Observations of sheared turbulence in the H-mode E_r well by phase contrast imaging on DIII–D*

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Phase Contrast Imaging (PCI) has been used on DIII–D to measure turbulent density fluctuations in several H-mode regimes, observing highly sheared turbulence in the E_r well. Two sources are identified: instabilities in the pedestal that extend into the E_r well and instabilities located in the well itself. PCI has a high bandwidth 10 kHz $< f <$ 2 MHz and wavenumber-resolved measurements over $1 < k < 25$ cm^{-1}, with a beam geometry that results in enhanced sensitivity to turbulence distorted by velocity shear. The sheared edge turbulence resolves into two frequency ranges with well-defined lab-frame phase velocities.

Studies of the medium frequency $f <$ 800 kHz turbulence in the Quiescent H-mode regime (QH-mode) scanned the plasma edge through the PCI beam, allowing the radial structure of the sheared edge turbulence to be reconstructed, revealing turbulence with $k_r < 0$ on the inner half of the E_r well and with $k_r > 0$ on the outer half. Varying the injected torque in QH-mode plasmas shows that the lab-frame phase velocity of this turbulence varied directly with the $\mathbf{E}\times\mathbf{B}$ velocity at the top of the pedestal. In combination, these observations suggest that an instability located at the top of the pedestal extends into the E_r well, where the shear distorts the turbulence.

The high frequency, high phase velocity turbulence is, in contrast, observed to change on sub-ms time scales with changes in the E_r well, forming within 100 μs of the L-H transition, and appearing and vanishing as the E_r well collapses and reforms during Limit-Cycle Oscillations (LCO) and at an ELM. The lab-frame phase velocity is seen to vary with $V_{\mathbf{E}\times\mathbf{B}}$ at the center of the well. The instability is sensitive to the shape of the E_r well, being absent in the very narrow well seen in QH-mode but often present in the wider well seen in ELM-free H-mode and wide-pedestal QH-mode.

The research presented here characterizes highly-sheared density turbulence in the pedestal and E_r well of non-ELMing H-mode regimes with the ultimate goal of understanding the role of turbulence in determining the structure in these regimes.

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