§13. Observation of abrupt Destabilization of GAM Associated with Chirping EGAMs in the LHD

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Zonal flow excited by nonlinear coupling of turbulence has attracted much attention in development of nuclear fusion reactors, because it can spontaneously regulate the saturation level of turbulence which induces particles and heat transport in magnetized fusion plasmas. Recent studies have clarified that the geodesic acoustic mode (GAM), which is an oscillatory zonal flow, is excited not only by turbulence but also by energetic particles. The energetic-particle driven GAM (EGAM) is routinely observed in LHD plasmas, and it usually has up-chirping frequency[1].

When the frequency of an up-chirping EGAM approaches twice the ordinary GAM frequency, abrupt excitation of a GAM has been observed in LHD[2], as shown in Fig. 1. The abruptly exited GAM has larger amplitude and a lower frequency than the initially excited EGAM. The phase relation between the GAM and the EGAM shows a common tendency in any events (Fig. 2). The specific phase relation indicates that the abrupt GAM excitation is closely related to the EGAM. The result cannot be explained by well-known driving mechanisms such as nonlinear coupling of turbulence [3] or interaction between energetic particles and a GAM [4]. In addition, the violation of the Manley-Rowe relation indicates that the excitation is not caused by a simple parametric coupling. Thus, the observed phenomenon is caused by a new excitation mechanism of the GAM.

A candidate mechanism of the abrupt excitation of the GAM is proposed in Refs. 5 and 6, in which a subcritical instability of the GAM is shown to be driven by a cooperative collaboration of fluid parametric coupling and kinetic nonlinearity. The phase relation, amplitude, and time scale can be reproduced by the model, quantitatively. Observed nonlinearity of the growth rate and the period doubling also seem to support the proposed nonlinear excitation mechanism. Thus, the experiment would be the first demonstration of the existence of the subcritical instability in magnetically confined plasmas. Since a subcritical instability is one of working hypotheses of the onset of abrupt phenomena such as the sawtooth oscillation and the disruption, this study would identify an experimental path to explore the abrupt phenomena.

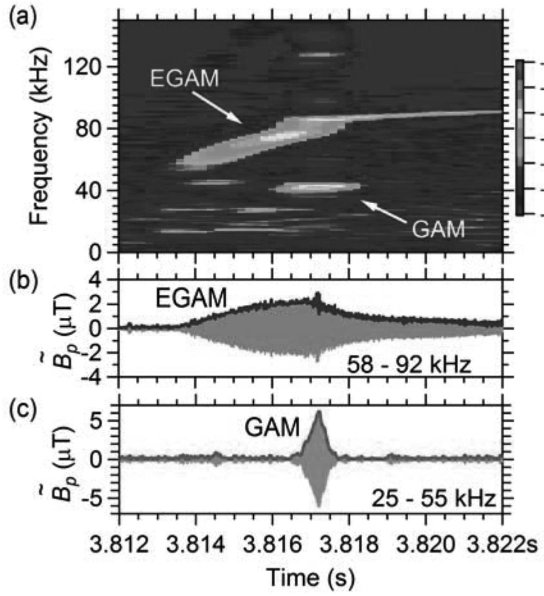

FIG. 1 (a) Spectrogram of a magnetic field fluctuation ($\tilde{B}_p$). (b) and (c) are waveforms of $\tilde{B}_p$ filtered by band-pass filters, and correspond to the EGAM and the abruptly excited GAM, respectively.

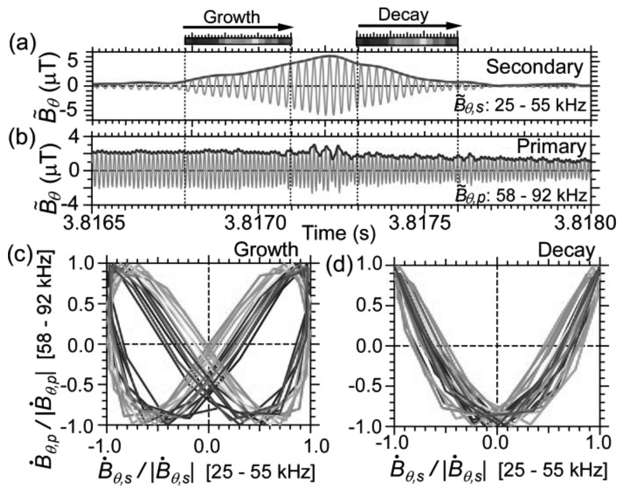

FIG. 2 (a) and (b): magnetic field fluctuation($\tilde{B}_\theta$) associated with the secondary mode and the primary mode, respectively. The bold curves show the envelopes. (c) and (d): Lissajous curves between $\tilde{B}_\theta$ associated with the secondary mode and the primary mode. (c) and (d) correspond to the growth period and decay period, respectively. The color indicates the time, and the corresponding color bars are plotted above (a).

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