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STATUS OF RF POWER COUPLER FOR HWR IN RISP*

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Abstract

A heavy-ion accelerator facility is under construction for Rare Isotope Science Project (RISP) in Korea. Four types of super conducting cavities, QWR, HWR, SSR1, and SSR2 are developed to accelerate the ion beams. The QWR cryomodule is already installed in the tunnel. The HWR cryomodule is transport to the tunnel. Here, the status of HWR RF power coupler is presented. After the fabrication, the coupler is test with high power RF. The some of the test results are described.

INTRODUCTION

Several prototype couplers are developed and tested for HWR cavities and cryomodules [1] [2]. With the bias tee, the mass production of HWR RF power coupler is proceeded. 104 couplers are fabricated, but 1 coupler could not accepted for assembly with the cryomodule. 4 couplers are re-fabricated due to the mechanical damage during the transportation from the vendor to IBS. Since 26th Jan 2021, 86 couplers are tested by applying high power RF up to 3.0 kW in standing wave mode. The number 86 means that the number of coupler to installation with HWR-type B cryomodule. Here, the requirements of HWR RF power coupler is summarized and the high power RF test results are introduced briefly.

Requirements

The requirements of RF power coupler for HWR cavity is presented in Table 1.

Table 1: Requirements for HWR RF Coupler

Parameters	Values
Frequency	162.5 MHz
RF power	0 ~ 4.0 W
External Q	$1.0 \sim 2.0 \times 10^6$
Coupling type	Capacitive
TiN Coating	Applied
Copper plating	Not-Applied
DC-bias tee	prepared

The HWR RF power coupler is assembled near the beam port of the HWR cavity, the RF coupling of coupler and cavity is by capacitive type. The external Q and required RF power is optimized as shown in Fig. 1 (a). There is a RF power limit by the HWR SSPA (4 kW). In Fig. 1 (b), the simulation and measurement of the external Q is presented. Measurement 1 and 2 are the measured external Q before the

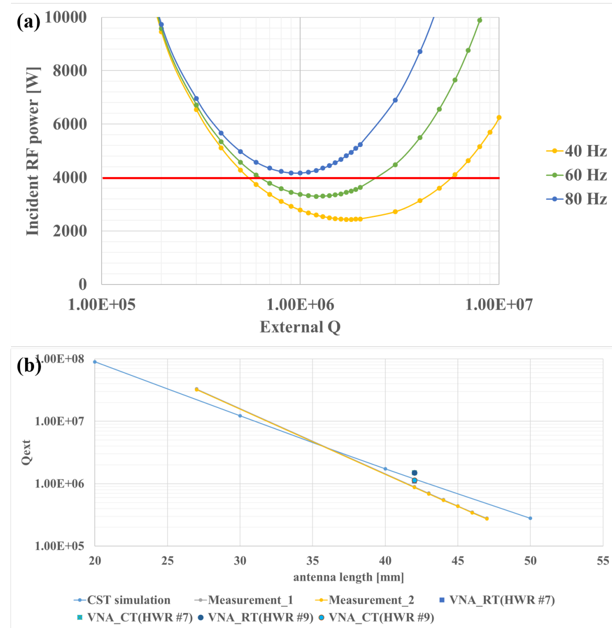

Figure 1: (a) Optimized RF power and external Q. (b) Measurement and simulation of external Q.

surface processing of the cavity. The trend of the simulation and the measurement of external Q could confirmed by the Measurement 1,2 in Fig. 1. Before the mass production of RF power coupler, two couplers are measured extenral Q in room temperature and cyrogenic temperture. both of the external Q are matched with the predictions. The TiN coating on the surface of the ceramic window is applied. The coating is proceeded after the brazing of the ceramic window and outer conductor. The copper plating at the RF surface of outer conductor is not applied for this coupler. Also, the effect of the DC-bias tee could confirmed at the prototype cryomodule test [1].

Figure 2: Installation of HWR cryomodule in the tunnel. DC-bias tee is assembled with the RF coupler in small picture.

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Installation in the Tunnel

HWR cryomodules are installed in the tunnel as shown in Fig. 2. In the figure, HWR A type cryomodules are presented. The RF transmission line is not assembled. In Fig. 2, DC-bias tee is assembled with the RF power coupler (small picture). The bias tee is located between the RF transmission line and RF power coupler.

FABRICATION

The drawing and fabricated HWR RF power coupler is described in Fig. 3. The antenna tip length is optimized by the measurement results of external Q. Two thermal intercepts are brazed with outer conductor. The bellows which is located between the thermal interceptor and the ceramic window is prepared for increasing the heat path from the room temperature. From the CF flange to the ceramic window parts are assembly with the cavity in the cleanroom. This part, so called cold section, is tested by high power RF after the 120 degree baking. The rest of the part are assembled after the loading of the cavity, coupler and tuner to the cryomodule. STS316L is mainly used for outer conductor (including bellows parts) and OFHC is used for inner conductor and thermal interceptor.

