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Development of large channel diameter plasma window using indirectly heated hollow cathode

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The plasma window (PW) is a plasma application technique that separates a high-pressure (10-100 kPa) and vacuum (~1 Pa) environment without using solid materials such as glass and stainless steel. The plasma inside the channel of the PW heats neutral gas flowing from the high-pressure environment, increasing the temperature of the gas and reducing the conductance. Due to the decrease in conductance, the mass flow inside the channel is suppressed, and the pressure difference between the entrance and exit of the PW is kept substantially high [1]. These features enable the PW to transmit the soft-X rays, electron and ion beams, which cannot pass through the glass and stainless steel, to the high-pressure region [2]. This prominent feature of PW is expected to pave the way for the new application of quantum science.

One of the applications of the PW under consideration is a differential pumping of the gas stripper for the heavy ion beams produced by accelerators [3]. The production of heavy ion beams, such as gold and uranium ions, has been extensively studied for rare isotope research. The PW can realize the gas stripper with less consumption of the helium gas and with reduced device size. For realizing this application, the PW with large channel diameter (more than 6 mm) is required to transmit the heavy ion beams to the gas cell.

We developed a PW, whose inner diameter was 8 mm, with an indirectly heated hollow cathode to achieve sufficiently high pressure separation capability and long operation duration. Schematic diagram of the cathode and the PW apparatus are shown in Figure 1 (a) and (b), respectively. The hollow cathode made of LaB_6 was heated by the C/C composite heater surrounding the hollow cathode to increase the thermionic electron emission. The PW developed successfully separated 2.4 kPa and 16 Pa, and the pressure separation capability was sustained for more than 1 hour, as shown in Figure 1 (c). Hβ Stark broadening measurement and the Thomson scattering measurement showed that the electron density and temperature inside the channel reached 10^{19}-10^{20} m^{-3} and 1.6 eV, respectively. The power balance analysis on the electron thermal energy revealed that the neutral density and temperature inside the channel, which are the critical parameter for assessing the pressure separation capability, were as high as 10^{23} m^{-3} and 4000 K, respectively.

We will introduce the detail of the newly developed PW apparatus and the quantitative analysis on the pressure separation capability of the PW.

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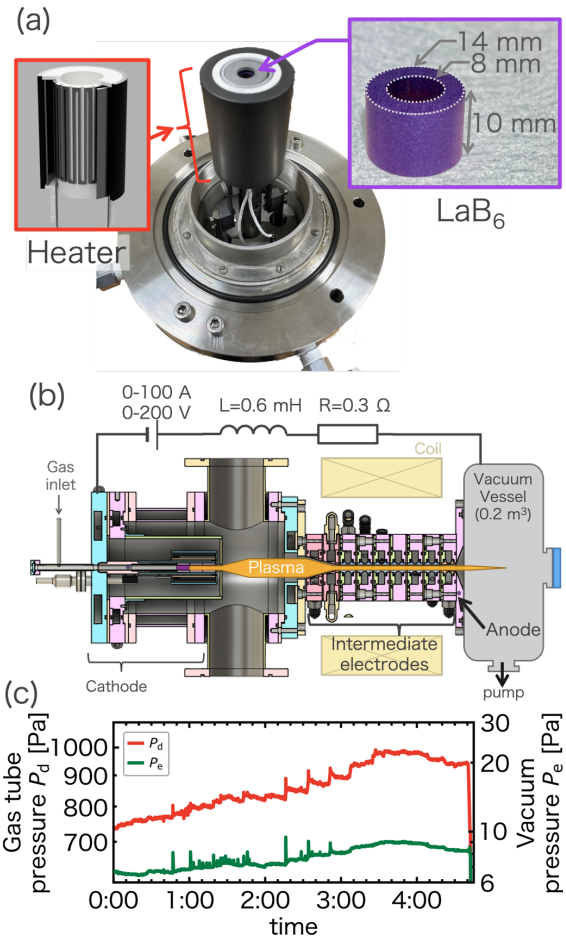

Figure 1 Schematic diagram of the indirectly heated hollow cathode (a), the plasma window apparatus (b). (c) Time evolution of the pressures at the gas tube and the vacuum vessel.

References

[1] A. Hershcovitch, PoP **5**(5), 2130-2136 (1998).
[2] B. T. Pinkoski *et al.*, RSI **72**(3), 1677-1679 (2001).
[3] F. Marti, Proceedings of LINAC2012, 1050-1054 (2012)