STATUS OF THE RAON ACCELERATOR SYSTEMS

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Abstract

The RAON is the heavy ion accelerator being built in Korea to build the In-flight Fragment (IF) and Isotope Separation On-Line (ISOL) facilities to support cutting-edge researches in various science fields. Superconducting linac with 200 MeV/u, 400 kW is the driver for the IF facility and the 70 MeV, 70 kW H^- cyclotron is the driver for the ISOL facility. These facilities are to provide high intensity stable beams and rare isotope beams for the users domestic and abroad. The design and prototyping efforts are under way such as superconducting cavities and magnets. Status of the RAON accelerator systems is presented.

INTRODUCTION

The RAON, heavy ion accelerator facility of Korea is under construction to support a wide range of cutting edge science programs in nuclear science, material science, bio & medical science, astrophysics, and atomic physics as well as interdisciplinary science programs [1]. The RAON facility will be a unique facility that has the 400 kW In-flight Fragmentation (IF) facility and the 70 kW Isotope Separator On-Line (ISOL) facility.

The driver accelerator for the IF facility is a superconducting linac that can accelerate up to 200 MeV/u in case of uranium beam and up to 600 MeV for proton beam with more than 400 kW beam power to the IF target and various other targets. The driver for the ISOL facility is an H^- 70-MeV 1 mA cyclotron that delivers 70 kW beam power to the ISOL target. The cyclotron has dual extraction ports with thin carbon foils for charge exchange extraction of H^- beam. The rare isotope beams generated by the ISOL system is re-accelerated by a chain of accelerators: RFQ, MEBT and superconducting linac SCL3 up to 18.5 MeV/u. The RI beams can be delivered to the low energy experimental hall or can be injected through P2DT to the SCL2 to accelerate to higher beam energy. The schematic layout of the RISP facility is shown in Fig. 1.

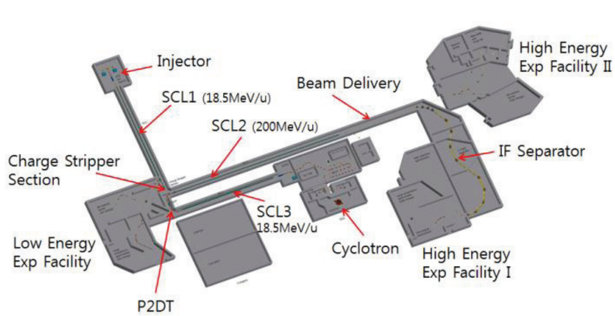

Figure 1: Plot of the RAON facility layout.

To meet the diverse demands, the RISP design is optimized to provide various high intensity stable ion beams and radioactive isotope (RI) beams from proton to uranium for domestic and international users. The RISP facility includes the In-Flight Fragmentation (IFF) facility and the Isotope Separator On-Line (ISOL) facility. The driver accelerator for the IFF facility is a superconducting linac that can accelerate to 200 MeV/u in case of uranium beam and that for the ISOL facility is a 70-MeV cyclotron. The IFF superconducting linac can deliver 400 kW beam power to the IFF target and the 70-MeV cyclotron can deliver 70 kW beam power to the ISOL target.

THE DRIVER LINAC

The driver linac consists of the injector, low energy superconducting linac (SCL1), charge stripper section, and high energy superconducting linac (SCL2) delivering beams to the IF target or other targets.

Injector

The injector consists of superconducting ECR ion source (ECR IS), Low Energy Beam Transport (LEBT), Radio Frequency Quadrupole (RFQ) and Medium Energy Beam Transport (MEBT). For ECR IS, superconducting magnets and dual high power RF sources of 28 GHz and 18 GHz are used to improve its performance. Figure 2 shows the configuration of superconducting magnets for the ECR IS that generates high magnetic field for confinement and minimizes mechanical stress. The

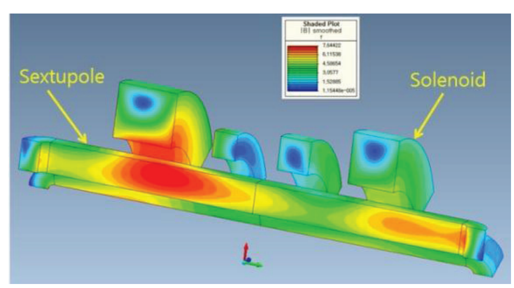

Figure 2: Plot of superconducting magnet assembly of the ECR ion source

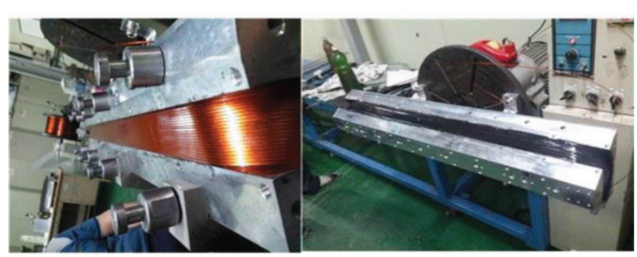

Figure 3: Photographs of the saddle type sextupole prototype for the ECR IS of RAON.

