OPTICAL DESIGN OF THE EBIS CHARGE BREEDER SYSTEM FOR RAON IN KOREA

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Abstract

Electron beam ion source (EBIS) will be used for charge breeding of rare isotope beams in Rare Isotope Science Project (RISP) the ISOL system. Simulations of EBIS charge breeder system are reported here. The electron beam simulation has been performed by using TRAK code. The electron beam collector deign was optimized based on these electron beam simulation. Ion beam simulation, including acceptance calculation, has also been performed by using TRAK and SIMION codes. In this work, we will also report simulation results on the charge breeding processes in addition to the electron and ion beam dynamics.

INTRODUCTION

In Korea, a heavy ion accelerator facility called RAON is being designed to produce various rare isotopes under the Rare Isotope Science Project (RISP). The RAON has a unique feature of having both Isotope Separation On-Line (ISOL) and In-Flight fragmentation (IF) systems for the various rare isotope productions. Electron beam ion source (EBIS) will be used for main charge breeder in the ISOL system. The EBIS charge breeder has significant advantages over the ECR option for high ion beam intensities, providing higher efficiency, shorter breeding times and significantly better purity of highly charged radioactive ion beams for further acceleration [1]. To reduce emittance of a beam injected into the EBIS, an RFQ cooler is planned to be used as in other facilities. Beam emittance is expected to be reduced by an order of magnitude to around 3 π mm·mrad at 50 keV [2]. The main design and simulation parameters were chosen based on those of the EBIS for the CARIBU project at Argonne National Laboratory [1].

SIMULATION AND OPTICAL DESIGN

The simulation of EBIS system is mainly classified into three parts such as the electron beam dynamics, the ion beam dynamics and electron-ion beam interaction. The TRAK, SIMION and CBSIM codes have been used to design the EBIS charge breeder system for the RISP.

Electron Beam Simulation

The electron gun with IrCe cathode is designed by BINP. The electron beam current is set to be 3 A at the beam energy of 20 keV. The electron beam simulation has been performed from an E-gun cathode to a collector by using TRAK code [3]. The electron beam trajectories are shown in Figure 1. The electron beam current density can reach up to 500 A/cm^2 by maximum magnetic field of about 6 T. This region, which has a maximum electron beam current density, is called ion trap region. The electron beam radius is around 0.45 mm in this region. The radial ion trapping is achieved through the space charge of the electron beam in the ion trap region. The axial trapping is achieved by biasing drift tubes.

The electron beam trajectories in the collector are shown in Figure 2. The electron beam is rapidly spread out from the entrance of the collector because magnetic fields are decreased by a magnetic shield. Furthermore, the electron beam trajecories depend on the potential applied to the repeller and collector body electrode. For the case of Figure 2, the applied voltages of the collector body and the repeller are 1 kV and -10 kV, respectively. The trajectories of electron beam are directly related to the corresponding power density distributions along the inner cylindrical collector surface. Figure 3 presents the corresponding power density distributions under different electrode voltage conditions.

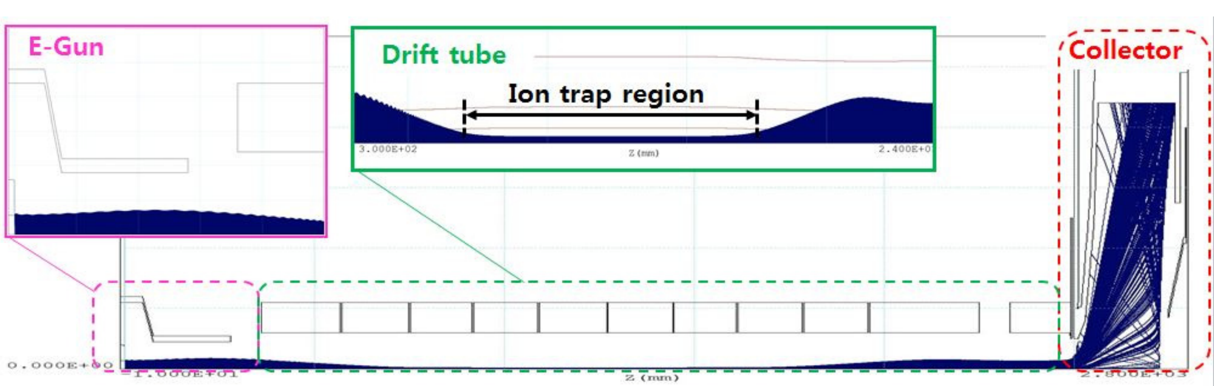

Figure 1: The electron beam trajectories from an E-gun cathode to a collector.

