IMPROVED CAPACITIVE COUPLING TYPE RF POWER COUPLERS FOR A CRYOMODULE WITH TWO 9-CELL CAVITIES

Dehao Zhuang, Fang Wang, Zhanglong Wang, Peiliang Fan, Lin Lin, Liwen Feng, Shengwen Quan, Kexin Liu, Institute of Heavy Ion Physics, Peking University, China

Abstract

A capacitive coupling [1] RF power coupler has been used for the DC-SRF [2] photoinjector at Peking University. Recently, improved capacitive coupling type power couplers, which will be used for a new cryomodule with two 9-cell cavities have been designed and fabricated. The main modifications include enlarging the supporting rods of inner conductors in order to increase heat conduction, moving the bellows from the quarter-wave transformer to the 50 Ohm coaxial line to avoid the mismatch during Q_{ext} adjusting. RF conditioning of two modified power couplers has been carried out and 10kW RF power passed the couplers with a duty factor 30%. In this paper, detailed design based on multi-physics analysis and the conditioning of this improved capacitive coupling type RF Power coupler are presented.

INTRODUCTION

A cryomodule with two 1.3GHz 9-cell cavities [2] is under construction at Peking University. The capacitive coupling type RF power coupler, which has been used for the DC-SRF photo injector, will still be used for this cryomodule will still use the kind of capacitive coupling type RF power coupler.

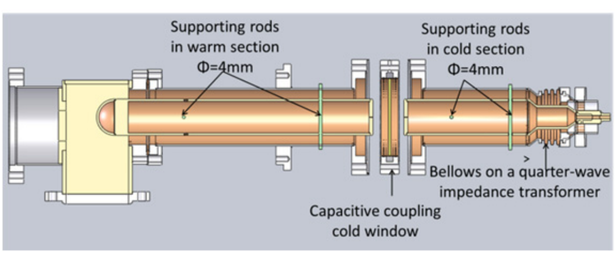

Figure 1: Structure of capacitive coupling type power coupler for the DC-SRF photoinjector at Peking University.

The capacitive coupling structure as shown in Figure 1 has the following advantages [3]: 1) the ceramic window is a whole disc, which makes it easy for fabrication and process. 2) As the inner conductor is divided into two parts, it is convenient to install the coupler into the cryomodule. 3) There is no axial stress due to the separation of inner conductor and window. However, problems of this kind of coupler have been found during the beam loading experiment of the DC-SRF photoinjector. An obvious temperature increase around supporting rods was observed when the power was over 8 kW. With the original design, the bellows is within the quarter-wave transformer. During Q_{ext} adjusting, the variation of the bellows' length will cause RF mismatching. Therefore, modified couplers have been designed and fabricated. In this paper, the design, fabrication and conditioning of this improved capacitive coupling type RF Power coupler are presented.

*Work supported by Major State Basic Research Development Program of China (Grant No. 2011CB808303 and 2011CB808304)
Email: kxliu@pku.edu.cn

ENLARGING SUPPORTING RODS FOR INNER CONDUCTOR

For solving the problem of temperature increase, we try to enlarge the supporting rods for inner conductor and the thermal analysis has been carried out.

We compared the temperature distribution of couplers with original design and modified design by using ANSYS code. Figure 2 shows the temperature distribution of the original PKU coupler with the input RF power of 10kW and the supporting rod diameter of 4mm. The highest temperature is 452.5K and it occurs at the end of the inner conductor.

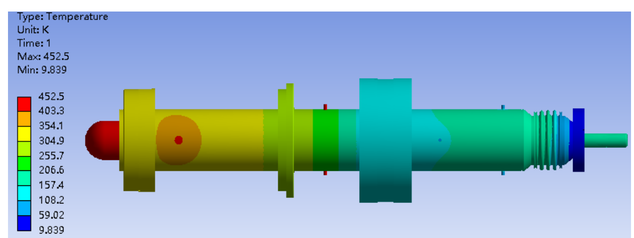

Figure 2: Temperature distribution of original power coupler at 10kW, CW.

Figure 3 shows the temperature distribution of the modified coupler with the input RF power of 10 kW and the supporting rod diameter of 24.1mm in warm section and of 18 mm in cold section. The highest temperature is 388.1K and it occurs at the end of inner conductors of the warm section.

