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Engineering Design of Electrostatic Quadrupole for ISOL Beam Lines

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1. Introduction

For the beam transportation in the ISOL system beam lines of the RAON, the electrostatic components were designed based on the beam dynamics calculation. In the ISOL system, the RI beam should be transported from the target ion source to post accelerator through various analyzing and charge-breeding systems such as PS (pre-seperator), HRMS (High Resolution Mass Seperator), RF cooler and A/q separator [1]. A reference particle for the beam dynamics calculation is $^{132}Sn^{1+}$. After charge breeder system, the charge state is boosted from +1 to +19 with ECR charge breeder and to +33 with EBIS charge breeder. Because the beam energy is as low as 50 keV, the electrostatic optics was adopted rather than the magnetic optics. The electrostatic quadrupole triplets were used for the beam focusing and the electrostatic bender is used for 90-degree bending. In this paper, the design procedure and engineering design of the electrostatic quadrupole are presented.

2. Design Procedure

The physics design of the electrostatic quadrupole is given by the beam dynamics calculation as shown in Fig. 1, which shows the beam envelop from the HRMS to the ECR charge breeder. The basic parameters to be determined include the aperature radious, the electrode radius, the electrode length and the applied voltage. The procedure to determine these parameters is shown in Fig. 2. Based on the maximum beam size in the quadrupole, the aperture size is determined to be 100 mm in diameter. Basic lattice is a quadrupole triplet composed of a 300-mm long quadrupole sandwiched by two 150-mm long quadrupoes with 100 mm gap between each quadrupole. The electrode pole tip radius is given by 1.15 times aperture radius, which results in the minimum higher-order components in the quadrupole field.

The breakdown voltage in vacuum condition depends on several factors such as vacuum level, electrode material and geometry. As a rule of thumb, the pole tip field should be limited less than 40 kV/cm [2, 3]. The beam dynamics calculation showed that the maximum electrode voltage is about 3.2 kV, which gives the maximum pole tip of about 3.6 kV/cm, far below the breakdown limitation. The voltage is applied to each electrode by using a vacuum feed-through with a spring contact mechanism.

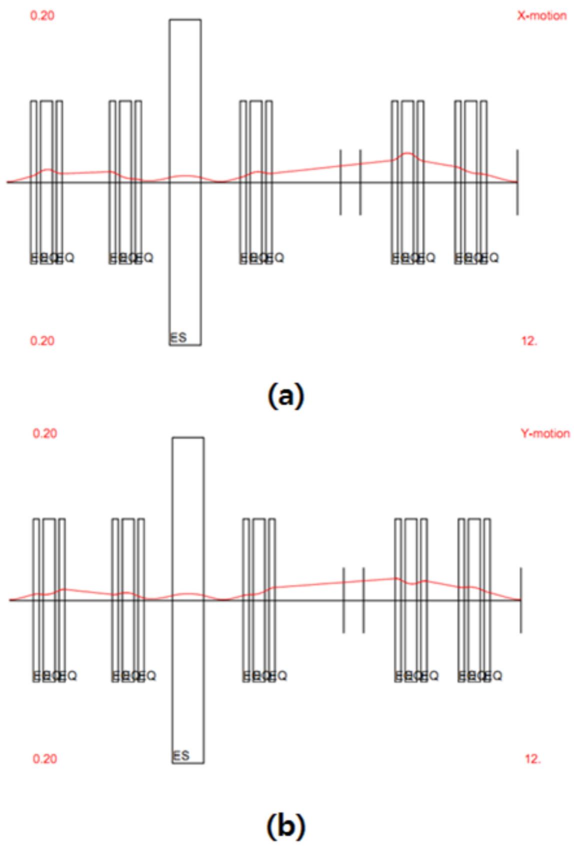

Fig.1. Beam envelop from HRMS to ECR charge breeder; (a) x plane envelop, (b) y-plane envelop.

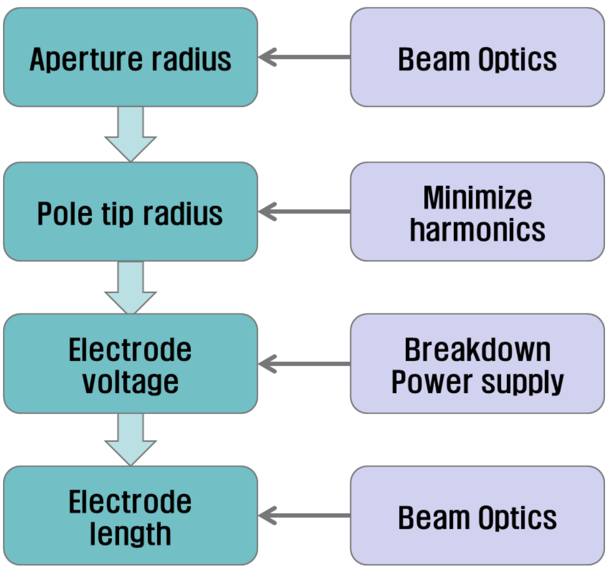

Fig.2. Design flow for ESQ parameters.

