THE INPUT COUPLER FOR THE KEKB ARES CAVITY

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Abstract

We have developed the input coupler for the ARES cavity and carried out the high-power test of the coupler by using the coupler test stand. The couplers have succeeded in transmitting the rf-power of about 1 MW (508 MHz, CW).

1. Introduction

For the KEK B-factory, the Accelerator Resonantly coupled with Energy Storage (ARES) cavity has been developed. The ARES cavity requires the rf-power of about 400 kW per cavity with the full beam loading of the B-factory. [1]

In order to feed the rf power to the ARES cavity, we have developed the new input coupler. [2] The target rf power to be transmitted by the coupler is set to 800 kW (CW) which is twice the required value.

It is well known that the performance of the coupler strongly depends on the ceramic window structure. The most powerful coupler in KEK is the output coupler of the UHF (508 MHz) klystron developed for the rf cavities of the TRISTAN. It can transmit the 1.2 MW (CW) rf power. [3] The klystron output coupler has the disk-type coaxial ceramic window. Thus the klystron output coupler is the good standard for the coupler of the ARES. However the vacuum condition of the input coupler of an accelerating cavity is much worse than that of klystron output coupler. Thus total performance of the input coupler is probably lower than that of the klystron output coupler.

The coupler is tested by using the high-power test stand before the installation in the ARES. Recently we succeeded the high-power test for the coupler in the test stand. The details of the results for the coupler test is described in the later section.

2. The structure of the coupler

The details of the design of the coupler are described in the reference. [2] The coupler consists of the door-knob transformer, the disk-type coaxial-ceramic window and the coupling loop.

The dielectric constant of the window ceramic is about 9. In order to match the impedance around the window, we designed two kinds of the impedance matching sections; (1) a choke structure; (2) an over- and an undercut structure. These structures are standard techniques for the impedance matching. The cross sectional views of the two types of the coupler are shown in Fig. 1 and Fig. 2, respectively. The output coupler of the UHF klystron in KEK uses the choke structure for the impedance matching of the window.

The surface of the window in vacuum side has the TiN coating of about 1 nm in thickness in order to reduce the coefficient of the secondary electron emission.

The coaxial wave guide of the coupler and the door knob transformer are made of copper and the rectangular wave guide is made of aluminum. The total weight of the coupler is about 50 kg.

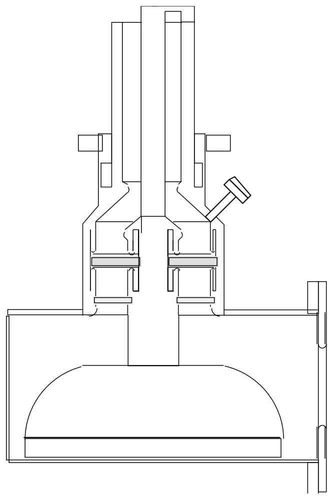

Figure 1. Schematic view of the coupler with the choke structure

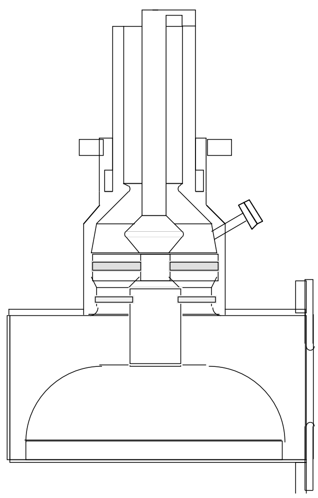

Figure 2. Schematic view of the coupler with the over and the undercut structure

3. The coupler test stand

We must carry out the high-power test of the coupler with rf power of 800 kW which is twice as many as the ARES cavity requires. However the ARES cavity can not accept the rf power of 800 kW because the cooling system of the cavity is not enough for such high rf power. Thus we made the coupler test stand. The test stand consists of (a) two input couplers to be tested ,(2) a small cylindrical cavity which connects the two couplers, and (3) the dummy load. The cavity is made of the copper plated stainless steel. The thickness of the copper plating is about 50 µm. The cavity is evacuated by the turbo molecular pump (300l/s). The cavity wall is cooled by the water (4 l/min). The rf power transmits from the one coupler to another through the cavity. Finally the rf power is absorbed in the water dummy load.

The schematic view of the test bench is shown in Fig. 3. Figure 4 shows the cross sectional view of the cylindrical cavity and the loops of the coupler. The two loops are in opposite directions as shown in the Fig. 4 in order to increase the coupling. The gap length between the loops is about 2 mm. The gap length is adjusted in order to tune the resonance frequency of the cavity system by changing the thickness of the metal gasket between the flanges (ICF203) of the coupler and the cavity and the strength of torque fastens the bolts of the flange. The VSWR of the test bench is less than 1.2 after the tuning.

