DESIGN OF A 10 MHZ HEAVY ION RFQ FOR A RIA POST ACCELERATOR

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Abstract

Design of a 10 MHz heavy ion RFQ is described. Main rf and mechanical parameters of the proposed accelerator component are given. This low frequency RFQ is capable of accelerating heavy ion beams from an initial energy of 2 keV/u to 8 keV/u, covering a charge to mass ratio from 1/10 to 1/240.

INTRODUCTION

Study of the fundamental properties of space and time is an extremely exciting area of investigation requiring innovative tools, and the ability to determine specific properties of matter and to understand how this matter interacts with its surroundings. What comprises matter as we know it, what are the fundamental constituents and how are these constituents interconnected? Questions such as these lead to more fundamental questions related to the history of the universe: what happened after its initial formation (and how and why), what are existing symmetries and their impacts, what is "dark matter", what theories best predict the present situation, and is there a grand unification scheme to explain known phenomena while predicting what remains to be discovered.

Recent publications [1,2] on rare-isotope accelerators provide interesting and informative discussions on technology status and needs, experimental programs, and justifications for exotic beams R&D facilities.

One part of an exotic beam facility is the post accelerator which accelerates ions generated from the target up to 12 MeV/u. An important component of this re-accelerator is the RFQ described in this paper.

RFQ DESIGN

As shown in Figure 1 the RFQ for the re-accelerator of a system designed to accept singly charged heavy ions from a gas stopper over a mass range A=10 to A=240 had to be at a frequency less than 20 MHz for good beam acceptance. Because our design uses 80 MHz for the higher energy superconducting quarter wave portion of the re-accelerator shown in Figure 2, the frequency for the RFQ must be a sub –multiple of 80 MHz resulting in a choice of 10 MHz to accelerate from 2 keV/u to 8 keV/u.

General Layout

The RFQ was designed to operate cw with maximum electric field on the inner surfaces not to exceed 1.75 times the Kilpatrick criterion for 10 MHz.

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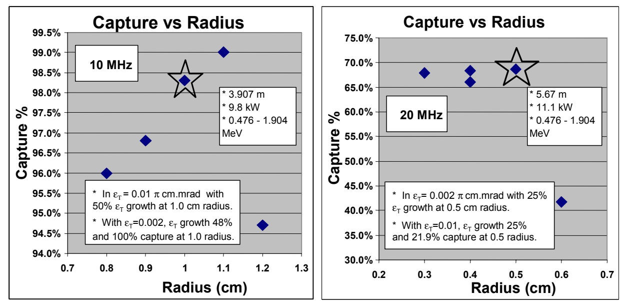

Figure 1: Percentage capture of ^{240}U 1+ DC beam in RFQs designed for either 10 MHz or 20 MHz. Notice the improved capture for the 10 MHz design as compared to the 20 MHz design even for input transverse emittance a factor of 5 larger.

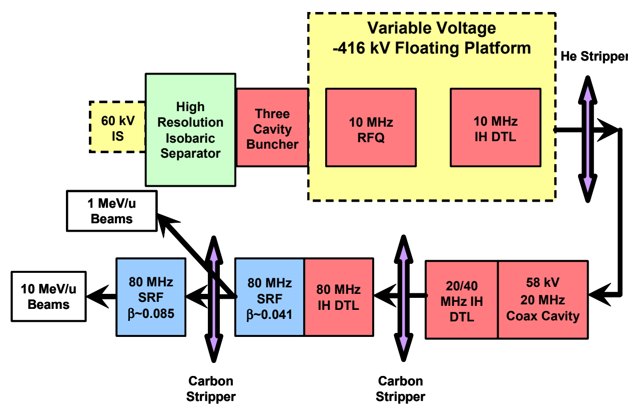

Figure 2: Schematic of 10 MeV/u re-accelerator for an exotic beams facility.

Figure 3 shows the excellent performance of the RFQ for heavy ion beams from ^{10}B to ^{240}U.

