Measurement of electron density and temperature in plasma window with diameter of 10 mm

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The ImPACT Fujita program[1)] aims to transmute the LLFP into stable or short-lived nuclei. A scheme utilizing neutrons generated by bombarding deuteron beams on the liquid lithium target has been studied. When the target is irradiated by a high-power beam, lithium vapor is generated. In order to separate the vacuum beam line from the target, the use of plasma window (PW) has been proposed. The original PW[2)] has an aperture of 2.36 mm in diameter. However, a beam with a diameter of 100 mm or more is expected in our project. Therefore, we started to test a new PW with a diameter of 10 mm based on the PW developed by Namba *et al.*,[3)] in order to study the possibility of enlargement of the diameter.

In the viscous flow through a circular pipe with a constant diameter, the conductance is obtained from the Hagen-Poiseuille equation.

$$C = \frac{\pi r^4}{8\eta L}\left(\frac{P_1 + P_2}{2}\right) [\mathrm{m^3/s}] \qquad (1)$$

Here, C, r, L, and η are the conductance, radius, length of pipe, and gas viscosity, respectively. P_1 and P_2 are the upstream and downstream pressure, respectively. PW separates the vacuum by high viscosity accompanying the high temperature of the arc plasma.

Figure 1 shows the experimental setup. Helium gas was introduced from the upstream side of the PW. The helium gas was ionized in the PW, and was evacuated by a mechanical booster pump. The flow rate Q was controlled, and the pressures P_1 and P_2 were measured.

Spectroscopic measurement of visible light was also carried out to investigate the plasma characteristics. The light emitted from the plasma was split into two paths, and focused on to two spectrometers. The electron density n_e was determined from the Stark broadening of the H_β line. In addition, the electron temperature T_e was determined from the Boltzmann plot by using the transition intensity of He I $2p^3$P-nd^3D.

The results are summarized in Table 1. As the flow rate was increased, the electron density was also increased. On the other hand, the electron temperature was decreased. The electron density was increased with the gas density, while the plasma was cooled by collision with neutral particles.

The pressure P_1 was increased with flow rate. But the contribution of plasma may be greater in the condition of smaller flow rate, because PW exploits its high temperature. We compared the dependency of P_1 on the flow rate under the condition with and without plasma, as shown in Fig. 2. The dotted line shows the fitting result by the power function. P_1 with plasma was 1.43 times larger than that without plasma in the condition of 1 [std L/min]. On the other hand, the factor was 1.38 in the condition of 2 [std L/min]. It was confirmed that the enhancement of P_1 by igniting plasma was slightly high at low flow rate condition. In order to obtain the relation in pressure, diameter, and required input power for a diameter of 100 mm, we plan to carry out the experiment with larger diameter.

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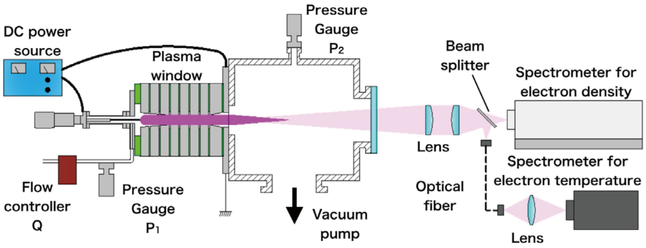

Fig. 1. Experimental setup.

Table 1. Experimental result for PW.

Q [std L/min]	P_1 [kPa]	n_e [1/cm^3]	T_e [eV]
1	8.21	1.94×10^{14}	2.69
2	10.3	2.48×10^{14}	0.192

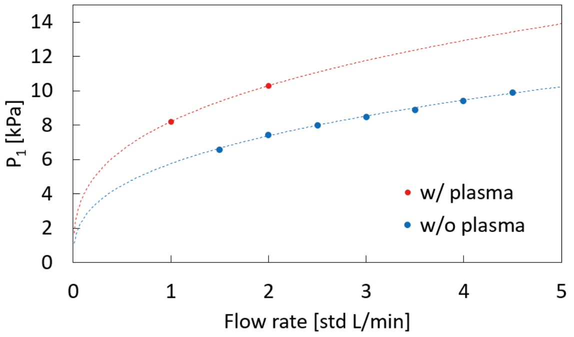

Fig. 2. Dependency of P_1 on flow rate.

References

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