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Small three-dimensional magnetic fields lead to big changes in fusion plasma turbulence

New insight into the interaction of magnetic field distortions and turbulence could lead to greater control in fusion devices

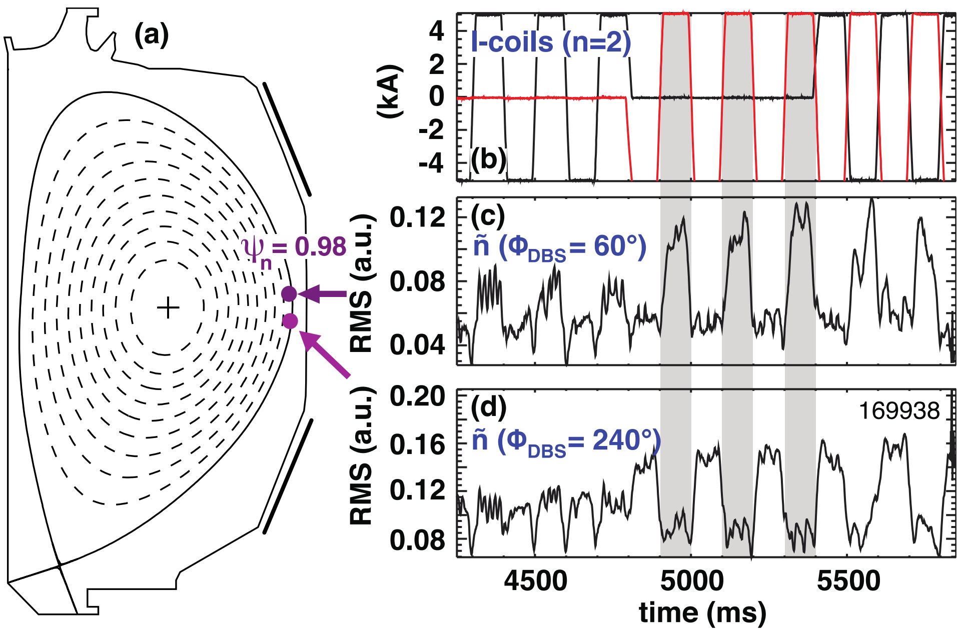

Image courtesy of Robert Wilcox

Measurements at the purple points are made on opposite sides of the tokamak, shown here in the cross section. The density fluctuations show the opposite relationship with respect to the applied 3D fields (top plot) at the two locations – one goes up while the other goes down.

The Science

Turbulence is a pervasive every day phenomenon and that can be observed in common situations like the roiling of boiling water, the curling of smoke from a candle or the wind buffeting our faces. Similar turbulence is present in high-temperature plasmas used for fusion energy research and is an important means by which a plasma loses its energy. Researchers are trying to expand our understanding of turbulence in an effort to control it in magnetic fusion plasmas, thereby leading to more efficient and sustainable plasmas. In recent experiments at the DIII-D National Fusion Facility in San Diego, scientists made a surprising discovery that small distortions to the large magnetic fields used to contain fusion plasmas produce surprisingly large changes in turbulence.

The Impact

These results provide deeper insight into the structure of outer layers of fusion plasmas as scientists seek to understand the turbulence well enough to predict its effect on the plasma and learn to control it. Theoretical modeling of these experiments indicates that these measured changes in turbulence are related to different responses of the ions and electrons as they move through the very slightly distorted magnetic field. Improved control of turbulence informed by these insights could lead to improved performance of plasmas that are being developed for fusion energy production.

Summary

The torus-shaped tokamak uses strong two-dimensional magnetic fields to hold the plasma in place for sustained periods of time. In such a magnetic field, the turbulence of the plasma is the same on one side of the tokamak as on the other. However, when scientists applied very small distortions to the magnetic field in the DIII-D tokamak, they discovered a very surprising behavior in the turbulence of the plasma density. Despite the fact that the distortion in the magnetic field was about 1 part in 10,000, the turbulence amplitude changed by about 50 percent. As shown in the figure, the density turbulence on opposite sides of the machine (separated by 180 degrees) showed different behavior. When the turbulent intensity at one measurement location increased, the intensity on the other side of the machine decreased. The researchers determined that the change in turbulence was due to a small change in the density from one side of the machine to another, yet another surprising result for such a small perturbation. Theoretical modeling indicates that these changes in density are related to different responses of the ions and electrons as they move through the very slightly distorted magnetic field. This deeper understanding of how the plasma responds to the magnetic fields may help researchers learn how to control the turbulence and improve plasma performance.

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doi: 10.1103/PhysRevLett.117.135001

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