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Impurity-Induced Core Turbulence Suppression and Reduced Transport in the DIII-D Tokamak[1]

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Long wavelength turbulence and ion heat transport are significantly reduced on the DIII–D tokamak as a result of neon-seeding of an L–mode Negative Central Shear discharge. Correspondingly, particle and energy confinement are increased. Fully saturated turbulence measurements near $\rho = 0.7$ in the wavenumber range $0.1 \leq k_\perp \rho_s \leq 0.6 (0.5 < k_\perp < 2.5\ \mathrm{cm}^{-1})$, obtained with Beam Emission Spectroscopy, exhibit nearly an order of magnitude suppression of total fluctuation power after neon injection. Fluctuation measurements obtained with Far Infrared scattering also show a reduction of turbulence in the core, while the Langmuir probe array measures reduced particle flux in the edge and scrape-off-layer. Gyrokinetic linear stability simulations of these plasmas are qualitatively consistent, showing a reduction in the growth rate of ion temperature gradient driven modes for $0 < k_\perp < 5\ \mathrm{cm}^{-1}$ as a result of impurity density gradient effects on the main fuel ion turbulence. The measured $\omega_{E\times B}$ shearing rate increased with neon at the BES observation radius, suggesting that impurity-induced reduction of growth rates is acting synergistically with $\omega_{E\times B}$ shear to decrease turbulence and reduce anomalous transport. Confinement time is nearly doubled in discharges with a neon puff, compared to similar reference discharges without any injected neon. Ion heat diffusivity is reduced to near neoclassical levels over much of the profile while the region of improved confinement expands radially well into a region of positive magnetic shear. Both ion and electron temperatures exhibit a broadened profile and higher peak temperatures. Effects of varying both the quantity and atomic number of the injected impurity on turbulence and resulting confinement are assessed. These results suggest an operational regime that achieves improved confinement while simultaneously maintaining a highly radiative L–mode edge.

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