DEVELOPMENT OF AN INJECTOR SECTION FOR THE HIGH INTENSITY PROTON ACCELERATOR AT JAERI

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Abstract

The injector section for the proton linear accelerator has been tested for the Neutron Science Project at JAERI. An RFQ H^+ beam test has demonstrated a maximum beam transmission rate of 90 % in the RFQ by optimizing the condition of the ion source. The beam test of the negative ion source has also been performed. In the cesium seeded operation, the H^- beam current of 21 mA was obtained with a current density of 33 mA/cm^2 and a duty factor of 5 %. We have designed and fabricated a new negative ion source based on these experiments.

1 INTRODUCTION

A high intensity proton linear accelerator with a beam power of 8 MW has been proposed for the Neutron Science Project (NSP) at JAERI [1]. The 2 MeV RFQ beam test has been performed to study the characteristics of the injector section of the accelerator. The RFQ accelerated the H^+ peak current of 80 mA which was 80 % of the design value [2]. At the beginning of the test, we could not measure the RFQ input current because the Faraday cup installed just before the RFQ led to noticeable error for the measurement due to the secondary electron effect. In the present test, we installed a current transformer at the entrance of the RFQ and evaluate the beam transmission rate in the LEBT and the RFQ. We have also developed a volume production type negative ion source to produce a high current H^- beam that is required for injection the beam into the storage ring [1].

2 RFQ BEAM TEST

The layout of the 2 MeV beam line is shown in Fig. 1. The beam line consists of an positive ion source (IS), a Low Energy Beam Transport (LEBT), an RFQ and a Medium Energy Beam Transport (MEBT).

Figure 2 and Figure 3 show the peak beam current (Ip) and transmission rate (Tr) in the LEBT and the RFQ as a function of the IS beam current. An applied voltage ratio Γ in these figures is defined by the ratio of the electric potential at the first electrode and the second electrode of the IS. When Γ is large, the IS current decreases but the emittance become small [3]. The Ip and Tr in the LEBT increased linearly with the IS current. The maximum Tr was 65 %. By considering the proton fraction in the IS beam to be 80 % and mass separation effect of the solenoid lens, the maximum Tr of the proton beam is estimated to be 80 %.

The Ip and Tr in the RFQ, on the other hand, had the

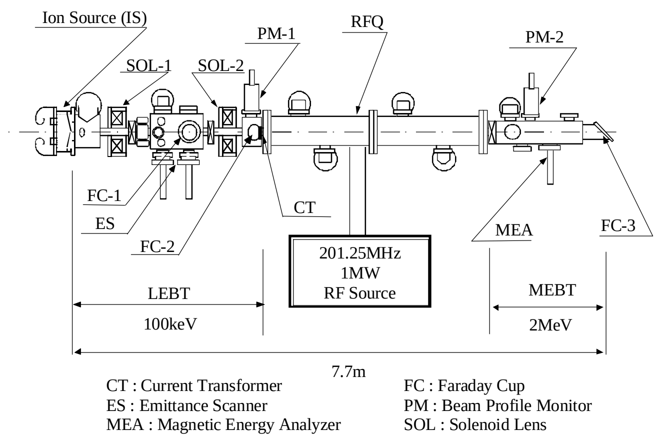


Figure 1: Layout of the 2 MeV beam line.

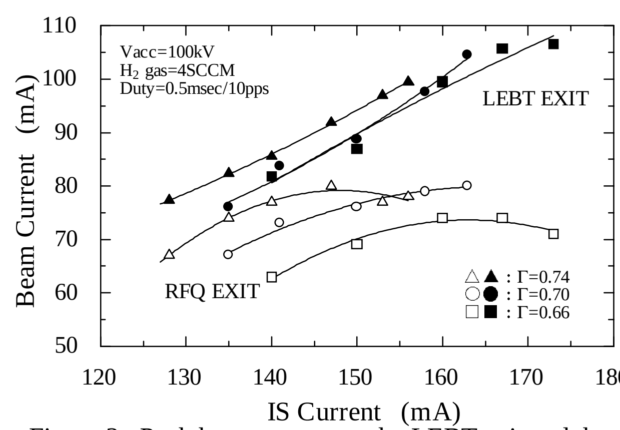


Figure 2 : Peak beam current at the LEBT exit and the RFQ exit as a function of the IS current.

