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Development of beam emission spectroscopy system in Heliotron J
ヘリオトロンJにおけるビーム放射分光計測システム開発

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This paper reports the development of Beam Emission Spectroscopy (BES) for the density fluctuation measurements in Heliotron J. To improve the performance of the previous BES system, we have installed the optimized viewing chords which can observe the whole plasma region. The solid angle and the observation volume of the objective optical system are also improved by 5 times and 2 times higher than that of the previous system. The signal-to-noise ratio of the beam emission intensity measured by avalanche photodiodes (APD) improved about 20 times higher than that of the previous system..

1. Introduction

To understand the characteristics of the anomalous transport is one of the important subjects to improve plasma confinement. The anomalous transport is thought to be induced by plasma turbulence which emerges as plasma fluctuation such as density, temperture, potential and magnetic fluctuations. Beam Emission Spectroscopy (BES) is a method to detect plasma density fluctuations. When a Hydrogen neutral beam is injected into the plasma, the beam particles are excited by the collisions with electrons or ions. A BES system observes Doppler-shifted H_α emission from the beam particles (beam emission). The amount of the Doppler-shift of this emission is decided by the beam velocity and the angle between sightlines and the neutral beam. The intensity of the beam emission has a relation with the plasma density and its fluctuation.

$$I_{BE} = \frac{A_{32}}{A_{31}+A_{32}}\left(n_i\sigma_i v_{beam} + n_e\langle\sigma_e|v_{beam}-v_e|\rangle\right)h\nu\Delta V\Delta\Omega/4\pi \quad (1)$$

Separating the beam emission from background light by spectroscopic method, the density fluctuation can be evaluated at the point where the beam and sightlines are crossed. In the previous work to check the feasibility of the density fluctuation measurement by BES for Heliotron J plasmas [1], we found improvement in the signal-noise-ratio (S/N) should be required. In this paper, the improvements in the BES system and the preliminary result of the BES measurement are described.

2. Experimental Devices

Heliotron J is a plasma confinement device based on a helical-axis heliotron configuration (R/a=1.2 m/0.2 m) with an L/M=1/4 helical coil [2].

Two tangential neutral beam injection (NBI) lines are installed in Heliotron J. The maximum acceleration voltage and injection power of each line are 30kV and 0.7 MW, respectively. One of these beam lines is used for BES measurement as a diagnostic beam. Each beam line has two ion sources (upper and lower), of which vertical tilting angle is ?3.5?.

To investigate the possible sightlines with a good spatial resolution for the Heliotron J configuration [1], model calculations were carried out based on the beam trajectory analysis taking the beam absorption process into account [3]. We have found the best ones by configuring the sightlines along the magnetic axis by using a newly designed viewing port. This system can observe the emission lights from the region of $0.07<r/a<0.94$ in a radial direction of plasma. By using a 16 channel optical fiber system, the high spatial resolution of $\Delta r/a$? ± 0.04 is realized. The emission light is transferred to an interference filter, and the beam emission is separated from the background light. The intensity of beam emission is measured with APD and 1 MHz ADC. Compared to the previous system, the solid angle is increased from 1.2×10^{-5} sr to 5.7×10^{-5} sr and the observation volume is increased from 28.9 cm^3 to 60.2 cm^3 by reconsideration of the optical system. The transmittance of the interference filter and the APD system are also modified to improve the S/N ratio.

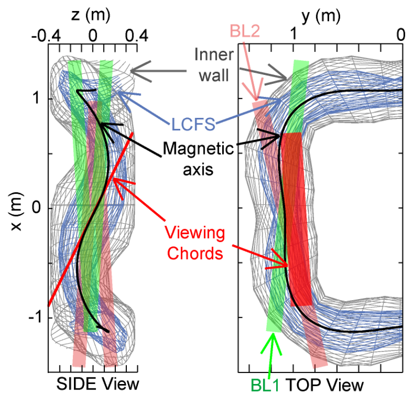

Fig.1. Sightlines of BES for Heliotron J

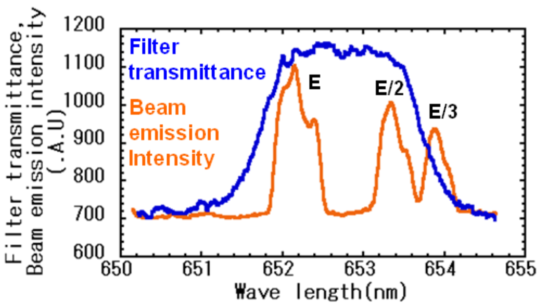

Fig.2. Filter transmittance and beam emission intensity measured by monochromator and CCD camera system.

3. Results and discussions

The beam emission has been confirmed by a monochromator and a CCD camera. Figure 2 shows the beam emission intensity and the transmittance of the interference filter as a function of the wavelength. The full, half and one-third energy components of the beam emission are separated well from the background light by using the interference filter. Because of the different injection angles of the two ion sources, each component of the beam emission shows multi peaks.

Figure 3 shows the time evolution of the beam emission intensity measured at r/a = 0.18, 0.45, 0.52, 0.88. The BES intensity in the center of the plasma is larger than that in the edge region.

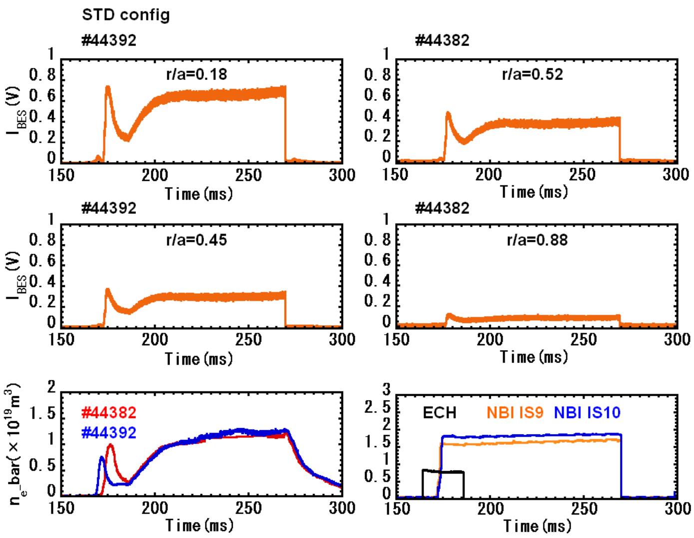

Fig.3.Time evolution of beam emission intensity

The S/N ratio at r/a = 0.52 is about 30, which is about 20 times higher than that of the previous system. To evaluate the radial structure of the density fluctuation, we will apply Fast-Fourier-Transform based spectrum analysis.

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