18PB-077

Effect of the Radial Plasma Profiles on Nonlinear Behavior of Turbulent Fluctuations in LHD Plasmas

LHDプラズマ乱流揺動の非線形過程に対するプラズマ半径方向分布の効果

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The response of the density and magnetic fluctuations in a transition of radial electric field is investigated in the edge region of LHD plasmas. Consequently, a new type of magneto-hydrodynamics (MHD) mode is observed. Their spatiotemporal structure is characterized by a low frequency of $f \simeq$ 2–5 kHz, a poloidal or toroidal mode number of m=2/n=2. In addition, it is found that the amplitude of H_α signals is suddenly enhanced, corresponding to the appearance of magnetic fluctuation with $f \simeq$ 2–5 kHz.

1. Introduction

Understanding and controlling plasma transport is a critical challenge to improvement plasma confinement. The plasma fluctuations have been considered as a primary origin of the plasmas transport. The recent progress on the study of the mesoscale structures gives us that they are nonlinearly generated by microscale fluctuations [1,2]. The magneto-hydrodynamics (MHD) modes are also found to interact with microscale fluctuations [3]. Although the study of turbulent transport is in progress, the transient transport events are still under a question. These facts indicated that identification of all the possible fluctuations and these nonlinear behaviors in confined plasmas remain urgent issues [4].

In the last experimental campaign on Large Helical Device (LHD), the response of turbulent fluctuations driven transport in a transition of radial electric filed (E_r) by scanning the neutral beam injection (NBI) power experiment was carried out to study the behavior of turbulent fluctuations in LHD plasmas.

2. Experiment

The LHD has a major radius R of 3.5 m (R_{ax} = 3.6 m), an averaged radius of 0.6 m, and a magnetic field strength on the axis B_{ax} of 2.75 T. The plasma is produced initially by electron cyclotron heating (ECH) with hydrogen gas and sustained with two perpendicular NBI powers. Figure 1 presents the typical time evolution of the plasma parameters in the discharge. The two tangential NBI in the codirection with a power of 4.0 MW and in the counterdirection with a power of 3.0 MW start at 4.0 s. A large jump of the central of T_e is observed at t $\simeq$ 4.0–4.1 s (transition timing), and the central of n_e start to decrease at t > 4.1 s. Furthermore, the poloidal rotation velocity starts to change from

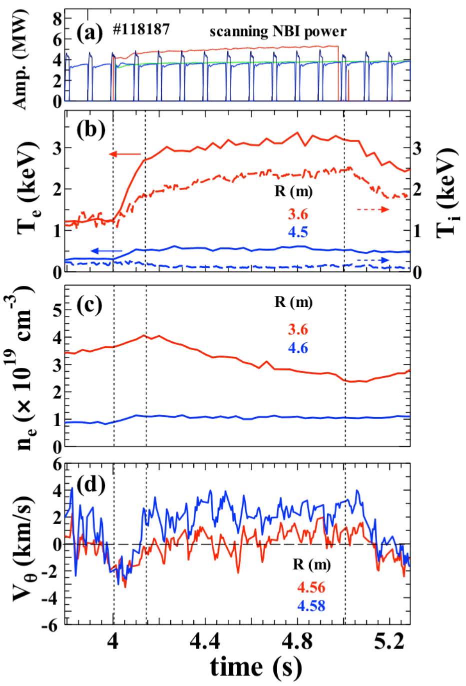

Fig. 1. Time evolution of (a) the NBI powers, (b) the electron temperature (T_e) and ion temperatures (T_i), (c) the electron density (n_e), and (d) the poloidal rotation velocity (V_θ) in the LHD.

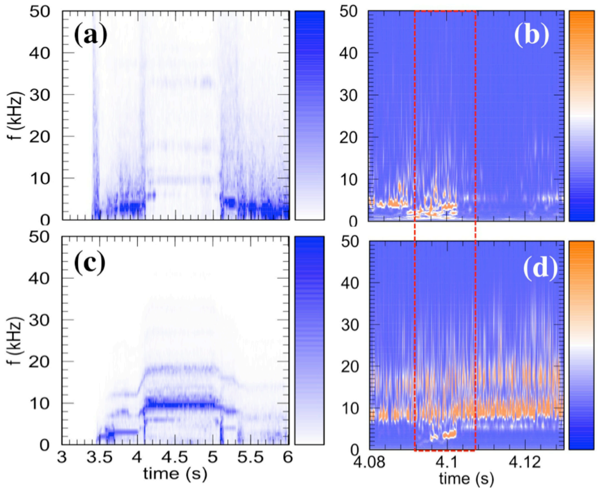

Fig.2. Temporal evolutions of (a) power and (b) wavelet spectrum of the density fluctuations at the edge plasma region (R ≃ 4.6 m), and (c) power and (d) wavelet spectrum of the magnetic fluctuations as a function of frequency.

