Proceedings of 2005 Particle Accelerator Conference, Knoxville, Tennessee

FABRICATION OF THE PEFP 3 MeV RFQ UPGRADE*

H. J. Kwon#, Y. S. Cho, J. H. Jang, H. S. Kim, Y. H. Kim
PEFP, KAERI, Daejeon 305-353, Korea

Abstract

A 100MeV proton accelerator has been developed at PEFP (Proton Engineering Frontier Project) as a 21C Frontier Project [1]. The goal of the first phase of the project is to develop a 20MeV accelerator. The 20MeV accelerator consists of in source, LEBT, 3MeV RFQ and 20MeV DTL. The 3MeV RFQ was already installed and being tested [2]. During preliminary test, some problems have been found out. Therefore it was decided to fabricate another RFQ. The RFQ upgrade includes some characteristics such as constant voltage profile, adoption of transition cell which are different from present one. In this paper, the fabrication of the PEFP 3MeV RFQ upgrade is presented.

INTRODUCTION

A PEFP 3MeV RFQ was already installed. During field tuning and high power test, some problems were found out. They are 1) inadequate tuning of the cavity – both frequency and field profile, 2) sharp edge in the vane end, 3) inadequate RF seal. Therefore it was decided to fabricate new RFQ and preliminary test with existing RFQ is going to progress until new RFQ replaces old one.

A new PEFP 3MeV RFQ, RFQ Upgrade, has been designed with the following features: 1) maintains constant voltage profile for easier tuning, 2) adopts a transition cell for better matching, 3) maintains resonant coupling, and dipole stabilizer rod for longitudinal and transverse stabilization, 4) modify the brazing surface for pre-brazing tuning, 5) determine the shape of the radial matching section and fringe field region through the machining of the mock-up model, 6) adopts new RF seal scheme compared with old one. Recently, brazing of two sections are completed and remaining two sections are prepared for brazing.

DESIGN

Overall Design

The parameters of PEFP 3MeV RFQ Upgrade is presented in Table 1. It is 4 vane type with 4 sections, two segments, which are resonantly coupled for field stabilization. The radial matching section consists of 6 cells for the smooth matching of the RFQ input beam controlled by the last solenoid of LEBT. In order to maintain the RFQ length similar to that of existing one, the shaper energy was determined as 86.5keV where the synchronous phase is linearly increasing. The ρ/r_0 of the vane is 0.87 and constant through the downstream which limits the surface electric field below the 1.8 Kirlpatrick. The fraction of the octupole components is less than 10% of the quadrupole value under those vane tip geometry.

The last cell of the RFQ is changed to adopt the transition cell to eliminate the energy uncertainty at the end of the RFQ and give the same physical length between horizontal and vertical vanes. Since it offers well defined ending region for RFQ, the additional fringe field region after the transition cell can be used for the transverse matching between RFQ and the downstream sections. The designed parameters of RFQ upgrade are shown in Figure 1.

Table 1: PEFP 3MeV RFQ Parameters

Frequency	350 MHz
Input / Output energy	50 keV / 3 MeV
Input / Output current	22 mA / 20 mA
Vane voltage	85 kV (constant)
RF Power (80% Q)	460 kW
Input emittance	0.02 cm-mrad (normalized rms)
Output emittance	0.022 cm-mrad 0.112 deg-MeV
Transmission rate	98.3 %
Duty	24 % (Max.)
Repetition rate	120 Hz
Total length	325 cm

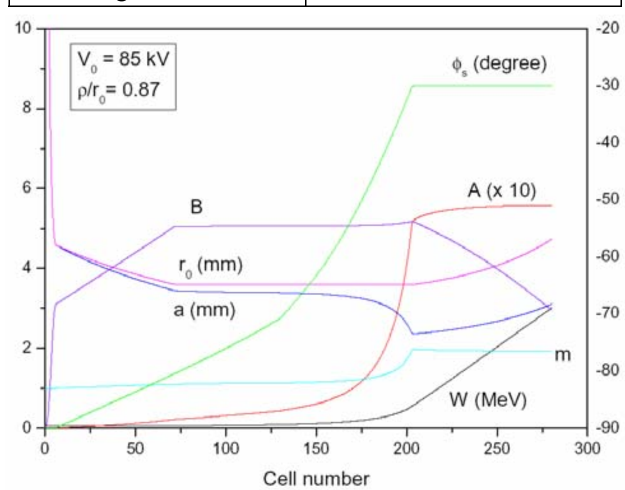

Figure 1: PEFP 3MeV RFQ Design Parameters: synchronous phase (ϕ_s), accelerating efficiency (A), focusing efficiency (B), mid-cell aperture radius (r_0), minimum radius curvature (a), transverse curvature radius of the vane-tip (ρ), modulation (m), and particle energy (W).

