RF TESTS ON THE INITIAL 2.8m SECTION OF THE 8m LONG ISAC RFQ AT TRIUMF

R. L. Poirier, P. Bricault, G. Dutto, K. Fong, R. Laxdal, A. K. Mitra, B. Uzat
TRIUMF, Vancouver, B. C., CANADA

Abstract

The ISAC RFQ is an 8 meter long, 4-rod split-ring structure operating at 35 MHz in cw mode. The rods are vane-shaped and are supported by 19 rings spaced 40 cm apart. The rings are unique in that the rf surfaces have been structrurely de-coupled from the mechanical support structure to improve dynamic stability. An initial 2.8m section of the accelerator (7 of 19 rings) was installed and aligned in the 8m, square cross-section, vacuum tank to allow rf and beam tests to be carried out. The stringent, +/- 0.08 mm, quadrature positioning tolerance of the four rod electrodes was practically achieved and a relative field variation along the 2.8 meter of the RFQ was measured to within +/- 1%, using the standard bead pull method, signal level measurements gave a frequency of 35.7 MHz, a Q of 8700 and a resonant shunt impedance of 292 k Ω.m. Compared to the initial 3 ring prototype, this represents a 21% increase in Q and a 30 % increase in shunt impedance. The seven ring section has been successfully tested with beam at full power.

1 INTRODUCTION

The accelerating system of the ISAC radioactive ion beams facility consists of an RFQ and a post - stripper DTL. Ion beams with $A/q \leq 30$ from the on line mass separator will be accelerated from 2 keV/u, to 150 keV/u through the RFQ and then to an energy up to 1.5 MeV/u through the DTL structure. The low charge-to-mass ratios of the ions dictate a low operating frequency to achieve adequate transverse focusing, and cw operation is required to preserve beam intensity. The reference design [1] for the RFQ is a four rod split ring structure operating at 35 MHz. The RFQ accelerator section is 8 meters long and is designed in 40 cm long modules with a peak potential between the electrodes of 74 kV. Full power tests on a single module [2] and on a three module assembly[3] enabled us to complete the basic electrical and mechanical design for the RFQ accelerator. The theodilite intersection method[4] was used to align two platen bases in the tank to allow 7 of the 19 rings to be installed in the first section of the 8m long vacuum tank. The alignment of the ring assemblies on the platens was accomplished by the same method. Because of the manufacturing procedures and alignment philosophy adopted [4], when the electrodes were installed on their mounting surfaces they were aligned by default with no shimming required. Figure 1 shows the vacuum tank installed on the concrete mounting pad in the accelerator building with seven rings assembled. The coupling loop, which was tested in the prototype test facility for 100 hours at 40 kW, was installed and used to feed the rf signal for calibrating the monitoring probes. The inside groove on the tank flange is for an rf spring contact.

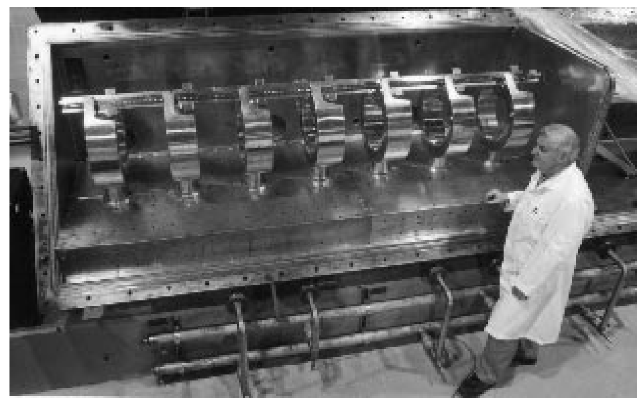

Figure 1. Seven rings assembled, installed and aligned in the bottom section of the vacuum tank

2 SIGNAL LEVEL TESTS

2.1 Frequency, Q and Shunt Impedance Measurements

The frequency and Q are measured with a network analyzer and the shunt impedance is derived from two independent R/Q measurements; ΔC method and input admittance method [5]. The input admittance of a parallel resonant circuit when plotted against frequency, produces a V-curve in the vicinity of the resonance. R/Q can be obtained from the slope of such a curve and is given by the equation,

$$R/Q = (2/f_o)*df/dy \quad (1)$$

where f_o = resonant frequency, dy = change in input admittance and df = corresponding change in frequency.
It can also be shown that R/Q is related to the change in frequency with change in capacitance and is given by the equation

$$R/Q = (1/pi*f_o)* df/dc \quad (2)$$

Results are compared to MAFIA calculations in table 1.

