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DESIGN OF RF POWER COUPLER TRANSMITTING BOTH 162.5 MHz AND 81.25 MHz POWER TO SRF CAVITIES FOR BISOL R&D RESEARCH

A.Q. Cheng, F. Zhu[#], S.W. Quan, F. Wang, J.K. Hao, M. Chen,
Institute of Heavy Ion Physics & State Key Laboratory of Nuclear Physics and Technology,
Peking University, Beijing, 100871, China

Abstract

RF power coupler is a key component of superconducting accelerating system. In BISOL (Beijing isotope separation on line type rare ion beam facility) deuteron superconducting linear accelerator, half wave resonators (HWRs) are adopted to accelerate deuterons. In post accelerator, quarter wave resonators (QWRs) will be used to accelerate heavy ions. For the pre-research of BISOL, we will fabricate a cryomodule which can provide the horizontal test of both 81.25 MHz QWR for the post-accelerator and 162.5 MHz HWR for the driver accelerator with the proper external quality factor. In order to reduce expenses, we are developing a RF power coupler which can transmit both CW 20 kW162.5MHz for HWR cavities and 1-5 kW 81.25MHz power for QWR cavities. Now the physics design of coupler has been finished, including RF structure optimization, MP simulation, thermal analysis and so on. Based on the design, A prototype of coupler will soon be fabricated and proceed the high power test.

INTRODUCTION

Beijing isotope separation on line type rare ion beam facility (BISOL) is a proposed facility which has an intense deuteron driver superconducting linac and a post-accelerator [1]. For the first stage of BISOL, the beam load reaches 10 mA of 162.5MHz HWR cavities for deuteron beams and 0.4 uA of 81.25MHz QWR cavities for secondary heavy ion beams. Peking University has developed a high current β =0.09 162.5MHz HWR for the deuteron driver linac and the cavity showed very goog performance [2]. A prototype β =0.085 81.25MHz QWR for post accelerator is under fabrication. To meet the requirements, the coupler should have the capability to transmit 20 kW CW RF power in 162.5MHz frequency and 1 kW CW RF power in 81.25MHz frequency. Based on the design experience of IFMIF coupler [3] and C-ADS coupler [4], the structure of each part of the coupler has been determined for further optimization. The parameters of coupler are shown in Table 1.

RF STRUCTURE OPTIMIZATION

The RF transmission of the coupler was optimized by CST code. Figure 1 shows RF structure of the coupler. Main structure of HWR coupler and QWR coupler are same, which is consist of two cylinder ceramic windows, bellow structures and coaxial transmission line. Cylinder type window has higher mechanical strength and better thermal endurance compared with disc type window. Meanwhile, two windows are safer to protect SRF cavities from being polluted. There is another impedance change segment for the 81.25MHz coupler because of the different flanges connected with the high current HWR cavity and the QWR cavity.

Table 1: Parameters of the Coupler

Parameter	Value
Frequency	162.5MHz/81.25MHz
Impedance	50ohm
Structure type	Coaxial
Window type	Double, cylinder ceramic
Coupling method	Antenna coupling
Power level	20kW@162.5MHz, 1kW@81.25MHz

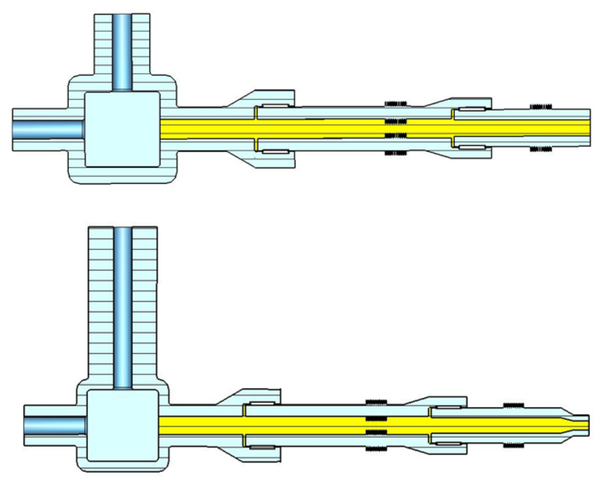

Figure 1: RF structure of coupler. The upper figure is 162.5MHz coupler and the lower figure is 81.25MHz coupler.

