OVERVIEW OF THE RISP SUPERCONDUCTING LINAC

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Abstract

The Rare Isotope Science Project (RISP) is launched in Korea to build the IF and ISOL facilities to support researches in various science fields. Superconducting linac with 200 MeV/u, 400 kW is the driver for the IF (In-flight Fragmentation) facility and the 70 MeV, 70 kW cyclotron is the driver for the ISOL (Isotope Separation On-Line) facility. These facilities are to produce high intensity RI beans with high purity near the neutron-rich drip line. Design aspects of the driver SCL is presented.

INTRODUCTION

The International Science and Business Belt (ISBB) was initiated by the Republic of Korea government to promote the research in the forefront basic science and to seamlessly couple science and business. As the core institute of the International Science and Business Belt plan, the Institute for Basic Science was founded in November 2011 and under the IBS the Rare Isotope Science Project (RISP) was launched. The RISP is to construct a world-class multi-purpose facility to support a wide range of cutting edge science programs in but not limited to nuclear science, material science, bio & medical science, astrophysics, and atomic physics as well as interdisciplinary science programs. 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 assessment of conceptual design is done and design changes are introduced [1].

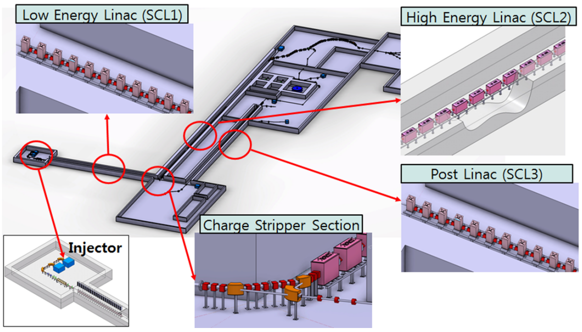

Figure 1: Schematic plot of the RISP facility layout phase.

THE DRIVER SCL DESIGN

Superconducting Cavities

The driver SCL for the IF facility 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 types are chosen and optimization of the geometric betas of SC cavities is done and an optimum set of β_g = [0.047, 0.12, 0.30, 0.53] is obtained. Its results are shown in Fig. 2. The Half Wave Resonator (HWR) is chosen to minimize the asymmetric field effects and to improve the quality. And for each type of SC cavities, optimization of the cavity geometry was conducted with respect to R/Q, QR_s, E_{peak}/E_{acc} and B_{peak}/E_{acc} etc. Table 1 lists the cavity parameters. Figs. 3 and 4 show the electromagnetic fields of the optimized SC cavities.

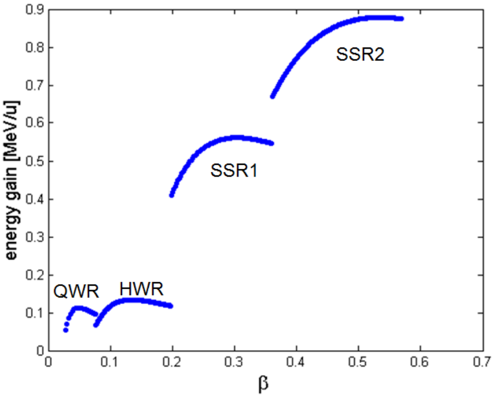

Figure 2: Plots of the optimized geometric betas of the superconducting cavities employed by the RISP.

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	-	24	138	88	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

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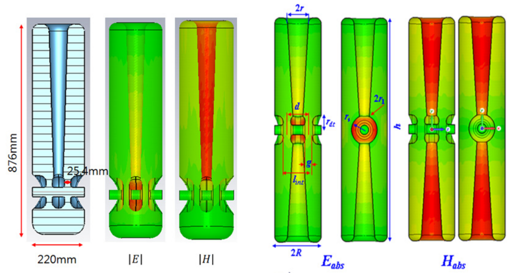

Figure 3: Plots of optimized QWR and HWR showing their electromagnetic fields.

