§7. Development of Helium Beam Probe for Edge Plasma Measurements

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For edge plasma measurements in LHD, a neutral helium beam probe (HeBP) has been developed for three years. In 2010 the final optimization of the injector and a new attempt to utilize the argon-helium (Ar-He) mixture gas were performed in HYPER-I and the R & D chamber.

The HeBP can measure edge 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. For T_e and n_e derivations, the collisional-radiative model is employed. The HeBP has an advantage of being free from a heat load which may result in impurity contamination in the plasma. The HeBP system consists of a beam injector and a photo detector coupled with a spectrometer or interference filters. 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 less than 5 MPa is injected to the plasma.

In order to optimize the beam injector, various kinds of Laval nozzles were tested in HYPER-I with a hydrogen plasma and in a R & D chamber with an electron beam, measuring the beam width. Figure 1 shows beam shapes for different nozzles in the HYPER-I plasma. It can be seen in Fig. 1 (a) that the beam through the conical nozzle is considerably wide. On the other hand, the beam collimation is improved with the Laval nozzle, especially with longer one, as shown in Fig. 1 (b) and (c). The beam widths with different throat diameters were also investigated in the R & D chamber, changing the injection pressure P of helium, as shown in Fig. 2. It is found that the Laval nozzle with throat diameter of 0.1 mm has the best performance in the range of 1.5 MPa < P < 7 MPa.

With regard to the beam species, it has been known that argon is frozen to be a cluster, passing through the Laval nozzle due to the adiabatic expansion (Joul-Thomson effect). If an argon cluster captures helium atoms in it, it is expected that helium density becomes large and the collimation is improved. Experiments to investigate the property of Ar-He mixture gas were carried out in the R & D chamber with electron beam. Unfortunately better collimation was not observed in the Ar-He mixture gas, as shown in Fig. 3.

In conclusion, it can be said that the Laval nozzle with the throat diameter of 0.1 mm and the length of 93.0 mm has the best performance. For the beam species, pure helium is better than Ar-He mixture gas. Based upon the results mentioned above, a beam injector for LHD is constructed. Experiments in LHD will start from 2011.

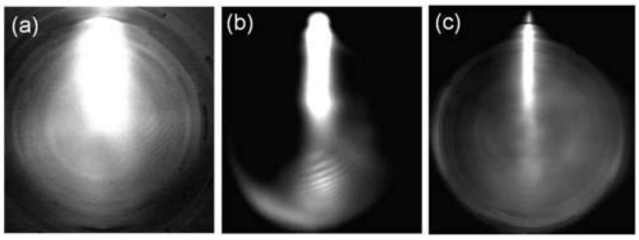

Fig. 1. Beam shapes in HYPER-I plasma, through (a) conical nozzle, (b) Laval nozzle of 19.3 mm long, and (c) Laval nozzle with 93.0 mm long. For each nozzle, diameter at the throat is 0.1 mm.

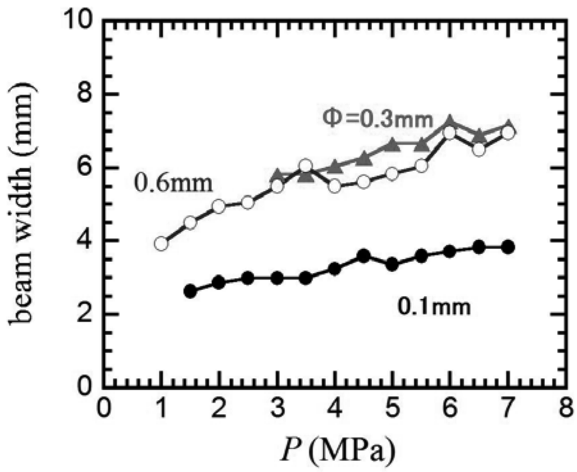

Fig. 2. Beam width (FWHM) as a function of injected helium pressure. Results with three Laval nozzles with different throat diameters are depicted.

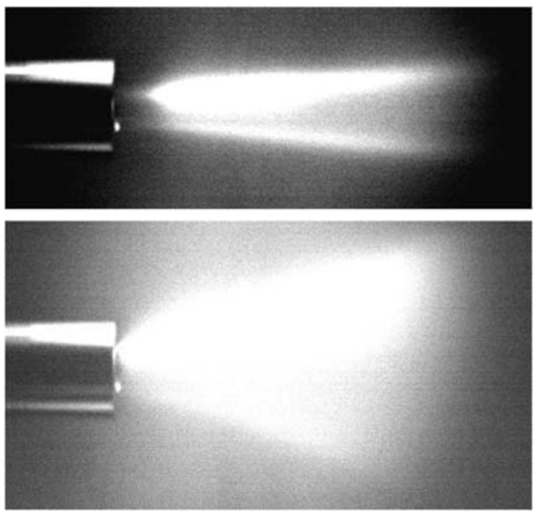

Fig. 3. Beam shapes (top: pure He, bottom: Ar-He mixture) visualized with electron beam.