

Abstract

The Radio-Frequency Quadrupole (RFQ) proton accelerator, consisting of 2 modules, was designed in the UHF band (800 MHz) to accelerate a proton beam with 20 keV energy to 2 MeV energy at a distance of less than one meter at KAHVE-Lab (Kandilli Detector, Accelerator and Instrumentation Laboratory). A prototype module of the RFQ (module 0) was manufactured from normal copper material to investigate the domestic producibility of the RFQ cavity. It was subjected to mechanical and vacuum tests. Moreover, it was completed to tune the EM field, and frequency parameters in accordance with the desired operating settings. The tuning of field distribution and frequency is a critical step in the successful operation of any RFQ accelerator, including the PTAK-RFQ module 0. A tuning algorithm developed for CERN was adapted for the PTAK-RFQ module 0 to obtain the desired field distribution, followed by frequency tuning as manual. This tuning algorithm relied on a response matrix, which used bead-pull measurements of individual tuner movements as inputs. Based on these measurements, the tuning algorithm provided predictions for corrective tuner movements needed to achieve the desired field distribution. The final RFQ was manufactured from oxygen-free copper material. It was subjected to a series of mechanical tests after being fully assembled for the first time. In this study, the ongoing testing and current status of the 800 MHz RFQ will be discussed.

INTRODUCTION

The Proton Testbeam in the Kandilli campus, known as the PTAK project (see Fig. 1), is an educational project as well a functional one as it will serve PIXE (Proton induced X-ray emission) experiments, which is one of the most common non-destructive ion beam analysis methods.

