§14. 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 case that EB waves approach the ECR layer from the lower field side the power is absorbed firstly by the energetic electrons due to large Doppler shifts and the residual power is absorbed by bulk electrons at the ECR layer. This may lead a significant development of energetic electrons since the group velocity of EB wave is extremely slow and therefore the absorption is quite high. On the other hand, linear theory predicts the absorption by such energetic electrons could be much reduced if the bulk electron density increases well beyond the plasma cutoff density.

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.

Microwaves injected from the lower field side are mode-converted at the UHR layer into the EB waves that propagate deep into the plasma and absorbed by electrons via the EC resonance. 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 a high mode-conversion efficiency, while a X-mode like polarization is favorable at the slast stage of discharges where the plasma is highly overdense and the density gradient becomes high.

In the LATE device microwaves from four 2.45GHz magnetrons are injected from four midplane launchers. The O-mode like polarization and the X-mode like one are selected for each launching system by using the polarizer[1] and twists respectively. Among many attempts with combinations of the polarization and microwave power control, the largest plasma current and highest density are obtained by injecting ~40 kW microwave power with the X-mode like polarization and ~20 kW power with the O-mode like polarization as shown in Fig. 1. The plasma current ramps up to 12 kA and the line-averaged density on the midplane reaches 5.5×10^{17} m^{-3} (L=0.55m inside the LCFS), which is ~7 times the plasma cutoff density. Comparing with the result where all the power is injected with the O-mode like polarization, the density is almost the same and the plasma current 20% higher. Six-chords interferometer measurements show that the increment in density is large at R=17~27cm (Figs.1(e) and (f)) when Ip > 10 kA.

In this discharge the increment in Ip becomes slow when Ip > 10 kA. In this stage, intermittent plasma ejections across the LCFS are observed as shown in Fig.2. These events are characterized by large spike signals on magnetic probes (Fig.2(d)). The difference of fast visible camera images upon the event clearly indicates that the intensity decreases inside the LCFS and increases outside the LCFS (Figs.2(e),(f) and (h)). The electron line density in the horizontal chord at R=12cm decreases ~40% on the largest drop (Fig.2(b)). Repetition of such large ejection events causes a gradual decrease in electron density and plasma current. Suppression or mitigation of these events will be therefore required to reach the higher density and higher current. Further observations on these events with additional magnetic probes and study on the dependence on poloidal field geometries will be performed in the next term.

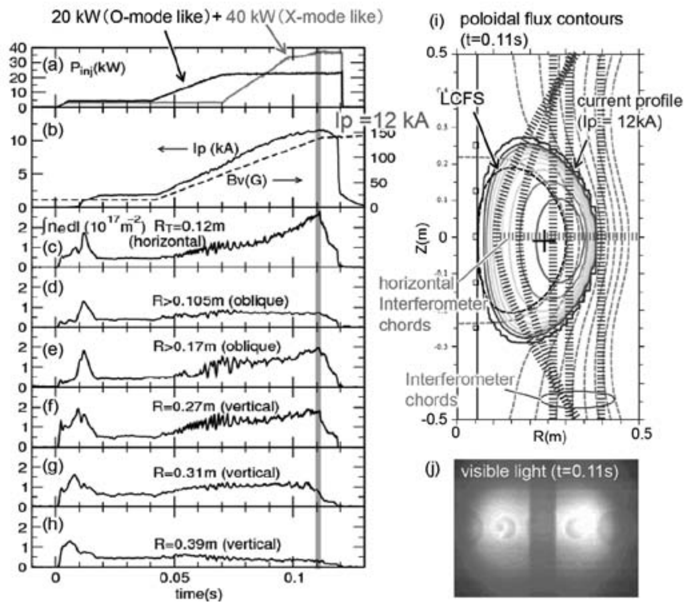

Fig. 1. Ip reaches12kA and the line-average density exceeds seven times the cutoff density

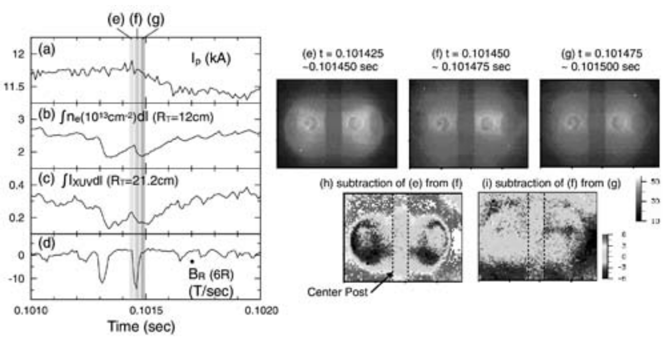

Fig. 2. Spikes are observed on magnetic probes and CCD images show plasma ejections across the LCFS.

1) Noguchi, Y. et al.: Plasma Phys. Control. Fusion **55** (2013) 125005.