peak value as a function of the IS current for each of Γ. When the Γ was large, the Ip and Tr became high. The maximum Ip and Tr of 80 mA and 90 % were obtained at the Γ of 0.74, respectively. We consider that improvement of the beam emittance from the IS is expected to enhance the Ip and Tr in the RFQ. Figure 4 shows the rms emittance measured about 1.2 m downstream from the IS and the Tr in the LEBT and the RFQ as a function of the IS current at the Γ of 0.70. The solenoid lens was not used during this emittance measurement to keep the ion source emittance. The emittance became minimum at the beam current of 170 mA. We obtained an unexpected result that the Tr in the RFQ decreased even if the emittance became small where the IS current was less than 170 mA. We consider that when the beam emittance from the IS is large, the beam of the peripheral region is lost in the LEBT, and the beam of the core region, which seems to have sufficient small emittance to be acceptable to the RFQ, can reach at the RFQ entrance. We have to perform more precise measurement of the emittance at the RFQ entrance and compare with the RFQ acceptance.

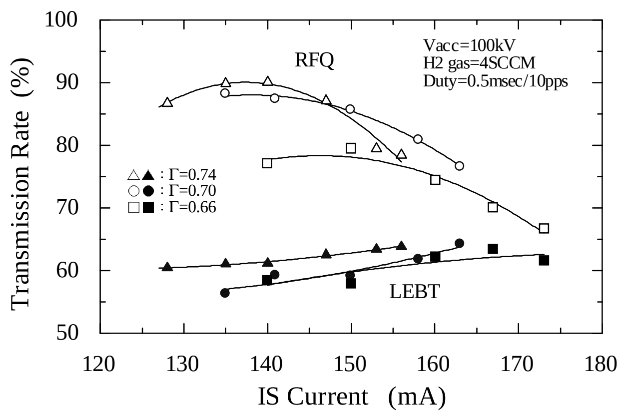


Figure 3 : Beam transmission rate in the LEBT and the RFQ as a function of the IS current.

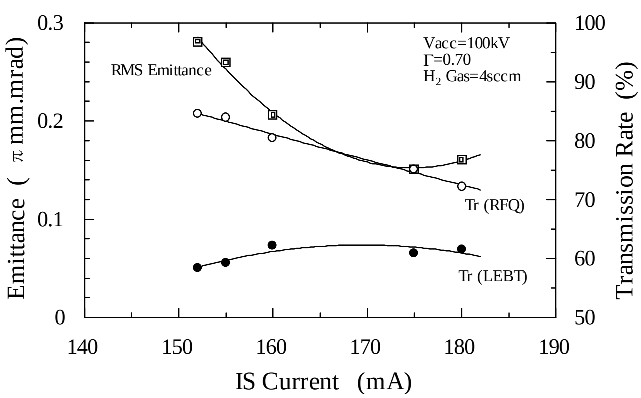


Figure 4 : Emittance of the IS and beam transmission rate in the LEBT and the RFQ as a function of the IS current.

3 NEGATIVE ION SOURCE

The required current of the negative ion source for the first stage of the NSP (the beam power of 1.5 MW) is 30 mA at an energy of 70 keV and a duty factor of 10 % [1]. To obtain a high beam transmission rate in the RFQ, the emittance should be as low as 0.1 πmm.mrad (rms).

3.1 Effect of Cesium for Negative Ion Source

The negative ion production test with cesium introduction was performed by modifying the positive hydrogen ion source which was used for the RFQ beam test [3]. The modified negative ion source has originally seven beam apertures of 9 mm in diameter to test the multi-beam merging method by the aperture displacement technique [4]. In the present experiment, the apertures in the peripheral region on the plasma electrode were masked with a thin molybdenum plate, and only the central aperture was used.

An oven containing the metallic cesium was installed to the plasma chamber via a valve. The cesium vapor was introduced into the chamber by opening the valve at the oven temperature of 280 ^{o}C. The amount of the cesium into the chamber was estimated to be about 100 mg .

The ion source was installed to the 2 MeV beam line. The beam current was measured by a Faraday cup (FC1) placed about 1.6 m downstream from the ion source.

