ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-MOP073

THE STUDY OF HIGH POWER COUPLERS FOR CIADS*

Z.Q. Lin†[1], T.C. Jiang[1], S.C. Huang, R.X.Wang, T. Tan, Z.Q. Yang, C.L. Li, Y.L. Huang,
S.X. Zhang, Z.H. Xue, M. Lu[1], F. Pan[1] and Y. He, Institute of Modern Physics, Lanzhou, China
Y.M. Li, GLVAC Industrial Technology Research Institute of High Power Devices, Kunshan, China
[1]also at University of Chinese Academy of Sciences, Beijing,China

Abstract

High power couplers with high operation reliability are needed for the superconducting cavities used in the Linac of CiADS project at IMP. This paper will report two works on high power coupler. The DC bias structure of the coupler was optimized to suppress the multipacting effect, where the series resistors were introduced to the wire of the DC bias to reduce the field propagating along the DC bias's wire. For the purpose of significantly decreasing the power needed to condition the coupler, we designed a new RF conditioning scheme, in which the coupler served as a standing wave resonator, and the positions of the crests and troughs of the wave were tunable. The details of the design mentioned above will be depicted.

INTRODUCTION

To suppress the multipacting discharge in the coaxial coupler. DC bias applied a high DC voltage to the inner conductor of the coupler to destroy the resonance condition of electrons. As an effective structure to improve the performance of the coaxial coupler, DC bias was utilized worldwide [1,2]. However, there were field (which came from the coaxial coupler) propagating along the wire of DC bias. The field would affect the transmission performance of the coaxial coupler and can interfere the DC bias power supply. The common method to solve the problem was introducing an inductance or ferrite choke to the wire of DC bias, however the methods were not always efficient [2]. In the project of CiADS, the severe interference of the DC bias power supply due to the field along the wire of bias was observed too. After the invalid attempt of the structures with inductance and ferrite choke, the series resistors were found to block electromagnetic field successfully.

To reduce the power needed for the conditioning of couplers, the resonant ring is the traditional choice. However, the actual power gain of this method is hardly more than 35-40 [3-5]. To increase the power gain, we proposed to change the couplers into a n*λ/2 resonator. The simulation power gain of this conditioning scheme can exceed 100.

THE OPTIMIZATION OF THE DC BIAS

In the project of CiADS, we used the simplified structure of DC bias (see Fig. 1) for the suppression of multipacting in the couplers. Figure 2 shows the detail of DC bias capacitor. In the actual operation, we found that there were field penetrating the DC bias capacitor and then propagating along the wire of DC bias. The field would affect the transmission performance of the coaxial coupler and can interfere the DC bias power supply. The common method to solve the problem was introducing an inductance or ferrite choke to the wire of bias, which was adopted in our experiments too.

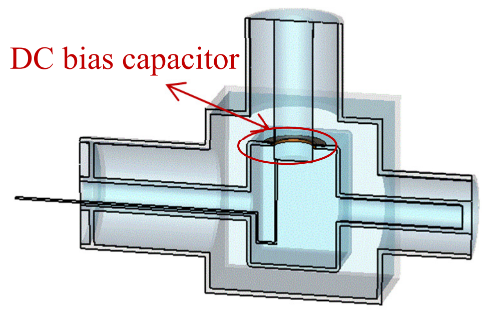

Figure 1: The simplified DC bias structure.

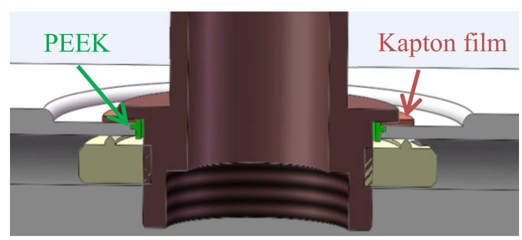

Figure 2: The detail of DC bias capacitor.

THE STRUCTURE WITH INDUCTANCE

Firstly, the inductance shown in Fig. 3 was adopted. However, the actual effect was not ideal ,which means that, the DC bias power supply was still disturbed heavily, and more importantly, the inductance was heated up seriously, so it is not applicable in our bias structure.

