DEVELOPMENT OF PEFP 20MEV PROTON ACCELERATOR*

Y.S. Cho#, H.M. Choi, S.H. Jan, I.S. Hong, J.H. Jang, H.S. Kim, K.Y. Kim, Y.H. Kim, H.J. Kwon, K.T. Seol, Y.G. Song, KAERI, Daejeon, Korea

Abstract

A 20MeV proton accelerator has been developed as a low energy part of PEFP (Proton Engineering Frontier Project) 100MeV accelerator. The 20 MeV accelerator consists of ion source, LEBT (Low Energy Beam Transport), 3 MeV RFQ (Radio Frequency Quadrupole) and 20MeV DTL (Drift Tube Linac). After the field tuning and high power RF conditioning of the accelerator cavities, the first beam test of the 20MeV accelerator is underway. During the test, the pulsed proton beam was extracted from the ion source by pulsing the high voltage power supply. Two 1.1 MW, 350 MHz RF systems were used to drive thee 20 MeV accelerator. The current transformers between DTL tanks and Faraday cups at the end of 20 MeV DTL were used to measure the beam current. In this paper, the development of 20 MeV accelerator is summarized and the first beam test results are discussed.

INTRODUCTION

The PEFP was launched by the Korean government in 2002 for the utilization of high-intensity proton beams. Its primary goal is to develop a high-current proton linear accelerator supplying 20MeV and 100MeV proton beams (Table 1 and Fig. 1). This machine will be applied to various applications in the low- to medium-energy range, or can be an injector for a high-energy proton machine in the next stage of development.

Table 1: Basic parameters of the PEFP accelerator [1]

Particle	Proton
Beam Energy	100 MeV
Max. Peak Current	20 mA
Repetition Rate	60 Hz
Pulse Width	1.3 ms
Max. Beam Duty	8%

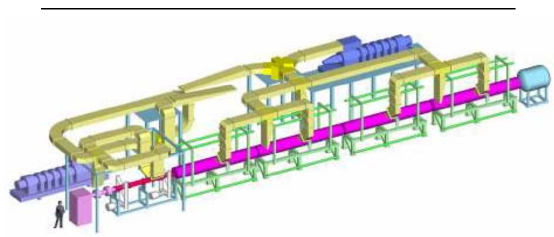

Figure 1: Layout of 20 MeV PEFP Accelerator

*Work supported by the 21C Frontier R&D program in the Ministry of Science and Technology of the Korean government
#choys@kaeri.re.kr

ACCELERATOR DEVELOPMENT

Proton Injector[2]

The injector includes a duoplasmatron proton source (Fig. 2), and a low-energy beam transport (LEBT). The beam current extracted from the source reached up to 50 mA at a voltage of 50 kV using a 150 V, 10 A arc power. The extracted beam has a normalized emittance of 0.2 π mm-mrad from a 90% beam current, where the proton fraction is larger than 80%.

To achieve 60 Hz pulsed operation, a high-voltage switch is installed in the high voltage power supply, whose rising and falling time is less than 50 ns. Fig. 3 shows the beam signal, which is measured with a faraday-cup at the exit of LEBT. With the semiconductor switch, the pulse length and the repetition rate can be easily changed.

The LEBT consists of two solenoid magnets that can filter the H_2^+, and two steering magnets that can control the beam position at the entrance of the RFQ. The transmission of the proton beam is 90%, with a variable beam current from 1 to 50 mA.

