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Development Status of New 3-MeV RFQ for KOMAC

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1. Introduction

Since the latter half of 2013, the Korea Multi-purpose Accelerator Complex (KOMAC) has been providing user beam services using a 100-MeV proton linac. With the proton accelerator operating for over 11 years and accumulating more than 35,000 hours of operation, we believe it is an appropriate time to establish a long-term plan to address aging-related issues.

The RFQ, used for the injector of the 100-MeV linac, was successfully developed and has been in operation for more than 20 years since its initial commissioning in 2004. However, the performance of the RFQ has gradually degraded over time.

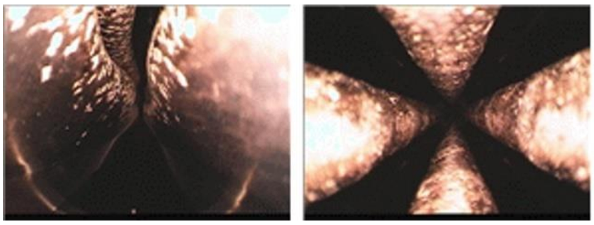

Fig. 1. Damaged RFQ vanes.

We suspect that the degradation in performance is due to damage to the RFQ vanes, which was confirmed through direct observation using an endoscope as shown in Fig. 1. We observed numerous arcing spots and surface degradation. Consequently, we have decided to design a new RFQ to replace the existing one with several modifications.

In the new design, we removed the resonant coupling structure in the middle of the RFQ to simplify the structure and facilitate tuning. Additionally, we increased the RFQ length from 3,266 mm to 3,537 mm to improve beam transmission efficiency in high-current mode. An error study on the new structure indicates that the design is robust against various error sources [1]. This paper will present the highlights of the new RFQ design and the current fabrication status.

2. Design of New RFQ

The new RFQ incorporates several improvements and modifications while maintaining a design similar to the existing RFQ. As a result, the new RFQ parameters, listed in Table 1, closely resemble those of the current RFQ. Although many parameters remain unchanged, a significant modification is the adjustment of the energy range in the gentle buncher section. In the old RFQ, the gentle buncher's energy range extends from 86.5 keV to 550 keV, whereas in the new RFQ, it ranges from 86.5 keV to 580 keV. While this difference is only 30 keV, our studies indicate that extending the energy range enhances beam transmission rates.

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	0.2 π.mm.mrad
Longitudinal emittance	0.107 deg.MeV
RFQ type	4 - vane
Vane voltage	85 kV
ρ/r_0	0.87
Length	353 cm

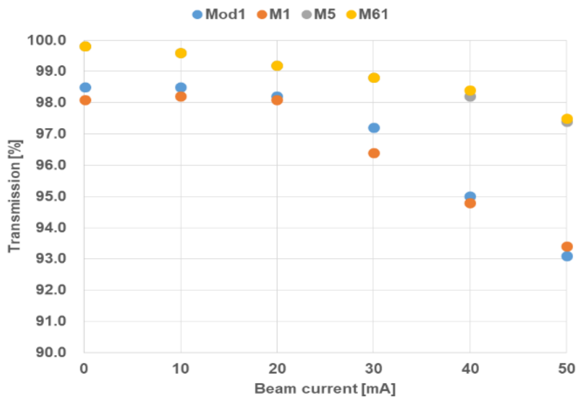

Fig. 2. Beam transmission rate with various case.

Figure 2 illustrates the beam transmission rate under different conditions. "Mod 1" represents the existing RFQ, while "M1" is similar to Mod 1 but without variations in the focusing parameter B. Cases "M5" and "M61" correspond to the increased energy range of the gentle buncher, with and without B variation, respectively. The data indicate that a wider energy range in the gentle buncher improves the beam transmission rate, with a more pronounced effect under high-current conditions.

Expanding the energy range of the gentle buncher necessitated changes to the total length and geometry of the RFQ. Figure 3 compares the old and new RFQs in terms of the modulation parameter (m) and the minimum aperture (a).