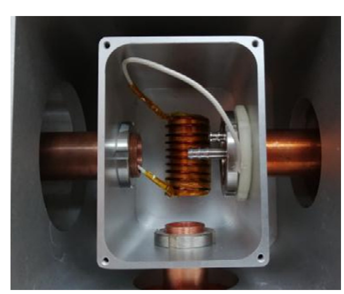

Figure 3: The series inductance in the wire.

ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-MOP073

There were two reasons for invalidation of inductance. One was that, in our structure, the field propagating along the wire of DC bias was relatively large. And the other was that, when the frequency of the field reached the microwave band, the filter effect of inductance(as a lumped element) was not obvious any more. The structure with ferrite choke had the same problems with that of the structure with inductance too.

THE STRUCTURE WITH SERIES RESISTORS

Enlightened from the filtering effect of coaxial line with a gap in the inner conductor, resistors were attempted to introduce to the wire(as shown in Fig. 4). Experiments were conducted to measure the S parameters, and the results showed that series resistor with large value can block the field along the wire successfully.

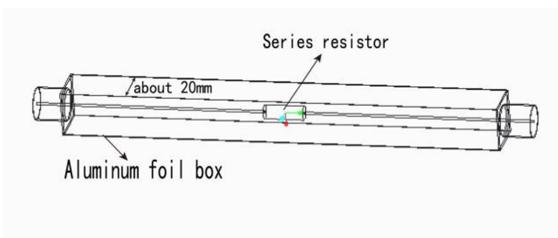

Figure 4: Series resistor in the wire.

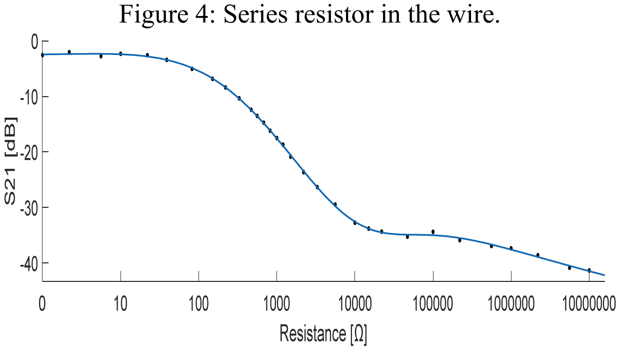

Figure 5: S21 parameter of the resistors.

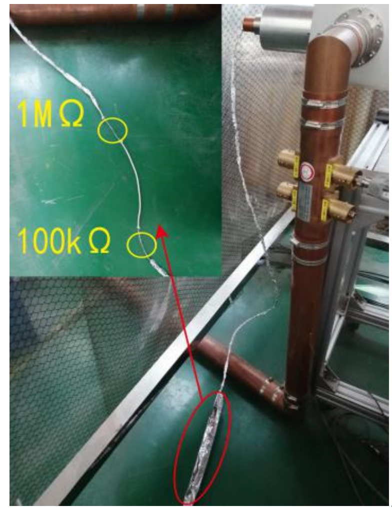

Figure 6: The final structure.

The experiments showed that the |S21| was positively correlated with the resistance of the series resistor as shown in Fig. 5. When measured the S parameters, the foil box was sealed, and the S parameters were related with the shape of the aluminum foil box which packaged the circuit, hence, the shape need to be kept nearly invariant during all the measurements. It worth noting that the S21 of the tested structure was related not only with the resistance of the resistors, but also with the types of them, because the electromagnetic parameters of the resistors with different types(even though they have the same resistance) varied from each other. The number of the resistors used in our experiments was RES KIT CFR25RS, which were produced by TE Connectivity.

In the actual operation, two series resistors were finally used (the two resistors were packaged in the aluminum foil marked in Fig. 6), and the former one was 1MΩ, and the later one was 100 kΩ. The structure presented in Fig. 6 was applied to the practical operation for six months, and showed the reliable and stable performance.

