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Study on Spatiotemporal Structures of Low-frequency Fluctuation Using Beam Emission Spectroscopy in LHD

LHDにおけるビーム放射分光法を用いた低周波揺動の時空間構造の研究

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The radial profile and spatiotemporal structure of the density fluctuation are investigated in the edge plasma region using beam emission spectroscopy (BES) which has two-dimensional measurement points in poloidal cross section. The spatiotemporal structure of the density fluctuation can be analysed by using the BES system. Consequently, a low-frequency fluctuation of f ~ 1.5 and 3.0 kHz is observed, which propagates to the electron diamagnetic drift direction, and is localized at $r_{\mathrm{eff}} \sim 0.57$.

1. Introduction

In order to realize thermonuclear fusion reactor, it is necessary to confine high-temperature and high-density plasma in a steady state. Fluctuations of plasma parameters have been considered to correlate with the properties of plasma confinement. Understanding of turbulent structures and its role in determining the transport is one of the important issues. As a first experimental approach to study the plasma fluctuations, it is necessary to investigate the characteristics of fluctuations based on precise measurements.

Beam emission spectroscopy (BES) [1,2] has been installed in the Large Helical Device (LHD) as a method for the measurement of local plasma density fluctuations and its radial and poloidal correlation. With this system, the magneto-hydrodynamic fluctuation was investigated.

2. BES System

In the BES measurement, light emitted from the collisionally excited neutral beam atoms (beam emission) in the intersection of the beam line and the sightline is detected. The fluctuations of the beam emissions are regarded as the local density fluctuations. In the present experiment, H_α emission from excited neutral beam atoms was measured as beam emission. Optical fibers are installed to obtain their 2-dimensional images in the poloidal cross section. Each measurement point is around 1.0 cm in diameter, and the spatial pitch Δx is 1.0 cm. The arrangement of the fibers can be selected in the radial or poloidal direction to measure the fluctuation structures in each direction. Radial distribution of the density fluctuations can be measured using the BES with the radially-aligned sightlines. In order to improve the signal to nose ratio, several fibers are bundled up to make slits and connected to detectors.

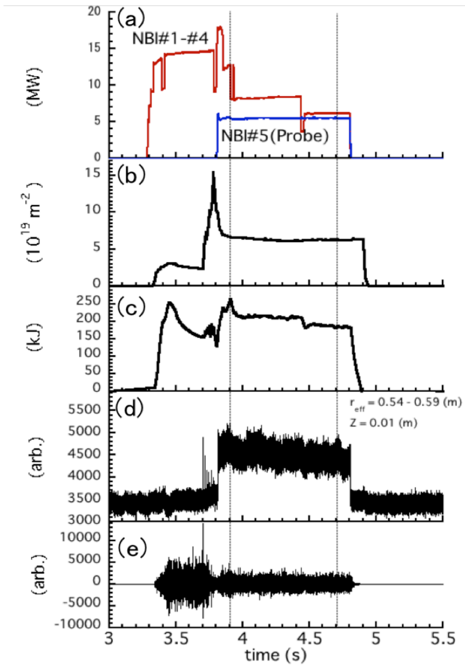

Fig.1. A typical temporal evolution of plasma parameters for a discharge in which low-frequency fluctuations appear (#120265): (a) the NBI powers, (b) the line-averaged density, (c) the stored energy, (d) the beam emission, and (e) the magnetic fluctuation.

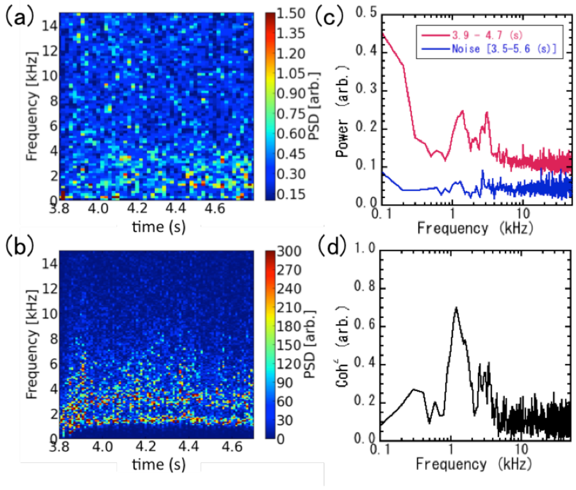

Fig.2. Temporal evolutions of power spectrum of (a) the density at the edge plasma region ($r_{\mathrm{eff}} \sim 0.57$) (b) magnetic fluctuations, and (c) power spectrum of the density fluctuation, and (d) coherence between the density and magnetic fluctuations in 3.9 s < t < 4.7 s.

