

POWER-CONDITIONING CAVITY DESIGN AND MEASUREMENT OF THE COAXIAL COUPLER FOR THE INJECTOR OF XIPAF PROJECT

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Abstract

For the RF high power conditioning on coaxial power couplers of the XiPAF (Xi'an Proton Application Facility), the RF high power-conditioning cavity was designed and manufactured. The cavity consists of a rectangular resonant cavity with two ports, which one is connected with input coupler from RF power source and the other one is connected with output coupler, and a tuner. The tuning frequency range could cover 325 (+0.5, -9.5) MHz. The measured Q factors are matched with the design results generally. But the S-parameter is not ideal compared to the simulation. This paper will present the design and low power measurement results of the cavity.

INTRODUCTION

The linac injector of XiPAF is powered by three Coaxial power coupler which two of them for the RFQ and one for the DTL [1]. The RF power will be coupled magnetically to the RFQ and DTL with the coupling loops. Couplers were designed to afford at least 300 kW in maximum 150 μ s RF pulse at 325 MHz operating frequency. After the measurement of the couplers employing a flexible copper sheet between the inner conductors of two couplers, a high power conditioning need to be performed to check the performance of the couplers. So the high power conditioning cavity is necessary.

COAXIAL POWER COUPLER

There are three coaxial power couplers used for the injector of the XiPAF project. Two of them should be installed in the RFQ symmetrically as shown in Fig. 1.

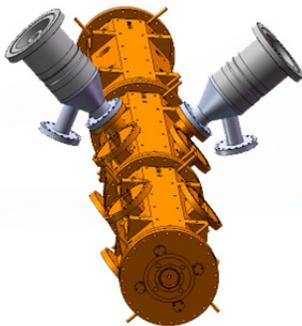


Figure 1: Two couplers installing in the RFQ symmetrically.

Another coupler should be installed in the DTL with a 45° included angle as shown in Fig. 2. Three couplers were designed with the same RF performance and structure except the square encircled by the coupling loop, which could adjust the coupling coefficient β with rotating the angle pivoting the axis of coupler. Main parameters of the couplers are listed in Table 1.



Figure 2: One coupler installing in the DTL.

Table 1: Main Parameters of the Couplers [2]

| Parameter Name | Description |
|----------------------|----------------------|
| Frequency | 325 MHz |
| Pulse power | 300 kW at least |
| Max pulse width | 150 μ s |
| Max duty factor | 7.5×10^{-5} |
| Impedance | 50 Ω |
| Max repeat Frequency | 0.5 Hz |
| Coupling coefficient | 0.53 (RFQ)/1.1 (DTL) |

Coupler Measurement

After manufacture of the first two couplers for RFQ, the measurement for them was performed at a testing stand as shown in Fig. 3. Two convertors from 6 1/8-inch coaxial transmission line to N connector were employed to measure the coupler's RF parameters. A cylindrical sleeve connected outer conductors of the coupler, and a flexible and stretchy copper sheet was placed between inner conductors, of which coupling loops were dismounted, to keep them in touch with each other as better as possible. The result of the measurement is shown in Fig. 4. The S_{11} parameter was measured as about -21.12 dB, and S_{21} parameter was measured as about -0.07 dB. In the simulating results, S_{11} is -35 dB, and S_{21} is -0.007 dB. Machining error and suboptimal RF contact may be the central incentive. But it although can satisfy the operating requirement of the RFQ.

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Figure 3: Couplers connected with converters in measurement.

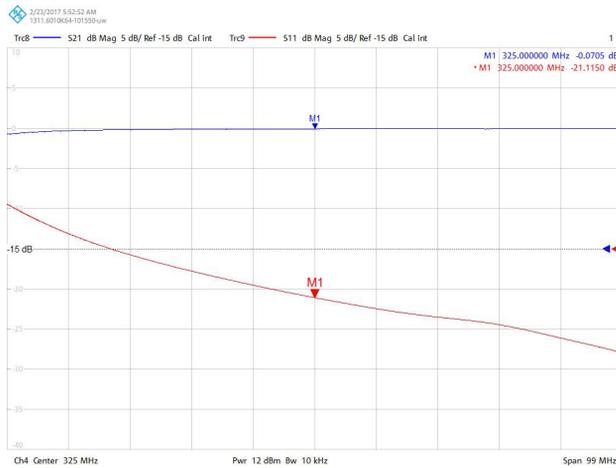


Figure 4: Measured result about the couplers RF performance.

DESIGN OF THE CAVITY

The cavity is based on a rectangular resonant cavity with TE₁₁₀ mode. The three dimensions of the cavity are 680 mm, 620 mm and 190 mm respectively. On the upper face of the cavity, two ports with CF 100 flanges are located the axis of symmetry of the two 680 mm edges. The distances of the ports from the two 620 mm edges are 75 mm. The lengths of the ports are 110 mm, which are matched with the output ports of the couplers. The coupling loop of the coupler is also modelled in the simulation process. The tuner is designed for the frequency tuning. The initial inserted depth is set to 25 mm for the 325 MHz eigenfrequency of the cavity. The coupling loops' squares were initially set as middle level where the distance between inner conductor and upper face of the coupling loop is 10 mm. The 3-dimension electromagnetic model is shown as Fig. 5. Its simulating result is shown as Fig. 6 [3]. The simulating result shows that S₁₁ parameter is about -25 dB and the S₂₁ parameter is about -0.1 dB. The Q₀ can be calculated as 4998, and Q_c is calculated as 5048. According the Eq. (1), the Q_L is calculated as 2511.