Figure 5 shows the negative ion current as a function of the arc discharge power for the operation with (Cs seeded) and without cesium (pure volume) . The operating duty factor was 5 %. In the pure volume operation, the ion current tended to saturate at high arc discharge power and was limited to be about 8 mA. In the cesium seeded operation, on the other hand, the beam current was enhanced and increased lineally with the arc discharge power. The negative ion current (density) of 21 mA (33 mA/cm^2) was obtained at the power of 35 kW. In addition, an electron to negative ion current ratio was 4 in the cesium seeded, while it was 34 in the pure volume. This is favorable for the high duty operation, because the heat dissipation in the extraction electrode due to the electron impact was too high for high duty operation.

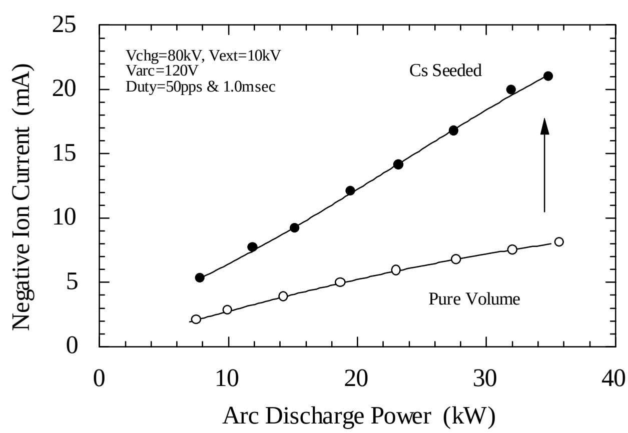
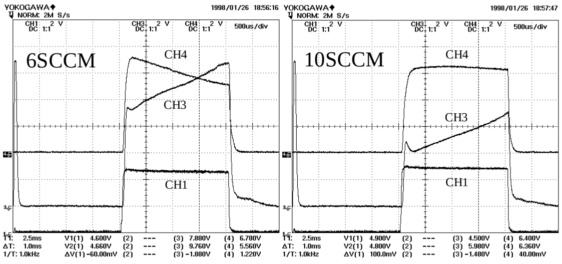


Figure 5 : Negative ion current as a function of the arc discharge power with and without cesium.

Another outstanding feature of the cesium effect was a reduction of a gas flow rate into the ion source. The low gas flow rate operation can decrease the stripping loss of the negative ion beam in the LEBT. Figure 6 shows typical waveforms of the pulsed beam at the flow rates of 6 and 10 sccm in the pure volume operation. The negative ion current (CH4 in the figure) fell down monotonously with the time at 6 sccm. The waveform was changed by increasing the gas flow rate and sufficient flatness was obtained at 10 sccm. In the cesium operation, on the other hand, the sufficient flatness was obtained even in a low flow rate operation. We consider that the variation of the waveform for the negative ion current occurs by varying the gas pressure in the plasma chamber. When the arc discharge starts, the hydrogen gas in the chamber is adsorbed on the surface of the chamber wall and the gas pressure suddenly decreases. In the cesium operation, the beam current is insensitive to the pressure in the chamber [5].



CH1 : Arc current, CH3 : Extraction current, CH4 : Negative Ion current

Figure 6 : Typical waveform of the pulsed beam at 6 and 10 sccm in pure volume operation. CH1, CH3 and CH4 show the arc current (80A/div.), extraction current (100mA/div.) and negative ion current (2mA/div.), respectively. The horizontal scale is 0.5msec/div.

3.2 New Negative Ion Source

We have designed and fabricated a new negative ion source to collect a experimental data to fulfil the requirement for the NSP. Figure 7 shows the conceptual illustration of the ion source. A plasma chamber is installed outside the insulator to change the configuration of the cusp and the filter magnets easily. The chamber is 150 mm in diameter and 200 mm in length. The aperture size of the plasma electrode is 8 mm in diameter. In the extraction electrode, permanent magnets are inserted to produce a dipole magnetic field. This field deflects the extracted electron and prevents the leakage of the electron to the acceleration gap. The electron suppression electrode is installed for trapping the leakage electron escaping from the extraction electrode.

