Development of High Density and Large Diameter Plasma Source in Superconducting mirror device Pilot GAMMA PDX-SC

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As a platform for DEMO divertor development, a linear plasma experimental device that can simulate the high-density divertor plasma expected in the DEMO reactor is required [1]. To contribute to developing such an experimental device, the Plasma Research Center at the University of Tsukuba is constructing a simple mirror-type device, Pilot GAMMA PDX-SC (Pilot device), using superconducting (SC) coils shown in Figure 1. In this presentation, we will report on the outline and initial results of a DC arc discharge plasma source using a hot cathode, which has been developed as a steady-state high-density plasma source for this system.

The aim of this research is to generate steady, high-density hydrogen plasma with an electron density of > 10^{19} m^{-3} and a diameter of ~10 cm (FWHM ~5 cm) in a divertor simulated region while maintaining the gas pressure in the main vacuum vessel, which is the plasma confinement region, at about 10^{-4} Pa. To achieve this goal, we have developed a thermal cathode arc discharge plasma source optimized for the magnetic field configuration of the Pilot GAMMA PDX-SC, based on the knowledge of the TPD-type plasma source as shown in Figure 2. The cathode is a 15 cm diameter LaB_6 disk, heated to the temperature of enough thermal electron emission by a carbon heater installed behind the disk, and a steady-state plasma is generated by a DC arc discharge between the cathode and the anode, each of which is placed between insulated intermediate electrodes. The plasma passing through the anode flows into the main vacuum vessel along the magnetic field created by the SC coil and through the differential pumping chamber. Each electrode is forced water-cooled for heat removal, and the inner diameter was designed and fabricated to follow the magnetic field lines with a radius of 1 cm at the throat at the center of the SC coil.

A discharge test using hydrogen was conducted during the rated operation of the superconducting coil (1.5 T magnetic field at the throat), and hydrogen plasma was successfully generated with a discharge current of 20 A (Figure 3). Despite preliminary low current discharge, the plasma density achieved 1.2 x 10^{19} m^{-3} for argon and 0.8 x 10^{19} m^{-3} for hydrogen at the magnetic throat of 1.5T.

Additionally, we are in the process of developing a high-power helicon discharge plasma source with a capacity of 30kW as an alternative option. During this presentation, we will be providing a detailed overview of the plasma source and its properties, as well as discussing the challenges associated with achieving a higher-density and higher-temperature plasma.

This work was partly supported by the NIFS Collaboration Research program (NIFS20KUGM148 and NIFS23KUGM174).

Reference

[1] K. Okano *et al*., Fusion Eng. Design **136** (2018).

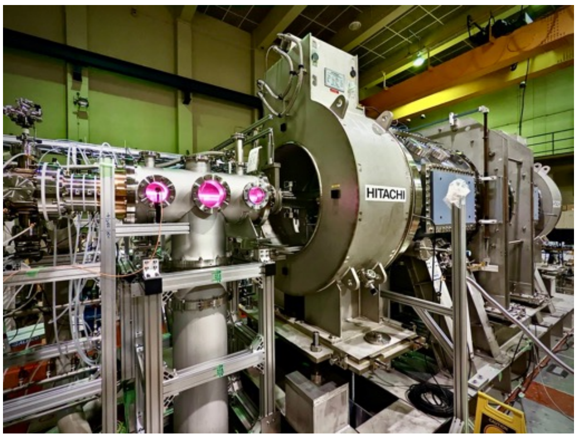

Figure 1. Superconducting mirror device Pilot GAMMA PDX-SC.

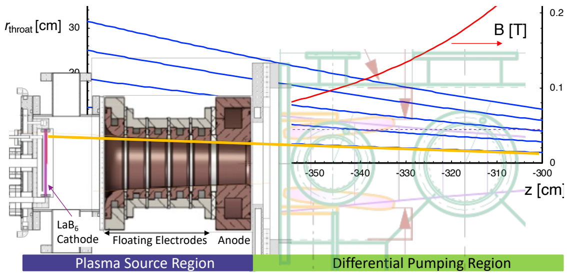

Figure 2. DC arc plasma source for Pilot GAMMA PDX-SC and magnetic field structure (orange lines are magnetic field lines with a throat radius of 1 cm).

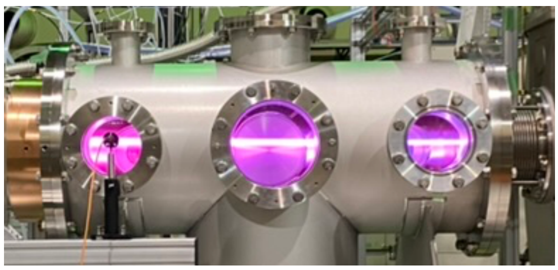

Figure 3. First hydrogen plasma viewed from the observation port of the differential pumping chamber (discharge current 20A).