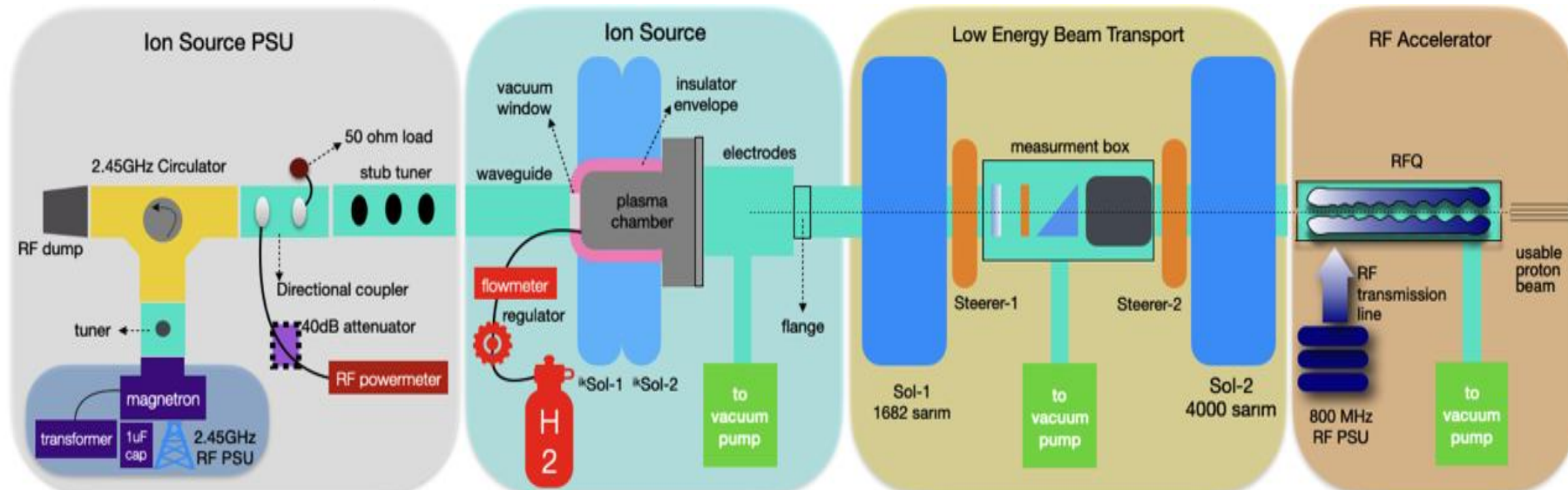


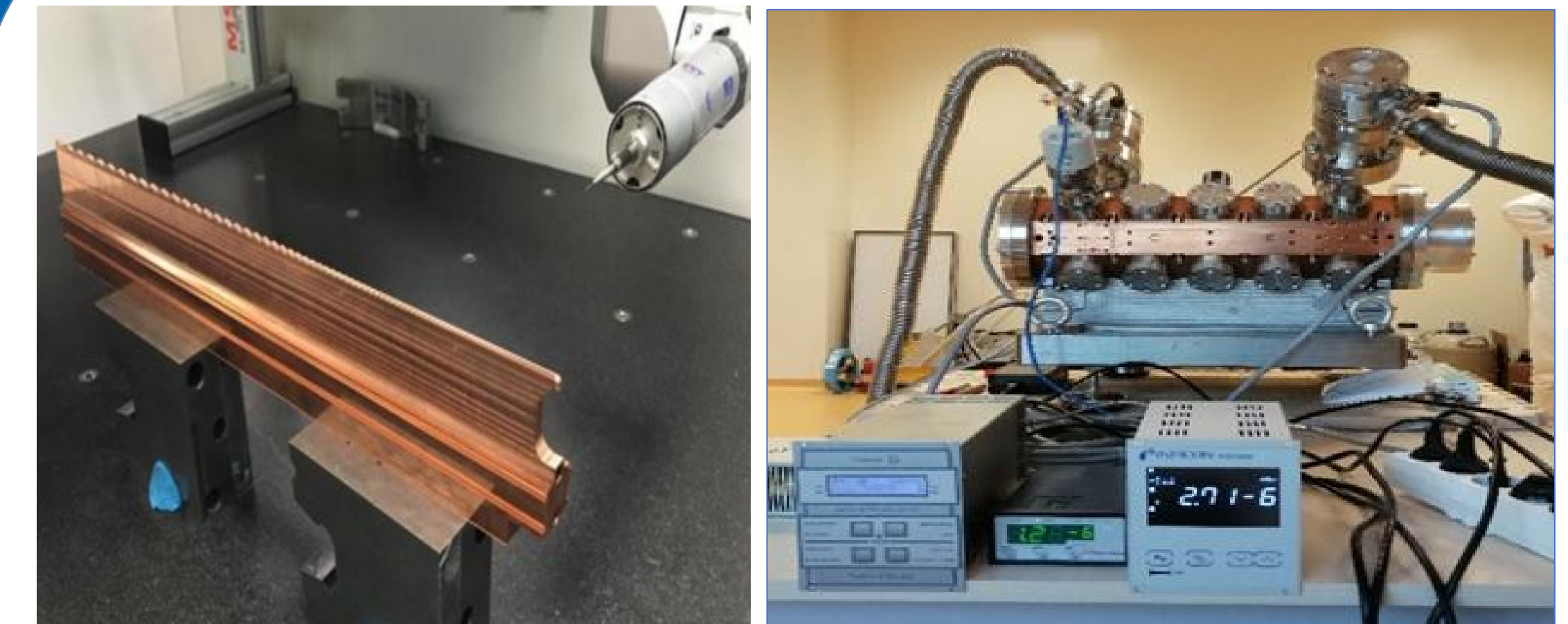
Figure 1: Layout of the PTAK project at KAHVE-Lab.

The first stage of the compact proton accelerator, which includes the ion source and the low energy beam transport (LEBT) section including the measurement box (MBOX), has been commissioned at the KAHVE-Lab, Turkey [1].

Table 1: Comparing recently introduced RFQs.

