STUDY OF ELECTRODE CONFIGURATION OF THE FOUR BEAM IH-RFQ LINAC

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Abstract

The multi-beam acceleration method, which is technique for accelerating low energy, high intensity, heavy ion beams by accelerating multiple beams to decreasing the space charge effect, and integrating these beams by a beam funneling system [1]. Working towards the commercialization of this method, at the Tokyo Institute of Technology we have been developing a 4 beam IH-RFQ linac. As part of the design work for the 4 beam IH-RFQ linac, we evaluated the cell parameters of the RFQ electrodes using a RFQ design code and a beam dynamics simulation code. Also, we evaluated the RF properties of several electrode layouts using a three dimensional electromagnetic simulation code. This paper reports on the results.

INTRODUCTION

The multi-beam acceleration method utilizes multiple beams to decreasing the space charge effect, then integrates these beams by a beam funneling system. The space charge effect has a property that is inversely proportional to the square of beam velocity and proportional to the beam current. Therefore, low-energy (from keV/u to several MeV/u) high-intensity (over 10 mA) heavy ion beam acceleration is the most severe condition.

We have been developing a 4 beam IH-RFQ linac shown in Figure 1, which consists of sixteen RFQ electrodes (4x4 set) and the stem electrodes installed alternately on upper and lower ridge electrodes. The RF electromagnetic field is stimulated by the TE111 mode. The electric field and magnetic flux distribution in a 4 beam IH-RFQ linac is shown in Figure 2. The RFQ electric field is generated by induced current through the ridge electrodes and the stem electrodes.

The electrical capacitance of the 4 beam IH-RFQ linac is large compared with that of a single beam type, because there of the large volume of the stem electrodes and the 4 set RFQ electrodes in the cavity. Therefore the resonance frequency of the 4 beam IH-RFQ linac is lower than that of a single beam type.

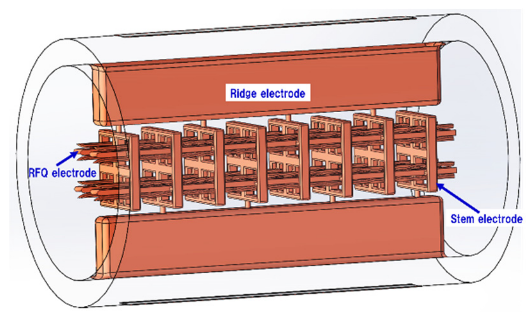

Figure 1: Configuration of the 4 beam IH-RFQ linac.

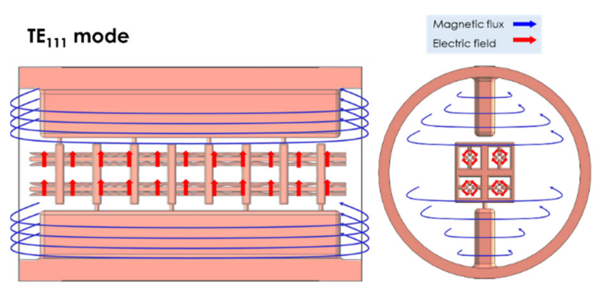

Figure 2: Electric field and magnetic flux distribution.

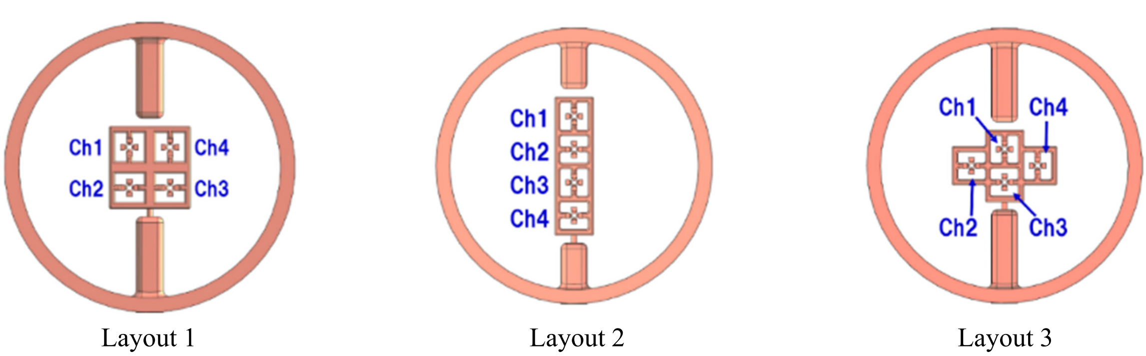

Figure 3: Electrode layouts of the 4 beam IH-RFQ linac.

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RF SIMULATION

We simulated the RF properties of the 4 beam IH-RFQ linac using the eigenmode solver of the three dimensional electromagnetic simulation software CST MICROWAVE STUDIO [2]. The simulated electrode layouts are shown in Figure 3. In addition, the cavity parameters of the 4 beam IH-RFQ linac are shown in Table 1. The result of the simulation is shown in Figure 4.

