DEVELOPMENT OF ION SOURCES FOR KOMAC

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Abstract

A Duoplasmatron ion source for the KOrea Multi-purpose Accelerator Complex (KOMAC) linear accelerator has been constructed. High voltage tests up to 50 kV have been successfully completed. Hydrogen beam currents of up to 20 mA have been extracted at 30 kV extraction voltage. This source has shown a low normalized emittance of 0.5 π mm mrad from 90 % beam current and proton fraction over 50%. High-density radio frequency (RF) plasma sources such as helicon and transformer coupled plasma (TCP) sources are under development especially for the continuous power (cw) ion source of both positive and negative ions.

1 INTRODUCTION

A high-current, proton linear accelerator, named as (KOMAC), is being proposed mainly for accelerator-driven transmutation technology (ADTT) by Korea Atomic Energy Research Institute (KAERI).[1] High-current, low-emittance, cw, ion sources are one of the crucial components of the accelerator. The multi-purposed KOMAC requires two types of ion sources, i.e. proton and negative hydrogen sources.

High-current proton sources are mainly built in a Duoplasmatron[2] type for pulsed operations, and recently electron cyclotron resonance (ECR) ion sources[3] are developed for steady-state operations. For negative ion sources, multi-cusp ion sources are prevailing and their lifetimes are extended significantly by replacing filaments with RF antenna.[4]

The requirements of KOMAC ion sources are described in section 2. A Duoplasmatron ion source has been built to provide high-current proton beam as a prototype ion source for KOMAC. This source will be described in section 3. Section 4 shows characteristics of the source. Possibility of high-density RF plasma sources such as helicon[5] and TCP[6] are discussed in section 5. Finally, the status of the KOMAC ion source development is summarized in the last section.

2 REQUIREMENTS OF KOMAC ION SOURCES

Since the KOMAC is proposed as a multi-purposed proton accelerator, both proton and negative hydrogen ion beams are required. Negative ion beams will be extracted for low or medium-energy beam applications in the middle of acceleration systems. Main proton beam for ADTT requires high-current, steady-state operations which provide more strict constraints for a stable, long-lifetime ion source. For 1GeV, 20 mA proton beam, KOMAC requires the ion source with the proton beam current of 30 mA at the extraction voltage of 50 kV. Normalized emittance of less than 1 π mm mrad is also required for good coupling of ion beam into RFQ.

3 EXPERIMENTAL SETUP

3.1 Duoplasmatron Ion Source

The Duoplasmatron ion source has three electrodes such as cathode, intermediate electrode, and anode. Plasmas are generated by arc discharges between the cathode and the anode. High density plasmas are formed by being compressed geometrically in the small hole of the intermediate electrode and then magnetically in the strong non-uniform magnetic field between intermediate electrode and anode. All electrodes are water-cooled for steady-state operations. The picture and the drawing of the assembled Duoplasmatron ion source is shown in Fig. 1.

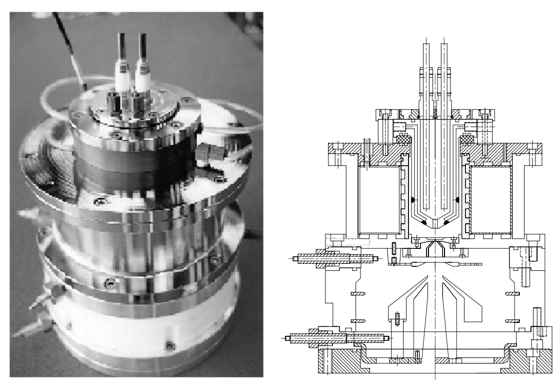

Fig. 1 A picture and a drawing of Duoplasmatron ion source.

Tungsten filaments are used to generate efficient arc plasmas at high temperature. Higher arc power can increase the proton fraction as well as the extracted beam current by increasing electron density and temperature. However, the level of arc power is limited by cooling capability and power supply. Arc currents of up to 10A can be provided in this source. The magnetic field from solenoid coils is measured up to 4 kG , and its structure is shown in Fig. 2. The intermediate electrode is made of soft iron to guide magnetic field lines and shield out extraction zone. No significant leakage of magnetic fields are confirmed in the measurements.

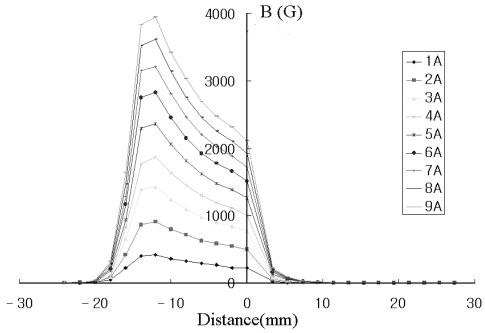

Fig. 2 Measured magnetic field strength between intermediate electrode and anode.

3.2 Beam Extraction System

Plasma expansion cup has been put in front of the anode to reduce beam divergence in sacrifice of beam intensity. Beam extraction geometry is confirmed by using IGUN code[7]. The simulated beam profiles with this extraction geometry shown in fig. 3 provide beam currents of 50 mA at 50 kV extraction voltage. The extraction system has been tested up to 48 kV without problems.

