

## SRF HALF WAVE RESONATOR ACTIVITIES AT CORNELL FOR THE RAON PROJECT\*

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### Abstract

The RAON heavy-ion accelerator requires ninety-eight 162.5MHz Half-Wave-Resonators (HWR) with a geometrical  $\beta=0.12$ . Cornell University will test a prototype HWR as well as develop a frequency tuner for this cavity. In this paper we report on the progress in designing, fabricating, and commissioning of new HWR preparation and testing infrastructure at Cornell. The HWR infrastructure work includes new input and pick-up couplers, a modified vertical test insert with a 162.5MHz RF system, a new High-Pressure-Water-Rinsing (HPR) setup, and a modified chemical etching system.

### INTRODUCTION

RAON, which will be a heavy-ion accelerator based In-flight Fragment (IF) and Isotope Separation On-Line (ISOL) facility, is now under construction in Korea [1, 2]. The name "RAON", which comes from a pure Korean word, can be literally interpreted as delight and happiness [3]. The accelerator consists of two Superconducting Linac (SCL) sections which require in total of ninety-eight 162.5MHz Half-Wave-Resonators (HWR) with a geometrical  $\beta = 0.12$  [4].

The prototype HWR for the RAON project has been designed by the Institute for Basic Science (IBS) [5]. The cavity is now under fabrication in Research Instruments (RI). The surface treatments of the cavity will be done by RI as well. The cavity, after the fabrication, will be firstly treated with 150 $\mu\text{m}$  Buffer-Chemical-Polishing (BCP), followed by 625 $^{\circ}\text{C}$  baking for 10 hours in a high-vacuum furnace; after a light BCP (5-10 $\mu\text{m}$ ), the cavity will be High-Pressure-Water-Rinsed (HPR) and cleanly assembled. A 120 $^{\circ}\text{C}$  baking is not adopted for the recipe because the intrinsic quality factor ( $Q_0$ ) of such low-frequency cavity is dominated by the residual resistance ( $R_0$ ) instead of the BCS resistance ( $R_{\text{BCS}}$ ); but the 120 $^{\circ}\text{C}$  baking can increase  $R_0$  [6], which would cause the HWR Q-degradation. In a HWR test, a Q-degradation has been observed after a 120 $^{\circ}\text{C}$  baking [7].

The cavity will be shipped to Cornell University under vacuum for vertical tests to evaluate its performance. Cornell will test 1) the bare HWR cavity without helium tank; 2) the dressed cavity with helium tank; 3) the frequency tuner for the dressed HWR. If the cavity performance is unsatisfactory after the test 1) or 2), the cavity can be retreated at Cornell. The geometry of the HWR cavity is complex and quite different from a regular 9-cell SRF cavity, thus the current cavity preparation and testing facilities at Cornell have to be modified for this project.

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### PREPARATION OF PERFORMANCE TESTING

#### Input and Pick-up Couplers

The external quality factor ( $Q_e$ ) of the input coupler should match up the  $Q_0$  of the HWR, i.e.  $\beta \equiv \frac{Q_0}{Q_e} \approx 1$ ,  $Q_e \approx Q_0$ , to obtain unity coupling during the measurements. The cavity will be measured at temperature 2-4.2K; hence the  $R_{\text{BCS}}$  corresponding to the temperature range is 0.3-18n $\Omega$  for the un-baked case, computed by the SRIMP code [8, 9] which is based on the BCS theory [10, 11]. The estimation of  $R_0$  is complicated because it relates to many factors. But since the HWR has a low-frequency and is only treated by BCP, the  $R_0$  has less sensitivity to flux trapping from ambient magnetic fields [12]. Therefore the  $R_0$  of the HWR mainly comes from the surface treatments. Based on this analysis and the MLC 7-cell SRF cavity experiences [13, 14], we can give a good approximation of the  $R_0$  with 3-10n $\Omega$ , thus the surface resistance is 3.3-28 n $\Omega$ . The geometry factor of the HWR is 36 $\Omega$ , from which it can be calculated that the highest  $Q_0$  (or  $Q_e$ ) can be  $\sim 1.1 \times 10^{10}$ . During the test, multipacting is likely to occur at very low fields [15, 16], which can be removed by RF processing. The RF processing requires strong coupling to fill and drain RF power quickly, i.e.  $\beta > 100$ ,  $Q_e \sim 1 \times 10^7$ . In summary, the range of the  $Q_e$  should be at least from  $1 \times 10^7$  to  $1.1 \times 10^{10}$ .

