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Observation of central high-k turbulence modulated by m/n=2/1 islands in HL-2A core plasmas

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High-k turbulence driven by the electron temperature gradient (ETG) mode is considered as one major candidate causing anomalous electron thermal transport in fusion plasmas[1]. And it can be coupled with larger scale turbulences, e.g. ion temperature gradient (ITG) and trapped electron mode (TEM). The plasma confinement can be affected by their mutual interactions. In addition to microturbulence, magnetohydrodynamic (MHD) modes, e.g. tearing modes (TM), are common in toroidal confinement devices, and they can significantly affect plasma stability and confinement. For example, by forming magnetic island, TM can have significant effects on the plasma equilibrium profiles, which could affect turbulences. A full understanding of the interaction microturbulence and MHD modes is crucial to control plasma stability and to predict performance of future fusion devices, given the common co-existence of the two in fusion plasmas influencing the plasma stability and transport. Numerical studies of the interaction are difficult if not impossible due to the vast spatial and temporal scale separation between microturbulence and MHD modes. On the other hand, experimental studies have proven fruitful on several major fusion devices[2,3].

In this study, the high-k turbulent density fluctuations ($\tilde{n}_{high-k}$) in the plasma core periodically modulated by the rotating m/n = 2/1 tearing mode islands is firstly observed by using laser collective scattering on HL-2A tokamak, which provides a direct measurement of the high-k fluctuation. It is observed that the small-scale turbulence, though quite far from the island region, can be significantly affected by the large magnetic island through altering the electron temperature profile and its gradient (q = 2 surface is at $\rho = -0.69$; while the measured turbulence is at $\rho \approx -0.28$).

The T_e at different locations on HFS is shown in Figure 1(a). The tangential laser collective scattering locally measures the high-k turbulence, and finds that the fluctuations are only enhanced at the O-point moments with a short-duration time (shown in Figure 1(a) and (b)). steep temperature gradient in the central region leads to the burst of high-k fluctuation periodically as island rotates. The T_e profile across the O-point of magnetic island can be deemed there is a quasi-ITB for electron[4], and at those moments, we found the long-range radial correlations in cross-correlation function (CCF) of $\tilde{T}_e$ between ECE channels. This is similar to that in non-local transient transport phenomena[5]. Moreover, a critical electron temperature gradient is found for the appearance of the short-duration enhanced $\tilde{n}_{high-k}$. Gyrokinetic simulations show that electron temperature gradient (ETG) mode is more unstable during the $\tilde{n}_{high-k}$ bursts.

This work illustrates that the macro-scale MHD activity can interact with the high-k turbulence in the core plasma. And the observed phenomenon is beneficial for understanding the formation of e-ITB and the electron transport in fusion plasmas.

References

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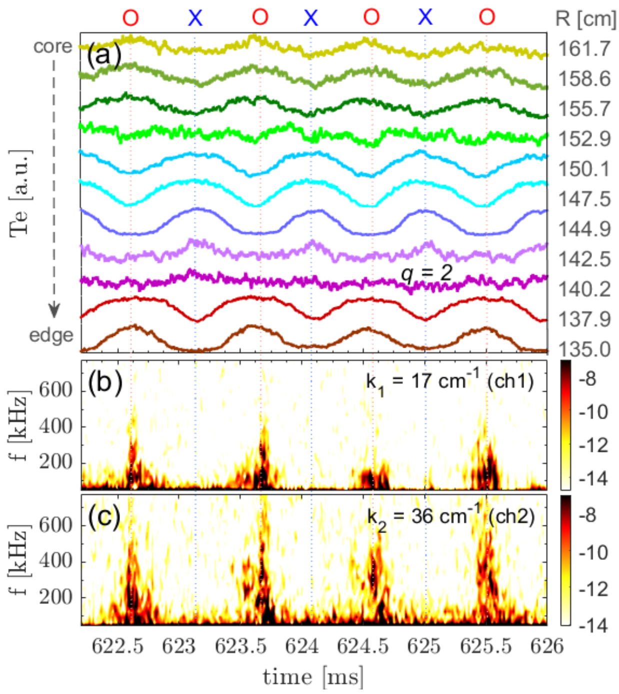

Figure 1. (a) T_e evolution at different measured channels in ECE; (b)the spectrogram of k = 17 cm^{-1} turbulence; (c) the spectrogram of k = 36 cm^{-1} turbulence. The O-/X-point passing-by moments of the islands are marked with vertical red/blue dashed line. The location of the measured turbulence is at R = 155 cm, which is far from the q = 2 surface (R = 140 cm).