§61. Study of Anomalous Transport of Fast Ions Induced by Interaction with AEs Using Hybrid Directional Langmuir Probe (HDLP)

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Anomalous transport of energetic particles induced by energetic-particle-driven Alfven eigenmode is one of the most important issues in burning plasma experiments such as ITER and is intensively studied in tokamak and helical devices. In order to understand the characteristics of energetic-particle-driven Alfven eigenmode, a set of Mirnov coils which can measure three-dimensional components of magnetic fluctuation was mounted on hybrid directional Langmuir probe (HDLP) in 13th LHD experiment campaign. The HDLP is a directional probe for measurement of co-directed fast ions at the outboard side of almost vertically elongated cross section in LHD [1]. The Mirnov coils were tilted along the magnetic field line at the probe position, and have sensitivities to parallel component (mainly toroidal component:$B^*_{\rm tor}$) and two perpendicular component; one parallel to the last closed magnetic surface (LCFS)(mainly poloidal component:$B^*_{\rm pol}$) and the other perpendicular to the LCFS(mainly radial component:$B^*_{\rm r}$). The increases of lost fast ions induced by bursting Alfven eigenmodes were observed with this HDLP, so far. In this fiscal year, it is progressed that the magnetic fluctuation and the response of fast ion flux were analyzed.

Figure 1 shows a typical discharge with bursting Alfvenic activities in the condition with magnetic axis of 3.70m, magnetic strength on the axis of -0.75T. Several modes were destabilized in different frequency ranges, and the nonlinear time evolutions were observed in complex manners. The response (increase) of fast ion flux observed with HDLP was observed. The magnetic fluctuation and fast ion flux show significant coherence in the lower frequency range than 70 kHz, while coherence is not clear in high frequency range. The coherence is considered to show the strength of interaction between the magnetic fluctuation and fast ions. The low frequency branches showing the clear coherence are considered to be located near the edge (close to the HDLP location). The high frequency ones without clear coherence are considered to be located in the core region (far from the HDLP location).

The phase relation between the magnetic fluctuation and the fast ion flux is important parameter indicating the strength of coupling between them. When the fast ions oscillates with the magnetic field with the same phase (zero phase), the frozen-in condition is completely satisfied, therefore the total and time-averaged energy transfer between them are zero. The finite phase corresponds to the resonant coupling and the existence of the net energy transfer between the mode and fast ions. The finite phase between the energetic particle mode (EPM) and fast ions was observed inside the last closed flux surface (LCFS) in Compact Helical System (CHS) plasma, and the energy transfer from fast ions to the EPM was identified [2]. In present experiment in LHD, the phase is $\delta\theta \sim 0.3\pi$. This finite phase seems to indicate the strong coupling between the magnetic fluctuation and fast ions, and the net energy transfer exists from the fast ions to the mode.

However, the HDLP position is several centimeter outside of LCFS in the LHD experiment, which is the different point from CHS experiment. The main interaction between the mode and fast ions is considered to be located inside the LCFS. The coupling between them at the outside of the LCFS should be discussed carefully. Further investigation is necessary to identify the interaction between the magnetic fluctuation and fast ions.

1) K. Nagaoka, K.Y. Watanabe, M. Osakabe, et al., Rev. Sci. Instrum. **79**, (2008) 10E523.

2) K. Nagaoka, et al., Phys. Rev. Lett. **100** (2008) 065005.

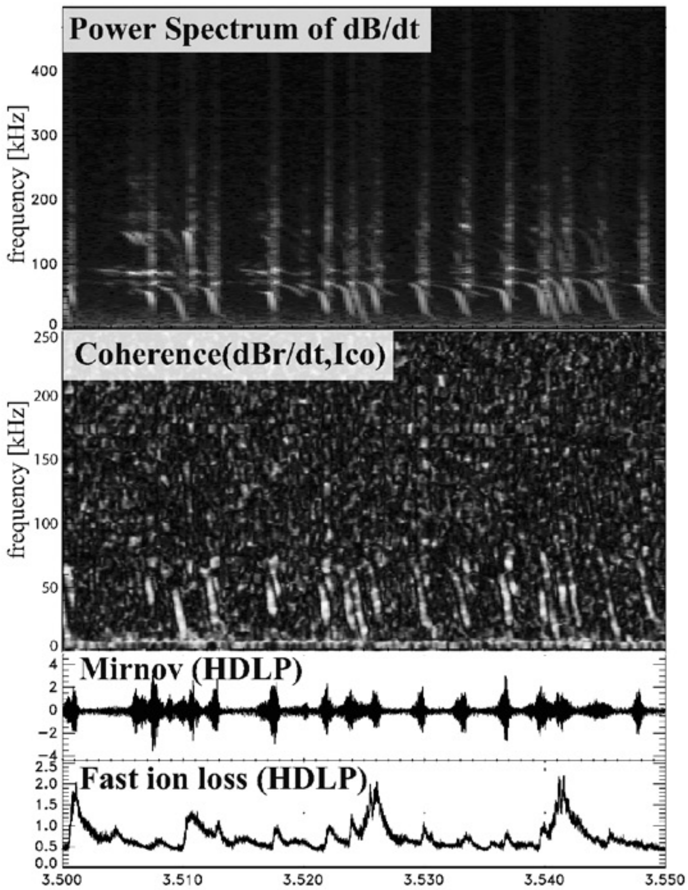

Fig. 1: The power spectrum of magnetic fluctuation, the coherence between the magnetic fluctuation and fast ion flux, the Mirnov signal and the fast ion loss flux measured with HDLP.