SIMULTANEOUS TWO BEAM ACCELERATION LATTICE DESIGN STUDY FOR THE POST LINEAR ACCELERATOR OF RISP

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Abstract

The Rare Isotope Science Project, RISP, is the research complex by using heavy ion accelerator, in which RISP research complex consists of front-end system, super conducting linear accelerator(SCL), ISOL system, In-flight system. The original purpose of post linear accelerator was for the alternative acceleration of stable driver beam from ECR ion source and unstable rare isotope beam from ISOL system. However, the post accelerator lattice was re-designed with new concept of acceleration method to get more benefits. The idea was the simultaneous acceleration of stable driver beam and RI beam by using the post accelerator lattice of average A/q value. In this proceeding, we will describe the results of beam dynamics study of simultaneous two beam acceleration at SCL3.

INTRODUCTION

RAON (Rare isotope Accelerator Of Newness) [1] is a key research facility of RISP. The post accelerator of RAON consists of ECR, ISOL, LEBT, RFQ, MEBT, Superconducting Linear accelerators 3 (SCL3), and etc. Figure 1 shows the layout of RAON.

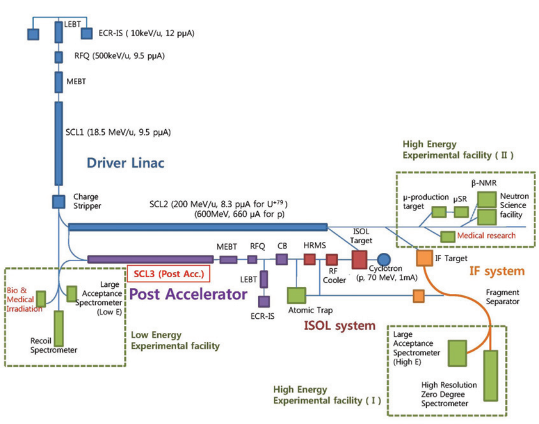

Figure 1: RAON scheme for RISP.

Especially, the post linear accelerator uses two ion sources for stable ion beam from an ECR ion source and for unstable ion beam from an ISOL system. The main goal for the optics design of post accelerator was the stabilization of two ion beams during simultaneous acceleration.

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THE LAYOUT OF POST LINEAR ACCELERATOR

The goal of post linear accelerator lattice design was based on conceptional design report of RISP [2]. The characteristics of redesigned post linear accelerator are listed in Table 1. Most important lattice parameter for the two beam acceleration was the average A/Q value of 6.925. The average A/Q value was taken to set the middle of the synchronous phase of two ion beam particles without particles loss for longitudinal direction.

Table 1: Basic Parameters of Post Linear Accelerator

Parameters	Value
Stable particle type (A/Q)	^{58}**Ni**$^{+8}$ (7.25)
Unstable particle type (A/Q)	^{132}**Sn**$^{+20}$ (6.6)
Average A/Q	6.925
Repetition rate	81.25 MHz
Beam energy	0.4 ~ 17.67 MeV/u
Number of QWR cavities	21
Number of HWR cavities	98
Number of quad. magnets	104
Linac length	98.21m

BEAM DYNAMICS STUDY OF SCL3

For the single ion beam acceleration, two different A/q ions are used for the accelerations. The post accelerator lattice was redesigned for the simultaneous two beam acceleration so that the 6.925 A/q lattice for the simultaneous two beam acceleration was selected [3].

The lattice of the post accelerator section was designed using the following conditions to avoid emittance growth and envelope instability. As shown in Fig. 2, the phase advance in transverse σ_{t0} and longitudinal σ_{l0} is kept lower than 90 degree per focusing period to avoid envelope instability with high current but the post accelerator of RAON lattice has very low beam current with stable and unstable beams.

