§22. Control of Bulk Ion Heat Transport by ECH in a Reversed Magnetic Shear Plasma

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In relatively low density plasmas, it is demonstrated that current drive by counter neutral beam injection (counter NBCD) generates a reversed magnetic shear configuration where the reversed shear Alfvén eigenmodes (RSAEs) and geodesic acoustic modes (GAMs) are excited by energetic ions [1]. A characteristic phenomenon is often observed, that is, the central ion temperature T_{io} often increases clearly in a certain time window of the reversed magnetic shear plasma. Although the mechanism of this phenomenon is not understood so far, it is interesting from point of view of NBI heating and energy transport of bulk ions. The final goal of this collaborative research is to clarify the cause and to develop a control method of the T_{io}-increase by using electron cyclotron heating (ECH) and/or electron current drive (ECCD). In this fiscal year 2014, we focus on understanding of the spontaneous T_{io}-increase.

Time evolution of T_{io} in a reversed magnetic shear plasma is shown in Fig.1 together with the waveforms of net plasma current I_p driven by counter NBCD and line averaged electron density $\langle n_e \rangle$. For the phase from t=4.8s to t=6.8s, $\langle n_e \rangle$ is kept nearly constant, while I_p increases from ~60 kA to ~120 kA gradually by a constant NBCD power. In the constant $\langle n_e \rangle$ phase, a clear increase in T_{io} is observed from t~5.8s to t~6.05s. In this shot, energetic-ion-driven GAM appears from t~4.3 s, and its amplitude gradually increases with the decrease of the rotational transform by counter NBCD. The frequency of the GAM stays constant (~18 kHz) till t=6.8s. When ECH is applied from t=6.8s to t=7.3s, $\langle n_e \rangle$ decreases considerably. The ion temperature T_{io} starts to rise again from t~6.6s, but it stops the increase and then decreases slightly during the former half of ECH pulse. Just after the switch-off of ECH, T_{io} quickly decays, as seen from Fig.1. It should be noted that the GAM frequency obviously increases in the electron heating phase by ECH but it does not show a clear response to the above mentioned spontaneous T_{io}-increase. From the time evolution of RSAEs, the off-axis minimum of the rotational transform ι_{min} is inferred to pass the rational value of 1/3 during the rising phase of the counter plasma current [1].

Density fluctuations due to micro-turbulence are measured by a 2 dimensional phase contrast imaging system using CO_2 laser [2]. In Fig.2, the radial profile of the phase velocity of the density fluctuations are shown for two time windows I and II indicated in Fig.1, where the density fluctuation level is shown as a contour plot. In the laboratory frame, strong density fluctuations propagating ion diamagnetic drift direction are recognized in the outer region of 0.6< r/a<1.0, where r/a is the normalized minor radius. It is inferred for this shot that ExB drift velocity is fairly small so that the strong density fluctuations would propagate also in the plasma frame. The characters of density fluctuations have no clear differences for both time windows. Although no clear correlation between the spontaneous T_{io}-increase and micro-turbulence characteristics so far, more detailed discussions are needed for clear understanding of the mechanism and controlling the spontaneous T_{io}-increase by ECH and/or ECCD.

[1] K. Toi et al., Phys. Rev. Lett. **105**, 145003 (2010).
[2] K. Tanaka et al., Rev. Sci. Instrum. 79, 10^E702 (2008).

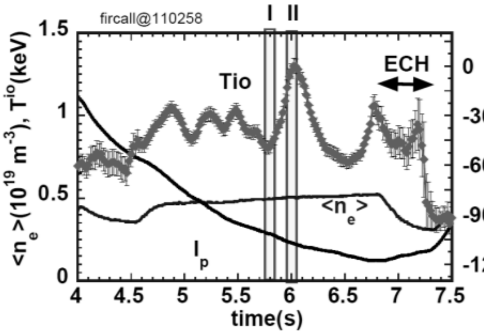

Fig.1 Time evolutions of T_{io}, $\langle n_e \rangle$ and I_p in a reversed magnetic shear plasma produced by counter NBCD. ECH of 2.5MW is applied from t=6.8s to 7.3s. Characteristics of density fluctuations are compared in Fig.2 for two time slices I and II.

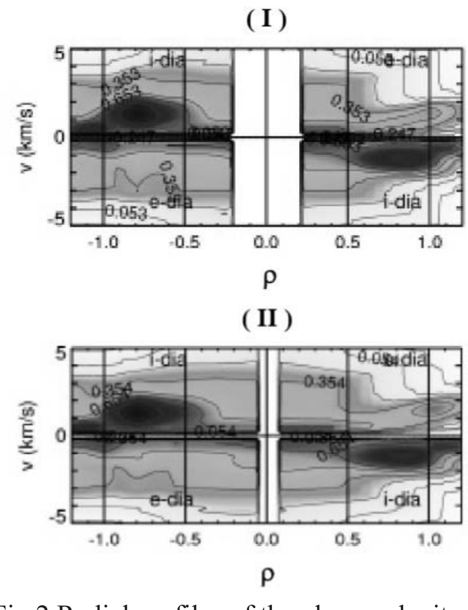

Fig.2 Radial profiles of the phase velocity and the density fluctuation level shown by a contour plot in two time slices I and II. The dark and light levels of the contour indicate the strong and weak fluctuation level, respectively.