Preliminary Study on 50MHz Heavy Ion RFQ without Pre-Bunchers

Yong-Sub Cho [a*], Ji-Ho Jang [a], Han-Sung Kim [a], Hyeok-Jung Kwon [a]
[a]*Proton Engineering Frontier Project, KAERI, Daejeon 305-353*
[*]*Corresponding author: choys@kaeri.re.kr*

1. Introduction

We are studying a Radio Frequency Quadrupole (RFQ) as a lower energy part for a 200-MeV/u heavy ion linear accelerator of the International Business and Science Belt Project. The RFQ accelerates the 10-keV/u heavy ion beams from ion source (hydrogen molecules to uranium) and injects the 300-keV/u beam to the superconducting linac. Table I shows the basic parameters for the RFQ accelerator. In this study, we assumed that pre-bunchers to accelerate two charge state is not required.

Table I: Basic RFQ Parameters

A/q	$\leq$ 8.5
Reference particle	$^{238}U^{28+}$
Beam current	3 pμA (= 84 eμA)
Input energy	10 keV/u
Final Energy	300 keV/u
Duty	100% (CW)
Beam power	214 W

2. Beam Dynamics

For the rf frequency, we chose 50 MHz which is slightly lower than others such as Isotope Science Facility at Michigan State University (80.5 MHz) [1] and Advanced Exotic Beam Laboratory (AEBL) at Argonne National Laboratory (57.5 MHz) [2].

Table II: RFQ Design Parameters

RF frequency	50 MHz (λ = 6 m)
Beta	4.62e-3 $\rightarrow$ 2.53e-2
Kilpatrick	<1.6
Vane voltage	70 kV
Emittance	0.1π mm-mrad (nor. rms)

We used the PARMTEQM code to create a RFQ structure with the parameters in Table II and to simulate the beam dynamics through the RFQ. The length of the RFQ is 6.3 m and the transmission rate is 84 % for uranium ion beam. Fig. 1 shows the beam traces along the heavy ion RFQ.

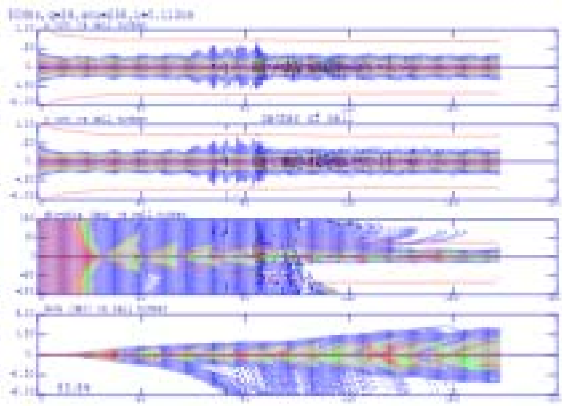

Fig. 1. Uranium Beam Traces along Heavy Ion RFQ

Fig. 2 shows the beam at the exit of the RFQ in phase space. The full beam size is about 5-mm diameter and the energy spread is within ±3% which is tolerable for the downstream superconducting accelerator. To verify the acceleration of ions from hydrogen to uranium, we simulated the argon beam with the same structure and the lower vane voltage. Fig. 3 shows the results that the transmission is 88% which is better than the uranium beam case. We are expecting that the transmission of any lighter ion is better than the uranium.

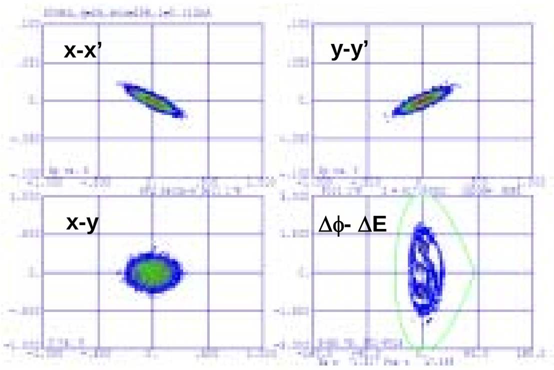

Fig. 2. RFQ Output Uranium Beam in Phase Space

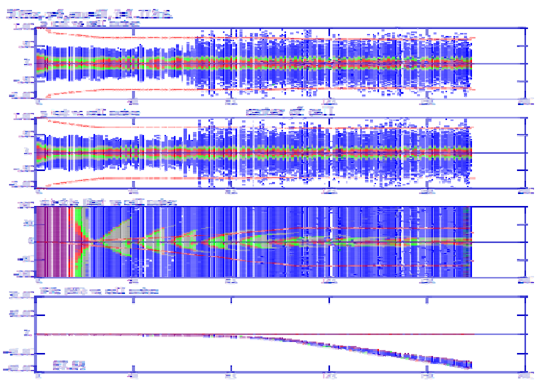

Fig. 3. Argon Beam Trace with the same RFQ

3. Resonator Design

For the structure of a heavy ion RFQ, we can consider a four-vane type which is efficient for proton, a four-rod type which is compact for heavy ions, and a four-vane with windows which is intermediate type. We chose the four-vane with windows structure to operate the RFQ at CW [3].

