§10. Influence of Electron Suppression Magnetic Field on H^- Extraction in Hydrogen Negative Ion Source

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Hydrogen negative ion (H^-) sources have been used for plasma heating in Large Helical Device (LHD). For development of higher performance negative ion source, H^- transport in ion source plasmas is one of important knowledge to improve extraction efficiency of the ions. It is well known that the H^- transport strongly depends on spatial distribution of plasma potential near beam extraction holes. This region has two kinds of magnetic fields, which are called as filter and electron suppression magnetic fields. The filter field improves H^- yield with optimization of production process by generation of low and high electron temperature region in ion source plasma. While, the electron suppression field decreases electron density near the extraction hole to suppress electron beam simultaneously extracted with H^- beams to avoid high heat load for beam extraction electrodes. Magnetic field structure constructed by them probably also affects H^- transport and extraction due to change of plasma near the extraction hole. In this study, we research influence of two kinds of magnetic field on ion source plasma to understand role for H^- extraction using experiment and calculation.

Fig.1 shows apparatus of our experimental setup [1]. A cylindrical ion source chamber has 9 cm diameter and 11 cm height. Filter magnetic field is produced by a pair of permanent magnets attached on side wall of the cylindrical chamber, whose strength is about 95 Gauss at an extraction hole. While, electron suppression magnets are installed onto the extraction electrode at downstream side. Maximum strength of the suppression magnetic field is about 700 Gauss at $(x, y, z) = (\pm 2\text{cm}, 0\text{cm}, 0\text{cm})$ in Fig. 1. Profiles of plasma parameters are measured by a movable Langmuir probe. It moves in the x direction, whose tip is located at 0.3 cm from surface of a plasma electrode. The probe measurements are carried out with 300 V beam extraction voltage.

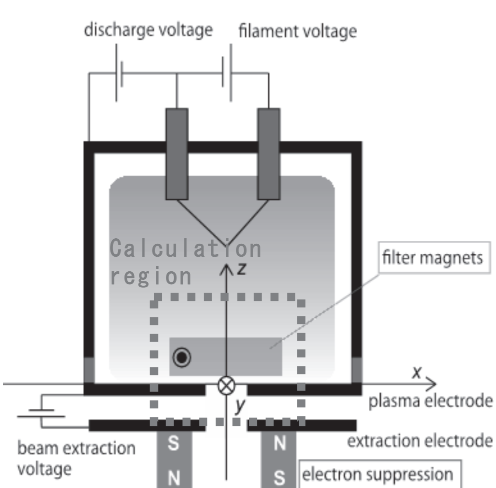

Fig. 1. Experimental setup and calculation region

The experimental results are analyzed with 2D3V Particle-In-Cell (PIC) simulation on x-z plane in Fig. 1. We simulate dynamics of H^-, H^+ and electron near the extraction hole in self-consistent manner, whose calculation region is shown with a dotted line in Fig. 1. Then, collision processes of these particles are ignored, and spatial distribution of magnetic field measured in the actual ion source is applied to the simulation code. When particles flow out from the calculation region, they are loaded into upper boundary in the z direction of the region and begin their new transport processes from there.

We show electron density profiles in Fig. 2, which are measured with the filter magnetic field superposed by the suppression magnetic field or not. It is confirmed that the suppression field makes the electron density decrease into half of another one. We analyze this result with collisionless PIC simulation. Though the present code have to be improved to obtain stable solution even in strong magnetic field, simulation results tend to show lower electron density than that of experimental one. Besides, we confirmed that electrons have tendency which concentrate at upper boundary of calculation region for z direction in simulation using magnetic field. It seems that electrons in the collisionless simulation are trapped by the magnetic field stronger than those of experiment. They have difficulty to flow toward downstream in z direction, thus electrons are concentrated at the upper boundary. It seems that collisionless PIC simulation cannot correctly evaluate electron transport across the magnetic field in ion source plasma. As future work, we analyze the experimental results with PIC taking into account particle collision processes to reasonably reproduce with simulation.

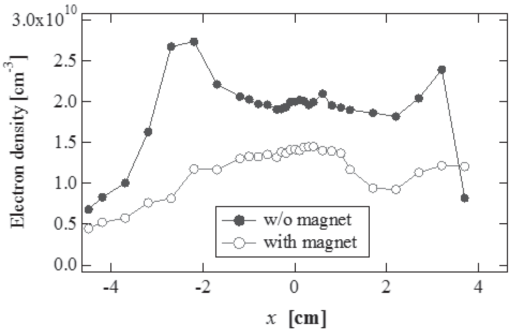

Fig. 2. Dependence of electron suppression magnetic field on experimental profiles of electron density in the x direction.

1) Matsumoto, Y., Nishiura M., Yamaoka H., Sasao M., and Wada, M. : Rev. Sci. Instrum. 85, (2014), 02A720