HIGH POWER CW RF PERFORMANCE TEST OF 3.4m RFQ OF VEC-RIB

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Abstract

The RFQ is designed and commissioned as a first post accelerator of RIB facility at VECC, Kolkata. It accelerates q/A ≥ 1/14 beams with input energy 1.7 keV/u to 99 keV/u. This 3.4 m long rod type RFQ with characteristic radius of 7.1 mm is operating at 37.8 MHz in CW mode. An inter-vane voltage of 54 kV is needed to achieve the final energy for a maximum power loss of 35 kW. Inter-vane voltage calibration has been done using power-loss measurement and X-ray end-point energy measurement method. This paper describes high power CW RF test of RFQ cavity.

INTRODUCTION

Radio Frequency Quadrupole (RFQ) linacs are now widely used as injectors for linear accelerators, synchrotrons and also as standalone accelerators in ion-implantation systems. The RFQ cavity is shown in Figure 1. This rod type RFQ is designed for acceleration of 1.7 keV/u, q/A ≥ 1/14 ions to about 99 keV/u as a pre accelerator for RIB (Radioactive Ion Beam) project [1-2].

Figure 1: RF structure of RFQ.

The resonant structure in the rod type RFQ is formed by four vanes supported by posts on a base plate. Each diagonally opposite pair of vanes is supported by two posts. The basic RF cell of 'four-rod' structure can be described as two coupled λ/4 transmission lines. The vanes act as capacitance and the posts as inductance. It is encased by 3.4m rectangular cavity, removable from top. The vanes, posts and base plate as well as the cavity are water cooled via embedded cooling channels. A water-cooled loop type coupler is used for RF power feeding to RFQ. The loop coupler have been indigenously designed and built [3].

ANSYS and CST microwave studio are used for RF-structure simulations. In order to study the effect of modulation on the RF characteristics the 3D model of the RFQ from CATIA was exported to ANSYS workbench, the resulting input file with nodes, elements, and suitable boundary conditions has been used for the RF simulation. The calculated resonance frequency and Q value with the modulated vanes were found to be 37.66 MHz and 8026, respectively. The estimated Rp was 65 kΩ. The RF parameters were measured at low power using a network analyzer. The calculated (with modulated vanes) and measured RF parameters for the RFQ are summarized in Table 1.

Table 1: RF structure parameters of RFQ

Parameters	**Calculated**	**Measured**
Frequency	37.66 MHz	37.83MHz
Q Value	8026	5393
Rp	65 kΩ	42kΩ

The loop coupler orientation was adjusted for 50 Ω coupling. The tenability 80 kHz was measured for two loop tuners with loop size 120X130 mm. The RF power was fed to RFQ cavity from a high power RF transmitter through a 31/8", 50 Ω coaxial transmission lines.

RF CONDITIONING

A new cavity has micro protrusions and contaminants on its RF surface. These imperfections can produce field emissions, which in turn cause multipactoring and sparking [4]. To Condition the cavity we use CW power at very small power level (< 1.0 kW). After allowing the vacuum to come back to its initial value, we increased power at the low duty and slowly to reach the highest vane voltage. The pulse RF power was then fed at higher and higher duty cycle and for each duty cycle power was increased slowly enough and stopping whenever there was an increase in the vacuum level. Vacuum was typically in the 10^{-7} torr range at the start of conditioning. During conditioning the vacuum was kept better than 10^{-6} torr and accordingly the RF input power was fed.

HIGH-POWER TESTS

For the high-power test a tetrode based high power (40kW) amplifier developed in collaboration with SAMEER Mumbai was used [5]. The amplifier circuit was tuned to produce 35 kW at RFQ frequency. When RF power was applied, the cavity was operated with vacuum ~ $4.0X10^{-7}$ torr range. The full RF power fed into the RFQ cavity fed at 30% duty cycle and up to 18 kW CW. The resonance frequency of the cavity drops about 15 kHz at 18kW power. the resonance frequency shift and inter-vane voltage with respect to fed power for RFQ is shown in Figure 2.