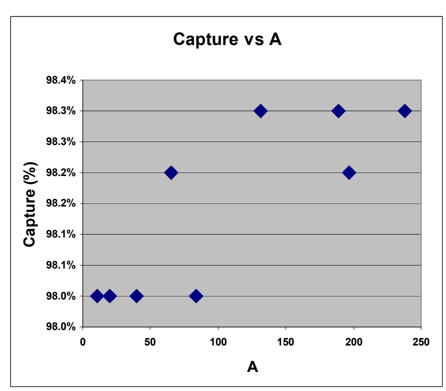

Figure 3: 10 MHz RFQ capture versus atomic number A.

Design Characteristics

Several rf structures were investigated for this low frequency RFQ including four rod, split ring, ring connected, four vane and split coaxial geometries. On the basis of compactness (small transverse dimensions), simplicity of manufacture, ease of alignment and tuning, mechanical stiffness, reliable frequency separation between operation mode and parasitic modes, and relatively high shunt impedance, the four rod geometry was selected as shown in Figure 4.

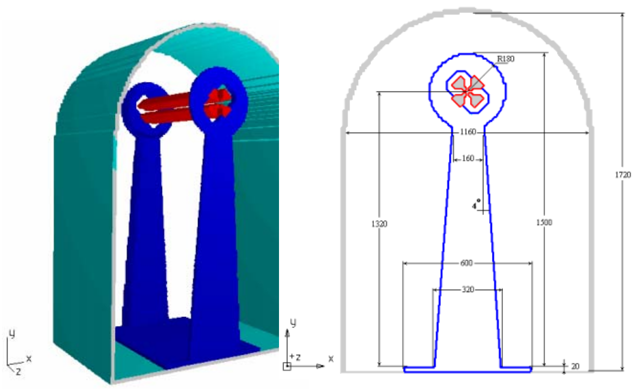

Figure 4: One resonant cell (L=0.76m) of four rod 10 MHz RFQ basic geometry using MAFIA 4.106.

Details of the aperture region are shown in Figure 5.

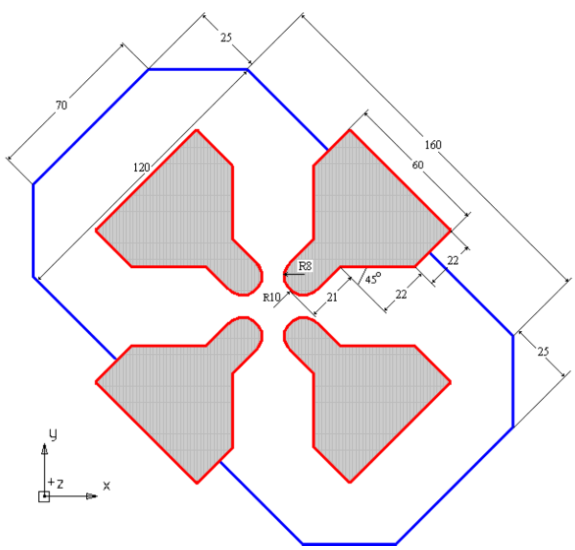

Figure 5: Radii - vane tip ρ=8 mm and aperture r=10 mm. This ratio ρ/r is optimal from the point of view of rf surface electric fields.

A voltage difference exists in a four rod geometry structure between the upper and lower rods, due to the distance difference from the base of the structure to the electrodes. This effect is shown in Figure 6.

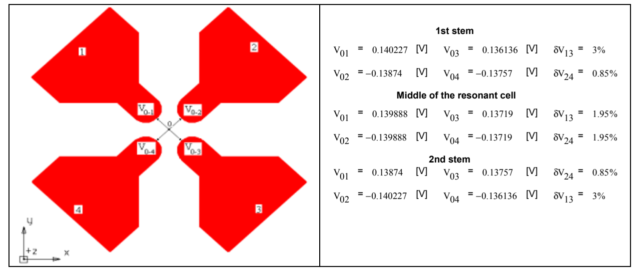

Figure 6: Four rod vane voltage differences.

To reduce these voltage differences, two stabilizing rings connecting opposite electrodes were added to each of the cells resulting in the improved performance shown in Figure 7.

