§39. Observation of MHD Mode with Higher Harmonics in the Edge Plasma Region of LHD

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MIR uses the radar technique for the measurement of the electron density profiles and its fluctuations with good time and spatial resolutions by probing the density-dependent cutoff layer in the plasma. In this work, we have observed a magnetohydrodynamic (MHD) mode by using the MIR in LHD[1-2]. This mode appears in the edge plasma region during perpendicular ion heating (NBI or ICRH), and it is accompanied with higher harmonics. Similar mode has been observed near the edge transport barrier region in H-mode plasmas, and is named the edge harmonic oscillation (EHO). However, the present mode appears without H-mode or transport barrier. High energy ions may play a role to destabilize this mode besides the pressure gradient at the rational surface, where this mode is localized.

A typical example of this MHD mode is shown in Fig.1. The LHD configuration is as follows: R_{ax} = 3.575 m, a_{av} = 0.6 m, B_t = 2.870 T, γ = 1.254 and B_q = 100 %. The plasma is basically heated by the co-injected NBI with the power of 8.6 MW and the counter-injected NBI with the power of 3.8 MW. Note the time resolution of Ti in Fig.1 is 0.1 sec. Fig.2 shows the time evolution of the FFT power spectrum of the MIR signal and the magnetic probe signal. At t=1.45 sec, when the plasma is heated by NBI in the co, the counter and the perpendicular directions, other mode appears in the FFT power spectrum of the MIR signals. In the FFT power spectrum of the magnetic fluctuations, this mode appears at t = 1.3 sec.

Fig.1 (e) shows the MIR and the magnetic signals showing the mode, which look semi-sinusoidal oscillation. This mode is accompanied with several higher harmonics. The frequency of this mode starts dropping right after turning off the perpendicular injected NBI with the power of 3.2 MW at t = 1.7 sec. Right after turning on the ICRH with the power of 1.9 MW, the mode with several harmonics appears. So, the perpendicular ion heating looks playing an important role to destabilize this mode. However, the present mode is sometimes observed during the tangential NBI heating in the case of low density and high temperature plasma.

The mode analysis of the magnetic probe signal provides the mode numbers of m/n = 3/4 at t = 1.6 sec and 1/1 at t = 2.3 sec, where m and n are the poloidal and the toroidal mode numbers. Since the magnetic probe signal is not strong enough to identify the mode numbers, the mode numbers is estimated from MIR signals. MIR ch.2 and MIR ch.8, which detect the frequency of 63 GHz, are poloidally separated with the distance of 84 mm at R = 4.55 m. It corresponds to θ = 4.9 degrees. The phase difference of the fundamental mode can be obtained from the cross power spectrum of these channels. At t = 1.55 sec, the phase difference ($\Delta\theta$) is about 14.8 degrees. So the poloidal mode number is m = 3, and the error is about 1. The mode number of higher harmonics is proportional to the frequency. This mode is localized in the narrow layer with the width of 3 cm near the ι = 4/3 surface in the edge plasma region.

This mode is destabilized by both fast ions and the pressure gradient at the rational surface. Frequency of this mode is much less than that of known Alfvèn eigen modes and is similar to the ion diamagnetic frequency. However, we have not obtained a clear evidence of the fishbone instability yet. This mode looks similar to EHO in H-mode plasma, but no clear transport barrier is observed. Increment of particle transport without hazardous edge localized mode (ELM) is a big issue for fusion reactor. MHD modes near the edge like EHO and the present mode might be a key to solve this problem. Therefore further investigation of this type of mode is required.

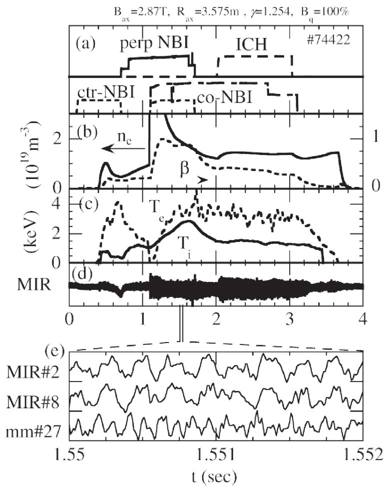

Fig. 1 The time evolution of (a) the heating power, (b) and (c) plasma parameters, and (d) the MIR signal.

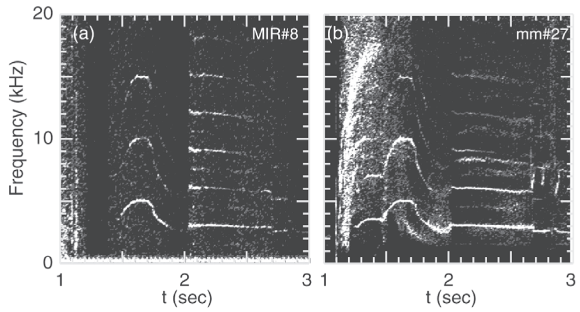

Fig. 2 The power spectrum of (a) the MIR signal and (b) the magnetic signal.

1) Yamaguchi, S., et al., Rev. Sci. Instrum. **77**, (2006) 10E930
2) Yamaguchi, S., et al., Plasma Fusion Res. **2**, (2007) S1038