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

Beam Dynamics

The beam dynamics calculation was carried out using PARMTEQM code. The input and output beam in the trace space are shown in Figure 2. In this simulation, 10,000 particles have been used. The Twiss parameters of the output beam in the transverse direction are given as α_x= -1.89, β_x= 17.80 cm/rad and α_y=1.33 β_y= 11.75 cm/rad in x- and y-directions, respectively. Figure 3 represents the configuration plots of the beam in the RFQ with the transmission rate of 98.3 %. The figure shows the particle distribution in x- and y-directions, the phase and energy deviation from the designed values, from the top part of the figure, respectively.

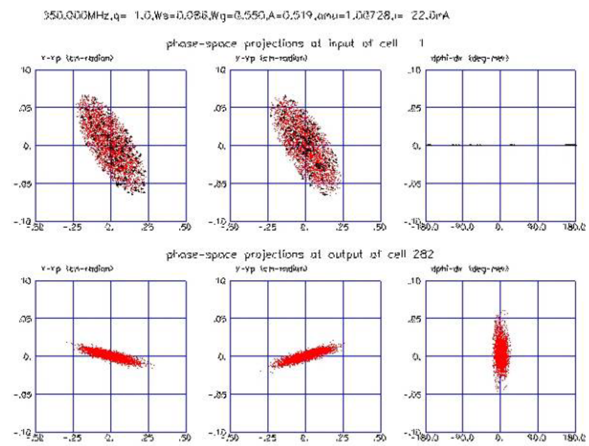

Figure 2: Input and output beam in trace space.

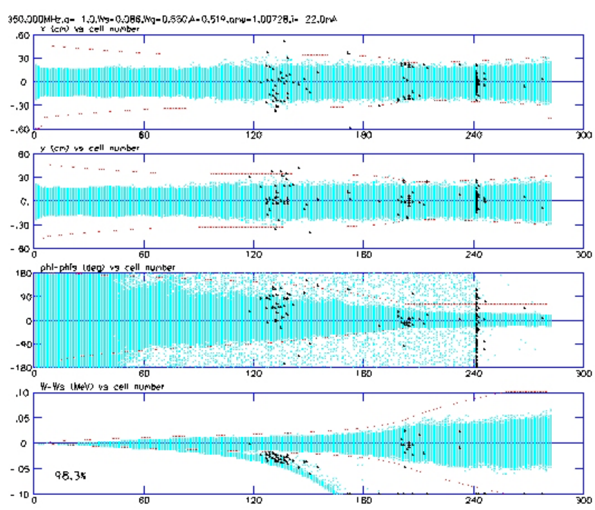

Figure 3: Configuration plot of the beam obtained by PARMTEQM with 10,000 particles.

Cavity Design

The cross section of the cavity was determined using SUPERFISH code. The widths of the vane skirt was adjusted to satisfy the resonant frequency. Undercut depths of the three regions, those are radial matching section, coupling plate region and fringe field region were determined using MWS code as shown in Figure 4.

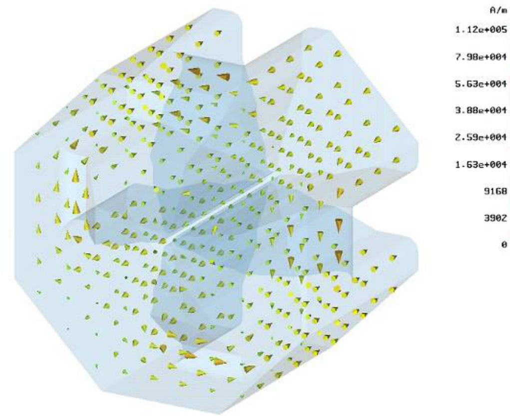

Figure 4: Undercut calculation using MWS code.

Engineering Features

The most serious problem of the existing RFQ is inadequate tuning. That is its frequency was higher than designed one and the field profile could not be adjusted because the measured field profile was beyond the limit which could be controlled by the tuners. Therefore, the brazing surface of the vane joint was changed from step geometry into flat one without any step in order to pre-brazing tuning. With those brazing surface geometry, the minor vanes can be translated to adjust the resonant frequency, quadrupole and dipole field profile.

A few geometries in radial matching section and fringe field region were considered to make smooth transition to the end of the vane, and final geometry was determined through the machining of the mock up model. The finalized mock up model is shown in Figure 5.

