§9. Integrated Modeling of Negative Hydrogen (H^-/D^-) Ion Production, Extraction and Acceleration in a Large Negative Ion Source for Neutral Beam Injection System

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In N-NBI (Negative-ion-based Neutral Beam Injector) system for large fusion devices such as LHD, the optimization of 1) negative ion (H^- /D^-) production, 2) H^- /D^- extraction from the source, and 3) H^-/D^- beam acceleration towards the target are the key R&D items to obtain intense high power N-NBI beam for plasma heating.

Recently, in the NIFS-R&D ion source which is scaled down with a half size of the LHD ones, the following interesting experimental observation has been reported under the "surface" H^- production case with the Cs-seeding[1)] : Plasma layer consisting of H^+ and H^- ions (i.e., electrons are excluded from the layer) is formed in the vicinity of the beam extraction aperture on the plasma grid (PG). Such plasma with positive and negative hydrogen ions is called "double-ion (DI) plasma", and it could have strong influences on the H- beam extraction from the ion source and the resultant H- beam optics.

In this study, we are developing a 3D3V PIC (Three Dimensional in real space and Three Dimensional in Velocity space Particle-in Cell) model[2, 3)] to understand the DI plasma formation (Fig.1).The electrostatic potential structure in the extraction region is solved self-consistently with the charged particle dynamics (H^+, H^- ion and electron). The electron diffusion across the filter magnetic field has been taken into account by $\tau_{//}/\tau_{\perp}$ model[4-5)] ($\tau_{//}$ and $\tau_{\perp}$ are the electron loss time along the field line and the diffusion time across the filed line, respectively).

In Fig.2, 2D contour maps of the density ratio n_{H-}/n_e in the extraction region are shown, where n_{H-} and n_e are H^- ion density and electron density, respectively. As seen from Fig.2, the thickness of large n_{H-}/n_e region, i.e., the DI layer, depends on the electron loss along the field line (parameter: $\tau_{//}/\tau_{\perp}$). This suggests that it is possible to control DI plasmas, the plasma meniscus and the resultant H- beam optics by optimizing field structure in the extraction region.

For further understanding of the formation mechanism and control of the plasma meniscus in DI plasma, more detailed 3D modeling and comparison with the experimental results are now underway.

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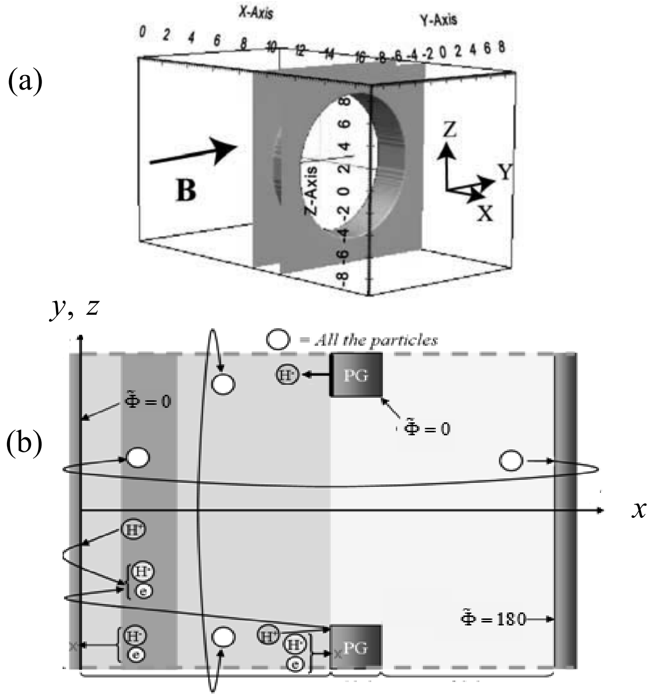

Fig. 1 3D3V PIC model for the extraction region in the H^- ion source: (a) Model geometry, and (b) Boundary conditions used in the simulation.[2]

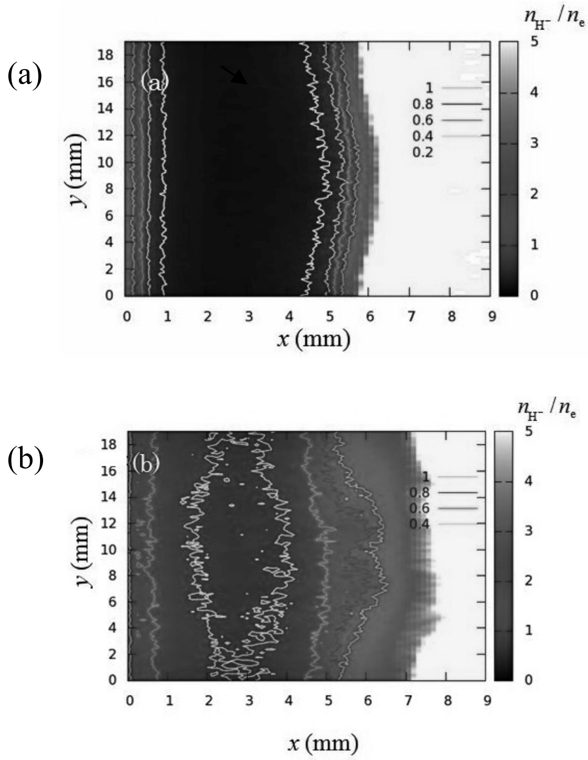

Fig. 2 2D contour map of the density ratio n_{H-}/n_e (n_{H-}: H^- ion density, n_e: electron density) in the extraction region by 3D3VPIC simulation. The profiles are plotted in the (*x*, *y*) plane in Fig.1(a) and the PG grid surface inside the source corresponds to the line *x*=9 mm. The results shown in (a) and (b) are those with the electron loss parameter (a) $\tau_{//}/\tau_{\perp}=0$ and (b) $\tau_{//}/\tau_{\perp}=0.16$.