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TST-2球状トカマクにおける静電結合型低域混成波アンテナを用いたプラズマ電流立ち上げ実験

Plasma current ramp-up experiments using capacitively-coupled lower-hybrid-wave antenna on the TST-2 spherical tokamak

高瀬雄一[1]，江尻晶[1]，辻井直人[1]，Charles Moeller[2]，Benedikt Roidl[1]，新屋貴浩[3]，矢嶋悟[4]，山﨑響[1]，曽根原正晃[4]，冨樫央[1]，吉田裕亮[4]，高橋航[1]，戸井田和弥[1]，北山明親[1]，佐藤暁斗[1]，武井悠稀[4]，田尻芳之[1]，松本直希[1]

Y. Takase[1], A. Ejiri[1], N. Tsujii[1], C. Moeller[2], B. Roidl[1], et al.

[1]東大新領域，[2]General Atomics，[3]量研機構，[4]東大理

[1]Frontier Sci., UTokyo，[2]General Atomics，[3]QST，[4]Science, UTokyo

On TST-2 [1], non-inductive plasma current (I_p) start-up by the lower hybrid wave (LHW) at 200 MHz is being investigated. Presently two capacitively-coupled combline (CCC) antennas located on the outboard midplane (outboard-launch antenna) and the top of the plasma (top-launch antenna) are used (FIG. 1). The CCC antennas can excite a traveling LHW with a sharp wavenumber spectrum and high directionality. In order to increase the driven I_p beyond the previous level of 16 kA, the position of the antenna side limiters was adjusted to reduce the density in front of the antenna, and the toroidal magnetic field B_t was increased by about 30%. Furthermore, additional limiters were installed on the top and the bottom of the plasma to control wave propagation and dissipation in the scrape-off layer (SOL), and further wall and antenna conditioning was performed. As a result, the LHW-driven I_p was increased up to 25 kA (FIG. 2).

FIG. 1. Photographs of the outboard-launch (left) and the top -launch (right) antennas.

According to ray-tracing/Fokker-Planck analysis using GENRAY/CQL3D, the current drive efficiency can be improved substantially by launching the LHW from the top of the plasma. Top-launching is advantageous because (1) the rays tend to propagate towards the plasma center even in high density plasmas, (2) the rays experience a large up-shift in the parallel index of refraction $n_{\parallel}$ during propagation, which improves wave accessibility to the core and strong damping in the core, and (3) the loss of wave power in the SOL plasma is avoided because the wave power is absorbed before the rays reach the SOL. The new top-launch antenna was installed on TST-2 in March 2016. Preliminary experiments demonstrated that I_p of 12 kA can be sustained using the top-launch antenna alone [2], but the discharge was quite sensitive to the plasma size and position, especially during the initial start-up phase. In order to overcome such a difficulty, both antennas are used. Simultaneous launching of the LHW (60 kW and 50 kW from the outboard-launch and top-launch antennas) has demonstrated that I_p of 21 kA can sustained.

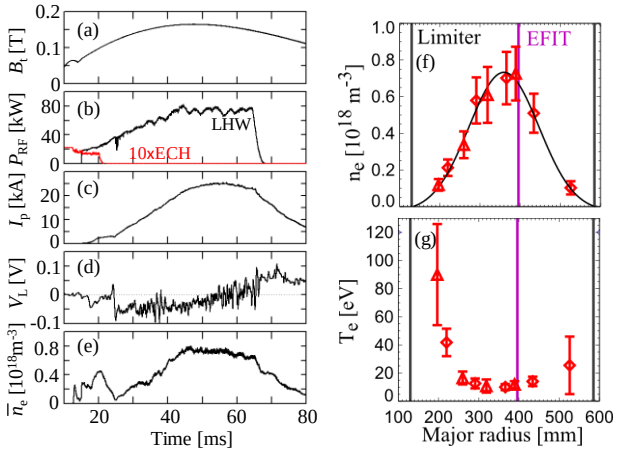

FIG. 2. Waveforms of (a) B_t, (b) net RF (LH and EC) powers P_{RF}, (c) I_p, (d) loop voltage V_L, (e) line-average density n_e, (f) and (g) electron density and temperature profiles measured by Thomson scattering at 55 ms.

[1] SHINYA, T., et al., Nucl. Fusion 55 (2015) 073003.
[2] EJIRI, A., et al., IAEA FEC (Kyoto, 2016) CN-234/EX/P4-48.