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BES on Compact Helical System for Density Fluctuations with Edge Transport Barrier Formation

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1. Introduction

A transition phenomenon which indicates the formation of edge transport barrier (ETB) has been observed in the neutral beam heated plasmas in the compact helical system (CHS), which is a low-aspect-ratio middle size heliotron (major radius = 1 m, minor radius = 0.2 m, toroidal period number = 8, poroidal mode number = 2) [1-3]. The beam emission spectroscopy (BES) has been developed in CHS to measure the local density fluctuations and gradients simultaneously [4-6]. In this article, we report the behaviour of the edge density fluctuations and gradients accompanied by the ETB formation in CHS measured using BES.

2. Experimental setup

Figure 1 is a schematic drawing of BES systems in CHS. The BES system in the present study detects Doppler-shifted H_α emissions from the collisionally excited neutral beam atoms (denoted as "beam emission") injected for the purpose of additional heating. One can regard the fluctuations of the signals as the density fluctuations [7]. Spatial channels of the BES consist of 16 optical fibers with object lenses which focus on the position along minor radius of CHS. The observable region is the intersection of the beam line and the sightline

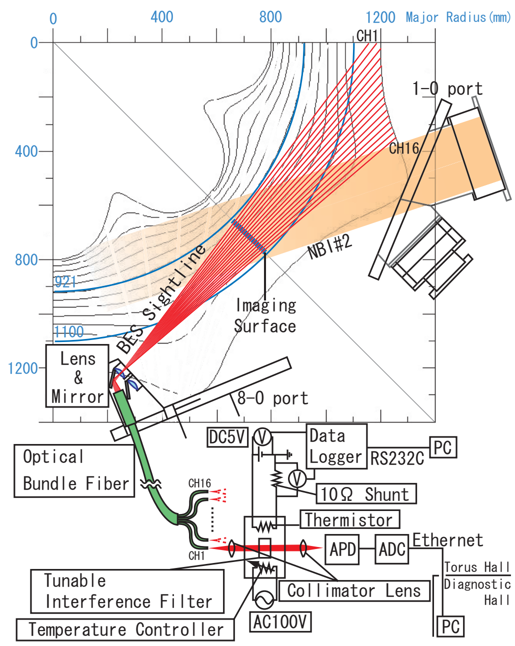

Fig. 1. Schematic drawing of the BES system on the CHS devise.

for each fiber channel. In order to determine the observable region in the normalized radius ρ, the three-dimensional equilibrium code VMEC [8] is applied to calculate the magnetic flux surface for β = 0.8 %. A typical width of each observable region in the normalized radius Δρis about ± 0.15 near the last closed flux surface (LCFS). BES can provide the density gradient ∇n and the inverse density scale length L_n^{-1} defined by $\nabla n/n$. ∇n and n are obtained from difference and average between the intensity of signals measured in adjacent sightlines, respectively.

3. Typical ETB discharge in CHS

A typical heating condition for the ETB discharge is shown in Fig. 2(a). Plasma was initiated by electron cyclotron heating (ECH) and further heated by two neutral beam injection (NBI) systems. The port through power of NBI was 1.4 MW for this shot. In the case that the heating power exceeds a certain threshold, a sudden drop in the temporal evolution of the H_α intensity signal can be observed as shown in Fig. 2(b). The line-averaged density as well as the stored energy start to increase at the transition [1-3]. Figure 2(c) and (d) show the BES signals for ρ = 0.95 and ρ = 1.03, which are just inside and outside of the LCFS, respectively. These facts indicate that the density inside the LCFS increases while that outside the LCFS decreases at the transition. L_n^{-1} between ρ = 0.95 and ρ = 1.03 increases at the transition and finally keeps a certain level as shown in Fig. 2(e).

We categorize the waveform into three phases as indicated in Fig. 2: (1) L-phase, which means the phase before transition, (2) density building-up phase, whose density keeps on increasing, and (3) the ETB-formation phase, which is after a saturation of density building up.

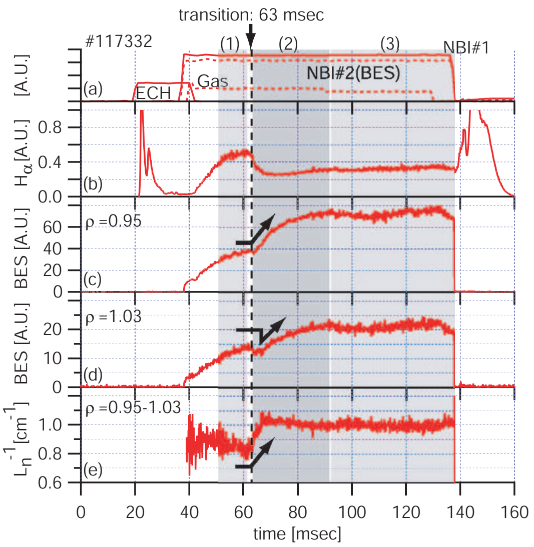

Fig. 2. Typical waveforms of the discharge with the ETB transition. (a) heating and fueling, (b) H_α intensity, (c) and (d) density for ρ = 0.95 and ρ = 1.03, respectively, and (e) inverse density scale length between ρ = 0.95 and ρ = 1.03. (c)-(e) are measured using BES.

4. EHO-like density fluctuations

Fig. 3 shows the fluctuation power spectra in the BES signals at several locations near the edge averaged over L-phase (52-62 msec), density building-up phase (64-74 msec), and the ETB-formation phase (110-120 msec).

