§33. Two-dimensional Density Fluctuation Measurement using Beam Emission Spectroscopy in Heliotron J

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In order to understand the anomalous transport induced by fluctuations (MHD/turbulence) in high temperature plasmas, it is important to clarify the spatial and phase structure of the fluctuations experimentally. Beam emission spectroscopy (BES) is a method to measure the density fluctuation at a local region at which the sightline intersects the path of neutral beam (NB). We have installed the BES system into Heliotron J[1]. This system has 16 viewing chords in the radial direction and has been widely used to measure the spaciotemporal structure of the density fluctuation[2,3]. This report describe the characteristics of the density flucutation obtained before the H-mode transition in high density NBI plasmas of Heliotron J[4].

Figure 1 shows the comparison of the time evolution of the plasma parameters between with and without H-mode transition. In the case when the H-mode transition occurred, a high intensity gas puffing (HIGP) was applied from t = 211 ms to 226 ms. In this case, a slightly decrease in W_{DIA} just after HIGP turn-off was observed, which was followed by a recovery of W_{DIA} from t = 233 ms. The recovery phenomenon is similar to that of the reheat mode. The repetitious fluctuation with the frequency of f = 5-30 kHz appeared after HIGP turn-on (t = 216 ms), which has toroidal mode number of n = 2 by the Mirnov coil array. The mode has a burst frequency of f = 0.8-3 kHz. With drop of $I_{H\alpha/D\alpha}$ at t = 240 ms, the density fluctuation of n = 2 mode disappeared and $\bar{n}_e^{FIR}$ started to increase again in spite of no additional fueling. As shown in Fig. 2, from the band-pass filtered BES signal, the density fluctuation with the burst frequency f = 0.8-3 kHz propagates in the outward direction. This propagation is also synchronized with $I_{H\alpha/D\alpha}$. The density fluctuation of the n = 2 mode, on the other hand, is localized at r/a = 0.9. These observations indicate that the burst of the n = 2 mode causes particle exhaust phenomena. When the amount of HIGP was not enough to trigger the transition, an n = 1 mode with frequency of f = 3 kHz was seen until HIGP turn-off. The particle exhaust by the n = 1 mode is not observed because of the weak response to $I_{H\alpha/D\alpha}$.

Just before the disappearance of the n = 2 mode, $\Delta I_{BE}/\Delta r$ shown in Fig. 2, corresponding to the density gradient at a local position, increases from t = 240 ms, which suggests an evolution of the density gradient at the peripheral region. At the same timing, the particle exhaust becomes small. The repetition of the increase/decrease of $\Delta I_{BE}/\Delta r$ is similar to "dithering" phenomena in L-H transition. After the disappearance of the n = 2 mode, a steep density gradient in the peripheral region (r/a = 0.8-1) was observed at the timing of the maximum W_{DIA} (t = 245 ms).

In summary, by the particle fueling scenario using HIGP, the H-mode plasmas are produced along with the formation of the steep density gradient at the peripheral region. The detailed analysis of the spatiotemporal structure of the edge density fluctuation reveals the relation between the particle exhaust induced by the n = 2 mode and the growth of the peripheral density gradient at the timing of the H-mode transition.

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2) S, Yamamoto, K. Nagasaki, et al., Proc. 25th IAEA FEC (2014), CN221, EX/P4-27.
3) S. Ohshima, et al., Nuclear Fusion **56** 016009 (2016).
4) S. Kobayashi, S. Ohshima, K. Ida, et al., 15th H-Mode WS, 2015/Oct/19-21, IPP Garching, (2015) Topic5:M5.

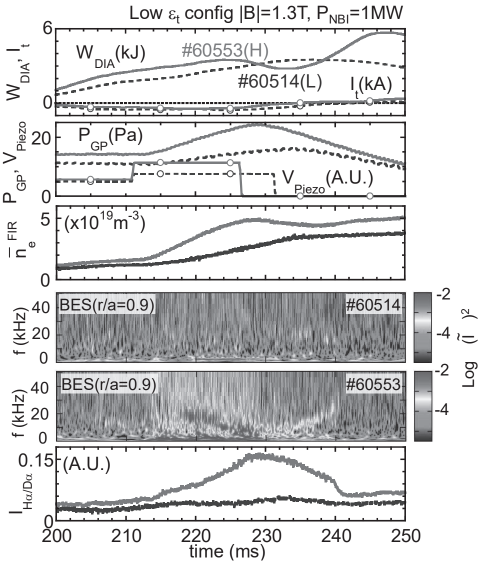

Fig. 1. Time evolution of plasma parameters obtained in H-mode transition (#60553) and no-transition (#60514) plasmas. H-mode transition occurred at t = 240ms for #60553 with change in the decreasing rate of $I_{H\alpha/D\alpha}$.

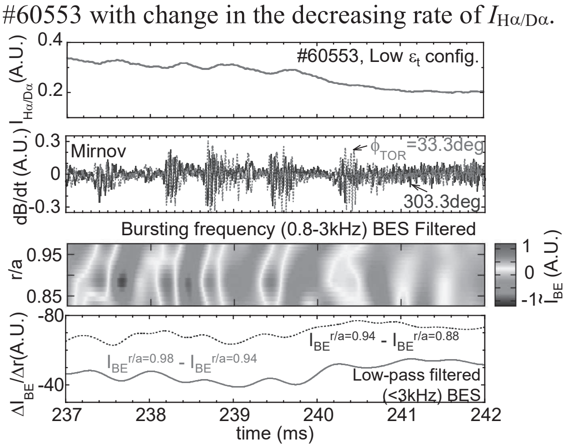

Fig. 2. Time evolution of $I_{H\alpha/D\alpha}$, two Mirnov coil signals, band-pass filtered density fluctuation for the burst frequency and difference of low-pass filtered (<3kHz) BES intensity between radially adjacent sightlines ΔI_{BE} normalized by its distance Δr.