§7. Heavy-ion Beam Collisions with High-density and High-temperature Plasmas for LHD-HIBP Diagnostics

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Interaction of heavy-ion beams with high-temperature and high-density plasmas is an important part of plasma diagnostics which requires a knowledge of rate coefficients for different atomic and molecular processes occurring in a plasma. Calculations of corresponding cross sections and rate coefficients have been performed by the CAPTURE and the LOSS codes [1-3]. In the present report, these data were used for estimation of the availability in super dense core discharge of LHD, the profile and fluctuation measurements using Au^+ and Au^{++} probe beams.

The heavy ion beam interaction is treated as following. The attenuations of the primary Au^+ ion beam current I_{B1} along l_1 before reaching the core region of the main plasma is given by

$$I_{B1} = I_{B0} \exp\left(- n_e \frac{\left\langle \sigma_{ei}^{1,2} v_e \right\rangle}{v_B} l_1 - n_{H^+} \frac{\left\langle \sigma_{loss}^{1,2} v_B \right\rangle}{v_B} l_1 \right),$$

where I_{B0} is the injected Au^+ ion beam current at the injection port, where their attenuation in the plasma edge region (l_0) is already taken into account. The superscript "1, 2"of σ denotes the charge variation of Au (this case corresponds to the ionization from Au^+ to Au^{2+}). The secondary product Au^{2+} ion beam current I_{B2} reaching the plasma exit boundary is given by

$$I_{B2} = \frac{\kappa_{mcp}\, I_{B1}\, \delta l}{v_B} \left(n_e \left\langle \sigma_{ei}^{1,2} v_e \right\rangle + n_{H^+} \left\langle \sigma_{loss}^{1,2} v_B \right\rangle \right)$$
$$\times \exp\left(- n_e \frac{\left\langle \sigma_{ei}^{2,3} v_e \right\rangle}{v_B} l_2 - n_{H^+} \frac{\left\langle \sigma_{loss}^{2,3} v_B \right\rangle}{v_B} l_2 \right),$$

where κ_{mcp} is the detection efficiency of the MCP and δl is the effective observation length in the central plasmas. The first term on the right-hand side represents the secondary ion production at the core along δl and the second term the ion attenuation along l_2 before reaching the edge plasma region which has also to be corrected for similar ion loss.

The calculated ratio of I_{B2}/I_{B0} is compared with the measured one under two conditions, as is shown in Fig. 2. In both cases, the calculated ratios have the lower tendency than the measured ratios. The difference would be due to the assumption of the uniform density and temperature of main plasma and impurity ions in plasma and edge regions for simplicity.

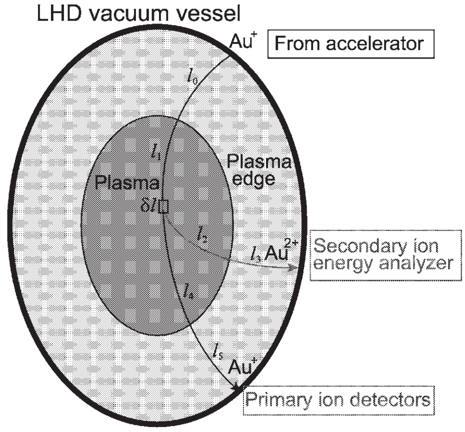

Fig. 1. Calculation model of HIBP beam intensity in simplified LHD plasma. Path lengths l_0, l_1, l_2, l_3, l_4, l_5, and Sample volume δl are indicated in this figure.

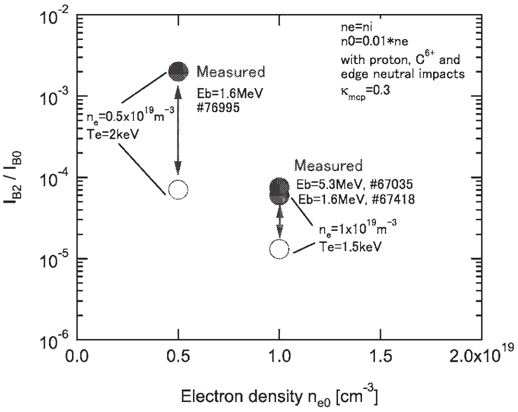

Fig. 2. Ratio of secondary and primary beam intensities is compared between calculated and measured data.

The plasma-sputter-type negative ion source is improved for the stable operation and longer life of filaments. The Einzel lens in between the ion source and the injector of the tandem accelerator is newly designed and replaced to new one, which is contributed to the stable beam output and low cesium consumption.

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2) Shevelko, V.P., Rosmej, O., Tawara, H., Tolstikhina, I.Yu., J. Phys. B 37, 201 (2004)
3) Nishiura, M., Ido, T., Shimizu, A., Janev, R. K., Kato, T., Shevelko, V. P., Kato, S. Tsukada, K., Yokota, M., Ogawa, H., Inoue, T., Nakano, H., Hamada, Y., LHD experimental group, Plasma and Fusion Res. 2(2007) S1099.
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