We designed an electric-coupler which has a straight antenna and will be mounted in the middle section of the cavity. The  $Q_e$  vs. insert depth curves simulated by Microwave Studio are shown in Fig. 1. The total travel range of the coupler is 50mm, which can tune the  $Q_e$  from  $\sim 1 \times 10^7$  to  $\sim 1 \times 10^{11}$  and give adequate margins for the measurements.

The 3D model of the input coupler is shown in Fig. 2 a). When the drive gears rotate, they turn the threaded shafts to drive the moving plate in linear motion. The threaded shafts are symmetrically placed around the below; the torque is evenly delivered from the input shaft to the three threaded shafts by the gears. Hence, symmetrical forces are applied on the moving plate to avoid binding with the traveling guides. A photograph of the input coupler is displayed in Fig. 2 b). The pickup coupler is a fix coupler with  $Q_e \sim 1 \times 10^{13}$  to match the required power level of the LLRF system. A feedthrough, displayed in Fig. 3 middle insert plot, is mounted on an adaptor to match the cavity flange. The 3D model and the photo-

graph of the pickup coupler are shown in Fig. 3 a) and b) respectively.

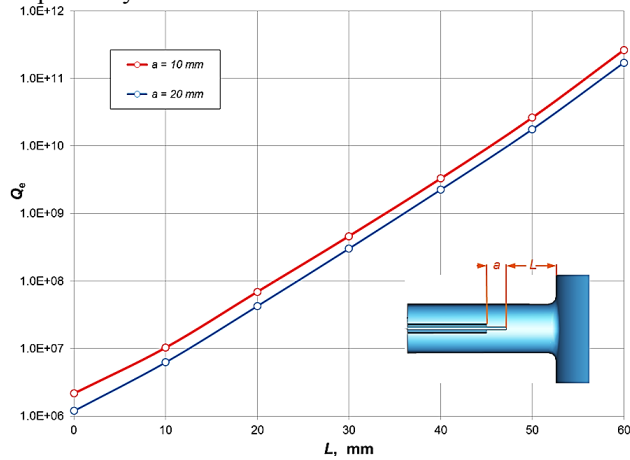


Figure 1: Curves of the  $Q_e$  vs. insert depth for the input coupler simulated with Microwave Studio.

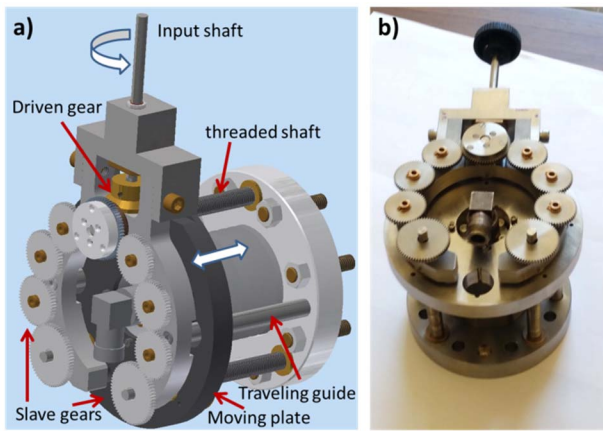


Figure 2: a) Diagram of the input coupler; b) the photograph of the input coupler.

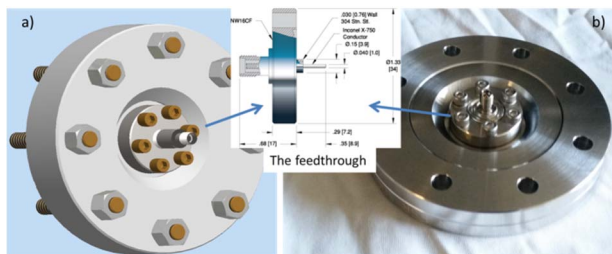


Figure 3: a) Diagram of the pickup coupler; b) the photograph of the pickup coupler.

