§32. 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 where the neutral beam injection (NBI) and the sightline intersect. 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 radial profile of the density fluctuation in the whole ($0 < r/a < 1$) plasma region [2,3]. In this FY, we have tried to calculate the frequency-wavenumber vector using using 16 × 2 (radial × poloidal) sightlines [4].

The experiments were carried out in ECH + NBI (co injection, P_{NBI}=0.3MW) plasmas at the density of $\bar{n}_e$ = $0.9\times10^{19}\mathrm{m}^{-3}$. In the discharge, a core localized mode with the mode frequency around 20kHz were observed. As compared with the noise level, the density fluctuation has a peak around r/a=0.15 (see Fig. 1). The coherece of the density fluctuation to the magnetic probe signal is 0.6.

In order to investigate the propagation of the density fluctuation both in radial and poloidal direction, we applied frequency-wavenumber analysis. The frequency-wavenumber spectrum $S(f,k)$ between two adjucent viewing chords (a and b) is determied as,

$$S_{ab}(f,k) = \frac{1}{M}\sum_{j=1}^{M} I_{\Delta k}\left[k - k^j(f)\right] \times \frac{\left|S_a^j(f) + S_b^j(f)\right|}{2}, \qquad (1)$$

where $S(f)$ and M are the fluctuation intensity and the number of ensembles, respectively. Figure 2(a) and (b) show the frequency-wavenumber spectra for the low frequency desity fluctuation between the poloidally and the radially adjacent sightlines, respectively. For the low frequency (~20kHz) mode, the poloidal wavenumber is in the range of 0.3-0.5 cm^{-1}, propagating in the ion diamagnetic directions. The radial wavenumber has a peak at 0.7 cm^{-1} in the outward direction. These results suggest the mode is considered to be a fast-ion-induced MHD instability.

Figure 3(a) and 3(b) shows the radial profile of the wavenumber in poloidal and radial directions, respectively. We have obtained a consistency in the poloidal wavenumber profile between the experimental observation and the assumption that the poloidal mode number m is 1 or 2. As shown in Fig. 3(c), the gap of the phase difference between r/a=0.15 and 0.4 is around π, representing the radial mode structure. In this case, the analysis of the poloidal mode number using the magnetic probe array was difficult because of its weak signal-to-noise ratio. The BES diagnostic developed in this study has a capability to clarify the mode structure in the core region even in the case that the mode identification by magnetic probe array is difficult. In order to understand the mode structure in detail, we are calculating the spatial and temporal evolution of the beam emission including the beam attenuation and sightline integration effects.

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2) S, Yamamoto, K. Nagasaki, et al., Proc. 25th IAEA Fusion Energy Conference (2014), CN221, EX/P4-27.
3) S. Ohshima, S. Kobayashi, et al., Proc. 25th IAEA Fusion Energy Conference (2014), CN221, EX/P4-26.
4) M. Kirimoto, S. Kobayashi, K. Ida, et al., Plasma Conference 2014, 2014/Nov./18-21, Niigata, 19PA-037.

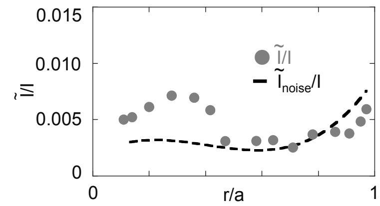

Fig. 1. Radial profile of density fluctuation intensity having the mode frequency of 15-20kHz observed in ECH + NBI plasmas. The dashed line shows the corresponding noise level of BES signal.

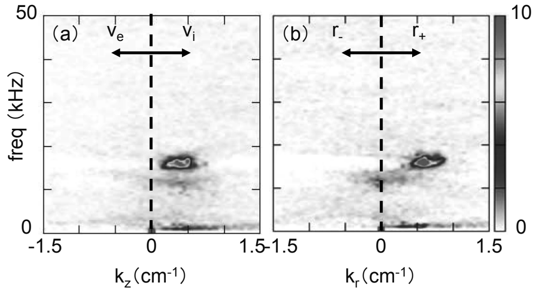

Fig. 2. Frequency-wavenumber spectra $S(f,k)$ for the density fluctuation at r/a=0.3 between (a) poloidally adjacent sightlines and (b) radially them.

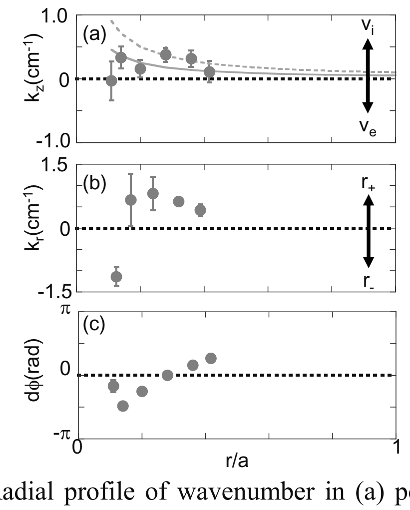

Fig. 3. Radial profile of wavenumber in (a) poloidal and (b) radial direction for the low frequency fluctuation and (c) radial profile of the phase difference.