# §47. Long-pulse ECCD Experiment in LHD

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ECCD experiments in LHD have been mainly performed with the pulse width of 600 ms using #5 gyrotron and injection power of up to 0.37 MW. So far, dependence of EC-driven current on $N_{//}$ (defined as cosine of the angle between the beam direction and toroidal direction on the magnetic axis) was obtained. The direction of driven current agrees with the prediction from the Fisch-Boozer theory in the case of beam injection from LFS.

However, a simple estimation tells that an $L/R$ time in the discharges is a few seconds. Here, $L$ denotes plasma inductance and $R$ plasma resistance, respectively. So 600 ms pulse width is not sufficient for precise evaluation of driven current in ECCD experiments, and long-pulse operation is required.

An example of such long-pulse ECCD experiment using the CW gyrotron with the available power of 0.1 MW is shown in Fig. 1. The magnetic configuration parameters were $R_{\text{ax}}$=3.75 m and $B_{\text{ax}}$= 1.5 T. The ways of plasma generation and sustainment were the same for these co- and counter-ECCD discharges, except for the direction of EC-wave beams. For co-ECCD, $N_{//}$ was set as 0.27 and for counter-ECCD, -0.29. Unfortunately in this set of discharges, neither reference discharges without EC-power injection, nor with ECH ($N_{//}$=0) were obtained. The 0.1 MW power from the CW gyrotron and the 2.4 MW in total from two NBIs generated and sustained the plasma from 2.3 to 7.3 s. The two NBIs were injected tangentially in co- and counter-directions to cancel their NB-driven currents. The cancellation of NB-driven currents is not perfect and it is time-dependent, appearing as a general time-trend in plasma currents. As a difference in plasma current $I_\text{p}$ between co- and counter-ECCDs, EC-driven current up to 5.5 kA is clearly observed. It takes more than 2 s for the EC-driven current to be saturated. Other global parameters such as line average density, plasma stored energy and electron temperature profile are nearly the same in co- and counter-ECCD cases. So the change in $I_\text{p}$ should be attributed to the EC-driven current, not to a possible change in the bootstrap current caused by a change in plasma parameters such as pressure profile.

Investigations on the EC-driven current profile and its development by using the Motional Stark Effect (MSE) measurement are under way. The NB injection is necessity for the MSE measurement. Figure 2 shows the distributions of rotational transform at the timing of 6.1 s, when the driven current is saturated, measured with MSE. As expected, significant difference in the rotational transform is observed at the core region by on-axis co- and counter-ECCDs. Driven current $I_{\text{co-ECCD}}$ - $I_{\text{counter-ECCD}}$ (or, sum of their absolute values) to cause the difference in the rotational transforms is estimated as about 3 kA, that is, half the difference in measured plasma currents of 5.5 kA. They are in the same level, but the cause of the discrepancy should be investigated.

Figure 2 shows the total EC-driven current density profile derived from the profiles of rotational transform at the timing of 6.1 s. Though separation of co- and counter-EC driven currents is difficult from this data set, it can be seen that the driven currents are well localized in the plasma core region with $\rho$ less than 0.25.

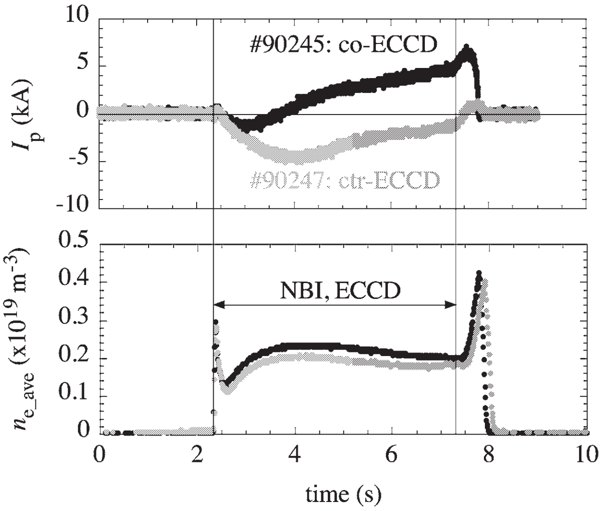

Fig. 1. Waveforms of plasma current and electron density in the ECCD experiment.

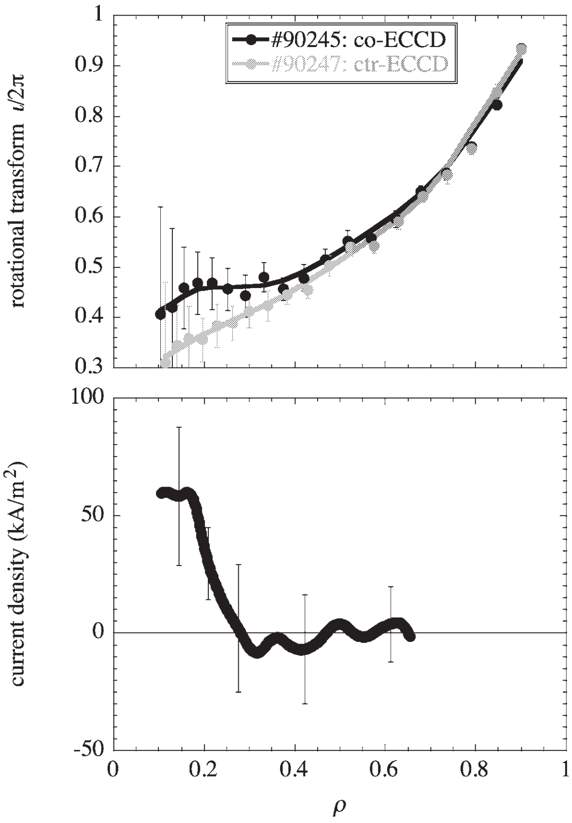

Fig. 2. Profiles of rotational transform and that of derived current density in the ECCD experiment.