Parameter	Symbol	HF	PIXE	PTAK
Input Energy (keV)	W_{in}	40	20	20
Output Energy (MeV)	W_{out}	5	2	2
RF (MHz)	f_0	750	750	800
Number of modules	-	4	2	2
RFQ length (mm)	-	1964	1072.938	980
Vane tip radius(mm)	ρ_0	1.504	1.439	1.392
Min. Aperture(mm)	a	0.9	0.706	0.642
Simulated Quality Factor	Q_{sim}	6440	5995	7036
RF Power Loss (kW)	P_0	350	64.5	48.5
Max. Surface Field(MV/m)	E_s	50	39.1	35.98
Kilpatrick value	E_K	2.0	1.5	1.38
Max. Duty Factor(%)	df	5	2.5	2
Acc. Transmission	T_{acc}	30	30	30

The PTAK-RFQ (800 MHz) will operate at a frequency higher than similar RFQs and therefore will have a shorter module length (see in Table 1)[2,3].



(a)

(b)

Figure 2: (a) View of the test module at CMM frame, (b) view of the setup for the initial vacuum tests of the PTAK-RFQ module 0

The test module of the PTAK-RFQ was manufactured from ordinary copper and all its mechanical, vacuum and RF tests were recently completed [2,3].

ONGOING STUDIES FOR PTAK-RFQ

General Layout of the 800 MHz PTAK-RFQ

The 20 keV energy proton beam will be accelerated up to 2 MeV through the 800 MHz RFQ. The design of the 800 MHz RFQ includes:

- a 4-vanes structure,
- assembling by means of bolts without the need for any soldering or brazing,
- finger-type RF shields to prevent RF leakages,
- special 3-D Viton O-ring vacuum seal to prevent vacuum leakages [2,3].

Field Tuning Algorithm of the 800 MHz PTAK-RFQ

A tuning algorithm developed for CERN was adapted for the PTAK-RFQ module 0 to obtain the desired field distribution, followed by frequency tuning as manual. This tuning algorithm relied on a response matrix, which used bead-pull measurements of individual tuner movements as inputs. Based on these measurements, the tuning algorithm provided predictions for corrective tuner movements needed to achieve the desired field distribution [2,3].

$$\Delta V = R \Delta T$$

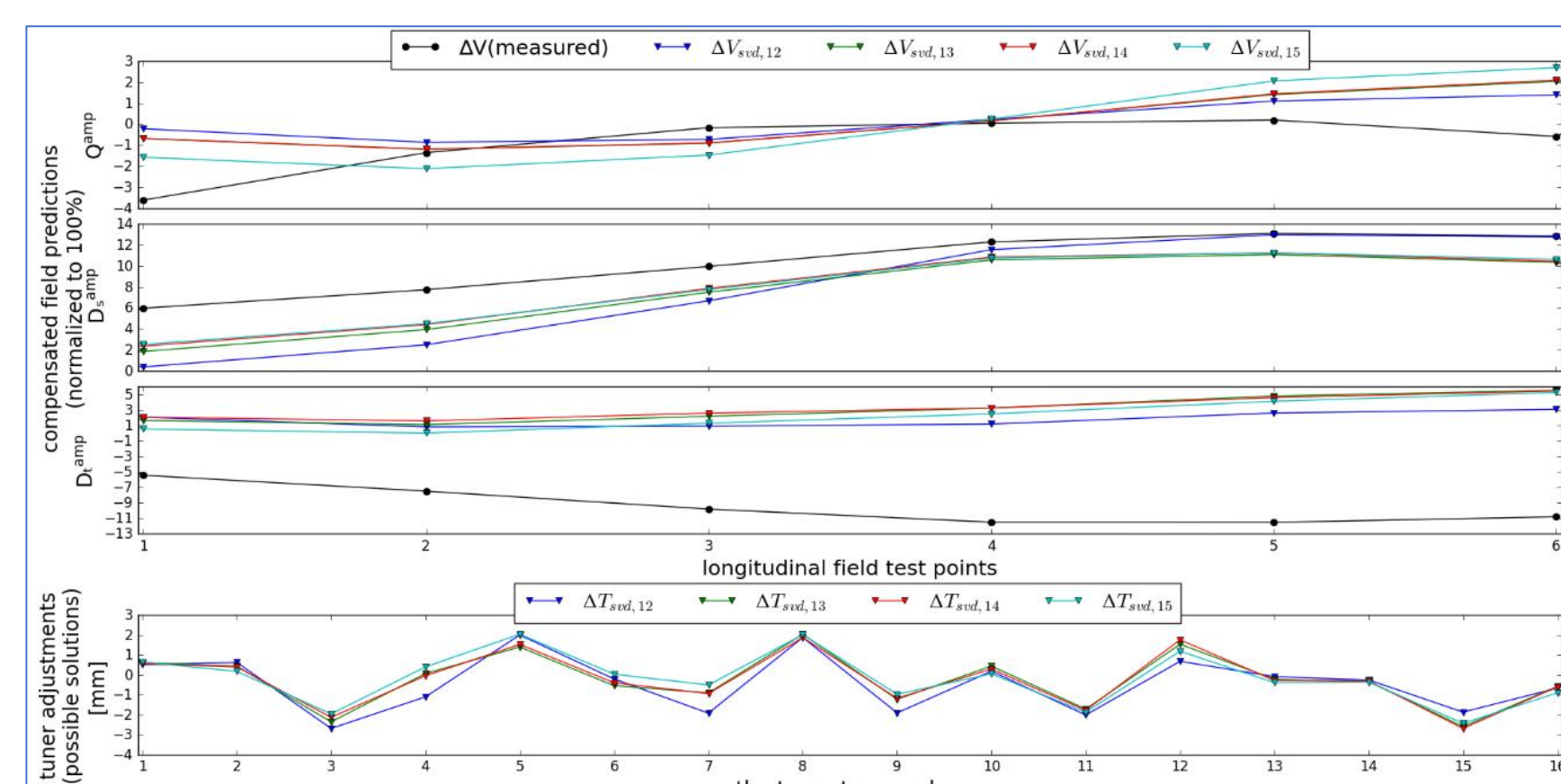
$$\Delta T = R^\dagger \Delta V, \text{ where } R^\dagger \text{ can be factorized as } R^\dagger = V \Sigma^\dagger U^\dagger$$