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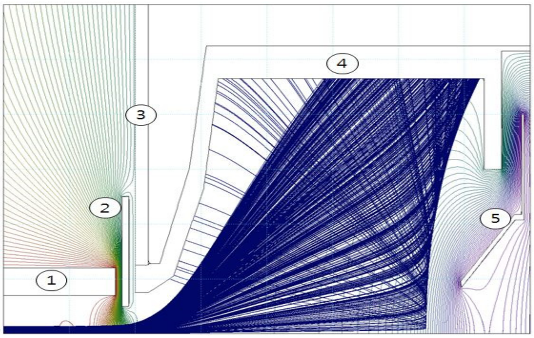

Figure 2: Electron beam trajectories in the collector (①drift tube, ② suppressor, ③ magnetic shield, ④ collector body, ⑤ repeller).

If the absolute repeller voltage increases, the end position of the electron beam dump will be placed further inside of the collector. Whereas the lower collector body voltage, the lower peak power density and the broader power density distribution. For each case of dashed line and straight lines in Figure 3, total power consumptions are 12kW and 15kW, respectively.

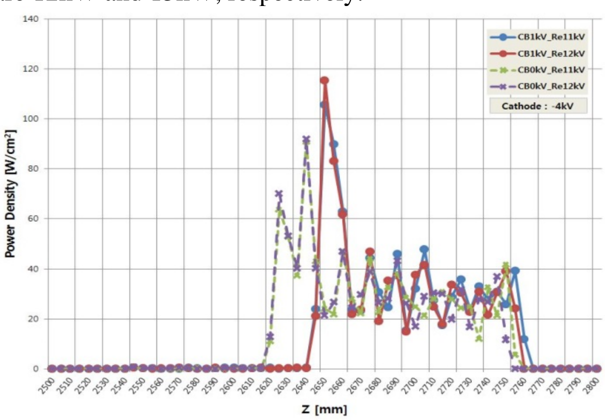

Figure 3: Power density distributions along the collector body for several different voltage settings.

Charge Breeding Progress

The charge breeding was simulated using CBSIM codes [4]. The breeding time of $^{132}Sn^{33+}$ is calculated to be 61 ms under the electron beam conditions of 3A and 20keV. In case of $^{133}Cs^{33+}$, the breeding time is about 67 ms. The estimated charge breeding results of Sn ions are shown in Figure 4.

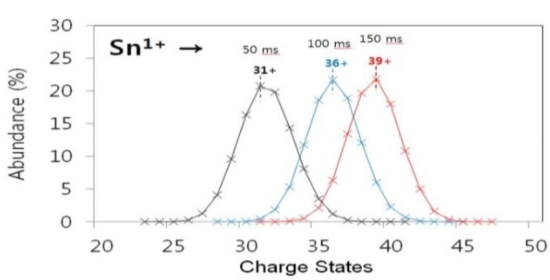

Figure 4: Charge state distribution of Sn ions after breeding times of 50ms, 100ms and 150ms.

Acceptance

An RMS acceptance of the EBIS system is estimated to be 52π mm·mrad assuming partial overlap between ion and electron beams. If 100% of ion-electron overlap is assumed, the acceptance is 14π mm·mrad (Fig. 5).

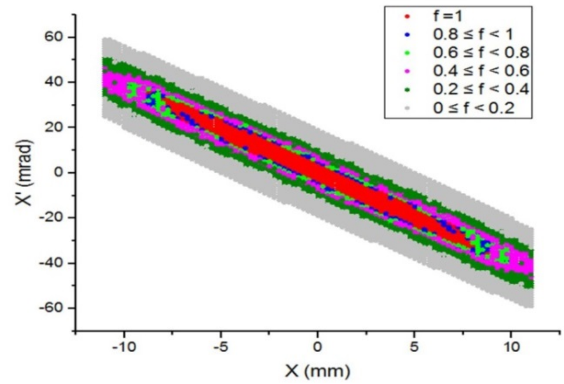

Figure 5: Phase-space of accepted ions.

