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Destabilization of beta induced Alfvén eigenmode and reversed shear Alfvén eigenmode on HL-2A tokamak

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Researches on beta induced Alfvén eigenmodes (BAEs) and reversed shear Alfvén eigenmodes (RSAEs) have been carried out on HL-2A tokamak. The BAEs can be excited when the q_{min} is beyond or below unity and the poloidal/toroidal mode numbers are *m/n = 3/2* or *m/n = 2/2*, respectively. The radial mode structures can be detected by the multi-channel microwave reflectometer, which is shown in Fig.1. Figure 1(a) presents the cutoff layers of microwave signals determined with the density profile measured by a frequency modulated continuous wave (FMCW) reflectometer. The cutoff layers of the 34–40 GHz microwave are located at the normalized radius of $\rho=0.31$, *0.24*, *0.165*, *0.07*. The density fluctuations $\delta n/n$ are filtered by the numerical pass-band filter with a frequency of 90–95 kHz and the mode is found to highly localize at $\rho=0.07$-*0.26*. The BAEs are confirmed by analyses based on the general fishbone-like dispersion relation (GFLDR) and Alfvén mode code (AMC), which support the experimental measurements in both mode frequencies and radial locations.

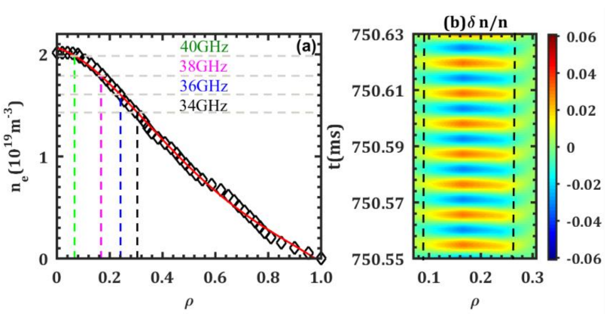

Figure 1: (a) The cutoff layers of 34–40 GHz microwave determined with the density profile measured by the FMCW reflectometer and (b) three dimensional density fluctuation.

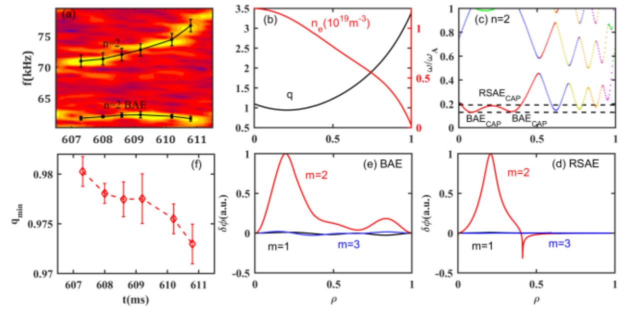

Figure 2: (a)Coexistence of BAE and RSAE. (b) The electron density and safety profile. (c) The Alfvén continuum calculated with n = 2. The corresponding radial mode structure of the RSAE and BAE are given in (d) and (e). (f) The q min deduced from theoretical equation

Coexistence of BAEs and RSAEs makes the direct estimation of temporal evolution of q_{min} from experiments possible. The RSAE frequency can be expressed by the formula $\omega_{RSAE}^2 = \frac{V_A^2}{R^2}\left(n - \frac{m}{q_{min}}\right)^2 + \omega_{BAE}^2 + \delta\omega^2$, where $\delta\omega^2$ determines a small deviation of the RSAE eigenfrequency from the finite pressure gradients and energetic ion pressure. The ratio of $\delta\omega^2/\omega_{BAE}^2$ is around 1.2%, so it can be neglected here. The dark circles are the experimental RSAE and BAE frequencies in Fig.2(a). Putting the two frequencies and mode number *m/n = 2/2* into theoretical calculation, the q_{min} are found to be below unity and decline from 0.98 to 0.972, which is given in Fig.2 (f).

Finally, nonlinear dynamics of RSAE during sawtooth will be given and the first observation of RSAEs coexisting with the frequency chirping toroidal Alfvén eigenmodes (TAE) and low frequency mode, and leading to decline of plasma configuration will be detailly discussed.

References

[1] P. W. Shi, et al Nuclear Fusion 59 (2019) 066015.