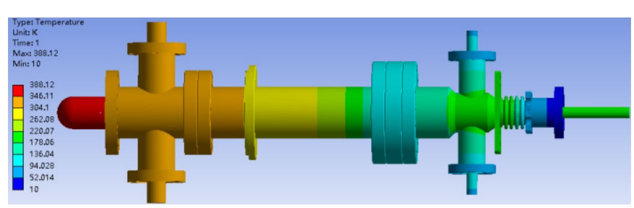

Figure 3: Temperature distribution of modified power coupler at 10kW, CW.

ISBN 978-3-95450-178-6

The simulation results show that the highest temperature of modified design is much lower than the original design due to the improvement of heat conduction.

MOVING BELLOWS OUT OFF THE QUARTER-WAVE IMPEDANCE TRANSFORMER

The bellows, which is used for adjusting Q_{ext}, was placed within the quarter-wave impedance transformer in the original coupler as shown in Figure 4. To investigate the effect of length variation of the bellows to RF matching, CST simulation has been carried out for evaluating S_{11} variation when the bellows is squeezed or stretched. The model used for CST simulation is shown in Figure 5. l_{in} is the length of inner conductor of the quarter-wave impedance transformer, l_{out} is the length of outer conductor containing the bellows, and dl is the difference between l_{in} and l_{out}.

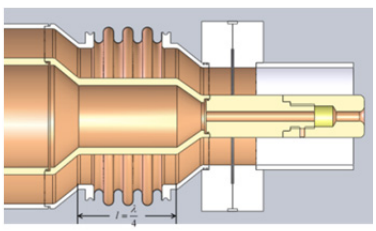

Figure 4: Bellows within the λ/4 impedance transformer.

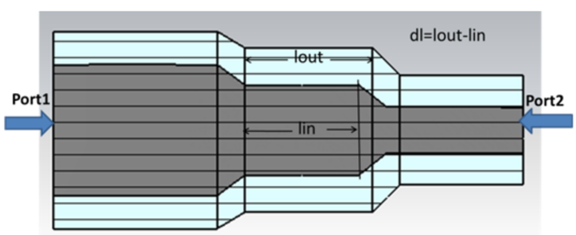

Figure 5: Model of a λ/4 impedance transformer used for CST simulation.

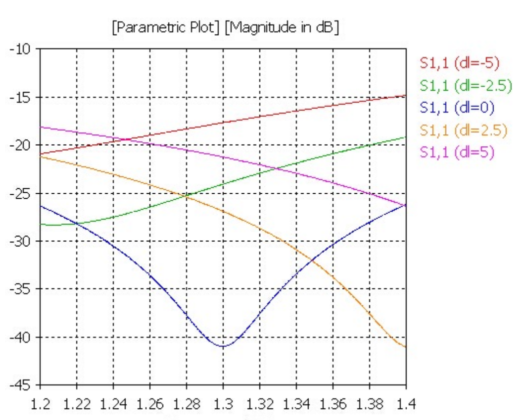

Figure 6: S_{11} vs. RF frequency with different dl.

The simulation result is shown in Figure 6. S_{11} will increase approximately 15dB when the length of bellows varies 2.5 mm. It means that the reflected power will increase more than one order in magnitude. But the bellows' length might be changed more than 2.5mm for Q_{ext} adjusting, and therefore, RF mismatch would be induced.

For avoiding the RF mismatch during Q_{ext} adjusting, the bellows should be moved from the quarter-wave impedance transformer to the 50 Ohm coaxial line as shown in Figure 7. It's obvious that the variation of the bellows' length will have no influence on the quarter-wave impedance transformer with this modified design.

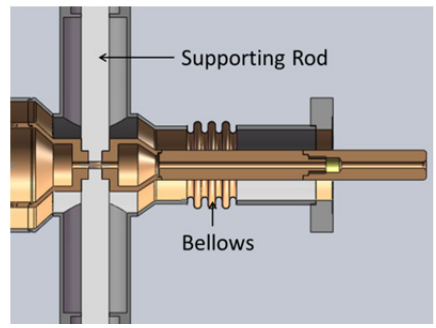

Figure 7: Bellows on 50Ω coaxial line.