Ion Beam Extraction Simulation

Figure 6 shows the ion beam trajectories in the presence of the electron beam in the extraction mode.

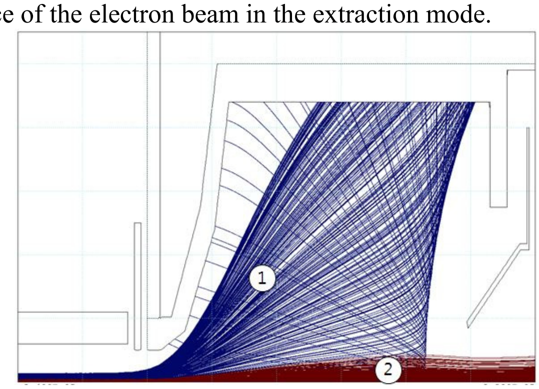

Figure 6: The trajectories of beam in the extraction mode (① electron beam trajectories, ② The $^{132}Sn^{32+}$ ion beam trajectories).

The ion transport simulation has been performed by using SIMION code [5]. The transport optics basically consists of two Einzel lenses. In particular, the repeller is shared for one component of the Einzel lens. Figure 7 shows the structure of the ion transport optics and ion beam distributions at each monitoring plane. The RMS emittance in the X-X' phase space is 44.4π mm·mrad at the starting plane. However, the emittance is increased to 60.6π mm·mrad at the plane #2, and the phase space is also distorted. For this type of ion transport structure with simple Einzel lenses, the potential distribution is asymmetric, and the acceleration section exists inside of the collector. Consequently, we expect that the emittance growth and phase space distortion occur in this case.

In case of CARIBU EBIS charge breeder, a steerer type Einzel lens is adopted to reduce the emittance growth rate [6]. Hence, in this study, we also have performed the ion transport simulations for case of an ion transport structure with the steerer type Einzel lens.

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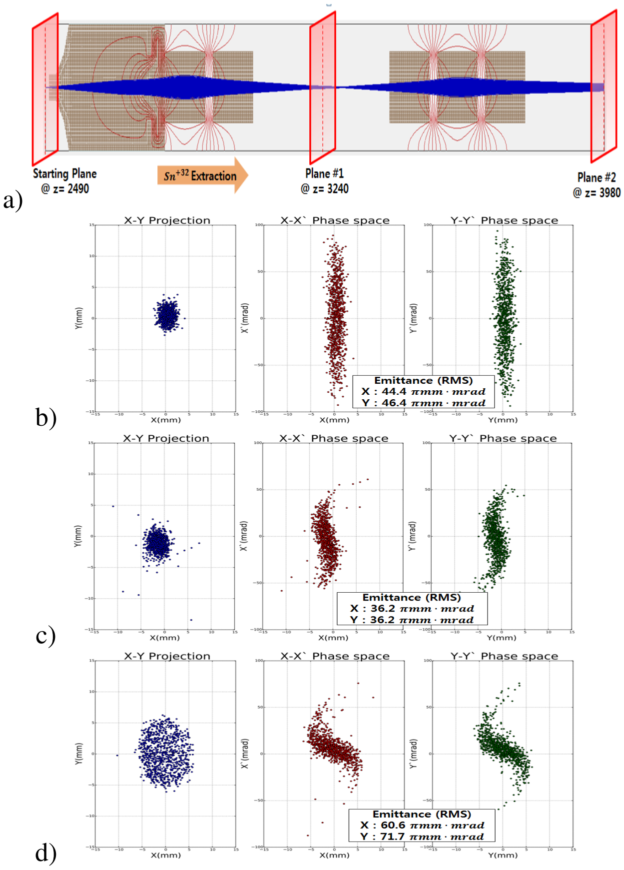

Figure 7: (a) Schematic of the ion transport optics and ion trajectories. Ion beam distributions at starting plane (b), plane #1 (c), and plane #2 (d).

