RFQ COLD MODEL RF MEASUREMENTS AND WAVEGUIDE-TO-COAXIAL LINE TRANSITION DESIGN FOR THE FRONT-END TEST STAND AT RAL

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Abstract

A 324MHz four vane RFQ cold model has been built, as part of the development of a proton driver front end test stand at the Rutherford Appleton Laboratory (RAL) in the UK. This paper will present the results of RF measurements performed on the cold model, which include analysis of resonant modes, Q-value measurements and electric field profile measurements using a bead-pull perturbation method. These measurements were done before and after brazing of the four vanes and the results were compared to Microwave Studio simulations. Additionally, a tuner has been designed, built and tested and the results will be presented together with the preliminary results of the electromagnetic design of waveguide-to-coaxial line transition structures for the four vane RFQ.

INTRODUCTION

In order to contribute to the development of high power proton accelerators (HPPAs), to prepare the way for ISIS upgrades and to contribute to the UK design effort on neutrino factories [1], a front end test stand (FETS) is being constructed at RAL in the UK. The aim of the RAL FETS is to demonstrate the production of a 60 mA, 2 ms, 50 pps chopped beam. A detailed description of the project and the current status is given in [2]. A RFQ for bunching the beam and accelerating it from 65 keV to 3 MeV will be used as the first accelerator element. The resonant frequency of the RFQ was chosen to be 324 MHz to have a sufficient high frequency for a serious test of the chopper and because of the availability of a klystron from Toshiba (E3740A), capable of delivering an average output RF power of 65.1kW and output peak RF power of 2MW, which has arrived at RAL and tendering for its power supply has started. Simulations of the particle dynamics as well as the modelling of the electromagnetic properties of a 4-vane and a 4-rod structure have been performed. The 4-vane type copper cold model has been manufactured, and analysis on its RF properties and electric field profile has been done. In addition, a mechanical tuner has also been built and tested to verify the simulation results on the tuning range. Furthermore, since the arrival of the klystron, work has also been carried out to investigate the waveguide-coaxial transition component to transfer RF power from the klystron, through a system of WR2300 waveguides and into the RFQ via a magnetic input coupler.

COLD MODEL RF MEASUREMENTS

The RF and Bead-pull Measurement Results

RF and bead-pull measurements were performed on the unbrazed and brazed RFQ, shown in Figure 1 and Figure 2 respectively. The setup in Imperial College to perform both measurements is shown in Figure 3.

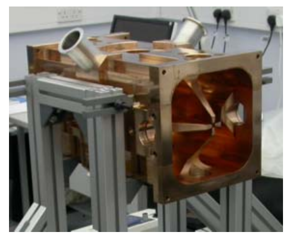

Figure 1: Unbrazed RFQ.

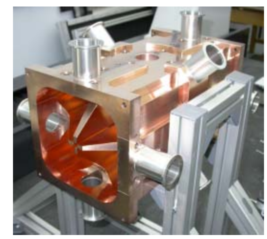

Figure 2: Brazed RFQ.

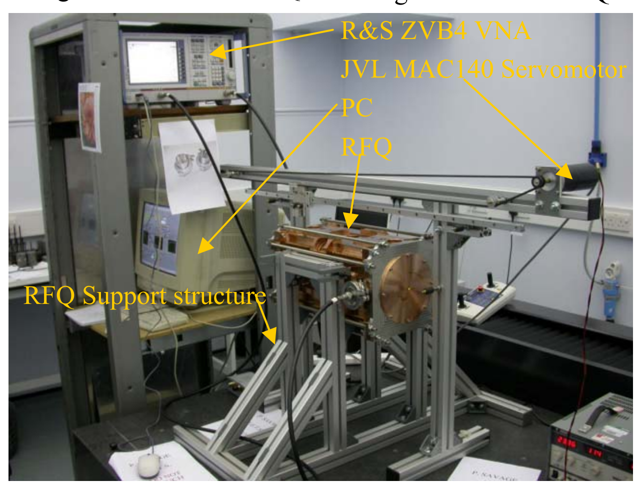

Figure 3: Brazed RFQ cold model with end-plates on bead-pull experiment setup in Imperial College London.

The 4-vane RFQ consists of four solid parts, each having a protruding electrode. The four parts were assembled onto the supporting structure, and the assembly literally sits on its own weight, giving the unbrazed RFQ shown in Figure 1. The brazed RFQ, shown in Figure 2, has all the tuner and coupler ports brazed on it. Some brazing materials were splattered into the vanes. This prompted that more care will be taken while brazing the eventual RFQ sections. Laser welding is still under consideration too. End-plates are made of stainless steel with grooves where currently only silver braids are inserted in order to improve the contact between the RFQ and the end-plates. The end-plates also consist of copper plates that are removable, so that the effect of different dipole rod structures can be explored in the near future.

