RF TEST ON THE PROTOTYPE RFQ AT IUAC

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Abstract

A prototype of four-rod RFQ with operating frequency of 48.5MHz is designed and constructed as an accelerator section of High Current Injector (HCI) system to accelerate ions with A/q of 6 from 8keV/A to 180keV/A. The HCI consist of superconducting ECR Ion source PKDELIS to inject high currents beam into the RFQ and further accelerated by Drift Tube Linac before being injected into the Superconducting LINAC. An initial modulated 1.17m section of the RFQ is designed and constructed to determine the specifications for final RFQ accelerator which will be 2.5m in length. The RFQ chamber made of stainless steel gives intrinsic quality factor of 2355 without surface treatment and proper RF contacts. To improve the quality factor and to reduce the power dissipation the chamber and the base plate were copper plated. The average thickness of the copper plating was 70 micron, which is more than the skin depth (10micron) of copper at 48.5MHz. The intrinsic quality factor and shunt impedance after copper plating improved to 3112 and 82.08 k-Ω respectively. With this quality factor the power required to generate 70kV inter-vane voltage is 29.85kW. High power RF test has been done to check the frequency and the temperature stability of the RFQ. The resonant frequency found to decrease with increasing RF power up to 20kW, while temperature of the cooling water rises marginally.

INTRODUCTION

A rod type RFQ vanes has been selected in order to decrease the diameter of the RFQ cavity. Also the design and tuning of the system become easier for this type of RFQ. Fig. 1 shows the RFQ electrode assembly as installed in the cavity. It consists of three main components; the rod type electrode, the electrode supporting posts, and the base plate.

The length of the electrodes is 1.17 meters with bore radius of 4 mm. The whole electrode assembly is inserted in RFQ cavity of internal dimensions 1194 x 500 x 355 mm. The material of electrodes and electrodes supporting posts is all copper while base plate and chamber is of stainless steel. Assembly of vanes has been achieved within an accuracy of 100 microns. The chamber can hold a typical vacuum level of 1×10^{-7} torr.

To improve the quality factor the inner surface of the chamber as well as the base plate is copper plated with a plating thickness of 70 microns. The results of the low power and high power RF measurements are given in the following section.

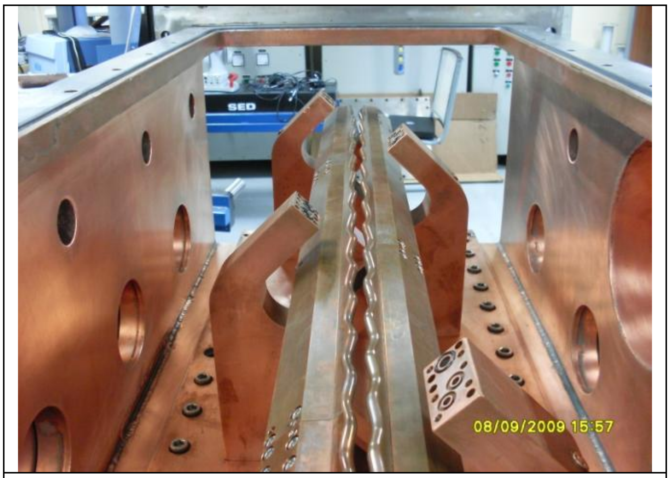

Figure 1: General assembly of the prototype of 1.17m modulated copper plated RFQ at IUAC.

LOW POWER RF TEST

The objective of low power RF test is to measure the following RF parameters which are essential to check the performance of the cavity. The perturbed resonance frequency (f), quality factor (Q) and unperturbed resonance frequency (f0) are measured with a network analyser [1], while capacitive variation method is used to determine the shunt impedance (Rsh) of the cavity. The idea in the capacity variation method is to perturb the inter-electrode capacitance of one quadrant of the RFQ by putting a small capacitor.

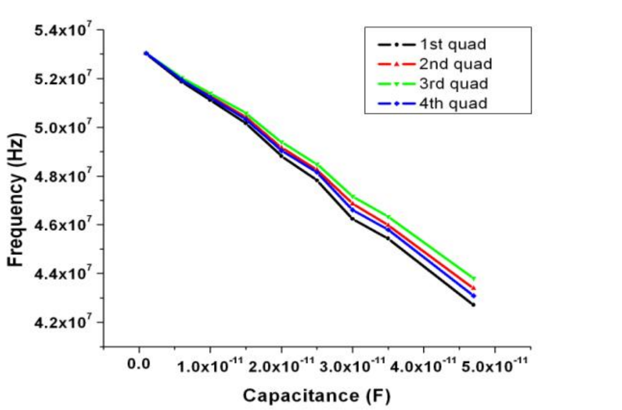

Figure 2: Frequency shift in capacitive variation method.