The RF seals are changed from helicoflex into various ones. For the section to section joint, the main RF seal is the direct contact of the raised surface, and canted coil spring which is located at the outside of the raised surface is used as a backup. A 0.3mm thick tin is used for both RF and vacuum seals of tuner and pick up port. Also c seal is used for the RF seal of the high power RF coupler.

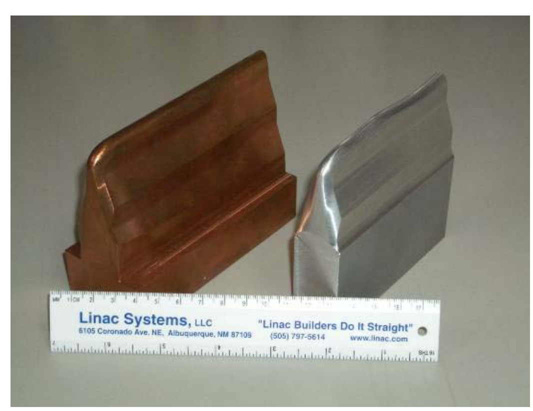

Figure 5: Mock up model of the end region.

0-7803-8859-3/05/$20.00 ©2005 IEEE

FABRICATION

The PEFP 3MeV RFQ upgrade consists of 4 sections. The length of each section is about 80 cm long. A RFQ section is divided into 4 pieces, two are minor vanes, two are major vanes, which are joined together through brazing. The cavity material is OFHC copper. The RFQ vanes are machined with CNC machine. During the machining of the vane tips, ball end mill was used with 45degree angle to the axis of the vane. Cooling channels which are located at the vanes and the wall were machined with gun drill. The flange is joined into the cavity after the pre-brazing tuning. The flange is also OFHC copper supported stainless steel plate. The machining of the vane tip region is shown in Figure 6.

The 4 pieces of vanes are joined through brazing. The brazing filler metal is BAg-8 and the brazing temperature is 850 degree C. The required time for brazing is about 24 hours which include warming and cooling time. The RFQ ready for brazing inside the furnace is shown in Figure 7.

Until now, brazing of the two sections of RFQ are completed and remaining two sections are waiting for brazing. The RFQ section 1 after brazing is shown in Figure 8. The vacuum leak test with He leak detector showed that the leak rate of the brazed RFQ was less than 1E-9 torr l/s.

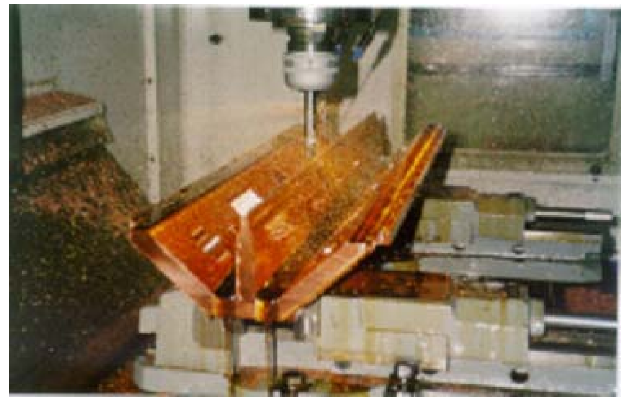

Figure 6: Machining of the vane tip.

Figure 7: RFQ installed in furnace for brazing.

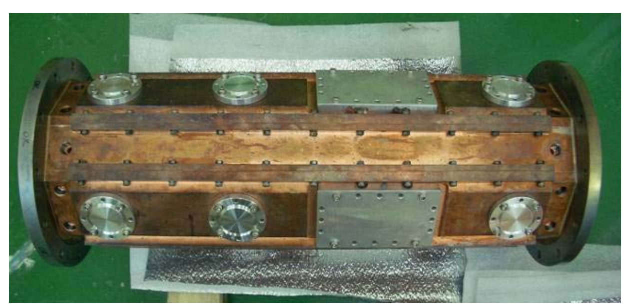

Figure 8: Brazed RFQ section 1.

CONCLUSIONS

A 3MeV RFQ upgrade has been developed at PEFP. It has features which are different from existing one. They are to maintain constant voltage profile, to adopt a transition cell, to modify the brazing surface, to determine the smooth transition at vane end region, and to adopt new RF seal scheme. Recently brazing of the first two sections were completed, and remaining two sections are waiting for brazing. After the completion of the fabrication of the sections, the field tuning of each segments will be done first, and then tuning of the whole RFQ which is resonantly coupled structure with two segments will be carried out.

REFERENCES

[1] B. H. Choi, “Status of the Proton Engineering Frontier Project”, in these proceedings.

[2] Y. S. Cho, “Test Results of the PEFP 3MeV RFQ Upgrade”, in these proceedings.