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COMMISSIONING OF SANAEM RFQ ACCELERATOR

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Abstract

The former SANAEM RFQ is upgraded with a newly manufactured cavity, made of oxygen-free copper (OFC), having the capability of accelerating protons from 20 keV to 1.3 MeV. In the assembling of cavity vanes, flanges, etc., indium wire is preferred over the brazing process providing a more flexible and easy method for vacuum sealing. After assembling the cavity, argon plasma cleaning is performed for the final cleaning and RF pre-conditioning. Vacuum tests revealed that levels of 2×10^{-7} mbar could be achieved quite easily. RF power conditioning of the RFQ cavity is successfully completed with the observation of quite few sparks. In the commissioning tests with the proton beam, a magnetic analyzer is used to measure the energy of the particles. This paper presents the strategy and the results concerning the commissioning of the proton beam with special emphasis on the RFQ cavity.

INTRODUCTION

The project SANAEM RFQ started in the year 2012 under the sponsorship of the Turkish Atomic Energy Authority (TAEA) (lately reformed as the Turkish Energy, Nuclear and Mineral Research Agency (TENMAK) in 2019) with the aim of developing local expertise and capabilities by designing, manufacturing and operating a proton beamline based on an 352.21 MHz RFQ accelerator cavity (Table 1).

Table 1: Design Parameters of the SANAEM RFQ

Parameter	Design	Realized
Frequency [MHz]	352.21	352.21
Input Energy [keV]	20	20.8
Output Energy [MeV]	1.3	1.3
Beam Current [mA]	1	~1
Inter-vane Voltage [kV]	60	60

The beamline starts with an Inductively Coupled Plasma (ICP) ion source of H^+ with 20 keV output energy, where the Low Energy Beam Transfer (LEBT) line consists of a beam diagnostic box, 2 solenoids and 2 steering magnets and followed by a vane type RFQ cavity and a beam analyzer magnet. An inductive type coupler was considered to ensure proper coupling with the RFQ cavity [1]. The accelerator is designed to operate in pulsed mode with 85 kW input power, 100 μs pulse length and 0.03% duty factor. The final status of SANAEM RFQ beamline can be seen in Fig. 1.

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Figure 1: Current view of SANAEM RFQ beamline.

Initially, a cold model was manufactured to develop bead-pull measurement setup and methods, and enhance electromagnetic practices. Subsequently, a copper plated aluminum RFQ cavity based on as-built drawings was manufactured to test the domestic machining capabilities. The first RFQ cavity, manufactured from aluminum and copper plated except the vane tips (Fig. 2), did not perform as designed mainly due to machining errors, revealed by CMM measurements [2]. Following the result of assessment on the machining capabilities of a highly dedicated company [3], it was decided to use the OFC billets, purchased at the start of the project and reserved for the final production of the RFQ cavity.

Figure 2: One of the firstly manufactured RFQ vane and deformed tips due to sparks.

The CMM measurements manifested that manufacturing errors of less than 10 microns were obtained. Before assembling, the vanes were cleaned chemically, then rinsed with deionized water and ethyl alcohol. In the assembly phase, indium wire was preferred over brazing, a highly skilled and more widely performed process, considering its well-known

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vacuum sealing performance and good electrical conductivity (Figs. 3, 4). After the cavity was assembled with the indium wire and bolted, external grooves were filled with a high vacuum compatible adhesive in order to make the RFQ cavity more robust.

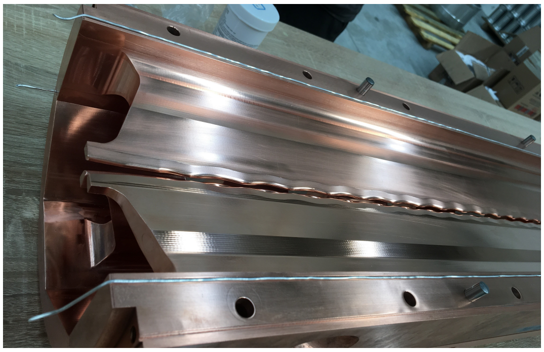


Figure 3: A view of the indium wires placed in the vanes' grooves during the assembly phase.