In order to install insulating film and air-cooling pipe more conveniently, both couplers use T-box. The left side of T-box connects to the RF power source. On the upper side of T-box, there is a short-circuit face which can be moved to adjust the mis-matching. Although T-box has frequency selectivity, we can adjust the size of outside box and the position of short-circuit face to guarantee the

[#]zhufeng7726@pku.edu.cn

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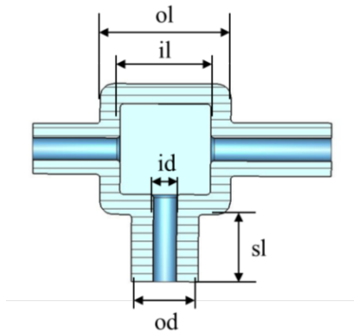
impendence matching for the whole coupler transmitting both 162.5MHz and 81.25MHz frequency.



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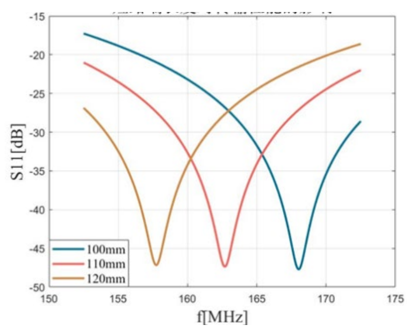

(b)

Figure 2: (a) The model of the T-box. (b) The center frequency changed as the position of the short-circuit face.

Figure 2 shows the cross section of the T-box. The position of the short-circuit face and the geometry parameters of the T-box affect the transmission properties. There are two methods to get both good S parameters at two different frequency. It can be achieved by changing the position of the short-circuit face of about 400 mm while using the same T-box. The other method is that position of the short-circuit face moves about 180 mm and the geometry parameters of the outer T-box also changed while keeping the same inner T-box. Because the T-box is under atmosphere and the outer T-box is easy to replace, we choose the second method of the T-box design.

After a series of optimization, a good S parameter result has been found. As shown in Fig. 3, the S11=-45.5dB when frequency is 162.5MHz and the S11=-41.8dB when frequency is 81.25MHz. The simulation results show that the coupler has good transmission properties for both frequencies.

MP SIMULATION

Multipacting (MP) can cause energy loss and heat generation, limiting the maximum transmission power. Normally MP can be suppressed by optimizing geometry of coupler, coating TiN film on ceramic windows and adding electrical bias. CST particle tracking mode is used to simulate MP in the coupler. Figure 4 shows the inhibiting effect of electrical bias. When transmitting 20kW RF power, 1kV electrical bias on inner coax can restrain MP by shifting resonant conditions. When transmitting higher RF power for the BISOL second stage with deutron beam current of higher than 20 mA, higher electrical bias or TiN coating is needed. For example, if power level gets to 50kW, we can find that 1kV electrical bias doesn't work but 2kV electrical bias is effective. If power level arises to 100 kW, simulation gives that MP can be suppressed by 1kV electrical bias and TiN film coating on the ceramics. For the first stage of BISOL, the designed coupler can transmit both CW 20kW 162.5MHz and 1 kW 81.25MHz power by just adding 1 kV electrical bias and without TiN film on ceramic windows.

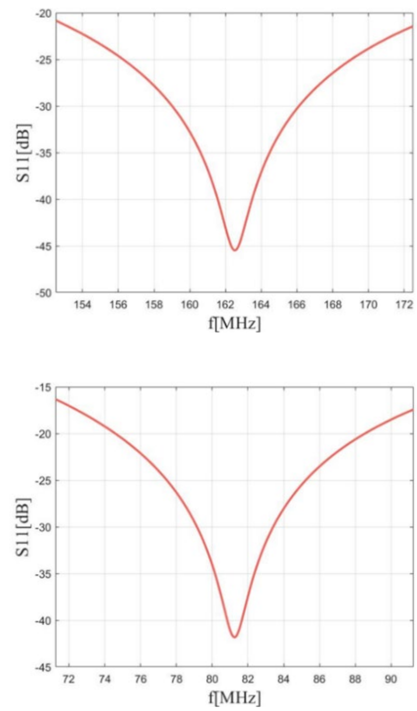

Figure 3: Optimized S-parameter of the coupler, S11 = - 45.5dB @162.5MHz, S11=-41.8dB @81.25MHz

THERMAL ANALYSIS

Because coupler plays a role of temperature transition between room temperature and 4.2 K, the requirement of thermal design is reducing the heat loss to the low temperature system and controlling temperature rise of the coupler when transmitting high RF power. In general, heat loss from coupler to the low temperature system includes static heat loss and dynamic heat loss, which can be balanced by copper plating on the surface of stainless steel outer conductor. In addition, increasing the number of thermal anchors and using bellows structure can also reduce the level of heat loss effectively.

