Spontaneous Formation of Spherical Tokamak by ECH on LATE

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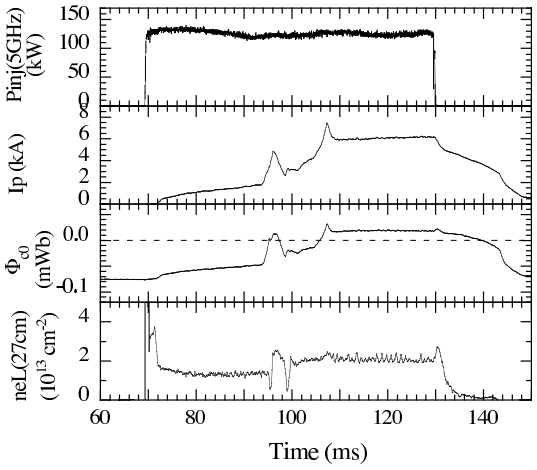
It is a crucial issue for realizing the compact reactor based on spherical tokamak to remove the center solenoid and to start-up the plasma current without Ohmic heating. It has been demonstrated that a spherical tokamak can be formed by injecting a microwave power at the electron cyclotron range of frequency in the solenoid-free LATE device [1]. In the course of these experiments, we have found the spontaneous formation of the initial closed flux surface under a steady vertical field.

Below figure shows the time evolution of the discharge with 5 GHz, 130 kW, 60 ms microwave power at the toroidal coil current I_T of 90 kAT and the steady vertical field of 80 G at the major radius of $R = 27.4$ cm. When the microwave power is injected, break down occurs at the fundamental electron cyclotron resonance and a weak toroidal plasma current starts to flow. When the plasma current gradually increases up to about 2 kA, it suddenly rises up to 5 kA within $\sim$ 2 ms. The flux within the center-stack becomes reversed and the formation of closed flux surfaces is shown by magnetic measurements.



The minimum microwave power for the spontaneous formation of closed flux surfaces is nearly proportional to the applied vertical field strength. This fact suggest that larger microwave power is necessary to increase the plasma pressure to flow pressure-driven current which is inversely proportional to the vertical field strength.

By analyzing the magnetic measurement data with a model current distribution, time evolution of the current distribution and the field configuration are estimated during these fast current rise and spontaneous formation of closed flux surfaces. It is shown that the plasma current flowing in the open field lines changes the surrounding field significantly, enhances the local magnetic mirror, and the fast current rise begins. During the current rise, small closed flux surfaces appear and become larger till the total current is limited by the equilibrium condition that the outward hoop force of the plasma current is balanced by the inward $\mathbf{J} \times \mathbf{B}$ force. These results suggest that two current drive mechanisms are involved with the spontaneous formation of initial closed flux surfaces, one is the pressure-driven current flowing in the open field lines and the other is the auto-selected current by the different direction of shift of drift surfaces of passing electrons around the small closed flux surfaces.

[1] M.Uchida, K.Higaki,T.Yoshinaga, et al., J. Plasma Fusion Res. Vol.80, No.2 (2004) 83.