$$\begin{bmatrix} 100 - V1 \\ 100 - V2 \\ \vdots \\ 100 - V10 \\ 100 - V11 \\ 100 - V12 \\ 0 - V13 \\ \vdots \\ 0 - V21 \\ 0 - V22 \\ 0 - V23 \\ 0 - V24 \\ \vdots \\ 0 - V32 \\ 0 - V33 \end{bmatrix} = \begin{bmatrix} \frac{\partial Q1}{\partial T1} & \frac{\partial Q1}{\partial T2} & \dots & \frac{\partial Q1}{\partial T32} \\ \frac{\partial Q11}{\partial T1} & \frac{\partial Q11}{\partial T2} & \dots & \frac{\partial Q11}{\partial T32} \\ \frac{\partial Qs1}{\partial T1} & \frac{\partial Qs1}{\partial T2} & \dots & \frac{\partial Qs1}{\partial T32} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{\partial Ds11}{\partial T1} & \frac{\partial Ds11}{\partial T2} & \dots & \frac{\partial Ds11}{\partial T32} \\ \frac{\partial Dt1}{\partial T1} & \frac{\partial Dt1}{\partial T2} & \dots & \frac{\partial Dt1}{\partial T32} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{\partial Dt11}{\partial T1} & \frac{\partial Dt11}{\partial T2} & \dots & \frac{\partial Dt11}{\partial T32} \end{bmatrix} \cdot \begin{bmatrix} T1 - 0 \\ T2 - 0 \\ T3 - 0 \\ T4 - 0 \\ \vdots \\ T29 - 0 \\ T30 - 0 \\ T31 - 0 \\ T32 - 0 \end{bmatrix}$$

