50keV, 50mA PULSED PROTON INJECTOR FOR PEFP*

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Abstract

Duoplasmatron type ion source with 50keV proton beam has been constructed and stably operated as the injector for Proton Engineering Frontier Project(PEFP). In DC operation, the beam current of 50mA with 50kV extraction voltage is routinely obtained. PEFP linac is aimed to pulsed proton beam by pulsed extraction tools from hydrogen plasma. A high voltage pulse switch is connected between accelerating electrode and ground electrode for this purpose. Consideration on the focusing of the pulsed proton beam with space charge compensation is in progress. Beam profile in front of RFQ is measured by optical measuring tools.

INTRODUCTION

PEFP proton linear accelerator requires both protons and negative hydrogen ions to meet a multi-use option.[1] For 20 mA proton beam at the final stage, PEFP proton accelerator requires the ion source with the proton beam current up to 50 mA at the extraction voltage of 50 kV. Normalized rms emittance of less than 0.3 mmmrad is also required for good matching of ion beam into RFQ.

PEFP linac should have flexibility in an operation mode as well. The machine parameters should define with the point of the beam users. Especially pulsed proton beam and negative hydrogen beam are required. The main parameters are summarized as follows.

Ion species	H+ , H-
Energy	100MeV
Max. Peak Current	20mA(H+), 3mA(H-)
Repetition Rate	120Hz
Pulse Width	0.1 ~ 2 ms
Max. Beam Max. Average	24 %
Current Duty	4.8mA

PEFP PROTON INJECTOR USING DUOPLASAMATRON SOURCE [2]

The duoplasmatron ion source has three electrodes such as cathode, intermediate electrode, and anode. Relatively low density plasmas are generated by arc discharges between the cathode and the anode. Higher density plasmas are formed by being compressed geometrically in the 0.7 mm diameter hole of the anode and then magnetically in the strong non-uniform magnetic field between intermediate electrode and anode. Tungsten filaments are used to generate thermionic seed electrons. Higher arc power can increase the proton fraction as well as the extracted beam current by increasing electron density and temperature. The axial magnetic field from solenoid coils in the source is measured up to 4 kG. The base pressure of aluminum vacuum chamber is less than 3x10-7torr, but the operation pressure is less than 2x10-6torr. The picture of the constructed ion source and diagnostic chamber is shown in Fig. 1 The ion source has reached beam currents of up to 50 mA at 50 kV extraction voltage with 150 V, 10 A arc power. The extracted beam has a normalized emittance of 0.2 mmmrad from 90 % beam current and proton fraction of over 80 %. The ion source was installed in front of LEBT and has been continuously operated so far. The pulsed operation mode of the ion source has been considered to reduce beam induced damage at the entrance of RFQ.

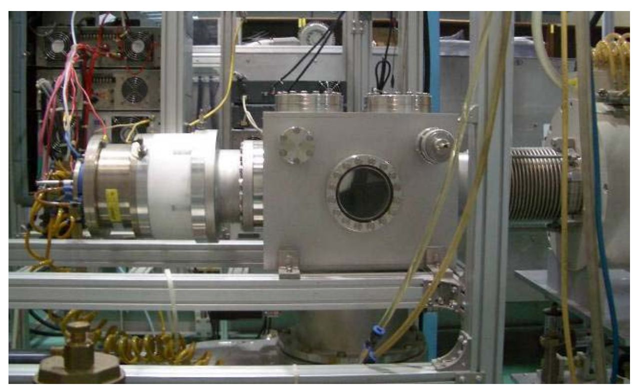

Fig. 1: Picture of the PEFP proton injector.