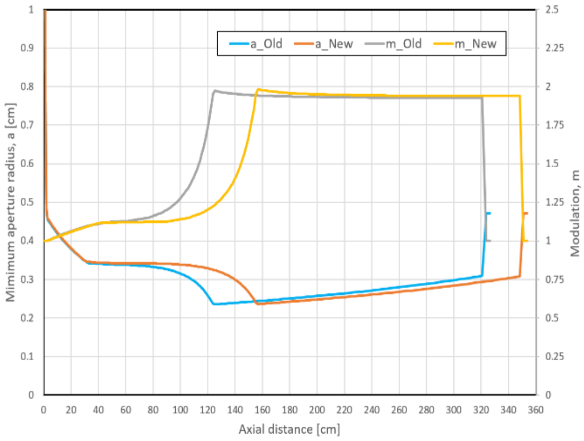

Fig. 3. Comparison between old and new RFQs in terms of modulation and minimum aperture.

Another critical aspect of RFQ design optimization involves adjusting the focusing strength. We optimized the focusing strength to align the phase advance between the end of the RFQ and the beginning of the DTL section. Figure 4 shows the phase advance per unit length for various focusing strengths, including the optimized value.

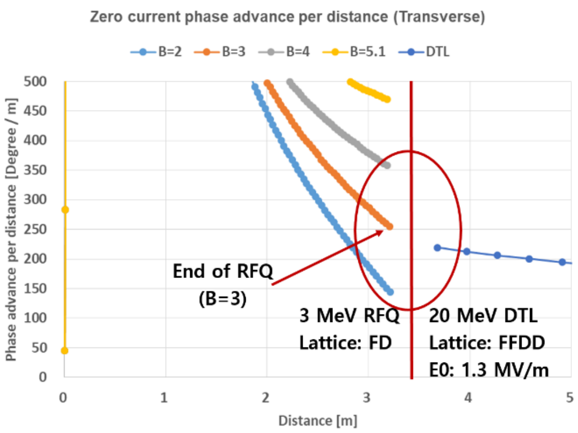

Fig. 4. Optimization of focusing strength for phase advance matching with DTL.

3. Fabrication Status

Figure 5 shows the 3D CAD model of the new RFQ, including auxiliary system interfaces such as vacuum pumping ports, cooling pipes, and a granite-based supporting structure. The new RFQ is currently under fabrication. Rough machining of the major and minor vanes, as well as drilling of the cooling channels, has been completed. To seal the cooling channels, we performed plug brazing using a gold-copper alloy as the filler material. This brazing process also serves as an annealing step to relieve stress induced during rough machining and to minimize component deformation during the final assembly brazing process.

At present, final machining is in progress. Upon completion, the parts will be inspected using a 3D scanner to verify dimensional accuracy. The components will then be assembled through brazing. Following assembly, field tuning and resonant frequency tuning will be conducted. The overall high-power RF test of the new RFQ is scheduled to be performed later this year.

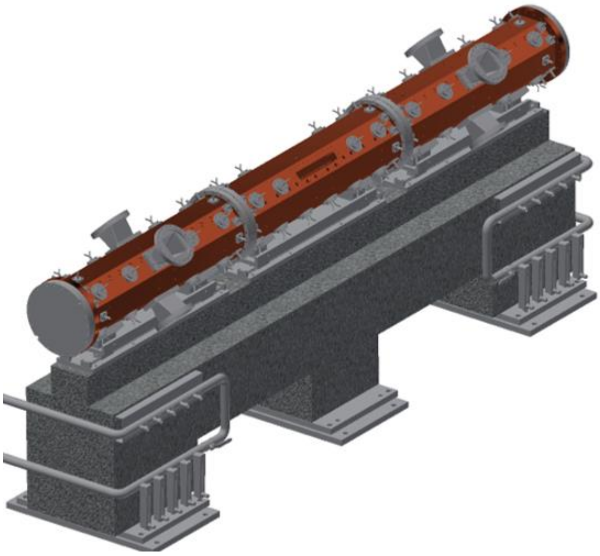

Fig. 5. 3D CAD model of the designed new RFQ.

Fig. 6. Vacuum leak check after plug brazing.

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.