Table 1. Comparison of measured values to calculated MAFIA values.

Parameter	MAFIA	Measured
Frequency (MHz)	34.7	35.7
Q	15175	8700
R_{shunt} (k-ohms)	174.9	104.4
R_{shunt} (k-ohms-m)	489.9	292.3
R/Q	11.53	12.0
Capacity (pfd/m)	142	132.6

Because of the size of the mesh used in the MAFIA calculations one would expect the calculated MAFIA frequency to be lower than the measured frequency.

2.2 Bead-pull measurements

The first set of bead pull measurements were made with a set of test electrodes made of aluminum with a radius of r_o and no modulation. Because the electrodes have no shoulder to rest the dielectric bead on when measuring the lower gap, the sagging of the bead was overcome by fabricating a bead carriage from Teflon that traveled down the centre bore of the RFQ and was captured by the tips of the four electrodes. Five bead pull runs were made for each set of measurements; carriage only and four separate runs with the dielectric bead in each of the four quadrants. The carriage only run was used as the average perturbation reference and the other four runs corrected accordingly.

Both the average peak field variation and the quadrupole field asymmetry were deduced from the measurements and are shown in figure 2. The results are within the target of +/- 1% field strength variation.

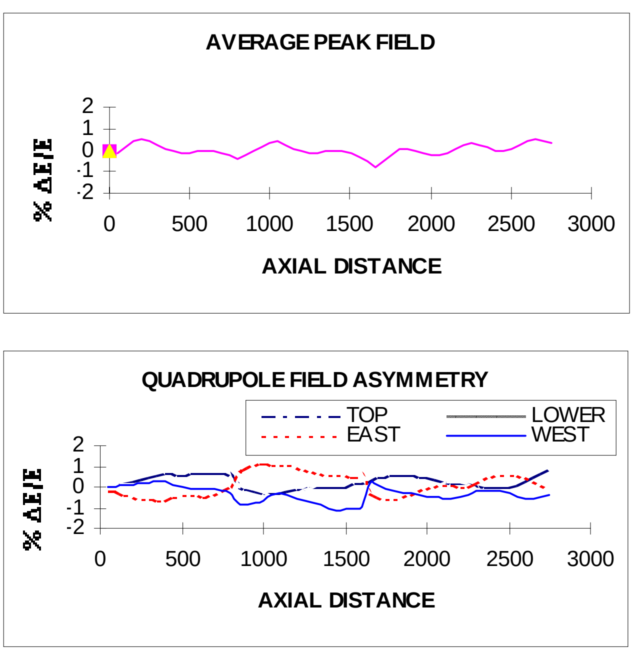

Figure 2. Average peak field and quadrupole field asymmetry for the non-modulated electrodes.

A similar set of results is shown in figure 3 for the copper electrodes with modulation. Because of the modulation, the teflon carriage for these bead pull measurements was guided by the straight edges of the electrodes. There is only one small area where the variation is slightly beyond the target of +/- 1%.

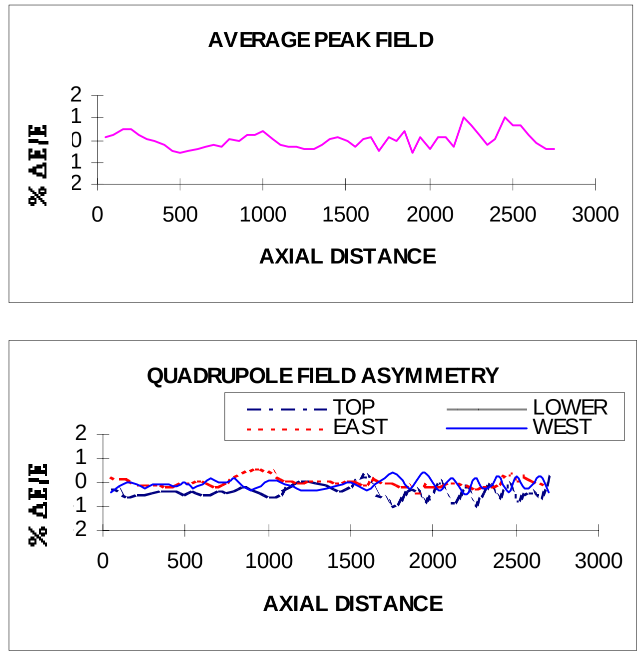

Figure3. Average peak field and quadrupole field asymmetry for the modulated electrodes.