In the PEFP, the ion source is matched to the 3.0 MeV RFQ by the LEBT. The LEBT is the long stainless steel pipe having two solenoid magnets. Inner diameter of the LEBT is 160 mm and the total length is 2.2 m. [3]

Non-destructive diagnostic method that gives the profile of a proton beam without the error of secondary emission electrons is used to the RFQ beam matching at the LEBT. Beam profiles monitor (BPM) using a charge coupled device or CCD, was constructed and evaluated. Gas molecules in the beam pipe interact with the passing proton beam and then the neutral or ionized residual gas is promoted to excited state. The CCD camera can collect the photons emitted by the electron transitions of the excited molecules, leading to measurement of the beam

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profile. Fig.2 shows the picture of LEBT and BPM. Preliminary test of LEBT focusing performance has been carried out. TRACE calculation for DC 20 keV, 2 mA proton beam with α= -0.5, β= 0.2 mm/mrad, and εN = 0.2 mm mrad, gives the predicted magnetic field of two solenoids for the matching between LEBT and RFQ. Magnetic field of the matched beam from TRACE simulation is 1.3kG for solenoid 1 and 2.1kG for solenoid 2. Magnetic field of the best focusing point measured from a DC proton beam is around 1.3G and 1.8kG respectively, agreed with those simulated results.

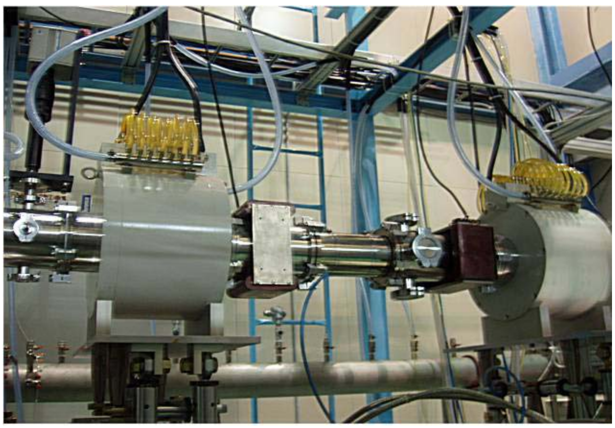

Fig. 2: Picture of LEBT and BPM.

EXTRACTION SYSTEM MODIFICATION FOR BEAM PULSING

Space Charge Compensation at Pulse Mode Operation

The electrons formed in the beam line cannot escape to the ion source; hence accumulate near the beam transport line. This can result in substantial space-charge compensation, reducing the beam spreading action. The compensation for dc ion beams under fixed vacuum conditions can be advantageous. The compensation needs a buildup time, determined by cross sections and residual particles. [4] The beam optics for the pulsed ion beams will change and be unable to be controlled during building the compensation process. The rising time of extraction potential obviously is the important parameter for pulsed beam. Less than 70 microsecond of the building time of 50keV proton beam can be estimated at the pressure of higher than 10-5 Torr.

The compensating process is determined by the radial potential distribution in the proton beam and the compensating electron density. The temperature of the electrons also is important due to well responding to potential well induced by proton beams.[5] Unfortunately, both are largely influenced by physical quantities, which are largely difficult to predict or to measure. To get homogeneous spatial compensation at pulse operation relatively high operating pressure and low noise and reliable system from extraction voltage are required.

Experimental Setup for Beam Pulsing

We introduce high voltage pulsing between extraction electrodes of the injector to get pulsed beams. High voltage switch is incorporated in the LEBT (20 mA, 50 keV) that will act as a beam pulser at a rate of around ~ 10 Hz with less than 50 ns rising and falling time.

A performance test with high voltage MOSFET switch (BEHLKE) has been conducted on the ion source power supply (10 kV). The switch was connected between the ion source power supply and the floating DC power supply rack for the filament and arc power of ion source as shown in Fig.3.

