2nd Harmonic ECCD experiment using 84 GHz EC-wave in LHD

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Electron cyclotron current drive (ECCD) is an attractive tool to control plasmas. Using well-focused EC-wave beams, plasma current can be driven locally so that ECCD can control the profiles of plasma current and rotational transform which affect the magneto-hydro dynamics (MHD) activities. In tokamak-type plasma confining devices, the effectiveness of the ECCD on stabilization of NTM (neo-classical tearing mode, one of the harmful MHD activities) has been demonstrated by driving currents within the magnetic islands. Also in helical-type devices which does not need the plasma current for plasma confinement, the ECCD is considered to be useful for control of the position of rational surface or compensation of bootstrap current which flows spontaneously due to radial pressure gradient in plasmas.

In the large helical device (LHD), ECCD experiments have been performed by using EC-waves with the frequency of 84 GHz. The EC-wave beam injection systems of LHD furnishes 2-dimensionally movable mirror which enables the beam direction control. One of the beam injection systems which is used for the ECCD experiment is composed of two inner-vessel mirrors which focus the EC-wave beam radiated from the waveguide transmission line and control the beam direction. The injection system is installed at the bottom port of LHD (1.5L-port), and the beam is injected from the low-magnetic field side (LFS). In the ECCD experiment, the position of the magnetic axis of the plasmas was set at 3.75m and the magnetic field at the magnetic axis was 1.5 T, that is, the second harmonic resonance field for the frequency of 84 GHz.

The EC-wave beam direction was toroidally scanned keeping the beam aiming positions being on the magnetic axis. The plasmas were generated and sustained by the EC-wave power of 310 kW and pulse width of 600 ms. The plasma current I_p does not saturate and keeps increasing during the pulse width, consistent with a rough estimation of current attenuation time (L/R) of the LHD plasma as several seconds order. I_p changes its direction according to the change of the EC-beam direction, and the direction of I_p agrees with the prediction from the Fisch-Boozer theory in the case of beam injection from LFS. So far the largest I_p with ECCD is about 3 kA at the end of EC-wave injection while I_p with ECH is nearly 0 kA.

The motional stark effect (MSE) measurement was applied to NB-sustained plasmas with additional 310 kW, 600 ms ECCD and ECH. The distribution of the rotational transform at the plasma core region in the case of positive (negative) ECCD shows significant increase (decrease). The estimated driven currents inside the normalized radius of 0.5 are about +-15 kA. It is considered that at the early phase of ECCD, a transient counter current due to a back electromagnetic force might reduce the total I_p.