DEVELOPMENT OF A LOW-ENERGY PROTON ACCELERATOR SYSTEM FOR THE PROTON ENGINEERING FRONTIER PROJECT (PEFP)

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Abstract

The development of a low-energy proton accelerator has started as the first phase of the Proton Engineering Frontier Project (PEFP). The low-energy proton accelerator system consists of a 50keV proton injector, low-energy beam transport (LEBT), 350MHz, 3MeV radio-frequency quadrupole (RFQ), 350MHz, 20MeV drift-tube linac (DTL), and rf system. The proton injector is under operation, RFQ is testing rf power, and a design of DTL has finished.

1 INTRODUCTION

The Proton Engineering Frontier Project (PEFP) that consists a construction of a 100 MeV proton linac and its application in the industries and the basic science areas is developing in Korea Atomic Energy Research Institute (KAERI) as Korean national research facility. In the first phase, an engineering design and construction for the low-energy proton accelerator system that includes injector, LEBT, RFQ[1], DTL[2] and RF system[3] are underway. In parallel, an applications of keV and MeV proton beams are being developed such as ion irradiators, surface modification of materials. In the second phase, a 100 MeV linac and several beam lines of 20 MeV and 100 MeV will be constructed, and several applications with high current proton beams, and an user program for future extension of the program are planned.

The development of a low-energy proton accelerator has started from September, 2002 at Daejon. After a 20MeV beam commissioning is finished, we will move a new site.

Subsequent sections of this paper describe the present status of the low-energy linac system.

2 LINAC SYSTEM

2.1 Injector

A dc injector capable of 50keV, 50mA proton beam operation constructed. It uses a dc duoplasmatron proton source. Injector includes proton source, power system, chamber, and diagnostics

Figure 1. Constructed Injector.

2.2 LEBT System

LEBT system was designed with the codes, TRACE 3D, POISON, PARMTEQM, and ANSYS. 2.2m-long test Low Energy Beam Transport (LEBT) system which match between the ion source and the RFQ linac was assembled. LEBT consists of two solenoid magnets, two steering magnets, and a beam line, as shown in Fig. 2.

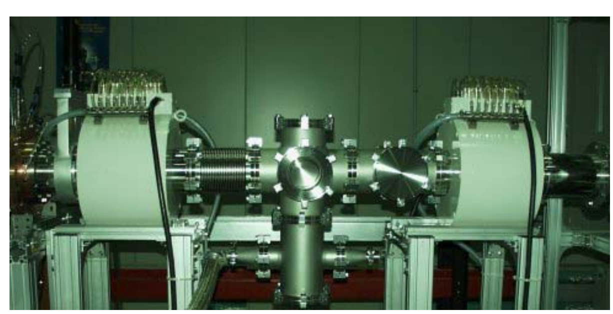

Figure 2. Assembled LEBT System.

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The 16cm-i.d, 20cm-long solenoid lenses with polar cores have 72000A/turns, maximum power loss, 8.1kW, and dc fields 5000Gauss at a beam axis. In order to control of X and Y motions, two steering magnets are placed in the LEBT. These can correct 1.7cm horizontal offset on the beam axis.

2.3 RFQ System

The design of the 3MeV RFQ cavity was performed by the beam dynamics codes, PARMTEQM [4], the thermal and stress analysis code, ANSYS, and the cavity design codes, SUPERFISH and MAFIA. The main parameters given in table 1.

Table 1. 3.0MeV RFQ Parameters.

PARAMETER	VALUE
Operating frequency	350 MHz
Particles	Proton
Input / Output Current	21 / 20 mA
Input / Output Energy	0.05 / 3.0 MeV
Input / Output Emittance, Transverse/norm.	0.02 /0.023 π-cm-mrad rms
Output Emittance, Longitudinal	0.246 MeV-deg
Transmission	95 %
Structure Type	4-vanes
Peak Surface Field	1.8 Kilpatrick
Structure Power	350 kW
Beam Power	68 kW
Total Power	418 kw
Length	324 cm

The RFQ cavity was machined into OFH-Copper and was integrated from four separate 81cm-long sections which was fabricated by vacuum furnace brazing. Fig.3 shows the assembled RFQ system.

The average RFQ cavity structure power by rf thermal loads is 350kW and the peak surface heat flux on the cavity wall is 0.13 MW/m^2. In the operation of the RFQ, a key issue is to remove this heat. To do it, we constructed 24 longitudinal coolant passages in each of the sections. Total flow designed is 1500l/min with more than 1MΩ-m. In the design of the coolant passages, we considered the thermal behaviour of the vane during an operation, the efficiency of cooling and fabricating cost. Cooling system constructed consisted of 38 flow meters, 38 thermocouples and 19 pressure gauges

In the RFQ, a beam loss designed is about 1mA of proton. Vacuum system[5] constructed to pump beam loss, LEBT gas load and out-gassing from the RFQ cavity and vacuum plumbing. Vacuum pumps which consists of a 600l/min roughing pump and two 3000l/s cryopumps are completely oil-free.

RF feed is in the third section. In order to supply the RF power in the RFQ, we studied an iris-type for 3.0MeV RFQ. The input coupler designed is the tapered ridge-loaded waveguide which is interesting from an electromagnetic point of view since the cutoff frequency is lowered because of the capacitive effect center, and could in principle be made as low as desired by decreasing the gap width sufficiently. . The RF vacuum window section consists of a straight WR2300 waveguide which includes a vacuum window and a port for vacuum pumping the waveguide.

