9th Asia-Pacific Conference on Plasma Physics, 21-26 Sep, 2025 at Fukuoka

First Detection of Electron Temperature Perturbation Caused by Beta-induced Alfvén Eigenmodes Associated with Locked Magnetic Islands

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The Beta-induced Alfvén Eigenmodes (BAEs) associated with strong tearing mode, so called m-BAE, were widely observed in ohmic plasmas without energetic particles [1-5]. In the magnetic island coordinate system, the m-BAE behaves as a pair of waves propagating in opposite directions poloidally and toroidally, forming a standing wave structure [1]. The standing wave nodes located near the O-point and X-point of the magnetic island [2,4]. Over the past several years, m-BAEs have been primarily detected using magnetic diagnostics. However, having only magnetic information on m-BAEs is insufficient for accurately locating their radial position and for supporting theoretical studies. Hence, there have been recent reports of m-BAE-induced perturbations in the radial electric field [3] and floating potential [4], providing new insights into both the excitation mechanisms of m-BAEs and their radial localization.

In recent experiments on J-TEXT, the electron temperature perturbation δT_e of m-BAE has been firstly detected through Electron Cyclotron Emission (ECE) system. Take discharge #1102236 as an example, a m-BAE with a frequency around 36 kHz is observed in the magnetic signal after the excitation of a $m/n = 2/1$ locked magnetic island using Resonant Magnetic Perturbation (RMP), as shown in Figures 1(b) and 1(d). Simultaneously, an oscillation around 36 kHz is also observed in the spectrogram and the Power Spectral Density (PSD) of the ECE signal, as presented in Figures 1(c) and 1(e). Figure 1(f) shows the coherence analysis between magnetic and ECE signals. The peak at 36 kHz indicating the oscillation detected on ECE is the same as that detected on magnetic signals, i.e., the δT_e of m-BAE. Additionally, multiple experiments indicate that the radial range of the m-BAE detectable by the ECE is very narrow and is located near the magnetic island boundary. By performing a phase scan on the locked magnetic island, we obtained the distribution of m-BAE intensity on the ECE in the toroidal direction relative to the O-point of the magnetic island. It exhibited a standing wave-like structure, with the standing wave nodes located near the O-point and X-point of the RMP induced vacuum magnetic island.

Simultaneous excitation of multiple m-BAEs was also achieved on J-TEXT, each associated with a different RMP-excited locked magnetic island. Take discharge 1104512 as an example, both 2/1 and 3/1 locked magnetic islands are excited simultaneously using RMP, as presented in Figures 2(c). Meanwhile, two m-BAEs associated with these two islands can be observed, as ±2/±1 B1 and ±3/±1 B2 shown 2(b), respectively. This phenomenon confirms that multiple m-BAEs can be excited by multiple islands simultaneously, thus supporting the hypothesis proposed in Ref. [5]. Moreover, in the $n = 2$ magnetic perturbation experiment on J-TEXT, a ±3/±2 m-BAE and ±3/±1 m-BAE can be observed simultaneously, which are speculated to be respectively associated with the locked 3/2 and 3/1 magnetic islands in the discharge.

We will conduct new experiments on the magnetic island-related BAEs on J-TEXT this May. The focus will be on the observation of the electron density perturbation δn_e caused by BAE and the study of factors affecting BAE intensity.

This work was supported by the National Natural Science Foundation of China (12375217) and the National MCF Energy R&D Program of China (No. 2019YFE03010004).

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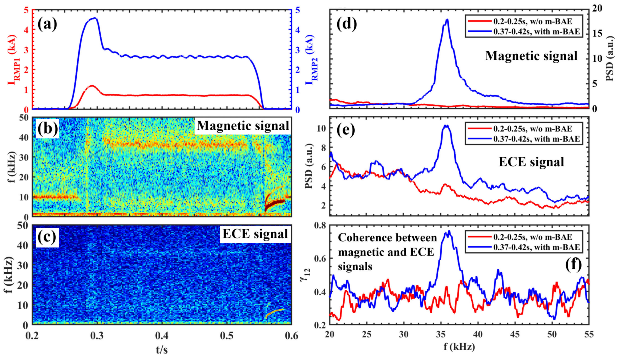

Figure 1. For discharge #1102236: (a) RMP current, (b) magnetic spectrogram, (c) ECE spectrogram, (d) PSD of magnetic signal, (e) PSD of ECE signal, and (f) coherence between magnetic and ECE signals.

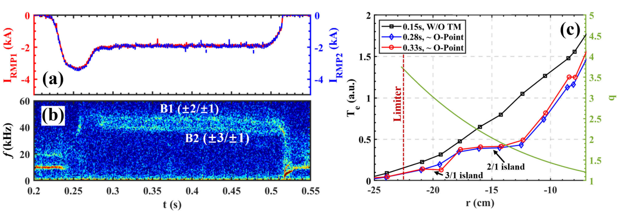

Figure 2. For discharge #1104512: (a) RMP current, (b) magnetic spectrogram, and (c) T_e profile from ECE.