§34. Third Harmonic Resonance Heating by Injection of 84 GHz-range Millimeter Waves

Shimozuma, T., Kubo, S., Yoshimura, Y., Igami, H., Notake, T., Mutoh, T.

High harmonic heating of the electron cyclotron resonance (ECR) is an attractive method to extend a heating regime of plasma parameters by alleviating the density limitation due to some cutoffs of the EC wave propagation. Effective third harmonic heating has been already achieved on the 2T LHD plasma by injection of 168GHz millimeter wave power from upper-port antennas [1)].

Because ECH power of 84GHz range has been upgraded up to 1.3MW, we have tried 3rd harmonic X-mode heating by injection of 84GHz range power at the magnetic field of 1T with the magnetic axis of 3.75m. When the same frequency is used, a cutoff density for the 3rd harmonic X-mode heating at 1T becomes 4/3 higher than that for 2nd harmonic X-mode heating at 1.5T. It is about $6 \times 10^{19}\mathrm{m}^{-3}$.

In the experiments, target plasmas were produced and sustained by only NBI. The electron temperature at the center was about 1 keV and the line-averaged density was $0.6 \times 10^{19}\mathrm{m}^{-3}$. ECH power (1.3MW) was injected from t=1.4sec and 1.5sec stair-likely as shown in Fig. 1. Obvious increase of the stored energy was observed during ECH pulse, although there was no change in the density.

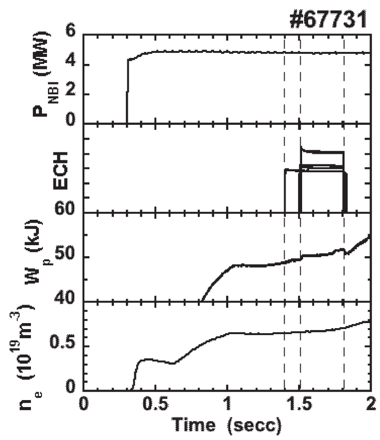

Fig. 1: Wave form of NBI power, ECH timing, stored energy W_p and line-avereged density from top to bottom.

Figure 2 shows electron temperature profiles just before (t=1.37sec) and during (t=1.57sec) ECH power injection. The plasma center was efficiently heated, and increment of the temperature reached 0.2 – 0.3 keV.

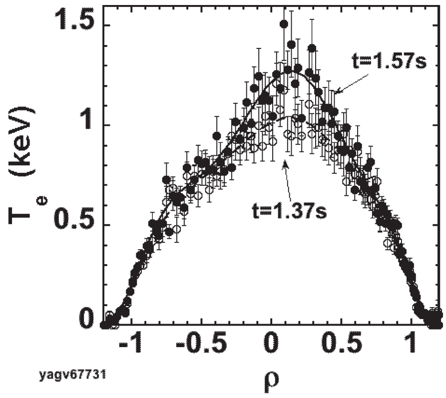

Fig. 2: Electron temperature profiles just before (t=1.37sec) and during (t=1.57sec) ECH. ρ is the normalized minor radius.

Absorbed power was estimated by the increment of $\mathrm{d}W_p/\mathrm{d}t$ before and after ECH-on timing. The dependence on the focal point R_{foc} of the upper-port antennas was examined (Fig. 3). The maximum absorption was obtained on the antenna focal position R_{foc}=3.7m, which was a little smaller than the ECR layer (3.75m). The absorption rate, however, is very low, because the temperature and density of the target plasma was fairly low.

Detailed calculations by ray-tacing in the LHD magnetic configuration is required to discuss the absorption rate and its dependence on the antenna focal point.

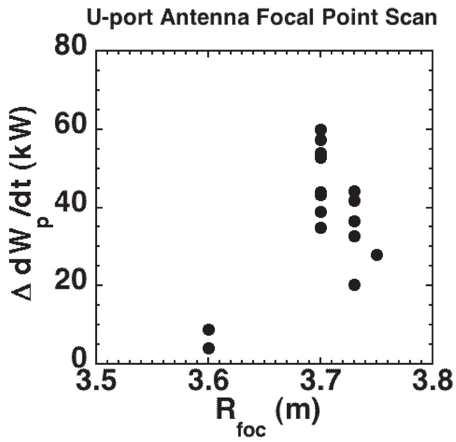

Fig. 3: Absorbed power was estimated by change of $\mathrm{d}W_p/\mathrm{d}t$ at ECH-on timing. Antenna focal point on the equatorial plane R_{foc} dependence is shown.

References

1) T. Shimozuma, H Idei, et al., 27th European Physical Society Conference on Controlled Fusion and Plasma Physics, Budapest, Hungary, 12-16 June 2000, P4.019