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Design of New 3-MeV RFQ for KOMAC Accelerator

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1. Introduction

A 100-MeV high power proton linac has been operated and used for user service since 2013 at KOMAC. The 100-MeV linac is composed of an ion source, LEBT (low energy beam transport), 3-MeV RFQ, 20-MeV DTL and 100-MeV DTL. The RFQ system takes crucial role of bunching the quasi-continuous beam from the ion source with proper focusing as well as beam acceleration from 50 keV to 3 MeV. The RFQ is a four-vane type with four sections. Notable design feature of the existing RFQ is that it utilizes the resonant coupling mechanism to stabilize the field profile along the longitudinal direction. The design parameters of the RFQ are summarized in Table 1. Figure 1 shows the installed KOMAC RFQ along with the cross-sectional view of the RFQ cavity [1-3].

The RFQ has been operated for almost 20 years since it was first commissioned in early 2004. The performance of the RFQ showed gradual degradation and the recent status in terms of the beam transmission efficiency is as low as 50%. One of the reason for such low performance might be the vane surface damage by arcing, which was confirmed by direct surface inspection using endoscope. We could find a lot of arcing spot and surface damage as shown in Fig. 2. Therefore, we decided to prepare a new RFQ to replace the existing one and performed basic design study by using PARMTECH code and SuperFish code. In the new design, we decide not to use the resonant coupling, based on the experience with a newly-developed 200-MHz RFQ study [4].

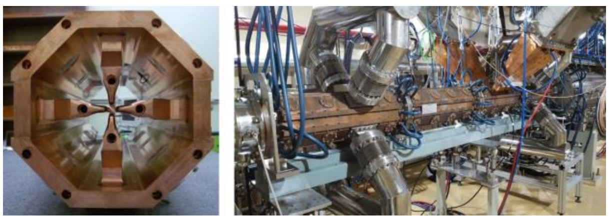

Fig 1. Existing RFQ at KOMAC

2. Design of the New RFQ

The design parameters of the new RFQ is almost same as the existing one, except the RFQ cavity length. Therefore the parameters shown in Table 1 is still valid for the new RFQ. The major change in the new design distinguished from the old existing RFQ is the gentle buncher energy range. From the beam dynamics study by using PARMTECH code, we found that beam transmission efficiency, especially for high beam current, improved by increasing the gentle buncher energy range, as shown in Fig. 3, at the cost of increased cavity length. The gentle buncher energy range of the old RFQ is from 86.5 keV to 550 keV. If we lower the gentle buncher starting energy from 86.5 keV to 54.0 keV and increase the gentle buncher end energy from 550 keV to 580 keV, the beam transmission efficiency at 50 mA improves from 93 % to 97.5 %.

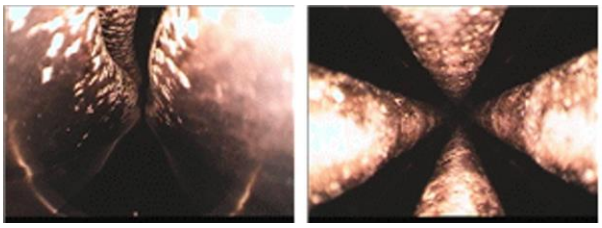

Fig 2. Damaged RFQ vane electrodes

Table 1: Existing RFQ parameters

Parameter	Value
Input beam energy	50 keV
Output beam energy	3 MeV
Operating frequency	350 MHz
Peak beam current	20 mA
Emittance (normalized rms)	0.2 pi mm mrad
Longitudinal output emittance	0.112 deg-MeV
Vane voltage	85 kV
RF power	460 kW
Maximum electric field	1.8 kilpatrick
p/r0	0.87
Duty factor	24% max.
Length	325 cm
Transmission	98.3%

Figure 4 shows the comparison between the existing RFQ and newly designed one in terms of the minimum aperture and modulation parameter. As can be seen in the figure, the length of the gentle buncher section is increased, which makes the cavity longer by about 30 cm.