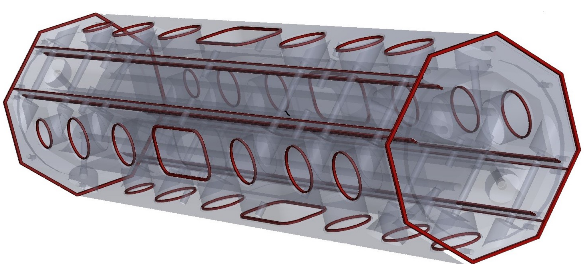


Figure 4: 3D view of employed indium wires.

All RFQ cavity components were assembled by the deployment of indium wire at all junction points. Consequently, a vacuum level of about 2×10^{-7} mbar was achieved readily by the use of 3 mechanical and 3 turbo pumps. On the other hand, bead-pull measurements were carried out by the use of LabVIEW software to ensure field flatness and determine the quality factor (Fig. 5) [4].

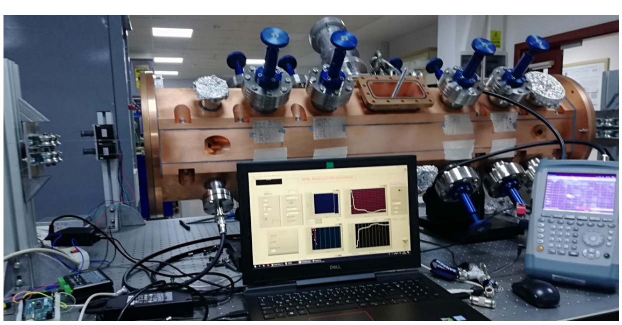
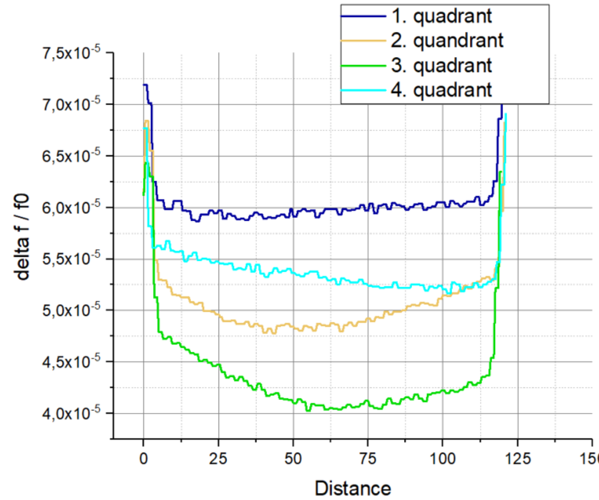
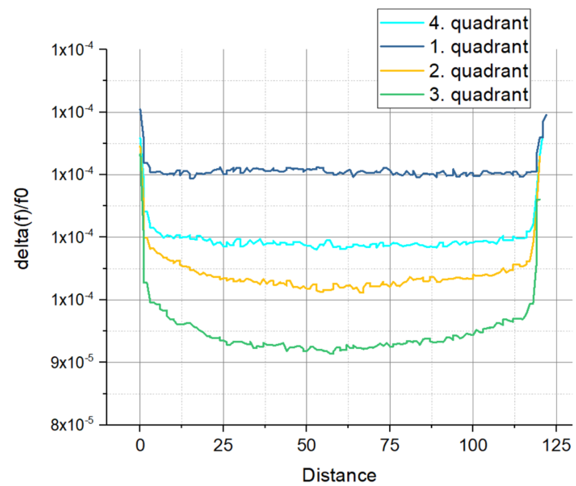


Figure 5: Bead-pull measurement setup.

Following the bead-pull and cavity tuning studies, the field flatness of 98.7% was achieved and the quality factor was measured to be 6200 (Fig. 6).



(a)



(b)

Figure 6: RFQ cavity field profile (a) before tuning and (b) after tuning.

Then, plasma cleaning, a widely known method in the industry, was applied to the RFQ cavity which improved the quality factor appreciably, namely from 6200 to 9200 (Fig. 7) [5]. Finally, the RFQ cavity was connected to the beamline and vacuum tests were carried out.

RF CONDITIONING

The RF conditioning procedure was initiated with the power level of 15 kW, after the multipacting analysis studies revealed that above about 10 kW RF power level no multipacting would be observed inside the vacuum section of the power coupler, and followed by an increase of 5 kW in each step with equal time intervals up to 100 kW [6].

