UPGRADE DESIGN OF PEFP 3MEV RFQ

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Abstract

The PEFP (Proton Engineering Frontier Project) 3 MeV RFQ has been fabricated and tested. Some problems, such as frequency and voltage profile tuning has been found during the experiments. To solve the problems, the upgrade design of 3 MeV RFQ has been decided. The main concept of this upgrade design is constant vane voltage profile with the same length of RFQ. The other parameters (350 MHz, 3 MeV, 20 mA) are the same with the previous RFQ. With constant vane voltage profile, fabrication of RFQ can be easier, and with the same mechanical dimension, other parts such as vacuum pumping station can be re-used. In this paper, the details of beam dynamics design and engineering design will be presented.

INTRODUCTION

The existing PEFP RFQ [1] has some problems such as the higher value of the resonant frequency than the designed one, and the tuning difficulty because the field profile has been measured beyond the limit that can be controlled by the slug tuners.

A new PEFP RFQ has been designed with the following features. The first change is the constant vane voltage for easier fabrication and simpler tuning. The second is the selection of the transition cell for the last cell of the RFQ [2]. The third is that physical dimension of the new RFQ is essentially same as the old one because we want to use the prepared components like vacuum system and wave guiding system connecting the RFQ and klystron. The fourth is that we have also maintained the resonant coupling method [3] in order to get the more stable field distribution. Finally we have decided the pulsed operation with the maximum duty factor of 24 % since it is sufficient for our purpose of the machines.

This paper contains the physics and engineering design considerations of the new 3 MeV RFQ for PEFP.

PHYSICS DESIGN CONSIDERATIONS

We have designed the RFQ by RFQ Design Codes developed and distributed by LANL [4]. They include programs like CURLI, RFQUICK, and PARI for the RFQ generation, PARMTEQM for the beam dynamics study, VANES in order to obtain the machining data, and other useful design tools.

RFQ physics design

The RFQ is 4-vane type with 4 sections. We have adapted the constant vane voltage for the simple cavity design, easier fabrication, and uncomplicated tuning process.

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 the old design, we have selected the shaper energy as 86.5 keV where the synchronous phase is linearly increased.

We have chosen the constant ρ/r_0 as 0.87 which limits the surface electric field below the 1.8 Kilpatrick field. The fraction of octupole components becomes less than 10 % of the quadrupole component value under this choice.

The last cell of the RFQ is changed to be the transition cell proposed by Crandall [2]. It should eliminate the energy uncertainty at the end of RFQ and gives the same length between the horizontal and vertical vanes. Since it offers well defined ending scheme for RFQ, the additional fringe field region after transition cell can be used for the transverse matching between the RFQ and the following

Table 1. PEFP 3MeV RFQ Linac Parameters

Frequency	350 MHz
Input / Output energy	50 keV / 3 MeV
Input / Output current	22 mA / 20 mA
Vane voltage	85 kV (constant)
ρ/r_0	0.87
Radial matching section	6 cells
Power	385 kW (total) 320 kW (Cu), 65 kW(beam)
Input emittance	0.02 cm-mrad (normalized rms)
Output emittance	0.022 cm-mrad 0.112 deg-MeV
Capture rate	97 %
Transmission rate	98.3 %
Duty	24 % (Max.)
Repetition rate	120 Hz
Total length	321 cm

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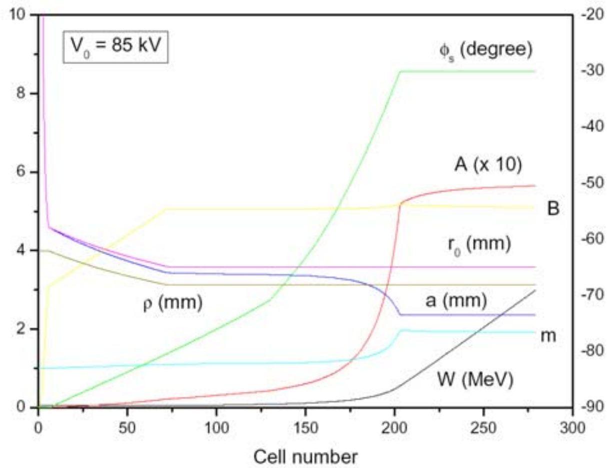

Figure 1: PEFP 3MeV RFQ Design Parameters: synchronous phase (ϕ_s), accelerating efficiency (A), focusing efficiency (B), mid-cell aperture radius (r_0), minimum radius curvature (a), transverse curvature radius of the vane-tip (ρ), modulation (m), and particle energy (W).

DTL. Since the length of the fringe field is not determined until now (it has been chosen as 2cm in this calculation), the total length should be changed by the matching work in near future.

The focusing efficiency (B) is linearly increased from the beginning of the shaper to about 30 cm in the axial direction where it becomes the maximum value of 5.15. The synchronous phase after gentle buncher is fixed as –30 degrees.

The new design parameters for PEFP RFQ are summarized in Table 1 and Figure 1.

Beam Dynamics

The first step is the process to find the matched input beam which will remove the undesired betatron oscillation. After simple calculation, we have got the following twiss parameters for input beam in transverse directions: $\alpha = 1.01$, $\beta = 5.01$ cm/rad. The input current is 22mA and the space charge effects are recalculated for each cell.

