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Beam Optics Study of KAHIF MEBT Beam Line

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1. Introduction

As an ion beam irradiation facility, KAERI Heavy ion Irradiation Facility (KAHIF) has been constructed at KAERI, Daejeon. The facility is being utilized for research the nuclear fusion materials and nuclear reactor materials, especially structural material study. The dedicated accelerator system could produce ion beams up to 1.0 MeV/u with 300 uA.[1-2] In KAERI, a few projects are proposed based on KAHIF accelerator system.[3] One of the major projects, the facility is now preferring to provide Fe ion beam. In order to deliver the stable Fe beam, the beam optics is studied and the results are presented in this paper.

2. Methods and Results

2.1 Overview of KAHIF Components

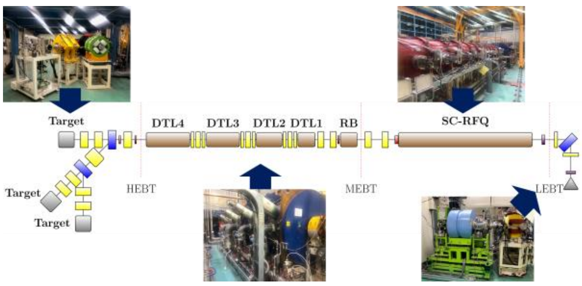

Fig 1. Layout of KAHIF.

The schematic layout of KAHIF beam line is shown in Fig 1. The accelerator system of KAHIF could be separated by three sections, Low Energy Beam Transport (LEBT) section, Middle Energy Beam Transport (MEBT) section and High Energy Beam ansport (HEBT) section. In LEBT section, 18 GHz Electron Cyclotron Resonator Ion Source (ECR-IS), Einzel lens, quadrupole magnets, bending magnet, and 25.96 MHz Split Coaxial Radio Frequency Quadrupole (SC-RFQ) are included. Ion beams are produced by ECR-IS and delivered to SC-RFQ. The entrance beam energy is 2.07 keV/u, the extracted beam energy is 178.4 keV/u through SC-RFQ.

MEBT includes the steering magnet, and quadrupole magnets and 51.92 MHz re-buncher (RB). In order to match the ion beam from 25.96 MHz SC-RFQ, the re-buncher is placed before 51.92 MHz interdigital H-mode drift tube linac (IH-DTL).

Currently, the target holder for studying nuclear materials is located between re-buncher and SC-RFQ. The ion beams with 178.4 keV/u and dozens of uA from SC-RFQ are enough to study the demonstrate material test for displacement per atom due to neutron.

2.2 Beam optics simulations of MEBT line

In order to confirm Fe ion beam acceleration in KAHIF, the beam optics of MEBT line has been simulated by TRANSPORT code. The initial twiss parameters for beam optics simulations are summarized in Table 1.

Table I: Twiss parameter for Beam Optics Simulations

Parameter	RFQ beam	DTL beam
Alpha (x)	+1	+0.1
Beta (x)	0.66 [m/rad]	0.99 [m/rad]
Alpha (y)	+1	+0.1
Beta (y)	0.66 [m/rad]	0.99 [m/rad]

For the initial beam conditions, the normalized full emittance was used as 0.6 pi mm-mrad and the normalized rms emittance was imported as 0.15 pi mm-mrad.

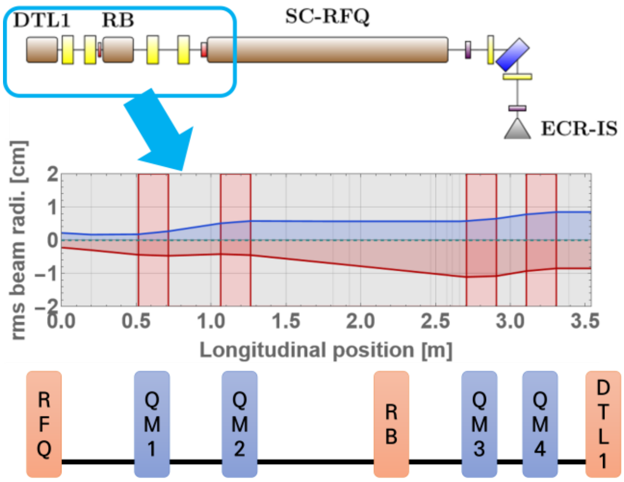

Fig 2. The $^{58}Fe^{2+}$ beam envelope simulation results.

