§17. Reduction of Heat Load on the Electrodes in Long Pulse Operation of a Negative Ion Source

Ando, A., Matsuno, T., Funaoi, T., Tanaka, N. (Dept. Electrical Eng. Tohoku Univ.),
Takeiri, Y., Tsumori, K.

i) Introduction

Neutral beam injection (NBI) system is one of the powerful and fruitful heating tools in fusion researches. A hydrogen negative-ion (H-) source was developed for a beam source with beam energy more than 100keV, and a large H- source has been successfully operated as a major heating device in LHD.[1),2)] For a long pulse operation, it is important to reduce heat load to the electrodes of a negative hydrogen ion source. Development of simulation codes and experimental investigation using a small source are requisite, since frequent verification using a large source is hard to perform due to large task of machine time and manpower. The purpose of this research is to analyze heat load to the electrodes for its reduction. As a first step, we have developed a RF ion source which can extract the same current density as the large source. Heat load on the electrodes can be tested in a long pulse or continuous operation.

ii) Experimental results and discussion

We have developed a RF driven hydrogen plasma source produced by the FET-based RF power supply with a frequency of 0.3-0.5MHz. [3),4)] The FET inverter power supply has many advantages of higher efficiency of rf generation and easier matching system than conventional vacuum-tube based rf sources. The small ion source consists in a cylindrical driver region and a expansion region. In the driver region a multi-turn loop antenna was wound around a cylindrical tube made of Al_2O_3 ceramic (inner diameter: 70 mm, outer diameter: 80 mm, length: 170 mm). Turn number of the antenna was changed to adjust optimal coupling. Axial magnetic field can be applied in order to enhance plasma production. In the source high density hydrogen plasma of more than 10^{18}m^{-3} can be operated, which is the same order of that in a large source by arc discharge. In the expansion region magnetic filter can be attached and cesium vapor can be injected to enhance the H^- production.

Figure 1 shows schematic of the electrodes of the source, which compose of a plasma grid, an extraction grid and an acceleration grid. H^- beam is extracted from a single hole with the aperture of 9mm in diameter. A set of permanent magnet is immersed in the extraction electrode to form the magnetic field as shown in the figure. Electrons are prevented from extraction by the magnetic field. The extracted ion beam trajectory was calculated as shown in the figure.

Figure 2 shows the dependencies of extraction current I_{ext} and acceleration current I_{acc} on the extraction voltage V_{ext}. Although both of the currents increased with V_{ext}, they were almost constant with the increase of V_{acc}. In order to enhance H^- beam a small amount of cesium (Cs) vapor were injected into the source. I_{ext} and I_{acc} were increased as shown in the figure. The beam current density was still low at 10mA/cm^2. We are going to increase V_{ext} to investigate H^- beam extraction characteristics with Cs effect and to test the heat load onto the electrodes.

1) Y.Takeiri, et al.., Nuclear Fusion, **46** (2006) S199.
2) K.Tsumori, et.al., Rev. Sci. Instrum., **79** (2008) 02C107.
3) A.Ando, et al., Proc. of 1st NIBS, AIP-Conf. No.**1097** (2009) 291.
4) A.Ando, et al., Rev. Sci. Instrum., **81** (2010) 02B107.

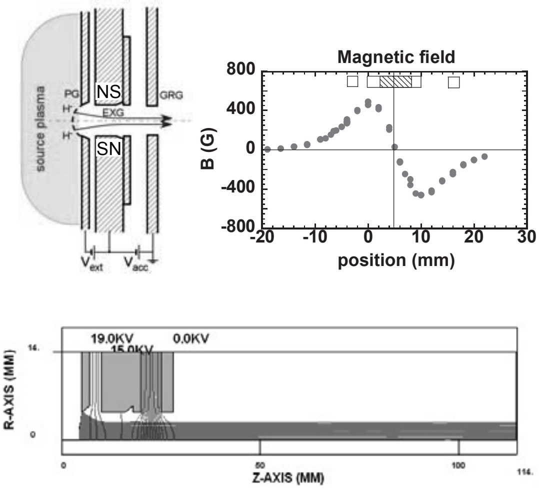

Fig.1 Schematic of the electrodes (upleft), magnetic field of permanent magnet immersed in the extraction electrode (upright) and calculated beam trajectory (down).

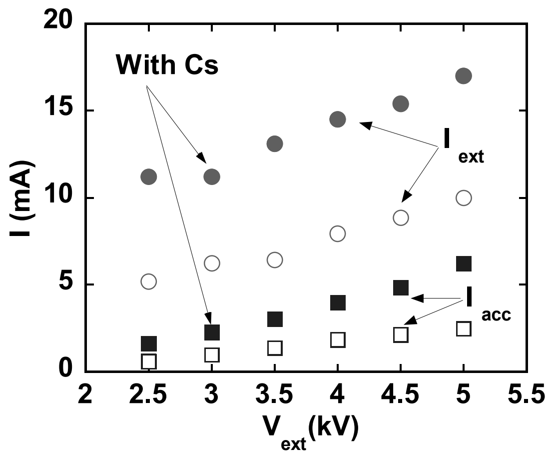

Fig.2 Extraction current (I_{ext}) and acceleration current (I_{acc}) as a function of extraction voltage (V_{ext}) with and without Cs seeding. V_{acc} = 5kV, p=1.2Pa, f=0.35MHz.