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

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In LHD, a reversed magnetic shear (RS-) plasma can be produced by counter neutral beam current drive to reduce the rotational transform in which plasma the reversed magnetic shear Alfven eigenmodes (RSAEs) and geodesic acoustic modes (GAMs) are quasi-stationary excited by energetic beam ions[1]. When the local minimum of the rotational transform profile ι_{min} passes the rational value predicted from the frequency sweep of RSAEs, the bulk ion temperature at the plasma center often increases spontaneously. The main purpose of this collaboration is to clarify the mechanism of the ion temperature rise and study the ECH effects.

The upper figure of Fig. 1 shows the spectrogram of the magnetic fluctuations. The frequency of RSAEs shows a characteristic frequency sweeping between ~ 20 kHz and ~65 kHz, and that of GAM is nearly constant (~18 kHz) in the phase from t=4.8 s to ~ 6.8 s. The lower figure of Fig.1 shows the time evolution of the bulk ion temperature at the plasma center T_{io} measured by X-ray imaging crystal spectroscopy (XICS). As seen from Fig.1, the plasma current I_p increases in the counter direction in nearly constant line averaged electron density $\langle n_e \rangle$. At the time t~5.6 s when the RSAE frequency reaches the minimum value of ~18 kHz it is inferred that the ι_{min} just passes the value of 1/3 [1]. The T_{io} increases linearly in time from t~5.6 s for ~200 ms. Then, it decreases linearly and returns to the value at t~5.6 s taking ~300 ms. From t~6.3s, T_{io} again increases. During ECH from t=6.8 s to t=7.3 s, T_{io} decreases gradually and $\langle n_e \rangle$ also decreases by about 30%, as seen from Fig.1. The electron temperature remains unchanged from t=4.8 s to 6.8 s. During ECH, the electron temperature near the center increases clearly. An interesting point in the time evolution of T_{io} is to behave oscillatory in time, responding to the time evolution of the rotational transform profile having a reversed shear shape. However, the mechanism is unclear and under investigation. In the RS plasma experiment, a new XICS was applied to obtain the radial profile of the bulk ion temperature T_i. The time evolutions of the ion temperature profiles are shown in Fig.2 in two typical phases where the temporal increase in T_{io} is observed. In the first T_{io}-increase phase, the ion temperature in the core region inside the normalized minor radius r/a~0.5 increases, as seen from the upper figure of Fig.2. The figure also shows the radial profile of the changes in the ion temperature from that at t=5.61 s, ΔT_i. During ECH, the T_i–profile shows a broad increase in contrast to the first phase. The time evolution of T_i-profile would provide important information for better understanding of the spontaneous T_{io}-rise. The other interesting fact is that the GAM frequency stays the same value of ~18 kHz during the T_{io}-rise and does not show the increase following the dependence of $\sqrt{T_{io}}$, as seen from the spectrogram shown in Fig.1. In the future study, the effects of impurity ions and the differences of the specific heats of electrons, bulk ions and energetic ions should be discussed on the ion temperature dependence on the GAM frequency.

[1] K. Toi et al., Phys. Rev. Lett. **105**(2010)145003.

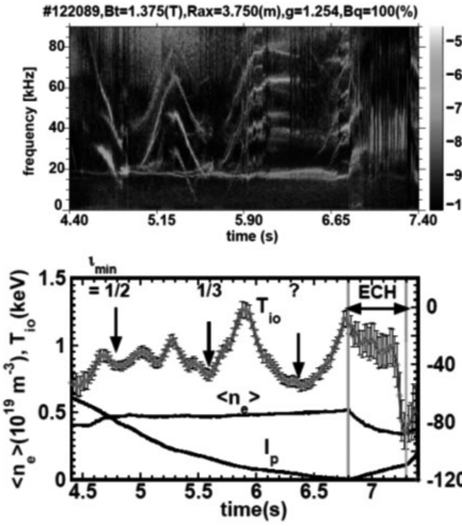

Fig.1 (Upper) spectrogram of the magnetic fluctuations in the RS-plasma, (Lower)time evolutions of T_{io}, I_p and $\langle n_e \rangle$. At the times indicated by the downward arrows, the value ι_{min} is inferred to be the rational values as 1/2 and 1/3 from the time evolution of the RSAE frequency.

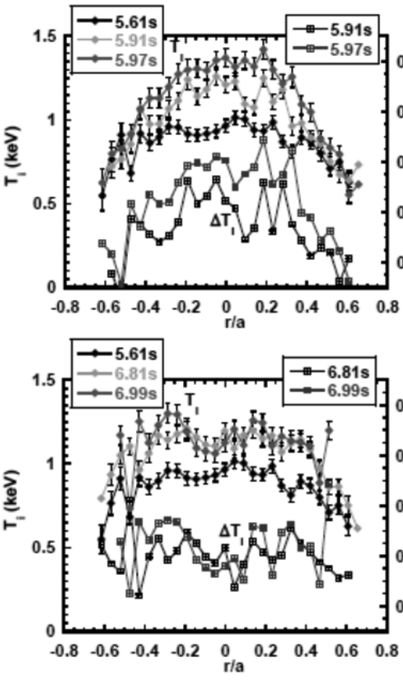

Fig.2 (Upper) T_i-and ΔT_i profiles in the phase from t=5.61s to t=6.09s. (Lower) T_i-profiles at t=6.81s and t=6.99s during ECH, compared with that at t=5.61s.