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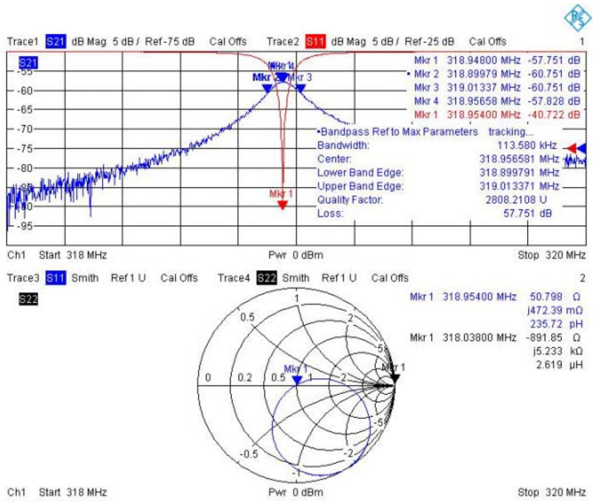

Figure 4: Brazed RFQ critical coupling at about 319MHz.

Table 1 shows the comparison between measured and predicted frequency and unloaded-Q values. Measured results on the brazed RFQ are not the optimised results. Further improvement could still be employed by using proper finger-strips to improve the contact between the stainless steel end-plates and the RFQ; the RFQ-side of the stainless steel end-plates could be coated with copper to improve conductivity; aluminium flush pieces coated with copper could be inserted into the unused coupler ports etc.

Table 1: Comparison of Simulated and Measured results on 400mm long RFQ cold model

	Quadrupole Frequency [MHz]	Quadrupole unloaded Q, Q_0
Predicted	319.7	9300
Measured BEFORE brazing	322.41±0.2	546±20
Measured AFTER brazing	318.954±0.001	5616±50

The bead-pull measurement was performed using the setup illustrated in [3] with a nylon bead of ∅5.8mm ($\varepsilon r \approx 2.3$) suspended on a ∅0.25mm nylon wire pulled via a servomotor. The semi-automated bead-pull measurement is controlled using LabVIEW.

Figure 5 shows the experimental result of the electric-field distribution, which shows good agreement with simulations for most points along the beam-axis. The field-flatness is calculated according to the formula [4]:

$$FF = \frac{E_{\max} - E_{\min}}{\frac{1}{N}\sum_{i=1}^{N} E_i} \text{ x } 100\%$$

For the unbrazed-RFQ, *FF*=21.2% whereas for the brazed-RFQ, *FF*=9.74%. The bead was placed in between 2 electrodes to perturb the quadrupole electric field. Asymmetry is observed in the field profile, could be due to input coupler positioning and silver braids unevenly placed in one of the end-plates.

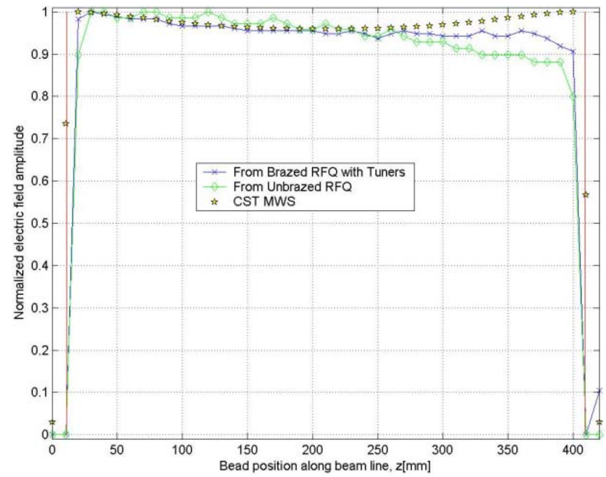

Figure 5: Electric-field distribution comparing between brazed and unbrazed RFQ cold model with simulations.

MECHANICAL TUNER DESIGN

The RFQ cold model mechanical tuner was designed and built for the purpose of investigating the RFQ frequency tuning range and to verify simulation results performed in CST Microwave Studio.

The mechanical tuner, shown in Figure 6, consists of a copper tuner plug connected to a linear-motion shaft enclosed inside a cylindrical housing. The shaft has a steering that rotates the shaft in order to move the tuner plug linearly forwards or backwards. Then, right above the steering is a displacement gauge that measures how deep the tuner plug has been inserted into the RFQ vane. Four of these mechanical tuners were made. They are assembled as shown in Figure 7.

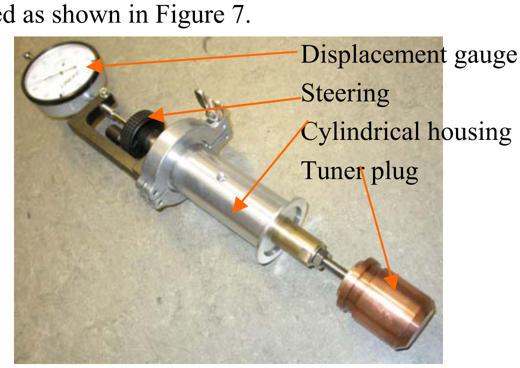

Figure 6: The mechanical tuner.

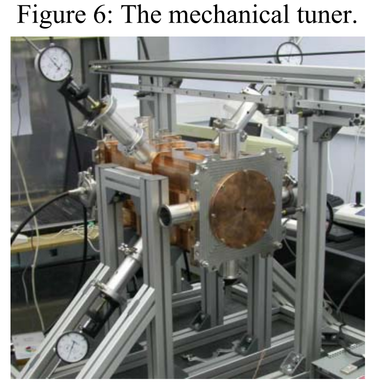

Figure 7: Mechanical tuners on brazed RFQ.