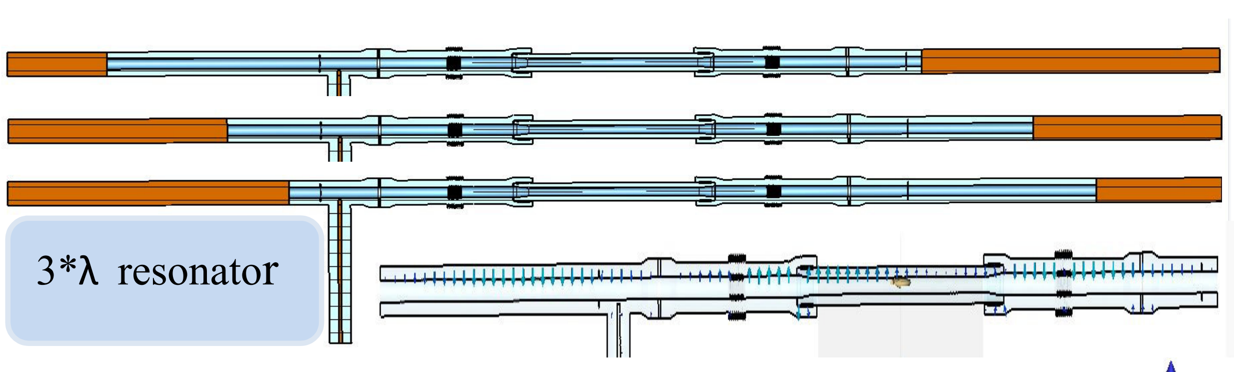

Figure 7: The schematic of couplers conditioning by n*λ/2 resonator.

ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-MOP073

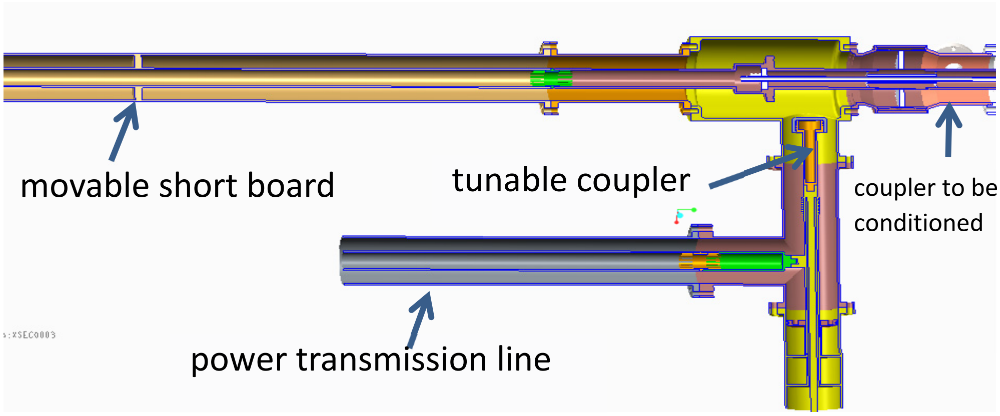

Figure 8: The right section of the structure's machine drawing.

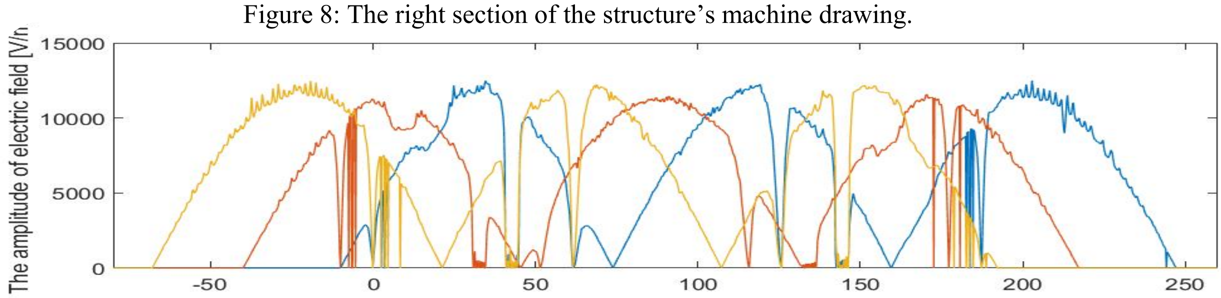

Figure 9: The field amplitude in coupler at resonant status.

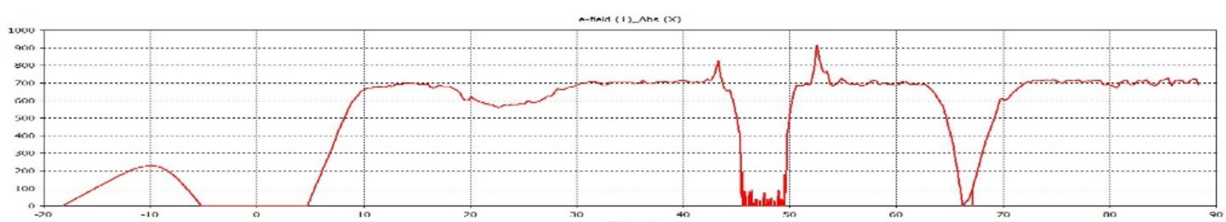

Figure 10: The field amplitude in coupler at traveling wave status.

