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Overview of recent MHD instabilities excited by energetic electrons in the HL-2A

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The physics of the energetic electron (EEs) excited instabilities in the medium tokamak can be utilized to simulate and analyze the analogous effect of alpha particles characterized by small dimensionless orbits [1], which may provide important experimental experiences for ITER [2] and have been investigated in many devices [3-10]. In this paper some new experimental results about the instabilities excited by EEs on HL-2A have been reported.

Energetic particle modes, including non-resonant fishbone (NRF) [11] and double fishbone [12] excited by EEs, have been observed in high-power ECRH/ECCD plasma with current ramp-up firstly. NRF usually has the saturated amplitude, slow changed or constant frequency and long-lasting time, as shown in Fig.1. The value of q_{min} is higher than unity slightly for NRF condition. The radial mode structures, frequency and growth rate are obtained by solving the dispersion relationship, which is in agreement with experimental phenomena. The double fishbone is observed utilizing the new-developed ECEI system. Two m/n=1/1 modes propagating in the opposite directions poloidelly are observed clearly, and the thermal energy transfer between the two modes was revealed, which is important to understand the nonlinear interaction between the two modes and the local heat transport during the MHD activity.

Toroidal Alfvén eigenmodes excited by EEs (e-TAEs) in high-power ECRH plasma are also observed, as shown in Fig.2. The frequencies, which are proportional to the Alfvén speed and the mode number of TAE are confirmed. It's proved that there exist the n=4, m=4 or 5 modes in the TAE gap from Alfvén continuum, and mode locates on the core of plasma with =0.23 according to the Alfvén mode code. The calculated frequency from the code is close to the experimental result. The e-BAEs in LHCD plasma are observed firstly on HL-2A, as shown in Fig.3. Two kinds of BAEs are excited by the EEs, with the frequencies in the range of 9-12 and 16-17 kHz, and their corresponding mode numbers are m/n=3/1 and 5/2, respectively. The modes all propagate electron diamagnetic direction in poloidal direction. The experiments show the obvious relations between the energetic electron distribution and the mode location. The energy distribution of the EEs corresponding to the excited modes is also investigated from the non-thermal ECE spectra.

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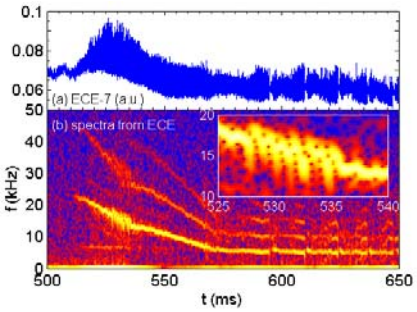

Figure 1 NRK excited by EEs during plasma current ramp-up in ECRH+ECCD plasma.

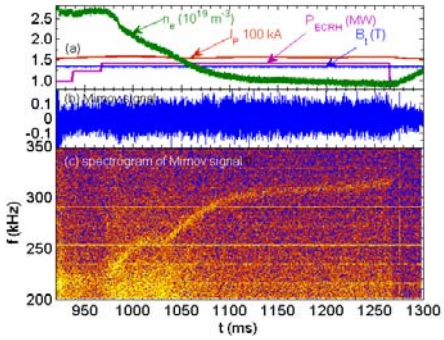

Figure 2 TAE exciteid by EEs in high-power ECRH plasma

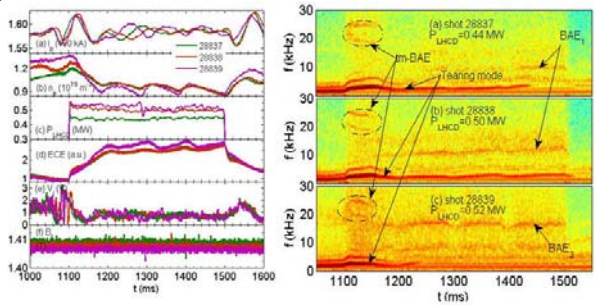

Figure 3 BAEs excited by EEs in LHCD plasma