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# STATUS OF THE CHINA MATERIAL IRRADIATION FACILITY RFQ*

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*Abstract*

The pulsed high power test and beam test of the China Material Irradiation Facility RFQ have been implemented. Before this, the radio frequency measurements and tuning are performed. In this paper, the processes and results of the radio frequency measurements, tuning, pulsed high power test and beam test will be presented. The results of tests are in good agreement with the design.

## INTRODUCTION

Material study is important for the fusion energy utilization. It is important to construct accelerator-based neutron sources for verification of materials candidate to fusion reactor. The IFMIF project is a part of ITER project for this purpose. As counterpart to CFTER, the CMIF project is proposed. As a key equipment of CMIF, the RFQ is designed to accelerate 10 mA CW deuteron beam from 20 keV/u to 1.5 MeV/u. The design procedure is expatiated in references [1] and [2]. The key parameters are listed in Table1.

Table 1: Parameters of CMIF RFQ

| Parameters | Values |
|---|---|
| Particle | D+ |
| Frequency (MHz) | 162.5 |
| Energy (I/O, MeV/u) | 0.02/1.55 |
| Beam current (mA) | 10 |
| Cavity length (m) | 5.34 |
| Inter-vane Voltage(kV) | 65 |
| Kilpatrick factor | 1.4 |
| Transmission efficiency (%) | 98.9 |

## TUNING OF CMIF RFQ

Fabrications of single modules were completed May 2017. And assembly of whole length cavity is completed during July 2017. Rf measurements and tuning of the RFQ was carried out during July and August. The tuning process was expatiated in references [3]. The tuning was implemented by utilizing 100 slug tuners. Owe to the utilization of PISLs, the dipole perturbative components are below 1% during tuning, so there is no need for tuning of dipole perturbative components. Therefore, the lengths of tuners with same longitudinal position will be set to the same length. The evolution of the lengths of tuners is plot in Fig. 1. The quadrupole perturbative component during tuning is measured and plot in Fig. 2.

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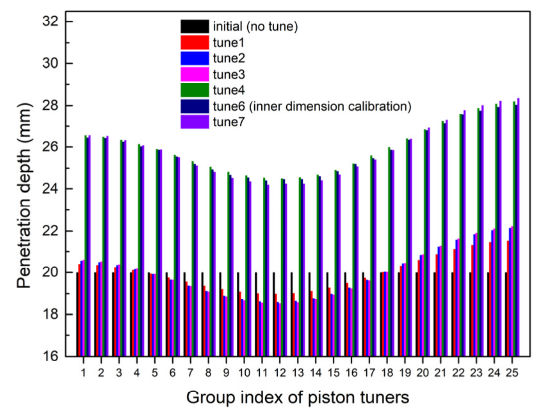


Figure 1: Evolution of lengths of slug tuner groups.

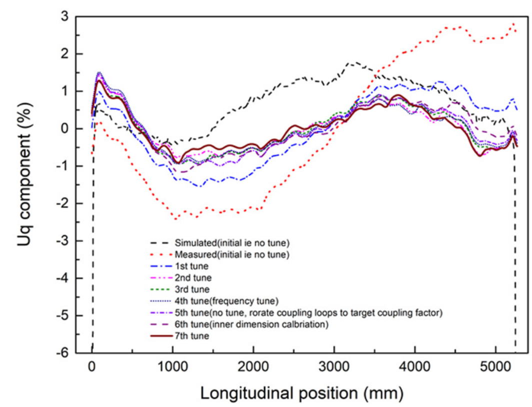


Figure 2: Evolution of the quadrupole perturbative component during tuning.

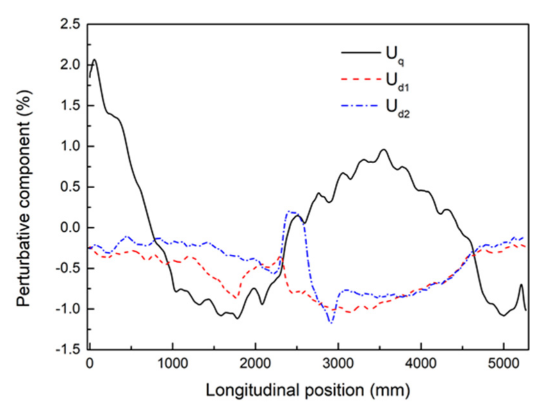


Figure 3: The measured perturbative components after the assembly of copper slug tuners.

