PROTON LINEAR ACCELERATOR DEVELOPMENT AND ITS UTILIZATION PROGRAM IN PEFP

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Abstract

PEFP (Proton Engineering Frontier Project) approved and launched by the Korean government in July 2002 includes a 100MeV proton linear accelerator development and its utilization program. As the first phase of the project (in 2002 ~ 2005) a 20MeV proton linac development program will be carried out. It consists of 50keV proton injector, 3MeV RFQ and 20MeV DTL. The 50keV injector had been developed, the 3MeV RFQ is under test, and the 20MeV DTL is being fabricated for the beam test in 2005. In parallel, application and utilization program using proton beam and accelerator technologies has been developed and some of them are being carried out. As the second fiscal year of the project, the details of the progresses in accelerator development will be reported.

INTRODUCTION

KAERI has been developing a proton accelerator since 1996, to prepare a future research tool for the purpose of utilizing proton beams. The first phase of the project was to develop a 20MeV, 20mA front end accelerator [1] including hardware developments of a 50keV proton injector, 3MeV RFQ, 20MeV DTL and a high power RF system. Within this phase of the project, a preliminary design of 1 GeV accelerator was also performed. As an extension, the Government approved the 2nd phase of the project, to build 100MeV accelerator in the frame of a national frontier program last year.

Official project name is the Proton Engineering Frontier Project (PEFP). It has three goals; to develop and to construct a high power proton accelerator of 100MeV, 20mA, and to develop proton beam utilization and accelerator application technologies, and to promote industrial technologies. The project will last for 10 years from 2002, with project budget of about 100M$. Beyond the project budget, a host institution or province will provide land, site development and related supporting facilities.

PROTON INJECTOR AND LEBT [2]

The proton injector capable of 20 mA, 50 keV proton beam is matched to the 3.0 MeV RFQ by using the LEBT. Non-destructive diagnostic method that gives the profile of a proton beam is of considerable interest for the RFQ beam matching at the LEBT. Two steering magnets were placed in the LEBT between two solenoid lenses to provide the desired beam position and angle at the RFQ match point. The steering magnets have a capability of independent control of X and Y motion.

Various beam focusing and steering features were easily studied using the CCD BPM in single shot mode over 3 sec, at a background gas pressure of 4 x 10^{-5} Torr. Low energy and current proton beam (20 keV, 2 mA) was used for the preliminary tests.

Figure 1 shows the intensity profile measured along the vertical line around proton beam. The measured smallest beam size, meaning the most efficient beam focusing, was obtained with $B_{sol\#1}$ = 1,300 G and $B_{sol\#2}$ = 1,800 G, being in good agreement with the TRACE results. In addition to the incident protons, the other light sources such as delayed decay, back scattered protons, and electrons by inelastic collisions, could broaden the recorded beam profile. Therefore we estimate the beam size to be less than 2.2 mm FWHM from the beam profile measurements.

Two steering magnets installed in the LEBT provide a wide range of beam centroid motion at the RFQ match point, permitting rapid, on-line correction of beam misalignment between the ion source and RFQ by using the CCD BPM. We also measured the current from the Faraday cup to find out the accurate and absolute beam position by comparing with the CCD beam profile.

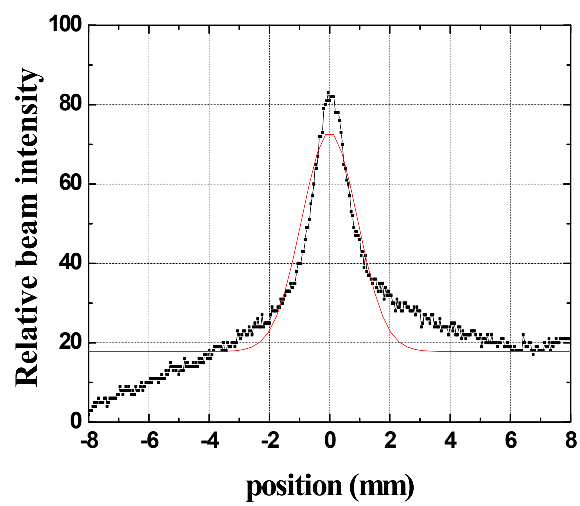

Figure 1: Intensity profile obtained along the vertical line around the proton beam.