3. Engineering Design

Based on the physic design of the electrostatic quadrupole, the engineering design was performed including the 3D field analysis. Fig. 3 shows the electric field vector distribution and Fig. 4 shows the potential distribution when the applied voltage to each electrode is 5 kV. The maximum field strength was 5.28 kV/cm, which is low enough to be free from the worry of the electric breakdown. The magnitude of the electric field along the beam axis is shown in Fig.5.

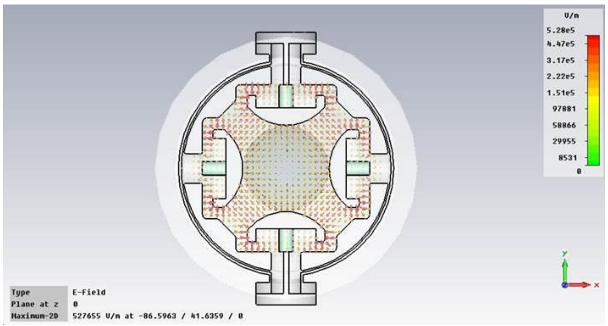

Fig.3. Electric field distribution in the quadrupole.

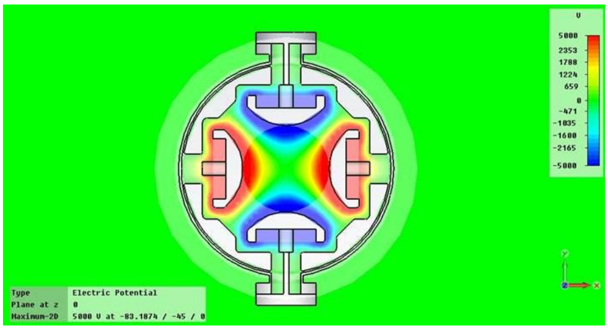

Fig.4. Potential distribution in the quadrupole.

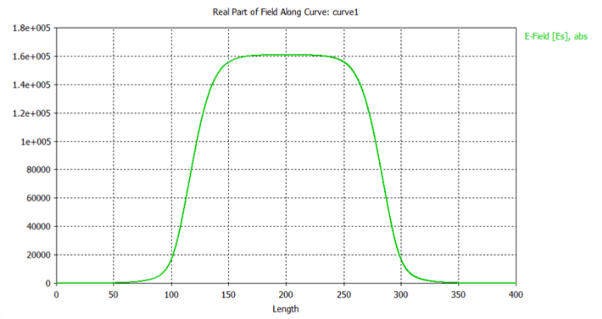

Fig.5. Magnitude of the electric field along beam axis.

Figure 6 shows the designed electrostatic quadrupole singlet. The flange is standard CF flange and the supporter is designed with consideration of position adjustment. Same design is applied to the electrostatic quadrupole triplet as shown in Fig.7. There is a ground plate between each quadrupole to clamp the field and to make the field symmetric. Total length is about 850 mm including the flanges. The feed-through for the electrical connection can be attached after insertion of the quadrupole module into the vacuum pipe.

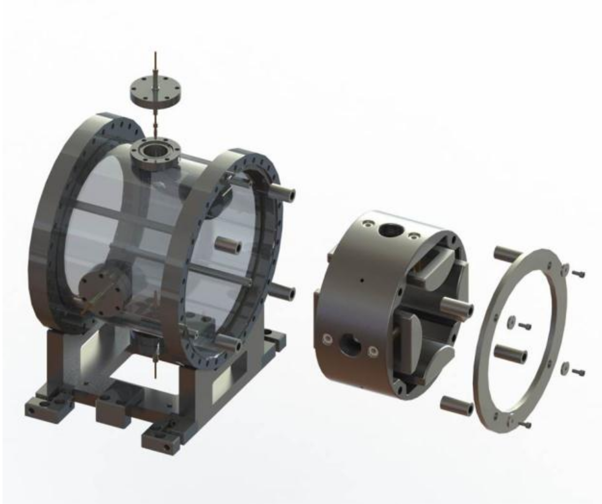

Fig.6. Electrostatic quadrupole singlet.

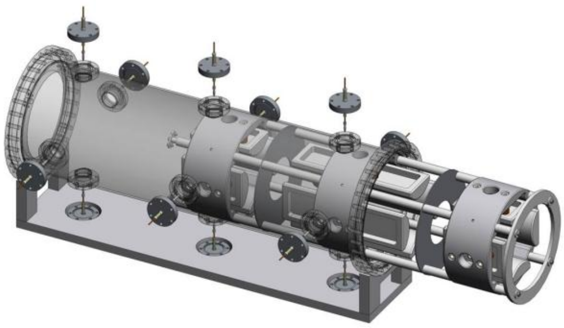

Fig.7. Electrostatic quadrupole triplet.

4. Summary

Based on the beam dynamics calculation, the electrostatic quadrupole triplet is designed. The effective lengths are 150 mm/ 300 mm and aperture diameter is 100 mm. The pole tip radius is 57.5 mm in circular shape. The 3D field calculation was performed and showed that the maximum field strength is far below the electrical breakdown limit.

Acknowledgements

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