§75. Off-axis ECCD Experiment Using 77 GHz EC-wave

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In LHD, significant electron cyclotron current drive (ECCD) up to 40 kA was performed in the on-axis, second harmonic resonance condition by use of high power 77 GHz EC-waves injected from outside port (2-O). The magnetic configuration was R_{ax}=3.75 m with B=1.375 T. The EC-wave pulse width was 8 s and the injected power was 775 kW. To verify a possibility of specific local modification of rotational transform profile, off-axis co-ECCD experiment was performed. The magnetic configuration was R_{ax}=3.75 m with B=−1.375 T. For plasma heating and current drive, NBI#3, 77 GHz EC-waves from 5.5-U and 2-O ports were applied all from 3.3 s to 5.3 s, limited from the operational duration time of NBI#3. The power of NBI#3 was 2.1 MW. One of two ion sources was used alternately to reduce NB power and thus NB-driven current. EC-waves from 5.5-U port of 794 kW were injected normally for on-axis ECH, and those from 2-O port of 782 kW were injected obliquely for on- and off-axis co-ECCDs in negative I_p direction. For on-axis ECCD, setting parameters for EC-wave beam injection were T_f=−0.3 m and Z_f=0 m so that parallel refractive index $N_{//}$ of the beam at the magnetic axis was −0.29. Here, T_f and Z_f denote the toroidal and vertical coordinates of the beam aiming position on a vertical plane imaginary set at R=3.9 m. For off-axis ECCD, the setting parameters were T_f=−0.3 m and Z_f=0.1 m.

The time evolutions of plasma parameters in the off-axis ECCD experiment are plotted in Fig. 1. There is no significant difference in the line average electron density n_e of ~0.3×10^{19} m^{-3}, plasma stored energy W_p of ~50 kJ, central electron temperature T_{e0} of ~3 keV, and unexpectedly even in the plasma current I_p. Figure 2 (a) shows the profiles of rotational transform $\iota/2\pi$. Though there is no clear difference in I_p for on- and off-axis ECCDs, $\iota/2\pi$ profiles show clear deference at around r_{eff}=0.2 m. The steep gradient in the $\iota/2\pi$ profile at r_{eff}~0.15 m for the off-axis case might be a result of the off-axis local ECCD at r_{eff}~0.1 m by setting Z_f as 0.1 m.

From the data of $\iota/2\pi$ profiles, Fig. 2 (a), the current difference between the on-axis and off-axis cases integrated inside the radius r_{eff} is derived and plotted against r_{eff} in Fig. 2 (b). From the MSE measurement, it can be said that the possible maximum difference in driven currents between the on- and off-axis ECCDs is ~5 kA, and it could be ~0 kA if the very small difference in the $\iota/2\pi$ profiles and resultant fluctuation in the current difference in the region of r_{eff}>0.35 are neglected.

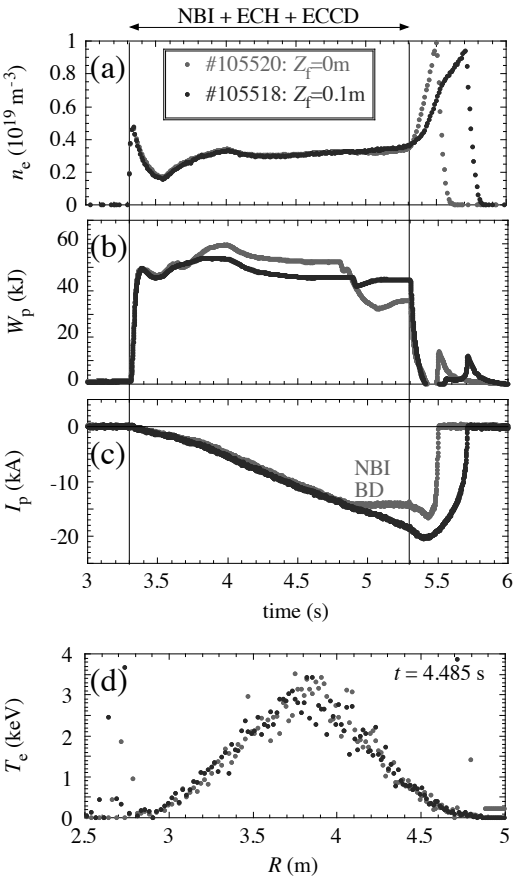

Fig. 1. Time evolutions in the ECCD experiment of (a): line average electron density, (b): plasma stored energy, (c): plasma current and (d): electron temperature profile at the timing t=4.485 s. The red color indicates on-axis ECCD and the blue one off-axis ECCD.

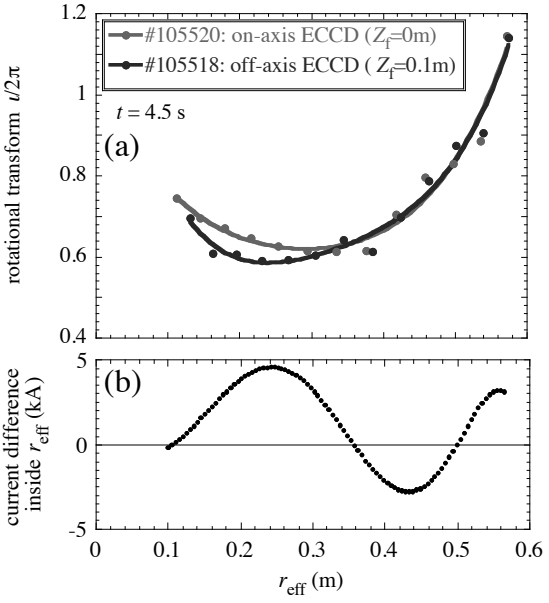

Fig. 2. (a): Radial profiles of rotational transform in the on-axis ECCD case (red) and off-axis case (blue). (b): Current difference between the on- and off-axis cases integrated inside the radius r_{eff}.