Evolution of micro turbulence wave number spectra and anomalous electron transport in dynamic experiments at FT-2 tokamak

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Fine scale drift wave turbulence excited due to the TEM and ETG mode instability is discussed nowadays as a possible candidate for explanation of the anomalous electron energy transport in tokamak plasmas, in particular in transport barriers. In spite of this the experimental information related to these modes till recently was not detailed, limited to frequency spectra measured by different modifications of the microwave reflectometry for TEM mode and missing for the ETG mode. At present new experimental techniques based on the microwave backscattering effect are being developed to fill in the gap at several tokamaks and first results confirming existence of the ETG mode scale turbulent fluctuations sensitive to electron temperature gradient have been obtained at FT-2 and DIII-D tokamaks. In particular, excitation of two (low and high frequency) modes possessing a factor of 2 different phase velocities was demonstrated in ohmic discharges at FT-2 under conditions when the ETG mode is unstable.

In the present paper we report results of systematic investigations of these small-scale turbulent low (LF) and high (HF) frequency modes performed in dynamic (fast (20 MA/s) current ramp up from 22 kA to 32 kA and lower hybrid (LH) heating) experiments at FT-2 tokamak (R = 55 cm; a = 7.9 cm; B_t = 2.2 T). Both frequency and wave number spectra (q-spectra) are measured with correlative enhanced scattering (CES) diagnostics utilizing X-mode probing from high field side performed out off equatorial plain simultaneously at different frequencies (f_i = 54-65 GHz) and measuring back scattering off density fluctuations with radial wave numbers $q_r > 4\pi f_i/c$ occurring in the very vicinity of the UHR. The turbulence q-spectra are reconstructed for $8 > q_r \rho_i > 0.8$ at a distance 1-3 cm from the limiter. It is found that all during the dynamic current ramp up discharge the LF component identified with the dissipative TEM mode possesses a wide q-spectrum which could be described by universal exponential dependence $|n|^2_{q_r} \sim |n|^2_0 \exp\{-q_r L\}$ in the range of 3-4 orders of amplitude, where $|n|^2_0$ is related to the turbulence level and $L \sim (1\text{-}2)\rho_i$ is a typical turbulence scale length. In agreement with theoretical predictions both parameters are found to decrease substantially after the current ramp up when the shear of the poloidal plasma rotation estimated from the Doppler frequency shift of the ES signal increases at plasma periphery. Simultaneously transition to the improved confinement resulting in suppression of anomalous electron transport is observed in the experiment.

The wave number spectrum of the HF turbulence component, identified as the ETG mode, looks very different from exponential. It is characterised by pronounced maximum at $q_r \rho_s \approx 9$ corresponding to the largest ETG instability growth rate. Behavior of HF ES component in the dynamic LH heating experiment, unlike the LF component, is correlated not with the electron thermal conductivity, but with the ratio of electron temperature and density scale lengths which is natural near the ETG mode threshold given, according to theoretical analysis, by condition $L_{n_e}/L_{T_e} > 0.8$.

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