3MEV RFQ [3,4,5]

The PEFP RFQ has been designed and constructed to accelerate proton beam from 50keV to 3MeV. The RFQ is a 324cm–long, 4-vane type and composed of 4sections with 36 slug tuners, 8 vacuum pump ports. A coupling plate is used between two segments to stabilize the longitudinal field. The transverse field stabilization is accomplished by dipole stabilization rods. The operation mode of the RFQ is pulse whose maximum pulse width and repetition rate are 2ms, 120Hz respectively. The peak RF power which considers the beam loading and 75% Q

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degradation is 535kW. The PEFP RFQ under test is shown in Figure 2.

Figure 2: PEFP 3MeV RFQ

After the initial multipacting, the power was increased and maintained to wait the field stabilization inside the cavity repeatedly. Recently, the klystron forward power was increased up to the 320kW at 352.1MHz as shown in Figure 3. In Figure 3, the upper part is the klystron forward power, and the lower part RFQ pick up signal. At this power level in Figure 3, continuous proton beam was injected into the RFQ from the ion source whose energy was 50kV. To avoid the damage of the RFQ resulted from the focused proton beam, the beam matching or focusing using LEBT was not used but the beam was rather spread into large area. The pulsed beam current from the Faraday cup at the location of 70cm downstream from the RFQ exit was shown in Figure 4. The beam current was about 2 μA.

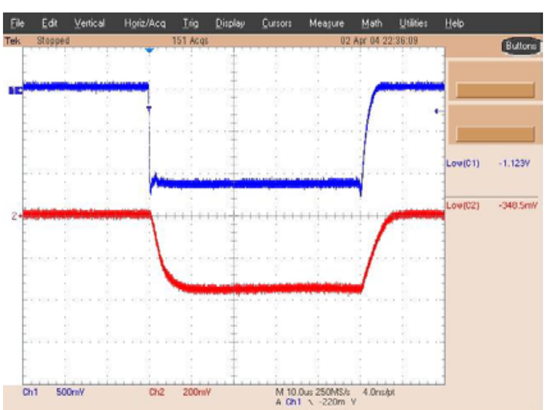

Figure 3: RFQ RF signal (10μs/div.)

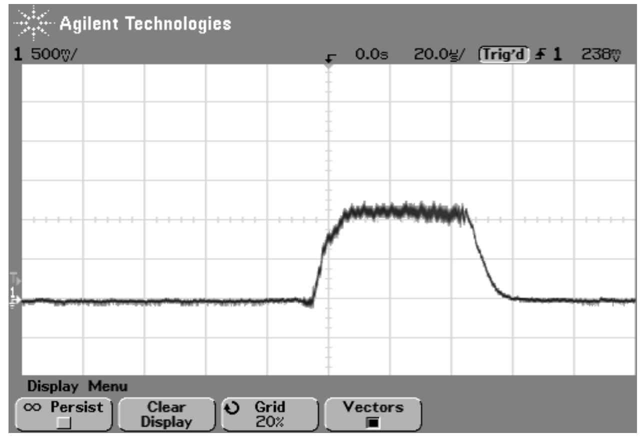

Figure 4: Pulsed beam signal from Faraday cup (10μs/div., 1μA/div.)

The high power RF system for driving the PEFP RFQ has been developed also. The RF system including klystron, circulator, RF window, input coupler, klystron power supply and cooling system have the capacity of operating at 535kW average power level. The TH2089F klystron was operated in pulse mode by modulating the input RF power from the RF generator, therefore the RF duty (or also pulse width, repetition rate respectively) can be adjusted easily for test purposes.

The RF power from the klystron was divided into two legs and delivered into the RFQ because of the power limitation of the RF window. The RF input coupler for the PEFP RFQ is the ridge loaded waveguide type with iris coupling. The coupling beta can be adjusted by controlling the hole at the end of the coupling slot. Two couplers are now installed in the PEFP RFQ as shown in Figure 2.

20 MEV DTL [6,7]

The main specifications of PEFP 20MeV are shown in Table 1.

