STATUS OF THE RISP SUPERCONDUCTING HEAVY ION ACCELERATOR*

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Abstract

Construction of the RISP heavy ion accelerator facility is in-progress in Korea with the In-flight Fragment (IF) and Isotope Separation On-Line (ISOL) facilities. The driver linac for the IF facility is a superconducting linac. Prototyping of major components and their tests are proceeding including superconducting cavities, superconducting magnets and cryomodules, the 28-GHz ECR ion source and the RFQ. Prototype superconducting cavities were fabricated through domestic vendors and tested at the TRIUMF showing promising vertical tests results. Progress report of the RISP accelerator systems is presented.

INTRODUCTION

The RISP heavy ion accelerator facility is a unique facility that has the 400-kW In-flight Fragmentation (IF) facility and the Isotope Separator On-Line (ISOL) facility [1,2]. The driver accelerator for the IF facility is a superconducting linac (SCL) that can accelerate up to 200 MeV/u for the uranium beam delivering more than 400 kW of beam power to the IF target and various other targets.

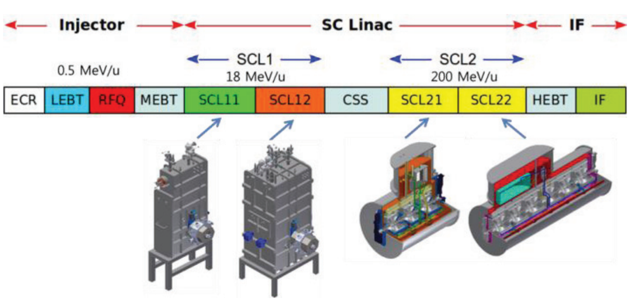

Figure 1: Plot of the RISP superconducting linac lattice.

Figure 1 shows the schematic drawing of the driver linac. The superconducting linac adopts the normal conducting quadrupole doublets as focusing elements. This design is free from the quench of superconducting solenoids induced by the beam loss.

Adoption of short cryomodules also provides flexibility in operation and maintenance. For example, cryomodules can be removed for repair while operating the facility. Also it is easy to reshuffle better performing cavities or cryomodules to enhance the performance. For long cryomodules, removal of one cryomodule stops the beam operation.

Studies show that cryogenic load of the RISP linac is similar to that of the FRIB adopting long cryomodule design. The heat-load of warm-cold transition is offset by that of the current leads of superconducting solenoids. Cost comparisons shows that the construction cost is very similar and only differs by a few percent.

Detailed design of the accelerator systems has been completed, and prototyping and testing of critical components and systems have been performed. In this paper, the status of the RISP accelerator systems is presented along with prototyping progress.

DRIVER LINAC

The driver linac consists of an injector (28-GHz ECR ion source, 500-keV/u RFQ) and SCL1 (QWR, HWR type), CSS (Charge Stripper Section) and SCL2 (SSR1, SSR2 type) that can accelerate a uranium beam to 200 MeV/u, delivering 400-kW beam power to the target. The driver linac can accelerate beams from proton to uranium.

Injector

28-GHz ECR ion source (ECRIS) for the driver linac was fabricated with a saddle-type sextupole and four solenoids made of NbTi wires [3]. Figure 2 shows the plot of the superconducting magnet assembly, the plot of ECRIS cryostat and actual ECRIS. Superconducting magnet tests have been carried out, achieving 95% (80%) of the design goal for the hexapole (solenoid) in a combined operation mode. Further magnet training is in progress. Preliminary beam extraction test was conducted for of the 28-GHz ECRIS with a part of the LEBT installed along with it. Preliminary beam extraction test is shown in Fig. 3.

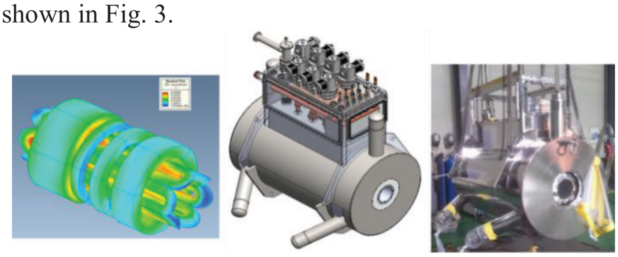

Figure 2: Plot of 28 GHz ECR ion source and its superconducting magnet assembly.

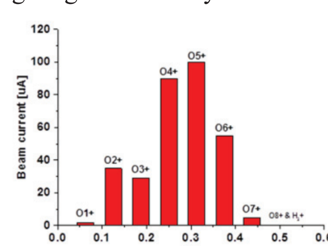

Figure 3: Initial ECR IS beam extraction test while maintain the magnets at the 50% of the design.

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The 81.25-MHz RFQ with a four-vane structure is 5-meter long and its input and output beam energies are 10 keV/u and 500 keV/u respectively. RFQ prototype was fabricated through a domestic vendor in 2014 and RF test is under way reaching a CW 11-kW and pulsed 15-kW at 10 % duty factor, while the design goal is 12 kW. RFQ prototype is shown in Fig. 4. The driver linac RFQ is under fabrication to be delivered by August 2016.

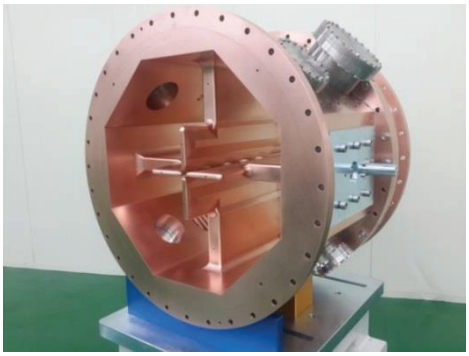

Figure 4: Photograph of 81.25MHz RFQ prototype.

