§11. Study of RF Generated Fast Electrons and Their Behavior in the Low Collisionality Regime

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The purpose of this research is to advance the physics understanding of high energy particles by creating high energy collisionless electrons with large displacements of drift surfaces from magnetic surfaces using the lower hybrid wave (LHW). Such electrons have large poloidal gyroradii and play important roles in affecting the equilibrium and forming the radial electric field, similarly to alpha particles created in burning plasmas. In FY 2015, emphasis was placed on increasing the plasma current (I_p) and on the analysis of LHW driven plasmas in TST-2. The former leads to increasing the density and energy of high energy electrons, while the latter is important for understanding and controlling high energy electrons.

The maximum I_p sustained by LHW excited by the outboard capacitively-coupled combline (CCC) antenna [1] was increased from 15 kA to 25 kA by the following three modifications: (a) increase of the toroidal field strength which improves wave accessibility to the plasma core, (b) change of the outboard limiter position to decrease the plasma density in front of the antenna, which reduces coupling from the antenna to the plasma, and (c) installation of new top and bottom limiters which probably reduced the power loss in the scrape-off layer (SOL). According to ray tracing analysis, a significant fraction of wave power can be lost in the SOL, and changes in the SOL plasma parameters may affect the magnitude of the LHW driven current. Thomson scattering measurements show that the electron temperature (T_e) profile is hollow, and the core T_e is low (10-20 eV) [2], suggesting that the contribution of bulk electrons to I_p is small, and that the LHW power is deposited mainly in the peripheral region. On the other hand, co-directed hard X-ray energy spectrum with an effective temperature of about 40 keV imply that I_p is driven by high energy electrons accelerated by the LHW. It should be noted that the effective temperature does not depend on I_p, which suggests that the confinement of high energy electrons is good.

RF power modulation experiments and RF power injection into Ohmic plasmas were performed. The response of the soft X-ray emission profile and the bulk T_e profile suggest that the RF power deposition moves towards the periphery as the toroidal field decreases and the plasma density increases. Flow velocity measurements [3] and 3-fluid equilibrium reconstruction [4] indicate that the potential and flow speeds are much lower than previous expectations that the prompt loss of high energy electrons generates a high positive potential in the plasma core. The reconstructed 3-fluid equilibrium shows that the effect of potential on high energy electrons is negligible, while the effect is significant for the bulk ion confinement.

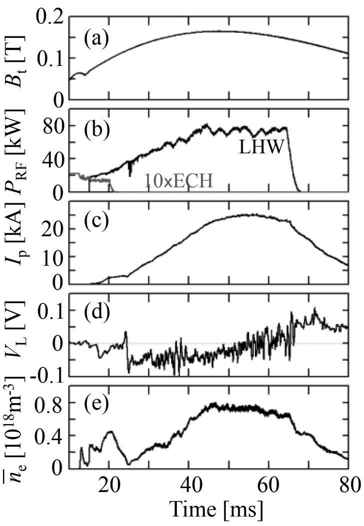

Fig. 1. Waveforms of the toroidal field B_t (a), net RF input powers P_{RF} (b), plasma current I_p (c), loop voltage V_L (d), and line averaged density n_e.

Based on these experimental results using the outboard CCC antenna and the results of wave propagation calculations under various conditions (e.g. Fig. 2), top launch is found to be advantageous for improved LHW power absorption in the plasma core. A new top-launch CCC antenna was designed, fabricated, and installed. In a preliminary experiment the maximum I_p of 12 kA has already been achieved.

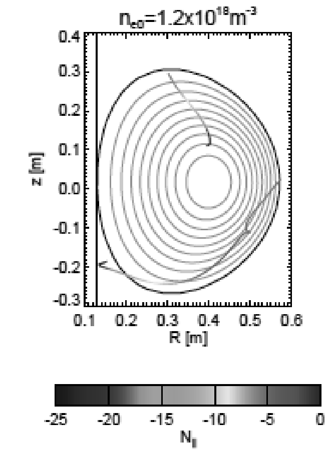

Fig. 2. Ray trajectories projected on a poloidal cross section for outboard and top launch cases.

[1] T. Shinya, et al., Nucl. Fusion **55**, 073003 (2015).
[2] H. Togashi, et al., JINST **10**, C12020 (2015).
[3] S. Tsuda, et al., Plasma Fusion Res. **10**, 1202064 (2015).
[4] A. Ishida, et al. Plasma Fusion Res. **10**, 1403084 (2015).