NSTX
National Spherical Torus Experiment • PROGRAM HIGHLIGHTS
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Imaging and Reducing Turbulence at the Edge of NSTX and C-Mod

Researchers from the U.S. Department of Energy's Princeton Plasma Physics Laboratory (PPPL), the Los Alamos National Laboratory (LANL), and the Massachusetts Institute of Technology (MIT) have captured high-resolution images of instabilities that cause heat to leak rapidly from the plasma edge of the National Spherical Torus Experiment (NSTX) at PPPL and the Alcator C-Mod tokamak at MIT. Advanced imaging cameras developed by Princeton Scientific Instruments, Inc. under a U.S. Department of Energy Small Business Innovative Research Project were used to freeze plasma action at a rate of up to 1 million frames per second.

In NSTX these instabilities emerge from the plasma edge as long filaments many meters in length and only several centimeters in thickness and then speed away toward the wall at hundreds of meters per second. These plasma filaments can carry plasma energy and particles to the nearby vacuum vessel wall, causing a release of wall surface atoms, which in turn cool the plasma edge. The phenomenon that drives the bursts is likely related to the cause for the so-called "Low-Confinement Mode." When such instabilities are absent or much reduced, the plasma edge forms a barrier against heat loss, resulting in a steep rise in pressure at the plasma edge. The higher edge pressure in turn raises the core plasma temperature and density resulting in the "High-Confinement-Mode," which is of great interest in magnetic fusion research.

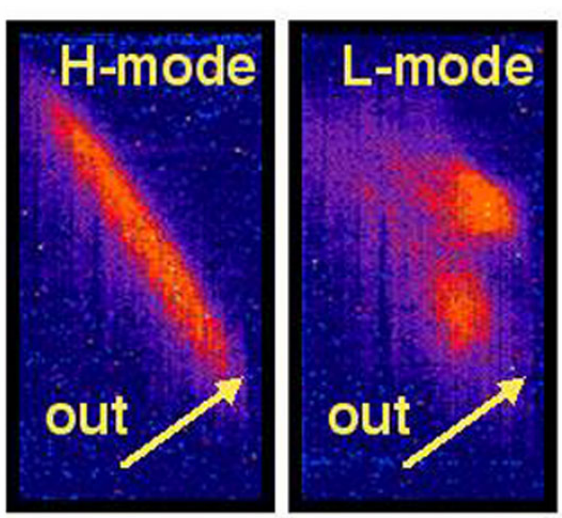


Figure 1: Sample images of edge turbulence in NSTX taken at 100,000 frames per sec. The plasma is highly turbulent in the "L-Mode" (right), but relatively quiescent in the "H-Mode" (left).

Images of the light emitted from a cloud of neutral helium atoms puffed into the plasma edge are shown in Figure 1. The camera view is directed along the magnetic field line. The intensity of the light in the image on the right indicates that instabilities can fluctuate wildly in space and time in an "L-Mode" plasma. The left image shows light emitted from an "H-Mode" plasma when the instabilities are suppressed. These are the highest resolution images of the motion of edge turbulence in fusion research plasmas ever obtained.

These images of edge turbulence reveal a fascinating variety of shapes and motions, often taking the appearances of flickering flames, swaying aurora, or explosive flares on the surface of the Sun (for more examples, please see http://w3.pppl.gov/~szweben/psi/). Plasma physicists are studying the complexity and looking at the relationship between these plasmas and space plasmas.

The plasma pressure slope coupled with the outward bulge of the magnetic field lines are believed to drive these instabilities. Sophisticated computational simulations are being developed by several groups around the world to help in understanding the instabilities. An example from researchers at the Lawrence Livermore National Laboratory (LLNL) is illustrated in Figure 2 below. Sheared and radial flows can be generated by the turbulence, and are believed to play a critical role in determining how the heat leak can be reduced or even stopped.

The simulations reproduce several important features of the instabilities, such as size, length, frequency range, and magnitude of the filaments. Experiments on NSTX, Alcator C-Mod, and DIII-D at General Atomics are continuing to clarify how the instabilities change with the size, field, shape, and plasma edge conditions. Progress will enable researchers to determine the conditions under which the instabilities can be reduced or completely avoided for long durations.

