Reduced electron thermal transport in low collisionality H-mode plasmas in DIII-D and the importance of TEM/ETG-scale turbulence

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Abstract. The first systematic investigation of core electron thermal transport and the role of local ion temperature gradient/trapped electron mode/electron temperature gradient (ITG/TEM/ETG)-scale core turbulence is performed in high temperature, low collisionality H-mode plasmas in the DIII-D tokamak. Wavenumber spectra of L-mode and H-mode density turbulence are measured by Doppler backscattering. H-mode wavenumber spectra are directly contrasted for the first time with nonlinear gyrokinetic simulation results. Core ITG/TEM-scale turbulence is substantially reduced/suppressed by $\boldsymbol{E}\times\boldsymbol{B}$ shear promptly after the L-H transition, resulting in reduced electron thermal transport across the entire minor radius. For small $k_\theta \rho_s$, both experiment and nonlinear gyrokinetic simulations using the GYRO code show density fluctuation levels increasing with $k_\theta \rho_s$ in H-mode (r/a=0.6), in contrast to ITG/TEM-dominated L-mode plasmas. GYRO simulations also indicate that a significant portion of the remaining H-mode electron heat flux results directly from residual intermediate/short-scale TEM/ETG turbulence. Electron transport at substantially increased electron to ion temperature ratio ($T_e/T_i \geq 1$, $r/a \leq 0.35$) has been investigated in ECH-assisted, quiescent H-mode plasmas. A synergistic increase in core electron and ion thermal diffusivity (normalized to the gyroBohm diffusivity) is found with applied ECH. From linear stability analysis, the TEM mode is expected to become the dominant linear instability with ECH due to increased electron-to-ion temperature ratio and a reduction in the ion temperature gradient. This is consistent with increased electron temperature fluctuations and core electron thermal diffusivity observed experimentally. The reduced ion temperature gradient likely results from a reduction of the ITG critical gradient due to increased T_e/T_i and reduced $\boldsymbol{E}\times\boldsymbol{B}$ shear. These studies are performed at ITER-relevant collisonality ($\nu_e^* \sim 0.05$, $r/a \leq 0.6$) and address transport in electron heat-dominated regimes, thought to be important in ITER due to α-particle heating.

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