§2. Electron Bernstein Wave Heating in Extremely Overdense Plasmas

Uchida, M., Maekawa, T., Tanaka, H., Kuroda, K. (Kyoto Univ.),
Igami, H., Kubo, S., Shimozuma, T., Yoshimura, Y.

There arises much interest in an electron Bernstein wave (EBW) since it can propagate into and heat overdense fusion plasmas, such as spherical torus (ST) and high-density helical plasmas. However the heating property of bulk and energetic electrons by EBW at an extremely overdense regime is not well examined. In the LATE device formation of ST by EBW at seven times the plasma cutoff density has been achieved[1]. In this study we investigate the change in the heating property of bulk and energetic electrons by EBW as the density increases far beyond the cutoff density.

In this term we have investigate the characteristics of bulk and energetic electrons in extremely overdense ST plasmas maintained solely by EBW using 7 chords interferometers, 4 chords hard X-ray PHA system and heat flux measurements on the limiters, comparing two different discharges with ~3 times and ~10 times the plasma cutoff density produced by 2.45GHz 60kW microwaves.

Figure 1(a) shows a typical discharge. Four 20 kW magnetrons are used for the experiment. Three polarizers are installed in three transmission lines to have a good mode conversion rate to EBW by using the injection polarization adjustment method[2]. The plasma current is ramped up to Ip ~ 12 kA by injecting the X-mode like polarization power of ~50 kW and the O-mode like polarization power of ~15 kW. The electron density increases as Ip increases and at the final steady state the line-averaged density on the midplane reaches 5.5×10^{17} m^{-3}, which exceeds seven times the plasma cutoff density.

Figure 1(f) shows a contour plot of the electron density profile at the final steady state estimated from the interferometer measurement with 7 chords (5 vertical and 2 horizontal) using a density profile model of $n_e = n_1\Psi^{\alpha} + n_2\rho$ (Ψ:flux function , ρ:parabolic profile model[3]). The electron density reaches ~10 times the plasma cutoff density at the peak, which locates near the magnetic axis.

The electron density significantly decreases when we set the ECR layer at slightly inboard side as shown in Fig. 2(a). Figs. 2(b) and (c) show the time evolutions of X-ray spectra along the vertical chords (R=33 and 40.5cm). Both the energy and photon counts in the lower density discharge are much higher than that in the higher density discharge. At the final steady phase, typical energies are 65keV for the higher density and 100keV for the lower density.

Heat fluxes due to the loss of energetic electrons are measured from the temperature rise on four Mo plates in the vessel (Fig. 2(d)). In the lower density, heat fluxes to the outboard limiter and bottom outer plate are much larger than the higher density case as shown in Fig.2 (f). This suggests that energetic electrons develop outside the LCFS due to Doppler shifted cyclotron absorption and they are lost to the outboard limiter and bottom outer plate, as shown in electron trajectories of 100 keV in Fig. 2(e).The total loss to the limiters and plates amounts to ~85% of the injected microwave energy. On the other hand they are suppressed in the higher density and the total loss becomes ~55% of the injected energy.

These results indicate that the development of energetic electrons is suppressed as the density increases from ~3 times the cutoff density to ~10 times the cutoff density, which is consistent with the linear theory.

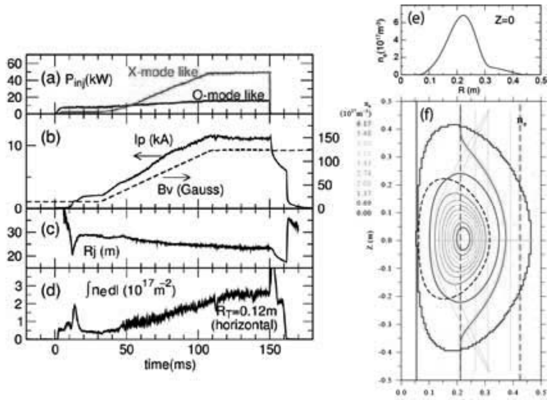

Fig. 1. (a)-(d) Typical discharge waveforms, (e) midplane profile and (f) contour plot of density estimated from 7 chord interferometer measurement.

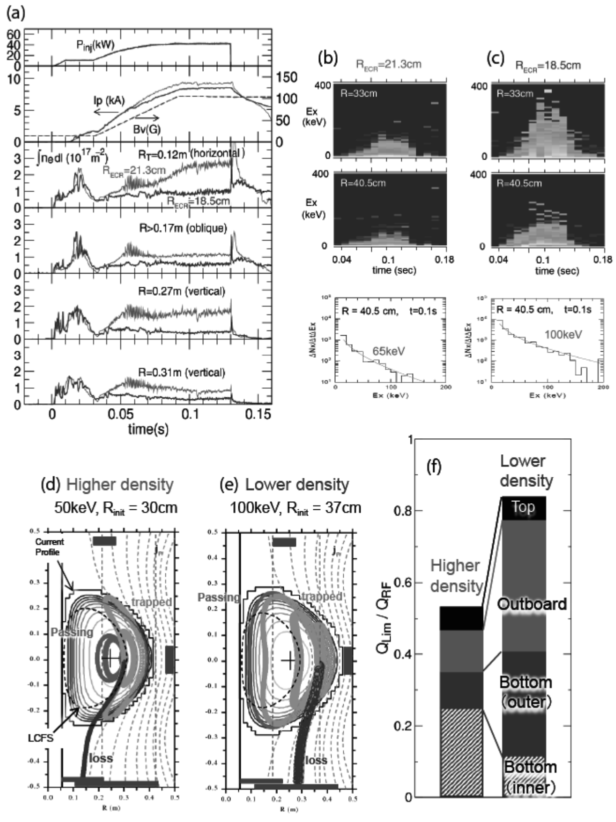

Fig. 2. (a) Discharge traces, (b)-(c) vertical chord hard X-ray spectra, (d)(e) electron trajectories, (f)heat flux to limiters.

1) Uchida, M. et al., Proc. 24th Int. Conf. on Fusion Energy 2012, IAEA-CN, EX/P6-18.
2) Igami, H. et al.: PPCF 48 (2006) 573-598.
3) Maekawa, T. et al., Nucl. Fusion 52 (2012) 083008