### HWR Handling Frame and RF Insert

A view of the HWR dressed without and with helium tank, is depicted in Fig. 4 a) and b). The bare-cavity weight is about 80lbs; the dressed cavity is about 130 lbs with the helium tank. A handling frame is needed to hold the cavity 1) on the RF insert for the cold tests, 2) on the HPR stand in cleanroom, 3) on the BCP system. The frame for the bare cavity holds the cavity flanges instead of the cavity body, which will not deform the cavity; thus it will not shift the cavity frequency. The frame for the dressed cavity is attached on the helium tank without touching the cavity body as well.

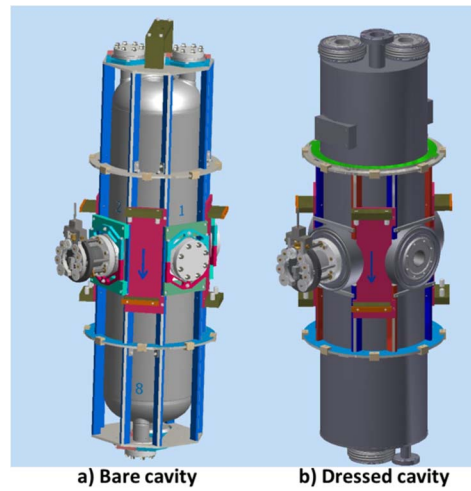


Figure 4: 3D modes of the bare cavity in a) and the dressed cavity in b) attached with the handling frame.

In the test 1) and 2), the whole cavity will be kept in a liquid helium bath. But for the tuner test (test 3), this setup would have the risk of damaging the tuner motor, if the tuner were placed into helium bath. Hence the liquid helium will be filled only into the tank, which needs a reservoir to be installed to the RF insert. Fig. 5 a) depicts the RF insert for the tests 1) and 2); the dark green represents the cryogenic Dewar; the pink shows the magnetic-field shielding layer; a drive-shaft from the top-plate connects the input coupler and a motor outside the Dewar. The reservoir will be installed on the insert after the test 1) and 2) as is shown in Fig. 5 b).

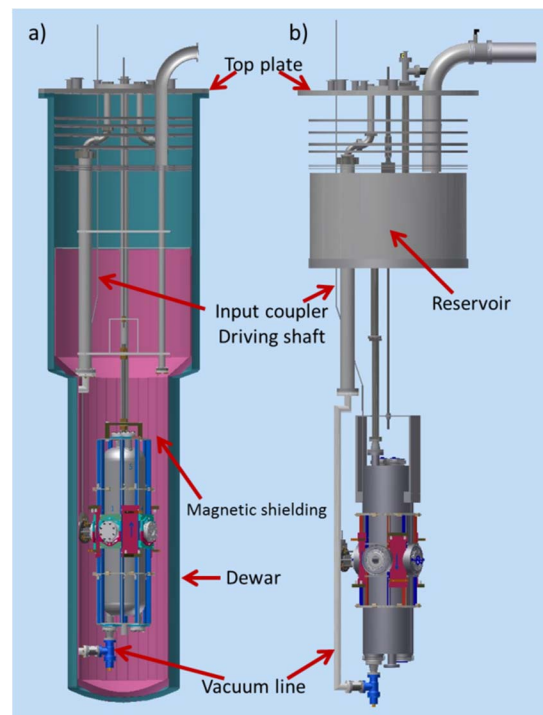


Figure 5: 3D models of the RF insert: a) the insert for the HWR vertical test with the view of the Dewar and magnetic-field shielding; b) A reservoir installed on the insert for the HWR cold tuner test.