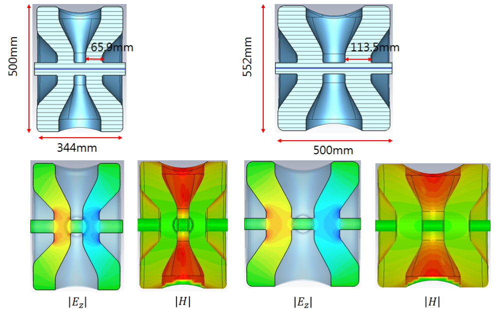

Figure 4: Plots of optimized SSR1 and SSR2 showing their electromagnetic fields.

SCL Layout

It is known that the position of each component in a cryomodule changes by no less than a millimeter in a random fashion during the cool-down of a cryomodule and it is not trivial to predict accurately enough alignment of superconducting solenoids in a cryomodule after the cool-down. Accurate alignment of focusing elements such as superconducting (SC) solenoids is very crucial for maintaining the beam quality of high intensity beams which is envisioned for the heavy ion accelerator. For high intensity operations, the foreseen uncertainty of no less than a millimeter displacement can induce intolerable level of beam loss, leading to activation of accelerator components and potential quench of superconductors inside cryomodules.

The previous SCL design with SC solenoids presents the following challenges and issues:

- Alignment of SC solenoids is not trivial to control. It is known that components in a cryomodule can move no less than a millimeter during cool-down.
- Small misalignment of SC solenoids by ±0.5 mm generates significant emittance growth (simulations indicate factor 2.5 emittance growth by the end of the short beta=0.047 SCL11).
- Heat deposit by the beam loss in the SC solenoids can be an issue such as quench.
- Operation of the SCL is not trivial for example due to the magnetization of surrounding elements in the cryomodule.
- The SCL employing long cryomodules that contain multiple cavities and solenoids can impose significant restriction on the beam diagnostics access. This leads to difficulties in the accelerator tuning for a high intensity operation.

These points raised concerns and studies have been initiated to come up with a better SCL lattice design that can enable high intensity beam operations by improving the beam quality and straightening complexities. These are crucial design considerations in designing the SCL, for the intensity heavy ion beams has increased steadily. The SPIRAL2 project also adopted quadrupole doublet focusing lattice for the high intensity ion beam acceleration (for instance 1 mA of heavy ion beams and 5 mA deuteron beam) [2].

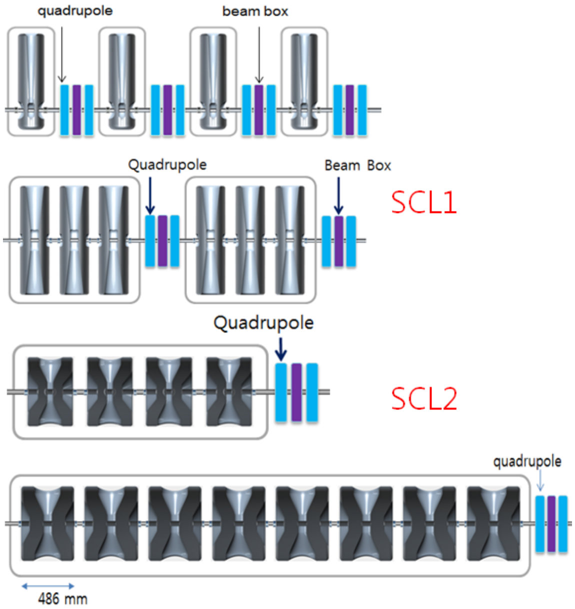

Figure 5: Plots of the SCL layout for each SC cavity type..

Cryomodule, Coupler and Tuner

The project can profit from the existing knowledge base, accelerating the learning process and minimizing the R&D workload and the project can concentrate on developing core design and technologies. Existing designs and products of cryomodules, couplers and tuners will be utilized as much as possible for the SCL design. It is planned to carry out R&D for couplers.

