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Development of a large negative hydrogen ion source operated with radio frequency power and calculation of a photo-neutralizer

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Plasma heating is one of the key issues to realize a thermonuclear magnetically confined fusion reactor. Neutral beam injection (NBI) heating techniques have been investigated for decades as typical reliable plasma heating tool. In the ITER-NBI system, it is necessary to develop a high performance 1 MeV class NBI system operated more than 1000 sec. So far, hydrogen/deuterium negative ion sources with beam energy above 100 keV have been developed and tested in fusion experiments. Development of a radio frequency (rf) negative ion source is necessary for the stable and long-pulsed operation because of its filament-free structures.

We have successfully developed a hydrogen negative ion source using an rf power supply with field-effect-transistor(FET)-based invertor. The rf frequency is around 300kHz and it can be operated with a high conversion efficiency of about 90 % from dc to rf.

Figure 1 shows the schematic of the ion source, which consists of two regions, driver and expansion regions. An rf plasma is produced in the driver region, where a RF loop antenna is wound around Alumina ceramic tube with 230 mm in inner diameter and 300 mm in length, which is almost the same diameter as that of the ITER NBI ion source. The high density hydrogen plasma above 10^{18} m^{-3} is successfully produced in the driver region with the gas pressure of 0.3 Pa. The plasma flows into the expansion region, where a cusp magnetic field around the chamber gives good effect in obtaining high density plasmas even in the operating pressure of 0.3Pa.

Figure 2 shows axial profiles of electron density and temperature in the source. The low electron temperature of about 1 eV is obtained near the plasma grid by increasing the magnetic filter field. Negative hydrogen ion beam were extracted and accelerated with three electrodes with cesium vapor injection into the source.

In addition to the source experiments, we have also performed a numerical simulation using PIC/MC

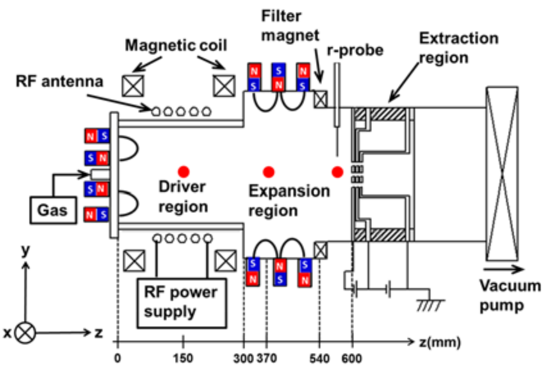

Figure 1 Schematic of the rf ion source.

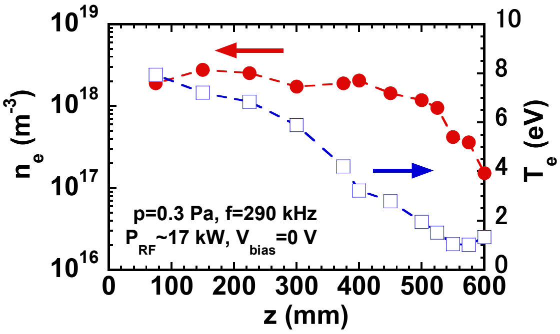

Figure 2 Axial profiles of electron density (closed circles) and temperature(open square) of the rf ion source.

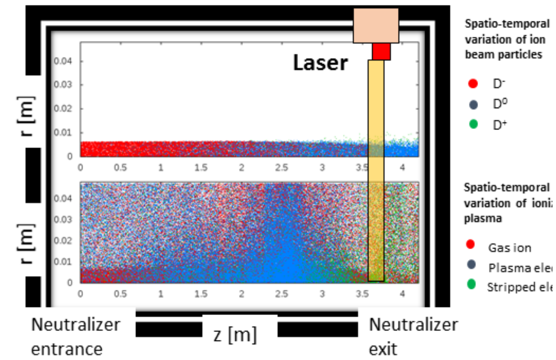

Figure 3 Simulation results of spatio-temporal variation of beam and plasma particles in gas and photo neutralization system.

(Particle-in-cell/Monte-Carlo) for a photo-neutralizer. The neutralization efficiency is enhanced up to 95% using the photo-neutralizer. We modeled different types of neutralizers (gas, photo and combined neutralizer) and studied the difference in the neutralization efficiency. Figure 3 shows one of the simulation results of spatio-temporal variation of beam and plasma particles in gas and photo neutralization system. Our simulation results indicate that a beam plasma formed in the neutralizer prevents the beam from diverging due to self-charge. We have found the importance of gas addition in a photo-neutralizer for minimizing the beam divergence.

References

1) Y. Takeiri, et.al., Nucl. Fusion 46, S199 (2006).
2) P. Franzen, et.al., Nucl. Fusion 47, 264 (2007).
3) A. Ando, et al., Rev. Sci. Instrum. 83, 02B122 (2012).
4) Y.Sasaki, et al., Plasma and Fusion Res., 11, 2405088 (2016).
5) K.Takahashi, et al., Phys. Rev. Lett., 116, 135001 (2016).