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Preliminary Design of 3.5-MeV Helium RFQ for Fusion Materials Radiation Damage Study

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1. Introduction

KOMAC (KOrea Multi-purpose Accelerator Complex) has developed a 100-MeV proton linac which includes a 50-keV ion source, a 3-MeV RFQ (Radio Frequency Quadrupole), and a 100-MeV DTL (drift tube linac) [1]. The RFQ technology can be also used to MeV ion beam applications. Especially helium beam with the kinetic energy of 3.5 MeV can be used to study the alpha particle irradiation from DT nuclear fusion reaction on the first wall of the fusion reactor. This work briefly summarized a 3.5 MeV helium RFQ design for alpha irradiation study.

2. RFQ Beam Dynamics Study

The design requirement of the RFQ is summarized in Table 1. The input energy is 100-keV for $^4He^{2+}$ ions. The output energy is 3.5 MeV which is the energy of alpha particle produced by DT reaction. The RF frequency is 200MHz. The average beam current is 0.1 mA with the peak beam current of 10 mA and the beam duty of 1%. For the stable operation, we choose a relatively small value of Kilpatrick number less than 1.6 overall the RFQ.

Table 1. RFQ design requirement.

Parameters	Values
Reference Particles	$^4He^{2+}$
Frequency	200 MHz
Input Energy	100 keV
Output Energy	3.5 MeV
Peak Beam Current	10 mA
Beam Duty	1%
Kilpatrick	< 1.6

In the first step, we determined the design parameters by the beam dynamics study. In this step, we used the RFQ design codes [2]. The selected design parameters are summarized in Table 2. We choose the vane voltage of 65 kV. The smaller value of vane voltage satisfied the Kilpatrick requirement less than 1.6 overall RFQ. However it generates a longer RFQ than for a larger vane voltage.

Table 1. RFQ design parameters.

Parameters	Values
Vane voltage	65 kV
Focusing efficiency	5.5
Modulation At the end of GB	1.9
Minimum aperture radius At the end of GB	2.52 mm
Average aperture radius	3.77 mm
Number of cells in radial matching section	6
RFQ Length	3700.285 mm
Vane length	3683.599 mm
Radial matching gap	8.363 mm
Fringe field gap	8.322 mm

The resulting RFQ becomes about 3.70 m long which includes the vane length of 3.68 m and gaps in the low energy part (called radial matching gap) and the high energy part (called fringe-field gap) as shown in Table 2. The number of radial matching cells is 6 and the length of radial matching is 32.935 mm. Figure 1 shows the behavior of the physical parameters over the RFQ cells. Those are the modulation m, the synchronous phase ϕ_s, the minimum aperture radius a, the average aperture radius r_0, the acceleration efficiency A, the focusing efficiency B, the kinetic energy W. We found that the total number of cells is 356.

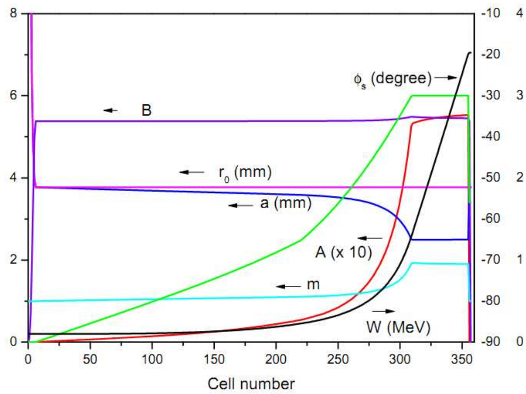

Fig. 1. RFQ parameters depending on cell numbers (m: modulation, ϕ_s: synchronous phase, a: minimum aperture radius, r_0: average aperture radius, A: acceleration efficiency, B: focusing efficiency, W: kinetic energy) .

Table 2. RFQ beam parameters (PARMTEQM result).

