§63. Third Harmonic EC Heating Experiment by 77 GHz High Power Injection

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The third-harmonic electron cyclotron heating by the injection of an extraordinary mode (X3 heating) has a 4/3 higher cut-off electron density than that of the second harmonic (X2) heating when a power source with the same frequency is used. The X3 heating can enlarge a possible heating region up to the higher density region. So far, we successfully performed X3 EC heating experiment using 168 GHz [1)] and 84 GHz gyrotrons [2)]. The X3 heating experiment using powerful 77 GHz gyrotrons was performed on a relatively high β plasma around $B \simeq 0.9$ T. The cut-off density is $5 \times 10^{19}\mathrm{m}^{-3}$. We selected the magnetic field strength of 0.95 T so that the position of the magnetic axis coincided with the electron cyclotron resonance (ECR), when the Shafranov shift was taken into account.

A target plasma was produced by co-injected NBI and sustained from t = 0.3 to 2.3 sec. The central electron temperature was about 1.2 keV, and the line-averaged density was $0.7 \times 10^{19}\mathrm{m}^{-3}$. The millimeter-wave power of 77 GHz was injected from 5.5U antenna (t =1.31 s - 1.81 s), 9.5U antenna (t =1.51 s - 1.81 s) and 2O antenna (t =1.71 s - 1.81 s). A time evolution of the core electron temperature (R =3.76 m) measured by Thomson scattering is shown in Fig.1. The core electron temperature increases with the increase of the injection power. Figure 2 shows the electron temperature profiles at t =1.25 s (before ECH) and t = 1.75 s (during final 77 GHz power injection). The increment of the electron temperature at the center achieved about 0.5 keV. The absorption rate of the ECH power for each antenna can be estimated by the calculation of an increment of dW_p/dt just before and after the turn-on timing of each ECH pulse. A density dependence of the absorption rate was estimated for each antenna in Fig. 3. The absorption rate generally has a tendency to increase with the density. The absorption rates for 5.5U and 9.5U antenna injection were so smaller than the expected values. Because millimer-wave (mmW) beams from the U-port antennas were injected almost tangentially to the ECR, more precise optimization of the antenna focal position was required. That for 2O antenna was about 20% as was expected, because the mmW beam could be injected almost perpendicularly to the ECR from this antenna.

1) T Shimozuma, *et al.*, 27th EPS Conference, Budapest, Hungary, 12-16 June 2000, P4.019

2) T Shimozuma, *et al.*, PFR, (2008) Vol.3, S1080-1 – S1080-5.

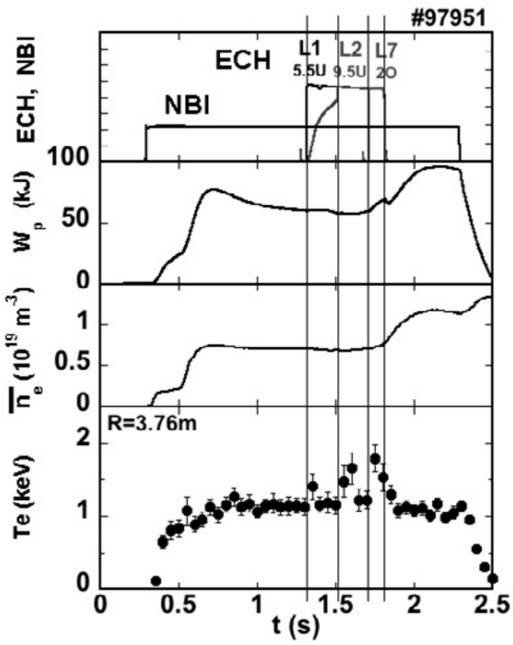

Fig. 1: Injection pattern of ECH and NBI together with the time evolution of line-averaged electron density , electron temperature and plasma stored energy.

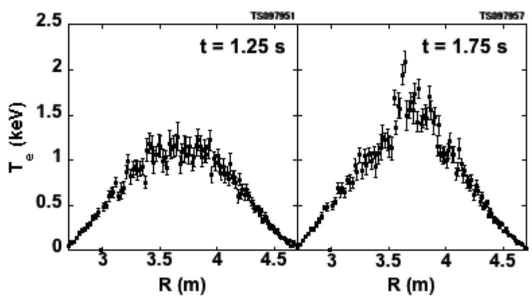

Fig. 2: Electron temperature profiles before ECH injection (t = 1.25 s and during the final 77 GHz injection pulse (t =1.75 s).

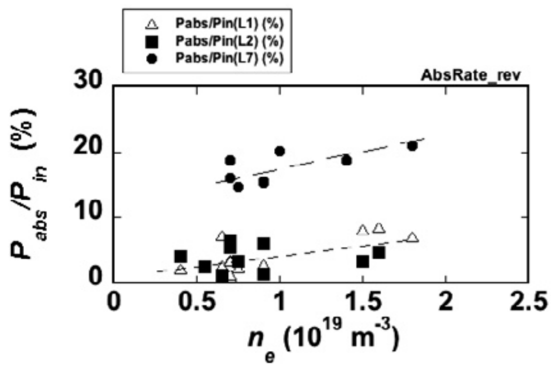

Fig. 3: Density dependence of ECH absorption rate for each antenna injection power