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The saddle type sextupole is more difficult to wind than the racetrack type one. Figure 3 shows how the saddle type sextupole is made. For the saddle type sextupole, one can wind ~20% more SC wires for the same space, thus can lower operating current. In March, the saddle type sextupole prototype for the ECR IS fabricated by a domestic company is delivered and tested achieving 120% of design magnetic field level. The first quench occurred at 380 A (design current is 415 A) and at the seventh quench it reached 480 A.

The LEBT (Low Energy Beam Transport) is to transport ion beams from the ECR ion source to the RFQ. Especially simultaneous transport of $^{238}U^{+33}$ and $^{238}U^{+34}$ is an important aspect of the design. The LEBT consists of two bending dipoles that form an achromat and electrostatic quadrupoles, solenoids, and chopper etc. The beam distributions at the LEBT entrance are shown in the upper plots and those at the exit in the lower plots of Fig. 4. The blue dots represent $^{238}U^{+33}$ beam and red ones $^{238}U^{+34}$ beam.

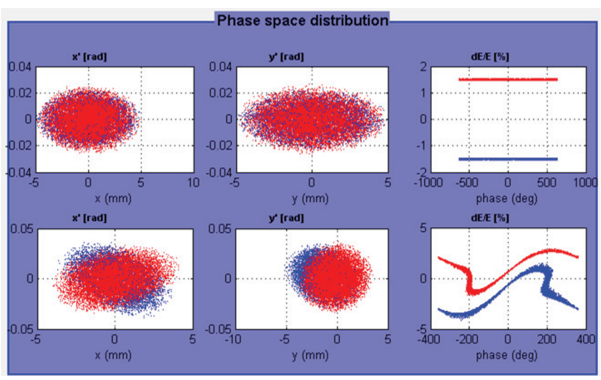

Figure 4: Plots of beam distribution at the LEBT entrance (upper plots), those at the LEBT exit (lower plots).

The RFQ is designed to accelerate two-charge state ($^{238}U^{33+}$ and $^{238}U^{34+}$ of 12pμA) beams from 10 keV/u to ~500 keV/u. The PARMTEQ is used to obtain the RFQ design parameters. Physics and engineering design is under way.

Superconducting Cavities

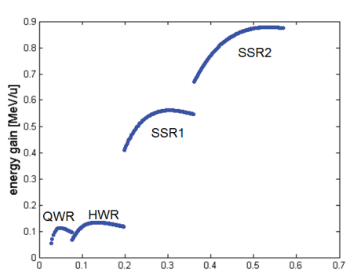

Figure 5: Plots of the optimized geometric betas of the superconducting cavities employed by the RAON.

The driver SCL is designed to accelerate high intensity heavy ion beams and to meet the needs of various users. Large cavity apertures (4 and 5 cm) are chosen to reduce uncontrolled beam loss on the superconducting cavities because beam loss is a serious issue for heavy ion beams. Cavity geometric betas are optimized and an optimum set of β = [0.047, 0.12, 0.30, 0.53] is obtained. Its results are shown in Fig. 5. More details of SCL design and cavity prototyping can be found in [2-4]

Table I: Cavity Parameters

Parameters	Unit	QWR	HWR	SSR1	SSR2
β_g	-	0.047	0.12	0.30	0.53
Resonant frequency	MHz	81.25	162.5	325	325
No of cavities	-	22	123	84	136
Aperture diameter	mm	40	40	50	50
QR_s	Ohm	17.5	41.2	86.1	104.7
R/Q	Ohm	472.3	264.8	237.0	298.0
V_{acc}	MV	1.02	1.07	2.04	3.53
E_{peak}	MV/m	30	30	30	30
B_{peak}	mT	54.1	40.8	52.2	62.3
Operating temp	K	2	2	2	2
P_0	W	2.7	2.0	4.8	8.4
Beam current (U)	pmA	9.5	9.5	8	8

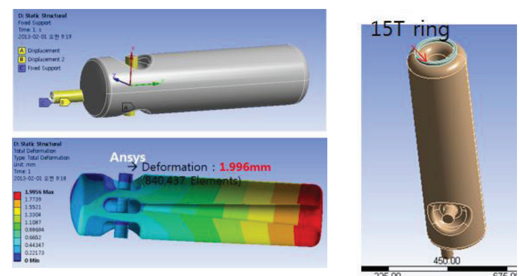

Figure 6: Plot showing thermal contraction due to cool-down to 2K and stiffener of 15mm reduces frequency shift by cool-down by factor 11.

Mechanical characteristics of the superconducting cavities is analyzed using the CST and ANSYS codes to study and to ensure that the cavity design meets the requirement of Lorentz force detuning, detuning due to helium pressure fluctuation (df/dP), microphonics detuning etc. EM design has been conducted to reduce B_{peak} and E_{peak} which in turn reduces the Lorentz force detuning. Stiffening the cavity endwalls and shell reduces the Lorentz force detuning and detuning due to helium pressure fluctuation. Endwalls of spoke resonators are reinforced with two types of ribs: donut ribs and daisy ribs. The design of the helium jacket is to be studied in light of the df/dP characteristics. Figure 6 shows the contraction due to cool-down and the modeling of stiffening structure of the QWR cavity. Figure 7 shows the mechanical vibration modes and its characteristic frequencies. Analysis shows that lowest frequency is 80 Hz for bare cavity and it is expected that stiffening and helium jacket would shift this frequency upward.

