

# CONSTRUCTION CRITERIA AND PROTOTYPING FOR THE ISAC RFQ ACCELERATOR AT TRIUMF

R.L. Poirier, P. Bricault, G. Dutto, K. Fong, K. Jensen, R. Laxdal, A.K. Mitra, G. Stanford  
TRIUMF, Vancouver B. C. Canada

## 2 PROTOTYPE MEASUREMENTS

### Abstract

The ISAC RFQ consists of an 8 metre long 4-rod split ring structure resonating at 35 MHz. The rods are vane-shaped and are supported by 19 rings. The challenge of the mechanical design is the stringent,  $\pm 0.08$  mm, positioning tolerance on the four rod electrodes for 150 kW cw operation. A 1.2 metre long prototype with three full-scale modules, each comprising one ring and 40 cm of electrode, has already been built and successfully tested to full power. This enables us to complete the basic electrical and mechanical design for the final unit. The initial 7-ring portion of the final RFQ will be assembled first, together with an off-line source and a portion of the LEBT, so that RF parameters and beam dynamics behavior in the injection region can be tested as soon as possible. For the final RFQ the cross-section of the vacuum tank will be square, rather than circular. This will facilitate alignment of the modules and copper plating of the vacuum tank. The scope of the paper is to report the latest results from the full power tests on the prototype and to describe mechanical and RF design features including RF coupling, alignment philosophy and the copper plating technique.

## 1 INTRODUCTION

The accelerating system of the ISAC radioactive ion beams facility consists of an RFQ and a post - stripper DTL [1]. Singly charged ion beams with  $A \leq 30$ , delivered from the on line mass separator with an energy of 2 keV/u, will be accelerated to 150 keV/u through the RFQ and then to a maximum energy of 1.5 MeV/u through the DTL structure [2]. The low charge-to-mass ratios of the ions dictates a low operating frequency to achieve adequate transverse focusing, and cw operation is required to preserve beam intensity. The reference design [3] for the RFQ is a four rod split ring structure operating cw at 35 MHz. Full power tests on a single module [4] were completed last summer and on a three module assembly last fall. The RFQ accelerator section is 8 meters long and is designed in 40 cm long modules with 74 kV potential between the electrodes. The alignment philosophy is to construct a solid base, maintain tight manufacturing tolerances, assemble with jigs and fixtures and EDM machine the critical mounting surfaces for the electrodes after assembly.

Figure 1 is a photograph of the three modules ready to be installed in the tank. As in the one module test the electrodes were aligned only to  $\pm 0.250$  mm but the average alignment was within the  $\pm 0.08$  mm tolerance.



Figure 1. Photograph of the three modules ready to be installed in the tank.

Many longitudinal bead pull measurements were made between adjacent electrodes. The measurement shown in figure 2 is an average value of the field variation for the four electrodes.

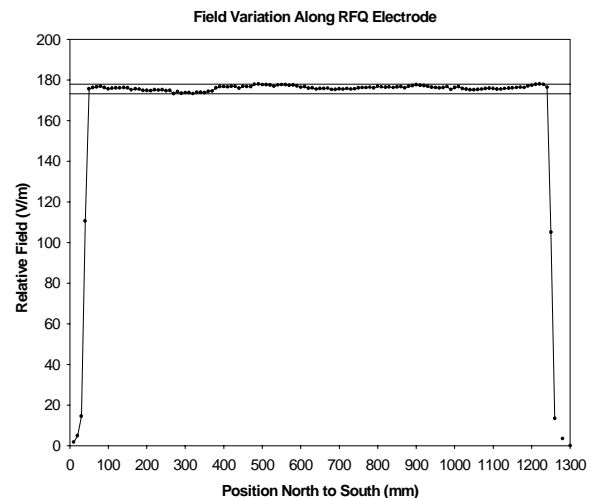


Figure 2. Field variation along the 120 cm length of the RFQ

A  $\pm 1.35\%$  field variation along the 120 cm of RFQ was achieved. Considering the rough alignment, this is in close agreement with the beam dynamics specification of  $\pm 1.0\%$  field variation along the 8.0 meters of the ISAC RFQ [5]. Table 1 summarizes the measured and MAFIA

calculation parameters on the three modules and compares them to the single module test. In both cases, a movement of less than +/- 0.050 mm was observed when the voltage was slowly increased to 85 kV and a dynamic movement of less than +/- 0.025 mm was observed due to cooling water and vacuum pumps. At the same time the frequency of the RFQ decreased by 24 kHz from signal level to full power compared to 36 kHz for the single module test. When the voltage was instantaneously applied a movement of 0.150 mm was observed on the electrode in the direction away from the beam center and returned to its aligned position within 6 minutes compared to 0.200 mm and 3 minutes respectively for the single module tests. The close agreement of the measured frequency of 34.38 MHz compared to the Mafia value of 34.16 MHz for the 3 module tests gives us confidence for the design of the 19 module assembly for the ISAC RFQ. Because the one ring module is in a three ring tank, the difference in frequency between measured and MAFIA values is greater.