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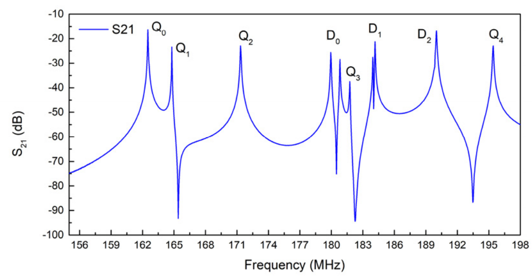


Figure 4: Frequency spectrum of the cavity after tuning.

The perturbative components after the assembly of copper slug tuners are plot in Fig. 3. After tuning, the frequency spectrum is measured and plot in Fig. 4. The $Q_0$ of cavity is derived by using the Smith circle fitting method [4], which is less vulnerable to coupling factor of pick up. The results of rf measurements and tuning is list in Table 2.

Table 2: Results of RF Measurements and Tuning

| Parameters | Values |
|---|---|
| Frequency (MHz) | 162.630 |
| $Q_0$ | 12560 |
| $U_q$ | ＜2% |
| $U_d$ | ＜1.5% |

## PULSED CONDITIONING OF CMIF RFQ

Due to the lack of cooling water, the condition is limited to the pulse low than 0.1 ‰ while the repetition keeps 1 Hz. The TH781 Tetrode Amplifier [5] is used for pulsed conditioning of CMIF RFQ. There is a splitter and phase shifter in the rf power transmission system. In order to lower the trip rate due to reflected power, critical coupling is obtained through adjustment of phase shifter. This is verified by the measured Smith Chart of S11 form the input of main transmission coaxial tube. The requisition of $Q_0$ value form Smith Circle fitting is plot in Fig. 5. The measured $Q_0$ value is in coincidence with that measured from couplers. Through evaluation using the measured $Q_0$ value, the nominal power should be 123 kW for reach the nominal intervane voltage. After 71 hours conditioning, this value is reached. The cavity power and vacuum during conditioning are recorded and plot in Fig. 6 and Fig. 7. The deterioration of vacuum at the late of test is contributed to breakdown of some of the cryo-pumps.

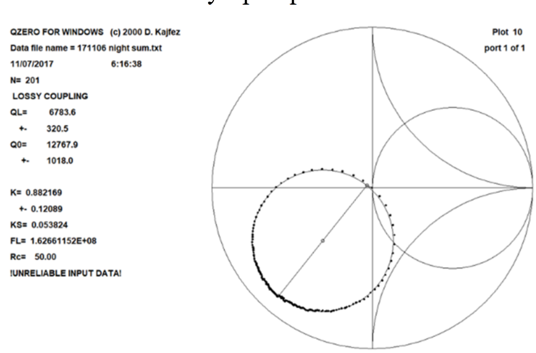


Figure 5: Smith Chart of S11 to the direction of cavity measured from the the main coaxial waveguide.

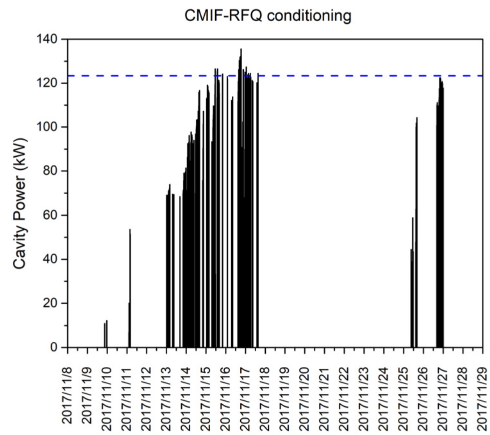


Figure 6: Cavity power records during pulsed conditioning(nominal power level is represented by blue dash line).

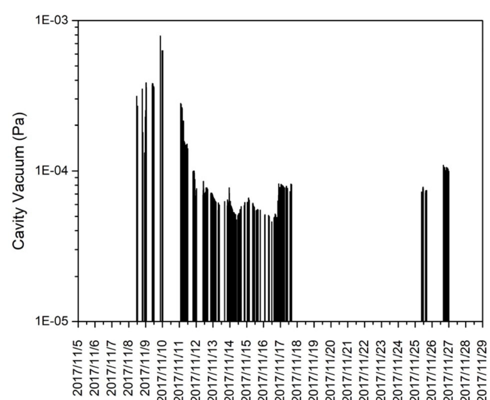


Figure 7: Cavity vacuum records during pulsed conditioning of CMIF RFQ.

