§51. Bulk Confinement Improvement Induced by Toroidal Alfven Eigenmode (TAE) Burst

Toi, K., Isobe, M.,
Ogawa, K. (Department of Energy Sci. Eng., Nagoya Univ.),
Osakabe, M., Ohdachi, S., Tanaka, K., Tokuzawa, T.,
LHD Experiment Group

Suppression of energetic ion driven MHD instabilities such as Alfven eigenmodes (AEs) is an important issue toward burning plasma experiments, because they would enhance redistribution and/or loss of energetic alphas born by DT fusion and beam ions injected for current drive. Accordingly, stabilization of AEs and reduction of energetic ion transport are being intensively investigated in many tokamaks. In LHD, AEs and AE-induced energetic ion losses are investigated [1]. On the other hand, detection of Alfven eigenmodes provides us useful information on MHD equilibrium, because the gap structure of shear Alfven spectra is determined by the radial profiles of the rotational transform and ion density. AEs would give us a possibility of MHD spectroscopy. If excited AEs are benign, they are not harmful for energetic ion confinement but can be used as a tool for the MHD spectroscopy. Another positive effect of AEs is that AE-induced loss of energetic ions might generate sheared flow that would suppress ambient micro-turbulence [2]. This process may lead to the formation of transport barrier. In tokamaks, this possibility was reported from AUS where the formation of internal transport barrier was triggered by energetic ion drive fishbone instabilities [3]. So far, the possibility is not so clear in other tokamak plasmas.

In LHD, however, an interesting event was observed in relatively high beta plasmas with TAE bursts in the inward shifted configuration of R_{ax}=3.6m at lower toroidal field $|B_t| \le 0.6$T, as shown in Fig.1. Each TAE bust expels energetic ions outside the confinement region. Just after the TAE burst, line averaged electron density, plasma stored energy expressed as the volume-averaged beta $<\beta_{dia}>$ and soft X-ray emissions jump up, having a sharp drop and slow recovery of Hα emission. Note that the short drop in $<\beta_{dia}>$ at the TAE burst reflects the energetic ion loss, because the diamagnetic loop can respond to energetic ions having finite velocity component perpendicular to the magnetic field line. Figure 2 shows the radial profile of the relative change of the soft X-ray intensity for that just before TAE burst. The barrier like structure seems to develop from the $\iota/2\pi$=1 surface. These data indicate a transient improvement of bulk plasma confinement triggered by TAE bursts, through transport barrier formation. Moreover, the phase velocity of density fluctuations of micro-turbulence measured by CO$_2$ laser phase contrast imaging increases transiently near the plasma edge region in the ion diamagnetic direction during TAE burst, having more than 20 % reduction of the density fluctuation amplitude (Fig.3). The transient increase in the phase velocity suggests the change of the radial electric field caused by the loss and/or re-distribution of co-passing energetic ions. In this shot, however, the improved confinement state is sustained only for a short time (less or nearly equal to global energy confinement time) in contrast to usual ETB formation through L-to-H transition[4]. A feedback process which will move plasma into a certain sustaining process from an initial state trigger by TAE burst might not complete.

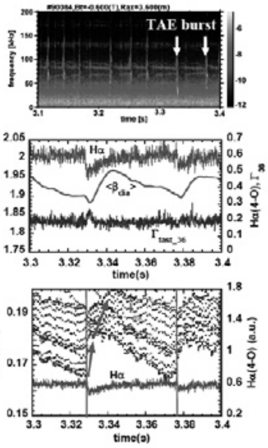

Fig.1 (top) Spectrogram of magnetic probe signal in the time frame of t=3.1s to 3.4s, (middle) Zoomed time evolutions of $<\beta_{dia}>$, Hα emission and energetic ion loss flux in the window of t=3.3s to 3.4s , and (bottom) Soft X-ray emissions I_{sx} from edge (<r>/<a> ~0.8) to interior (<r>/<a>~0.2), respectively.

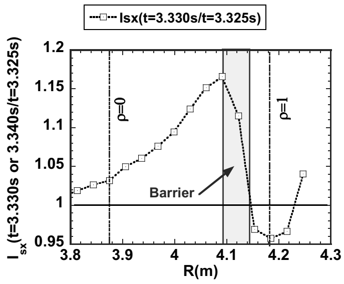

Fig.2 Radial profile of the relative change of soft X-ray emission for that just before the TAE burst(t=3.325s). The barrier location formed by TAE burst is indicated with a shaded zone.

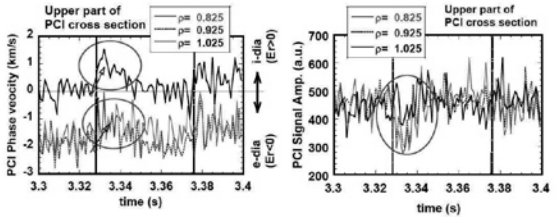

Fig.3 Time evolutions of the phase velocity and amplitude of density fluctuations measured with CO$_2$ laser phase contrast imaging.

[1] K. Toi, M. Isobe, M. Osakabe et al. to be published in Chap.4, Fusion Sci. Technol..
[2] K.L.Wong et al., Nucl. Fusion **45**, 30 (2005).
[3] S. Günter et al., Nucl. Fusion **41**, 1283 (2001).
[4] K. Toi, F. Watanabea, S. Ohdachi et al., to be published in Chap.3, Fusion Sci. Technol.