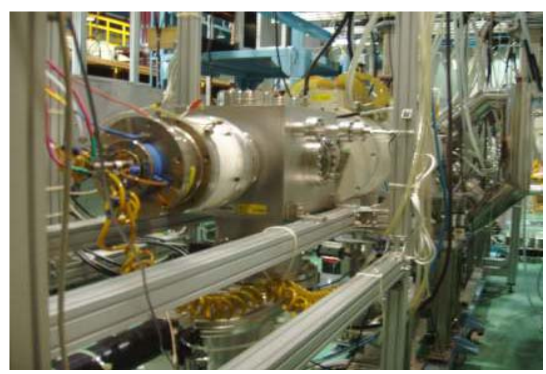

Figure 2: PEFP Proton Injector

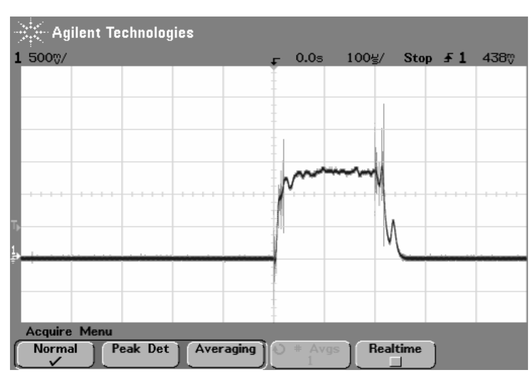

Figure 3: Beam signal at the LEBT exit

(1mA/div. 200us pulse)

RFQ [3]

The PEFP RFQ is designed to accelerate the 20 mA proton beam from 50 keV to 3 MeV. It is the usual four-vane type. The entire structure is separated into two segments that are resonantly coupled for the field stabilization. The RF power is fed into the cavity through two iris couplers in the third section.

A 3 MeV, 350 MHz PEFP RFQ has been installed at KAERI site as shown in Fig. 4. A low power field tuning was completed to satisfy the design requirement. A test stand was installed at KAERI test facility, and the RFQ was conditioned up to the designed power level at the reduced duty factor (Fig. 5). The beam test was performed, and the RF operating point could be determined from the output current characteristics depending on the RF amplitude.

Figure 4: PEFP 3MeV RFQ

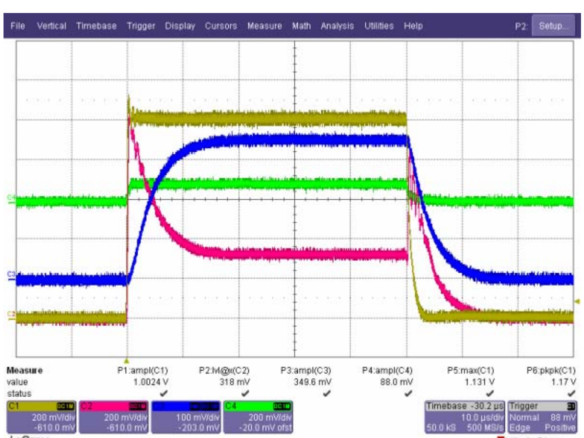

Figure 5: RF signals for RFQ

(Ch1 : forward, Ch2 : reflect, Ch3 : cavity, Ch4 : klystron reflect, horizontal : 20 μs/div.)

DTL[4]

The PEFP 20 MeV DTL consists of four tanks that accelerate the 20 mA proton beam from 3 MeV to 20 MeV. The total length of the DTL is about 20 m. The FFDD lattice configuration has a magnetic field gradient of 5 kG/cm, and an effective field length of 3.5 cm. The fabricated DTL has been tuned and installed at the KAERI site, as shown in Fig. 6. The tuning goals for the PEFP DTL are achieving frequency deviation less than ± 5kHz from the design value and field variation less than ±2% through the tank with the tilt sensitivity against the perturbation less than 100%/MHz.

Figure 6: PEFP 20MeV DTL

A 1 MW klystron supplies the RF power into the four tanks (Fig. 7). The klystron and circulator for the 20 MeV DTL have been installed, and the power supply system for the RF system has been prepared. The klystron has been tested up to the power of 800 kW.