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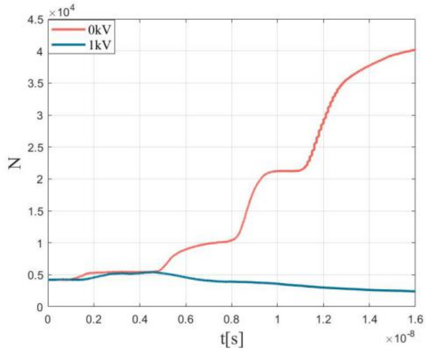
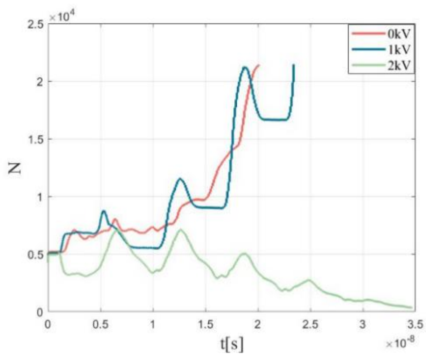


(a)



(b)

Figure 4: Inhibiting effect of electrical bias. (a) The power level is 20kW (b) power level is 50kW.

Thermal analysis was done by ANSYS code. In the thermal simulation, the RF power is selected as 20 kW. From the temperature distribution results in Fig. 5, it can be found that without air cooling the maximum temperature is 330K located at inner conductor, but with air cooling the maximum temperature is just 303K. Through the comparison, air cooling is a good method to control the temperature rise. Besides, the heat loss to 4.2 K is 1.5W and the heat loss to 77K is 6.2W. this analysis indicates that 20kW is a safe power level for our coupler in real operation.

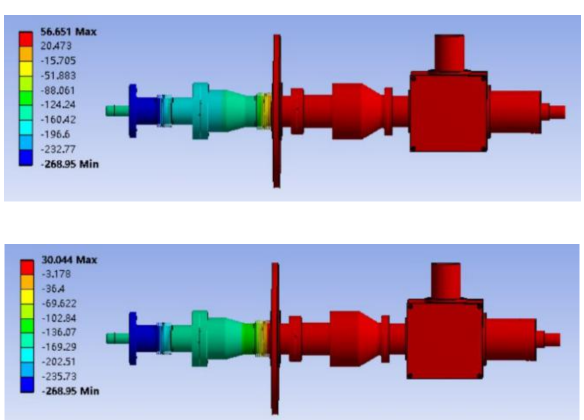


Figure 5: Temperature distribution result. The upper figure is coupler without air cooling and the lower figure is coupler with air cooling.

CONCLUSION

A prototype input power coupler which can transmit both 162.5MHz and 81.25MHz frequency power to SRF HWR cavity or QWR cavity has been designed. RF structure optimization, MP simulation and thermal analysis of the coupler have been finished. The mechanical design of the coupler is in process. It will be fabricated and proceed the high power test soon.

REFERENCES

[1] Yanlin Ye, Proposed BISOL Facility – a Conceptual Design, EPJ Web of Conferences, vol. 178, p. 01005, 2018.

[2] F. Zhu, J.K. Hao, S.W. Quan, The effect of nitrogen infusion on a 162.5 MHz low beta superconducting HWR cavity, Nuclear Inst. and Methods in Physics Research, A 937 (2019) 21 – 25.

[3] H. Jenhani et al., "Input Power Coupler for the IFMIF SRF Linac", in Proc. 3rd Int. Particle Accelerator Conf. (IPAC'12), New Orleans, LA, USA, May 2012, paper WEPPC001, pp. 2200-2202.

[4] F.B.Meng et al. "The study and design of RF coupler for Chinese ADS HWR Superconducting Cavity", Chinese Physics C Vol. 38, No. 11 (2014) 117002.