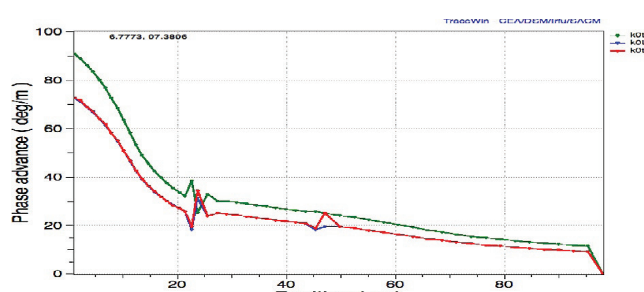

Figure 2: The phase advance per meter of post accelerator.

The transition lattice matching section between different cavity's lattices was precisely matched to avoid beam emittance growth and some mismatch of beam envelope. Therefore, the envelope at the lattice transition section should be changed smoothly as possible and should be kept off the high peaks in the envelop along the linac. The phase advance ratio of each periods are kept to 0.8. This phase advance ratio was selected to keep the quadrupole field strength below 25T/m.

Figure 3 shows the beam emittance of simultaneous two-beam simulation in the post accelerator. The transverse rms beam emittance are slightly increased vertically and two beam was well focused until end of post accelerator. The longitudinal normalized RMS emittance was increased approximately three times. Because, the longitudinal beam center of two ions beam at the end of linac are splitted so that the entire longitudinal emittance was increased. As shown in Fig. 4, the initial synchronous phase was increased smoothly from -40deg to -30deg to reduce beam loss.

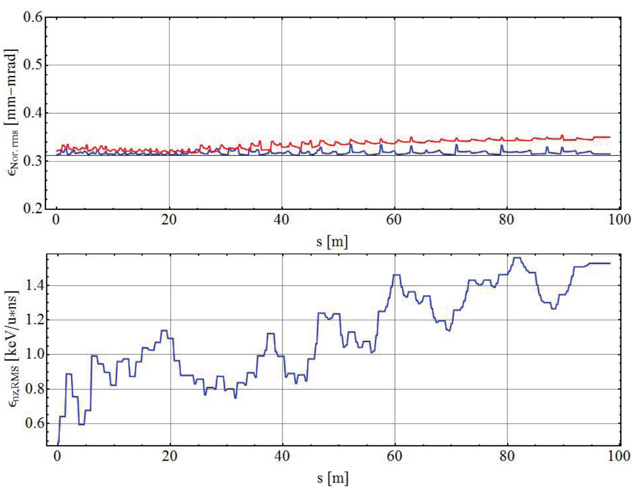

Figure 3: The two beam emittance for the exit of post accelerator.

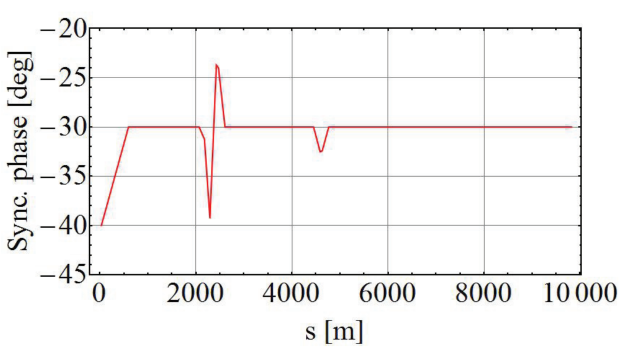

Figure 4: The synchronous phase of SCL3.

The multi particle simulations have been performed for the SCL3. The QWR cavities have steering effects for the transverse direction so that we should correct the beam orbit even though there is no errors. The top figure of Fig. 5 shows the beam envelope of SCL3 with steering effects of QWR section and the bottom figure of Fig. 5 shows the beam envelope of SCL3 after the beam orbit correction by using several steering magnets.

