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Design and Fabrication of the ESQ triplet for RAON LEBT

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1. Introduction

The RAON accelerator is the heavy ion accelerator being built in Korea. Injector of RAON accelerator, which is composed of Electron Cyclotron Resonance Ion Source(ECRIS), Low Energy Beam Transport(LEBT), Radio Frequency Quadrupole(RFQ), and Middle Energy Beam Transport(MEBT), will deliver several kinds of heavy ion beam to the main driver linear accelerator[1]. LEBT is composed of some focusing elements such as electrostatic quadrupole and solenoid, and et al, to remove the impurity extracted from the ion source and to deliver the target heavy ion beam.

2. Design

2.1 Basic 2D design

The design parameters which are given from the beam optic analysis were summarized in the Table I.

Table I: Design parameters for the ESQ triplet

parameter	value
Bore radius	60 mm
Applied potential	10 kV
Effective length	150 mm

The electrode shape was designed considering the above design parameters and some aspects for machining and assembly of the ESQ triplet. In an ideal electrostatic quadrupole, the electrodes would be hyperbolic in shape. One could achieve a perfect quadrupole field without any multi-pole fields if we apply the infinite hyperbola shape to the electrode. However, fabrication and assembly concerns act as limitations to the manufacture and use of infinite hyperbolic electrodes. Instead, circular electrodes, which are easier to fabricate and assemble with minimal error, will be used. This will introduce additional, multi-pole fields which can be minimized, but not eliminated. Considering the beam pipe inner diameter of LEBT is 120mm, the distance between the opposite electrodes is also 120mm. As the rule of thumb, the optimum value of the radius for the circular shaped electrode is 1.15 times of the bore radius. Considering that, the optimum radius of the electrode is 69mm in the case that the bore radius is 60mm. Using Poisson-superfish code, we review the multi-pole field strength according to the variation of the circular shaped electrode, Fig 1.

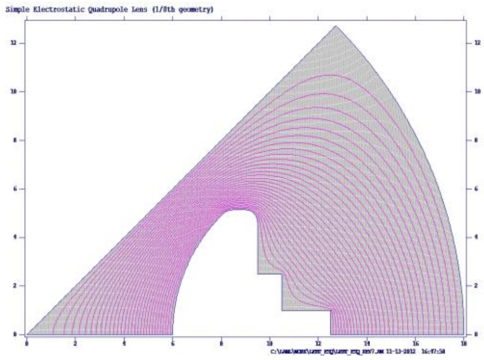

Fig. 1. Electrode shape for 2D Electro-static analysis.

If we assume that there is no misalignment of the electrode, we can calculate the multi-pole field just originally induced by the electrode shape. Due to the symmetric characteristics of the quadrupole, just 12-pole and 20-pole could exist. As shown in Fig. 2, the 12 pole field varies by the variation of the pole shape, and is larger than 20 pole field relatively. As expected, optimum pole tip radius is about 70mm, and the multi pole field strength is less than 0.3% of the quadrupole field.

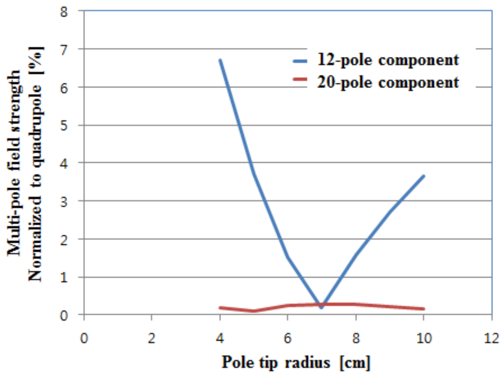

Fig. 2. Analysis result for the optimum circular pole shape

2.2 3D design

Through the 3D analysis, the length of the electrode to satisfy the effective length of 150mm was determined as shown in Fig. 3. Effective length was calculated with the following equation and the length of the electrode was determined as 100mm.

$$L_{eff} = \frac{\int_{Z_{min}}^{Z_{max}} E(z)dz}{E_{max}} \qquad (1)$$

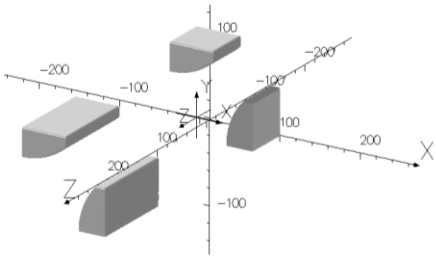

Fig. 3. 1/8 3D model for the calculation of the ESQ effective length.

3. Fabrication

A ground plate was inserted between each quadrupole set which composed the whole ESQ triplet as shown in Fig. 4. This grounded plate sustains the constant effective length of each quadrupole set even though the applied potential for each quadruple set varied.

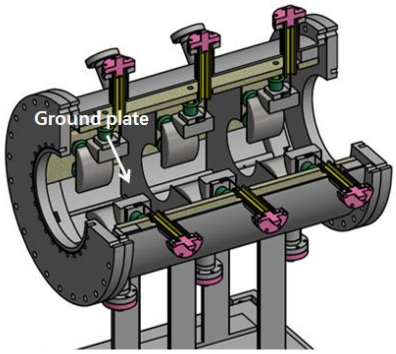

Fig. 4. 3D schematics of the designed ESQ triplet

Each electrode is assembled onto the inserting structure which is composed of 4 straight bars and 2 circular rings as shown in Fig. 5. The distance between each electrode is measured during assembly and adjusted with foil spacers.

Fig. 5. Assembled electrodes structure of the ESQ triplet

Then, the assembled electrode structure was inserted into the vacuum chamber, Fig. 6. We are assure the co-axial structure between the electrode structure and the vacuum chamber using a precisely machined align pins which are shown in Fig. 7. We also installed the sputtering shield, Fig.7, to protect the surface contamination of the ceramic insulator by the beam loss which can cause the electrical breakdown.

Especially, the highly charge ion beam accelerator need the relatively high vacuum level because the beam can loss its charge state easily through the charge exchange process with the residual gas. So the metal wire seal which has relatively low leak rate was used instead of the o-ring seal for the vacuum chamber, Fig. 8

Fig. 6. Assembly of the electrode structure and the vacuum chamber.

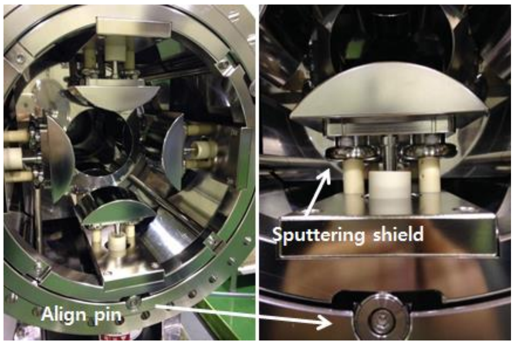

Fig. 7. The assembled ESQ triplet.

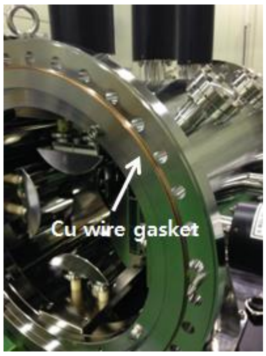

Fig. 8. Vacuum seal for the vacuum chamber.

4. Conclusions

ESQ triplet was designed and fabricated for the RAON accelerator LEBT. Test procedure will be done to verify the performance in near future.

REFERENCES

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[2] B. Durichkovic, P. Gibson, R. Kersevan, and G. Machicoane, FRIB driver linac vacuum model and benchmarks, Vacuum, Vol.104, p13, 2014.