Table 1. RF Measurements on the RFQ Prototype

Parameters	One Module		Three Modules	
	Measured	MAFIA	Measured	MAFIA
Q	7200	14000	7150	14500
R/Q	62.7	69.5	26.1	24.5
kW/module	8.0	3.7	6.45	3.4
Freq. (MHz)	35.18	34.40	34.38	34.16

The operating pressure at full power for the single module tests was  $9.5 \times 10^{-7}$  torr. However with the increased power for the three modules the pressure increased by almost an order of magnitude to  $8.5 \times 10^{-6}$  torr. This proved to be too much for the coupling loop RF window which failed after 15 hours of continuous operation. The vacuum was improved by a long mild bake out and by replacing the end cover vacuum seals with Viton "O" rings. This enabled us to reach a base pressure of  $5.5 \times 10^{-8}$  torr and a pressure of  $1.1 \times 10^{-6}$  torr with RF on. As expected, a measurement with the mass spectrometer indicated the highest component to be water vapor. This factor of 20 from RF off to RF on, can be explained by the outgassing due to high operating temperature in a section of the vacuum tank that did not get properly copper plated [2]. A new copper plating technique has been designed and tested for the final RFQ tank and we expect that this will eliminate the outgassing problem. Subsequently we were able to run 100 hours continuously at 20 kW, 40 hours continuously at 30 kW and subsequent runs for 17 and 14 hours at 30 kW without failure of the coupling loop RF window. This gives confidence in designing the 150 kW RF window required for the ISAC RFQ (see figure 3).

### 3 RF CONTROLS

For the RFQ prototype, a simplified control system is used. The control turns on, turns off or pulses the RF. The cavity voltage can be feedback regulated in the pulsed or cw mode. Adaptive feedback control can be turned on in pulsing mode to reduce the turning on transient. All these are achieved using a stand alone digital signal processor. For the 8 meter long RFQ, the control system will be housed in a VXI mainframe. The VXI slot-0 controller will provide supervisory and communication tasks for the controller.

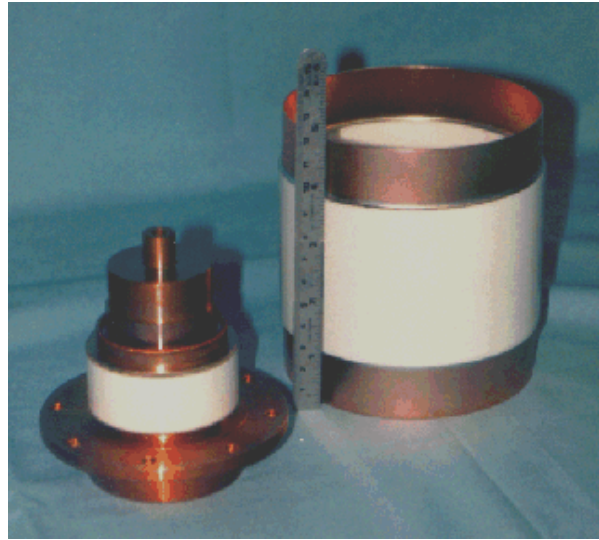


Figure 3. Photograph of the RF windows for the prototype and ISAC RFQ

### 4 RFQ VACUUM TANK

Unlike the prototype, the vacuum tank for the ISAC RFQ, shown in figure 4, is square in cross-section. Note that the tank is split diagonally by an "O" ring flange into two triangular parts, tank base and tank lid. The copper plating is easier to do in two parts. Also we maintain full unobstructed side access to the RFQ modules for ease of installation and alignment. The tank weighs approximately 12 tons and is constructed of plate steel which will be chemically treated (descaled) and surface ground before fabrication. The tank base forms a stable internal horizontal platform on which to mount the RFQ components. It is a 1.58 cm (5/8") thick steel plate mounted on two heavy "I" beams running the full length of the tank with attached footpads. The vertical back plate is 3.8 cm (1.5") thick and will have most of the penetrations for vacuum pumps, vacuum gauges, RF coupling loop and RF diagnostics. The triangular shaped lid is 1.25 cm (1/2 ") thick reinforced by tubular section ribs and weighs approximately 5 tons. The copper plating is a cyanide bath process which uses a different chemical solution than that used to copper plate the prototype tank.

