RF Conditioning of 75 MHz Prototype Heavy Ion RFQ

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Abstract

The Pelletron Accelerator Facility (PAF), Mumbai is engaged in development of a 75 MHz prototype Heavy Ion Radio Frequency Quadrupole (RFQ). The RF characterization of this RFQ consisting of 1.34m modulated vanes is completed. The medium power conditioning of the RFQ was started with the available 1 KW RF amplifier and results are discussed.

Introduction

A 75 MHz heavy ion RFQ is being developed at PAF, BARC-TIFR. The beam dynamics design [1] and electromagnetic design [2] of this RFQ was completed and a 1.42 m prototype RFQ with 1.34 m of modulated vanes (see Fig. 1) is fabricated to study RF characteristics [3] & power coupling methods.

Fig. 1 Fabricated Model of Prototype RFQ

The resonant structure of the RFQ consists of four electrodes called vanes, assembled in quadrupolar symmetry on support posts called stems arranged on a base plate. The resonant structure consisting of vanes, stems and base plate is enclosed in a SS304 vacuum chamber of dimension 1420mm x 500 mm x 300mm.

Setup for RF Conditioning of RFQ

The RF Conditioning setup was commissioned at PAF, BARC-TIFR (see Fig. 2). An air cooled 75 MHz, 1 KW pentode based RF amplifier operating in class C mode is developed in collaboration with RFSS (formerly VPID), TPD, BARC [4]. A continuous wave 75 MHz signal from the signal generator is amplified via a solid state driver (150W) and then coupled to EIMAC 5CX1500 pentode (1.5KW, 110MHz) based power amplifier. A 'pi' type impedance matching network is utilized at the input and output of the amplifier.

A Turbo Molecular Pump (80 L capacity) was used to evacuate the vacuum chamber with RFQ assembly. A base pressure of 5×10^{-7} Torr, before application of RF power, is acceptable for beginning power tests. A cold cathode gauge is used to monitor the vacuum in the cavity. A dual axis movable RF Coupler assembly was designed, installed and optimized to get proper coupling using VNA. The forward and reflected power was measured on wattmeter and the pickup signal was observed on the Oscilloscope.

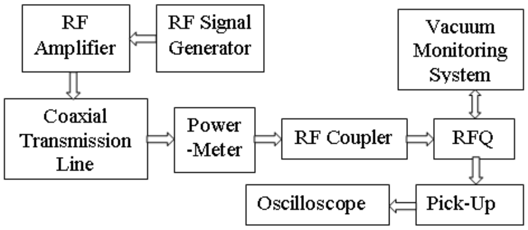

Fig. 2 Set Up for RF Conditioning of RFQ

RF Conditioning of RFQ

The conditioning of prototype heavy ion RFQ was done both in air as well as in vacuum. Initially the 200 watt amplifier and later 1 KW amplifier was used for the conditioning of prototype RFQ. The purpose of applying 1-10 watt of power in air was to optimize the inductive loop coupling by observing reflected

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power on the wattmeter. Later RF power was ramped to 100 watts in steps and 0.4 watts of reflected power was measured under maximum coupling. Under vacuum (< 5E-6), reflected power increased to 80-90% of the forward power. Whether in air or vacuum, the applied power was always continuous. Initial conditioning led to vacuum fluctuation to 2E-5 arising from degassing in the RFQ. Once vacuum level recovered to 3E-6, medium power (> 20 W) was applied. However, the measured reflected power was >80% of applied power. It was decided to open the RFQ chamber in order to ascertain the cause of this behaviour. Visual inspection of the RFQ electrodes showed extensive discolouration of the electrode surfaces and considerable spark effect (see Fig. 3).

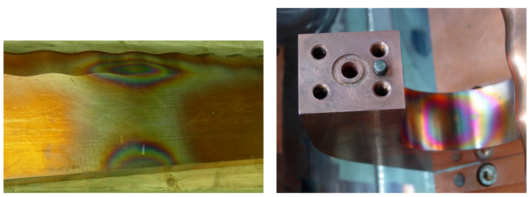

Fig. 3 Vane and Stem Discoloration

We understood that good vacuum properties were essential for RFQ performance. The prototype RFQ was disassembled and chemically cleaned to remove surface adsorbents and contaminants. The vanes, stems and base plate were cleaned in alkaline soap solution, then in anhydrous citric acid dissolved in deionized water for 5-10minutes and then rinsed in DI water. Each vane and stem was vacuum dried to avoid wet marks on the surface.

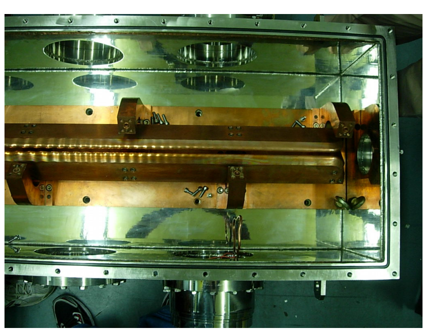

Fig. 4 RFQ under Assembly

The prototype RFQ was assembled and installed in the cleaned vacuum chamber (see Fig. 4). A new inductive RF coupler with larger area (circumference~57cm) was made from copper wire and installed in the RFQ chamber. A vacuum of 3E-4 is achieved in 15 minutes and 1E-6 in three days time. RF power was applied in steps monitoring the reflected power; pick up signal and vacuum level (see Fig. 5).

Multipacting was observed even at low power i.e. 5-10 watts. SF6 gas was employed to curb the multipacting and speed up the conditioning. The method used was to flush the prototype RFQ cavity with SF6 for 2-3 seconds and then pump it out. The SF6 formed a monolayer on copper parts reducing secondary electron coefficient and hence controlling multipactoring.

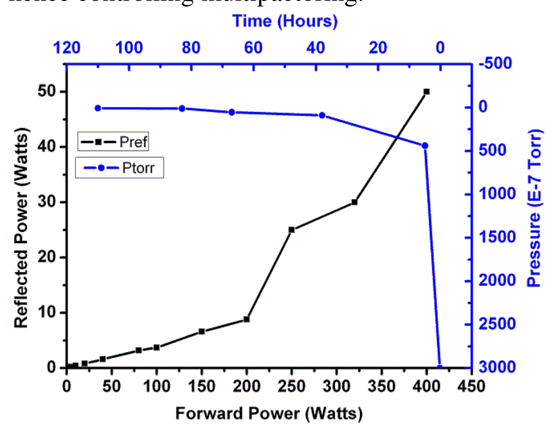

Fig. 5 RFQ Conditioning Graph

The resonant frequency decreases (< 6 KHz) with increasing RF power which was tuned accordingly. For short duration (5minutes), 800 watt power was fed and 84 watts of reflected power was recorded. At RF power levels >400 watt, N type RF connector dielectric breakdown was noticed. High Power Coupler design, essential for coupling 1KW and higher power to RFQ, is in progress.

References

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[3] N. Mehrotra et al., RF Testing of 75 MHz Prototype Heavy Ion RFQ, InPAC-2011.

[4] S. Rosily et al., Development of 75 MHz, 1 kW RF Amplifier, InPAC-2009.