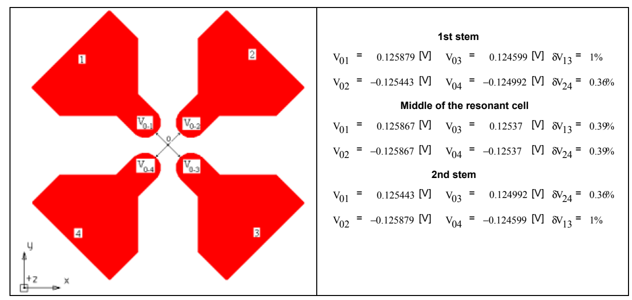

Figure 7: Four rod vane voltage differences with stabilizing rings.

The final RFQ design with six stabilizing rings is shown in Figure 8.

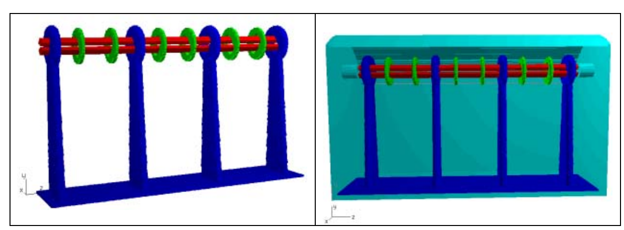

Figure 8: 10 MHz RFQ final geometry with stabilizing rings.

The ripple of the electrode fields along the length of the RFQ are shown in the following figure.

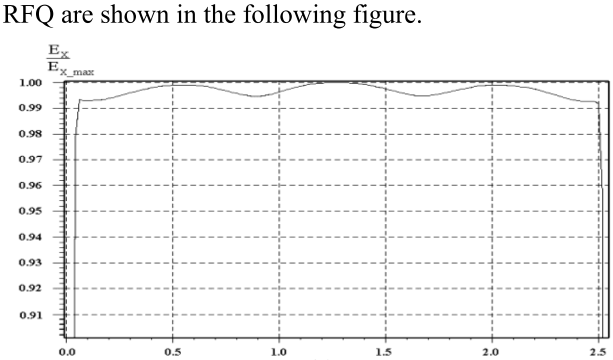

Figure 9: Normalized electric field along length of RFQ.

Magnetic flux density is shown in Figure 10. Magnetic flux density (B) is very small (<0.2 mT) on the side surface and the top of the tank. On the end plates B is about 1.5 mT. Requirement for rf contacts to the tank at this location are not very critical making it possible to consider mechanical rf joints.

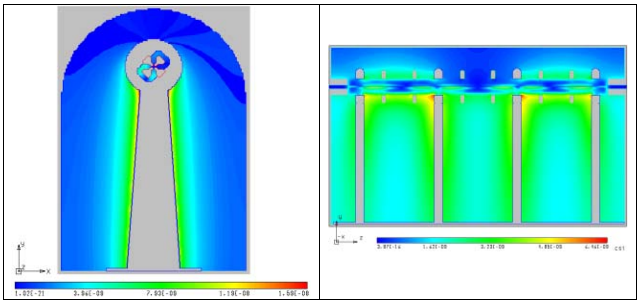

Figure 10: Magnetic flux density for the 10 MHz RFQ.

Calculations gave the following rf parameters for a 117 kV intervane voltage: quality factor - 12360, total rf losses – 16.9 kW, stem rf losses – 11.6 kW, tank rf losses – 1.4 kW, electrode losses – 2.7 kW and ring losses – 1.2 kW.

SUMMARY

A viable 10 MHz RFQ has been designed to accelerate singly charged heavy ions covering a mass range from A=10 to A=240.

REFERENCES

[1] Stan O. Schriber, "Rare-Isotope (Heavy Ion) Accelerators", Proceedings of 11th Workshop on RF Superconductivity, 8-12 September 2003, Travemunde, Germany

[2] J.A. Nolen, "Prospects for High-Power Radioactive Beam Facilities Worldwide", ANS AccApp'03 Topical Conference, 1-5 June, 2003, San Diego, California.