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Estimation of current distribution using flux loops in the low aspect ratio torus experiment device (LATE)

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Elimination of a central solenoid (CS) from the tokamak is quite beneficial since the structure of device will be significantly simplified. For spherical torus (ST) devices, elimination of the CS is crucial since there is only a small space in the center column. In the Low Aspect ratio Torus Experiment (LATE) device, start-up and formation of ST plasmas solely by the microwave power in the electron cyclotron range of frequency has been explored, where a plasma current up to ~ 20 kA has been non-inductively initiated, ramped-up and maintained by electron cyclotron heating and current drive by electron Bernstein waves [1].

In such experiments, information on the plasma current distribution is quite important for understanding start-up physics. There are several current drive mechanisms in the start-up, including an equilibrium current in the initial stage [2] which is driven in open magnetic field configurations, a cross-field passing electron current in the next stage [3] which brings about the magnetic flux surface closure, and an ECCD current after the closed flux surface formation [1]. Their spatial distributions are quite different. In the LATE, we use a model function of current density distribution having seven fitting parameters which are determined to match the observed flux loop signals detected outside the vacuum vessel. In this paper, we describe this model method and the magnetic measurement system.

Figure 1 shows the poloidal cross section of the LATE vacuum vessel. 17 flux loops are located surrounding the plasma. The current profile model has 7 fitting parameters (center coordinates R_0, Z_0, minor radius a, ellipticity κ, triangularity δ, radial shift of current peak σ, peaking index α, peak current density j_0).

The magnetic signals come from the poloidal field coil currents, the plasma current and the eddy currents induced in the vacuum vessel. The contribution from the plasma current is obtained by subtracting the contributions from the poloidal field coil currents and the eddy currents from the magnetic signals.

Figure 2 shows the typical start-up discharge. The plasma current is initiated and ramped up to ~20 kA by a 5 GHz microwave power of 190 kW [1]. The estimated plasma current distribution for Ip = 20 kA extends beyond the LCFS, which are attributed to large outward shift of current carrying high energy electrons and trapped electrons (E ~ 100 keV). The differences between the observed flux signals and fitted ones are less than 1 % in average.

References
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[2] K. Kuroda *et al*, Plasma Phys. Control. Fusion **58**, 025013 (2016)
[3] T. Maekawa *et al*, Nucl. Fusion **52**, 083008 (2012)

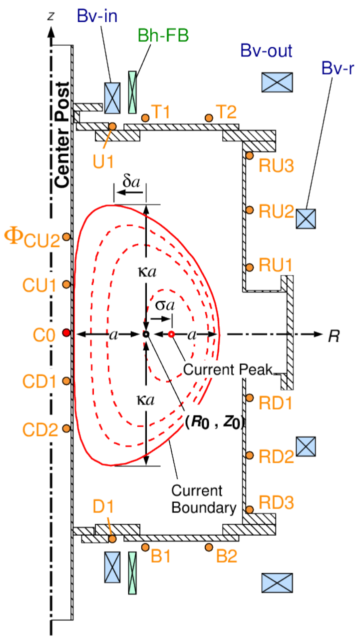

Figure 1. Flux loops (orange) and current distribution model.

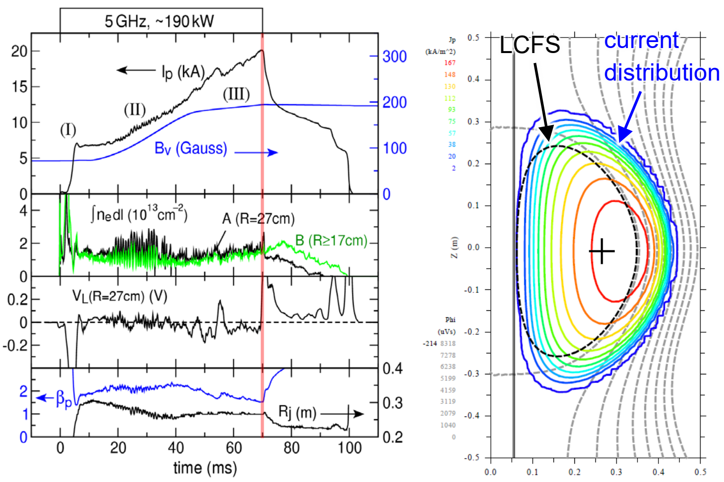

Figure 2. Typical discharge (left) and estimated plasma current distribution (right) just before the microwave pulse (t = 70 ms). Plasma current is generated and ramped up to Ip ~ 20 kA solely by a 5GHz microwave power of 190 kW. Differences between flux signals and fitted ones are less than 1 % in average.