We designed the resonator with MWS (Micro Wave Studio) code, and tuned the resonance frequency by adjusting the sizes of the windows. Fig. 4 and 5 show the electric and magnetic field pattern in the resonator.

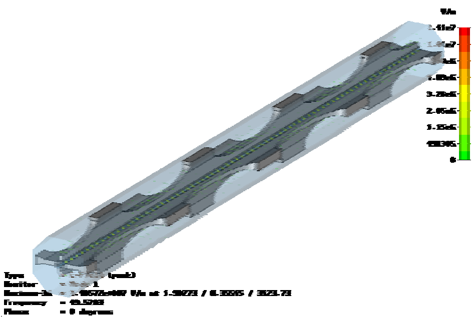

Fig. 4. Electric Field Pattern in Resonator

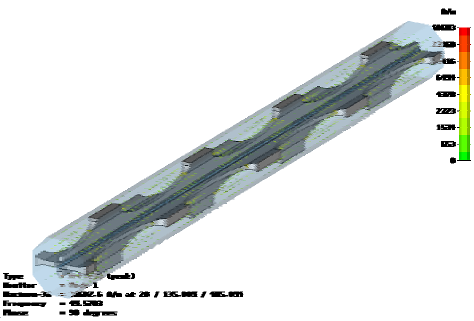

Fig. 5. Magnetic Field Distribution in Resonator

The electric field is concentrated on the vane tips, and the magnetic field is concentrated around the windows. The field ripple due to the windows on the vanes is less than 1% as shown in Fig. 6.

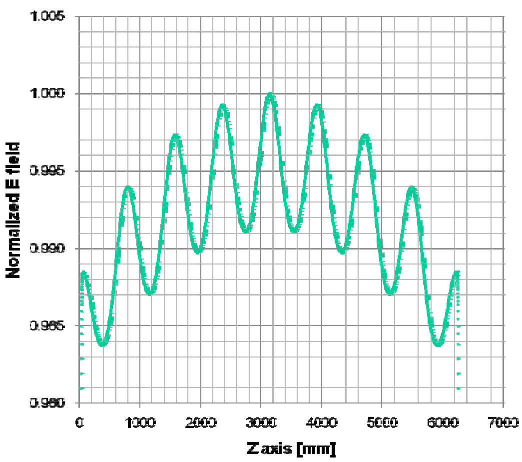

Fig. 6. Electric Field Ripple along RFQ

Table III shows the design parameters of the RFQ resonator. The frequency difference between the quadrupole mode and the nearest dipole mod is 18 MHz which is sufficient for the stable operation. We need a 100-kW class rf source with semiconductor to operate the RFQ. The rf coupler is easy to fabricate, and the Kilpatrick 1.47 is achievable by conventional surface treatments. The specific rf power loss 11 kW/m is manageable by a water cooling channel along the RFQ vanes.

Table III: RFQ Resonator Design Parameters

Operating frequency [MHz]	50.0
Frequency of the nearest mode [MHz]	67.95
Q factor	9448
Total RF power losses [kW] @ 70kV Vane-to-vane voltage	70.5
Kilpatrick	1.47
Specific RF power losses [kW/m]	11.2

4. Conclusions

We designed a heavy ion RFQ without pre-bunchers, which can accelerate single charge state ions from hydrogen to uranium. If an ion source can not supply enough beam current with single charge state, we need pre-bunchers to accelerate two or more charge state ions such as $^{238}U^{28+}$ and $^{238}U^{29+}$ from an ion source. In that case, the RFQ is shorter but the total system is more complicated. The ion source performance is very important for the RFQ design.

Acknowledgement

This work was supported by the Ministry of Education, Science and Technology of the Korean Government.

REFERENCES

[1] Isotope Science Facility at Michigan State University: Upgrade of the NSCL rare isotope research capabilities, MSUCL-1345, 2006.

[2] D.L. Schrage, P.N. Ostroumov, A. Barcikowski, M. Barcken, B.Clifft, F. DePalola, B. Rushthoven, S. Sharma, S.I. Sharmamentov. W.F. Toter, G. Waldschmidt, J.W. Rathke, T. Schultheeiss, N.E. Vinogradov and A.A. Kolomiets, Journal of the Korean Physical Society, Vol. 50, No. 5, p.1363, 2009.

[3] Thomas P. Wangler, RF Linear Accelerators 2nd Edition, Wiley-VCH Verlag GmbH & Co. KGaA, pp. 276-277, 2008.