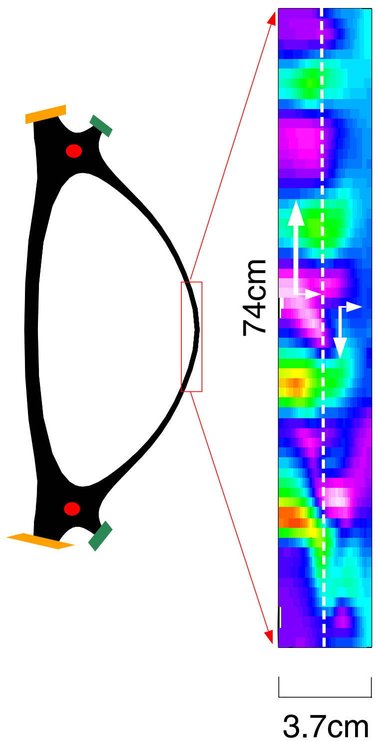
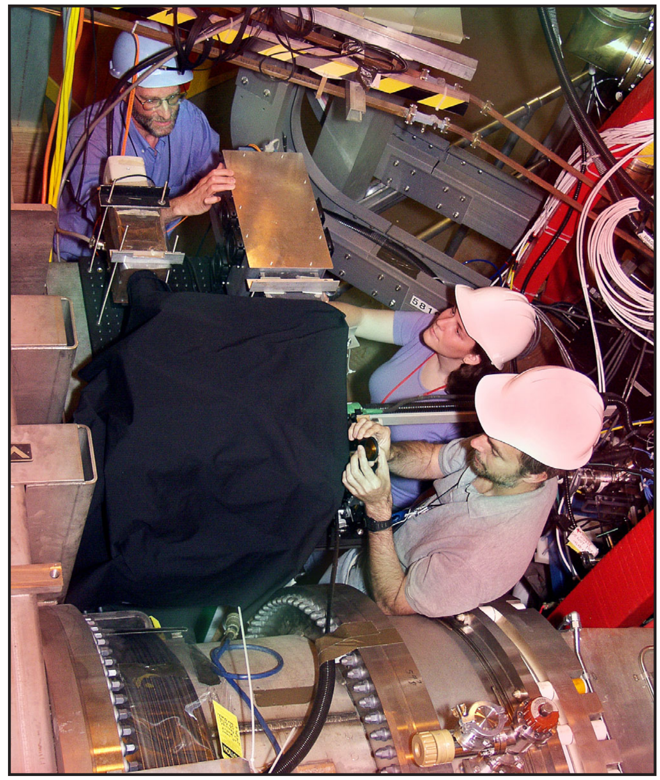


Figure 2: Computer simulation of instabilities at the edge of an "L-Mode" plasma in NSTX, produced by X. Xu et al. of LLNL. The color variations show the calculated fluctuations in plasma density resulting from the instability.



Changing the optical interference filter used for the gas puff imaging diagnostic of edge turbulence in NSTX are, from left, Stewart Zweben of PPPL, graduate student Amy Keesee of West Virginia University, and Ricardo Maqueda of LANL.

About NSTX

NSTX is a national magnetic fusion experimental facility, located at the U.S. Department of Energy's Princeton Plasma Physics Laboratory, to test the physics principles of the innovative Spherical Torus (ST) confinement concept. The ST concept promises new opportunities for exciting scientific discoveries toward an optimized confinement system and an affordable energy development path. The NSTX National Research and Facility Operations Teams have produced exceptional results since the start of experimentation in September 1999.

NSTX Program participants include scientists from: Princeton Plasma Physics Laboratory; Oak Ridge National Laboratory; University of Washington; Columbia University; General Atomics; Johns Hopkins University; Los Alamos National Laboratory; Nova Photonics; Lawrence Livermore National Laboratory; University of California - San Diego; University of California - Davis; University of California - Los Angeles; Massachusetts Institute of Technology; University of California - Irvine; Sandia National Laboratory; Princeton Scientific Instruments; CompX; Lodestar; New York University; University of Maryland; and Dartmouth University.

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