§4. Measurement of Damping Rates of Stable TAEs Excited by Application of External Alternating Magnetic Perturbations in CHS

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In a burning plasma, so-called toroidal Alfvén eigenmodes (TAEs) which can exist in a spectral gap formed by poloidal mode coupling due to the toroidicity of the magnetic configuration are concerned to be the most dangerous AEs, because weak continuum damping is expected. An active sensing method for direct measurement of the damping rate of AEs was successfully performed in the JET[1] or Alcator C–mod[2] tokamaks, or the Compact Helical System (CHS) heliotron/torsatron[3].

In CHS, we have tried to excite AEs and measure the damping rates by applying alternating magnetic field perturbations with a couple of electrodes inserted in the plasma edge[4]. Two electrodes are placed 180 degrees apart in the toroidal direction, in order to specify the toroidal mode numbers of the applied perturbation fields. Small magnetic field perturbations perpendicular to the confinement magnetic field line are generated by an alternating in-phase current along the field line induced by these electrodes. This electrode technique can effectively excite shear Alfvén waves.

A typical result of the experiment is shown in Fig. 1. The frequency of applied external perturbation was swept from 10 to 300 kHz in 0.1 s to search for expected TAE frequencies, using the single electrode. The transfer function G(ω) as a plasma response was experimentally evaluated with the ratio of the magnetic probe signal to the electrode current signal. In this picture, two resonant peaks labeled as A and B are obviously observed in the swept frequency range. Eigenfrequencies and damping rates for the observed resonances were successfully derived by numerical fitting of experimentally obtained transfer function G(ω) to a model function of a general viscous damping system, as shown in Fig.1. That is, the eigenfrequency and damping rate are 172kHz and 12% for the resonant mode A, and 276kHz and 12% for the mode B, respectively. The observed eigenmodes A and B , were respectively identified as n=2, m=2+3 TAE and n=2, m=3+4 TAE through comparison with the calculated shear Alfvén spectra (Fig.2(a)). These TAE gaps are located near the plasma edge, as seen from Fig.2(a).

The eigenfunctions of these gap modes were also calculated with the AE3D code[5], as shown in Fig.2(b)(c). The spiky structures of the eigenfunctions indicate strong interaction of the gap modes with shear Alfvén continua $\omega = k_{//}\upsilon_A$. The continuum damping due to the above–mentioned Alfvén resonance is thought to be a dominant damping mechanism in the plasma edge region where electron Landau damping and radiative damping are estimated to be fairly small.

[1] A. Fasoli *et al.* : Nucl. Fusion **47**, S264 (2007)
[2] J. A. Snipes *et al.* : Plasma Phys. Control. Fusion **46**, 611 (2004)
[3] G. Matsunaga *et al.* : Phys. Rev. Lett. **94**, 225005 (2005)
[4] T. Ito *et al.* : submitted to Phys. Plasmas (2009).
[5] D. A. Spong and Y. Todo : presented at the 49th Annual Meeting of the Division of Plasma Physics, Orlando, Florida, 2007

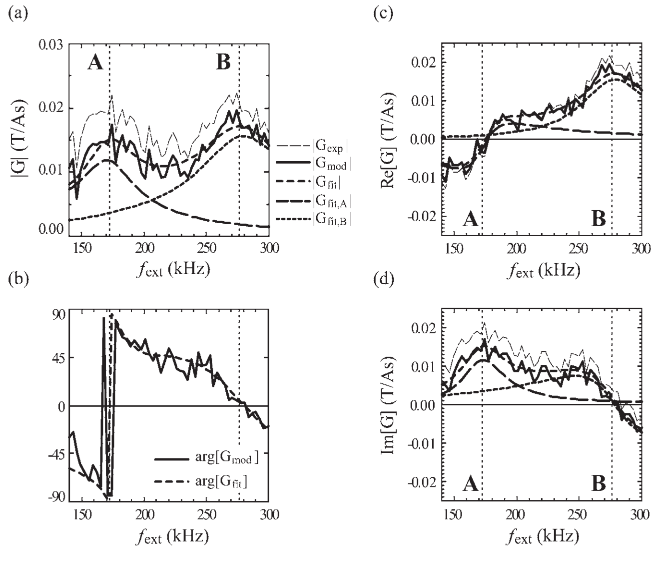

Fig. 1 Experimentally obtained (labelled G_{exp}) and fitted (labelled G_{fit}) transfer functions, shown as a function of the driving frequency *f*ext. The solid curve labelled G_{mod} indicates the transfer function that "noise" components were removed. The curves labelled $G_{fit,A}$ and $G_{fit,B}$ indicate the fitted curves for respective mode A and mode B. (a)absolute value , (b)phase (arg(G)), (c)real part and (d) imaginary part of the transfer functions.

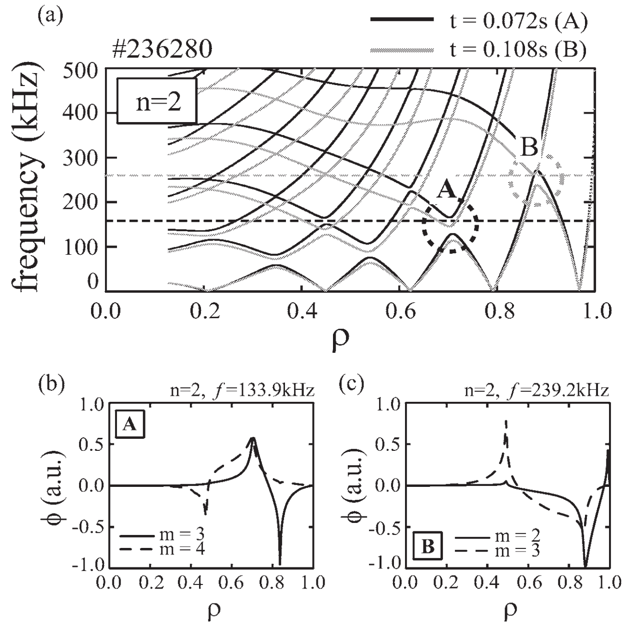

Fig. 2 (a) n = 2 shear Alfvén spectra calculated for the timings when the mode A(black curve) and B(gray curve) were excited. The horizontal broken lines indicate the observed eigenfrequencies of modes A and B. Calculated eigenfunctions of the modes A and B are shown in Figs.(b) and (c), respectively.