§25. Preliminary Result of Edge Plasma Measurements with Helium Beam Probe

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The helium beam probe (HeBP) can measure edge electron temperature T_e and density n_e simultaneously using the spectroscopic technique [1] with the collisional-radiative (CR) model [2]. Three (667.8, 706.5, 728.1 nm) line emissions from helium atoms in the plasma are utilized to derive T_e and n_e, where different dependence of each line intensity on T_e or n_e is employed.

The HeBP system consists of a beam injector and a photo detector coupled with a spectrometer or interference filters. To minimize the perturbation (density increase) due to the introduced helium atoms, a pulsed beam injection system with a fast solenoid valve (response time $\tau < 160$ μs) is utilized. The valve is directly coupled with a Laval nozzle which collimates and accelerates the beam. The plenum pressure of helium is 3 - 5 MPa. In order to optimize the beam injector, various kinds of Laval nozzles were tested in the linear ECR device HYPER-I with a hydrogen plasma. A prototype HeBP system was installed in LHD, as shown in Fig. 1. The pulsed beam for about 1 ms was injected from about 3 m below the plasma through a improved Laval nozzle of 397 mm long (throat dia. 0.2 mm). The He I emission image was focused separately on three 50000 pixel bundle fibers for three line spectra through individual lenses and interference filters. Though each optics is not exactly aligned on a line of sight, parallax is small enough to be neglected. Those images were finally detected simultaneously with a fast CMOS camera at the frame rate of 3000 fps.

Experiments were performed in the neutral beam heated plasma, where the magnetic axis position R_{ax} was at 3.60m. The Helium was injected to the plasma at $t = 5.606$ s during the density decreasing phase. In such a low density discharge about ~ 10^{18} m^{-3}, perturbation by the helium injection was not so small, i.e. about 10 % of density rise was observed. In Fig. 1, an emission profile of He I (706.5 nm) detected with the fast camera with an interference filter is also shown. It is found that the plasma shape (poloidal cross section) near the lower X-point is seen. However the boundary is not so clear, compared to that observed with the lithium beam probe [3]. This is caused by the divergence of the helium beam, since its density is much larger than that of the lithium beam.

Using three emission images for three spectra, the electron temperature T_e and the density n_e were derived with the CR model. Figure 2 shows two-dimensional profiles of T_e and n_e. Intensity ratios for two spectra were calculated between each pixel in the image data. In this experiment, however, limited pixels with relatively high emission signal were employed for the analysis, i.e. pixels with emission intensity more than 50 % of the maximum.

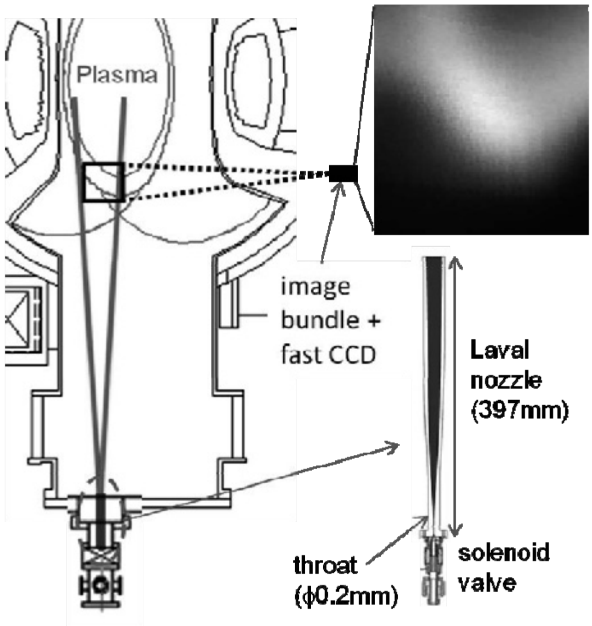

Fig. 1. The HeBP installed in LHD. Detail of injector and He I emission image captured with a fast CMOS camera are also inserted.

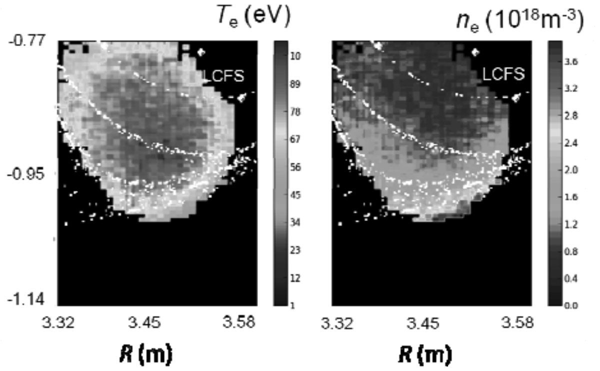

Fig. 2. Two-dimensional T_e and n_e profiles. The last closed flux surface (LCFS) and stochastic region outside the LCFS are superimposed.

In these plot, low T_e and n_e regions can be found inside the last closed flux surface (LCFS), which is thought to be wrong. This is caused by the path integral effect due to the thick beam width. Emission signals from plasma boundary are overlapped with those from the core region. Such a thick beam also degrades the spatial resolution of diagnostics despite the optics.

Further improvement of the beam injector is required to obtain the precise data.

1) Schweer, B. et al.: J. Nucl Mater **196-198** (1992) 174.
2) Goto, M., Quant, J.: Spectrosc. Radiat. Transfer **76** (2003) 331.
3) Takahashi, Y, et al.: Plasma Fus. Res. 1 (2006) 13.