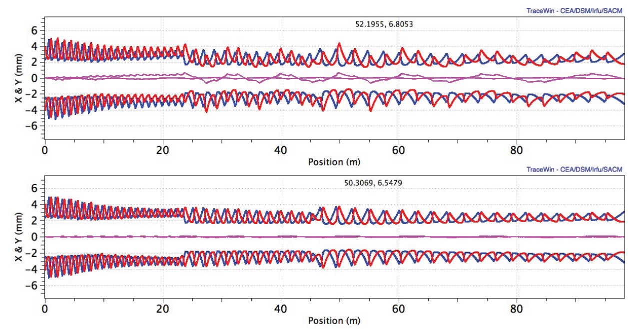

Figure 5: The QWR steering effects for the post accelerator. The beam orbit before correction(top) and the beam orbit after the steering effects correction(bottom).

The longitudinal RF acceptance of the SCL3 was analyzed by using the TraceWin code at zero current condition. The analyzed RF acceptance is plotted in Fig. 6. The calculated RF acceptance was 15.56 keV/u-ns.

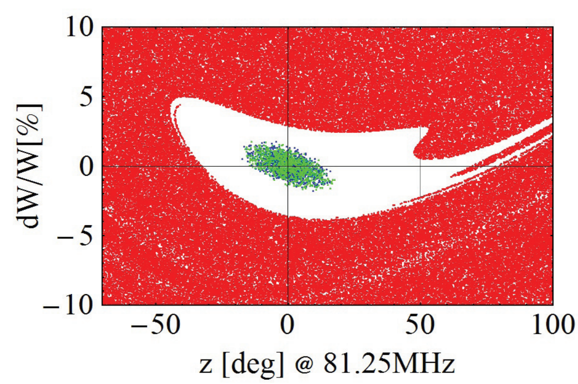

Figure 6: The RF acceptance of the post accelerator lattice.

Figure 7 shows the simultaneous two-beam multi particles tracking simulation results at the end of post accelerator in RAON. In the figure, the radioactive beam of ^{132}**Sn**$^{+20}$ from the ISOL system is represented to red color and the stable beam of ^{58}**Ni**$^{+8}$ commonly produced in an ECR source is represented to green color. At the end of post accelerator, the ^{58}**Ni**$^{+8}$ beam is extracted to send to low energy experimental area while the ^{132}**Sn**$^{+20}$ beam is injected for further acceleration into SCL2 section.

THE MACHINE ERROR AND CORRECTION STUDY

The main sources of error in the post accelerator are element misalignments, the precision and stability of the RF system. The errors and their typical values are listed in Table 2. For statistical significance, the error simulations were repeated 500 times and every simulation are used the different random seed. The 2000 particles were tracked in every simulation.

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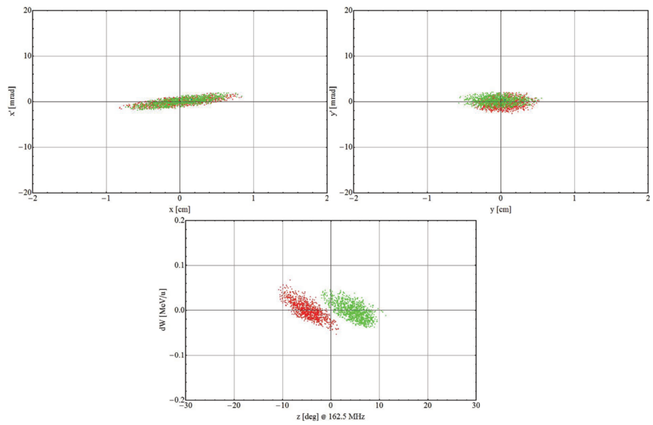

Figure 7: The beam distributions at the exit of post accelerator.