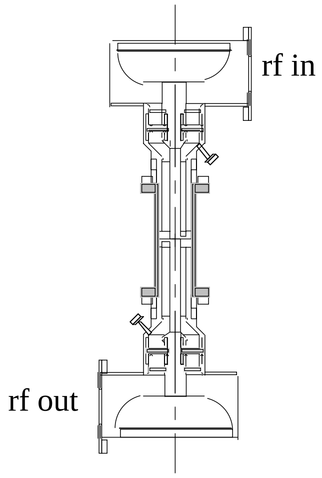

Figure 3. Schematic view of the coupler test stand

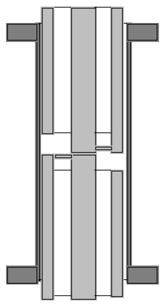
Figure 4. Cross sectional view of the cylindrical cavity with two loops

The rf properties of the test bench has been estimated by using computer simulation code (HFSS [4]). Figure 5 shows the S_{11} and S_{12} parameters simulated by the HFSS code for the system consists of the two coupling loops and the cylindrical cavity. It shows the extremely wide band property. Because the unloaded Q value (Q_0) of the cylindrical cavity is high, the wide band property (the low loaded Q value) of the cavity means that the external Q value (Q_{ex}) for the loop coupling is extremely low. Because the low Q_{ex} and the high Q_0 means the strong coupling of the loops, the cylindrical cavity does not accumulate the rf power and the wall loss is small. Thus we can easily cool the cavity.

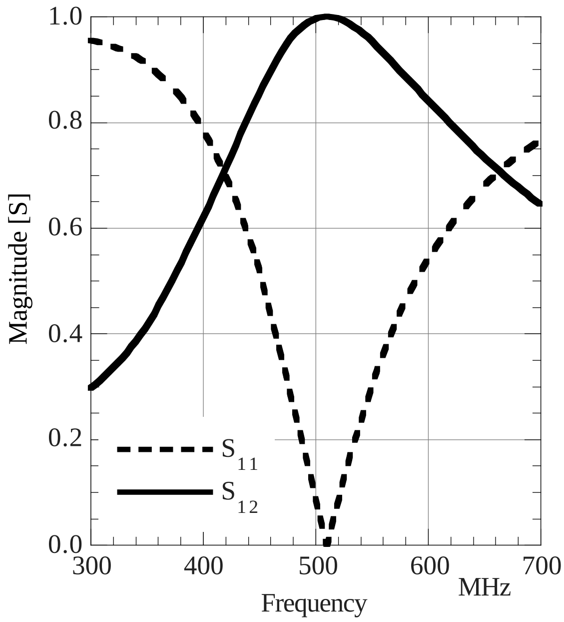

Figure 5. Calculated S_{11} and S_{12} parameters of the cylindrical cavity with two loops

4. The results of the high-power test

The high-power test of couplers are being carried out from the last December. Four couplers (two couplers have the choke structure and others have the over- and

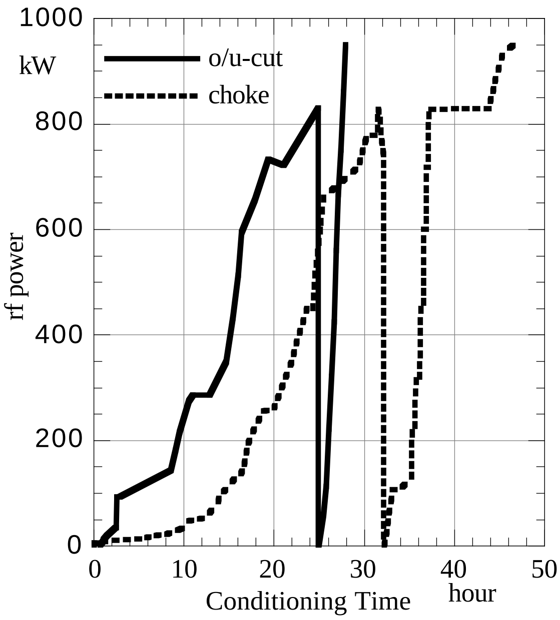

Figure 6. Conditioning history of the couplers.
“o/u-cut” means the over- and undercut structure.

undercut structure) have been tested. The conditioning history is shown in Fig. 6 for both types of coupler. When the rf power exceeded the level of about 800 kW, we measured again the temperature of the cooling water and cavity wall at the several rf power level (50, 100, 200, ..., 800 kW) for the check of the first data of the temperature rise for the system. After the second measurement we increased the rf power more than 800 kW.

