§36. Characteristic Evolution of Electron and Ion Temperatures in a Plasma with Non-Monotonic Rotational Transform Profile

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In a tokamak plasma, the reversed magnetic shear configuration where the global magnetic shear changes negative to positive toward the edge having a zero shear layer has received much interest because an internal transport barrier is easily formed and it is a promising candidate for steady-state operation in ITER [1]. It is interesting and significant to investigate whether or not a configuration with the reversed magnetic shear can be realized in stellarator /helical plasmas and how the plasma in the configuration behaves.

This configuration was realized in an LHD plasma where large counter plasma current was driven by neutral beam injection (NBI)[2, 3]. A typical discharge waveform is shown in Fig.1, where the toroidal field is B_t=1.3T and the magnetic axis position of the vacuum field is R_{ax}=3.75m. The plasma current reaches ~140 kA by two counter NBI systems having about 2MW absorption power and about 180 keV hydrogen beams. The line averaged electron density is kept constant ($<n_e>\approx 0.6\times10^{19}$ m^{-3}). Appreciable amount of neon is puffed into a plasma by a short pulse (~70ms) at t~0.8s to enhance NB power absorption and minimize electron return current in NB current drive, where the effective charge Z_{eff}~ 6. Electron temperature profile is a parabolic shape having ~ 1.3 keV at the plasma center in the constant $<n_e>$ phase. Electron density profile is considerably hollow, where $n_e(0)/n_{emax}$~0.5. The beta value of beam component $<\beta_h>$ is comparable or higher than that of bulk plasma (~0.5%). That is, energetic ion effect is expected to be significant in these plasmas. The rotational transform $\iota/2\pi$–profile measured by motional-stark-effect (MSE) spectroscopy is non-monotonic, as shown in Fig.2. In the time window shown in Fig.1, the position of the minimum $\iota/2\pi$ moves inward from ρ~0.7 to ρ~0.4, and the minimum value gradually decreases, passing through the rational values $\iota/2\pi$=1/2 and 1/3. At these timings, electron temperature measured by electron cyclotron emission (ECE) T_e^{ECE} exhibits sharp drops at $t=t_1$ and $t=t_2$ in Fig.1.

In a similar shot with that shown in Fig.1, the central ion temperature measured by soft X-ray crystal spectroscopy has increased linearly for more than global energy confinement time from the time when the minimum of the rotational transform approaches or passes $\iota/2\pi$=1/3, as shown in Fig.3. The mechanism of this ion temperature rise is under investigation.

[1] Editors of "Progress in the ITER Physics Basis", Nucl. Fusion **47**, S1 (2007).

[2] Toi, K., et al., *10th IAEA Technical Meeting on Energetic Particles in Magnetic Confinement Systems*, Kloster Seeon (Germany), 8-10 Oct., 2007.

[3] Toi, K., et al., *35th EPS Plasma Physics Conference*, Crete (Greece), 9-13 June 2008, paper No.P1.054.

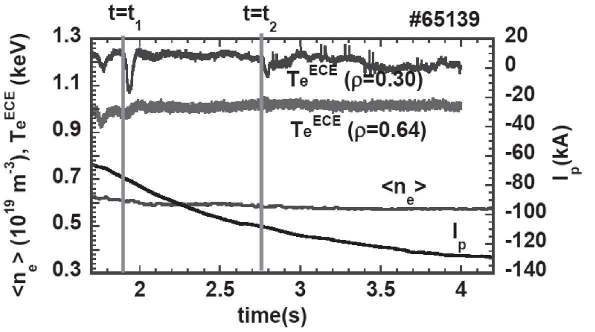

Fig.1 Typical waveform of a RS-plasma of LHD. T_e^{ECE} has sharp drops when the minimum of the rotational transform has passed the rational values 1/2(at t=t_1) and 1/3(at t=t_2)(vertical lines).

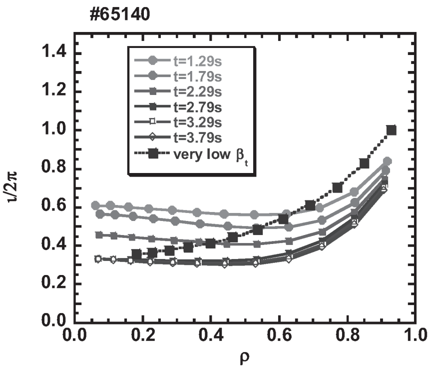

Fig.2 Time evolution of the rotationalTransform profile measured by MSE. The dotted curve indicates the profile in the vacuum.

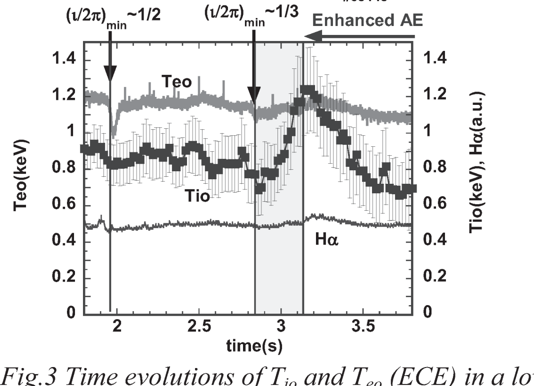

Fig.3 Time evolutions of T_{io} and T_{eo} (ECE) in a low density RS plasma of $<n_e>=0.5\times10^{19}$ m^{-3}. Hα emission indicates an enhanced loss from t~3.1s.