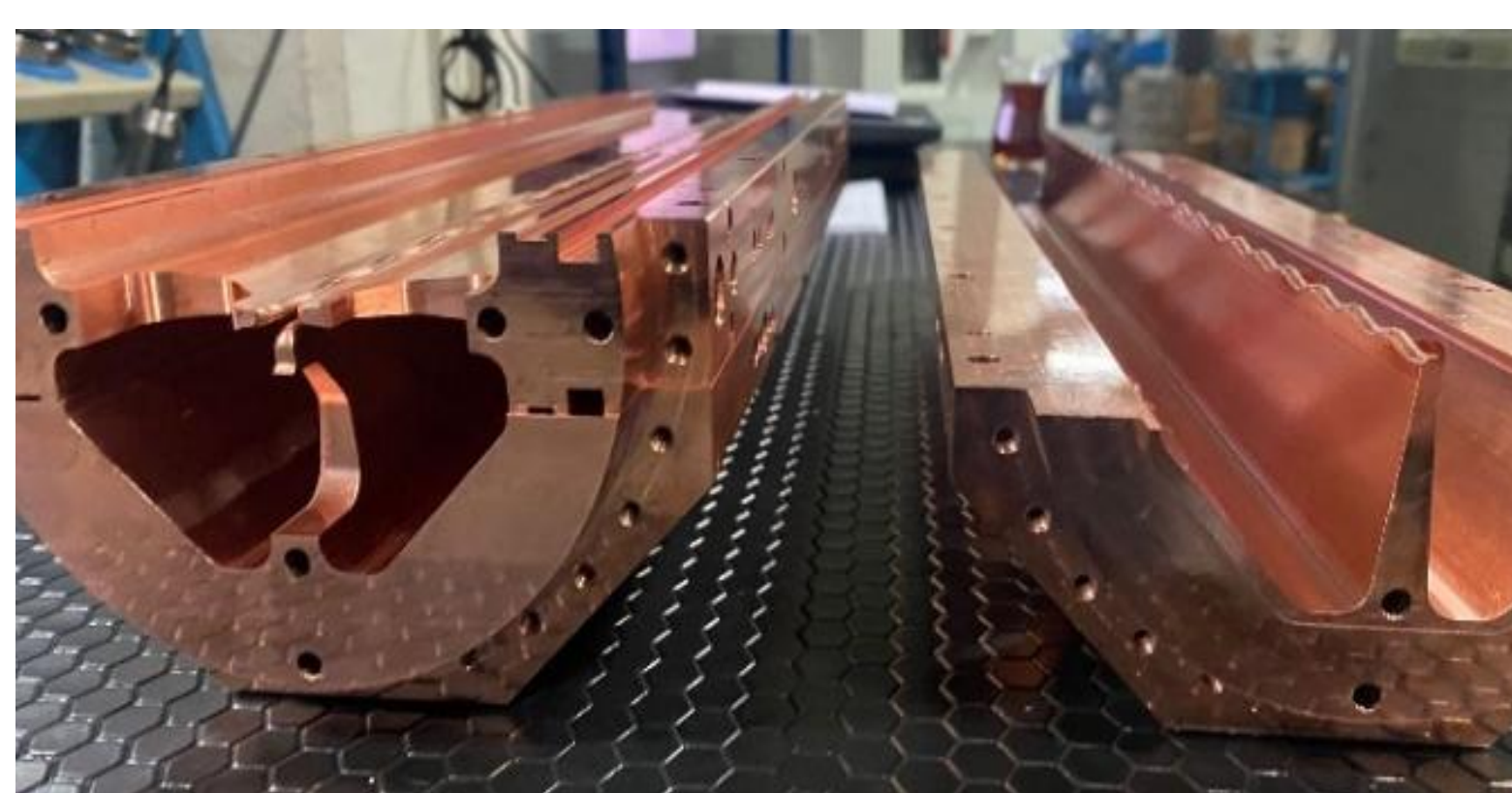
-n possible useful solutions for tuner lengths to compensate field amplitudes is given by $\Delta T_{svd,t} = V \Sigma_{M,P,t}^\dagger U^\dagger \Delta V$ ($t = 1, 2, \dots, (L-1)$)