To improve the vacuum pressure in the LEBT, two differential pumping ports are equipped with the ion source. In the present experiment, a turbo molecular pump of 1,300 l/sec was installed at one of the ports. Figure 8 shows the negative ion current as a function of a vacuum pressure in the LEBT. The pressure was measured 0.2 m downstream from the grounded electrode of the ion source. When the differential pumping system was used, the vacuum pressure in the LEBT was improved from 7.5×10^{-5} to 1.0×10^{-5} Torr and the negative ion beam current was enhanced by 1.7 times.

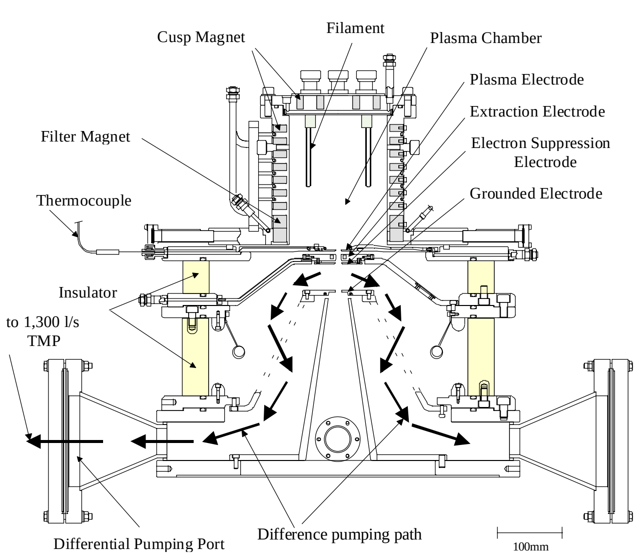


Figure 7 : Schematic drawing of new negative ion source

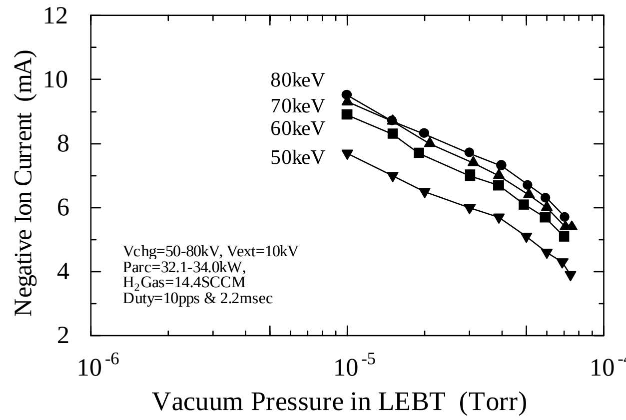


Figure 8 : Negative ion current as a function of the vacuum pressure in the LEBT

4 CONCLUSIONS

The injector section of a high intensity proton accelerator has been tested. By optimizing the ion source parameter, the maximum RFQ beam transmission rate of 90 % was obtained. We observed that the transmission rate is not a simple function of the value of the beam emittance.

The beam test of the negative ion source has been performed. By introducing the cesium into the plasma chamber, the negative ion current of 21 mA was obtained with a current density of 33 mA/cm^2 and a duty factor of 5 %. We have just started the beam test of the new negative ion source. The differential pumping was effective to decrease the stripping loss of the negative ion beam in the LEBT. The beam test will be continued.

REFERENCES

[1] M. Mizumoto., et al., "High Intensity Proton Accelerator for Neutron Science Project at JAERI", in these proceedings

[2] K. Hasegawa., et al., "The R&D Status on the Front End of the High Intensity Proton Accelerator in JAERI", Proceedings of the 1996 Linac Conference, Geneva, Switzerland, (1996), 665

[3] H. Oguri., et al., "A High Brightness Hydrogen Ion Source for the BTA at JAERI", Proceedings of the 1994 Linac Conference, Tsukuba, Japan, (1994), 381

[4] H. Oguri, et al., "Development of a Negative Ion Source for a High Intensity Linac", Proceedings of the 1996 Linac Conference, Geneva, Switzerland, (1996), 668

[5] Y. Okumura, et. al., "Cesium Mixing in the Multi-Ampere Volume H- Ion Source", Proceedings of 5th Int. Symp. on the Production and Neutralization of Negative Ions and Beams, BNL, NY, (1990), 169