## PULSED BEAM TEST OF CMIF RFQ

The beam test system as shown in Fig. 8 was built which consists of ECR ion source, LEBT, RFQ and diagnostic plate. The diagnostic instruments include a Faraday cup (FC) in LEBT, a fast current transformer (FCT), a beam position monitor (BPM), and a beam dump in D-plate. In order to decrease difficulty of shielding, $H_2^+$ is selected as the test beam instead of deuteron.

After the power of cavity could sustain at the nominal level, the beam test was performed. Due to the lack of instruments of beam diagnostic, an FCT and a BPM were assembled on the diagnostic plate to measure the time of flight of the accelerated beam bunch (Fig. 9). It is worth noting that for our circumstance, the signal amplitude of beam bunch at the BPM is 0 while peak at the FCT (Fig. 10). The measured beam energy is 3.11±0.01 MeV.

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Figure 8: View of RFQ test area.

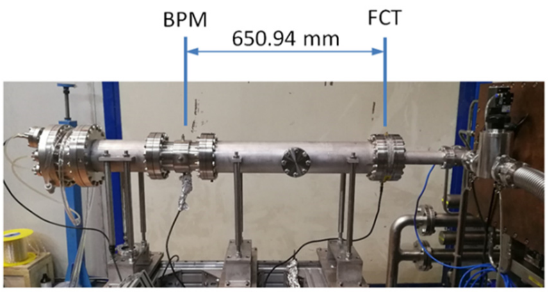


Figure 9: configuration of FCT and BPM on D-plate.

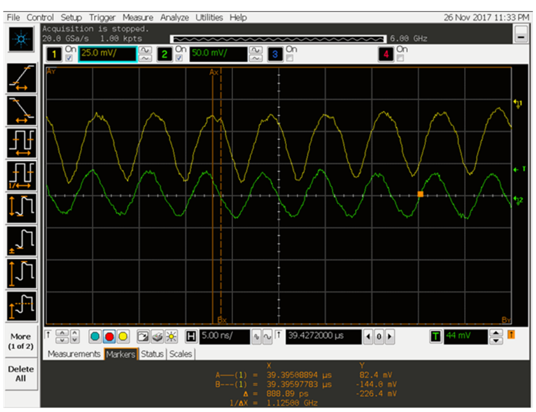

Figure 10: Signals of beam bunches on FCT(yellow) and BPM(green).

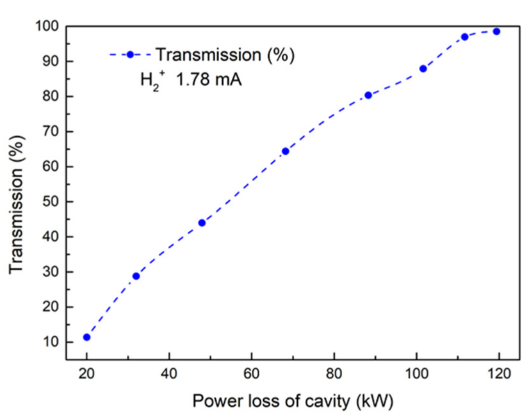


Figure 11: Measured Beam Transmission as a function of RF Power.

The beam current is measured using FC and beam dump in D-plate. The measured current in the FC was 8.04 mA, and the current at the beam dump was 7.85 mA. The transmission efficiency from FC to beam dump is 97.6 %. An experiment was also performed to explore the variation of the beam transmission corresponding to the change of cavity power, and the results are plot in Fig. 11.

## CONDITIONING OF CMIF RFQ ON LINE

An upgrade plan has been performed on the 25 MeV proton Linac in Institute of Modern Physics, CAS. One main change is replacement of the origin ADS-RFQ [6] by CMIF-RFQ. Then the accelerator can accelerate Helium ion to do some material irradiation research. In 27 April, 2018, the CMIF RFQ was hoisted into tunnel of the 25 MeV proton Linac. The conditioning on beam line was started on 26 May, 2018. The RF power is provided by two solid-state amplifiers [7]. In order to protect RFQ, spark rate is recorded as a criterium for evaluating the state of the conditioning process. The conditioning level will not be increased until there is no spark in several hours. Due to the occupation of the power source for 973 RFQ test [8], the conditioning is suspended and will continue next week.

## CONCLUSION

The tuning, rf measurements, conditioning and beam test of CMIF RFQ had been implemented in 2017. As a part of the upgrade 25 MeV Linac, the CW condition of CMIF RFQ should be completed in 2018. And CW beam test will be also performed after the nominal power level reached.

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