§7. Performance of Molecular Helium Beam Collimated with Laval Nozzle

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For the simultaneous measurements of electron density and temperature, a neutral helium beam probe (HeBP) has been developed and applied in various plasma devices. In fusion experimental devices, i.e. tokamaks and stellarators, it has been utilized to diagnose edge plasma properties. The HeBP has an advantage of being free from a heat load which may result in impurity contamination in the plasma. Observing emissions from helium atoms in the plasma with spectroscopic technique, electron temperature T_e and density n_e can be derived by using the collisional-radiative (CR) model. The HeBP was first proposed in the TEXTOR tokamak in 1992[1)] and has been used in many devices. In LHD, the HeBP is used to observe the stochastic region where the Thomson scattering system cannot be applied.

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, as shown in Fig. 1, and the pressurized helium gas less than 4 MPa is injected though it. Passing though the Laval nozzle, the helium gas is collimated and accelerated to the supersonic velocity. Since the spatial resolution depends on the beam width, a collimated beam is favorable for precise measurements. The beam spread results in a significant deterioration of the spatial resolution in LHD, since the distance between the injector and the plasma is more than 3 m.

In order to see the performance of the Laval nozzle, preliminary tests were performed in HYPER-I which is a linear plasma device with an electron cyclotron heating system. The HYPER-I can generate relatively dense plasmas more than ~ 10^{19} m^{-3} with its high power klystron and whistler mode injection. The helium beam was injected to the cylindrical plasma from the radial direction. The emission profiles of He I light were obtained two-dimensionally with a CCD detector from the longitudinal direction through an interference filter ($\Delta\lambda_{FWHM}$ = 1 nm).

Figure 2 shows the images of emission from the helium beam captured with the CCD. It can be seen from the Fig. 2 (a) that the beam through the cone-shaped nozzle spreads over the injection port. On the other hand, it is found that the beam through the Laval nozzle is well collimated. To estimate the beam widths quantitatively, the full-width at half-maximum (FWHM) of the beam was measured from each emission profile shown in Fig. 3. Clear difference between two nozzles was shown that the FWHM for the Laval nozzle was 34 mm, while 120 mm for the cone-shaped nozzle, which presents the advantage of the injector with the Laval nozzle.

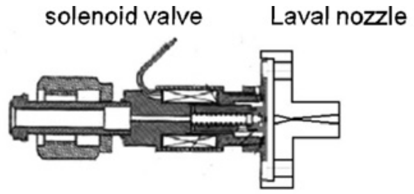

Fig. 1. Helium gas injector. Solenoid valve is directly coupled onto Laval nozzle.

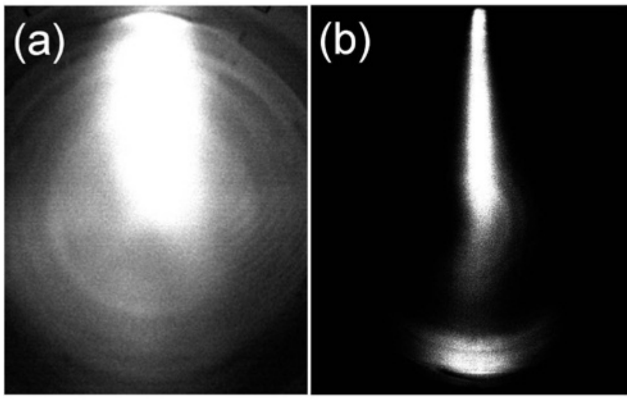

Fig. 2. Images of helium beam emission captured with CCD detector from the longitudinal direction. Helium beam is injected through (a) cone-shaped nozzle and (b) Laval nozzle.

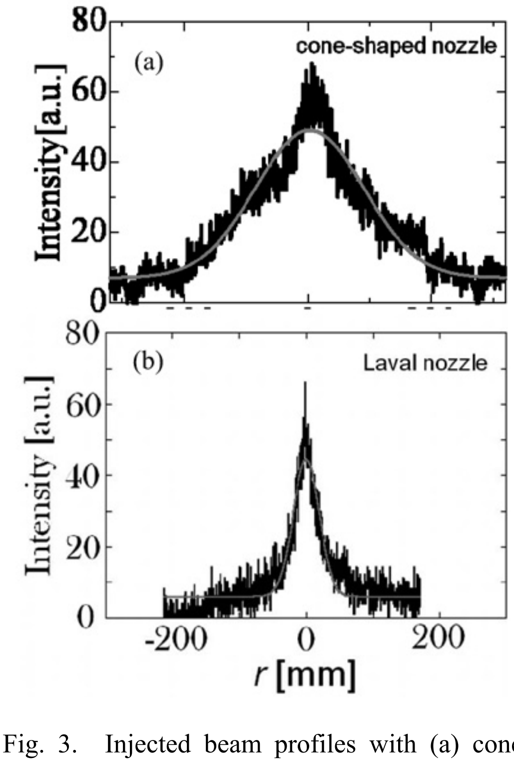

Fig. 3. Injected beam profiles with (a) cone-shaped nozzle and (b) Laval nozzle.

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