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Current Status of Development of High-Density Radio Frequency Plasma Source with Flat Loop Antennas for Pilot GAMMA PDX-SC

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For realizing the demonstration power plant (DEMO) and future fusion reactors, it is critical to reduce the heat load to the divertor. Currently, divertor simulation experiments are being conducted using many linear devices to investigate the physics of detachment plasma, which is one of the methods used to reduce the heat load [1]. In order to investigate detachment plasma in a more relevant plasma condition, which is expected in the entire scrape-off layer (SOL) and divertor region in DEMO, higher electron densities of the order of 10^{20} – 10^{21} m^{-3} and electron and ion temperatures above 100 eV in the steady state are required [1]. In addition, a large plasma diameter under a strong magnetic field is expected in a real-scale DEMO-grade divertor region [2].

As one of the radio frequency (RF) plasma sources, helicon plasma (HP) sources are expected to generate the steady-state, high-density and large diameter plasma by high-power discharge with a flat type antenna. However, hydrogen plasma generation, which is important for divertor fundamental research, has thermal problems due to the effects of high temperature atoms caused by dissociation, or other factors. In addition, the physical properties of HP sources in the high-density, such as density saturation due to neutral particle depletion, are complex and remain unclear. Therefore, our group has been developing a novel HP source using flat antennas to investigate these fundamental challenges [3].

The novel plasma source has two-turn flat loop antenna, which is one of the flat-type antennas (Fig. 1). The antenna is made of cooper and has a water channel for cooling to realize high-power and high-density plasma generation. An RF power supply, 30 kW, 13.56 MHz continuous wave, and a matching box with two variable condensers were connected to the antenna. The plasma source development was carried out using the CTP (Compact Test Plasma) device, and argon and hydrogen discharges were performed by varying a magnetic field configuration and its field strength using two magnetic coils up to about 0.1T. Figure 1 shows the picture of argon discharge experiment on the CTP. It shows the strong (blue light) intensity, which shows argon visible lines, and a characteristic of helicon plasma.

The plasma source can be installed to the Pilot GAMMA PDX-SC (Pilot device), which is under construction for fundamental research of the DEMO relevant divertor plasma. The Pilot device has two superconducting magnets, generating strong magnetic field of up to 1.5 T. To the best of our knowledge, it is the first example of HP plasma generation by flat loop antenna under such a strong magnetic field.

In this presentation, we will report the experimental results during the discharge under different magnetic fields by the CTP and the Pilot device.

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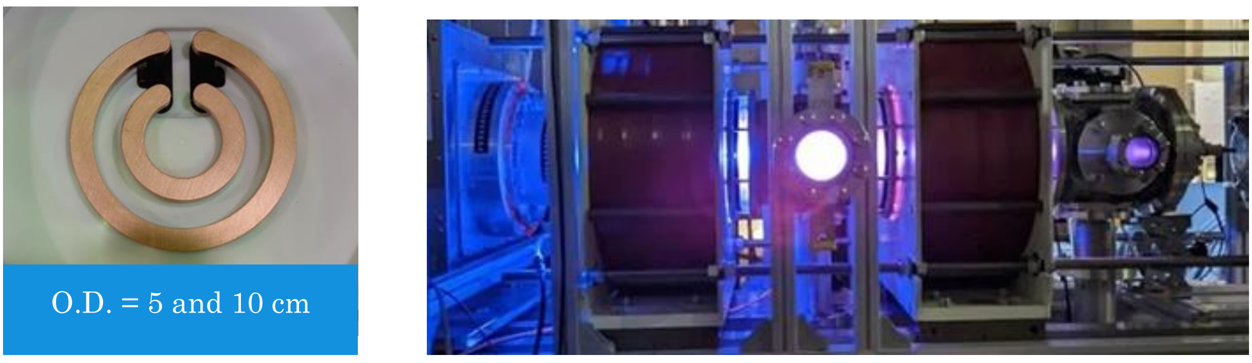

Figure 1. The novel plasma source with two-turn flat loop antenna, and the CTP photograph during argon discharge. The antenna outer diameter (O.D.) was 5 and 10 cm. The antenna was installed on left hand side of picture.