Experimental Study of Density Gradient Stabilization Effects on High-k Turbulence

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Theory and experiments have shown that electron temperature gradient (ETG) turbulence on the electron gyro-scale, $k_\perp \rho_e \leq 1$, can be responsible for anomalous electron thermal transport in typical NSTX H-mode plasmas. Electron scale (high-k) turbulence is studied in NSTX using a high-k microwave scattering system [Smith RSI. 2008]. We report on the stabilization effects of the electron density gradient on electron-scale density fluctuations in a set of neutral beam injection (NBI) heated H-mode plasmas. Density gradient was previously identified as a stabilizing mechanism of ETG turbulence in [Ren PRL. 2011]. The absence of experimental high-k density fluctuations is correlated with large equilibrium density gradient, consistent with linear stabilization of ETG modes by using the analytical ETG linear threshold [Jenko PoP. 2001]. The scattered power from electron-scale turbulence is anti-correlated with the equilibrium density gradient, suggesting density gradient as a nonlinear stabilizing mechanism of high-k turbulence. Larger equilibrium density gradient leads to higher values of the wavenumber corresponding to the maximum in the fluctuation spectrum and to a lower value of the plasma frame frequency of detected density fluctuations. Linear gyrokinetic simulations using GS2 show a clear correlation between the wavenumber value at the maximum linear growth rate and the local value of the electron density gradient. Higher values of the electron density gradient are also shown to reduce the value of the real frequency of instability from GS2. Nonlinear electron-scale gyrokinetic simulations show that high electron density gradient reduces electron heat flux and stiffness, and increases the ETG nonlinear threshold, reaffirming a nonlinear change in ETG turbulence and fluctuation spectrum from large equilibrium density gradient as predicted from previous ETG nonlinear simulations [Ren PoP. 2012, Guttenfelder NF. 2013].