The resonance frequency and the unloaded quality factor (Q_0) calculated in each electrode layout are shown in Table 2. The resonance frequencies of layout 1 and 3 are approximated and are around 2 MHz higher than that of layout 2.

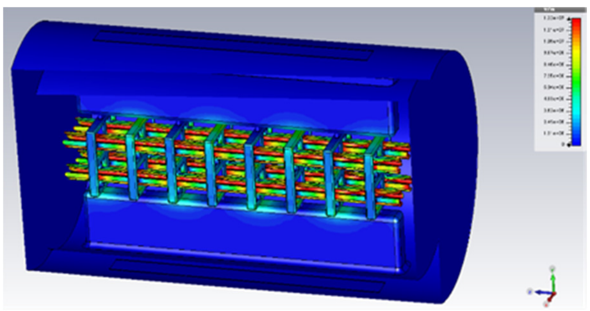

Figure 4: The state of the electric field simulation.

Table 1: Cavity Parameters of the 4 Beam IH-RFQ Linac

Cavity diameter [mm]	410
Cavity length [mm]	800
Ridge electrode width [mm]	47
Stem electrode number	8
Stem-ridge electrodes distance [mm]	15
RFQ electrodes length [mm]	770

BEAM DYNAMICS SIMULATION

The cell parameters of the RFQ electrodes have been evaluated using the RFQ design code RFQUICK [3]. Currently, we confirmed the cell parameters which can accelerate C^{2+} ion up to 39.6 mA in a length of 770 mm. The cell parameters are shown in Figure 5 and Figure 6. The results simulated using the RFQ beam dynamics code PARMTEQM [4] are shown Figure 7 and Table 3.

Table 2: The Simulated Resonance Frequency and Q_0

Layout	Resonance frequency [MHz]	Q_0
1	47.7	4549
2	45.6	4430
3	48.1	4439

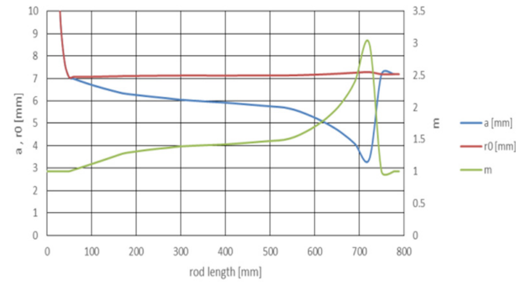

Figure 5: Cell parameters (1).

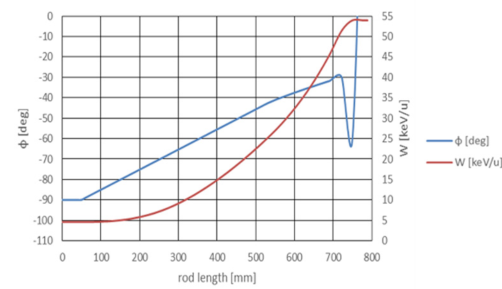

Figure 6: Cell parameters (2).

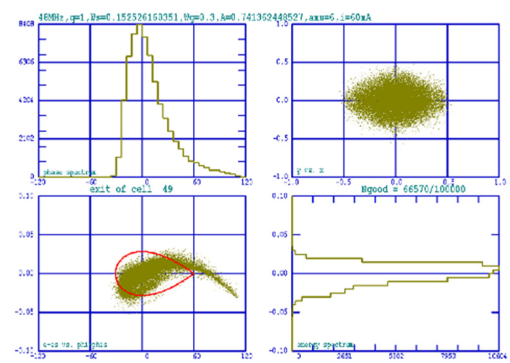

Figure 7: Beam simulation results.

Table 3: Designed Beam Parameters

Operation frequency [MHz]	48
Charge to mass ratio (q/a)	1/6
Input beam current [mA]	60
Output beam current [mA]	39.6
Transmission [%]	66.4
Input beam energy [keV/u]	4.58
Output beam energy [keV/u]	53.9
Input beam emittance [π mm mrad RMS]	0.1
Output beam emittance ε_x [π mm mrad RMS]	0.31
Output beam emittance ε_y [π mm mrad RMS]	0.37
Max. field at inter-electrode gap [Kilpatrick]	1.8

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SUMMARY

As part of a feasibility study of a 4 beam IH-RFQ linac, the resonance frequency and the unloaded quality factor of the acceleration cavity were simulated for three electrode layouts. The RFQ cell parameters were evaluated using RFQUICK and PARMTEQM. In the near future, we will complete the prototype design for the 4 beam RFQ linac with a 4 beam laser ion source using a direct plasma injection scheme.

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