§14. Formation of Minimum-B Torus by ECH

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

Plasma current up to Ip=8 kA and 20 kA had been achieved in the Low Aspect ratio Torus Experiment (LATE) device by microwave injections at the frequencies of 2.45 GHz and 5 GHz, respectively [1]. In these plasmas a fast electron tail in the energy range of ~100 keV is developed by ECH and it carries the current. The pressure of the fast electron tail dominates over the bulk pressure, generating a poloidal beta of ~1.5-2.0 and an averaged beta of ~4%. While the detailed equilibrium analyses shows that these plasmas already have a minimum-B on the mid plane, its location is outside the last closed flux surface at the weak field side. The main purpose of the study is to extend the minimum-B region inside the LCFS by generating more powerful fast electron tail. Then, the plasma would offer a useful test-bed for study of stability and transport in toroidal plasmas with a magnetic well.

The experimental results and analyses had showed that electron Bernstein (EB) waves which were mode-converted from the injected electromagnetic waves heated bulk electrons and also generated the fast electron tail. Therefore, we concentrated on the improvements of the mode conversion rate and hard X-ray detection system for measurement of fast electron tail.

Microwaves injected from weak field side are mode-converted at the upper hybrid resonance layer into the EB waves that propagate deep into the plasma and absorbed by electrons via electron cyclotron resonance. The group velocity of the EB waves is quite low, being in the order of the electron thermal velocity, and therefore, the waves can be absorbed even in the small LATE device. Another important point is that the EB waves should have a high N//, say in the range of 2~3, where N// is the parallel component of the refractive index to the magnetic field. Parallel momentum of the waves is proportional to N// and the high N// waves drive tail electrons more parallel to the filed line, which is advantageous for confinement and current generation. Taking these points into account we redesigned the injection system which has a capability of injecting an elliptical polarization wave with arbitrary ellipticities to search for optimal injection polarization.

Figure 1 shows the principle of the polarization converter and the injection system for the LATE device. Linearly polarized mode propagating as a TE10 mode in the rectangular waveguide from the magnetron is transformed into a TE11 mode in the circular waveguide. Then the TE11 mode propagates through the polarization converter composed of a half-wave section and a quarter-wave section. Both sections are a circular waveguide that contains a thin Teflon plate across the diameter. Any TE11 mode is a superposition of two TE11 modes; electric field of one mode is parallel to the plate and another is perpendicular. The wave numbers of these modes is different. The half-wave section generates the phase difference of $\pi/2$, and the quarter-wave section does $\pi/4$. Then, the direction of the electric field of the TE11 mode rotates by 2θ via the half-wave section (see figure 1) and then transferred into an elliptical wave via the quarter-wave section. The polarization characteristics of the output wave depend on the tilt angles of half-wave plate and quarter-wave plate as shown in the figure.

A preliminary experiment showed that a left-handed elliptical mode to the toroidal field gave a better result than the case with linear polarization mode that was used in the previous injection system. The density and the soft X-ray emission intensity increased.

Vertical chord hard X-ray detection system having two chords was fabricated in addition to the horizontal system. Both chords are movable and a radial X-ray emission profile can be obtained on shot by shot bases. A preliminary profile is consistent with the prediction for the fast electron tail from the equilibrium analyses.

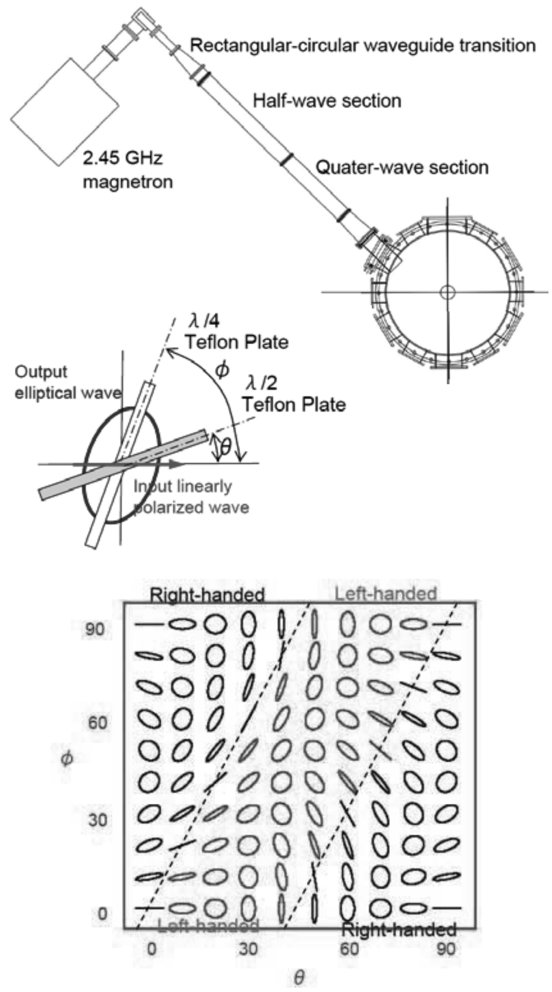

Fig. 1. A combination of half-wave plate and quarter-wave plate converts a linear polarization to arbitrary elliptical polarization.

[1] Uchida M, Yoshinaga T, Tanaka H and Maekawa T, Phys. Rev. Letters Vol 104 065001 (2010)