Note that coherent fluctuations having the fundamental frequency of around 4 kHz and the 2nd harmonic frequency of around 8 kHz appear at $\rho = 0.95$ in the ETB formation phase. The mode, which is similar to the edge harmonic oscillations (EHO) in Tokamaks [9, 10], is observed only when the heating power is much higher than the threshold of the ETB transition. The threshold port-through heating power of ETB transition in the standard magnetic configuration is about 1.0 MW for the density range of the discharge shown in Fig. 3 [1]. The EHO-like mode is observed for the heating power higher than 1.2 MW at present.

There is the $\iota = 1$ rational surface just inside the LCFS. When LCFS and the $\iota = 1$ surface were shifted by modifying the magnetic configuration, the location of the EHO-like mode followed them. On the other hand, under such the magnetic configuration that the $\iota = 1$ surface are expected to be outside of the LCFS, the EHO-like mode disappears. It may suggest that the EHO-like mode has something to do with the rational surface inside the LCFS [6]. The localization of this mode is a common observation for the EHO in Tokamaks [10] and EHO-like mode in this study.

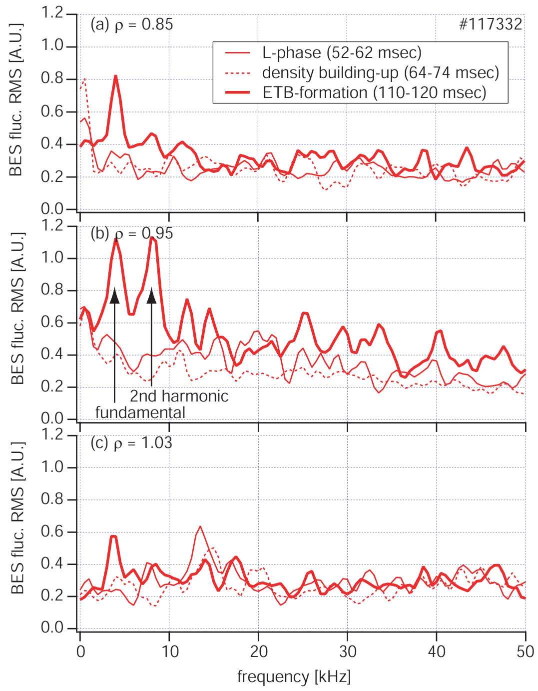

Fig. 3. Fourier power spectra of the density fluctuations near the plasma edge averaged over L-phase (52-62 msec, solid line), density building-up phase (64-74 msec, dashed line), and the ETB-formation phase (110-120 msec, solid bold line). (a) $\rho = 0.85$, (b) $\rho = 0.95$, and (c) $\rho = 1.03$.

Figure 4 shows the amplitude of the fundamental mode plotted against ∇n. The EHO-like mode is enhanced when ∇n achieves a certain threshold. ∇n keeps almost constant after the enhancement of the mode. For the discharges with EHO-like mode, both ∇n and L_n^{-1} in the ETB-formation phase did not vary significantly even if the heating power was increased [6]. There is a possibility that the onset of the EHO-like mode saturates the density gradient. It seems analogous to the fact that the EHO enhances the particle transport in

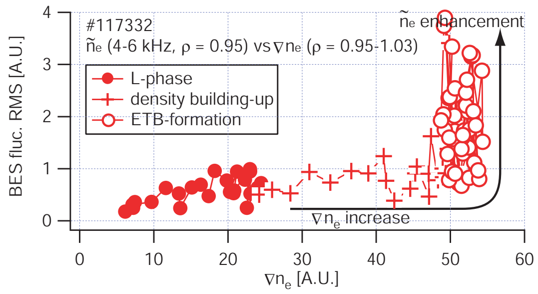

Fig. 4. The amplitude of the fundamental frequency of the EHO-like mode as a function of the density gradient measured using BES.

Tokamaks [11]. This should be investigated in the future.

5. Summary

The BES diagnostics showed steepning of the density gradient near the LCFS at the ETB transition in CHS. The EHO-like mode was observed just inside the LCFS in the ETB-formation phase. It had the fundamental (f = 4 kHz) and 2nd harmonic ($2f$ = 8 kHz) frequencies. There seems to be a threshold in the density gradient for enhancing the EHO-like mode. After the excitation of the mode, the density gradient saturates. To investigate the relationship between the EHO-like mode and the particle transport will be the next step of our study.

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References

[1] S. Okamura et al., J. Plas. Fus. Res. **79**, 977 (2003)
[2] S. Okamura et al., Plasma Phys. Control. Fusion **46**, A113 (2004)
[3] T. Akiyama et al., "Edge Transport Barrier Formation and Power Threshold Properties in CHS", presented in this conference
[4] T. Oishi et al., Rev. Sci. Instrum. **75**, 4118 (2004)
[5] T. Oishi et al., J. Plasma Fusion Res. SERIES **6**, 449 (2004)
[6] T. Oishi et al., "EHO-like density fluctuations measured using Beam Emission Spectroscopy in ETB discharge on CHS", *submitted to* Nucl. Fusion
[7] R. Fonck et al., Rev. Sci. Instrum. **61**, 3487 (1990)
[8] S. P. Hirshman et al., Comput. Phys. Commun. **43** 143 (1986)
[9] C. M. Greenfield et al., Phys. Rev. Lett. **86**, 4544 (2001)
[10] W. Suttrop et al., Plasma Phys. Control. Fusion **45**, 1399 (2003)
[11] K. H. Burrell et al., Plasma Phys. Control. Fusion **44**, A253 (2002)