2003-236-N0 -- A FULL POWER TEST MODEL OF THE 12-MHZ HYBRID-RFQ FOR ACCELERATION OF RADIOACTIVE IONS WITH CHARGE-TO-MASS RATIO 1/240

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Purpose: The acceleration of singly-charged heavy-ions up to uranium in the front end of the Radioactive Ion Beam (RIB) linac of the Rare Isotope Accelerator (RIA) can be provided by room temperature accelerating structures. This section consists of a pre-buncher followed by three sections of continuous wave (cw), normally-conducting Radio Frequency Quadrupoles (RFQs). As was shown by our group, the hybrid RFQ can provide effective acceleration of well bunched ion beams. We have developed the concept of hybrid RFQ. The current work is to build the engineering test model and show full-power operation of cw hybrid RFQ.

Approach: There are no accelerators for the beams with charge-to-mass ratio as low as 1/240. However, such an accelerator for the RIB linac is absolutely necessary in order to provide high efficiency for RIA. The scope of these studies was to develop complete specifications for the fabrication of a full-power test model. Particularly, the important issues were the alignment of 40 drift tubes, tuning of uniform electric field distribution in the accelerating gaps, determination of exact geometrical dimensions for a full scale test model to provide the expected resonant frequency. To answer these questions, we have developed, fabricated, and tested a 2:1 aluminum cold model of the hybrid RFQ. The rf measurements have been carried out by Dr. Nickolai Vinogradov, a postdoc researcher.

Technical Progress and Results: The Hybrid Radio Frequency Quadrupole (H-RFQ) is an accelerating structure designed to accelerate low-velocity heavy ions with a q/A ratio = 1/240. The assembly drawing of the H-RFQ is shown in Figure 1. The H-RFQ structure consists of three sections of drift tubes and two RFQ sections. In the drift tube sections the beam is accelerated and defocused transversely. Transverse focusing is provided by the RFQ sections. Each of the RFQ sections consists of two sets of non-modulated vanes with a length of $\beta\lambda$ separated by a drift space of $\beta\lambda/2$. The appropriate focusing strength is achieved by proper selection of the distance between the vanes. Using the combination of the drift tube and RFQ structures a factor of two higher output beam energy is achieved when compared to a conventional RFQ accelerator.

A half-scale (24.25 MHz) aluminum cold model of the Hybrid RFQ has been designed, built and tested. The goals were to determine the final resonator dimensions, accelerating and focusing field distribution, quality factor and coupling to the external power supply. The experimental investigation of the 24.25 MHz H-RFQ cold model was carried out using both an HP Network Analyzer and a standard bead-pull technique using a phase-locked loop. The first measurements of the electrodynamics parameters of the cavity revealed three important shortcomings of the cold model. These are: the measured quality factor (Q) turned out to be 3.5 times lower than the calculated value, the frequency was approximately 2 MHz high, and there was a tilt in the field amplitude distribution of the third drift tube section.

To address the low Q, a stiffer spring material was used to improve the RF contacts. In addition, we used special conductive silver grease. After these modifications were made the measured quality factor was stable and was about 70% of the calculated value. To improve the resonant frequency, the dimensions of the H-RFQ model have been changed. Cylindrical inserts to lengthen the vertical stubs of the cavity were designed and installed to lower the resonant frequency. Table 1 summarizes these results. To improve the final problem of the field tilt, capacitive tuners were installed at appropriate locations. These tuners removed the field tilt in the end of the third drift tube section. The final distribution of electric field along the structure is shown in Figure 2. The amplitude of the field in the accelerating gaps is uniform within ±1.5%. That is fully acceptable from the beam dynamics point of view.

Table 1. Electrodynamics Parameters of the H-RFQ.

	MWS simulation	Measurement before the modification	Measurement after the modification
Frequency, MHz	24.6	26.5	24.25
Quality factor	4700	1350-2300	3150
R_{sh}/Q, Ohm	$7.1 \cdot 10^4$	—	$6.9 \cdot 10^4$

The designed resonant frequency, uniform field amplitude distribution and high quality factor in the resonator were obtained after slight modifications of the model designed by the MWS code. Complete specifications for the final design of the 12 MHz hybrid RFQ have been established and detailed drawings of the full-power 12.125 MHz H-RFQ are being developed.

Essential progress has been made in development of engineering concept of the full-scale hybrid RFQ. All internal parts will be made from high-purity oxygen-free copper with the cooling channels. The copper bars with drift tubes and RFQ will be manufactured by the brazing in the vacuum furnace. The cylindrical parts of the RFQ enclosure will be made from bimetal consisting of mild steel and copper.

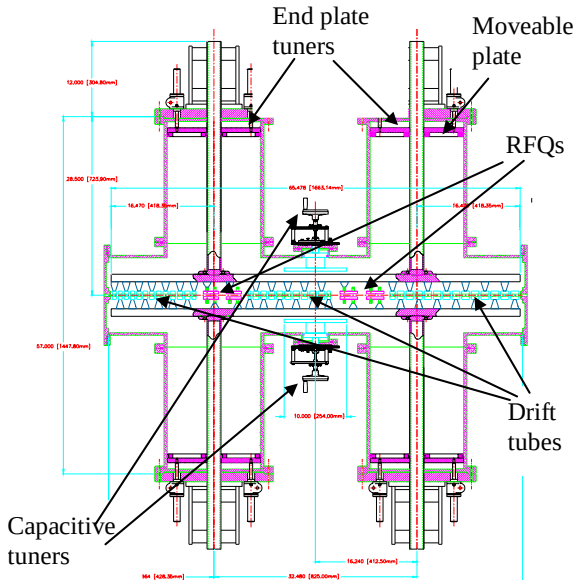

Fig. 1. Assembly drawings of the H-RFQ cold model

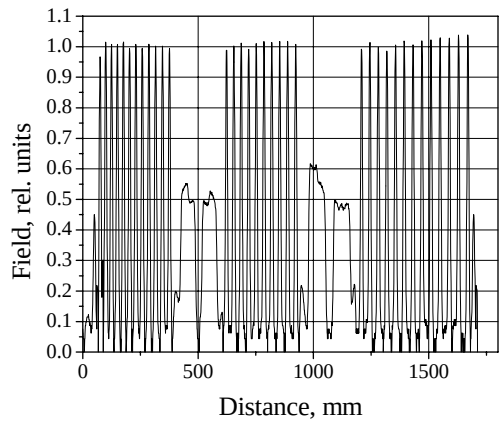

Fig. 2. Field distribution along the H-RFQ.

Specific Accomplishments:

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