

Fabrication of New 3-MeV Radio Frequency Quadrupole for KOMAC

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1. Introduction

Since its commissioning in 2013, the 100-MeV proton linear accelerator (linac) at the Korea Multi-purpose Accelerator Complex (KOMAC) has provided stable beam services for a broad range of scientific and industrial applications. With more than 11 years of continuous operation and over 35,000 accumulated beam hours, the facility has entered a phase in which systematic aging management has become essential.

The radio-frequency quadrupole (RFQ), which has served as the injector since its initial commissioning in 2004, has exhibited gradual performance degradation. Endoscopic inspections of the vane surfaces revealed extensive arcing marks and surface erosion, indicating that cumulative surface damage is the primary cause of the observed deterioration (Fig. 1). To address this issue and ensure long-term operational stability, a new RFQ has been designed to replace the existing structure. The upgraded design incorporates several modifications aimed at improving mechanical reliability, beam transmission efficiency, and operational robustness.

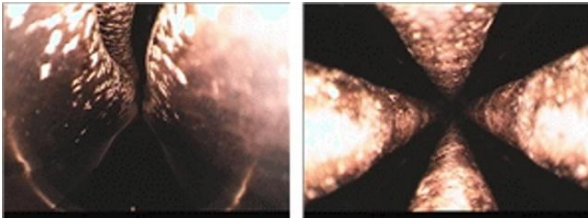


Fig. 1. Damaged RFQ vanes.

2. Design Highlights of New RFQ

In the revised design, the resonant coupling structure previously located at the midsection of the RFQ was eliminated to simplify the mechanical configuration and enhance field tunability. The total cavity length was extended from 3,266 mm to 3,537 mm to improve high-current beam transmission performance.

A significant modification was implemented in the gentle buncher section, where the output energy was increased from 550 keV to 580 keV while maintaining the same input energy of 86.5 keV. Beam dynamics simulations indicate that this adjustment substantially enhances transmission efficiency under high-current conditions, while preserving tolerance against various alignment and field errors.

Furthermore, the transverse focusing strength was carefully optimized to achieve smooth phase advance

matching between the RFQ exit and the entrance of the downstream drift tube linac (DTL) [1]. This optimization contributes to minimizing emittance growth and improving overall beam quality in subsequent acceleration stages.

Table 1: Design parameters of the new RFQ

Parameter	Value
Input beam energy	50 keV
Output beam energy	3 MeV
Operating frequency	350 MHz
Transverse emittance	0.2π mm.mrad
Longitudinal emittance	0.107 deg.MeV
RFQ type	4 - vane
Vane voltage	85 kV
ρ/r_0	0.87
Length	353 cm

3. Fabrication Status

Fabrication of the new RFQ is currently underway. The major and minor vanes have completed rough machining and cooling-channel drilling. To ensure mechanical integrity and reliable sealing of the cooling channels, plug brazing was performed using a gold-copper alloy (AuCu, 50:50). This process also served as an annealing step to relieve residual stresses introduced during machining, thereby minimizing deformation during the subsequent assembly brazing process.

Final machining and dimensional verification using three-dimensional scanning techniques are in progress, followed by precision brazing assembly. Figure 2 presents the three-dimensional CAD model of the new RFQ, including interfaces for auxiliary systems such as vacuum pumping ports, cooling pipelines, and the granite-based support structure. Figures 3 illustrates a minor vane under final machining. Figure 4 and 5 show the brazing setup for final assembly and the temperature record during the brazing process, respectively. The remaining procedures include resonant frequency adjustment, field tuning, and full-power RF conditioning, which are scheduled for completion within this year.

The upgraded RFQ is expected to restore and enhance the injector performance of the 100-MeV linac, thereby ensuring reliable long-term operation of the facility. The design modifications and fabrication

strategies presented in this work may also serve as a practical reference for RFQ replacement or upgrade projects at other accelerator facilities encountering similar aging-related challenges.

