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Turbulence "Hot Spots" Near Tokamak Plasma Boundary Produced by Small Applied Fields

New work explains the effects of small applied 3D magnetic fields on plasma density and turbulence that lead to particle and heat losses.

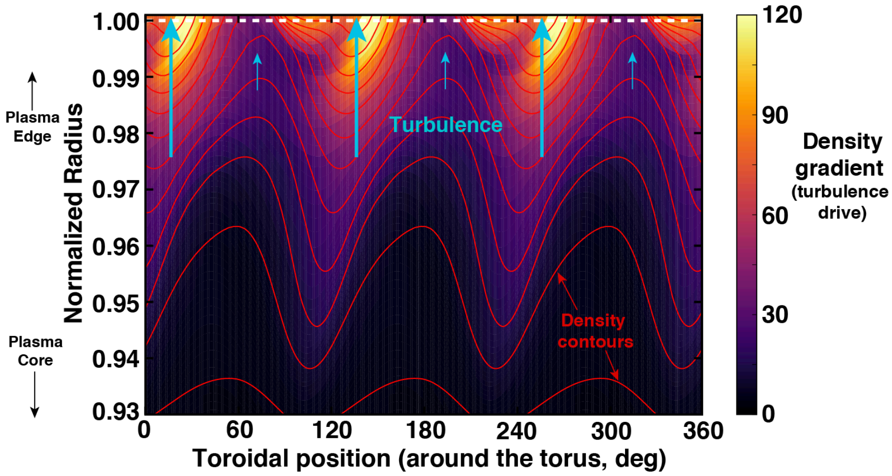

Image courtesy of R Wilcox

Simulated plasma density (red contours) and density gradients (colored shading) are shown near the edge of the DIII-D tokamak. Regions with increased local gradients also show an increase in measured fluctuation amplitudes.

The Science

When 3D magnetic fields are applied to suppress edge heat burst instabilities in a tokamak, the amplitude of edge turbulence is observed to vary with the toroidal angle. This variation of fluctuations is found to be due to changes in density gradients that arise due to the effects of the 3D fields on particle motion, as predicted by new simulation techniques.

The Impact

Understanding and extrapolating 3D effects in a tokamak plasma is critical to determine what impact they may have on heat fluxes to the material surfaces of any future reactor, such as potentially increasing peak heat loads at certain locations. The toroidally asymmetric gradients and fluctuations observed here may also be at least partially responsible for an unexplained particle loss phenomenon known as "density pump-out" where particles are lost from the plasma when 3D fields are applied.

Summary

Periodic edge heat burst instabilities can be suppressed in tokamaks by applying small 3D magnetic fields. The new insight reported here is that when these fields are applied, edge density gradients vary as one moves around the plasma torus. It is found that regions with increased normalized density gradients are correlated with increased measured density fluctuation amplitudes. These toroidally asymmetric fluctuations may cause an increase to the peak heat fluxes to the material surfaces, which are already difficult to handle. Rather than these gradient changes being caused by the simple displacement of magnetic flux surfaces, equilibrium modeling using the M3D-C1 code shows that the density actually changes locally *within the flux surfaces* due to the interaction of the 3D fields with particle trajectories. Good qualitative agreement between pedestal measurements and the equilibrium modeling at different toroidal phases provides a basis for confident extrapolation of the physics model to future experiments, although improved measurements and modeling are required to get a fully quantitative match to theory. The effects may also be partially responsible for a poorly understood phenomenon known as "density pump-out". Overall, these results provide a much stronger foundation for prediction of how to optimize the use of 3D fields to regulate instabilities in fusion plasmas.

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Publications

R.S. Wilcox et al., "Evidence of Toroidally Localized Turbulence with Applied 3D Fields in the DIII-D Tokamak." Phys. Rev. Lett. **117**, 135001 (2016). DOI: 10.1103/PhysRevLett.117.135001

R.S. Wilcox et al., "Modeling of 3D magnetic equilibrium effects on edge turbulence stability during RMP ELM suppression in tokamaks." Submitted to Nuclear Fusion.

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