-For each of the 16 possible solutions, there are corresponding predictions,

$$\Delta V_{svd,t} = R \Delta T_{svd,t}$$



Current Status of the 800 MHz PTAK-RFQ

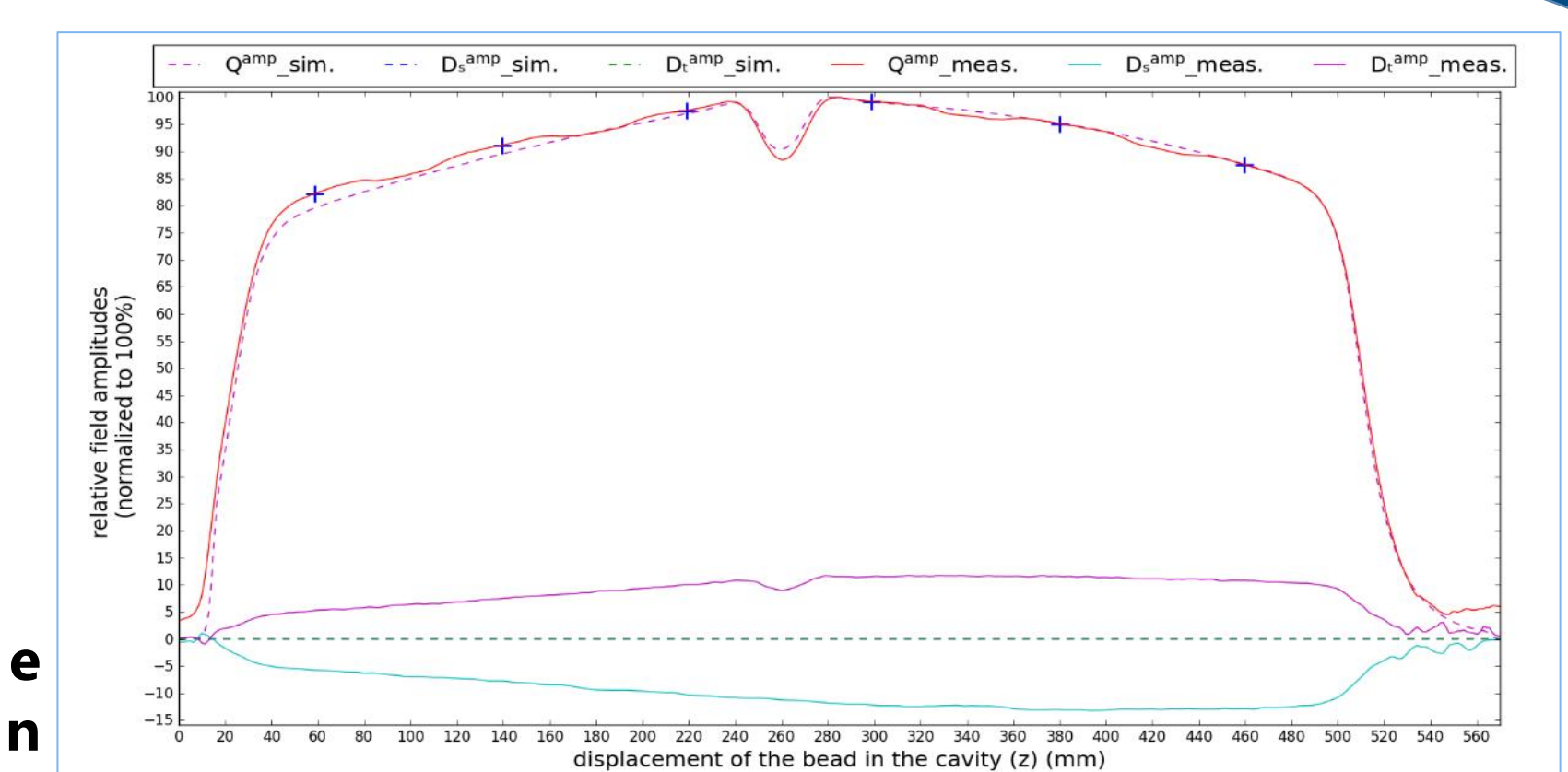


(a)

(b)

Figure 3: (a) Fabricated vanes of the 800 MHz RFQ and (b) view of the rough assembly of each module. The mechanical, vacuum and RF tests of the test module of the PTAK-RFQ contributed to the emergence of its final design. In addition, the previous experience has also led to facilitating solutions in the production process of the final PTAK-RFQ such as addition of alignment pins and enlargement of intersecting channel widths. Hence, the 800 MHz four-vane RFQ, which consists of two modules, was successfully produced from oxygen-free copper material (see Figs. 2(a) and 2(b))[4].

