§55. Development of a Beam Emission Spectroscopy System for LHD Plasmas

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It has widely been recognized that microturbulence in plasmas is a leading candidate to drive anomalous transport in torus plasmas. This microturbulence 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"). The beam emission can be distinguished from the bulk plasma emission by taking advantage of 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. We have developed a BES system in the compact helical system (CHS) as the world's first trial to apply BES to a helical device.[1] Based on the achievement in CHS, we started to develop a BES system in LHD since the last fiscal year.

Figure 1 is a schematic drawing of BES systems in LHD. About 140 mm in the poloidal cross section is focused onto the 13 channel fiber array having a width of 13 mm by using an object lens having the focal length of 400 mm. Each fiber has a numerical aperture of 0.2 ,a core diameter of 0.8 mm, and a clad diameter of 1.0 mm. Spatial resolution which corresponds to the width of a sightline and the spatial pitch between sightlines are 8.6 and 10.8 mm on the focal plane, respectively. The spatial pitch Δx yields the Nyquist wavenumber, $k_N = \pi / \Delta x$, of 2.9 rad cm^{-1}. Using the ramor radius evaluated from electron temperature, $\rho_s = (2m_i T_e / e)^{1/2} / B$, of 3.05 mm in the case of $T_e = 1$ keV and B = 1.5 T, the wavenumber range $k\rho_s < 0.89$ is measureable.[2] To separate the beam emission from the background emission, a grating monochromater was designed. Low F-number was required to avoid the loss of the photon flux. We used a pair of achromatic lens, f = 300 (D = 100 mm) and 150 mm (D = 80 mm), and obtained the effective F-number of 300/80 = 3.75.

Figure 2 (a) shows a temporal evolution of the BES signal near the plasma edge. The BES signal is observed during the period in which the probe beam, NBI #3, applies. It was measured under the condition aiming at production of high beta plasmas. In this condition, it is known that the edge MHD instabilities are often observed. The solid trace in Fig. 2 (b) shows the frequency spectrum of the BES signal which indicates an oscillation with a frequency of approximately 2.0 kHz appears clearly in the density fluctuation. The noise level of the density fluctuation (dotted trace in Fig. 2 (b)) is evaluated based on the BES signal before the beam is injected. The solid bold trace in Fig. 2 (b) is a spectrum of coherence between the density fluctuation and the magnetic fluctuation during the period in which the 2.0 kHz oscillation appears, revealing a coherence of more than 0.5 for this frequency, which indicates that this oscillation is an MHD instability.[3]

The signal to noise ratio should be improved for future to measure the turbulence which will appear in the frequency range of several tens or hundreds of kilohertz.

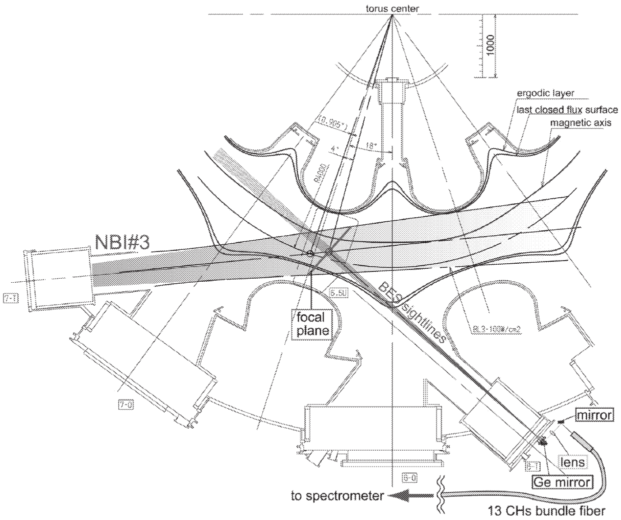

Fig. 1. Schematic drawing of the BES system in LHD.

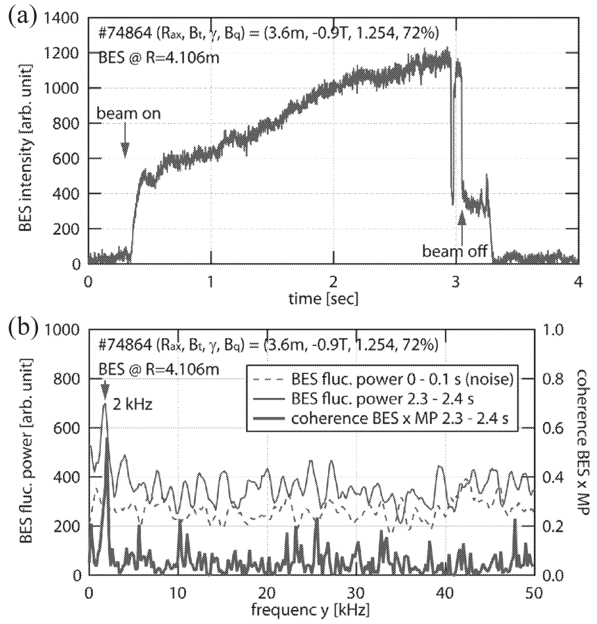

Fig. 2. (a) temporal evolution of the BES signal near the plasma edge. (b) frequency spectrum of the density fluctuation and coherence between the density fluctuation and the magnetic fluctuation.

Reference
1) Oishi, T. et al., Rev. Sci. Instrum. **75**, (2004) 4118.
2) Kado, S. et al., Meeting Abs. Phys. Soc. Japan **61**, 1, 30aUD-12 (2006) 240. ISSN 1342-8349 [in Japanese].
3) Oishi, T. et al., Meeting Abs. Phys. Soc. Japan **62**, 1, 20aQA-5 (2007) 211. ISSN 1342-8349 [in Japanese].