§16. Beam Probe Imaging Diagnostic

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Imaging diagnostic methods are widely used in many fields of science. We can derive information or insight more from a visualized image than from simple one-dimensional graphic data. We have developed two-dimensional beam probe imaging diagnostic for CHS, which is an extension of a normal one-dimensional Lithium Beam Probe (LiBP). The observation area covers significant part of the edge region of the CHS as shown in Fig. 1., where chaotic magnetic field structure outside the last closed flux surfaces (LCFS) is superposed. Since the beam injection angle is mechanically changed shot-to-shot, the 2-D image of the beam emission is obtained with multiple discharges of identical operational conditions.

Experiments for the magnetic divertor configuration with the magnetic axis of R_{ax} = 1.016 m and the magnetic field strength of 0.93 T is here introduced as an example. The average electron density for the target plasma is about 2 x 10^{19} m^{-3} in the NBI plasma. Two-D contour map of the beam emission intensity is first measured and then it is converted to 2-D electron density. The emission intensity increases as the beam penetrates into the plasma. It reaches maximum and then decreases as the beam further penetrate, which is due to the beam attenuation in the core plasma. Although the beam intensity changes gradually in time, it does not affect the density reconstruction calculation, because the beam intensity is calibrated shot-to-shot by detecting the beam emission at the gas puff phase just before the magnetic field is terminated.

The two-dimensional map of the edge density distribution is reconstructed from the emission data by the use of density reconstruction algorithm as shown in Fig. 2. The dots in the image indicate the observation points for the data set. The vertical position y = 0 in the figure is the equatorial plane of the torus and x = 1275 mm corresponds to the position where the LCFS crosses the equatorial plane. Since the density reconstruction calculation loses accuracy in the core plasma region where beam attenuation is too strong, the reliable density profile is limited near and outside the LCFS. It is suggested in the figure that the plasma shifts upward in the chaotic field region near the separatrix, although the chaotic magnetic field structure has up-down symmetry. It is noted that the up-down asymmetry is sustained in steady state. The observed asymmetry is considered to be due to the cross-field plasma flow.

Since the 15 keV Li beam travels 17 mm during the life-time of 2P state, the beam emission shifts down stream of the beam from the electron location that contribute to beam excitation. In the present experiments, however, the electron density is around 10^{19} m^{-3} near the LCFS, where shortening of the life-time occurs due to the loss processes from the 2P state such as ionization, charge exchange, excitation to upper levels, stimulated de-excitation to 2S state etc. Taking these rate coefficients into account, the spatial shift and blurring becomes smaller. It is less than 10 mm near the LCFS.

The temporal resolution of the measurement is determined by the time constant of the phase sensitive detection (3 msec), which gives time resolution about 10 msec. The beam current is 0.1 mA at the moment. The time resolution will be improved by increasing the beam current. A lithium ion gun with the beam current of 10 mA is under development, with which the frequency response of tens kHz range is expected.

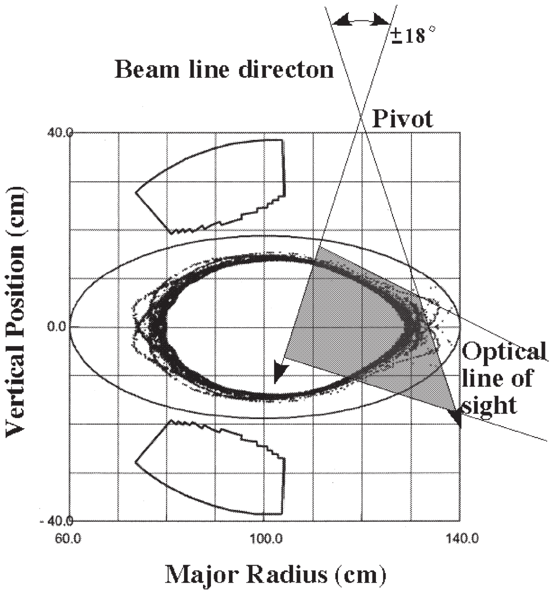

Fig. 1. Observation area superposed with chaotic magnetic field structure for the magnetic divertor configuration.

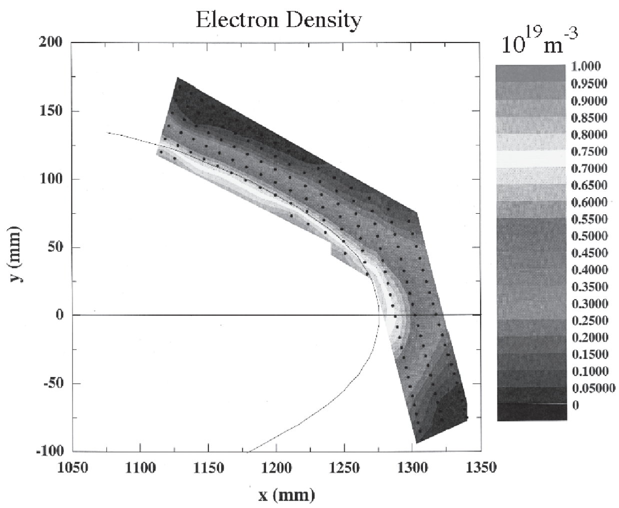

Fig. 2. Two-dimensional electron density profile reconstructed from the emission profile.

Reference

1) Nakamura, K. et al., Nuclear Fusion **47**, (2007) 251.