RF Measurements on the IFMIF RFQ High Power Test Modules

A. Palmieri, F. Grespan, E. Fagotti, A. Pisent, P. Bottin

INFN, Laboratori Nazionali di Legnaro, Legnaro (Padova), Italy.

INTRODUCTION

In order to allow proper operation of the IFMIF RFQ [1], it is necessary to perform a campaign of RF measurements on the cavity aimed, on one hand, at determining the basic RF parameters (frequency, Q0, etc.), on the other hand at verifying the field uniformity upon successive tuner settings as predicted by the tuner algorithm [2]. These measurements also involve the determination of the proper depth of the end plates and the positioning and length of the Dipole Stabilizers (if any). In this contribution the results of such measurements will be presented for the case of the IFMIF RFQ High Power Test Modules, consisting of one RFQ segment composed of the three (out of 18) highest energy modules plus the prototype II used as low energy termination and two termination plates. Such modules underwent a High Power Test described elsewhere in this Annual Report [3]. In Fig 1 the schematic of those modules is described.

![Image](image1.png)

**Fig.1** The RFQ used for the High Power test: overall length 2.022 m. From left to right: Prototype II, module 16, module 17 and module 18.

TEST STEPS

In the initial setup the RFQ was equipped with dummy aluminium tuners and with dummy end cells.

Measurement Step 0 consisted of the determination of mode Spectra and field profile with tuner flush and dummy End cells at nominal insertion of $h_{EC1}=h_{EC2}=12$ mm on both sides of the RFQ. The measurements were performed with metallic bead as in [4]. In Fig.2 the perturbative components $\delta U_q/U_{q0}$, $\delta U_{qd1}/U_{q0}$ and $\delta U_{qd2}/U_{q0}$ are shown. It is worth noticing that, due to the fact that the Prototype 2 was about 1.4 MHz higher in frequency than the TE21 cut-off one [5], the voltage has a large negative tilt in the low energy part. As for the frequency values, the results are the following: for the Q modes $f_{q0}=174.77$ MHz $f_{q1}=190.79$ MHz $f_{q2}=226.52$ MHz with unloaded $Q_0$ ($f_{q0}$) = 7040, while for the D modes $f_{d0}=171.38$ MHz (degeneracy= 10 kHz) $f_{d2}=190.86$ MHz (degeneracy= 30 kHz) $f_{q2}=228.68$ MHz (degeneracy= 50 kHz). These results agree within ±0.3% with the simulations Due to the fact that there is a 3.4 MHz distance between $f_{q0}$ and $f_{d0}$, no Dipole Stabilizers are needed.

![Image](image2.png)

**Fig. 2 Perturbative components vs z for the fq0 frequency: tuners flush and hEC1=hEC2=12 mm.**

In Measurement Step 1 all the tuners were set at 4.6 mm insertion in order to get the operational frequency of 175 MHz and in Step 2 the insertion of the end plate at the Low Energy Side was reduced to 0 mm in order to reduce the voltage drop at the beginning of the RFQ (Fig. 3).

![Image](image3.png)

**Fig. 3 Perturbative components vs z for the fq0 frequency. Tuners at 4.6 mm, hEC1=0 mm, hEC2=12 mm**

In Step 3, the tuning algorithm was applied to the series of 20 tuners (5 tuners/quadrant) up to the attainment in two iterations of the required ±2% value for $\delta U_{qd1,2}/U_{q0}$ in all RFQ modules at $f_{q0}=175.014$ MHz, (except Prototype 2, which is not to be used for the final RFQ). In Fig. 4 the perturbative components are shown.
In Step 4 the dummy coupler was inserted and the measurement was repeated in order to check its effect. It was found that only little shifts (in the order of 0.4%) occurred. In Step 5 the Dummy End Cells were replaced with the final ones (equipped with the RF joint) and the Q0 was measured again, resulting in a value of 12500, 78% of the 2D one, and well above the acceptance value of 9000.

In Step 6, the dummy tuners were replaced in three batches with the copper ones (batch one 8 copper tuners in position 1 and 4, batch 2 with 16 copper tuners in position 1, 2, 4 and 5, batch 3 with all the 20 copper tuners) and at each replacement the bead pulling was repeated. The results of the final measurement after completion of tuner replacement is shown in Fig. 5.

Fig. 5 Perturbative components after the tuning procedure (final tuners and final end cells).

Finally, once the RFQ (together with its support) was moved from the measurement hall (next to the LNL brazing facility) to the 3rd Experimental Hall (where the High Power test were scheduled), a final bead pulling measurement was performed in order to check whether the voltage profile was changed. Also in this case, a very little effect (less than 0.5%) was observed in the measured components. In the following Fig. 7, the final tuner settings are shown. It has to be noticed that, in correspondence of the Prototype II the tuner depths are negative (tuner extracted from the cavity), since the algorithms aims at recovering the negative slope due to the local detuning. In any case the tuner settings are all within the tuning range of [-15 mm, 30 mm].

COUPLING COEFFICIENT MEASUREMENT

Prior to the beginning of the High Power Tests, the final copper RF coupler, already tested at full power on an Al Cavity [6] was installed in the RFQ and its return loss was measured. Since the coupler was designed in order to have a coupling coefficient equal $\beta_0=1$ for $Q_0 = Q_{0\text{min}} = 9000$, and since the coupling coefficient scales with loop rotation angle $\alpha$ according to the law $\beta(\alpha) = \beta_0 \cos(\alpha)^2$, the optimum coupling angle is equal to about 32°. Now, with a rotation of about 30°the Return Loss was equal to 57 dB confirming the accuracy of the previous estimation (Fig. 7).

Fig 7: Return loss of the coupler mounted on the RFQ with 30° rotation angle

References: