§29. Radial Profile of Density Fluctuation Measurement Using Beam Emission Spectroscopy in Heliotron J

Kado, S., Iida, Y., Abe, S. (Univ. Tokyo), Kobayashi, S., Kagawa, T., Ohshima, S., Mizuuchi, T., Okada, H., Minami, T., Murakami, S., Lee, H.Y. (Kyoto Univ.), Oishi, T., Ida, K., Okamura, S.

Plasma turbulence has long been an important subject in the confinement of particle, momentum and energy in magnetically confinement fusion plasmas. The technique of beam emission spectroscopy (BES) has been developed to evaluate the radial and/or the poloidal structure of the density fluctuation and the wavenumber. In this study, we describe the recent development in the radial profile measurement of the density fluctuation by BES in Heliotron J.

Figure 1 shows the schematic view of the BES system in Heliotron J. The counter (BL1) neutral beam is imaged onto a twenty-channel fiber bundle using a vacuum compatible mirror and a set of lens mounted in the newly-installed viewing port. Because the heating neutral beam is used as diagnostic one and the Heliotron J magnetic configuration has complicated 3-dimensional shape, the numerical calculation was carried out to determine the optimized sightlines [1]. Briefly, when the sightlines are almost aligned to a magnetic field line in the beam intersection region, the spatial resolution can be minimized. A good spatial resolution ($\Delta r/a \sim \pm 0.07$) is achieved from the plasma core to the edge region ($0.1 < r/a < 1$). The measurable wavenumber range $k_N\,\rho_i$ is estimated to be smaller than 0.7 in the case that the ion Lamor radius ρ_i is 0.2 cm in the standard parameter of Heliotron J plasmas. In order to obtain significant signal-to-noise ratio, the detector apparatus is modified: It consists of a set of relay lenses, an interference filter and an avalanche photodiode (APD). The center wavelength (656.1-656.2nm) and the passband (1-2nm) of the interference filter, mounted between the relay lenses, are selected to admit the full and half components of the Doppler shifted beam emission. To reduce the losses by the lens aberration and transmission, the filtered beam emission is directory focused on the active photosensitive area of APD whose diameter is ϕ3. The cutoff frequency of pre-amplifier of APD is set to be 200 kHz.

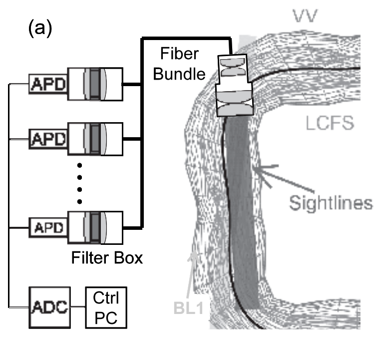

Fig. 1. Schematic view of the BES viewing sightlines and NBI(BL1) in Heliotron J.

The beam emission was measured in the NBI heated plasmas, in which fast-ion-driven MHD instabilities were observed. We obtained an intense beam emission more than 50 times higher than that of the previous prototype BES system. Power spectra of the beam emission fluctuations are shown in Fig. 2 (a). Compared with the dark current spectrum, prominent signal level was obtained. Note that relatively strong peaks at f = 15 and 50 kHz, being due to the noise from the pre-amplifier, should be eliminated in the analysis. Three intense modes (denoted A, B and C) were observed clearly in the frequency range of 25-90 kHz. The mode B (f = 62-70 kHz) was observed strongly at the sightlines inside r/a<0.5, however the peripheral chords observed the lower frequency mode (C, f = 21-25 kHz).

The beam emission fluctuation level, $\tilde{I}_{BE}/<I_{BE}>$, which is regarded as being proportional to the density fluctuation ($\tilde{n}(\rho)/n(\rho)$) at the local position, is plotted in Fig. 2(b) as a function of the normalized minor radius ρ. If the density profile is assumed to be parabolic, the radial profile of the density fluctuation (i.e. $\tilde{n}(\rho)$) for mode B is peaked one and higher in the core (ρ<0.6) region. The density fluctuation for the mode A spreads in the whole region, while the mode C is localized in the edge region. Although the observed frequency and the toroidal mode number for the mode A is consistent with the analytical results for GAE, the radial structure of the density fluctuation and phase difference will be compared with the stability analysis.

1) S. Kobayashi, et al., Rev. Sci. Inst. **81**, 10D726 (2010).

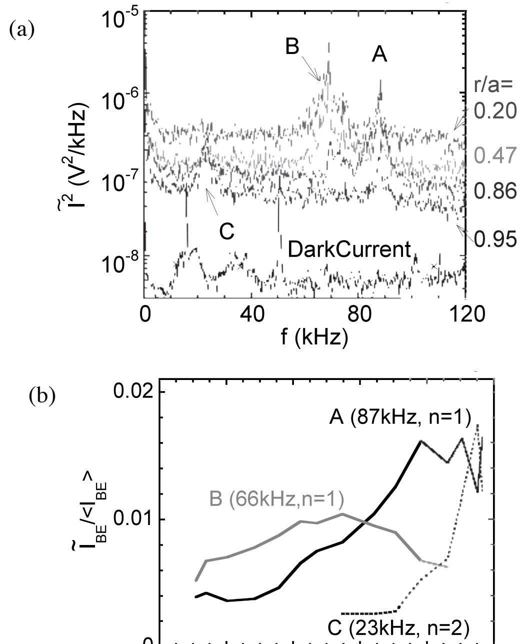

Fig. 2. (a) Power spectra of the beam emission at r/a=0.20-0.95 obtained in the NBI heated plasmas of Heliotron J (#46382, #46392), and (b) radial profile of the beam emission fluctuation for the mode A-C.