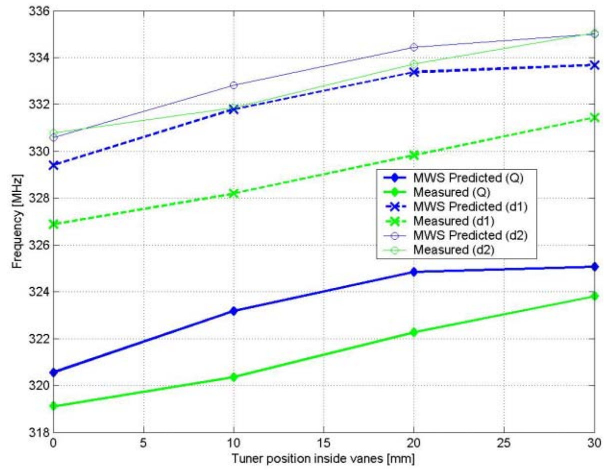

Figure 8: Comparison of tuning range results.

Figure 8 shows a plot of the frequency tuning range when all four tuners were inserted from 0mm to 30mm into the 4 vanes, and compares between measured and MWS calculated results. The change in frequency due to tuner position seem to correspond well between measured and calculated within tuner positions 10mm to 20mm, giving a change of about 0.2MHz/mm. It also shows that the dipole modes (d1 and d2) are well away from the quadrupole mode (Q).

WAVEGUIDE-COAX TRANSITION

Transition Structure Design Results

At the waveguide-to-coax transition, two transition structures have been investigated, namely the doorknob and t-bar impedance-matched structure shown in Figure 9 and Figure 10 respectively. Its task is to transfer a 324MHz RF power from the klystron, which has an output power capability of 2MW peak, via a WR2300-waveguide system, then to a magnetic power coupler and into the RFQ. The coax section of the structure has an inner conductor diameter of about 67mm and outer diameter of 162mm (a typical HELIFLEX HCA618-50 Series Air coax cable dimension) in order to withstand the peak RF power and matched at 50Ω.

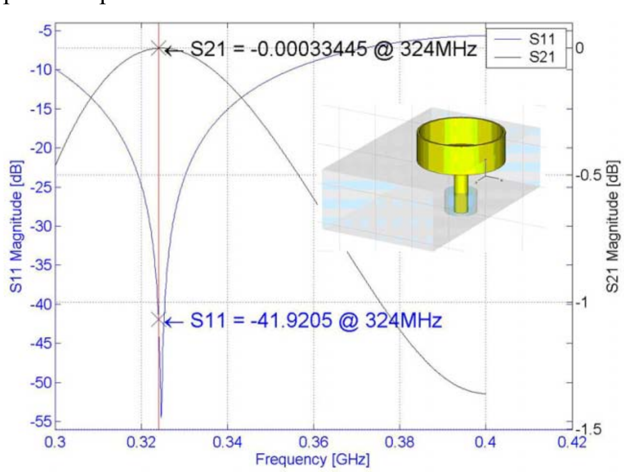

Figure 9: Doorknob transition structure simulation result.

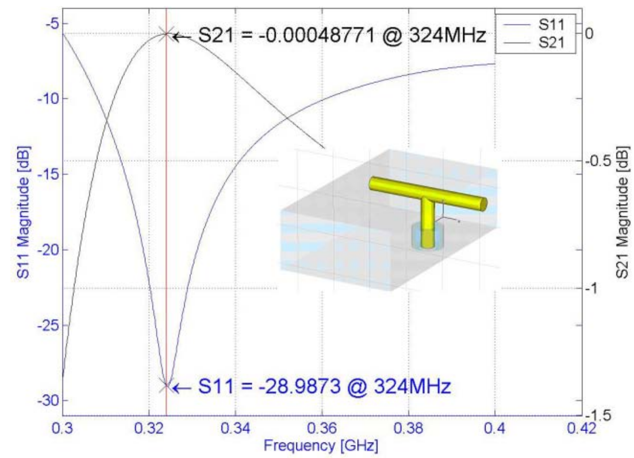

Figure 10: T-bar transition structure simulation results.

Simulation preliminary results, shown in Figure 9 and Figure 10, of both transition structures currently show desirable values. However, much needs to be considered on RF window positioning, cooling channels, electron probe ports etc., in order to finalize on the desired transition structure to be built. Currently, it is thought to build four identical transition structures as the total RF power from the klystron will be split into four equal powers into each of the four 1-meter long RFQ section.

DISCUSSION AND CONCLUSION

RF measurements on the brazed RFQ presented are preliminary results, where there is still room to optimise the cold model structure, and more improvements can still be made. Important lessons were learnt on the processing of the RFQ parts too. Further work will continue on optimising the cold model, warm measurements and cooling effects will be investigated where results are anticipated to be produced at the end of 2007.

ACKNOWLEDGEMENTS

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