§20. Density Fluctuation Measurement Using Beam Emission Spectroscopy on Heliotron J

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A beam emission spectroscopy (BES), measures the Doppler-shifted light emission from the neutral beam (NB) atoms, that are excited through the collision with the plasma ions and electrons. This technique has been regarded as advantageous for understanding the physics of MHD activities and long-wavelength plasma turbulence both in Tokamak and Helical devices.

This report describes the development and application of beam emission spectroscopy to Heliotron J to measure the density fluctuation. One of the key subjects for the development in the BES is to minimize the radial extent of the observation region. It had been revealed, however, that different from the conventional BES systems, when the heating NB was used as the probe beam and viewing chords were located on the midplane of the torus, the three-dimensional structure of the magnetic flux surface of Heliotron J leaded to a significant overlap of the observing flux surfaces. Therefore, we investigated the optimum sightlines for BES for Heliotron J using numerical model calculation and [1].

One candidate for the BES sightlines is shown in Fig. 1, where twenty sightlines with 10mm pitch are drawn. As shown in the figure, since the magnetic axis of Heliotron J has square shape in the top view and sinus shape in the side view, the viewing chords are selected so as to be parallel to the magnetic axis in the beam region. The sightlines can observe the whole plasma region ($0<\rho<1$) with the spatial resolution $\Delta\rho$, determined from the half width at 1/e height of the beam emission intensity, of less than ±0.055. The spatial resolution in absolute units was ±8mm. The spatial pitch between sightlines Δx is 10 mm, which yields the Nyquist wavenumber, $k_N = \pi/\Delta x$, of = 3.1 rad cm^{-1}. The measurable wavenumber range $k_N\rho_S$ is estimated to be smaller than 0.6 in the case that the ion Lamor radius ρ_S is 0.2 cm in the standard parameter of Heliotron J plasmas (the ion temperature of 0.3 keV and the magnetic field strength of 1.25T).

To discuss the feasibility of the density fluctuation measurement by BES in Heliotron J, the optical system with fifteen sightlines from the present viewing port was installed into Heliotron J. Figure 2 shows the spectral profile of the beam emission at ρ=0.4 for the counter-NBI (BL1) plasmas at the line-averaged electron density $\bar{n}_e$ of $1\times10^{19}m^{-3}$. The acceleration voltage of the hydrogen beam (E_b) was 27kV. The three Doppler-shifted components of the beam emission (full, half and third energy components) are clearly separated without strong impurity line emissions. The spectral profile for the full energy beam component was compared with the model calculation. The split of the beam emission is owing to the difference of the observation angle between the upper and lower ion sources of NB. A good consistency between the experimental result and the model calculation is found assuming a spectral broadening of 0.1nm which is due to the instrument function of spectrometer and Zeeman effect. Note that the numerical analysis show that the beam emission intensity by the electron impact excitation was estimated to be 1.4-1.5 times higher than that for the ion because of the relatively low electron temperature (~0.4keV) in the NBI plasmas of Heliotron J.

We are installing (1) optical fiber arrays for the optimized sightlines as shown in Fig. 1. to improve the spatial resolution and the signal-to-noise ratio and (2) ten sets of interfere filter and avalanche photodiode for the fast sampling BES measurement.

1) S. Kobayashi, S. Kado, T. Oishi, *et al.*, Rev. Sci. Instrum. 81, 10D726 (2010).

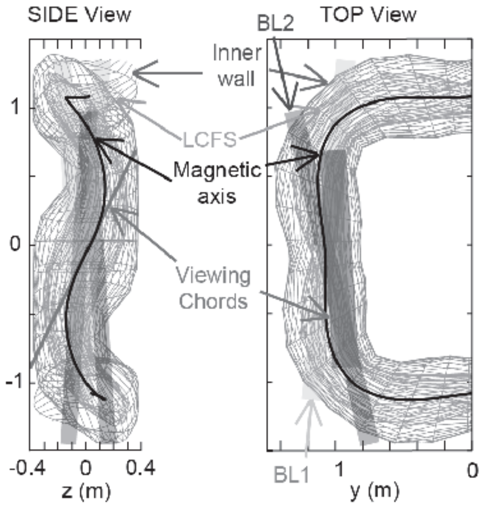

Fig. 1. Schematic view of BES viewing chords, 20 sightlines for the whole plasma measurement using newly-designed viewing port. The co- and counter-NBI beamlines are also shown in the figures.

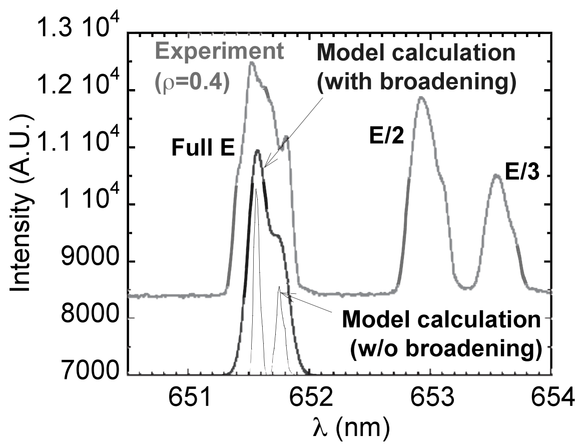

Fig. 2. Spectral profiles of the beam emission deduced by the numerical calculation and measured by the monochromator.