The conditioning speed for the coupler with the over- and the undercut structure was faster than that for the coupler with choke structure where the rf power is less than about 100 kW. It was probably caused by the difference of the initial vacuum level in the cavity. For the coupler with choke structure, the initial vacuum level was about 10^{-8} torr, while it was about 10^{-9} torr for the coupler with the over- and undercut structure. (Because the Klystron was replaced just before the coupler test, we had to wait a few weeks for starting the test of the coupler with the over- and undercut structure after the setting of the coupler in the stand. During such period the vacuum condition was improved.)

Finally every tested coupler successfully transmitted the rf power of 950 kW. The maximum power is limited by the interlock level of the klystron control system at present. No damage was observed on the couplers after the high-power test.

Fig. 7 and 8 show the wasted power in the coupler and in the cavity, respectively. They were calculated by the temperature rise of the cooling water. The rf-power loss on the cavity wall is about 0.06 % of the transmitted power and the loss in the coupler is about 0.2 % of the transmitted power. In particular, the power loss around the window is about 0.1 % of the input power. It is small enough for the practical operation. The power loss near the window with the choke structure is about 50 % bigger than that near the window with the over- and undercut structure since the pass length of the current of the choke structure is longer than that of the over- and undercut structure. Furthermore the curves for the power loss have some fluctuation at the region where the rf power is more than about 700 kW. However we did not observe any abnormal condition for the vacuum of the cavity and the arc around the window. We are considering about the origin of the fluctuation now.

We also measured the x-ray from the stand during the test for the radiation safety. The measured the x-ray level was as same as the natural background level.

5. Conclusion

We have developed the input coupler with the coaxial ceramic window for the ARES cavity. We have also constructed the coupler test stand. The couplers have succeeded in transmitting the rf power of 0.95 MW in the stand. The results of the high-power test shows that the performance of the coupler is highly enough for the practical operation of the ARES cavity.

6. References

[1] K. Akai, E. Ezura and Y. Yamazaki, Proc. IEEE Part. Accel. Conf., San Francisco, California, 1735 (1995)
[2] F. Naito, et al., Proc. IEEE Part. Accel. Conf., San Francisco, California, 1806 (1995)
[3] S. Isagawa, et al., Proc. IEEE Part. Accel. Conf., Washington D.C., 1934 (1987)
[4] HP Part No. 85180A., HP Corp.

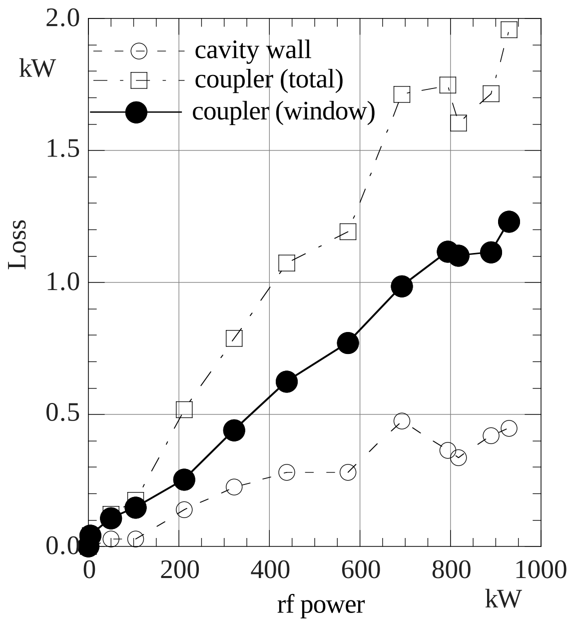

Figure 7. Power loss in the cavity and the coupler with the choke structure

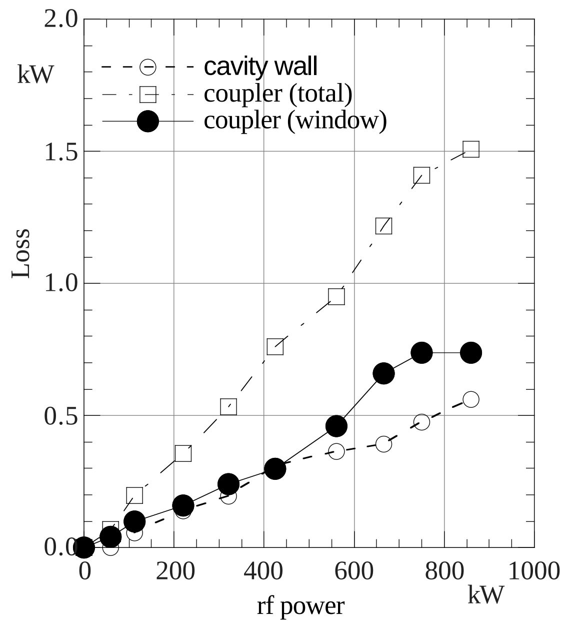

Figure 8. Power loss in the cavity and the coupler with the over- and undercut structure