RF CONDITIONING OF THE MODIFIED RF POWER COUPLER

Sketch of the modified RF power coupler is shown in Figure 8. The supporting rods are enlarged from Φ4mm to Φ16mm (cold section) and Φ28.1mm (warm section) and the bellows is moved from the λ/4 impedance transformer to 50Ω coaxial line.

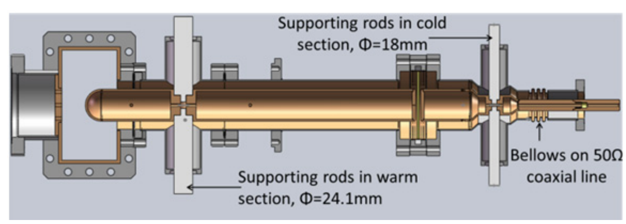

Figure 8: Modified power coupler.

When the fabrication of modified RF power couplers was finished, RF conditioning has been carried out. A test bench (see Figure 9) has been constructed for RF power coupler conditioning. Traveling wave passes two RF power couplers one by one in pulse mode, and RF power, vacuum pressure and temperature are monitored. During the conditioning, duty factor was increased from 5% to 30%. With each duty factor, the input power was increased gradually from 0 to 10kW. Figure 10 shows RF power (upper) and vacuum (lower) records of 2.25 hours at the duty factor of 30%.

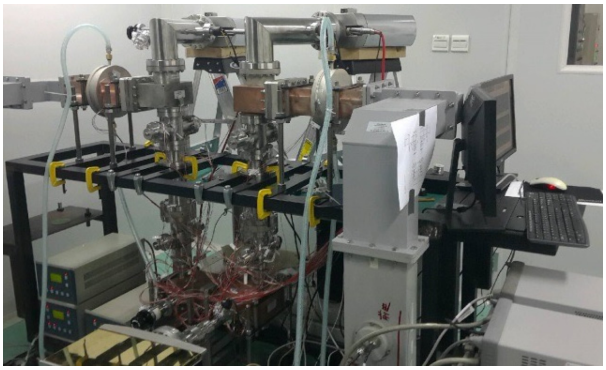

Figure 9 :Test bench for RF power coupler.

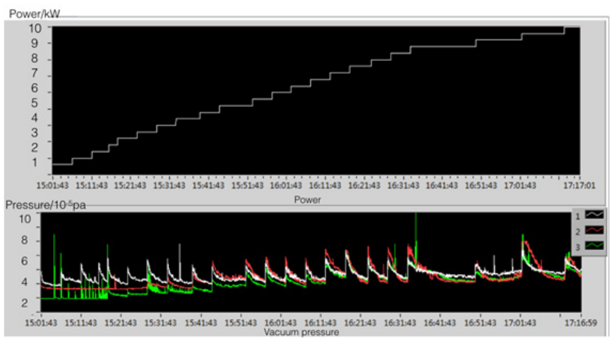

Figure 10: Records of RF power (upper) and vacuum pressure (lower) during conditioning.

The highest temperature of 29.8°C occurs at one end of supporting rods when the RF power is 10kW and duty factor is 30%. This temperature is much lower than the highest temperature of 52°C in the end of supporting rod of original power coupler. Heat conduction has been improved by enlarging the supporting rod remarkably.

CONCLUSION

The design of capacitive coupling type power coupler has been improved. The supporting rods of inner conductors have been enlarged from Φ4mm to Φ16mm (cold section) and Φ28.1mm (warm section) in order to increase heat conduction. The bellows has been moved from the quarter-wave transformer to the 50 Ohm coaxial line to avoid the RF mismatch during Q_{ext} adjusting. After conditioning, 10kW RF power with duty factor of 30% can be passed the couplers and the highest temperature at the ends of supporting rods has been reduced to 29.8°C. Two modified power couplers have been assembled to the cryomodule with two 9-cell cavities.

REFERENCES

[1] Matsumoto, et al. “A new design for a superconducting cavity input coupler”, PAC 2005. Proceedings of IEEE, 2005.

[2] Zhu, F., et al., “Status of the DC-SRF photoinjector for PKU-SETF”, Proc. SRF 2011.

[3] Fei-Si, H. E. et al., “Design of a capacitive main power coupler for RF superconducting accelerators”, Chinese Physics C 32.7 (2008): 584.

ISBN 978-3-95450-178-6