Figure 2 shows the input and output beam in the trace space. In this simulation, we have used 10,000 particles. 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. It is impossible for the beam to directly enter into the following DTL. The main difficulty comes from the fact that the focusing efficiency of the high-energy part of the RFQ becomes much stronger than that of the first part of the PEFP DTL. We are now studying the matching problem to get a simple and reasonable solution.

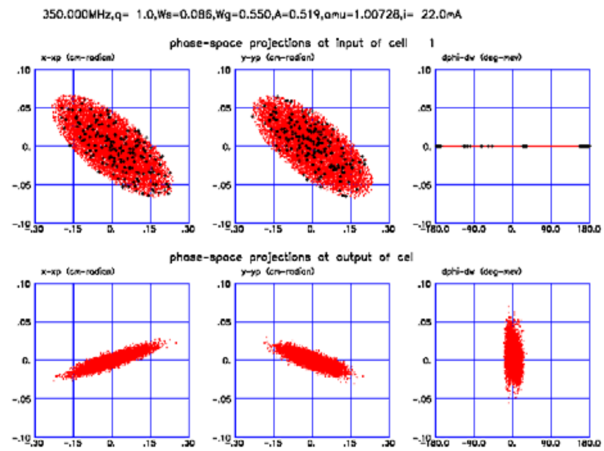

Figure 2: Input and output beam in trace space.

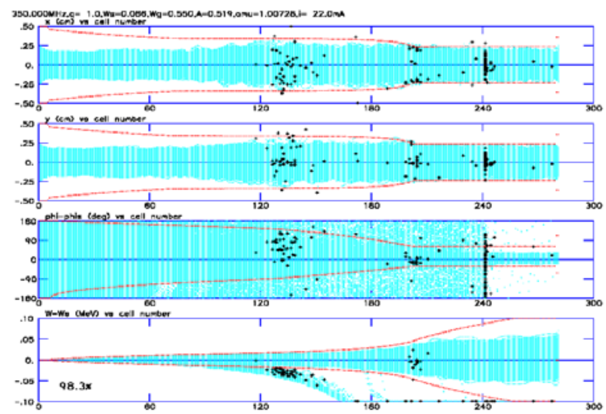

Figure 3: Configuration plot of the beam obtained by PARMTEQM with 10,000 particles.

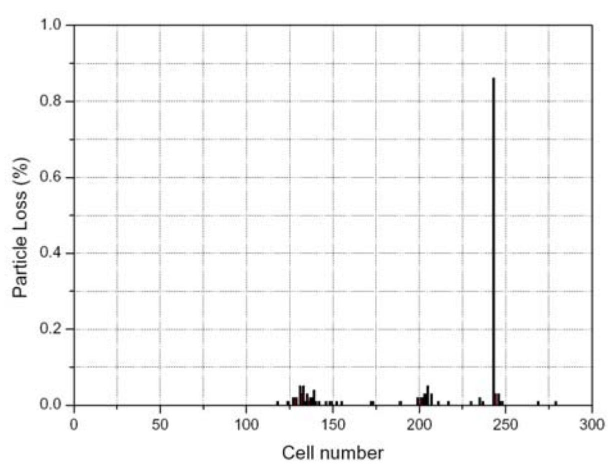

Figure 4: Particle loss (%) versus cell number.

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 4 shows the particle loss in percentage terms for each cell. Even though the losing rate after gentle buncher is relatively higher than the other parts of the RFQ, its magnitude is less than 0.9 %.

ENGINEERING DESIGN CONSIDERATIONS

The physical dimension of the new RFQ is essentially same as the old one because we want to use the prepared components like vacuum system, input-coupler, LEBT, and wave-guide. Because the maximum duty is also changed from cw to 24%, the cooling requirements and rf seal requirements are lowered. Due to the conditions, there are no main changes in mechanical designs in the new RFQ.

During the test of existing RFQ, we found that there are some problems in brazing of cooling channel. Cooling channels are redesigned without any brazing point inside the vacuum.

There was some problem during the CNC-machining of RFQ vane, especially in entrance side. To check this, the machining check had been done. Figure 5 shows the sample of RFQ vane machining, and it is within the requirements. As some minor changes, we will eliminate the brazed flanges of sections, and put o-ring grooves directly on the cavity.

Figure 5: Vane end for machining check.

CONCLUSION

We have designed a new 3 MeV RFQ which has the similar geometrical dimension as the existing one. The main changes are the pulse operation, the constant vane of 85 keV along the full vane tips, and the transition cell in order to remove the energy uncertainty and use the fringe field region for matching between RFQ and DTL. For the field stabilization, the resonant coupling method is adapted.

There is no major changes in engineering desing, and machining check had been done. It will be machined and brazed in this year, and will be tested in next year.

REFERENCES

[1] J. M. Han, et al, “Design of a 350 MHz CW RFQ for the KOMAC Project”, APAC’98, Tsukuba, March 1998.

[2] K. R. Crandall, “Ending RFQ Vanetips with Quadrupole Symmetry”, LINAC’94, Tsukuba, August 1994.

[3] M. J. Browman and L. M. Young, “Coupled RadioFrequency Quadrupoles as Compensated Structures”, LINAC’94, New Mexico, September 1990.

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