§5. Characteristics of Anomalous Transport of Fast Ions Due to Bursting Energetic Particle Mode in CHS

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Bursting energetic particle modes (EPMs) were identified in neutral beam (NB) heated plasmas in CHS, and a resultant enhancement of fast ion loss was observed by lost ion probe and neutral particle analyzer [1]. A directional Langmuir probe (DLP) was also applied to NB heated plasmas to observe fast ion behaviors inside the last closed flux surface [2].

The bursting EPMs were excited in the outward shifted configuration of R_{ax}=0.974m, when beam pressure becomes fairly high comparable to the bulk plasma pressure. The frequency is close to the gap frequency of toroidicity-induced Alfven eigenmode (TAE) at the beginning of the burst, then quickly shifts down to almost 50kHz. The poloidal and toroidal mode numbers are m=3 and n=2, respectively. The co- and ctr-directed ions current were measured by the DLP inserted at outboard side in the horizontally elongated cross section in CHS. The co-directed flux oscillated (fast response) and increased (slow response) with the EPM burst, while no response was observed in ctr-directed flux (see Fig. 1(a)). The response to the EPM of co-directed ion flux was identified as the fast ion response to the EPM because of only tangentially co-injected NB. The fast response is proportional to the EPM amplitude and the slow one to the squared amplitude of the EPM. The phase relations of ion currents (both fast ions and bulk ions) to the EPM were obtained by cross coherence analysis, which are shown in Fig. 1 (b). The bulk ions also weakly oscillate with the EPM (coherence ~ 0.4) and the phase is in phase with the EPM, indicating that the bulk ions oscillate keeping the frozen-in condition. On the other hand, the fast ions have a finite phase (not equal to 0) thus strongly interact with the EPM. The radial flux induced by magnetic fluctuation is given by

$$\Gamma_r \sim \delta n_f \left[\delta V_r + V_\parallel \left(\delta B_r / B \right) \right] \sin\varphi \propto \delta B_{\mathrm{EPM}}^2 \sin\varphi \cdot \qquad (1)$$

In frozen-in condition (bulk ion case), the eq.1 vanishes (ϕ=0). For the fast ion flux, eq.1 does not vanish and there exists a radial flux depending on δB^2. The observed phase indicates the generation of outward flux of resonant fast ions. Therefore the slow response is identified as a fast ion flux produced by the phase difference between fast ion flux and the EPM given by eq.1 [3]. The energy transfer is also give by similar equation as eq.1, and has a same dependence on the EMP amplitude and the cross phase. The experimental observation indicates the energy transfer from fast ion to the EPM. From the local observations of magnetic fluctuation and fast ion response, it is concluded that fast ions destabilize the EPM bursts and the resultant transport of resonant fast ions outward to the plasma was induced. The total flux of fast ion induced by the EPM is still unknown because of complex locality of fast ion loss.

[1] Isobe, M. et al., Nucl. Fusion **46**, S918 (2006).
[2] Nagaoka, K. et al., Plasma. Fusion Res., **1**, 005 (2006).
[3] Nagaoka, K. et al., Phys Rev. Lett. **100**, 065005 (2008).

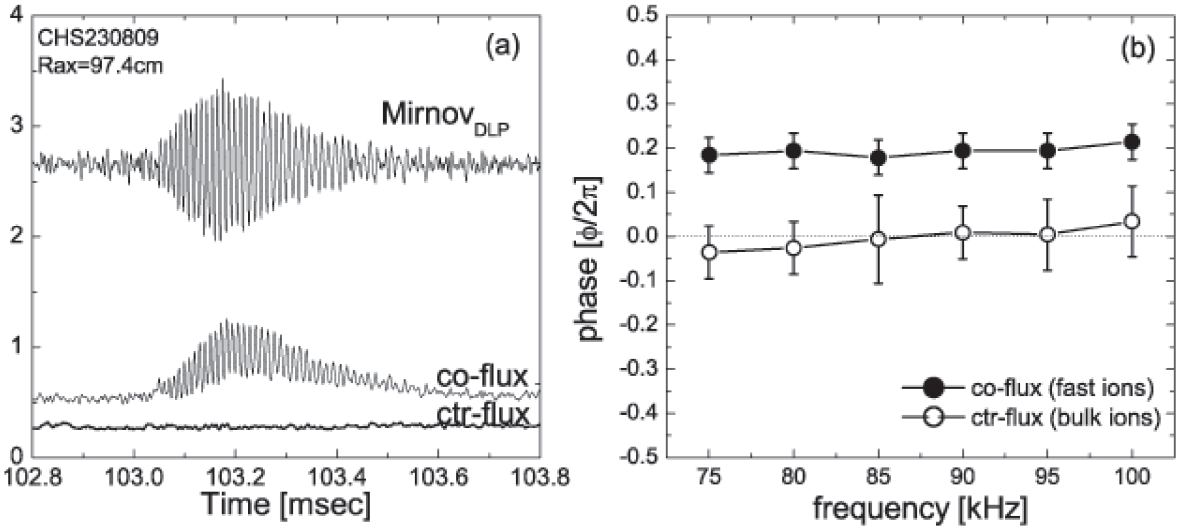

Fig. 1 (a) The Mirnov signal, co- and ctr directed ion current measured by the DLP, when the EPM burst occurs. (b) The phase relation between the magnetic fluctuation and ion fluxes. The closed circles show for fast ions and the open ones for bulk ions. The bulk ion current keeps in phase during the EPM burst which means the frozen-in.