3 FULL POWER TESTS

In preparation for full power tests the RFQ tank was baked out for three days at 60° C by uniformly mounting eighty-four 500W heaters on the tank walls, covered with a glass fibre blanket to contain the heat. At the same time 60 degree water was circulated through the structure cooling system. A base pressure of 1.4 *10-7 torr was achieved, which increased to 4.0*10-7 torr with full RF power applied. Although the bake-out temperature created a longitudinal growth of ~ 2.0 mm in the tank, the elasticity of the mounting system coped with this and the growth returned very close to zero at operating temperature. The RFQ tank went through several bake out cycles as we encountered a few water leaks. Initial tests were carried out at half voltage (36 kV) in order to do beam tests with N14 [6]. Following beam tests, 76 kV (2kV above design value) was achieved on the electrodes within four hours at the anticipated power level of 30 kW. The x-ray level during this time was 0.5 microseverts at 0.5m from the tank wall. We were able to maintain this condition for two hours before our first major amplifier overload occurred. Subsequently, we were never able to achieve the above voltage for the same power. A voltage versus power curve in figure 4 shows the power requirement for three different days of operation, although it did remain at the lower power level for the beam tests with N28 [7]. The RFQ operated continuously for 15 hours at nominal voltage plus various runs for 5 and 10 hours before being interrupted by an amplifier trip. Automatic recovery from a high standing wave ratio is being incorporated in the RF controls to cut the RF drive rather than trip the amplifier.

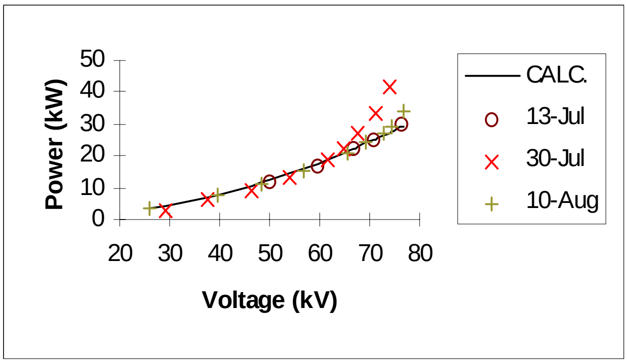

Figure 4. Voltage versus Power for the RFQ

When the lid was removed there was evidence of strong multipacting in the 7 cm gap between the RF shroud and the tank lid front wall as shown in figure 5. This could be the explanation for the additional power requirement at higher voltages. We plan to short out this gap to prevent multipacting in that region.

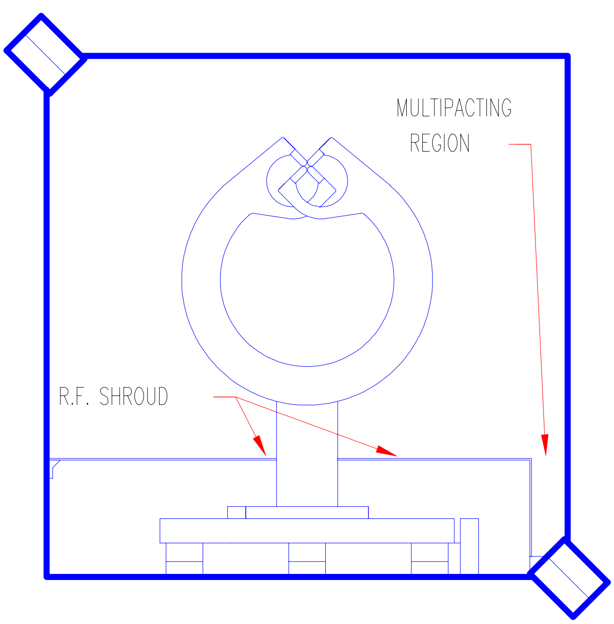

Figure 5. Cross-section schematic of RFQ tank and rings

4 CONCLUSION

Except for the increased power requirement, the RF behaved very well and agreed with the calculated predictions. The successful beam tests [7] in giving full agreement between expected and measured beam behavior (beam capture ~ 80%), indicate that the mechanical design, fabrication and alignment philosophy adopted was very successful. The remaining 12 rings will be installed in Spring 99 and commissioning of the RFQ in its final configuration by the end of 99.

5 ACKNOWLEDGMENT

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6 REFERENCES

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