Table 1: PEFP DTL Parameters

Input /Output energy : 3.0 / 20.0 MeV
Beam current : 0 ~ 20 mA
RF frequency : 350 MHz
Peak RF power : 1 MW
Duty factor : Max. 24 %

We divided a DTL tank into two sections and bolted together with RF and vacuum seals for the manufacturing and installation conveniences. Tank must have the high electrical and thermal conductivity to reduce the power loss and to cool the cavity efficiently. Considered these we choose the forged seamless low carbon steel pipe. This material has high mechanical strength and high resistance for corrosion.

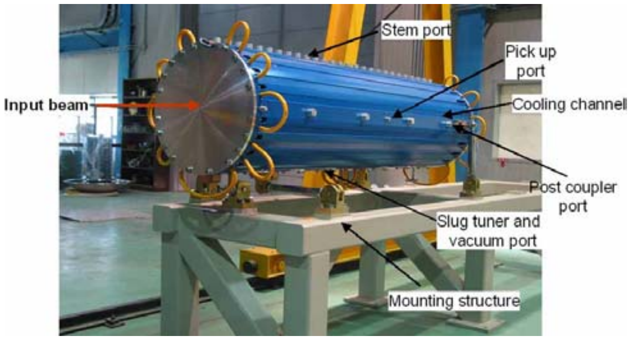

Figure 5: The fabricated DTL tank (1 section)

DTL have to operate under UHV range about 10^{-7} mbar to minimize the beam loss. To satisfying this requirement, the tank inner surface – occupying the most system area – must has minimized outgassing rate. And to reduce the RF power loss, the surface passing through 350 MHz is required the finest surface roughness. The designed roughness is Ra 0.3 μm.

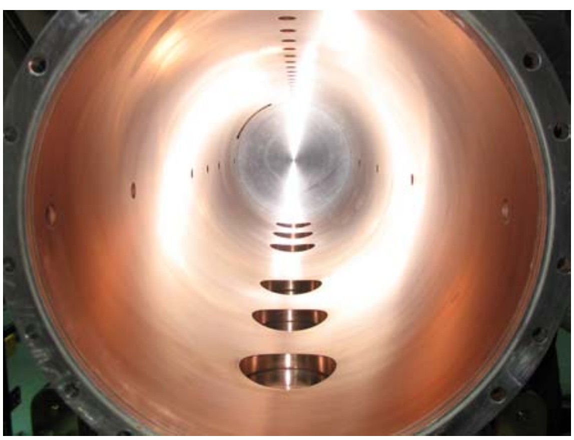

Figure 6: Copper Plated Tank 1

The PEFP DTL adopted the pool-type electromagnet as a focusing magnet. EQM was fabricated one bulk core and commercial copper wire whose dimension was 3mm×2mm. The EQM was assembled in the DT successfully as shown in figure 7. Measured effective length of the fabricated DT was 34mm which was smaller than calculated value. But it seems that GL satisfies the design value of 1.75kG/cm•cm and can be improved to 2.0kG/cm•cm if magnetic saturation improved because there are some margin in the cooling capacity.

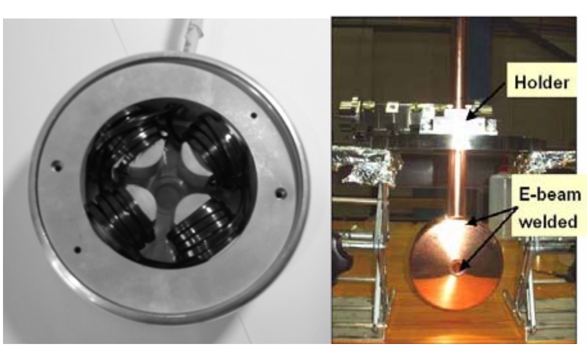

Figure 7: EQM and DT

CONCLUSION

PEFP is developing the 100MeV proton linac for the industrial, and basic science areas as Korean national research facility. In the 1st phase, the 20MeV accelerator that includes injector, LEBT, RFQ, DTL and RF system has been fabricated and tested. In parallel, many applications with keV and MeV accelerators are being developed such as ion irradiators, surface modification of polymers. In the 2nd phase, a 100MeV linac and several beam lines of 20MeV and 100MeV will be constructed, and several applications with high current proton beams, and a user program for future extension of the program are developed.

ACKNOWLEDGMENT

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