§58. High-density Plasma Heating by EC-waves Injected from High-field-side

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To realize electron Bernstein wave (EBW) heating by slow X-B scheme, new inner-vessel mirrors were installed close to a helical coil, that is, at the high-field-side (HFS) region. A 77 GHz EC-wave injected from the existing injection antenna system is reflected at the new mirror and then the wave in the X-mode polarization propagates in plasmas through a fundamental resonance layer and toward upper-hybrid-resonance (UHR) layer. At the UHR layer the X-mode wave is expected to be converted to an EBW and then the EBW is expected to propagate toward the plasma core region and be absorbed. The configuration of the slow X-B scheme is seen schematically in Fig. 1. The new mirrors consist of three plane mirrors: two of them reflect the EC-waves to different poloidal directions (two trajectories in Fig. 1) and one of them reflects the waves with some toroidal angle.

Here the experimental results obtained with one of the mirrors are described. The experiment was performed with the magnetic field configuration of magnetic axis position R_{ax} = 3.6 m and magnetic field B = 2.705 T, so that the fundamental resonance layers for 77 GHz exist in the plasma core region. Target over-dense plasmas (line-average electron density $n_e \sim 7.5 \times 10^{19}$ m^{-3}) were sustained with 5 MW power from an NBI, as seen in Fig. 2. Here the plasma cut-off density for 77 GHz wave is 7.35 $\times 10^{19}$ m^{-3}. Four ECH pulses with 775 kW power in X-mode polarization were injected (25 ms on and 25 ms off) from HFS to the target plasmas. During the power injection period from 5.2 s to 5.375 s, only when the EC-waves were injected from HFS, the electron temperature evidently increased at the core region by ~ 40 eV and the plasma stored energy W_p also increased with each ECH pulse. W_p of the target plasma was slightly increasing with time (see Fig. 2, from 4.8 s to 5.2 s). When the EC-wave beams were injected from low-field-side as usual ways of fundamental O-mode injection, no effect on W_p was seen. In Fig. 3 a time-evolution of the difference in the stored energies between the cases of HFS injection and without ECH, considering the difference in the target plasmas and the increasing trend in W_p. The power absorption efficiency is evaluated as ~ 71% from the changes in the time-differential of W_p, dW_p/dt, at the on-off timings of ECH. Here, the energy confinement time of the target plasma is evaluated as 120 ~150 ms from both of the decay in W_p and ISS95 scaling.

So far, distinction of the heating effects by fundamental X-mode heating and X-B heating is not clear. Further experiments in the near future will make the distinction and suggest the ways to improve the scheme for over-dense plasma heating more effectively.

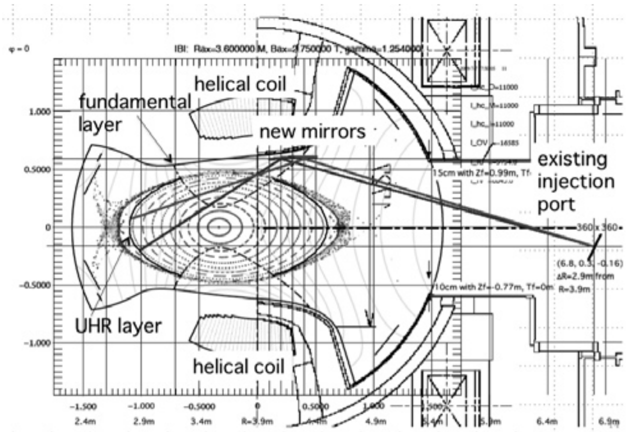

Fig. 1 A schematic drawing showing the idea of HFS injection of EC-waves by use of the inner-vessel mirrors installed near the helical coil.

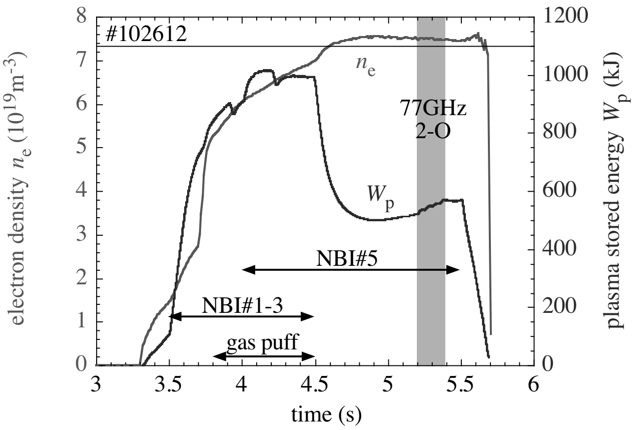

Fig. 2 Waveforms of line-average n_e, W_p and heating sources ECH and NBIs in the experiment of EC-wave HFS injection. The period of EC-wave pulses injection is indicated by gray region.

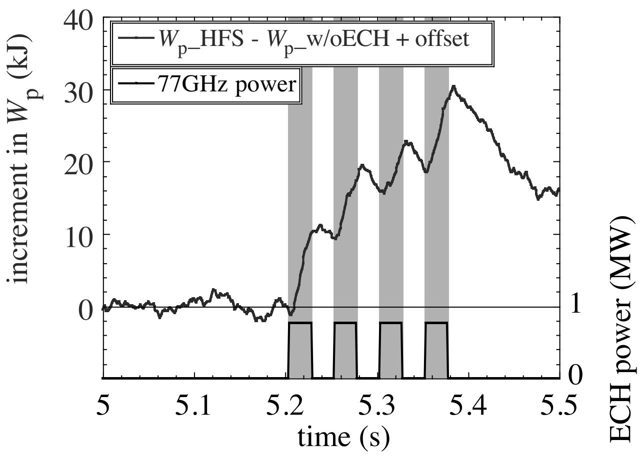

Fig. 3 Increments in the plasma stored energy W_p (difference in W_ps of two discharges with and without EC-waves) caused by EC-wave pulses injected from HFS in X-mode polarization.