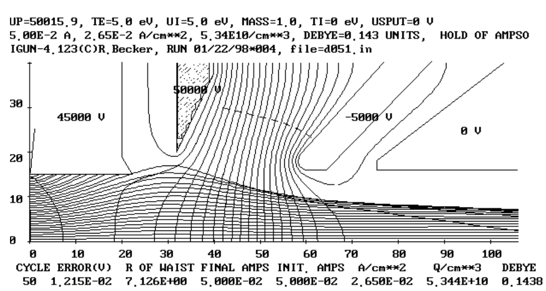

Fig. 3 The extraction electrodes and beam profiles in IGUN simulation.

3.3 Beam Diagnostic Setup

Experimental setup for the diagnostics of the ion beam is shown in Fig. 4. Deflecting magnets are installed to measure ion beam components. To measure beam emittance, multi-slit apertures and scanning probes are located at 20 cm and 50cm respectively from the anode. Faraday cup is also attached at the end of the chamber to measure total beam current.

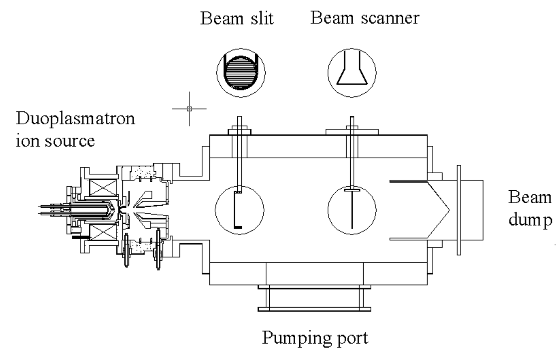

Fig. 4 Experimental setup of ion beam diagnostics.

4 PERFORMANCE OF THE ION SOURCE

The ion source of KOMAC linear accelerator has obtained beam currents of up to 20 mA at 30 kV extraction voltage. This source shows a low normalized emittance of 0.5 π mm mrad from 90 % beam current as shown in Fig. 5.

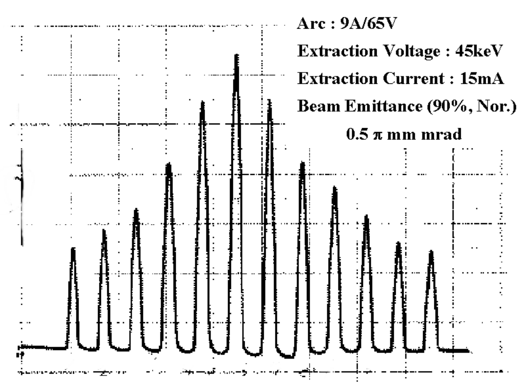

Fig.5 Beam emittance measured by multi-slit and beam scanner set.

Deflection magnet measured proton fraction to be only over 50 %. However, proton fraction shows strong dependency on arc currents as shown in Fig. 6 so that it may be increased sufficiently further by increasing arc power.

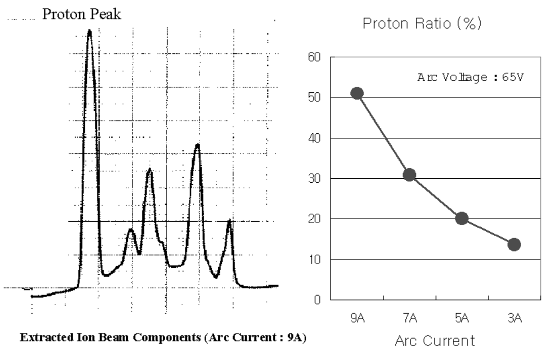

Fig. 6 Proton fraction measurements and their dependency on arc powers.

5 RF ION SOURCE DEVELOPMENT FOR KOMAC

The duoplasmatron ion source is getting close to the parameters set for KOMAC, still extracted proton beams have not reached the goal. As an another option, high-density plasma sources using RF powers are considered for KOMAC ion source. High density helicon ion sources are under development for dc, high-current ion sources.[8] Noting that helicon wave can propagate in a low-frequency, low-field, high-density regime, the helicon plasma source may be a good candidate as an ion source for cw high-current, low-emittance accelerators. KOMAC also requires negative hydrogen source as well as proton ion source for extracting beam currents between accelerating sections. Multi-cusp volume ion sources with RF antenna are well accepted negative ion sources, but TCP may be another good choice. The TCP source developed for the plasma processing in microelectronics show many favorable characteristics for volumetric negative ion sources. High density plasma generation region is located close to the antenna sitting outside of the plasma chamber, and it may be well separated with the extraction region where low electron temperature is required. Moreover, TCP does not require magnetic field for plasma generations, electron filtering will be much easier as well. Feasibility studies of TCP plasmas will be valuable. Since the antennas for these sources are located outside of the plasma chamber, ion sources may reduce contaminations significantly without any filament or immersed RF antenna. Even high-voltage isolator fro RF sources may be eliminated in this sources.

6 CONCLUSION

A Duoplasmatron ion source for the KOMAC linear accelerator has been constructed and tested. High voltage tests up to 48 kV have been completed successfully. Hydrogen beam currents of up to 20 mA have been extracted at 30 kV extraction voltage. This source has shown a low normalized emittance of 0.5 π mm mrad from 90 % beam current and proton fraction over 50%. Emittance requirements of KOMAC has been achieved, but proton fraction is still too low to obtain 30 mA proton beam into RFQ. Optimization of the source will be continued to increase beam current and proton fraction to meet KOMAC requirements. High-density, RF plasma sources are under development as another possible solution for high-current dc ion source. Helicon plasmas shows favorable characteristics so far. For a negative ion source, TCP plasma sources may be another choice.

7 REFERENCES

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