THE FIRST STEP OF RFQ DEVELOPMENT IN KBSI

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Abstract

The RFQ for accelerating an ion beam is being developed in Korea Basic Science Institute (KBSI). The KBSI RFQ is designed to accelerate 1 mA lithium beam (Q/A=3/7) at 88 MHz. It is considered to be a 4-vane RFQ structure. The injection beam energy into RFQ is 12 keV/u, the output beam energy downstream from RFQ is 300 keV/u. The RFQ has to show stable operation, meet availability, and have the minimum losses so as to guarantee the best performance/cost ratio. At the first step, two dimensional geometry structure was studied using SUPERFISH code for the resonance frequency of quadrupole and dipole modes. Three dimensional field distributions were investigated by CST microwave studio. The beam dynamics in RFQ accelerator were studied using PARMTEQM code. Based on these results, the structural analysis should be studied and a cold model will be fabricated and investigated. The practical KBSI RFQ will be manufactured in next year.

INTRODUCTION

The lithium (Li) ion beam source and accelerator are being developed in KBSI for a fast neutron radiography facility [1]. Li^{3+} ion beam will be produced by 28 GHz electron cyclotron resonance (ECR) ion source which is under development. The beam energy and current from ion source are expected to be 12 keV/u and 1 mA, respectively. The beam will be transmitted to RFQ through low energy beam transport (LEBT) system. The RFQ will accelerate 1 mA of Li^{3+} beam current from 12 keV/u at LEBT to 300 keV/u. The structure type of RFQ is decided as the 4 vane geometry. For the next part of RFQ, a superconducting linac, which is quarter wave resonator (QWR), will be used for the ion beam accelerator. In our linac system, the same frequency in the accelerators (RFQ and QWR) will be used.

Table 1: The Preliminary Parameters of the RFQ

Parameters	Value	
Input energy	12	keV/u
Output energy	300	keV/u
Beam current	1	mA
Ion	Li^{3+}	
Operation mode	CW	
Frequency	88	MHz
Structure type	4 vane	

Therefore, we selected the frequency of 88 MHz for the QWR considering operation frequency bandwidth of accelerators. The preliminary parameters of KBSI RFQ are listed in table 1.

BEAM DYNAMICS

PARMTEQM code was used to design the structure of RFQ and to simulate the beam dynamics in the RFQ. For the maximum transmission efficiency with minimum emittance growth, various design parameters of RFQ should be optimized [2]. Also, maximum surface voltage has to be limited under the consideration of continuous wave mode operation [3]. Therefore, the Kilpatrick limit of 14.2 was selected as a conservative value for the prevention of electric breakdown.

Table 2: The Design Parameters of the RFQ

Design parameters	Value	
Vane voltage	73	kV
Beam current	1	mA
Minimum aperture, a	4.68	mm
Average radius, r_0	5.67	mm
Modulation parameter, m	1 ~ 2.15	
Transverse focusing parameter, B	6.6	
Synchronous phase, φ_s	-90→-30	Deg
Maximum surface electric field	<14.2	MV
Transmission efficiency	>99	%
Structure power dissipation (SUPERFISH)	2.453	kW/cm
Beam power	672	W
Total length	2043	mm
Input emittance, $\varepsilon_{x,y,rms,n}$	0.187	mm.mrad
Output emittance, $\varepsilon_{x,rms,n}$	0.283	mm.mrad
$\varepsilon_{y,rms,n}$	0.281	mm.mrad
$\varepsilon_{z,rms,n}$	3.053	MeV.deg

The input beam parameters from LEBT to RFQ were used from the calculated values by TRANSPORT code. Our LEBT system consists of the beam diagnostic devices, analyzing magnet, steering magnet and solenoids [1]. Beam power and structure power dissipation also calculated by PARMTEQM and SUPERFISH code. In our RFQ design, the transverse emittance is increased

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almost 50% and further study is required to reduce this increment of beam emittance.

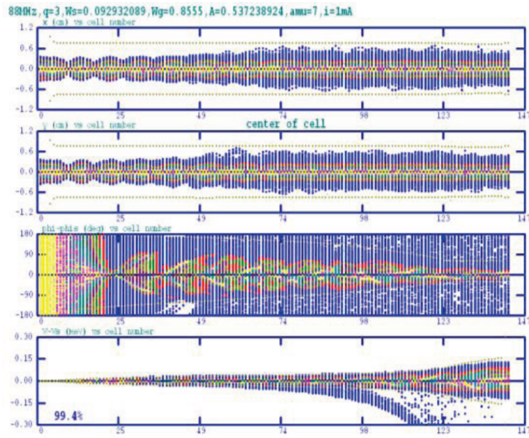
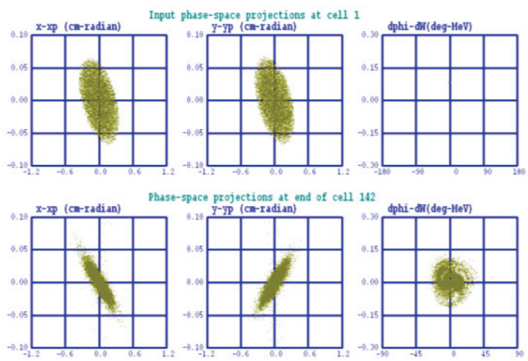
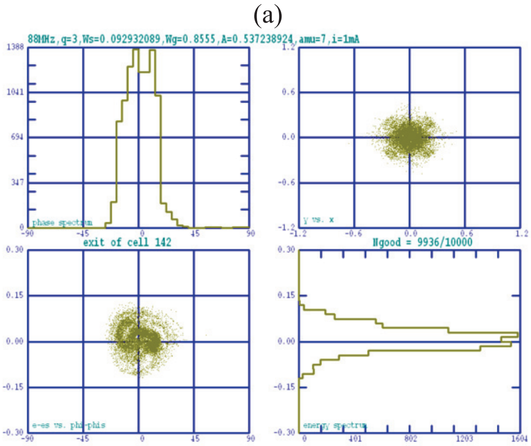


Figure 1: x, y, phase and energy coordinates verses cell number.