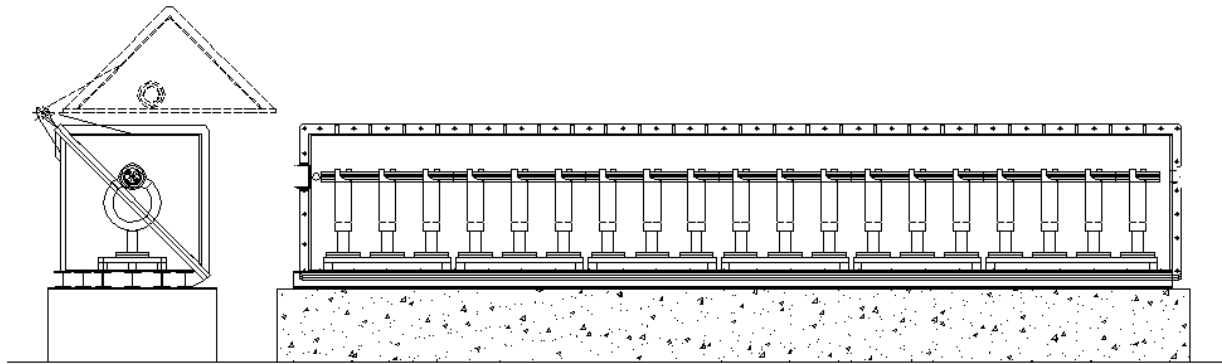


Figure 4. RFQ vacuum tank installed on its concrete pad with lid removed and RFQ modules installed

Each piece is plated separately to avoid the possibility of a section of the tank not being uniformly copper plated due to air trapped in the solution. Several sample coupons have been successfully copper plated, giving a much better copper plating finish than the prototype tank.

### 5 RFQ ALIGNMENT

Maintaining the tight alignment tolerance of  $\pm 0.08\text{mm}$  over the 8 meter length of the four electrode, 2 arm structure requires special manufacturing and assembly techniques and procedures.

The pedestal type structure with cantilevered electrode mounting has inherent stability considerations including static deflections, thermal distortions, mechanical vibrations and manufacturing tolerances. Static deflections are primarily a factor in the electrode itself. We expect to see the electrode displaced in the order of 10 to 15 microns between supports. Thermal effects are minimized by extensive cooling within the assembly and separating the heat affected areas from the structural supports. The vibration effects are largely indeterminate, however displacement amplitude has been minimized by increasing structural stiffness. Empirical data from the prototypes indicate vibration effects are not a significant factor.

Manufacturing and assembly tolerances could easily consume all of the alignment error budget. Tight controls must be maintained to meet our target. As the critical item is the position of the electrodes, accuracy starts there. Manufacturing technology limits us to 25 microns on the electrode straightness. This, combined with simple deflection constitutes up to half of our alignment error budget. Thus we must achieve a near perfect electrode mounting surface on each of the 38 electrode mounts. They must all be nearly identical and in the ideal position within a few microns. To achieve a near ideal individual ring assembly we must eliminate the accumulation of tolerances which can produce a substantial assembly error. This is accomplished by assembling the ring structure in a precision fixture from a series of moderate accuracy components. The fixture serves to position the components within an envelope of acceptability to ensure that the assembly falls within the range of the finishing

operation. Once everything is assembled, a final high precision operation machines the electrode mounting faces relative to the ring base plate within an accuracy envelope of 5 microns. The individual ring assemblies are then positioned on a platen surface of equal accuracy, thus establishing a uniform beam centerline. The orientation and positioning of the ring bases are established through precision machining of reference datum on the base and platen. During installation in the tank a laser will define the centre line. Digital targets mounted on the rings will provide positional feedback capable of a couple of micron accuracy. This feedback will allow the platen assembly of three or four rings to be oriented precisely to the beam.

### 6 ACKNOWLEDGMENT

The authors wish to thank R. Roper, B. Waraich, P. Harmer, J. Tanguay and Q. Walker for the mechanical design, fabrication and assembly work, B. Uzat and J. Lu for the amplifier work, and P. Bourquin and W. Pirkl from CERN for helpful discussions on the fabrication, assembly and alignment of the RFQ.

### REFERENCES

- [1] P. Schmor et al, "Status of the TRIUMF ISAC-Facility for Accelerating Radioactive Beams", These proceedings
- [2] R. Laxdal et al, "A Separated Function Drift Tube Linac for the ISAC Project at TRIUMF", These proceedings
- [3] P.G. Bricault and H. R. Schneider, "Simulation of the TRIUMF Split Ring 4-Rod RFQ with MAFIA", Proc. 1995 Particle Accelerator Conf. and Int. Conf. on High-Energy Accelerators, p1125 (1995)
- [4] R.L. Poirier, P.J. Bricault, K. Jensen and A.K. Mitra, "The RFQ Prototype for the Radioactive Ion Beams Facility at TRIUMF", Proc. XVIII LINAC Conference, CERN, p405 (1996)
- [5] S. Koscielniak, TRIUMF, Private communication.