

## §6. Development of Helium Beam Probe and Preliminary Diagnostics in HYPER-I

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In order to diagnose fusion plasmas, some beam probe methods have been developed and employed in major fusion devices. The beam probe has an advantage of being free from a heat load which may result in impurity contamination in the plasma. Thus it is often used for edge plasma measurements in place of the Langmuir probe. The helium beam probe (HeBP) which is one of the beam probes appropriate for edge plasma measurements utilizes neutral helium for a beam species. It can measure electron temperature  $T_e$  and density  $n_e$  simultaneously with the collisional radiation model. The HeBP was first proposed in TEXTOR tokamak in 1992<sup>1)</sup> and has been used in many devices.

In LHD, a pulsed HeBP is planned to be installed for the edge plasma diagnostics. To minimize the helium introduced in the vacuum vessel, a pulsed beam injection system is employed. A fast solenoid valve which can be controlled within 1 ms is coupled with cone-shaped nozzle. Pressurized helium gas at 0.3 MPa is fed directly from a regulator without a buffer cylinder.

Before the installation in LHD, the HeBP system was tested in HYPER-I which is a linear plasma device with an electron cyclotron heating system. HYPER-I can generate relatively dense plasmas more than  $\sim 10^{19} \text{ m}^{-3}$  with its high power klystron and whistler mode injection. Thus HYPER-I is appropriate to simulate the fusion edge plasmas. The microwave at 2.45 GHz is injected in the longitudinal direction from one end of the chamber. The magnetic field is applied to have a resonance with the electron cyclotron frequency at  $z \sim 0.5 \text{ m}$  where the origin of the  $z$ -axis is at the injection window of the microwave. The beam injector is installed about 0.5 m downstream ( $z \sim 1 \text{ m}$ ) from the resonance point. In order to form a clear boundary between the plasma column and the vacuum region, a circular limiter can be installed upstream from the injector to detach the plasma from the vessel wall. Although the helium gas injected through the fast solenoid valve is shortly pulsed, the net quantity is considerably large compared to the working gas quantity. Therefore an additional turbo molecular pump is installed on the opposite side to the injection port.

The optical system to observe the emission from the helium beam is also prepared. The 2-dimensional profiles of the emission light are measured with a CCD detector (PixelFly; 1280H  $\times$  1024V pixels, 12 bit,  $\sim 12 \text{ fps}$ ) through the interference filter ( $\Delta\lambda_{\text{FWHM}} = 1 \text{ nm}$ ), in the longitudinal direction from another end of the chamber. For the precise measurements of spectra from helium beam, a Czerny-Turner type spectrograph (Oriel MS-257;  $F = 3.9$ ,  $f = 257 \text{ mm}$ ,  $6.5 \text{ nm/mm}$ ) coupled with a CCD detector (Andor DV420-BV; 1024H  $\times$  254V pixels, 16 bit) is also utilized. To obtain radial profiles of the spectra, a 7-channel fiber

array is installed in a side port perpendicular to the injector. The time resolution of the spectrograph system is 1 – 5 ms. A Langmuir probe can also be inserted across the beam to obtain the local  $T_e$  and  $n_e$ , for the comparison with HeBP. A schematic drawing of the experimental setup is shown in Fig. 1.

Preliminary experiments were performed in Ar plasma to see if the beam can be identified in the background plasma. Figure 2 shows a 2-dimensional He I (706 nm) profile measured with the CCD detector at the end of the vacuum chamber. It can clearly be seen that helium beam is injected from the top of the figure and penetrate up to the plasma center. Since no special nozzle like “Laval nozzle” is employed, the beam width is relatively large as  $\sim 5 \text{ cm}$ . Thus the spatial resolution of HeBP at this stage is also about 5 cm. For the better resolution, the beam should be collimated with Laval nozzle and skimmer.

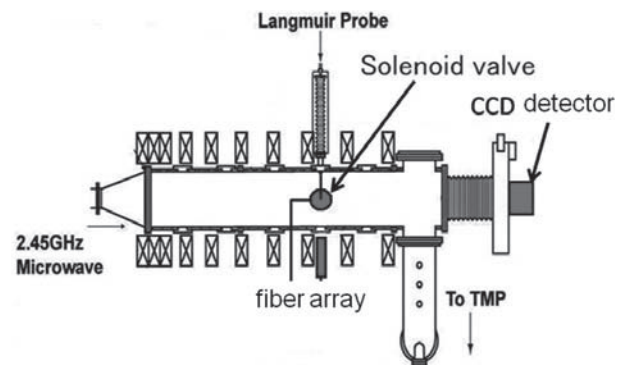


Fig. 1. Schematic drawing of experimental setup.

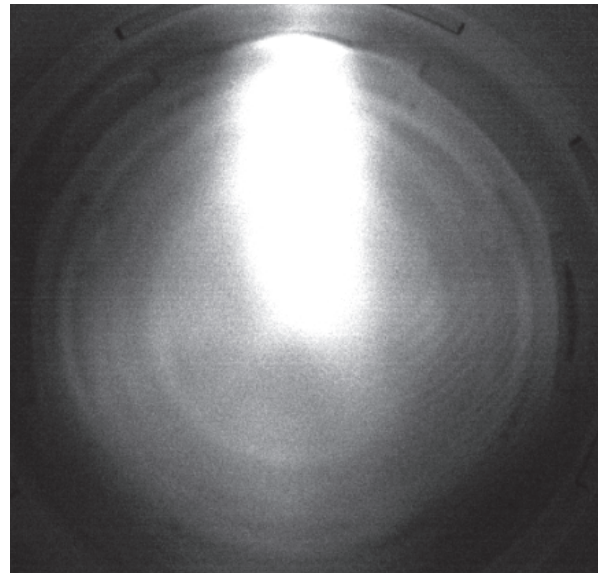


Fig. 2. A CCD image of He I (706 nm) emission taken from the chamber end.

1) Schweer, B. et al. : J. Nucl. Mater. **196-198** (1992) 174.