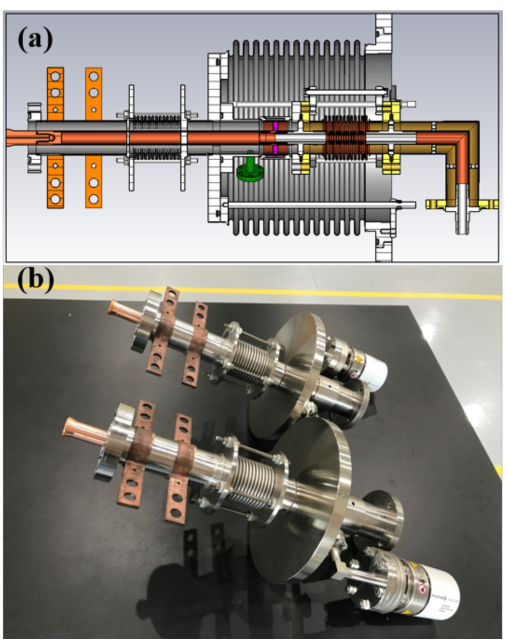

Figure 3: (a) Drawing of HWR RF power coupler. (b) Fabricated RF power coupler (cold section).

RF TEST

After the final brazing of the RF power coupler, the ultrasonic cleaning is applied to the coupler. The 120 degree baking of the coupler is conducted in 2 days. The cold section of RF power coupler is delivered to IBS for RF test. In this RF test, the temperature of the ceramic window is mainly checked. The temperature at the bellow part and tube part are also monitored. One coupler could not passed this high power RF conditioning. Some contamination around the ceramic window and scratches at the RF surface are observed after the RF test from the non-passed coupler.

Test Setup

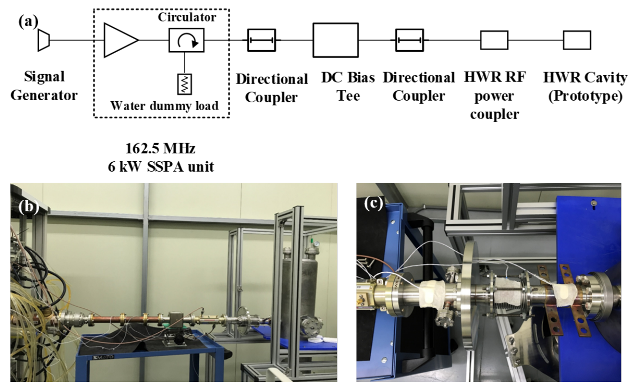

Figure 4: (a) Block diagram of test setup. (b) Test bench. (c) Temperature sensors at the coupler.

In order to apply the high power RF to the HWR RF power coupler, the the bench is prepared as shown in Fig. 4. Figure 4 (a), the block diagram is describes the test setup. Using the prototype cavity, the electromagnetic wave is applied as standing wave mode. The node of standing wave is closed to the ceramic window. The SSPA includes three circulators to protect the amp. Three temperature sensors(PT100) are attached at the test coupler, ceramic window, tube part, bellows part. The cold cathode gauge is located the lower port of HWR cavity.

Test Results

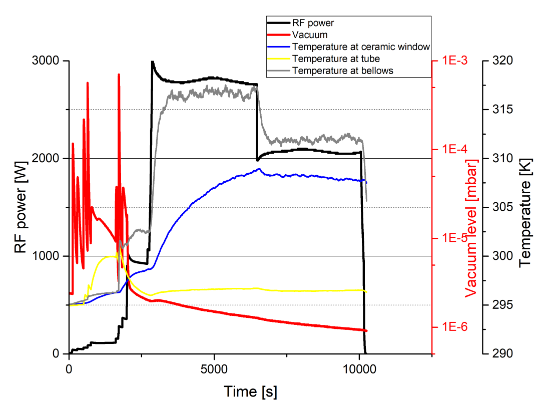

Figure 5: Drawings and fabricated coupler.

Typical test results of HWR RF coupler is presented in Fig. 5. When the vacuum level is reached under the 2.0×10^{6} mbar, the RF is turned on. The vacuum level and the temperature at the tube part is affected by RF turn o n. At least 1 hours to condition the coupler is necessary. After the conditioning, the RF power is increased up to 3.0 kW. Applying 3.0 kW in 1 hours, the temperature are checked.