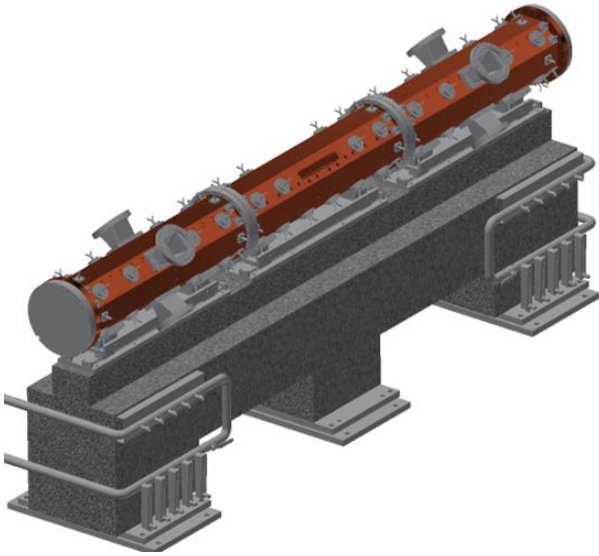


Fig. 2. 3D CAD model of the designed new RFQ.



Fig. 3. RFQ minor vane under final machining.

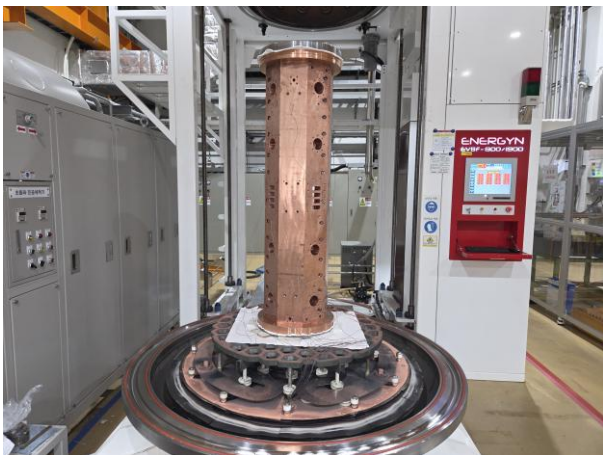


Fig. 4. Brazing setup for final assembly.

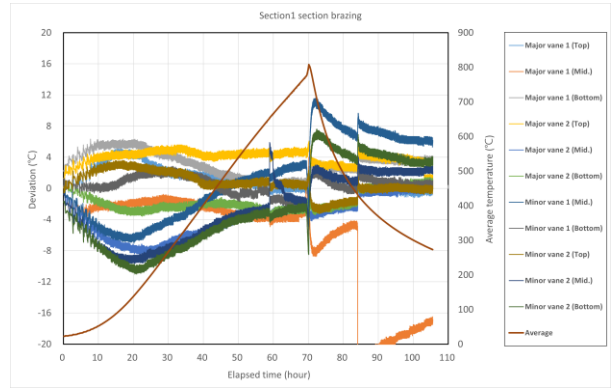


Fig. 5. Temperature record during brazing process.

4. Summary

A new RFQ has been designed and is currently under fabrication to replace the aging injector of the 100-MeV proton linac at KOMAC. The redesign focuses on enhancing mechanical reliability, beam transmission efficiency, and operational robustness in response to performance degradation observed after extended operation. Key improvements include the elimination of the midsection resonant coupling structure, extension of the cavity length to improve high-current transmission, and optimization of the gentle buncher section to increase the output energy while maintaining error tolerance. In addition, the transverse focusing strength was carefully adjusted to ensure smooth beam matching with the downstream DTL. Fabrication processes, including precision machining, plug brazing AuCu alloy for stress relief and cooling-channel sealing, and dimensional verification, and final brazing for whole assembly are completed. The design and fabrication strategies presented in this work may provide practical guidance for similar RFQ replacement or upgrade projects in other accelerator facilities confronting aging-related challenges.

ACKNOWLEDGMENTS

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REFERENCE

[1] H. S. Kim, S. H. Moon, D. H. Kim, S. H. Lee, H. J. Kwon, New 3-MeV RFQ Design and Fabrication for KOMAC, LINAC2024 proceedings.