19PA-037

Two-dimensional Measurement of Density Fluctuation using Beam Emission Spectroscopy in HeliotronJ
ヘリオトロンＪにおけるビーム放射分光法を用いた密度揺動二次元計測

Mitsuaki Kirimoto[1], Shinji Kobayashi[2], Hirotsugu Matsuda[1], Tohru Mizuuchi[2], Fumimichi Sano[2], *et al*.
桐本充晃[1], 小林進二[2], 松田啓嗣[1], 水内亨[2], 南貴司[2], 大島慎介[2], 長崎百伸[2], 山本聡[2], 門信一郎[2], 岡田浩之[2], 原田伴誉[1], 笠嶋慶純[1], 臧臨閣[2], 羽田和慶[1], 釼持尚輝[1], 大谷芳明[1], 安枝樹生[1], 鈴木文子[1], 呂湘潯[1], 程崧明[1], 中山裕介[1], 木谷壮志[1], 西川幸佑[1], 村上弘一郎[1], 洪重遠[1], 元嶋誠[1], 吉沼幹朗[3], 居田克巳[3], 中村祐司[1], 木島滋[2], 佐野史道[2]

1Graduate School of Energy Science, Kyoto University, Gokasho, Uji, 611-0011, Japan
京都大学エネルギー科学研究科　〒611-0011 京都府宇治市五ヶ庄
2Institute of Advanced Energy, Kyoto University, Gokasho, Uji, 611-0011, Japan
京都大学エネルギー理工学研究所　〒611-0011 京都府宇治市五ヶ庄
3National Institute for Fusion Science, 322-6 Oroshi-cho, Toki 509-5292, Japan
核融合科学研究所　〒509-5292 岐阜県土岐市下石町322-6

This paper reports the development and experimental observation of the density fluctuation by Beam Emission Spectroscopy (BES) in Heliotron J. To obtain the two-dimentional stracture of the density fluctuation, the sightlines are improved in radial and poloidal direction from 16×1 to 16×2 . The density fluctuation with a frequancy of 15–20kHz was measured in the core (r/a<0.4) region of the ECH+NBI plasma. The propagation direction of the fluctuation was estimated to calculate the frequancy-wavenumber spectra by two-point correlation analysis. As a result, the poloidal propagation of the fluctuation was the ions diamagnetic drift direction, in the laboratory system.

1. Introduction

To improve the plasma confinement, measurement of plasma fluctuation is important to understand mechanism of the turbulent transport. The density fluctuation has been measured by the technique of beam emission spectroscopy (BES) in many torus devices [1]. BES system installed in Heliotron J has 16 sightlines in the radial direction, and the radial profile of the density fluctuation has been measured [2]. To understand the spatial structure of the density fluctuation in detail, the 2-D measurement of the density fluctuation is required. In this study we improve the BES system to obtain the propagation of the fluctuation in radial and poloidal directions.

2. BES System

The principle of the BES is as follows; when neutral beam is injected into the plasma, the beam particle collides with an electrons or ions, and neutral beam particles are excited and de-excited. Then we can evaluate the density fluctuation from the beam emission released at de-excitation.

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

We installed additional 16 sightlines along with the 16 existing sightlines. The observation region of BES in radial direction is r/a=0.11~0.97 in a standard configuration. Distance of the optical fiber in the poloidal direction dz is 0.74cm.

3. Analytical Method

The frequency-wavenumber spectra S(f,k) analysis is used to evaluate a propagation direction of the density fluctuation.

$$S(f,k)=\frac{1}{M}\sum_{j=1}^{M}I_{\Delta k}[k-k^j(f)]\times\frac{\left|S^j_{z^+}(f)+S^j_{z^-}(f)\right|}{2} \quad (2)$$

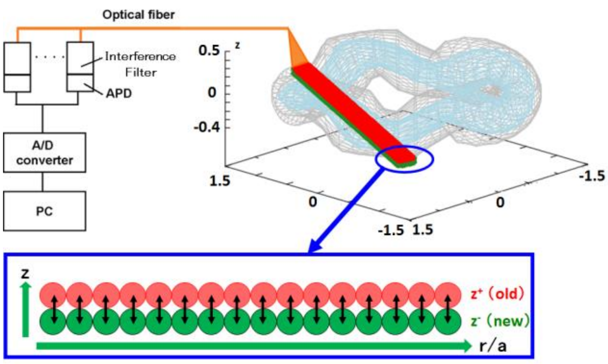

Fig.1. Overview of the BES system

Here, the indicator function $I_{\Delta k}(x)$ is defined as

$$I_{\Delta k}(x) = \begin{cases} 1, & -\Delta k/2 \le x \le \Delta k/2 \\ 0, & others \end{cases} \qquad (3)$$

$S^{j}{}_{z^+}(f)$ and $S^{j}{}_{z^-}(f)$ are power spectra measured at two points. $k^j(f) = \Delta\theta^{j}{}_{z^+z^-}(f)/\Delta x$ is the local wavenumber, $\Delta\theta^{j}{}_{z^+z^-}(f)$ is the phase difference between the two signals.