For the couplers and tuners, there are a few existing prototypes and products such as the SPIRAL2 project, the Project-X, and the FRIB etc. These are natural candidates for the frequencies are quite close or identical to the frequency of the RISP cavities.

Charge Stripper Section

One of the critical components of the driver SCL is the charge stripper because of high power deposited in the stripping material in a small area. Charge stripper strips

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electrons from heavy ion beams to enhance the acceleration efficiency in the following SCL2. Recent studies done by FRIB indicate that carbon foils show fast decay of performance, which makes this type of stripper is very unlikely to satisfy the requirements [4]. The FRIB looks at other options of the charge stripper which include liquid lithium stripper developed at the ANL, gas stripper, gas stripper with plasma windows, and plasma stripper [5]. These options are being considered for the project as well. Even though carbon foils may have defects in full beam power, it is still useful for low beam power operation especially during the testing, commissioning, and possibly early low power operation stages.

Beam Diagnostics and Collimation

The beam boxes located at every doublet are reserved for various diagnostics devices such as beam profile monitors, beam current monitors (BCM), Faraday cups, emittance scanners, bunch shape monitors (BSM), etc. Beam position monitors (BPM) will be installed with quadrupoles, providing beam position and phase data. This feature is a very strong merit in light of beam diagnostics for beam operation and commissioning. There are beam boxes periodically placed for necessary beam diagnostics and this is critical for operation and accurate machine tuning. For instance four profile monitors installed in series can easily establish matching [3]. Because the beam box is in the warm section, maintenance and alignment are straightforward.

Figure 6 shows a preliminary beam diagnostics configuration of the driver SCL. For the charge stripping station, required beam diagnostics are BPMs, beam profile monitors, beam current monitors, and beam loss monitors, etc.

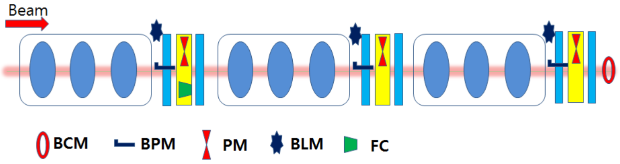

Figure 6: Schematic plot of the SCL beam diagnostics configuration.

Another advantage is that collimators can be installed at the beam boxes to improve beam quality as shown in Fig. 7. These collimators can minimize the uncontrolled beam loss to the superconducting cavities.

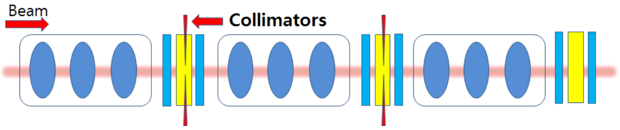

Figure 7: Schematic plot of the SCL beam collimation configuration.

Cost Estimation

Cost estimation is conducted including the cost for cavity, tuner, coupler, internal cryogenics, vacuum system, cryomodule and processing & cryomodule assembly cost. Cost comparison between the two driver SCL options shows that the cost difference between the two options is in the error range of cost estimation, which is less than 1 % of the driver SCL cost. And cost estimation is made for both the driver SCL and the ISOL SCL assuming that we keep the same lattice choice for the ISOL SCL as well. The cost estimation shows that the overall combined cost difference is less than 2 % of the total cost when switching to the SCL lattice with NC quadrupoles. This difference is in the error range of cost estimation and it is concluded that cost is not an issue in adopting the proposed SCL lattice.

CONCLUSION

The design of the RISP driver SCL is conducted, optimized for the acceleration of high intensity heavy ion beams. Types and parameters of SC cavities are chosen to facilitate the goal. Geometric beta and cavity geometry are optimized for better performance.The driver SCL consists of QWR and HWR, SSR1 and SSR2 with relatively large beam apertures of 4 cm and 5 cm to minimize the heavy ion beam loss. The SCL adopts the lattice with normal conducting quadrupoles rather than superconducting solenoids. There are regularly placed beam boxes for the beam diagnostics and collimation.

ACKNOWLEDGEMENT

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