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Edge plasma measurements with helium beam probe in LHD
LHDにおけるヘリウムビームプローブを用いた周辺プラズマ計測

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A supersonic helium beam probe has been developed for edge plasma measurements in LHD. After the research and development for several years on a test bench and a small plasma device, a proto type injector was made and installed in LHD this year. In the preliminary experiment, the pulsed beam at 1 – 3 MPa were injected in LHD. The line emission from helium atoms were detected with a fiber array coupled with a spectrometer. One-dimensional emission profiles were obtained in the neutral heated plasma. Comparing the profiles with those obtained in ordinary helium gas puffing discharges, indication of localized emission source due to the collimated beam was identified.

1. Introduction

Experimental study of edge plasma is crucial since it plays an important role in particle and energy transport. For edge plasma measurements, a supersonic helium beam probe (HeBP) has been developed in LHD [1]. The HeBP can measure electron temperature T_e and density n_e simultaneously with high time and spatial resolutions, using three (667.8, 706.5, 728.1 nm) line emissions from helium atoms in the plasma. It is an advantage of HeBP to be free from a heat load which may result in impurity contamination in the plasma.

In 2010 optimization of the injector were almost completed in a test bench and HYPER-I which is a small linear plasma device. In this research and development (R&D) study, it was concluded that the helium gas flow can be collimated with a Laval nozzle at the pressure of ~ 3 MPa [2]. Based on this result, a proto type injector was made and the HeBP system was installed in LHD.

In this conference, the summary of the R&D results are presented. After describing the injection system and optical detection system, results from preliminary experiments in LHD are presented.

2. HeBP system installed in LHD

The performance of the HeBP depends on the quality of the beam, i.e. its density and divergence. Hence it is essential to produce dense (bright) and thin beam for good time and spatial resolutions, reducing the integral effect along the line of sight. On the other hand, it is generally required for diagnostics not to disturb plasmas by the measurement. To minimize the density increase due to the introduced helium atoms, a pulsed beam injection system with a fast solenoid valve (response time $\tau < 1$ ms) is employed. The valve is directly coupled onto a Laval nozzle to collimate and accelerate the beam, through which the pressurized helium gas at 1 - 3 MPa is injected to the plasma, as shown in Fig. 1. In order to avoid the incorrect action of the fast solenoid valve due to the strong ambient magnetic field (~ 800 Gauss), it is covered by the magnetic shield made of ferromagnetic materials.

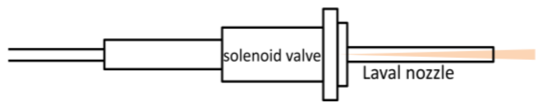

Fig. 1. Fast solenoid valve and Laval nozzle.

For the optical detection for three helium lines, a one-dimensional fiber array connecting to a spectrometer (f = 25 cm, F = 3.9) is utilized. A back-illuminated CCD detector is attached at the position of the exit slit to acquire the spectra. In the derivation of T_e and n_e with this spectroscopic technique, the collisional-radiative model is employed.

The beam is injected into LHD almost radially, and the fiber optics is viewing nearly perpendicular to the beam, as shown in Fig. 2. In this configuration, the spatial resolution of the optics is about 8 mm, although it is actually defined by the beam width.

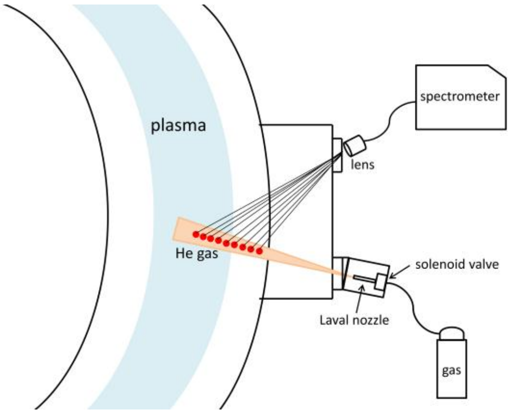

Fig. 2. Schematic of experimental setup.

2. Experimental results

Preliminary experiments were carried out with the neutral beam heated plasma in LHD. Fig. 3 shows radial profiles of He I (667.8 nm) light from the helium beam (open circles) injection discharge, together with the ordinary helium gas puff discharges (closed circles). The abscissa indicates the effective minor radius based on the equilibrium calculations. In this experiment, the helium gas pressure for the beam injection was ~ 1 MPa.

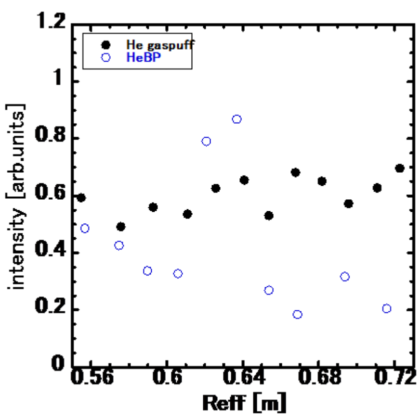

Fig. 3. Emission profile of He I light (667.8 nm).

It can be seen that the HeBP emission increases gradually from outer to inner region, which indicates that the emission is localized near the beam. In this situation, the emission reflects the local electron density. On the other hand, the gas puff profile is almost flat. This is because He I emission source is uniformly located at the periphery of the torus plasma where the local information is lost due to the integral effect along the line of sight.

With the collisional-radiative model, n_e and T_e profiles were reconstructed as shown in Figs. 4 (a) and (b), together with those obtained with the Thomson scattering. It seems that those profiles measured with HeBP are almost flat, except a little increase in n_e at R_{eff} ~ 0.68 where the Thomson data start to increase. These results suggest that the collimation of the beam is still insufficient at this stage. Higher injection pressure or longer Laval nozzle is expected.

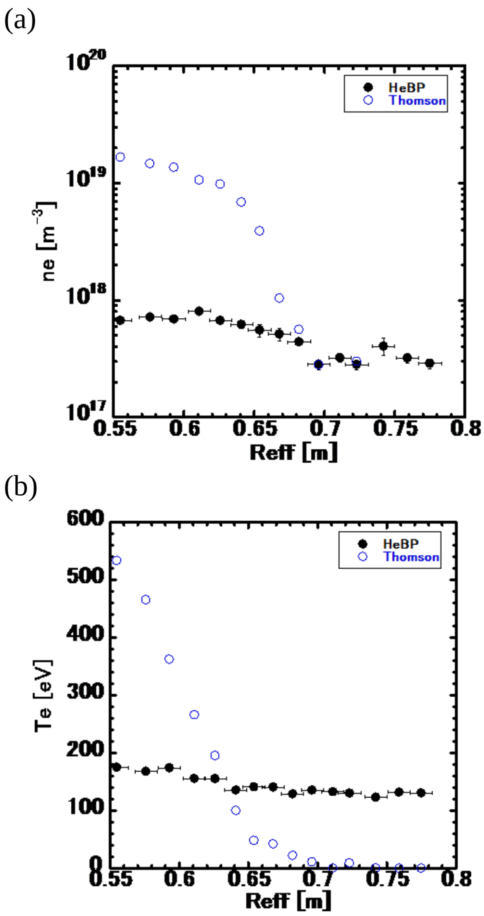

Fig.4 (a) Electron density and (b) temperature profiles measured with HeBP (closed circles) and Thomson scattering (open circles).

4. Reference

[1] T. Morisaki, et al., Proc ICPP2000 (2000).
[2] K. Okamoto, Master’s thesis (2011).