The net inter-electrode capacitance then increases and the resonance frequency shifts lower. Capacitors used for the perturbation are 1pF to 35pF and is small compared with the effective inter-electrode capacitance which is approximately 100pF. We determine R_{sh}/Q by calculating the slope $d\omega/dc$ of the curve [2] shown in Fig. 2.

The electric field distribution along the length of the cavity and the quadrupole symmetry is checked by Bead Pull method. We used a fully automated bead puller system. Self-exciting loop is used to minimise the possible long-term temperature drift while measuring the frequency shift. Results indicate that the distribution of the electric field is symmetrical within the beam radius and tend to asymmetrical in region greater than the beam radius.

The RF test has been done on modulated vanes with and without copper plating of the chamber walls and base plate. The RF result stainless steel chamber and copper plated chamber is summarized separately in table 1 and table 2 respectively.

Table 1: The RF characteristics of modulated 4-rod RFQ with stainless steel chamber

RF parameters	Designed Value	Simulated	Experimental
f_0	48.5 MHz	-	53.02
Q	-	4000	2355
R_{sh} /Q	-	-	23.65
R_{sh}		80k-ohm	55.7k-ohm
P_{in}	-	30kW/m	43kW/m

Table 2: The RF characteristics of modulated 4-rod RFQ with copper plated chamber

RF parameters	Designed Value	Simulated	Experimental
f_0	48.5 MHz	-	53.02
Q	-	4000	3112
R_{sh} /Q	-	-	26.37
R_{sh}		80k-ohm	82.08k-ohm
P_{in}	-	30kW/m	29.85kW/m

Comparison result indicates that the copper plating has improved the quality factor from 2355 to 3112. This brings down the power required to generate 70kV inter-electrode voltage from 43kW/m to design value of 30kW/m.

HIGH POWER RF TEST

The purposes of high power RF tests are to check the resonant frequency and temperature stability of the four-rod RFQ.

To maintain the temperature stability of the cavity during high power run, independent cooling water channels are allocated for the RFQ electrodes and posts. A 35kW commercial RF amplifier of operating frequency 48.5MHz with ±1MHz bandwidth has been used. Before feeding power into the cavity the RF amplifier was tested with dummy load up to 10kW.

An air cooled RF power coupler is designed to feed power in the cavity. Coupler is made of 500mm long copper tube whose inner and outer diameter is 4 and 6mm respectively, shown in Fig 3. To minimise the reflected power, coupling coefficient is optimised at 0.84.

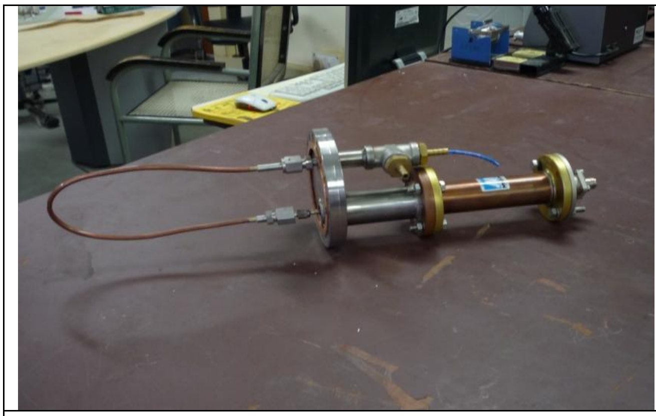

Figure 3: View of the Air cooled RF Coupler

Base pressure of 1.6×10^{-7}Torr was maintained before feeding RF power. We encountered vacuum fluctuation due to degassing in the cavity in the beginning of the power feeding, which was cured when degassing stopped. After this the vacuum pressure was below 1.2×10^{-6}Torr at any RF power level. We fed 20kW in the cavity in small steps. The resonant frequency was found to decrease with increasing RF power. To minimise the power reflected from the coupler we continuously tuned the operating frequency of the RF Amplifier. The temperature of the cooling water rises marginally.

CONCLUSION

The modulated prototype RFQ provides a bench to test for the fabrication of the full 4-meter modulated RF for the IUAC accelerator augmentation program. Bead pull measurement and high power RF test has provided useful results.

REFERENCES

[1] Paul J. Petersan and Steven M. Anlage, “Measurement of resonance frequency and quality factor of microwave resonators: comparison methods”, J. appl. Phys. 84 (1998) 3392.

[2] Hiroshi Fujisawa, “A cw 4-rod RFQ linac”, NIM A 345 (1994) 23.