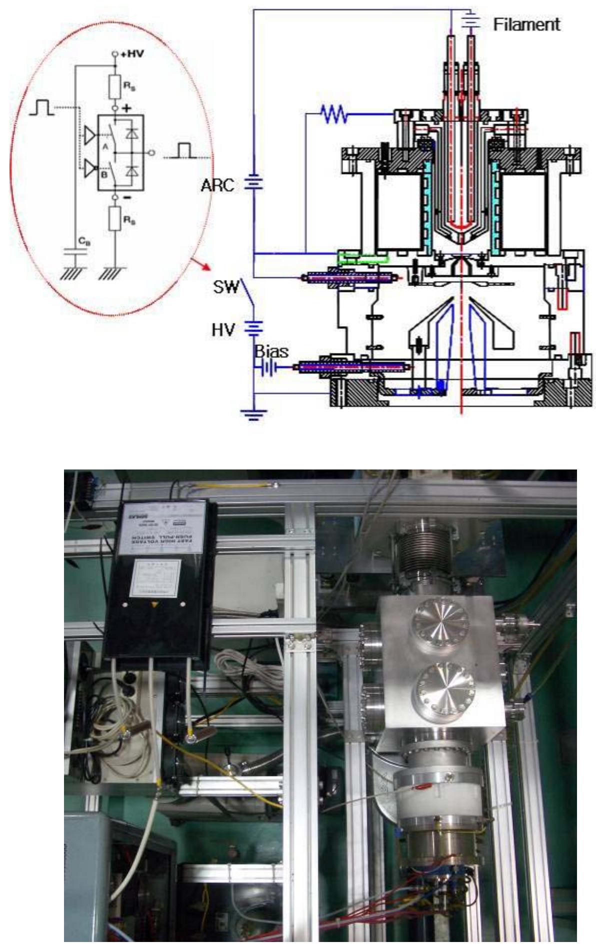

Fig. 3: Schematic diagram and picture of the installed high voltage pulse switch.

This connection actually allows to pulse the accelerating voltage of the extraction electrode against anode without affecting the arc and filament. The falling time is very long due to a resistance of an accompanied working resistor and load capacitance.

In order to reduce the falling time, we are going to replace the switch with a fast high voltage switch. The switch consists of two identical MOSFET switching paths that form a so-called half bridge circuit respectively push-

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pull circuit. Both switching paths are controlled by a common driver, which also provide a logic negation for one of the switches. As shown in Fig.4 the falling time at 200micro sec of a duty is very short around a few micro seconds.

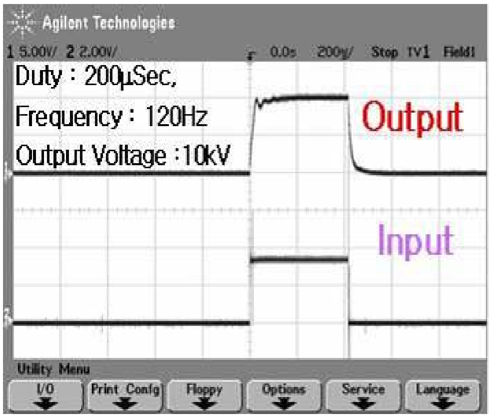

Fig. 4: Output voltage of the fast high voltage switch.

We are performing a study on focusing pulsed proton beam at the front of RFQ. The effect of space charge neutralization at pulsed beam extraction of LEBT will be checked, by comparing how the match changes into the RFQ from TRACE calculations between 0 mA and 20 mA of beam current, with no changes in lens settings. An operating pressure for a pulse mode with reasonable compensating build-up time less than 100 microseconds will be chosen as one of operating windows. Optimised focusing magnetic field intensity of the solenoids at a fixed pressure with variance to well focused beam currents near the entrance of RFQ can be obtained.

CONCLUSION

A high current proton injector for the PEFP linear accelerator has been constructed and reliable proton beams have been obtained successfully. Hydrogen beam currents of up to 50mA have been extracted at 50kV extraction voltage.

The focusing study on pulsed proton beams of the injector is in progress. After testing the focusing performance of pulsed beam at the front of RFQ we will carry out a beam commission between the injector and RFQ.

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