§53. Observation of Energetic-Ion Losses Fluctuating with the Same Frequency as Toroidicity-Induced Alfvén Eigenmodes in LHD

Isobe, M., Ogawa, K. (Dept. Ener. Sci. Engi., Nagoya Univ.), Toi, K., Spong, D.A. (ORNL), Osakabe, M., LHD Experiment Group

To realize self-sustained D-T burning plasmas, fusion-born energetic alphas should be confined long enough to heat the bulk plasma. In addition to effective alpha heating, losses of alphas have to be suppressed down to acceptable level to prevent plasma-facing components from the localized damage due to the impact of escaping alphas. Better understanding of transport and loss processes of these energetic ions is therefore essentially required. The scintillator-based lost fast ion probe (SLIP) was lately developed and installed at the outboard side of a horizontally elongated poloidal cross section of LHD so as to study behavior of escaping beam ions having co-going passing and transitional orbits while Alfvénic modes excited by beam ions are present. The SLIP can provide gyroradius, i.e. energy and pitch angles of escaping beam ions simultaneously as a function of time [1].

Fig. 1 shows a typical time trace of neutral beam (NB)-heated hydrogen discharge with toroidicity-induced Alfvén eigenmodes (TAE) [2]. The magnetic axis position and toroidal field strength are R_{ax} of 3.6 m and B_t of -0.6 T, respectively. In this shot, three NBs (H^+) with injection energy of 180 keV were tangentially injected. The ratio of initial beam ion velocity to the Alfvén velocity was about 2. The volume-averaged beam ion beta value $<\beta_h>$ is estimated to be ~ 1 % and is comparable to the plasma beta value $<\beta>$. Strongly excited TAEs with m/n=~1/1 and resistive interchange modes (RICs) with m/n=1/1 can be seen in quasi-stationary phase, i.e. 2.8 s≤t≤3.2 s. Here, m and n represent poloidal and toroidal mode numbers, respectively. Note that TAEs and RICS often coexist in the parameter range shown above. Shear Alfvén continua (n=1) calculated by STELLGAP code [3] for the discharge shown in Fig.1 is shown in Fig. 2a. A TAE eigenfunction was also calculated using AE3D code [4] for m=0~10 with the assumption of n_i=n_e and was found in experimentally observed frequency range as shown in Fig. 2b. This TAE is the odd parity mode and has the peak of the eigenfunction at r/a~0.6.

An interesting observation is that experimentally observed high-frequency fluctuations of loss rate to SLIP Γ_{SLIP} of co-going beam ions are correlated with the TAE mode frequency (~70 kHz). Fig. 3 shows time traces of Γ_{SLIP} and the spectrogram of the coherence obtained with correlation analysis between Γ_{SLIP} and Mirnov coil signal [5]. High-frequency beam ion loss fluxes correlated with TAE are often observed in energy E and pitch angle χ(=atan($v_{//}/v$)) range of E/χ=~180 keV/45-55 degrees. Also, the analysis shows that escaping beam ions at E/χ of 6-23 keV/25-35 degrees fluctuate in the TAE frequency range. This observation suggests that co-going beam ions play an important role in exciting the TAE in the plasma shown in Fig.1. The similar phenomena are also observed in charge-exchanged fast neutrals measured with E//B-NPA lately improved in time resolution [6].

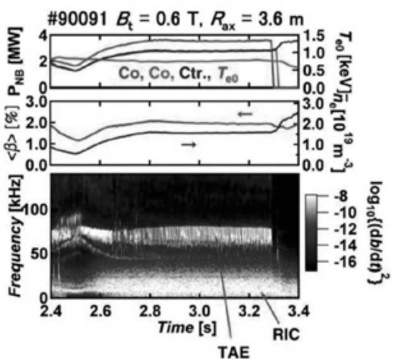

Fig. 1. Typical time trace of NB-heated discharge with TAE (m/n=~1/1) in LHD.

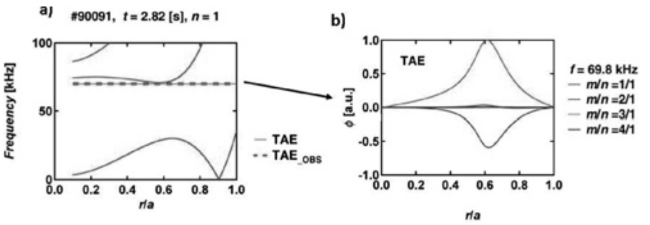

Fig. 2. a)Shear Alfvén spectra (n=1) calculated by the STELLGAP code. b)Eigenfunction of the TAE mode calculated by the AE3D code.

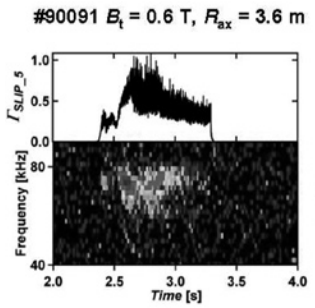

Fig. 3. Beam ion loss rate to SLIP Γ_{SLIP} at E/χ of ~180 keV/45-55 degrees (the above figure) and spectrogram of the coherence γ between Γ_{SLIP} and Mirnov coil signal (the bottom figure).

1) Ogawa, K. et al.: J. Plasma Fus. Res. SERIES **8** (2009) 655.
2) Chen, C.Z. and Chance, M.S.: Phys. Fluids **29** (1986) 3695.
3) Spong, D.A. et al.: Bull. Am. Phys. Soc. **44** (1999) 215.
4) Spong, D.A. et al.: Phys. Plasmas 17 (2010) 022106.
5) Ogawa, K. et al.: accepted for publication in Nucl. Fusion.
6) Osakabe, M. et al. : Proc. of 11th IAEA TM on Energetic Particles in Magnetic Confinement Systems, 21-23, Sep. 2009 Kyiv, Ukraine. **IT-5**.