The Field Tuning for the 800 MHz PTAK-RFQ



(a)

(b)

Figure 5: the comparison between simulated field components and measured field components: (a) before the field tuning and (b) after the final field and frequency tuning [2, 3].

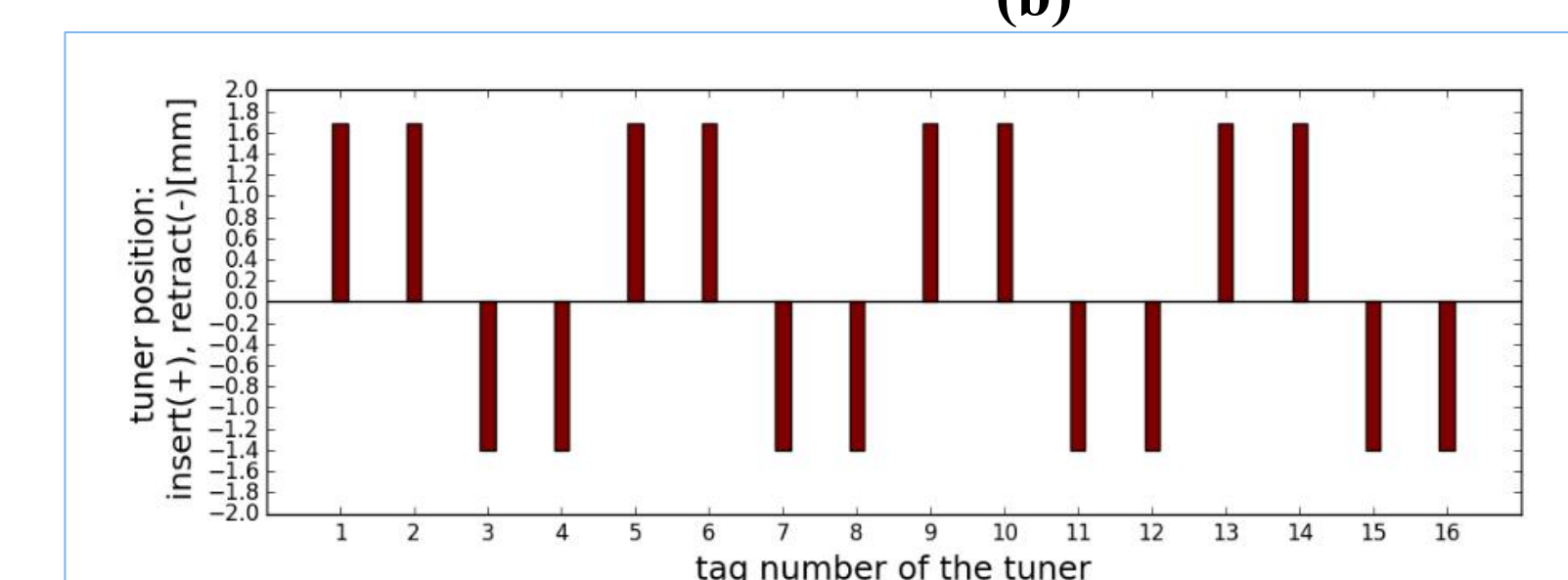


Figure 4: Final tuner lengths after the field and frequency tuning

Firstly, it has been subjected to several mechanical, surface and alignment tests.

- The vane tip errors were found to be less than 20 μm .
- The roughness was measured to be less than 0.2 μm on the lateral surfaces.
- Finally, the 4 vanes were disassembled and reassembled multiple times to measure the vane alignment repeatability. This alignment error is reduced from 40 μm to about 25 μm due to the alignment pins.

Vacuum tests are currently ongoing [4].

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