Using expression (2), wave vector is evaluated. Because a direction of the wave vector is equivalent to the propagation direction of the fluctuation, we can measure the propagation direction of the fluctuation from the sign of wavenumber. In this study, the positive value of k_θ is defined as a fluctuation drift propagating in the ions diamagnetic drift direction.

4. Experimental Results and Discussion

In the ECH+NBI plasma, we measured the density fluctuation using the 16×2 sightlines. Figure 2 shows the time evolutions of heating (NBI,ECH), line-averaged electron density, stored energy and the BES power spectral density (PSD) at r/a=0.3. A relatively high intensity ($\tilde{n}/n$=0.8%) fluctuation was observed in the frequency range of f=15-20kHz. Figure 3 shows the radial profile of the low frequency fluctuation intensity. The value of the coherence to the magnetic prove signal is 0.4, so it is expected that the fluctuation is driven by an MHD instability.

Figure 4 shows the the frequency-wavenumber spectra S(f,k) at r/a≈0.28. The poloidal and radial wavenumbers (k_θ, k_r) were obtained in the range of $20<k_\theta<45$ m^{-1} and $75<k_r<125$ m^{-1}, respectively. Figure 5 shows the radial profile of the poloidal and radial wavenumbers (k_θ, k_r). From these, the poloidal mode number m is expected to be 1~2, and in the laboratory system, the fluctuation propagates in the ions diamagnetic drift direction, and the radial propagation of the fluctuation is outward direction. But the mode has been not identified yet. So we have to discuss the characteristics of this mode with taking the ploidal flow, density and temperature profiles into account.

Acknowledgments

This work was supported by NIFS collaboration research programs (NIFS10KUHL030, NIFS14KUHL060, NIFS12KUHL052, NIFS13KUHL053, NIFS14KUHL065, NIFS14KLPR027).

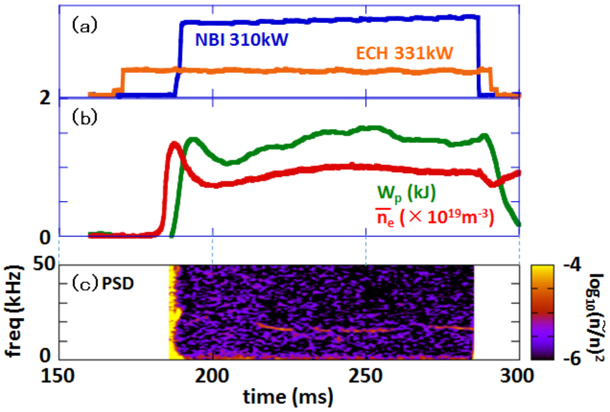

Fig.2. Time evolutions of heating (NBI,ECH), line-averaged electron density, stored energy, and the BES PSD at r/a=0.3

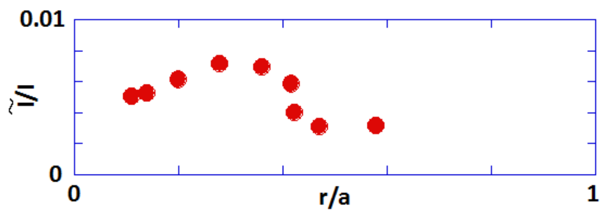

Fig.3. The radial profile of the fluctuation intensity and coherence to the magnetic probe signal (f:15-20 kHz)

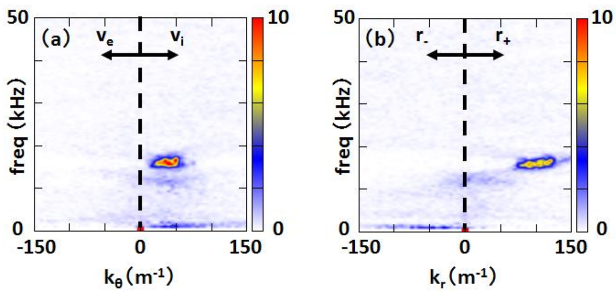

Fig.4. S(f,k) spectrum at r/a≈0.28

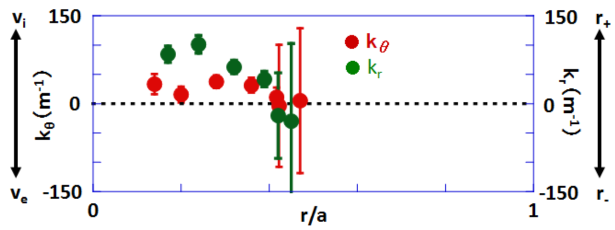

Fig.5. The radial profile of k_θ and k_r of the fluctuation (f:15-20 kHz)

References

[1] G.R.Mckee , et al , RSI v75 (2004) 3490

[2] S.Kobayashi , et al , RSI v83 (2012) 10D535