§29. Development of ECH Method for High Density Plasma Heating

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Recently, there arises considerable interest in ECH methods by using mode-converted electron Bernstein (EB) waves for heating and current drive in high density plasmas. The O-X-B method, where obliqely injected O waves are mode-converted to X waves at plasma cutoff layer and then to EB waves at upper hybrid resonance layer, is a possible way to excite EB waves in the plasma. Here we present the numerical study for application to LHD and the preliminaly results on LATE [1].

We investigated numerically application of the O-X-B method to LHD plasmas and found that the method was feasible if we injected an 84 GHz gyrotron power from the 2-O port antenna. The linear theory predicts that mode conversion efficiency from X waves to EB waves is essentially 100 %, but that of O to X waves depends sensitively on the propagation angle at the plasma cutoff layer. Therefore, we calculated numerically its efficiency by using a model plasma for the injection from the 2-O port antenna onto each position of the plasma cutoff surface at $\rho = 0.8$, where the propagation angle of the O waves injected from 2-O port is uniquely determined for each surface position. Fig.1 shows a contour plot of mode-conversion efficiency from O waves to X waves for the injection point at the surface and shows that there is a hole centered at y= 0.85 m and z=-0.46 m, where the efficiency is greater than 50 %. Here the scale length of density gradient at the surface is assumed to be 7 % of the plasma radius. The width of the hole is 10 cm in y direction and 4 cm in z direction. Although this is narrow, focusing of the waves onto the area is still possible by using the 2-O port antenna.

In the LATE device, 2 GHz microwave power in the range of 20-50 kW from a klystron was injected with pulse lengths less than 100 ms as shown in Fig.2. Careful adjustment of ramp-up rate of the vertical field (Bv) was needed to obtain stable current ramp-up discharges. As shown in Figs.2 (b) and (c), the flux loop signal, which is roughly proportional to the plasma current, increases roughly in proportion to Bv from t=0.04 s to 0.08 s. So far, plasma current could be ramped-up to 5 kA. The electron density estimated by a 70 GHz interferometer along the vertical chord at R=27 cm is $\sim 10^{11} cm^{-3}$, which is about twice of the plasma cutoff density. This result suggests that ECH/ECCD by mode-converted Bernstein waves takes place.

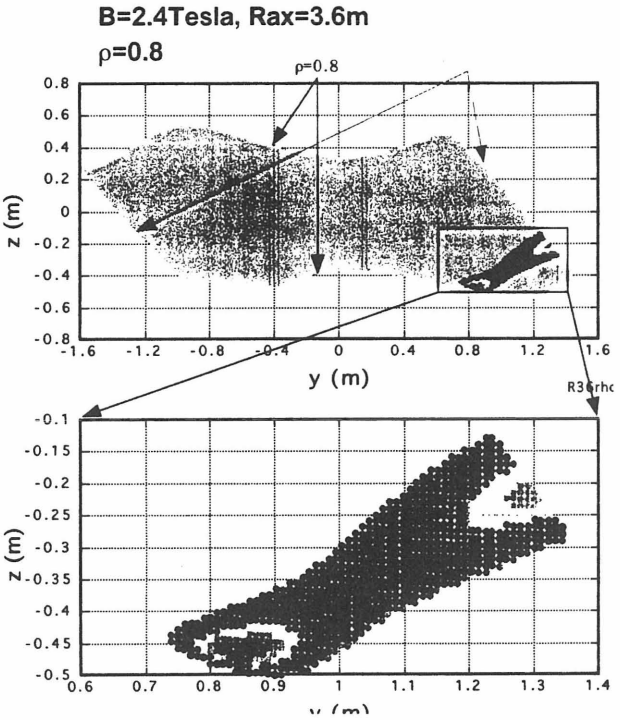

Fig.1 Contour plot of mode conversion efficiency (LHD)

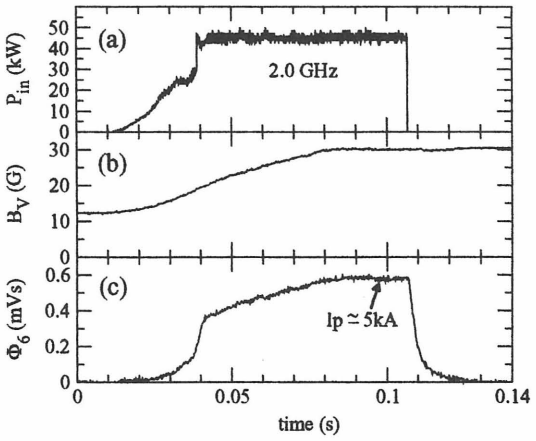

Fig.2 Plasma current ramp-up discharge (LATE)

References

[1] T.Maekawa et al.,Annual Report of NIFS (2000-2001), p.239