(a)



(b)

Figure 2: Beam dynamics results simulated by PARMTEQM code. (a) the phase-space projection of beam at first and last cell in RFQ, (b) the energy, phase spectrum of beam at last cell in RFQ.

As shown in Fig. 1, using 10000 particles, the beam transmission efficiency of 99.4% through RFQ was achieved. The figures from top to bottom show x, y, phase and energy coordinates as a function of the cell numbers, respectively. Synchronous phase is changed from -90 to -30 degree. The number of cells in RFQ is 142 and total length is to be 2043 mm.

Fig. 2(a) shows phase-space beam projection at first and last cell in RFQ and Fig. 2(b) shows phase spectrum (top-left) and the energy spectrum (bottom-right) at the exit of RFQ.

RFQ STRUCTURE

The dynamic parameters of RFQ code as a function of length from PARMTEQM is shown in the Fig. 3.

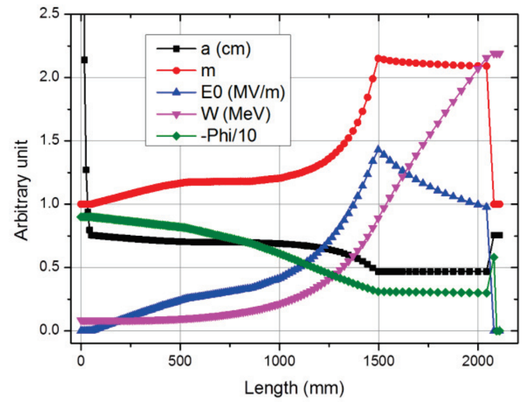


Figure 3: The dynamic parameters of RFQ design.

According to parameters obtained from PARMTEQM code, we decided whole vane geometry as a result of simulation by SUPERFISH code for resonance mode of RFQ. The quadrant cross-section of RFQ is shown in Fig. 4. Total cross-section of RFQ at beam axis is the octagonal shape and the length between top and bottom is 724 mm. The calculated resonance frequency for quadrupole mode was 88.001 MHz. The frequency difference between quadrupole and dipole mode was 2.512 MHz. The Q-factor of cavity was 19905 and shunt impedance was 7189 MΩ/m .

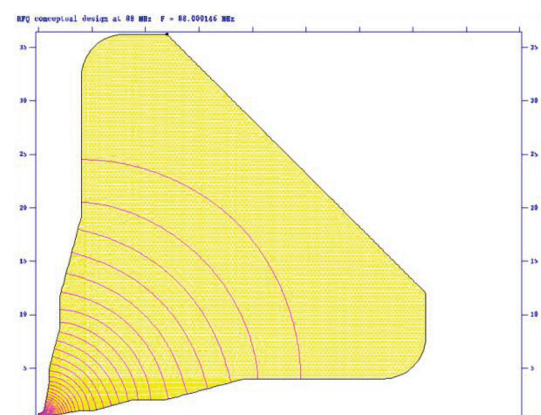


Figure 4: The RFQ transverse section, one quadrant in SUPERFISH code.

Fig. 5 shows electromagnetic simulation results by using CST microwave studio. 3D modelling was proceeded with the set of data from PARMTEQM and SUPERFISH code. The calculated Q-factor was 13676. The resonant frequency of RFQ modelling was 88.672 MHz at quadrupole mode and the frequency difference with nearest dipole mode is 847 kHz. It is considered that

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the discrepancy of frequency in between 2D and 3D model is caused by vane cutback and alternation of aperture size along the beam axis. Although trivial changes arise in both models, overall frequency characteristic of RFQ structure represents fixed value around 88 MHz. The changes, however, are thought to be improved by structure optimisation and frequency tuning method. Also, either mode separation between quadrupole and dipole mode or mode suppression of dipole mode will be selected for the stable operation of RFQ. From now on, more intensive study will be made in this point of view.

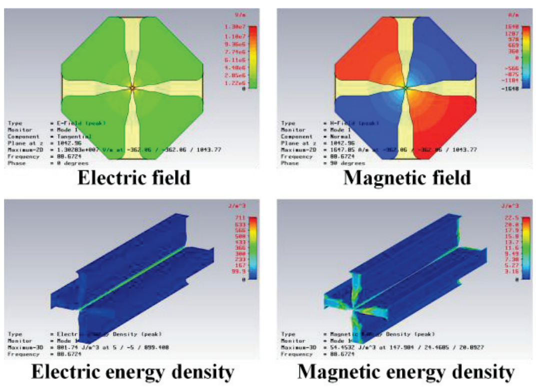

Figure 5: 3D RFQ structure simulation results with CST microwave studio.

SUMMARY

A RFQ for Li ion beam is under development in KBSI. A study of beam dynamics and electromagnetic modelling was performed by using codes and further studies are being processed. After verification of electromagnetic modelling, the appropriate cooling of RFQ should be studied and mechanical design will be followed.

ACKNOWLEDGMENT

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