Chaos Can Control Edge Instabilities

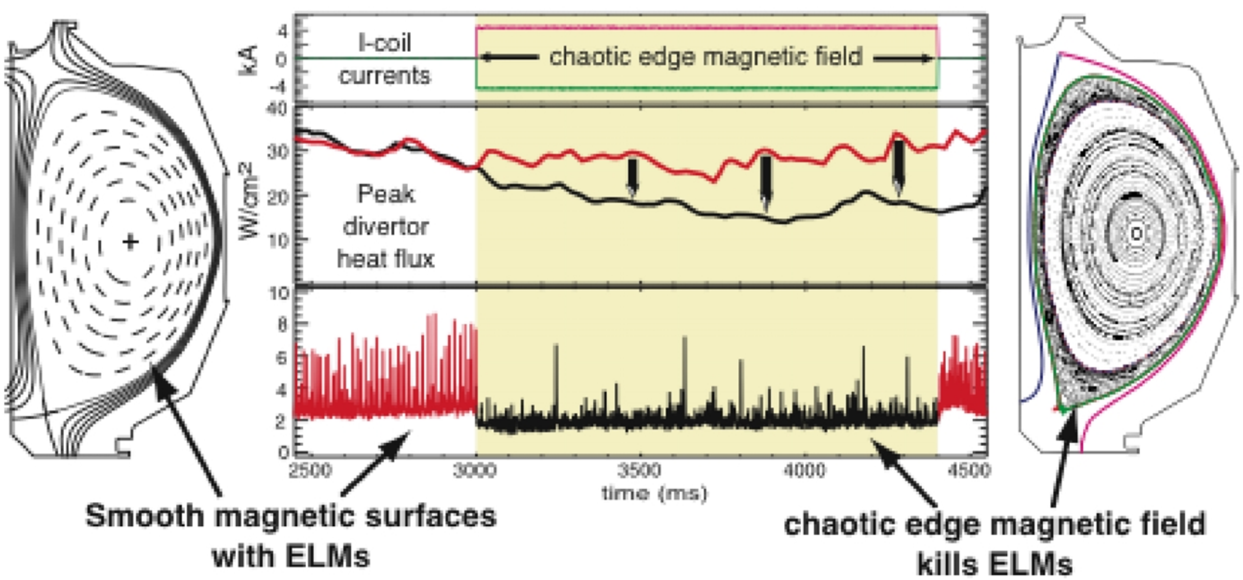
Chaotically or stochastically wandering field lines in the edge layer of a tokamak plasma can prevent deleterious edge instabilities.

An important issue for next step fusion devices is control of large instabilities triggered at the edge of the tokamak that are encountered as the energy content of the plasma increases. These plasma instabilities, known as Edge Localized Modes (ELMs), limit tokamak performance both directly, via large transient heat loads to the plasma chamber walls and indirectly, by limiting the edge parameters, which impact the plasma performance. Understanding the complex physics of ELMs has been a major fusion research challenge for many years.

Recently, a team of scientists from the DIII–D National Fusion Facility and several international fusion research laboratories investigated a novel approach to controlling ELMs by applying a small resonant magnetic field from special coils located inside the DIII–D vacuum vessel (T.E. Evans et al., "Stochastic Boundary Effects on the DIII–D Pedestal Region," to be published in Bull. Am. Phys. Soc., 2003.) This resonant field creates "chaotic" like magnetic fields in the plasma edge, where the ELMs occur. In normal operation, the magnetic lines of force which confine the plasma wind around the torus on smooth closed concentric surfaces as shown on the left below. When the internal coils are pulsed on, as shown in the shaded region below, the magnetic surfaces break up because the magnetic lines of force point in randomly varying directions as they wind around the torus, The spatially chaotic structure of the magnetic field can be visualized by in the contour type plots on the two sides of the time line plot. The smooth and separated contours on the left represent smooth surfaces. The contour plot on the right with the random points scattered around the edge (and at regions in the core) represent "chaotic" field lines. For the high performance DIII–D discharge shown here, large repetitive ELMs (the fast red spikes below) occur until the coils are pulsed on at 3000 ms. The resulting chaotic magnetic field, as shown on the right, reduces the frequency and amplitude of the ELM instabilities for the duration of the applied magnetic pulse (black trace below), and spreads out the energy flowing to the material surfaces, lowering the peak heat flux, as seen by comparing the red (ELMing) and black curves below. Assuming this approach can be extended to next step devices it holds the promise of increasing material lifetimes without degrading plasma performance.

Work supported by U.S. Department of Energy under Contract No. DE-AC03-99ER54463.

Contacts: T.E. Evans, General Atomics, (858) 455-4269, Todd.Evans@gat.com
T.S. Taylor, General Atomics, (858) 455-3559, Tony.Taylor@gat.com
Paul Thomas, CEA, France, paul.richard.thomas@cea.fr



An international team of top fusion scientists from the US, France, Germany, Japan and Australia assembled at the DIII–D facility in July to take on the take on the formidable task of controlling high heat flux impulses due to edge plasma instabilities known as Edge Localized Modes (ELMs).