Low level RF (LLRF) system constructed include the RF reference, resonance control of the RFQ cavity, klystron control, interlocks, and feedback loop. The main function of the LLRF system is to control RF fields in the RFQ cavity and maintain field stability in the range of ±1.0% peak to peak amplitude and ±1.0^o peak to peak phase. All RF feedbacks loops will use baseband In-phase and Quadrature techniques. Maximum output power of the LLRF system is 200W. The software control of the LLRF system performs with EPICS.

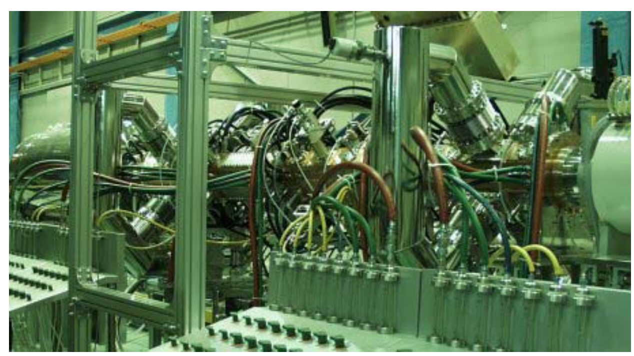

Figure 3. Assembled 3.0MeV RFQ system.

2.4 DTL System

The available structures for the 20 MeV proton accelerator are a coupled cavity DTL (CCDTL), a super-conducting cavity linac, and a conventional DTL. The CCDTL has a merit that the QM can be located at the outside of cavity. Since the high shunt impedance structure should be operated at the higher frequency than that of RFQ, a matching section is necessary to compensate the structure/frequency change and the cavity becomes longer. For the super-conducting cavity, more R&D is necessary for lower beta region. Therefore the most suitable choice is the conventional DTL in spite of its disadvantage that the QM has to be installed even inside the short first drift tube in the first tank.

The operating frequency of RFQ is 350 MHz and the conventional DTL is also working at the same frequency in order to make the matching easy between RFQ and DTL.

The 20 MeV accelerator should be constructed within next 2 years, and should deliver the proton beam to users. With this schedule, the RF system for 20 MeV DTL should be separated from the other parts of the 100 MeV accelerator. From the construction cost estimate, one RF system for the DTL is preferred. The RF power is limited to 900 kW.

Table 2. DTL design parameters

Parameter	Value
Tank diameter	54.44 cm
Drift-tube diameter	13 cm
Bore radius	0.7 cm
Drift-tube face angle	10 degrees
Drift-tube flat length	0.3 cm
Corner radius	0.5 cm
Inner nose radius	0.2 cm
Outer nose radius	0.2 cm
Stem diameter	2.6 cm
Frequency tolerance	0.001 MHz

The required RF power for the 20MeV DTL is described in Table 3, which is an output results of the PARMILA code considering 25% power margin from the SUPERFISH code input data. The total required power is about 900kW which can be covered with one 1MW klystron.

Table 3: Required RF power for 20MeV DTL

Tank #	Cu power (kW)	Beam power (kW)	Total power (kW)
1	141.6	83.4	225.0
2	138.8	86.2	225.0
3	138.3	85.7	224.0
4	137.1	83.9	221.0
Total (kW)	555.8	339.2	895.0

The power distribution in each tank is within ±1%. The schematics of RF power delivery system is shown in Fig. 4. The RF power from one 1MW klystron is split into four legs by magic tee to drive four DTL tanks respectively. Each leg has a phase shifter to adjust the phase of the RF field in each tank. With this type of power distribution, the amplitude of the RF field in each tank can be maintained within ±1% of the design value in spite of feeding equal power into each tank.

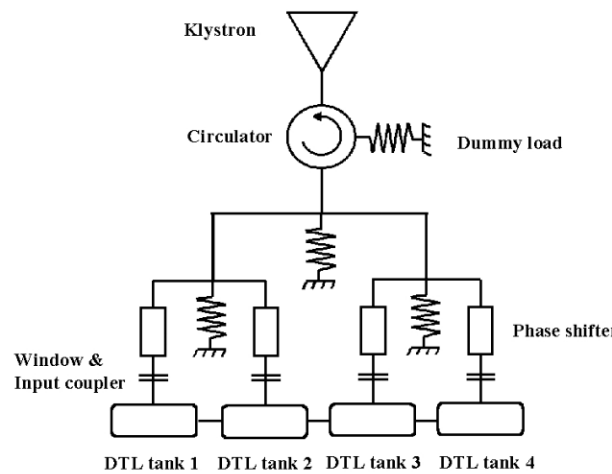

Figure 4. Schematics of RF power delivery system for 20MeV DTL

3 SUMMARY

Injetor and LEBT system has been constructed. The fabrication, electrical test, and vacuum leak test of the RFQ cavity has been completed. The low-energy linac system will be constructed in May, 2005 and the beam commissioning up to 20MeV will be finished. In 2007.

4 ACKNOWLEDGMENT

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REFERENCES

[1] J.M. Han et al., “ 3.0MeV KTF RFQ Linac”, Proc. of the 2002 Linear Accel. Conf., Gyeongju, Korea.

[2] Y.S. Cho et al., “Dedign of 20MeV DTL for PEFP”, these proceedings.

[3] H.J. Kwon et al., “The RF Power Delivery System Design and Its Component Characterization for PEFP DTL”, these proceedings.

[4] K.R. Crandall et al., “RFQ Design Codes”, LA-UR-96-1836, (Revised February, 1997).

[5] M.I. Park et al., “The Vacuum Systems for PEFP LINAC”, these proceedings.