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The temperature variation at the ceramic window and the bellows part is described in Fig. 5. The temperature at the bellow part is more affected by RF power lever than the temperature at the ceramic window part. The absence of the copper plating could be main reason of this temperature variation. Typically, the temperature of ceramic window is saturated under the 318 K. After the applying 3.0 kW in 1 hour, the RF power is decreased to 2.0 kW. Also, the RF power is maintained as 2.0 kW in 1 hour. With the 2.0 kW RF power, the ceramic window temperature is saturated under 310 K. The air conditioner is set to 299 K, but the air conditioner was not affected the test results.

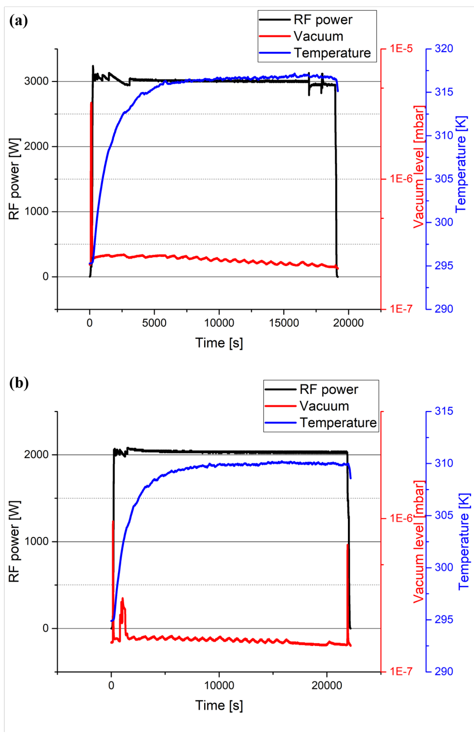

Figure 6: (a) 6 hours test results of applying 3.0 kW. (b) 8 hours test results of applying 2.0 kW.

In order to check the saturation temperature with RF power, the RF power is applied in long term. Figure 6 (a) shows the 6 hours test results with 3.0 kW RF power. The temperature at the ceramic window is almost saturated in 1.5 hours. Figure 6 (b) shows the 8 hours test results applying 2.0 kW RF power to the coupler. The temperature at the ceramic window is almost saturated in 2.0 hours. By these test results, the RF test process is optimized as shown in Fig. 5.

Figure 7, 8 are the RF test results of non-passed coupler and the visual inspection results. Unlike the normal coupler which has the similar RF test results as shown 5, the ceramic window temperature is more increased than 310 K with low RF power level as shown in Fig. 7. The coupler could not conditioned applying RF power due to the heat loss from the ceramic window. And the vacuum level could not stabilized. The inside of the coupler is visually observed as shown in Fig. 8. Some contamination around the ceramic window

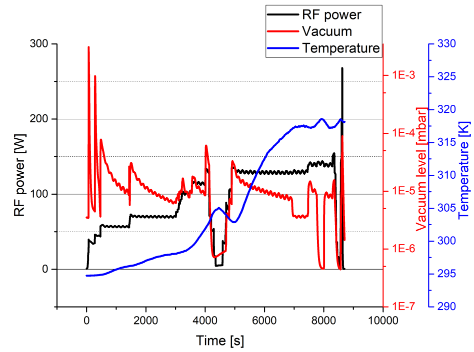

Figure 7: RF test results of non-passed coupler.

and inner conductor is observed (left picture in Fig. 8). This contamination could occur the heat loss at the ceramic window with small RF power level. Also some scratch marks are checked at the RF surface of outer conductor. Normal coupler are visually inspected, but no serious contamination or scratch marks are observed as Fig. 8.

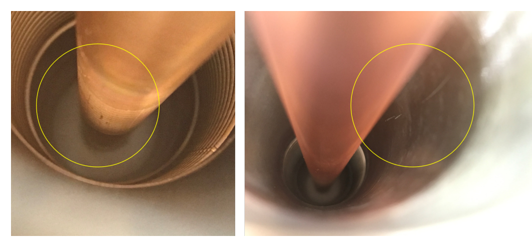

Figure 8: Visual inspection of non-passed coupler.

CONCLUSION

In order to construct the heavy-ion accelerator in RISP, the HWR RF power coupler is developed and the mass production is almost completed. 86 couplers which are installed in HWR B-type cryomodule are conducted the high power RF test. To check the status of coupler, the temperature at the ceramic window is mainly monitored. Applying 3.0 kW RF power, the temperature of ceramic window is saturated under 320 K in 1 hour. One coupler could not passed the high power RF test due to the excessive heat loss at the ceramic window with low RF power level. Some contamination and scratch marks are caused the more heat loss than normal coupler which has no surface problems. Now, all of the HWR RF power couplers are ready to assemble with the cryomodule.

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