It is important to avoid multipacting barriers as much as possible and the design should be optimized by using the CST electron tracking code. Multipacting analysis will be conducted for the combined structure of the cavity and power coupler. Analysis is on-going and shows that some multipacting bands can be found at low cavity field.

Thermal analysis is done for the superconducting cavities and special attention will be paid to high

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magnetic field region, around the coupler port, and beam tubes etc. The thermal analysis of SSR2 cavity for instance shows that the beam tube temperature rises to 6.1K when the operating temperature is 4K.

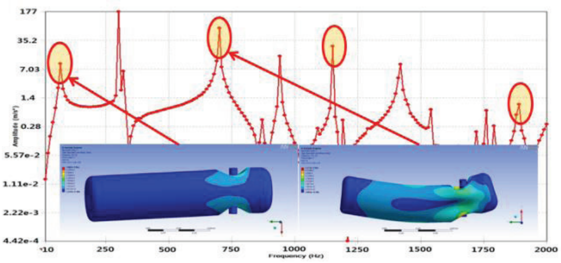

Figure 7: Analysis of mechanical vibration modes and characteristic frequencies.

Prototyping of superconducting cavities are under way in two tracks. Four types of superconducting cavities are optimized by the IBS. Fabrication of cupper and niobium cavities is proceeding through industry for each type of cavities and it is under bidding process. The other track is to do prototyping in collaboration with international laboratories with sufficient experience in superconducting cavity prototyping and production. Through this cavity prototyping process will be checked independently.

Cryomodules, Couplers and Tuners

The project can profit from the existing knowledge base, minimizing the R&D workload. Existing designs and products of cryomodules, couplers and tuners will be utilized as much as possible for the SCL design. Figure 8 shows the cryomodule design. For the design, we are benchmarking the existing design. Detailed engineering design is under way and prototyping of cryomodules and couplers is carried out.

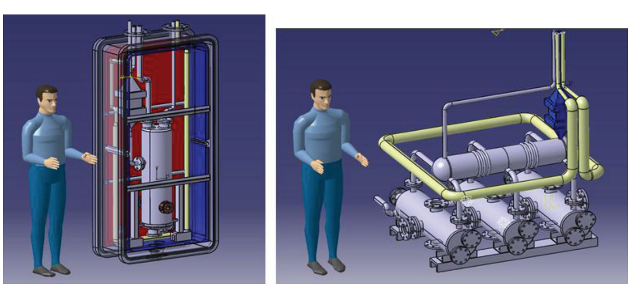

Figure 8: Plots of the SCL QWR (the left plot) and HWR cryomodules (the right plot).

Beam Physics

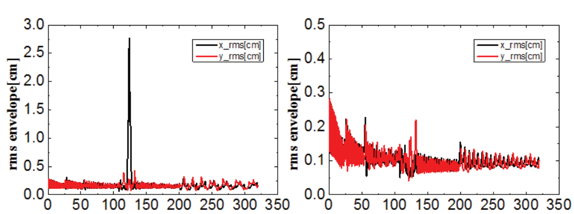

Figure 9: Plots of the start-to-end beam dynamics simulations for uranium beam (left plot) and proton beam (right plot).

Start-to-end beam dynamics simulations are done for various ion beams such as uranium, proton, carbon, and calcium beams. Effects of machine imperfections are studied as well. Figure 9 shows, for instance, the plots of rms beam sizes for uranium beam and proton beam respectively along the SCL1, Charge Stripper Section and the SCL2. The spike in x beam size at ~125 m is due to uranium beams going through the charge stripper section producing multiple charge states.

IF SYSTEM

Design of IF target, beam dump and separator is progressing. Figure 10 shows the schematic layout. Thermal and mechanical analysis of target and beam dump is being done. Development of IF target is under way [5]. Baseline design of separator is fixed now. Prototyping is going on for the High Tc Superconducting magnets. Beam delivery system from the SCL2 to the target is designed, consisting of second order achromats.

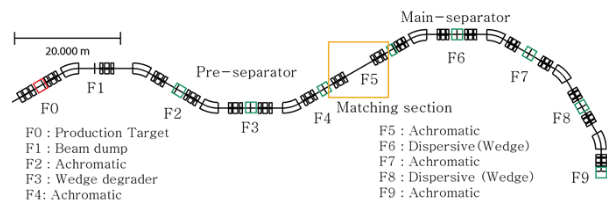

Figure 10: Schematic plot of the target and separator.

CONCLUSION

The design of the RAON accelerator system is well progressing, optimized for the acceleration of high intensity heavy ion beams. Prototyping is progressing including SC magnets and cavities, IF target and RF systems [6]. The first edition of RAON Technical Design report will be available soon.

ACKNOWLEDGEMENT

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