§10. Formation of Minimum-B Torus by ECH

Maekawa, T., Tanaka, H., Uchida, M., Watanabe, F. (Kyoto Univ.),
Toi, K., Kubo, S., Shimozuma, T., Igami, H.

In this term we have looked for conditions for better coupling of microwave power to the plasma by changing toroidal field strength and attemped to control the current carrying fast electron tail by applying a weak radial magnetic field. Both experiments have been carried out by using 2.45 GHz microwave power up to 60 kW from three 20 kW magnetrons in the low aspect ratio torus experiment (LATE) device. [1)]

Dependence of heating and current drive performance of electron Bernstein (EB) waves on the electron cyclotron resonance (ECR) location was investigated to seek better coupling condition to the plasma core region. It was found that the plasma current is ramped up to Ip ~ 10 kA with ~10 times the plasma cutoff density when the ECR layer is located at R = 20 cm, slightly inside the vessel center of R = 25cm.[2)] In this configuration, the upper hybrid resonance (UHR) layer is located just inside the second harmonic resonance layer and the ECR layer locates just inside the current center. Therefore, EB waves mode-converted from the electromagnetic waves at the UHR layer are already in the first propagation band between the ECR and 2nd ECR layers. They can propagate towards the ECR layer without any barrier and effective heating of bulk electrons by EB waves is expected at the plasma core before the ECR layer. The line density is about four times higher than the previous case, where ECR layer located at 14 cm and EB waves may be in the second propagation band and absorbed at rather peripheral regions before 2nd ECR layer.

Soft X-ray and extreme ultra violet emission profiles show significant increase just outside the ECR layer with the increase of Ip. In addition, impurity line radiation at higher excitation energies such as CV (304eV) and OV (72eV) strongly increases as Ip reaches 10 kA. These suggest that the bulk electron temperature also increases by EB wave heating.

Hard X-ray pulse height analysis (PHA) along vertical chords shows that the energy and population of energetic tail electrons decrease in the low field side when the bulk density increases. Magnetic measurement and equilibrium analysis show that the perpendicular pressure of tail electrons decreases while the parallel pressure increases in the plasma center. These modifications of tail electron distribution may be due to change of power absorption of EB waves by the bulk and tail electrons.

In toroidal fusion plasmas, particle and energy transport caused by stochastic magnetic fields are very important for controlling plasma performance and MHD instabilities. Magnetic perturbation (MP) coils have been installed for transport study of bulk and fast electrons produced by EB wave heating and current drive. The MP coils are constituted by 4 sets. Each one is wound around a horizontal port outside the vacuum vessel, generating a radial static field. In the LATE device, the formation of closed magnetic surface is mainly generated by current carrying high energy electron tail which is increased with increase in external vertically field strength (*B*v). It is comparatively easy to observe effects of MP fields on the high energy electron.

When a weak MP field was applied, interesting effects on bulk and tail electrons were observed as follows.[3)] In a certain range of low *B*v (30~50Gauss) where Ip<5kA, the plasma current slightly decreases, but confinement of bulk electrons is hardly changed. On the other hand, the plasma current increases by ~1kA in higher plasma current discharges with *B*v ≥55Gauss where Ip>6kA. Furthermore, a rapid increase in line-averaged electron density as well as in impurity line radiation at higher excitation energies such as CV (304eV) and OV (72eV) are also observed. In the latter case of higher plasma current, the equilibrium analysis from magnetic data shows that the electron pressure component perpendicular to the toroidal magnetic field decreases, while the parallel one clearly increases. Additionally, the hard X-ray PHA indicates that high energy electrons with mainly perpendicular velocity component decreases at the peripheral region at the lower field side. These results suggest that decrease of trapped electrons and increase of passing electrons take place by the weak field of MP.

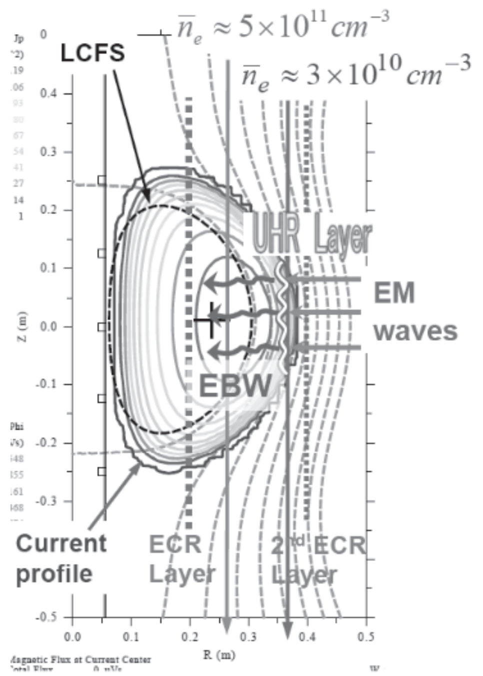

Fig. 1. EB waves mode-converted from the EM waves propagate towards the ECR layer without barrier and absorbed at the plasma core before ECR layer.

1) "Recent EBW-driven current startup experiments on LATE" T. Maekawa et al., US-J workshop on RF physics on plasmas, Feb. 8-9, 2011, Toba, Japan
2) M. Uchida et al., JSPF 27th annual meeting 02P76
3) F. Watanabe et al., JSPF 27th annual meeting 02P42