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

Oishi, T.,
Kado, S. (Univ. Tokyo),
Ida, K., Yoshinuma, M., Nakano, H.,
Yamazaki, K. (Nagoya Univ.)

Beam emission spectroscopy (BES) has been proposed as a method for the measurement of local value and spatial correlation of plasma density fluctuations. The BES system measures emissions from the collisionally excited neutral beam atoms (denoted as "beam emission"). Beam emission can be distinguished from bulk plasma emission by taking advantage of the Doppler shift. Since the observable region is the intersection of the beam line and the sightline for each fiber channel, local values and their correlations are available.

The BES system has been developed in the large helical device (LHD)[1-3]. It has sightlines passing through the plasma in poloidal direction from 10.5L port by using the 50 channel fiber array. A neutral hydrogen atomic beam for heating (NBI#1) is used as the probe beam. The angle between the sightline and the beam line is 101°. 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}. A grating spectrometer to separate the beam emission from the bulk plasma emission consists of a collimator lens with f = 200 mm 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% for the time-resolved fluctuation measurement by using Avalanche Photo-Diode detectors and 30%for the spectral image measurement using a CCD camera.

Figure 1 shows the wavelength spectrum of the detected emission including the beam emission. The measurement was performed for the discharge aiming at investigation of the transport of core plasmas (#111144, B = 2.75 T, R_{ax} = 3.6 m, γ = 1.254, B_q = 100 %). The beam energy of NBI#1 was 190 keV. The beam emission component separated from the background H_α emission is successfully observed because of the high energy of NBI with negative ion sources, even in the configuration in which the angle between the beam and the sightline is close to a right angle. Figure 2 shows the temporal evolution of the BES raw signal (#111108). The magnetic configuration was same as stated previously. NBI#1 was injected from 3300 msec to 6300 msec. Modulation ECH was applied from 4300 msec to 6300 msec. Signals appear and disappear when NBI#1 turns on and off, respectively.

In the discharge shown in Fig. 2, a coherent density oscillation having a frequency of 0.4 kHz was observed in the BES signal. Radial profile of coherence and phase of the 0.4 kHz oscillation is shown in Fig. 3. Measurement positions shown in Fig. 3 cover the normalized minor radius of about from 0.36 to 0.94. A channel of R = 4.102 m (not indicated in this figure) was taken to be a reference. The coherence profile has two structures of R = 4.05 m – 4.1 m and R = 4.1 m – 4.16 m. The phase differs by 0.5 rad between two structures. Thus, measurement of density fluctuations and its spatial structure is under progress, even though the physical understanding of this spatial structure has not been clarified.

As other results, MHD density fluctuation having a high coherence with the magnetic fluctuation (#110320), or rapid change of local density accompanied by ELM-like burst (#111514) were observed using BES. For the future study, improvement of the signal to noise ratio and optimization of optics for two dimensional measurements are planned for investigation of the interaction between meso-scale turbulence and microturbulence to clarify the mechanism of the non-local transport in plasmas.

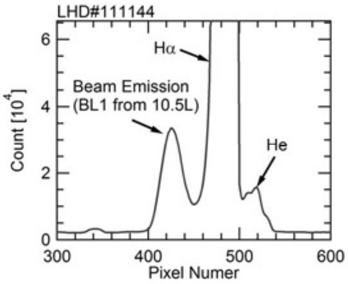

Fig. 1. Wavelength spectrum of the detected emission in the BES measurement.

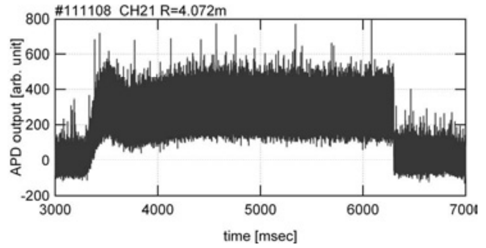

Fig. 2. Temporal evolution of the BES raw signal.

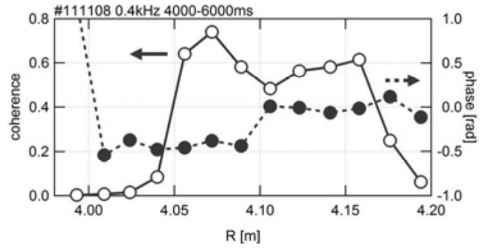

Fig. 3. Radial profiles of coherence and phase of 0.4 kHz coherent oscillation. Reference BES channel is located at R = 4.102 m (not indicated in this figure).

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.