THE NEW SCHEME OF COUPLER CONDITIONING

To reduce the power needed for conditioning, we put a pair of couplers face to face, and connected the movable short board to the tail of each coupler. The schematic diagram of the scheme was shown in Fig. 7. As can be seen, when the length between the two short boards closed to n*λ/2, the field between the boards can keep resonant. The positions of the wave crests and wave troughs can be changed by moving the two short boards. An introduced small coupler with tunable β was used to transmit power to the n*λ/2 resonator, because the coupled β of the introduced small coupler varied with the position of the resonant standing wave in the conditioned couplers. The right section of the structure's machine drawing was shown in Fig. 8. Through simulation we found that, at the same input power, the maximal amplitude of field in the n*λ/2 resonator was more than 10 times of the field amplitude in coupler at the status of traveling wave (see Figs. 9 and Fig. 10).

It means that, to get the same field amplitude, the power needed for the couplers at traveling wave status was more than 100 times of the power needed for the couplers at n*λ/2 resonatant status .

The electromagnetic field distribution in the n*λ/2 resonator was similar to that in the coupler at standing wave status. And the couplers had been proved to can be conditioned well at just standing wave status by changing the phase of reflecting wave [6]. So we considered that the n*λ/2 resonant conditioning method will be effective too.

The mechanism of the coupler conditioning is utilizing the electron produced by multipacting to bombard to wall of coupler, and reduce the SEY of the wall. We could also use the DC bias the promote the multipacting in the resonant coupler to ensure the effect of the conditioning [7].

CONCLUSION

Series resistors to optimize the DC bias wire were proved to be effective to block the field propagating along the bias wire. The |S21| of the structure was in the positive

ISBN: 978-3-95450-211-0 doi:10.18429/JACoW-SRF2019-MOP073

correlation with the resistance of the series resistor. The DC bias structure with series resistors has been applied to the practical operation for six months, and showed the reliable and stable performance.

To significantly reduce the power needed for conditioning, we put a pair of couplers face to face, and connected the movable short board to the tail of each coupler. When the length between the two boards closed to n*λ/2, the field can keep resonant. To ensure the conditioning effect, the positions of the wave crests and troughs can be moved along the couplers by moving the two short boards, and the introduced small tunable coupler was applied to ensure the match between the power transmission line and the n*λ/2 resonator. The simulation power gain of this conditioning scheme can exceed 100.

REFERENCES

[1] B. Kaizer *et al*., "Warming rate reduction of the SARAF rf couplers by application of a high voltage DC bias", in *Proc. LINAC'14*, Geneva, Switzerland, Aug.-Sep.2014, p. 1168.

[2] P. N. Ostroumov *et al*., "Suppression of multipacting in high power RF couplers operating with superconducting cavities" *Nuclear Instruments and Methods in Physics Research Section A,* vol. 856, pp. 77-80, 2017.

[3] V. Veshcherevich *et al*., "High power tests of first input couplers for CORNELL ERL injector cavities", in *Proc. PAC'07*, Albuquerque, New Mexico, USA, p. 2355.

[4] A. Buechner *et al*., "Results of ELBE window and coupler tests with a resonant ring", in *Proc. EPAC'08*, Genoa, Italy, Jun. 2008, p. 1479.

[5] A. Jha *et al.*, "Development of traveling wave resonator based test bed for high power transmission line component testing", *AIP Conference Proceedings* , vol. 1689, p. 070006, 2015.

[6] W. Xu *et al.*, "Design, simulations, and conditioning of 500 kW fundamental power couplers for a superconducting rf gun", *Physical Review Special Topics - Accelerators and Beams,* vol. 15, no. 7, Jul. 2012.

[7] P. Wei-Min *et al.*, " High power conditioning of the input coupler for BEPCII superconductingcavity", *Chinese Physics C,* vol. 32, no. 9, Sep. 2008.