§10. Electron Bernstein Wave Heating in Extremely Overdense Plasmas

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There has been considerable interest in electron Bernstein (EB) wave heating and current drive since EB waves can propagate into and be cyclotron-absorbed in overdense fusion plasmas, such as spherical Tokamak and high-density helical plasmas. However the heating property of bulk and energetic electrons by EB waves at an extremely overdense regime is not well understood.

In the LATE device formation of spherical tokamak plasmas by EB waves at seven times the plasma cutoff density has been achieved. In this study we firstly explore a way to increase the electron density up to 10 times the plasma cutoff density. Then we investigate the change in heating property of bulk and energetic electrons by EB waves as the density increases far beyond the cutoff density.

In this term we have improved the 2.45 GHz ECH system in order to extend the plasma current and the density. A 20 kW, 2sec magnetron has been newly installed and the total injection power (four magnetrons) has been extended up to 80 kW. In addition, the polarizers[1)] have been installed in three transmission lines to have the better mode conversion rate to the EB waves by using the polarization adjustment of incident wave[2)].

The mode conversion rate from the incident waves to the EB waves depends on the density gradient near the UHR layer. At the early stage of discharges where the density is low and the density gradient also low, an O-mode like polarization has high mode-conversion efficiency, while a X-mode like polarization is suitable at the final stage of discharges where the plasma is highly overdense and the density gradient becomes high.

As a result of many attempts with combinations of polarization and microwave power control, a plasma current up to 12 kA is ramped up and kept steady for 40 ms by injecting ~50 kW microwave power with the X-mode like polarization and ~15 kW power with the O-mode like polarization, as shown in Fig.1. The line-averaged density on the midplane reaches $5.5\times10^{17}\,\mathrm{m^{-3}}$ (L = 0.55 m inside LCFS) at the final steady state, which is more than 7 times the plasma cutoff density.

In Fig. 2, trajectories of plasma current versus line-averaged density are plotted to compare the two discharges with the O-mode like polarization injection and the combination injection of X and O-mode like polarization shown in Fig.1. In the case of the combination injection, the plasma current reaches 20% higher while the density is almost the same. This result implies that the increment of EB wave power due to the better mode conversion from incident wave is consumed by more tail electron heating.

A new horizontal interferometer chord has been added by using a mirror and the waveguide switch, which can change the chord of tangency radius of Rt = 12 cm and 35.5 cm. In a similar high density discharge of Ip~10 kA and $\bar{n}_e \sim 5\times10^{17}\mathrm{m^{-3}}$, the density measurement along Rt =35.5cm indicates that the UHR layer is well inside of the 2nd ECR layer. It is confirmed that the EB waves are mode-converted at their first propagation band (between the 1st and 2nd ECR layer), after which the EBW propagate towards the 1st ECR layer and heat the bulk electrons as well as current carrying tail electrons.

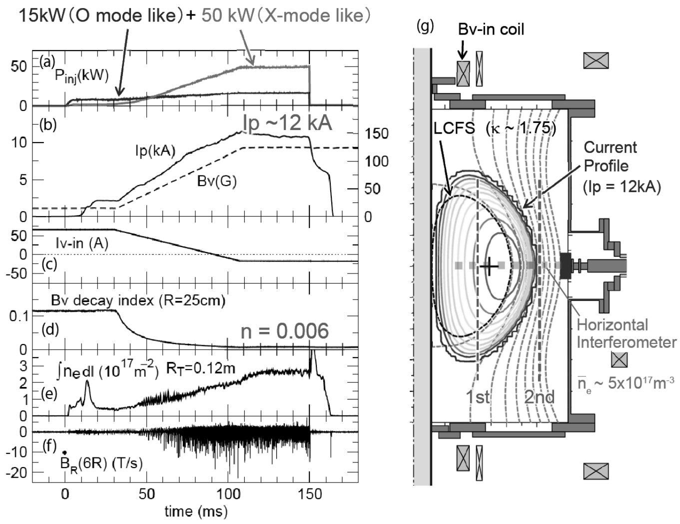

Fig. 1. Ip is ramped up to12kA and kept steady for 50 ms, where the density reaches 7 times the plasma cutoff density.

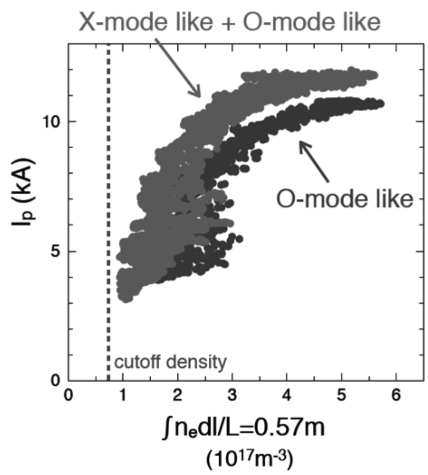

Fig. 2. Trajectories of plasma current versus line-averaged density in two discharges with O-mode like polarization and X-mode + O-mode like polarization

1) Noguchi, Y. et al.: Plasma Phys. Control. Fusion 55 (2013) 125005.
2) Igami, H. et al.: Plasma Phys. Control. Fusion 48 (2006) 573-598.