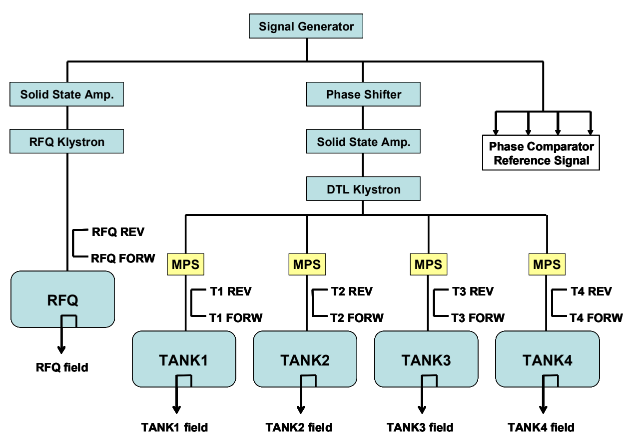

Figure 7: Schematic layout of the RF power flow

The high power RF test was carried out. The resonant frequencies of each DTL tanks were adjusted by controlling the wall temperature of each tank. During test the global operating condition was adjusted by controlling the coolant temperature. The peak RF power to each tank is 150 kW. The waveforms of the cavity field and reflected RF power are shown in Fig. 8.

The beam test within the radiation safety limit of the KAERI test facility was carried out to check the overall machine performance. Because the PEFP DTL has no empty drift tubes that can accommodate the beam diagnostic devices, the current transformer (CT) should be installed between DTL tanks. The beam parameters after the LEBT were adjusted with the two solenoids and two steering magnets. During the adjustment, the parameters were selected from the RFQ exit beam current and beam transmission through the DTL and 100% transmission through the DTL has been achieved at about 1mA peak current level. The beam current signal from the CT at the exit of the RFQ and the Faraday-cup at the exit of the DTL is shown in Fig.9.

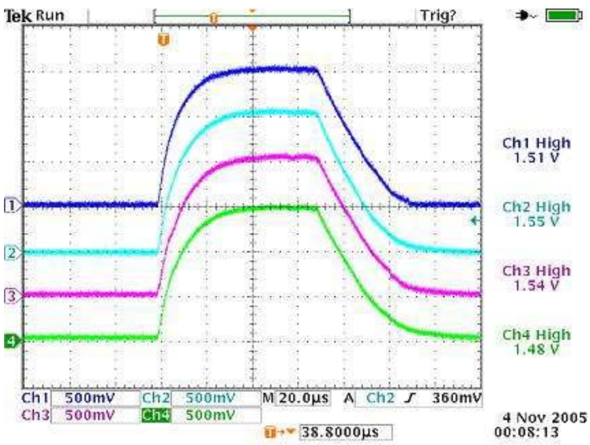

Figure 8: Cavity field waveform
(CH1: tank1, CH2: tank2, CH3:tank3, CH4:tank4)

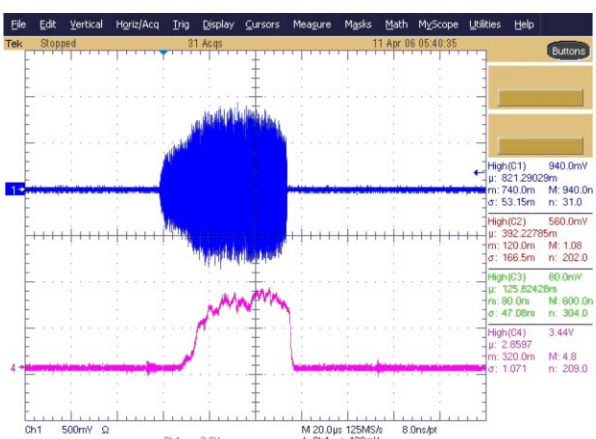

Figure 9: Beam Signals

(CH1: ~1mA at RFQ exit, CH2: ~1mA at DTL exit)

SUMMARY

At the KAERI test facility, we have developed the proton linear accelerator technologies, such as ion source, RFQ, DTL, and RF. With these technologies, we have constructed a 20 MeV proton linear accelerator (Fig. 10), which is the low energy part of the 100 MeV machine, and tested it. The initial beam test within the radiation safety limit of the KAERI test facility has been completed. After the construction of the final site for the 100MeV machine, it will be moved and commissioned. The experiences with the 20 MeV machine will be helpful for the construction of the 100 MeV proton accelerator.

Figure 10: PEFP 20 MeV Accelerator

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