§4. Radial Correlation Structure of Fluctuation in Electron ITB Plasmas of LHD

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The internal transport barrier (ITB), a steep temperature gradient that is observed in the plasma interior, has been formed in LHD. The ITB has the potential to enhance operating performance in burning plasmas such as ITER, and thus the phenomenological understanding of ITB is progressed. Dynamic transport experiments indicate the negative temperature dependence of the heat diffusivity inside the ITB$^{1)}$. A spontaneous change of the second derivative of the temperature profile inside the ITB (the curvature transition) is observed in the LHD$^{2)}$. More in-depth knowledge, however, is required to control stationary burning in nuclear fusion reactor by ITBs. The crucial rule of meso-/macro-scale fluctuations in determining the turbulent level has been recognized$^{3)}$. Identification of such fluctuations and their impacts on the confinement is urgent issue to be clarified.

Typical time evolution and radial profile of electron temperature, T_e, in an ITB plasma of LHD (major radius of 3.5m, averaged minor radius of 0.6m, magnetic field of 2.83T and line averaged density of $5\text{x}10^{18}$ m^{-3}) are shown in Fig. 1. A concave curvature appears at 1.8s and changes abruptly to weak curvature at 1.9s, where ρ is the normalized radius. The transition from a convex to a concave profile is observed during ITB formation triggered by an edge perturbation$^{4)}$.

A conventional heterodyne radiometer is used to track the time evolution of the electron temperature. Due to the thermal noise, it is difficult to detect micro-turbulence by simply using the ECE diagnostics. A correlation technique and narrow-band filters (~100MHz) are required to observe fluctuations with short radial correlation length. Recently, mutual coupling between meso-scale fluctuations (e.g. zonal flows) and micro-turbulence has been examined as a course of formation of the turbulence structure. Thus the structure of meso-scale fluctuations contain some information about the micro-turbulence. The meso- and macro-scale structure can be detected by a conventional radiometer (filter band width ~500MHz) by using of a correlation technique.

To detect fluctuation components with meso-scale radial correlation length, the squared coherence between T_e at 29 radial positions and a reference one is estimated. Figure 2 shows contour maps of the squared cross coherence as a function of frequency, f, and ρ, here the reference position is selected as the ITB foot. A low but finite frequency (6kHz) component appears in the ITB plasma. The strong radial correlation is observed inside the ITB region only. The cross-correlation between ECE and the envelope of the reflectometry signal clarifies the fact that the long distance structure detected by ECE modulates the micro-turbulence in low-density LHD plasmas$^{5)}$. Thus, the meso- and macro-scale fluctuation structures are considered to be correlated with the radial heat transport. The dynamic behavior of the meso-scale fluctuation will clarify the causal relationship between the turbulence and the formation of the ITB.

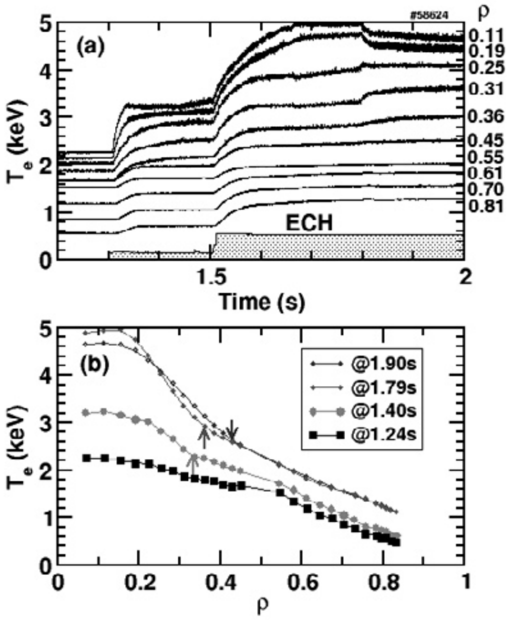

Fig.1 (a) Typical time evolution of T_e at different radii and (b) radial profile of T_e at t=1.24s (no ITB), 1.4s (weak ITB), 1.79s (concave ITB) and 1.9s (weak curvature ITB). Arrows denote the ITB foots.

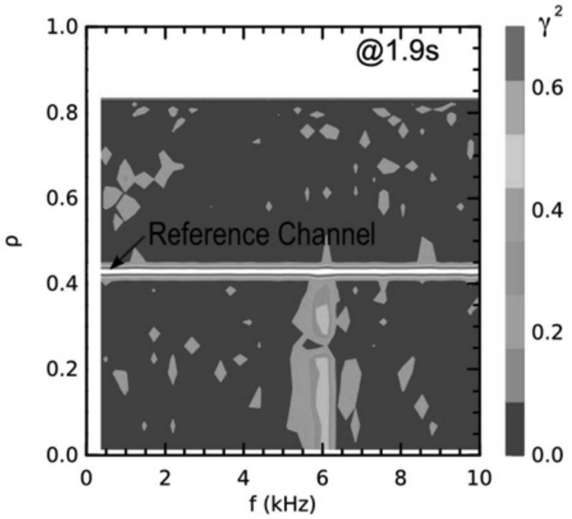

Fig.2 Contour map of the squared coherence between 29 channels and a reference one at 1.9s. The sampling time is 4 μs and the time window for FFT is 8ms. The 30 ensembles are averaged.

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[5] Inagaki, S. et al., PFR **3** S1006 (2008)