§37. Discovery of Reversed Shear Alfvén Eigenmodes and Geodesic Accoustic Modes Excited by Energetic Ions in a Helical Plasma

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Reversed shear Alfven Eigenmode (RSAE) excited in a reversed magnetic shear (RS-) tokamak has received much attention [1], because the RS-configuration achieves high performance plasma. Recently, in LHD a RS- configuration was realized by generating a non-monotonic rotational transform ($\iota/2\pi$) profile with intense counter neutral beam current drive. Figure 1 shows spectrograms of magnetic probe signal in the RS plasma [2, 3]. Two types of coherent magnetic fluctuations up to ~100 kHz are clearly identified, where the beam ion pressure is significant. One is a set of modes of which frequency chirps up or chirps down in about 0.3s, and the other is a mode with almost constant frequency (~18kHz). All the former modes have the same toroidal mode number n=1, and the latter has n=0. We have calculated cylindrical n=1 shear Alfvén (SA-) spectra using the experimentally obtained radial profiles of $\iota/2\pi$ and electron density, taking into account impurity content. The time evolution of the minimum or maximum of AS-spectra agrees well with the observed frequency of the m~3/n=1 fundamental mode indicated with arrows in Fig.1, except around t~2.8s where the observed frequency stays the minimum of ~20 kHz. The minimum is close to the geodesic acoustic mode (GAM) frequency evaluated including energetic ion pressure [4]. This fact is consistent with the theory of RSAE developed for RS-tokamak [5]. In conclusion, the n=1 frequency-sweeping fundamental mode is energetic ion driven RSAE identified for the first time in a helical plasma. On the other hand, the frequency of n=0 mode corresponds to GAM frequency. This mode is thought to be energetic ion driven GAM which was observed for the first time in a helical plasma. These RSAE and GAM were also detected with microwave interferometry, as shown in Fig.2. Moreover, potential fluctuations of these modes were detected by heavy ion beam probe. As shown in Fig.3, the amplitude reaches very high level, ~0.9 kV, which is comparable to electron temperature. The multitude of n=1 modes of which frequency is shifted by GAM frequency are generated through nonlinear coupling between these RSAE and GAM, which is seen in Figs. 1 and 2 [2,3].

[1] Fasoli, K. et al., Nucl. Fusion **47**, S264 (2007).
[2] Toi, K. et al., *10th IAEA Technical Meeting on Energetic Particles in Magnetic Confinement Systems*, Kloster Seeon (Germany), 8-10 Oct., 2007.
[3] Toi, K. et al., *35th EPS Plasma Physics Conference*, Crete (Greece), 9-13 June 2008, paper No.P1.054.
[4] Winsor, N. et al., Phys. Fluids **11**, 2448 (1968).
[5] Breizman, B.N. et al., Phys. Plasmas **12**, 112506 (2005).

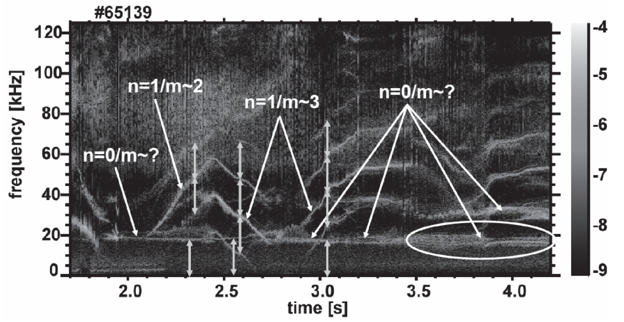

Fig.1 Spectrogram of magnetic probe signal. The length of vertical arrows is equal to the n=0 mode frequency, by which n=1 modes driven by nonlinear coupling between RSAE and GAM are identified. An ellipse indicates the splitting of n=0 mode spectrum, which is a typical signature of energetic ion driven mode.

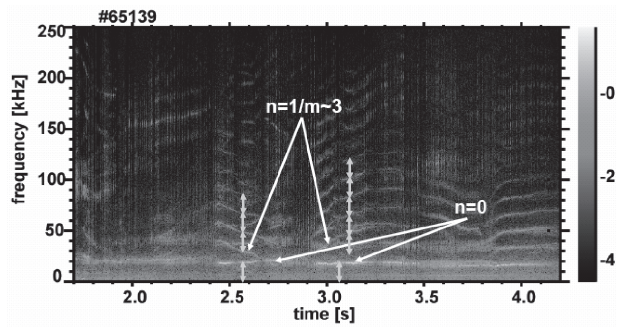

Fig.2 Spectrogram of microwave interferometry signal in a shot shown in Fig.1. The length of vertical arrows is equal to the n=0 mode frequency.

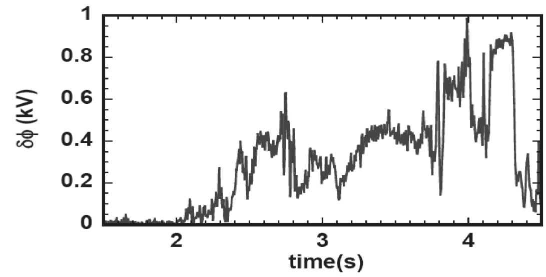

Fig.3 Time evolution of the potential fluctuation amplitude of GAM driven by energetic ions.