### HPR Setup

As the HWR structure is complex, the HPR nozzle should go through all the ports at the cavity ends and the beam-pipe ports to rinse all the inner surfaces. The cavity is loaded and unloaded to the HPR stand by a cart which has a build-in rotator and spinner. The cart can align the cavity ports with the HPR wand when the cavity is in the horizontal position (Fig. 6 a)) and in the vertical position (Fig. 6 b)). During a HPR, the cavity moves up-and-down lifted by the HPR stand; DI water is jetted onto the cavity surfaces by the tuning wand and nozzle.

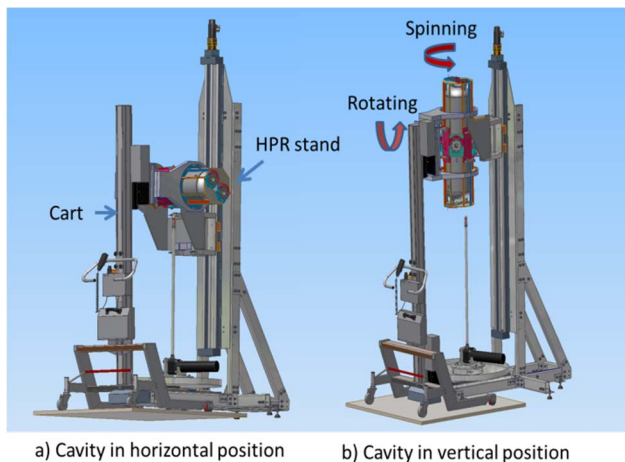


Figure 6: Diagram of loading the cavity onto the HPR stand a) when the cavity is in the horizontal position; b) when the cavity is in the vertical position.

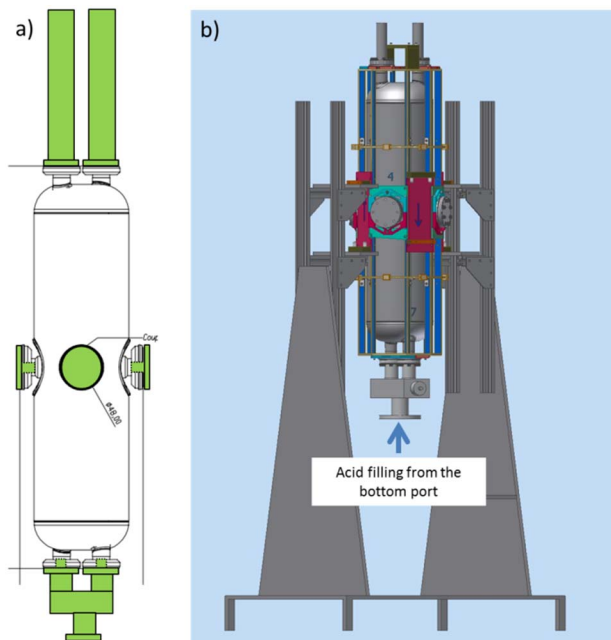


Figure 7: a) Diagram of the HWR installed with the BCP fixtures; b) 3D model of the bare cavity attached with the handling frame on the BCP rack.

### BCP Setup

As Fig. 7 a) and b) is shown, the HWR is setup vertically on the BCP rack; two chimneys are installed on the top two ports; the middle ports are blocked by the blank flanges; an acid filling line is connected the bottom two flanges to the acid tank. In a BCP, the acid is transferred from the bottom ports to the cavity; cooling water is sprayed on the exterior surfaces of the cavity to keep the acid temperature below 20°C; the waste gases produced in chemical reactions are exhausted from the chimneys on the top. Instead of circulation the acid inside the cavity, we dump the acid back to acid tank and refill the cavity with the acid every 10 min. After the etching, the cavity will be filled with DI water and put into an ultrasonic tank to remove the residual chemicals on the surfaces.

## CONCLUSION

On the base of the current cavity facility, Cornell University now is developing the cavity treatment and testing infrastructure for the prototype HWR cavity of the RAON project. These efforts will expand our capabilities to treat and test low- $\beta$  and low frequency cavities at Cornell. For the project, we have completed the input and pickup couplers design and fabrication. The HWR handling frame, the RF insert, the HPR setup, and the BCP setup have been designed and will be completed very soon. First HWR testing will start in late 2016.

## ACKNOWLEDGMENT

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