DEVELOPMENT AND FUTURE PLAN OF THE NEGATIVE HYDROGEN ION SOURCES FOR NBI AT SWIP

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1. INTRODUCTION

A radio frequency negative hydrogen ion source with an extraction area of 0.32 × 0.4 m² has been developed at SWIP. A full solid-state RF generator, providing a total power of 80 kW at a frequency of 2 MHz, is used to generate plasma[1]. The design parameters for this source are 5 A at 200 kV for 3600 s. Currently, the maximum beam current, beam energy, and beam duration achieved are 13 A, 198 keV, and 5000 s, though these values have not been reached simultaneously.

2. SOURCE DESIGN AND STRUCTURE OPTIMIZATION

The ion source consists of a driver with an inner diameter of 280 mm and a length of 140 mm, along with an expansion chamber with the dimensions of 500 × 600 × 250 mm³. The antenna consists of a four- turn coil, a framework made of Teflon, and the outer perimeter of the coil is surrounded by soft iron material. A Faraday screening made of molybdenum coated copper is installed inside the quartz vessel to prevent damage of the quartz from plasma etching. The magnetic filtering field is generated by an array of 10 magnets, each with dimensions of 90 mm×50 mm×20 mm. It produces a magnetic field with the strength of 7 mT near the plasma grid. Pressure controlled gas feeding technique has been developed so that the plasma can be generated without a start filament. The extraction system consists of three grids: the plasma grid, the extraction grid, and the ground grid. The maximum voltage can be applied on the extraction gap is 10 kV, while the maximum voltage on the acceleration gap is 200 kV. The extraction area is 0.0409 m², consisting of 266 holes with a diameter of 14 mm each.

Three-dimensional fluid models have been developed to study the effects of the gas pressure, the configuration of the magnetic filter field, the effect of the Faraday shield on the electron density, electron temperature and negative hydrogen ion distributions. [2-5] According to the simulation results, a soft iron magnetic shielding layer, approximately 6 mm thick, was added to the backplate of the ion source expansion chamber. This magnetic shielding layer, together with the filtering magnetic field and the confinement cusp-field, forms the magnetic field configuration of the ion source.

3. EXPERIMENTAL RESULTS

The electron density and temperature distributions of the plasma before the PG are measured by movable static probes. Experiments on the effects of the above-mentioned source parameters on the plasma parameters are conducted to verify the simulation model. And the experiments on the cesium operation has also been conducted.

Currently, at an RF power of 35 kW, the extracted negative hydrogen beam parameters are 13 A at 100 keV for 0.1 s, with a corresponding beam current density of 317 A/m². For long-pulse operation, the beam parameters are 50 keV at 0.25 A for 5000 s. For high beam energy operation, the parameters are 198 keV at 0.15 A for 3 s. The design parameters have not yet been achieved simultaneously due to limitations in the ion source test stand, which currently lacks a dedicated calorimeter. As a result, the beam energy impacting the back plate of the vacuum chamber must be kept within limits, and the electrode transparency is too high to withstand long-pulse, high-power beams simultaneously. Additionally, the ratio of electrons to negative hydrogen ions remains below 1. Some typical results are shown in Fig. 1.

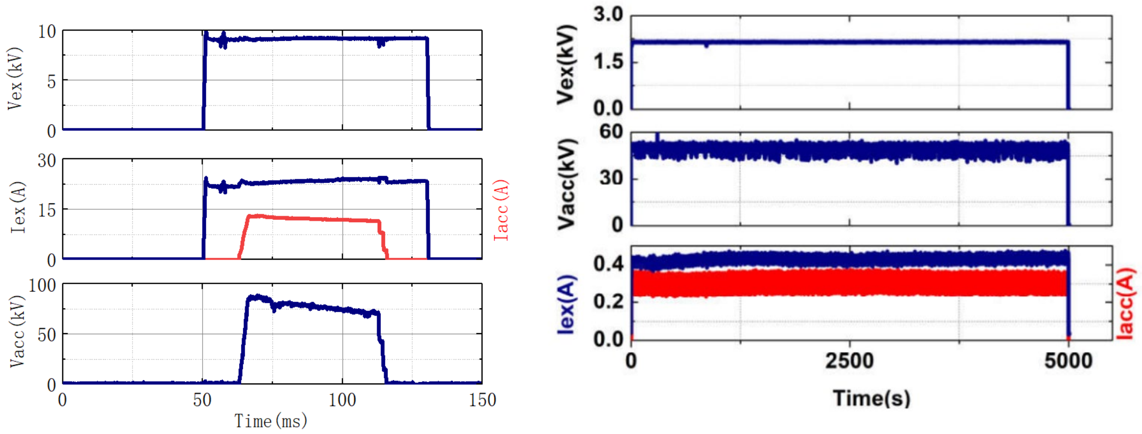

Fig. 1 Typical Waveforms of the extraction current, extraction voltage, acceleration current and acceleration voltage (a) short pulse with high current, (b) long pulse operation

4. FUTURE PLAN

Furthermore, another ion source with three drivers, an extraction area of 0.32 × 1.2 m², and a three-stage acceleration system has been developed. The test stand for this source is larger and includes a calorimeter capable of withstanding high-power beam energies. The design parameters for this source are 300 A/m^2 at 500 keV for 100 s. The first plasma has been successfully generated, and a small beam current of approximately 0.4 A has been extracted, with a pulse length of 100 s.

5. SUMMARY

A radio-frequency negative ion source with an extraction area of 0.32 × 0.4 m² has been developed. It consists of a driver with an inner diameter of 280 mm and a length of 140 mm, coupled with an expansion chamber measuring 500 × 600 × 250 mm³. The magnetic filter field strength is approximately 7 mT. The source operates without the need for a start filament. Currently, the maximum beam current, beam energy, and beam duration achieved are 13 A, 198 keV, and 5000 s. The design parameters are achieved, though not simultaneously. Building on the development of the single-driver source, a three-driver, three-stage acceleration ion source has been developed and is currently in operation.

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