Superconducting Cavities

All four types of the superconducting cavities (QWR, HWR, SSR1, SSR2) were designed by the IBS and their prototypes fabricated through the domestic vendors and delivered in 2014 to the IBS [4]. Additional design efforts are undertaken to design the SSR1 cavity in collaboration with TRIUMF. Their photographs are shown in Fig. 5. Lately vertical tests of the QWR and HWR cavities were carried out in collaboration with the TRIUMF using its SRF test facility.

Figure 5: Photographs of prototype superconducting cavities [QWR(top left), HWR(top right), SSR1(bottom right), SSR2(bottom left)].

Figures 6 and 7 show the vertical test results of the prototype QWR and HWR cavities. QWR prototype cavity showed very excellent results. These measurement data were limited only by cryogenic capacity of the facility. At 2K especially, the B_{peak} of the QWR prototype reached ~130 mT reaching 210% of the design field goal.

The HWR prototype showed some sign of field emission after the initial BCP and HPR. Additional BCP was done and the test results are shown in Fig. 7. We also observed multipacting band near the operation gradient and subsequent design modification is undertaken.

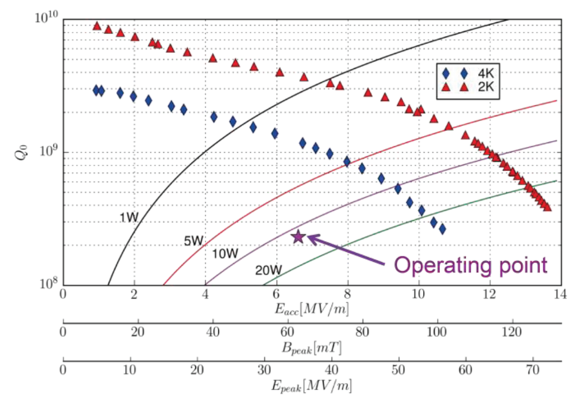

Figure 6: Plot of the vertical test results of the QWR prototype at 2K and 4K. For the 4K (2K) test, 160% (210%) of design field goal was achieved. Operating point for 4K is shown.

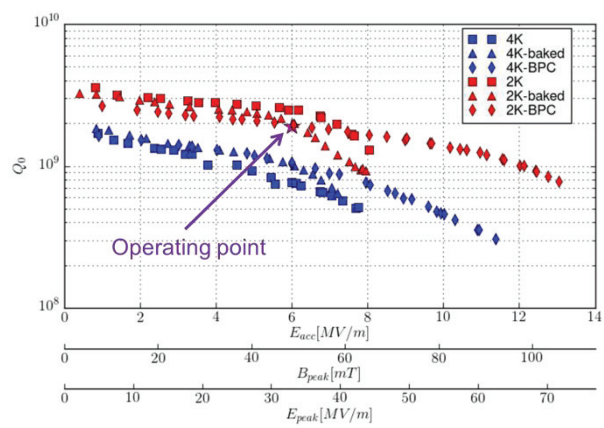

Figure 7: Plot of the vertical test results of the HWR prototype at 2K and 4K. For the 2K test, 200% of design field was achieved. Field emission took place around 5MV/m and another BCP/HPR was done. Multipacting band near the operating gradient is observed and subsequent design modification is undertaken.

Couplers and Tuners

Prototyping of couplers for the superconducting cavities (QWR, HWR, SSR1, SSR2) is carried out in collaboration with the IHEP, KEK etc. Lately prototype HWR couplers with 5-kW nominal RF power were fabricated and tested up to 15KW (5kW) in travelling (standing) wave mode in collaboration with the IHEP. Prototype SSR couplers with nominal RF power of 20kW were fabricated and under test. Figure 8 shows the prototype HWR and SSR couplers.

Figure 8: Photograph of the prototype HWR coupler (left) and prototype SSR couplers (right).

Prototyping of tuners is in progress. Figure 9 shows the prototype QWR tuner and SSR tuner. Prototype QWR tuner is being tested now.

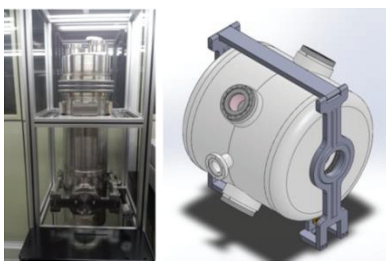

Figure 9: Plots of the prototype QWR and SSR tuners.

Cryomodules

Following the engineering design of each type of cryomodules, prototype cryomodules were fabricated through domestic vendors and basic tests were carried out such as vacuum tests and thermal load measurements. Figure 10 shows the photographs of cryomodule prototypes. Alignment deformation is measured during the cool-down.

Table 1 lists the design and measured static loads of the cryomodule prototypes. The measurement confirms that the design meet the requirement.

Table 1: Cryomodule Static Load Measurement

Cryomodule	Design Static Load	Measured Static Load
QWR Type	3.2 W	3.9 W
HWR Type	14.7 W	13.5 W

CONCLUSION

Prototyping reports of major subsystems such as 28-GHz ECR IS, RFQ, superconducting cavities, couplers, tuners, and cryomodules are presented. Prototypes of superconducting cavities show results surpassing the design requirements. 28-GHz ECR ion source SC magnets achieved 95% (80%) of design goals for the hexapole (solenoids).

Figure 10: Photos of prototype cryomodules fabricated through domestic vendors.

ACKNOWLEDGMENT

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