§6. Study on Tokamak-helical Hybrid Configurations with a Low Aspect ratio

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The TOKASTAR-2 is a small toroidal device in which plasma confinement with tokamak configurations, stellarator configurations and tokamak-stellarator hybrid configuratins are possible[1]. The main objectives of this device are to evaluate effects of helical field application on tokamak plasma and to study effects of the plasma current on compact stellarator configuration. The pulsed vertical field (PVF) coils and the additional helical field (AHF) coils were installed in FY 2011.

In FY 2015, study on the effect of helical field on tokamak plasmas by a high-speed camera, triple probe measurement of helical plasmas and preliminary measurement of magnetic surface by electron beam were performed.

The radial movement of tokamak plasma was studied by a high-speed camera (FASTCAM SA4) typically with a frame of 256×128 pixels and 86,400 frames per second[2]. In the previous measurements, the field of view was limited to R ≦ 115 mm due to the window flange and the outer leg of a TF coil. In order to expand the field of view, we installed a surface plane mirror and a structure for supporting the mirror and adjusting its angle. The camera lens was also changed from a F-mount lens (f = 50 mm) to a wide-angle lens (C-mount lens f = 16 mm). After the modification, the field of view covered the whole radial range between inner and outer walls. The radial profile of light emission intensity was compared for two discharges, one without the helical field and the other with helical field in Fig. 1. In these discharges the vertical field was common and weaker than the optimum value. The plasma touched the outer wall repeatedly, as shown by vertical arrows, in a discharge without helical field. The plasma current decreased after the contact with the outer wall and the plasma moved inward. After that the plasma current increased, the plasma moved outward and touched the outer wall again. This process was revealed for the first time by the improved camera system. In a discharge with helical field, the plasma position was stable and the plasma touched the inner wall during the discharge. Thus the external helical field contributed to the horizontal position stability in this condition namely with a weak vertical field.

Langmuir probe measurement was done for helical plasmas without plasma current. Previous measurements needed a large number of shots to evaluate the density or the temperature at one spatial point since the probe data was obtained for a fixed probe voltage in the single probe or the double probe methods. The triple probe method was adopted in FY 2015 and the evolution of the electron density and the electron temperature was obtained in a single discharge. Then the radial profile was obtained by changing the probe position shot by shot. It was observed that the electron density was higher in discharges with helical field than in those without helical field in expected closed flux surfaces when the electron cyclotron resonance layer of 2.45 GHz RF wave was located inside. On the other hand, the electron temperature difference was not clear.

The position or the size of closed flux surface would be affected by error fields. A system was developed for measurement of magnetic surfaces by using electron beam. In a vacuum test chamber without magnetic field, the electron beam was successfully detected by a probe current even for a very low acceleration voltage of 10 V. In TOKASTAR-2, the electron beam was detected for a acceleration voltage of 40 V at expected positions when the toroidal field only or the toroidal field and the vertical field were applied, but not detected when the helical field was applied. We might have some problems in operation of the electron gun in magnetic field, which will be studied in detail in FY 2016.

1) Oishi, T. et al.: J. Plasma Fusion Res. SERIES **9** (2010) 69.
2) Sakito, T. et al.: Plasma Fusion Res. **11** (2016) 2402074.

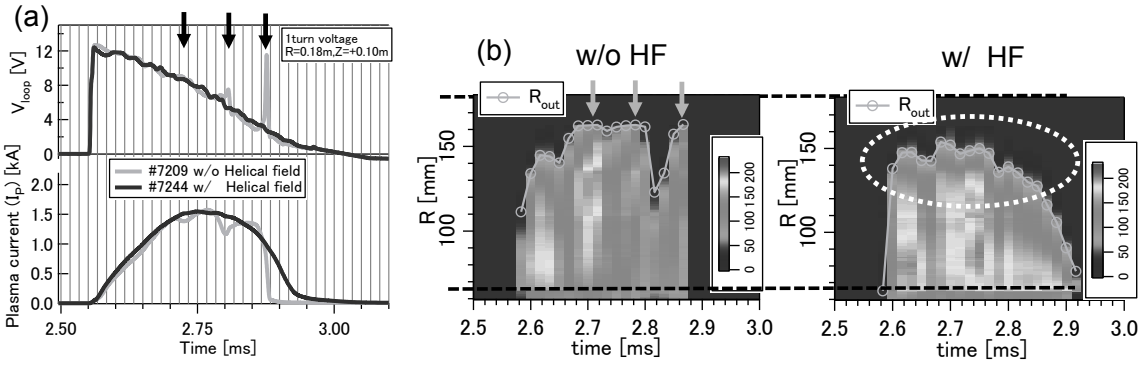

Fig. 1. (a) Outer loop voltage and plasma current and (b) contour plot of evolution of radial distribution of light emission intensity averaged in the vertical direction, for a discharge without helical field and a discharge with helical field.