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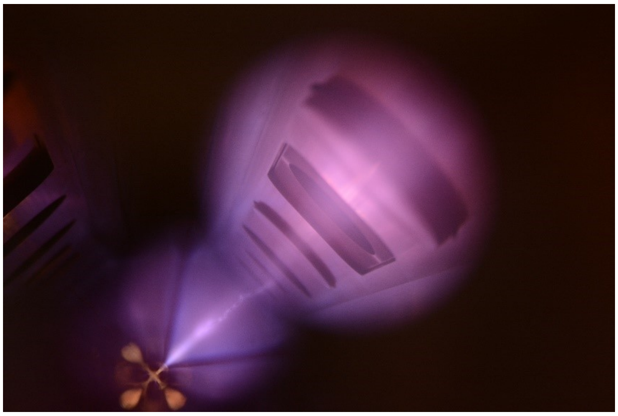

Figure 7: An image taken during plasma cleaning.

The RF waveforms observed during RF conditioning display a good matching between the transmission line and the RFQ cavity (Fig. 8).

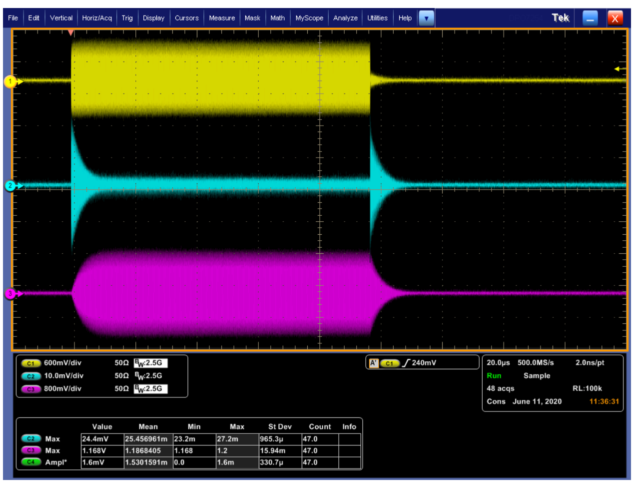

Figure 8: RF waveforms of the RFQ cavity (yellow-RF input, turquoise-reflection, violet-RF build-up inside).

BEAM COMMISSIONING

Prior to particle acceleration studies, beam alignment operation was carried out by laser and beam-based methods to ensure mechanical and magnetic alignment. Solenoid and steering magnets were adjusted in order to keep the beam aligned from the ion source, in the center along the beam tube. At the output of the second solenoid (just before the RFQ), beam centering was checked again using phosphorus screen, and the current was measured again with a moveable Faraday cup as approximately 1 mA.

The proton beam was first accelerated to 1.3 MeV on January 24, 2020 at the RFQ output by visualizing on a screen of monitoring tube.

CONCLUSION

The upgraded SANAEM RFQ cavity has been manufactured, assembled and conditioned successfully. Nearly all accelerator components were manufactured by local companies except RF power amplifier tube (TH595). The design goal of accelerating proton beam to 1.3 MeV was achieved by the end of project schedule. It can be concluded that the plasma cleaning procedure and use of indium wire enhanced the quality factor and vacuum level of the RFQ accelerator cavity.

ACKNOWLEDGEMENTS

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REFERENCES

[1] E. Cicek *et al.*, "A compact RF power coupler design for the SANAEM RFQ accelerator", *AIP Conference Proceedings*, vol. 2042, p. 020057 2018. doi:10.1063/1.5078929

[2] G. Turemen *et al.*, "Manufacturing and the LLRF Tests of the SANAEM RFQ", in *Proc. 7th Int. Particle Accelerator Conf. (IPAC'16)*, Busan, Korea, May 2016, pp. 964–967. doi:10.18429/JACoW-IPAC2016-MOPOY051

[3] Böke Mühendislik Makina Savunma ve Havacılık San. Tic. Ltd. Şti., Ankara, Turkey, https://www.bokemakina.com/tr

[4] LabVIEW System Design Software, http://www.ni.com/labview

[5] E. Cosgun *et al.*, "Manufacturing, Assembling and Plasma Cleaning of New SANAEM RFQ", *JINST*, to be published.

[6] E. Cicek *et al.*, "Electromagnetic simulations, manufacturing and low power measurements of a 352.21 MHz RF power coupler for the SANAEM RFQ project", *Journal of Instrumentation*, vol. 13, p. T10005, 2018. doi:10.1088/1748-0221/13/10/t10005