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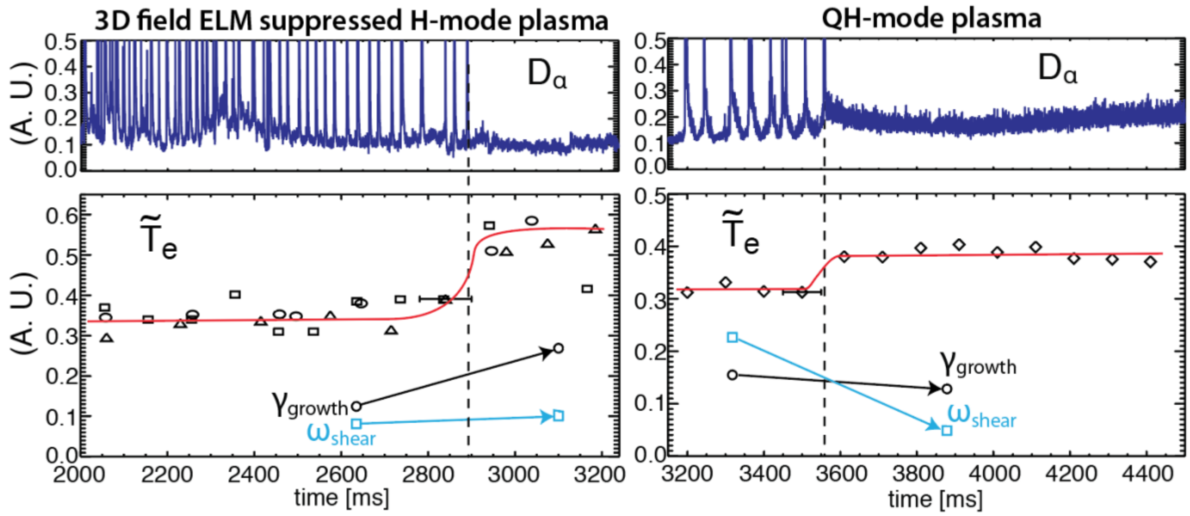
Physics of increased Electron Turbulence at the Edge of Non-ELMing High-Performance Plasmas on DIII-D

Identifying relevant physics of increased turbulence during high-performance plasmas will form a basis for developing predictive capability for these plasmas in the future.



The upper left panel shows D_α radiation, light from deuterium atoms, where the spikes indicate edge localized mode bursts (ELMs). The lower left panel shows that edge electron temperature turbulence increases when 3D magnetic fields suppress ELMs (at 2800 ms) in a high-performance (H-mode) plasma. The right figure shows the D_α radiation and edge electron temperature turbulence in an ELM-free Quiescent H-mode (QH-mode) plasma, indicating that turbulence increases when the ELMs are suppressed (at 3600 ms). In both figures, the general trend of the linear growth rate of turbulence (γ_{growth}), increasing turbulence, and velocity shear (ω_{shear}), suppressing turbulence, is observed.

The Science

Turbulence is one of the main transport mechanisms in magnetic fusion plasmas, and its destabilizing mechanisms should be understood to predict and improve future fusion plasma performance. This study shows that the changes in turbulence in high-performance plasmas can be explained by changes in the turbulence drive process (profile gradients) and in the turbulence suppression mechanism (velocity shear) in two distinct high-confinement regimes.

The Impact

The changes in turbulence in high-performance plasmas observed in this study provide direct insight into how turbulence controls edge transport in high-performance fusion plasmas without edge localized modes (ELMs), which are instabilities at the plasma edge. Measuring the properties of the turbulence will improve physics understanding of high-performance plasmas free of ELMs, potentially leading to full predictive capability of reliable high-performance tokamak reactors.

Summary

This study reports the increased edge turbulence of electron temperature and density ($\tilde{T}_e$ and $\tilde{n}_e$), accompanying ELM-free/suppressed high-confinement mode (H-mode) operation compared to the ELMing H-mode. ELMs can damage plasma-facing components in future fusion devices due to their large energy bursts. Therefore, non-ELMing H-mode operation is desirable in the future.

The correlation between the increased turbulence and non-ELMing state provides a direct insight into how turbulence controls edge transport during non-ELMing H-mode operation. Simulation results generally reproduce the increased turbulence near the plasma edge during non-ELMing phase in two distinct non-ELMing H-mode regimes, Quiescent H-mode (QH-mode) and 3D field ELM suppressed H-mode. This analysis result also provides physics insight into the mechanisms responsible for the increased turbulence in each non-ELMing H-mode regime. The physical mechanisms identified as responsible for the increased turbulence are different for the two non-ELMing regimes, although the turbulence response is similar. In the 3D field ELM-suppressed plasma, analysis suggests that turbulence is increased due to the increased driving gradients, increasing the growth rate of the instability. In contrast, driving gradients are decreased in the QH-mode. However, a further decrease in the measured velocity shearing rate reduces the ability of slow shear to suppress turbulence in the QH-mode. This finding provides a physical explanation of the increased turbulence during non-ELMing H-mode operation and enables validation of models near the plasma edge, an important region that is not well understood. These are exciting results improving the physics understanding of non-ELMing H-mode operation, potentially leading to full predictive capability.

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Publications

C. Sung, et al., "Increased electron temperature turbulence during suppression of edge localized mode by resonant magnetic perturbations in the DIII-D tokamak", Physics of Plasmas, 24, 112305 (2017); 10.1063/1.4999785

C. Sung, et al., "Physics of increased edge electron temperature and density turbulence during ELM-free QH-mode operation on DIII-D" submitted to Physics of Plasmas

Related Links

DIII-D user facility: https://diii-d.gat.com/diii-d/Home