The $^{58}Fe^{2+}$ ion beam optics simulation result is shown in Fig 2. Considering the margin of the charge state, the $^{58}Fe^{2+}$ ion is selected. From Fig 2, Fe ion beam is transported to the HEBT line with the operation of quadrupole magnets. The sample holder is positioned about 1.6 m from SC-RFQ. The simulation results in the Fig 2 indicates Fe ion beam envelope is enough to cover the sample size.

The beam size is also simulated and the results are presented in Fig 3.

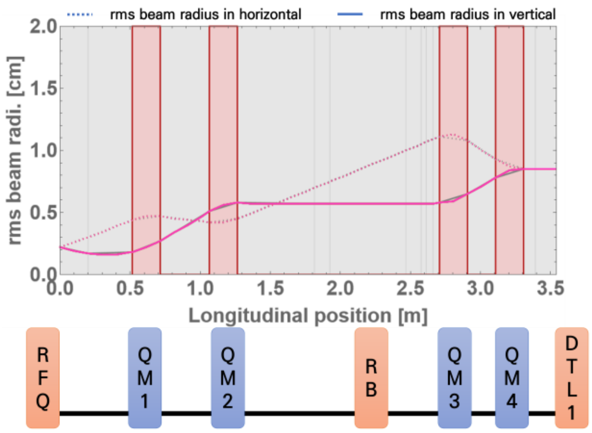

Fig 3. The rms beam radius simulation results

From the Fig 3, the rms beam size is confirmed that it starts to increase after the extraction at SC-RFQ. The QM1 and QM2 are help to focus the beam radius, horizontally and vertically. Between the QM2 and QM3, the radius of beam is growing in the horizontal direction. Before the entrance at DTL1, the radius of beam is focused by QM3 and QM4.

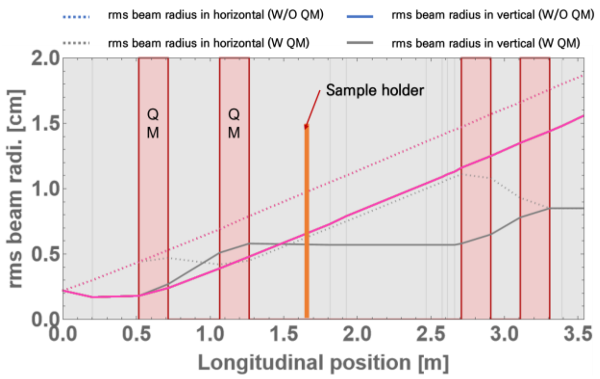

Fig 4. The rms beam size with QMs and without QMs.

Considering the case which the QMs are not operating, the beam line optics is studied in Fig 4. Because of the sample holder position, the QMs which are placed after SC-RFQ are not operating during the beam service. The sample holder size is 2.0 cm x 2.5 cm. With and without operation of QMs, the beam optics is simulated with Fe ion beam (Fig 4). At the sample holder, the radius of beam is grown about 1.0 cm in horizontal direction and 0.5 cm in vertical direction. With the operation of QMs, the radius of beam is maintained under 1 cm in the both directions.

3. Conclusions

Beam optics simulations by TRACK-3D has been studied for Fe ion beam acceleration in KAHIF MEBT line. Considering the charge state margin, $^{58}Fe^{2+}$ ion beam is selected to simulation of beam optics. The envelope and beam radius size in MEBT line are studied. At the sample holder position, the Fe ion beam is checked for user service. Also, the effect on beam line by quadrupole magnets which are located after SC-RFQ are studied. With the QMs, the radius of beam will be maintained in 1 cm. Without the QMs, the radius of beam will be increased up to 1.5 cm in horizontal direction.

These beam optics study results are expected to use actual Fe ion beam commissioning. For the future works, the beam optics will be simulated with other charge states of Fe ion.

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