Table 2: The Errors and their Typical Values of the Post Accelerator

Error	Value	Distribution
Quad displacement	0.15mm (max)	Uniform
Quad rotation (z-axis)	5mrad (max)	Uniform
Quad field error	1% (rms)	Gaussian
Cavity displacement	1mm (max)	Uniform
Cavity field error	1% (rms)	Gaussian
Cavity phase error	1% (rms)	Gaussian

In order to check the effects of machine error, we have simulated the case with and without correction by using transverse correctors with the errors in Table 2. Figure 8 shows centroid beam orbit along the post accelerator. We clearly see that before correction the centroid beam orbit was exceedingly destroyed. The rms centroid orbit for vertical direction was destroyed until 8mm. After applying transverse corrections the centroid orbits are well corrected along the beam center. Figure 9 shows 4 times rms beam emittance along the post accelerator. For the orbit correction, we used two BPMs and two correctors within two period. The 4 times vertical rms emittance was increased around 4 times larger than no error case. The 4 times rms emittance was prominently reduced in the transverse emittances after applying the correctors. The longitudinal 4 times rms emittance was extremely increased for a few seed case. However, the 4 times rms longitudinal emittance is also prominently reduced after the orbit correction.

CONCLUSION

The beam dynamics study of post accelerator lattice for RAON was performed to accept simultaneous two beam acceleration. The lattice was redesigned to cover stable ion beam and RI beam, simultaneously. The A/q of post accelerator lattice used to 6.925, in which A/q value was an average value of two ion beams. By using redesigned post accelerator lattice, two ion beams are well accelerated without beam loss. The machine error study was also performed to check

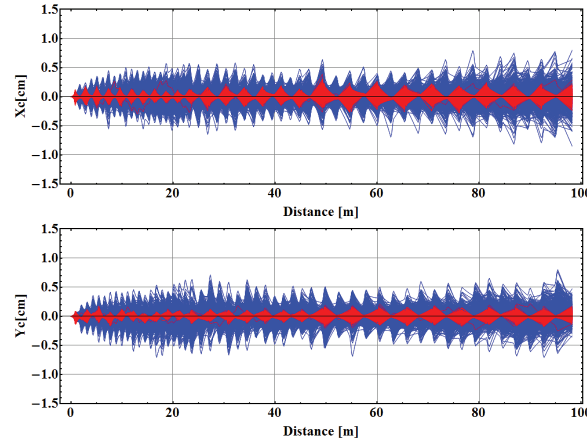

Figure 8: The centroid beam orbit of two beam simulation for the with(Red) and without(Blue) correction cases.

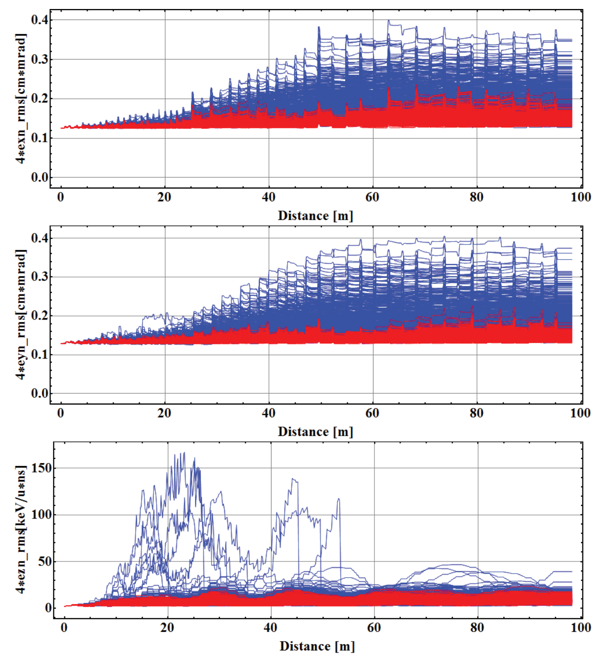

Figure 9: The vertical and longitudinal beam emittance of two beam simulation for the with and without correction cases. Before correction(Blue) and after correction(Red).

the machine imperfection. The start-to-end simulation for the simultaneous two beam simulation will be performed.

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