§13. Measurement of Density Fluctuations in LHD Using Beam Emission Spectroscopy

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It has widely been recognized that microturbulence in plasmas is a leading candidate to drive anomalous transport in torus plasmas. In addition, investigation of the interaction between meso-scale turbulence and microturbulence has become more important to clarify the mechanism of the non-local transport in plasmas. Therefore, development of the diagnostics of fluctuations is needed because the turbulence manifests itself as fluctuations in the plasma densities, potentials, and temperatures. Beam emission spectroscopy (BES) has been proposed as a method for the measurement of long wavelength plasma density fluctuations. The BES system measures emissions from the collisionally excited neutral beam atoms (denoted as "beam emission").

We have developed two BES systems in the large helical device (LHD). They have sightlines passing through the plasma in toroidal direction from 6T port and poloidal direction from 10.5L port, which is denoted as "toroidal sightline system" [1] and "poloidal sightline system" [2], respectively. In the development of the poloidal system, we tried to extend the radial width of observable region using the 50 channel fiber array. The spatial pitch between sightlines in the plasma Δx = 9.2 mm yields the Nyquist wavenumber, $k_N = \pi / \Delta x$, of 3.4 rad cm^{-1}. Using the Larmor radius evaluated from T_e = 1 keV and B = 1.5 T, $\rho_s = (2m_iT_e / e)^{1/2} / B$, of 3.05 mm, the wavenumber range $k\rho_s$ < 1.04 is measureable. A grating spectrometer to separate the beam emission from the background emission consists of a collimator lens with f = 200 and D = 71.4 mm, a camera lens with f = 200 mm and D = 100 mm, and a grating with 2160 grooves per millimeter. A beam splitter located between the camera lens and the exit slit separates the intensity of the signal into 70% and 30%. The 70% component is focused on the optical fibers placed at the exit slit for the time-resolved fluctuation measurement by using Avalanche Photo-Diode detectors with a sampling rate of up to 1 MHz. On the other hand, the 30% component is focused on a CCD camera as a spectral image.

Figure 1 shows the BES signal obtained using the poloidal system. The measurement was performed for the discharge aiming at investigation of the magnetic island dynamics (#104693, B = - 1.75 T, R_{ax} = 3.6 m, γ = 1.254, B_q = 100 %). Temporal evolution of the BES signal almost corresponds that of local electron density. Signals appear and disappear when the probe beam (NBI#1) turns on and off, respectively. Rapid increase of the density was observed when the combination of the neutral beams changed.

The frequency spectrum of the density fluctuation located at intermediate of the minor radius is shown in Fig. 2. Oscillations with the frequency of 0.2 kHz, 0.8 kHz, and 1.3 kHz were observed. Radial profile of coherence of the 0.2 kHz oscillation is shown in Fig. 3 as the spatial structure of the mode. A channel of R = 4.04 m was taken to be a reference of the coherence shown in Fig. 3. It is revealed that the coherence is increasing and radial region having high coherence is broadening as time goes by[3]. As stated above, measurement of density fluctuations and its spatial structure is under progress. Optimization of the system for the measurement of meso-scale turbulence is planned for the future.

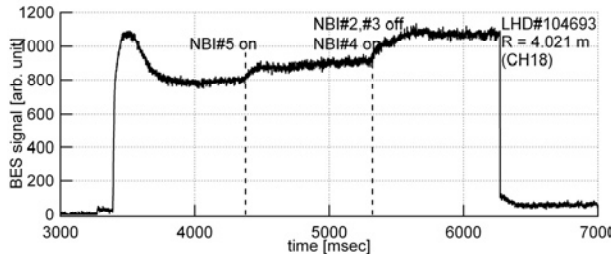

Fig. 1. Temporal evolution of the BES signal.

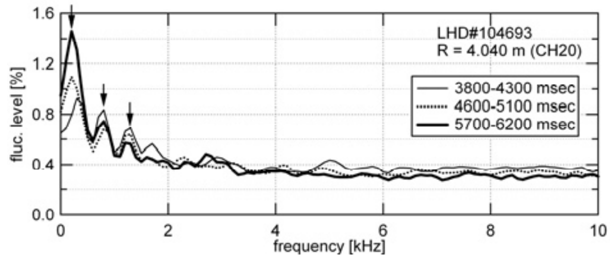

Fig. 2. The frequency spectrum of the density fluctuation.

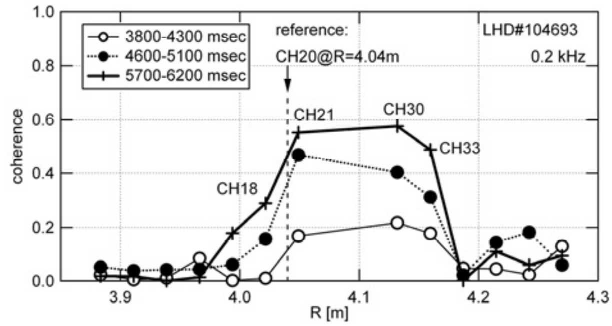

Fig. 3. Radial profile of coherence of the 0.2 kHz oscillation.

1) Kado, S., Oishi, T., Yoshinuma, M., Ida, K., Rev. Sci. Instrum. **81** (2010) 10D720.
2) Oishi, T., Kado, S., Ida, K., Yoshinuma, M., Nakano, H., Yamazaki, K., Rev. Sci. Instrum. **81** (2010) 10D719.
3) Oishi, T., Kado, S., Ida, K., Yoshinuma, M., Nakano, H., Yamazaki, K., *presented in* 1st APTWG International Conference, Toki, Japan, 2011/06/14-17, C-P13.