negative to positive value at the transition timing. Usually, the poloidal rotation velocity corresponds to the E_r, since the contribution of the toroidal rotation velocity to the E_r is much smaller than that of poloidal rotation velocity [5]. Therefore, it is confirmed that the transition from negative E_r to positive E_r can be controlled by the scanning NBI power experiment in the edge plasma region.

3. Results and Discussion

The density fluctuations are obtained with a microwave reflectometer in edge plasma region. The low frequency fluctuations (f < 20 kHz) are suddenly reduced at the transition timing, as shown Fig. 2(a), (b). On the other hand, the low frequency of magnetic fluctuation is enhanced at the transition timing, which are obtained with a magnetic probe, as shown Fig. 2(c). Interestingly, the magnetic fluctuation with $f \simeq$ 2–5 kHz has suddenly appeared at the transition timing, as shown Fig. 2(d).

Figure 3 (a) demonstrates the auto-power spectrum of magnetic fluctuation at the transition timing, the peak of fluctuations with $f \simeq$ 2–5 kHz are clearly observed. The cross-coherence spectrum between the density and magnetic fluctuations is shown in Fig. 3(b), the fluctuation with $f \simeq$ 2–5 kHz also has a significant level. This implies that the magnetic fluctuation with $f \simeq$ 2–5 kHz has strong relation with the density fluctuation in edge plasma region. In Fig. 3(c), (d), the contour plot of the cross-correlation function of the magnetic fluctuation with $f \simeq$ 2–5 kHz for the poloidal and toroidal direction is indicated during the transition timing. The cross-correlation between signals from magnetic probes using the 12-channel poloidal

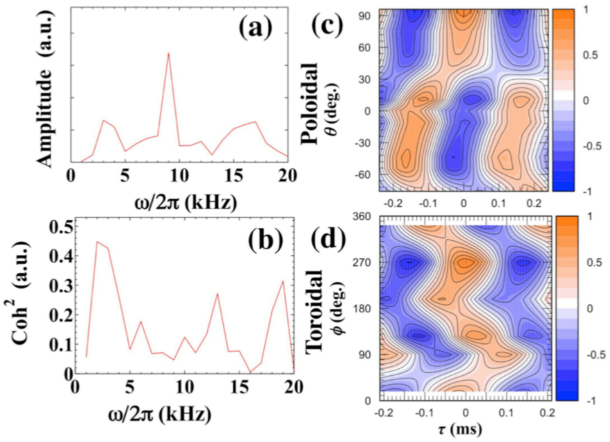

Fig.3. (a) Auto-power spectrum of magnetic fluctuations, and (b) cross-coherence spectrum between density and magnetic fluctuations, and contour plot of the cross-correlation function of the magnetic fluctuations with $f \simeq$ 2–5 kHz for (c) poloidal and (d) toroidal directions at $t \simeq$ 4.1s.

array shows the poloidal mode number m = 2, and the 6-channel toroidal array shows the toroidal mode number n = 2.

Furthermore, it is confirmed that the amplitude of H_α signal is suddenly enhanced, corresponding to the appearance of magnetic fluctuation with $f \simeq$ 2–5 kHz.

4. Summary

We have observed a new type of MHD mode when a transition of the radial electric field occurs in the edge plasma region. Their spatiotemporal structure is characterized by a low frequency of $f \simeq$ 2–5 kHz, a poloidal or toroidal mode number of m=2/n=2. In addition, it is found that the amplitude of H_α signal is suddenly enhanced, corresponding to the appearance of magnetic fluctuation with $f \simeq$ 2–5 kHz.

Acknowledgments

The authors acknowledge all the members of LHD experiment group for their assistance. This research was supported by a Grant-in-Aid for Scientific research (No. 23246164) of MEXT japan.

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