DESIGN OF RF POWER COUPLER FOR RISP HALF WAVE RESONATOR*

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Abstract

RF power couplers for half wave resonators (HWR) are being developed for the Rare Isotope Science Project (RISP) in Korea. It is required to deliver up to 6 kW RF power at 162.5 MHz to the HWR in CW mode. The RF coupler is a coaxial capacitive type using a disc type ceramic window. Design studies for the 2^{nd} prototype HWR RF coupler are presented.

INTRODUCTION

The rf power coupler serves as a stable rf power deliever to the resonator and a barrier for ultra-high vacuum between the resonator and air side. It is also a thermal bridge between the room-temperature and cryogenic temperature at the resonator. It should be minimize the thermal loss. Table 1 shows the coupler design parameters.

Table 1: RF Coupler Design Parameters

Parameter	Value
Frequency	162.5 MHz
Type	Capacitive
Nominal power	6 kW
Return loss	<30 dB
Impedance	50 Ω to 90 Ω
Q_{ext}	2×10^6

CONCEPTUAL DESIGNS

Figure 1and 2 show the conceptual designs HWR coupler. Both couplers are based on 3-1/8" EIA coaxial line. Inner diameter of HWR port for the coupler is 48 mm. The couplers have a disc type ceramic window of 8 mm thickness with 5 nm and 10 nm TiN coating [1]. The difference between Type A and Type B couplers are the presence of the cooling line. There are two bellows in both coupler designs. A bellow structure in warm section is used for assembly with cryomodule and for adjusting thermal contraction. The other one in cold section is to adjust Q_{ext}. There are three ports for diagnostics near the RF window (e-pickup, arc detector, vacuum gauge). The outer conductor is made of stainless steel with 20 μm copper plating on the inner surface. The main design difference between the two types of coupler is the presence of air-cooling line. The type A coupler has no cooling line for inner conductor. The air-cooling is only in Type B coupler. In order to insert the air-cooling, a transition box (T-box) is introduced [2]. In Figure 1, there is an impedance matching section which utilizes the $\lambda/12$ stucture [3]. Instead of the $\lambda/12$ stucture, the T-box is used for impedance matching in Type B coupler.

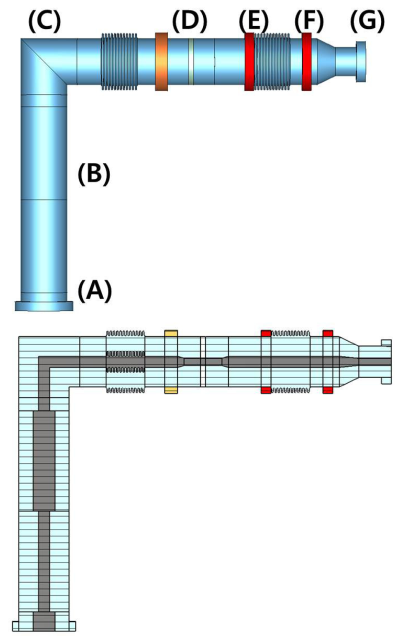

Figure 1: RISP 2^{nd} prototype HWR coupler Type A. (A) RF power input. (B) Impedance matching section. (C) Elbow section. (D) RF window section. (E) 40 K thermal intercept. (F) 4.5 K thermal intercept. (G) Cavity port.

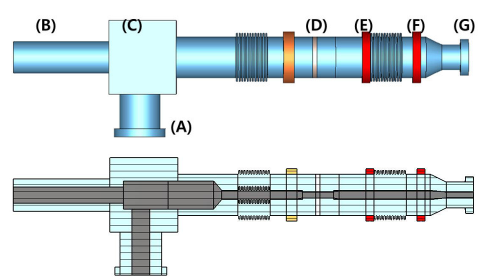

Figure 2: RISP 2^{nd} porototype HWR coupler Type B. (A) RF power input. (B) Air-cooling line. (C) Transition Box (T-box). (D) RF window section. (E) 40 K thermal intercept. (F) 4.5 K thermal intercept. (G) Cavity port.

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CST SIMULATIONS

Electromagnetic Simulation

Electromagnetic (EM) simulation for the coupler has been conducted by using CST MWS. Figure 3 shows the electric field distribution for each coupler design.

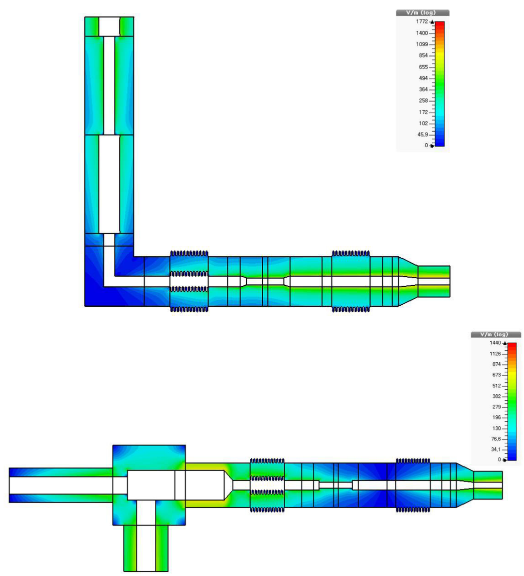

Figure 3: HWR coupler EM simulation. The upper figure shows the electric field distribution for the type A coupler and the lower figure represents the electric field for the type B coupler.