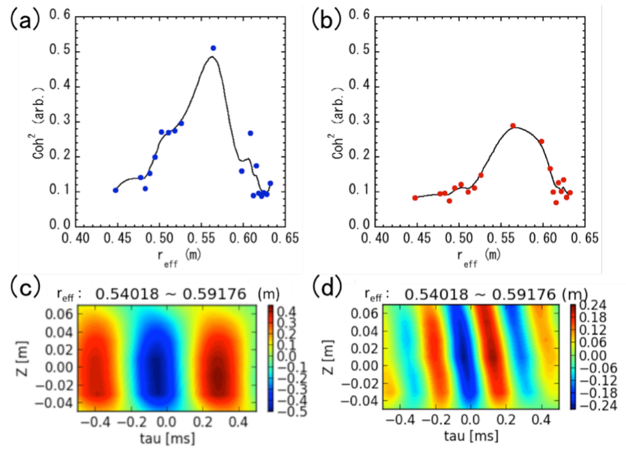

Fig.3. The radial profile of the coherence between the density fluctuation measured using BES and the magnetic fluctuation of (a) $f \sim 1.5$ and (b) $f \sim 3.0$, and contour plot of the cross-correlation function of the density fluctuation of (c) $f \sim 1.5$ and (d) $f \sim 3.0$ for poloidal direction at $r_{\mathrm{eff}} \sim 0.57$.

3. Experiment

Experimental observations are carried out in the LHD, which has a major radius R of 3.5 m (R_{ax} =3.6 m) and an averaged radius of 0.6 m. This experiment was aimed to achieve the high β plasma, where the toroidal magnetic field strength at the magnetic axis B_{ax} was 1.00 T, and the magnitude of the quadrupole field B_q was 100%. Figure 1 shows the typical experimental conditions and temporal evolution of plasma parameters for a discharge in which the low-frequency fluctuation appears: (a) the NBI powers, (b) the line-averaged density, (c) the stored energy, (d) the beam emission, and (d) the magnetic fluctuation. Additional gas was puffed to increase density. Correlation analysis is applied during the quiet period in 3.9 s < t < 4.7 s which is shown by the vertical lines in Fig.1.

4. Results and Discussion

Low-frequency density fluctuations (f < 10 kHz) have been detected by the BES in the edge region. Figures 2 (a) and (b) show the temporal evolution of frequency spectrum of the density and magnetic fluctuations, respectively, measured at $r_{\mathrm{eff}} \sim 0.57$. Figure 2 (c) demonstrates the averaged auto-power spectrum of the density fluctuation in the quiescent period of 3.9 s < t < 4.7 s. Coherent peaks at $f \sim 1.5$ and 3.0 kHz are observed. High cross-correlation between the density and magnetic fluctuations shown in Fig. 2 (a) indicates that the oscillation may be MHD modes. Figures 3 (a) and (b) show the radial profile of the coherence for the peaks at $f \sim$ 1.5 and 3.0 kHz, respectively. Significant coherence values are observed at $r_{\mathrm{eff}} \sim 0.57$. For that radial position, polidal structure of the modes is analysed. Cross-correlation function was calculated with respect to the magnetic fluctuation as a reference signal. Figures 3 (c) and (d) shows the contour plot of the cross-correlation function of the density fluctuations. The vertical direction Z almost corresponds to poloidal direction at the location of the BES sample volume. For the fluctuation component at $f \sim 3.0$ kHz the fluctuation is found to propagate in the electron diamagnetic drift direction with a wave number of $k_\theta \sim 3.3$ /m and a phase velocity of $v_\theta \sim 0.9$ km/s .

5. Summary

Density fluctuation measurement has been conducted in LHD using the BES system which has two-dimensional measurement points in poloidal cross section. At present, the low-frequency density fluctuations have been detected in the edge region. The spatiotemporal structure of the low-frequency density fluctuation was calculated with the magnetic fluctuation as a reference signal, and the fluctuation was found to propagate the electron diamagnetic drift direction.

References

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