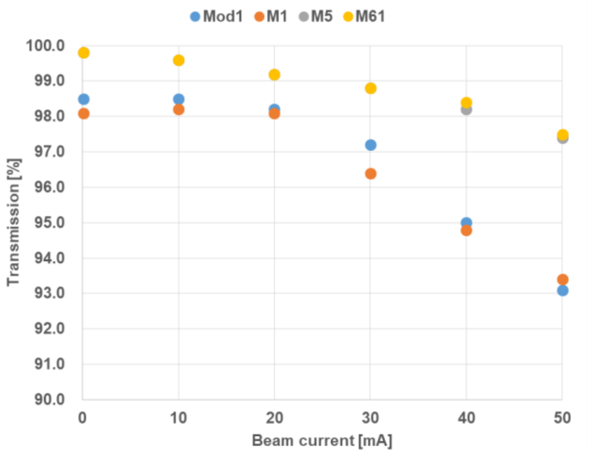

Fig. 3 Beam transmission efficiency as a function of the beam current. Mod1 case is for the existing RFQ, M1 case is same as Mod1 without focusing parameter B variation, M5 and M61 cases are for the increased gentle buncher energy range without focusing parameter B variation and with B variation, respectively.

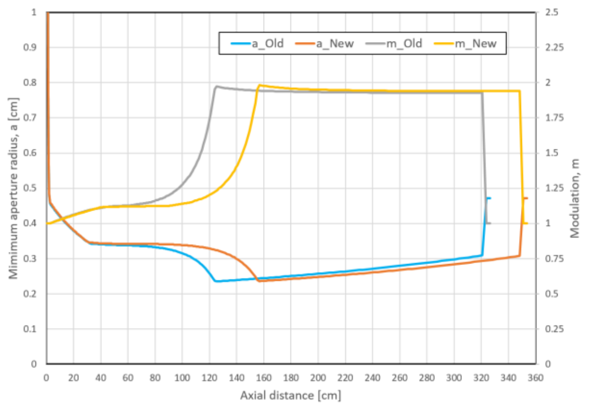

Fig. 4. Comparison between the existing RFQ and new RFQ in terms of the minimum aperture and modulation parameter along the beam axis.

At the acceleration section after the gentle buncher, the minimum aperture is slightly increased, while the modulation parameter is nearly constant, which makes the focusing strength B gradually decrease. By changing the focusing parameter, we can adjust the phase advance per unit length at the end of the RFQ and match the phase advance to the value of DTL section (Fig. 5). Because the average aperture is continuous varying along the beam axis, we have to adjust the cross-section of the RFQ to make correct resonant frequency. The geometric parameter for the RFQ cross-section. We adjusted the vane skirt width to correct the resonant frequency by using SuperFish code. Total number of cell of the new RFQ is 334 including the radial matching section at starting end and transition cell at the end of RFQ, and as many of the cross-sections were generated.

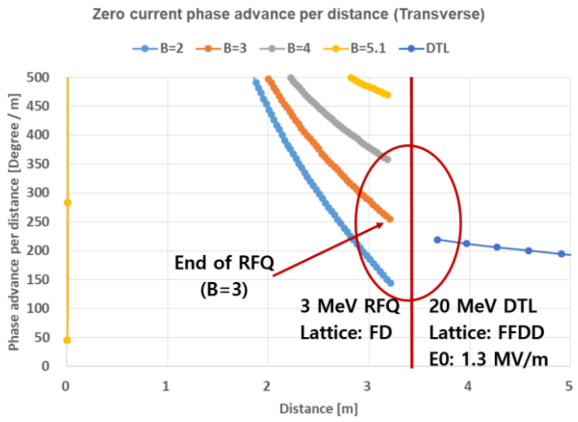

Fig. 5. Adjusting the focusing strength to matched the phase advance between the RFQ and DTL.

3. Conclusions

We have designed the new RFQ to replace the existing one. For better beam transmission efficiency and immunity to the input beam error, we increased the gentle buncher energy range, which resulted in increase in the cavity length. The fabrication of new RFQ will start in next year. Before that, we finalize the RFQ engineering design including full 3D electromagnetic analysis and mechanical analysis.

ACKNOWLEGEMENTS

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