§54. MHD Instabilities Driven by Suprathermal Electrons Produced by Second Harmonic ECRH in LHD

Isobe, M., Tokuzawa, T., Toi, K., Ogawa, K.
(Dept. Energy Eng. Sci., Nagoya Univ.), Muto, S., Kubo, S., Yoshimura, Y., Shimizu, A., Osakabe, M., Kobayashi, S. (IAE, Kyoto Univ.),
LHD Experiment Group

Fast-particle driven MHD instabilities such as fishbone modes and Alfvénic modes are of great concern in current magnetically confined fusion plasma experiments since those instabilities may lead to anomalous transport of D-T produced alphas in a future reactor or reactor-relevant plasma such as ITER. Experiments concerned with this theme have been carried out by means of beam ions and/or ICRH-produced fast ions. This is because those fast ions are commonly used in auxiliary heating of target plasmas and are super-Alfvénic in many cases. It should be noted that according to theories, suprathermal electrons are also capable of destabilizing those instabilities since excitation of those instabilities depends on precessional drift frequency of charged particle (case for trapped particle), not on mass [1]. After MHD instabilities driven by suprathermal electrons were recognized in DIII-D [2] and Compass-D [3], experiments for corroboration have been performed in several toroidal devices. In regard to helical/stellarator, MHD modes associated with trapped suprathremal electrons produced by second harmonic ECRH have been recognized in HSX [4] and CHS [5]. In LHD, experiments based on the method used in HSX and CHS was initiated in 2008.

A typical spectrogram of magnetic fluctuation in fairly low-density second harmonic ECRH plasma of LHD (n_e<1.0x10^{18} m^{-3}) is shown in Fig. 1. B_t and R_{ax} were 3.6 m and +1.51 T(CW), respectively. ECR waves at f_{RF}/P_{RF} of 82.7 GHz/0.19 MW, 84 GHz/0.35 MW and 77 GHz/0.62 MW were injected in this shot. Resonance layer position for 77 GHz was placed at the valley of two helical winding coils in anticipation of substantial creation of helically trapped suprathermal electrons. $T_e(0)$ measured with Thomson scattering diagnostic was about 10 keV or a bit more. After t=0.4s, magnetic fluctuations can be seen in the frequency range less than 20 kHz. The mode frequencies are extremely lower than TAE gap frequency expected in MHz range for this shot. The mode frequencies tend to decrease as n_e (T_e) increases (decreases). It is hard to say mode numbers because of the weak amplitude but it is n≠0 mode. The Ge detector for hard X-ray diagnostic with perpendicular line of sight shows fairly developed perpendicular X-ray energy spectrum up to ~300 keV in the n_e region < 1.0x10^{18} m^{-3} whereas it does not in the region > 1.0x10^{18} m^{-3}. It should be noted that the magnetic fluctuation seen in Fig. 1 was not observed in n_e > 1.0x10^{18} m^{-3}. Judging from the mode frequency range, possible candidates to explain the observed low frequency mode might be geodesic acoustic mode (GAM), beta-induced Alfvén eigenmde (BAE) and beta-induced Alfvén-acoustic eigenmodes (BAAE), in addition to energetic-particle modes (EPM). The time evolution of the mode frequency suggests that BAAE and GAM seem to be possible candidates. Fig. 2 shows T_e versus MHD frequencies expressed as a function of sound velocity C_s for each mode. In this calculation, T_i was fixed to be 0.5 keV measured with E//B-NPA in similar discharges and pure hydrogen plasma was assumed. The observed mode shown in Fig.1 is not classified into GAM because the frequency is different and it is n≠0 mode. In the viewpoint of frequency range, BAAE [6] looks a most likely candidate to explain the observed low-frequency mode but effect of Doppler shift due to plasma rotation coming from E_r has to be carefully considered. Also, the gap structure for BAAE has to be calculated. Finally, the spectrogram of magnetic fluctuation during modulation of 77 GHz ECR wave is shown in Fig. 3. The fluctuation frequency was significantly changed according to "on/off" state of 77 GHz gyrotron. The change of observed mode frequency is probably associated with the change of plasma temperature.

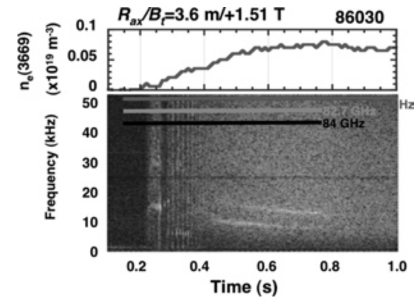

Fig. 1. Magnetic fluctuations observed in fairly low-density 2nd harmonic ECRH plasma of LHD.

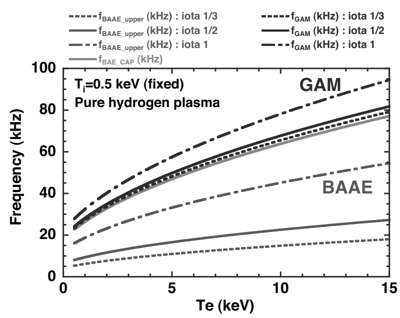

Fig. 2. MHD frequencies as a function of T_e.

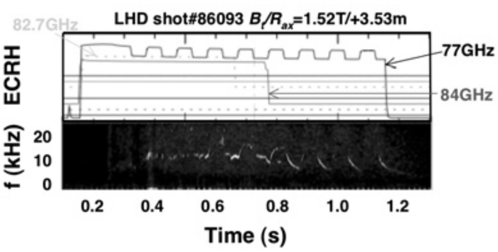

Fig. 3. Spectrogram of magnetic fluctuation during "on/off" modulation of 77 GHz ECR wave.

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3) Valovič, M. et al. : Nucl. Fusion **40** (2000) 1569.
4) Deng, C.B. et al. : Phys. Rev. Lett. **103** (2009) 025003.
5) Isobe, M. et al. : accepted for publication in Nucl. Fusion.
6) Gorelenkov, N.N. et al. : Phys. Lett. **A370** (2007) 70.