Multipacting Study

As the diameter of HWR cavity-coupler port is changed, the coaxial structure which could minimize the multipacting (MP) problem has been studied in analytical and computer simulations (CST Particle Studio) [4] [5]. From the computational study, the coupler impedance has been determined as 90 Ω.

- Multipacting prediction: The multipacting prediction for coaxial line has been studied by many other groups [6] [7] [8]. Most of the studies are based on parallel plate model with the resonant condition for multipacting. Following is an estimation for predicting the 2-point 1^{st} order multipacting power [9].

$$P_n = \frac{A(\omega d)^4}{2\pi^2(2n-1)^2}\frac{m_e^2}{e^2}\frac{1}{Z}, \tag{1}$$

  where P_n is n-th order of 2-point multipacting power, A is 0.25 for standing wave (SW) and 1 for traveling wave (TW), ω is the angular frequency, d is the gap between the outer conductor and the inner conductor, m_e is the mass of the electron, e is the charge of the electron, and Z is the impedance of the coaxial line. The calculated result using the Eq. (1) is summerized in Table 2. In the Table 2, D_1 is the diameter of the outer conductor at the cavity port and D_2 is the diameter of the outer conductor at the vacuum section. The cavity port and the rf window section are the most dangerous section where the probability of multipacting is relatively high.

Table 2: Analytically Predicted 2-point 1^{st} order Multipacting Power

Parameter	**1^{st} prototype**	**2^{nd} prototype**
Impedance	50 Ω	90 Ω
D_1	40 mm	48 mm
D_2	70 mm	77 mm
Analytical P_1 (SW)	0.1 kW(D_1)	0.6 kW(D_1)
	1.4 kW(D_2)	3.9 kW(D_2)
Analytical P_1 (TW)	0.5 kW(D_1)	2.4 kW(D_1)
	5.5 kW(D_2)	15.9 kW(D_2)

- Multipacting simulation: The MP simulations for the 1^{st} and the 2^{nd} coaxial strucures are represented in Figure 4. The outer conductor diameters of the 1^{st} prototype HWR coupler are 40 mm and 70 mm. The cavity port section diameter is 40 mm and the outer conductor diameter at the vacuum section of the coupler is 70 mm. In 2^{nd} prototype coupler, the diameters 40 mm and 70 mm have been changed to 48 mm and 77 mm, respectively. The multipacting simulation for coaxial line has been used PIC solver in CST PS. Figure 4 shows the results of the simulations. The total emitted secondaries are a summation of emitted secondaries during 8 rf cycles for a given rf power. In order to determine the impedance of the coupler, the total emitted secondaries have been calculated as a function of the coaxial impedance with a fixed outer conductor diameter. The simulation results are in medium agreement with the predicted results.

According to these analyses, the coupler impedance has been determined as 90 Ω.

CONCLUSION

Design of the 2^{nd} prototype HWR rf coupler has been studied for RISP. Two type of RF couplers has been designed. The type A coupler has no air-cooling line but uses the $\lambda/12$ structure for impedance matching. The type B coupler has T-box which serves the inlet of cooling line and impedance matching.

CST has been used for EM and MP simulation. The MP simulation with the PIC solver agreed with the analytically predicted MP power. The thermal analysis and the mechanical analysis are in progress.

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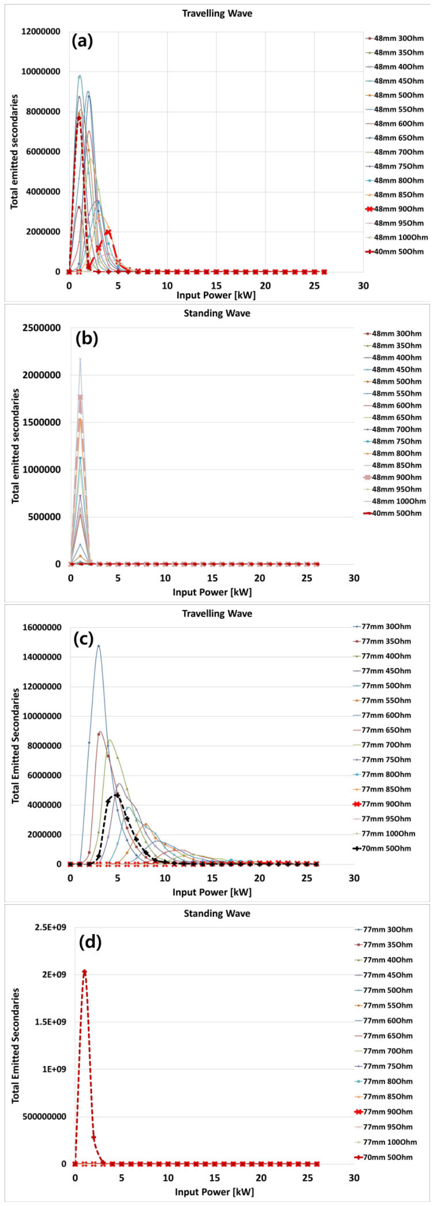

Figure 4: HWR coupler MP simulations. (a) and (b) are the total emitted secondaries for 48 mm and 40 mm with parametric impedance and input power in TW and SW mode, respectively. (c) and (d) are the total emitted secondaries for 70 mm and 77 mm in TW and SW mode respectively. Each figure has the 1st prototype coaxial line (black dotted line) for comparing with the 2nd prototype coaxial structure.

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