Sept 2018

Steady as she goes:

Scientists tame damaging edge instabilities in steady-state conditions required in a fusion reactor

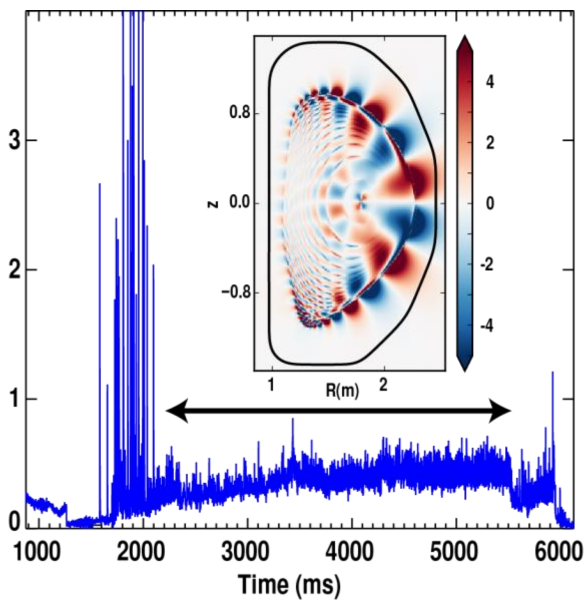

Image courtesy of Raffi Nazikian

Simulation of the edge distortion in blue and red induced by applying a 3D magnetic field to a high pressure plasma (a), the dramatic mitigating effect of the distortion on edge energy bursts called ELMs (b). Shown are the lead physicists R. Nazikian of the Princeton Plasma Physics Laboratory (left) and C.C. Petty of General Atomics in front of the DIII-D National Fusion Facility in San Diego.

The Science

Fusion reactors need to run in a steady state and must reduce or eliminate intense bursts of heat and particles called edge localized modes (ELMs) that collide with the walls of the reactor. Researchers on the DIII-D tokamak in San Diego have discovered that conditions required for steady-state operation are also highly beneficial for suppressing the ELMs. Applying 3D magnetic fields from coils placed outside the plasma produces ripples in the edge of the plasma that are particularly effective in reducing the magnitude of the ELMs. Making this effectiveness possible is high plasma pressure, produced by external heating, that enables the plasma to drive more of its own current in the plasma edge — an important factor required for achieving a steady-state fusion reactor. Higher pressure and current in the plasma edge produces more amplification of the external magnetic ripple. The higher the amplification the more effective is the applied magnetic ripple for suppressing the ELMs. Measurements on the DIII-D tokamak confirm both the strong amplification of the external 3D magnetic field and the weakening of the ELM bursts in these high edge pressure plasmas. Surprisingly, this method of ELM suppression is effective even at low levels of plasma rotation and for a wide range of plasma current suitable for steady-state reactors.

The Impact

The discovery of a synergy between high-pressure steady-state plasma conditions and the amplification of the 3D magnetic field for ELM suppression opens up new avenues for optimizing future tokamak experiments and steady-state tokamak reactors. Superconducting tokamaks in Asia, such as the KSTAR device in South Korea, will soon be exploring this synergy in joint experiments with DIII-D and PPPL researchers. Longer term, researchers are exploring new 3D magnetic coil designs that are better optimized for driving edge-distortion magnetic ripples in these high pressure plasmas. Further experiments will explore the underlying causes of ELM suppression, which will be essential for developing reliable extrapolations of these effects to reactor scale.

Summary

External 3D magnetic fields drive strong distortions in high-pressure plasmas that are beneficial for suppressing bursts of heat called ELMs. The same conditions of high edge pressure are also beneficial for driving plasma current that will allow tokamaks to run steady state. The beneficial effect of the edge distortions on ELMs is observed over a range of plasma conditions, including plasma current and rotation, relevant to future steady-state tokamak reactors. New experiments are being planned on DIII-D in San Diego and on the superconducting experiment KSTAR in South Korea to further explore and extend these results.

Contact

Raffi Nazikian
Princeton Plasma Physics Laboratory
rnazikia@pppl.gov

Funding

Supported by the U.S. Department of Energy (DOE), Office of Science, Office of Fusion Energy Sciences, using the DIII-D National Fusion Facility, a DOE Office of Science user facility under awards, DE-AC02-09CH11466 and DE-FC02-04ER54698.

Publications

R. Nazikian, C.C. Petty, *et al*, "**Grassy-ELM regime with edge resonant magnetic perturbations in fully noninductive plasmas in the DIII-D tokamak**" 2018 *Nucl. Fusion* **58** 106010

C.C. Petty, R. Nazikian, *et al*, "**Advances in the steady-state hybrid regime in DIII-D—a fully non-inductive, ELM-suppressed scenario for ITER**" 2017 *Nucl. Fusion* **57** 116057

Related Links

https://www.pppl.gov/news/2018/08/steady-she-goes-scientists-tame-damaging-plasma-instabilities-and-pave-way-efficient