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負イオン源における 3D3VPIC 法を用いたプラズマメニスカス形成及びビームハロに関する研究

Study of Plasma Meniscus Formation and Beam Halo in Negative Ion Sources Using 3D3V PIC Model

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1. Background, purpose

The neutral beam injection (NBI) system is one of the promising candidates for heating and current drive in future fusion reactors. In the NBI-System, the negative ion sources are required to produce high energy, high current density and long pulse negative ion beams.

In surface-produced negative ion sources of NBI system for fusion device, it has been reported that negative ion beam consists of two Gaussian parts, namely, a beam core with good beam optics and a beam halo with poor beam optics. Since the beam halo cause the heat loads on the acceleration grid, it may limit the injection power and the beam pulse length. Thus, to understand the physical mechanism of the beam halo formation in negative ion sources is inevitable for the suppression of the beam halo.

Recently, it is reported by the 2D3V-PIC (Particle In Cell) simulation that the beam halo is possibly caused by relatively deep penetration of an H^- ion emitting surface (plasma meniscus) into the source[1]. However, the simulation results don't agree well quantitatively with the experimental result. Therefore, for quantitative analysis of the beam halo, our PIC code is extended to the 3D3V-PIC model. The purpose of this study is to verify mechanism of the beam halo formation and plasma meniscus formation with the 3D3V-PIC model. In this study, the plasma meniscus and the consequent beam halo fraction are compared between the 2D and 3D models.

2. Simulation model

The simulation model in the present study is almost the same as the previous 2D3VPIC model[1, 2, 3]. The equation of motion, the Poisson's equation and the simulation domain is extended to the three dimensions.

Figure 1 shows a schematic view of our 3D simulation model. The volume of the simulation domain is 17mm × 19mm × 19mm in the *x*, *y,* and *z* directions, respectively. The simulation domain includes the plasma grid (PG) with a single aperture. The thickness of the PG and the radius of the PG aperture are 2 mm and 6 mm, respectively

The normalization of the physical quantities, reduced-size scaling, various boundary conditions and the main physical parameter are based on ref [1].

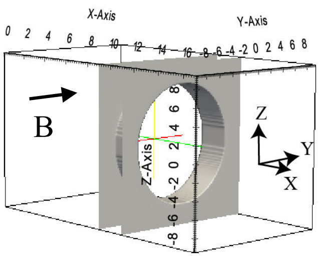

FIG. 1 3D geometry of the simulation volume showing one plasma grid aperture.

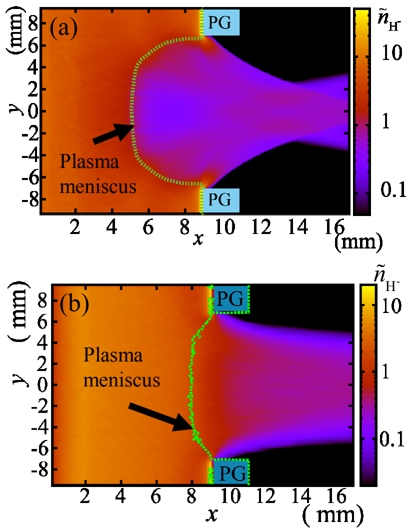

FIG. 2 Negative ion density distribution
(a) 2D3V PIC model (b) 3D3VPIC model

3. Simulation Result

Before full 3D calculations, we have done the 2D calculation to compare the 3D results with those by the 2D model. Figure 2 shows the negative ion density profiles of (a) by the 2D3VPIC model, and (b) by the 3D3VPIC model in the *x*-*y* plane (z=0mm). In Fig. 2(a) and (b), the broken line show the contour with gradφ = 0. This contour defines a plasma meniscus.

As seen from the comparison between Fig. 2(a) and (b), the plasma meniscus in the 2D model penetrates more deeply into the plasma source region and the curvature is larger. In the 3D model, the aperture is modeled as a hole while it is modeled as a slit in the 2D models. This is a reason why the penetration of the meniscus is small in the 3D model.

The beam halo fraction to the total beam current is estimated to be 51.5% in the 2D model while around 6.3% in the 3D model. This value reasonably agrees with the fraction observed in the experiments quantitatively[4, 5].

4. Reference

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