust power by impurity radiation is a viable option.

Different experiments, aimed at understanding the physics that sets the heat-flux footprint size, have discovered its width is independent of the magnetic field line length. This behavior appears counter-intuitive at first, but is part of a growing body of evidence that self-regulatory heat transport mechanisms are at play, which tend to clamp the width of the heat flux profiles at a critical scale-length value.

Another aspect of the plasma-wall challenge is the elimination of transient heat loads, which arise from a relaxation oscillation produced spontaneously in many high performance plasmas. These oscillations help expel unwanted impurities that can contaminate the plasma, but they can also lead to unacceptably high power loads. Ongoing experiments are studying a confinement regime that simultaneously achieves good energy confinement without accumulation of impurities and without the oscillations.

These new findings will be presented in three invited talks at the American Physical Society, Division of Plasma Physics 52nd annual meeting on November 8-12 in Chicago.

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