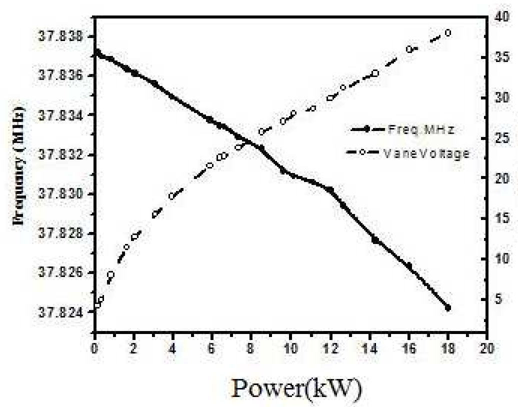
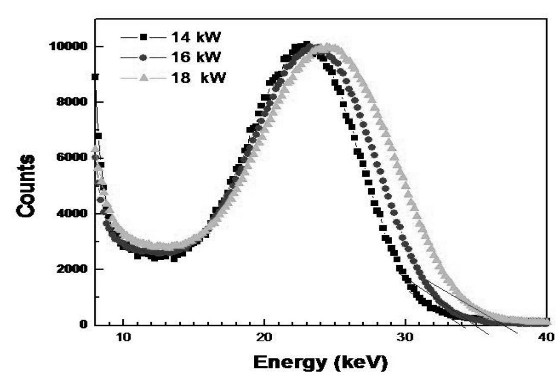
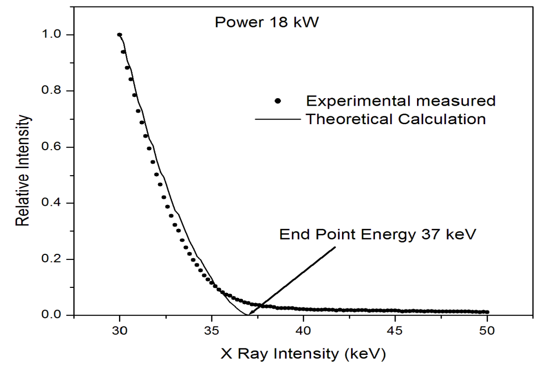


Figure 2: Plot of resonant frequency and vane voltage versus RF power for RFQ.

Inter-vane voltage calibration was performed by two methods first using power-loss measurements and second with X-ray end-point energy measurements. In the first method, the power loss between coupler and pickup-probe was measured by a HP Network Analyzer and it was equal to 42.7 dB. The pick-up probe power was measured directly by a power meter during operation that helped to calculate the vane voltage as shunt impedance of the cavity is known. At high power levels, the X-ray end point method provides a non invasive and precise technique for measuring inter-electrode voltage [6].



(a)



(b)

Figure 3: (a) The x-ray spectrum measured for the RFQ (b) Experimental data fitted for 18 kW power.

The X-ray spectrum corresponding to different RF power level of RFQ was measured using HPGe semi planar detector (Type: NGP 1000-15 of DSG, Germany).The detector was placed right beside the perspex window. Maximum energy of the X-rays corresponds to the inter-vane voltage of the RFQ is shown in Figure 3(a). In order to locate the end point energy of the experimentally measured spectrum accurately. The spectrum was fitted theoretically to locate the end point energy [7]. The best fit for the 18kW spectrum is shown in Figure 3(b), which corresponds to the peak voltage of 37 kV. Similar fitting has been carried out for other two power levels of 14 kW & 16 kW to extract the peak voltage.

CONCLUSION

The 3.4m RFQ operating at a frequency of 37.83 MHz was powered up to the full power load at 30% duty cycle and up to 18 kW CW. The measurement of drift in the frequency with the power level and the measurement of vane voltage using X-ray technique are presented. The beam tests for the RFQ have been successfully conducted and ion beams of O^{5+}, N^{6+} and Ar^{4+} has been tested with a measured transmission efficiency of around 80%.

ACKNOWLEDGEMENT

The author would like to thank A. K. Mitra of TRIUMF, Vancouver, Canada and K. P. Ray of SAMEER, Mumbai, India for their useful suggestions.

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