Energy	3.526 MeV
Transmission Rate	91.9%
Input Emittance (rms)	0.20 π mm-mrad
Output Emittance (rms, transverse)	0.21 π mm-mrad

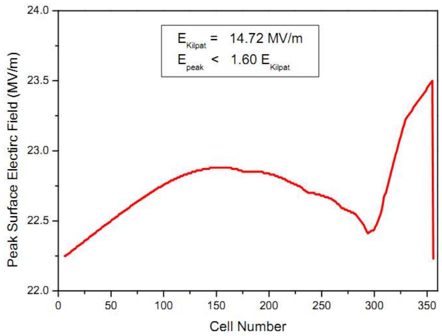

Fig. 2. Peak surface electric field.

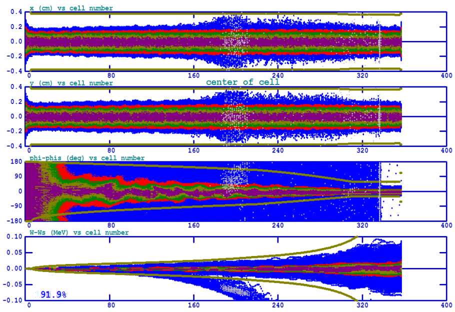

Fig. 3. Configuration plots of beams in RFQ.

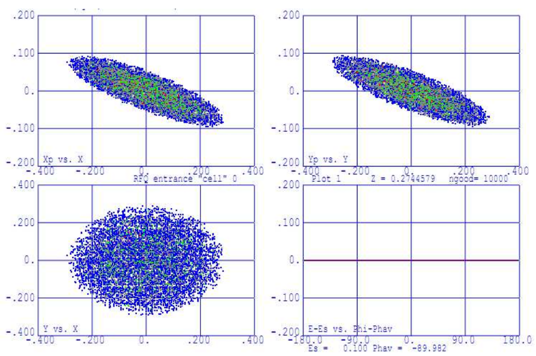

Fig. 4. RFQ matched input beam in phase spaces.

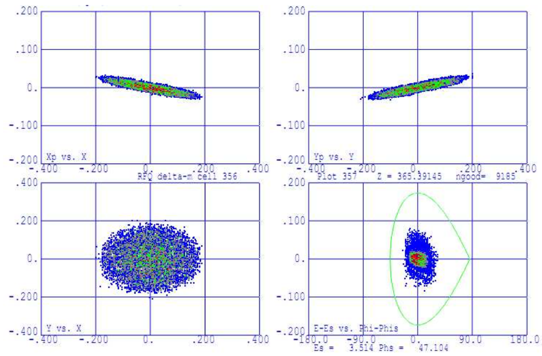

Fig. 5. RFQ output beam in phase spaces.

Table 2 summarized the beam dynamics result. The output energy is 3.5 MeV and the transmission rate reaches about 92%. The normalized rms emittance is slightly increased from the input value of 0.20 π mm-mrad. Figure 2 shows the surface electric field over the RFQ which shows that the condition of the Kilpatrick less 1.6 is satisfies. The helium beam behavior is configuration space is shown in Figure 3. We found that the transmission rate is 91.9%. The matched input beam and the resulting output beam are shown in Figure 4 and Figure 5, respectively.

3. Conclusions

We have studied a 3.5-MeV helium RFQ for the fusion material damage study, especially for the alpha particle effects produced by DT reaction. The total length is about 3.7 m, which is compact to be installed in a general experiment hall with a reasonable radiation shielding. For the ion source of He, we are considering a microwave ion source.

ACKNOWLEDGEMENT

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REFERENCES

[1] K. Y. Kim, Y. S. Cho, J. Y. Kim, K. R. Kim, and B. H. Choi, “The Proton Engineering Frontier Project: Accelerator Development”, JKPS, vol. 56, p 1936, 2010.

[2] K. R. Crandall, T. P. Wangler, L. M. Young, J. H. Billen, G. H. Neuschaefer, D. L. Schrage, “RFQ Design Codes”, LA-UR-96-1836.