§4. Response of Alfven Eigenmodes Driven by Energetic Ions on Electron Cyclotron Heating in LHD

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Energetic-ion-driven Alfven eigenmodes (AEs) may degrade the performance of magnetically confined fusion plasmas and is considered to become more serious in fusion burning plasmas. Recently, stabilized responses of AEs to electron cyclotron heating (ECH) were observed in DIII-D tokamak[1)] and TJ-II heliac[2)]. In DIII-D, reversed shear Alfven eigenmodes (RSAEs) is stabilized when ECH with the focal point near the location of q minimum is applied. In TJ-II heliac, two step responses of AEs were observed. One is transition from unstable continuous mode to bursting modes with frequency chirping with marginally stable condition[3)], when ECH is applied with off-axis resonance condition. The other is significant reduction of the mode amplitude observed when the additional ECH is applied. The strongest stabilizing effect was observed with on-axis ECH condition in TJ-II, which is very interesting in contradiction to the DIII-D results. These observations attract much attention from viewpoint of the possibility of external control of AEs in future burning plasmas.

In order to understand the physics mechanism of stabilizing effect, joint experiments were carried out in 17th LHD experimental campaign.

NBI-driven AE's have been produced with the three NB injectors, NB1 and NB3 (co) and NBI2 (counter) in low-field plasmas (1.375 T). We have studied the effect of additional ECH power (three gyrotrons and launchers, all of m with Npar≈0) on the AEs. Plasma density (collisionality) has been scanned by means of additional gas puff.

a) In the first part of the experimental session, each gyrotron (all of them on-axis) has been timed sequentially, stepwise, so as to provide a three-step ECH power scan during the shot. Depending on plasma conditions and applied ECH power, a complex variety of effects over the AEs has been observed. b) In the last part of the session, more clear effects have been measured, applying fully modulated ECH power of all three gyrotrons (in phase) over low-density plasmas. In this scenario, the power deposition radius has been changed to four additional off-axis positions: rho≈ 0.3, 0,45, 0.6 and 0.75.

Figure 1 shows one of the clearest examples found of AE stabilization due to the ECH application. Three ECH pulses are affecting the AE behaviour. The first pulse (only one gyrotron during most of the time) produces a weak stabilizing effect (to be confirmed by RMS analysis). The second and third pulses, with full ECH power, produce a strong stabilizing effect (with some delay, probably related to the corresponding slowing-down time) on the AE with frequency close to 260 kHz. Interestingly, in correlation with the higher-frequency mode stabilization, another (previously weaker) AE, with lower frequency, around 210 kHz, appears to be destabilized (also with some time delay. Analyses of the toroidal mode numbers gives values of n=-1 and n=0, respectively. Further analyses are needed to understand the origin of this clear correlation.

1) M.A. Van Zeeland, et al., Plasma Phys. Control. Fusion, 50, 035009 (2008).
2) K. Nagaoka, T. Ido, E. Ascasibar, et al., Nuclear Fusion, 53, 072004 (2013).
3) H.L. Berk, B.N. Breizman, et al., Phys. Plasmas 6, 3102 (1999).

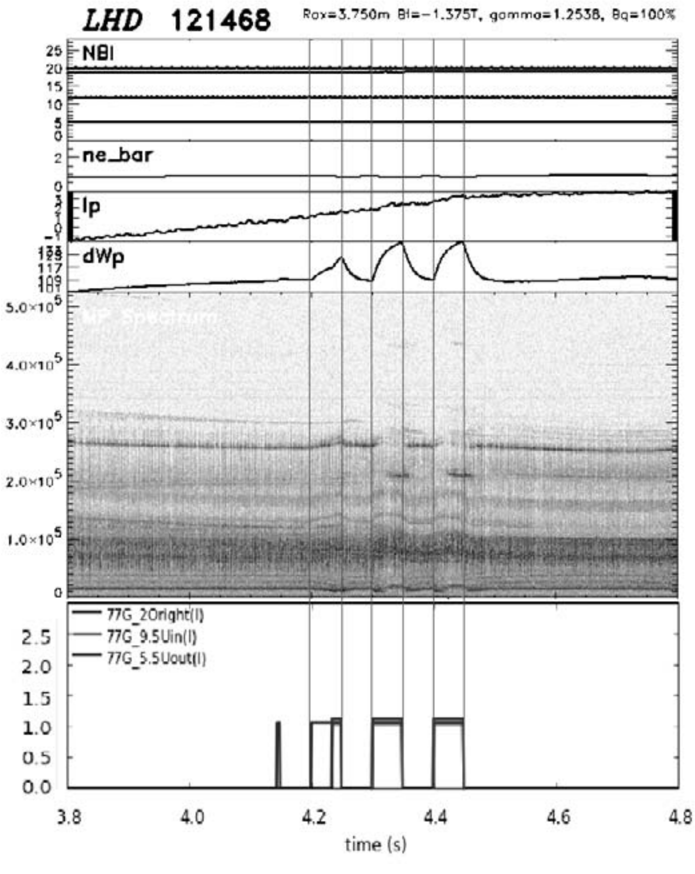

Fig. 1.: Modulated on-axis ECH power (lower box) is applied during the continuous phase of AE activity, produced by NB injectors NB1(co) and NBI3 (ctr) (upper box). Line average plasma density is constant, around 0.8 x 1019 m-3. A clear stabilizing effect is observed in the AE with frequency close to 260 kHz, accompanied by the de-stabilization of a (previously weaker) mode with lower frequency, close to 210 kHz.