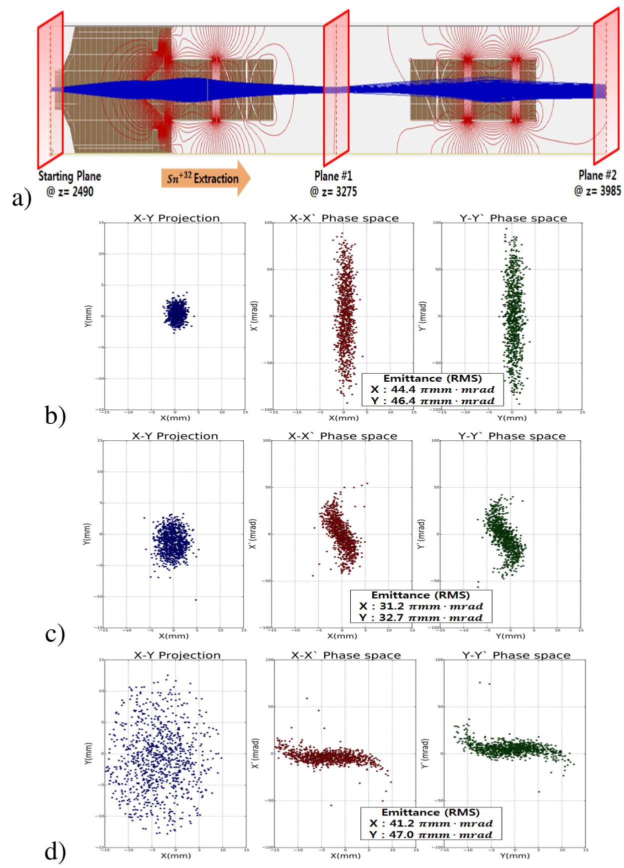

Figure 8: (a) Schematic of the ion transport optics and ion trajectories. Ion beam distributions at starting plane (b), plane #1 (c), and plane #2 (d).

Figure 8 shows the structure of the steerer type Einzel lens ion transport optics and ion beam distributions. The emittance growth is suppressed under this structure. The RMS emittances in the X-X' phase space are 44.4π mm·mrad and 41.2π mm·mrad, respectively at starting plane and plane #2.

However, a shift in beam position and a broadening of beam distribution in the X-Y projection are resulted at the plane #2. We need to further optimize the simulation and to perform careful design studies of the ion transport optics.

CONCLUSION

Based on the numerous simulations presented in this paper, design of the electron gun test stand is finished for the RISP EBIS system. For the ion transport part, we plan to perform more detailed simulations and careful design studies for future work.

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REFERENCES

[1] S. Kondrashev, C. Dickerson, A. Levand, P. Ostroumov, R. Vondrashek, A. Pikin, G. Kuznestov, M. Batazova, "Commissioning of CARIBU EBIS charge breeder sub-systems," in Proceedings of 12th Heavy Ion Accelerator Technology Conference (JACoW, 2012), pp. 165-169.

[2] Jongwon Kim, Jae-Eun Han, Hyock-Jun Son, Kun-Hui Yi, Liangji Zhao, Jin-Soo Kim, "An EBIS System for Rare Isotope Science Project in Korea", AIP Conference Proceedings;2015, Vol. 1640 Issue 1, p38.

[3] TRAK8.0, Field Precision LLC, New Mexico, U.S.A.

[4] R. Becker, O. Kester, Th. Stoehlker, "Simulation of charge breeding for trapped ions," in Journal of Physics: Conference Series 58 (IOP Publishing, 2007), pp. 443-446.

[5] SIMION8, Scientific Instrument Services, NJ, U.S.A

[6] C. Dickerson, B. Mustapha, A. Pikin, S. Kondrashev, P. Ostroumov, A. Levand, and R. Fischer, "Simulation and design of an electron beam ion source charge breeder for the californium rare isotope breeder upgrade", Physical Review Special Topics – Accelerators and Beams 16, 024201 (2013).

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