$$\frac{1}{Q_L} = \frac{1}{Q_0} + \frac{1}{Q_e} \quad (1)$$

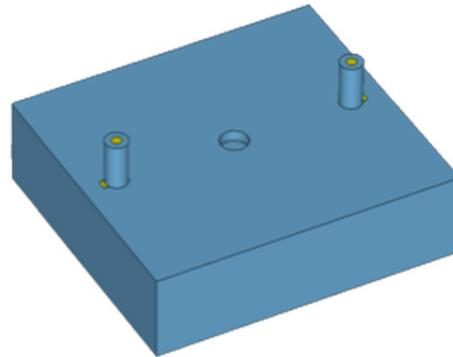


Figure 5: 3-dimension electromagnetic model structured with CST code.

The magnetic field distribution is shown in Fig. 6. The coupling loop is located in the area where the magnetic field intensity is almost maximum. The eigenfrequency changes following with the inserted depth of the tuner is shown as Fig. 7. The tuning capability is about 325±0.8 MHz corresponding with 25±5 mm inserted depth.

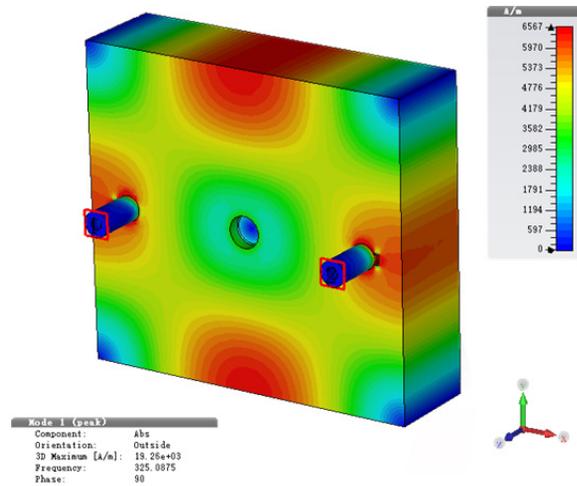


Figure 6: Magnetic field distribution of the power-conditioning cavity.

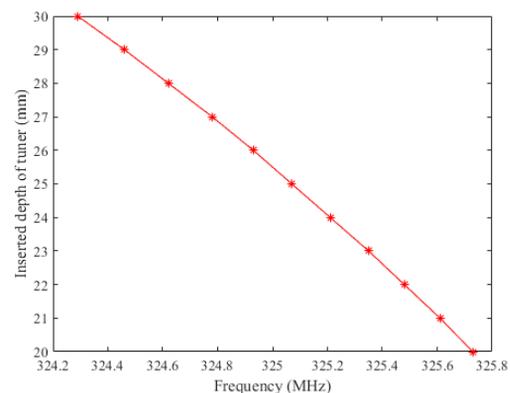


Figure 7: Inserted depth of the tuner vs. eigenfrequency of the cavity in simulating results.

MEASUREMENT OF THE CAVITY

Vacuum

After manufacture of the cavity, the vacuum leakage detection was performed. All of the welded joints and the sealed flanges were checked with a leak detector. The leak rate is lower than 1×10^{-12} Pa·m³/s.

Tuning Capacity

The tuning capacity of the tuner was examined as shown in Fig. 8. In the atmospheric environment, the inserted depth of the tuner is 19 mm, when the cavity is resonant. The tuning capacity of the tuner can cover from 316.81 MHz to 326.49 MHz in this status, and the tendency is shown as the red curve in Fig. 9. When the pressure inside the cavity was vacuumed to 1×10^1 Pa by the vacuum leak detector, the tuner's tuning capacity looks like the blue curve in Fig. 9. The tuning range is from 315.48 MHz to 325.44 MHz.



Figure 8: The manufactured power-conditioning cavity connected with two coaxial power couplers in measurement.

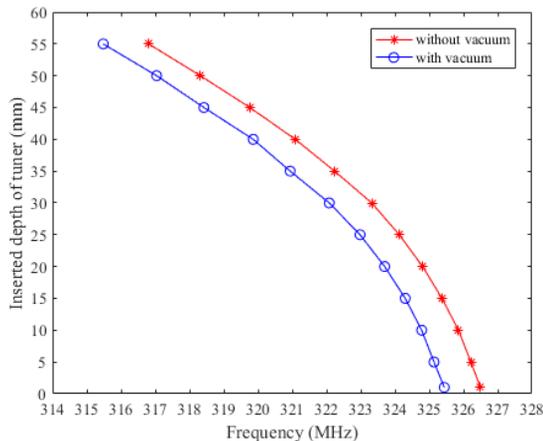


Figure 9: Tuning capacity of the tuner when the cavity with and without vacuum.

S-parameter and Q Factor

The S_{11} , S_{22} , S_{21} is about -5.29 dB, -4.55 dB and -7.55 dB respectively. Although there are some difference between the design results and measured results, the reflecting power ratio would reach 22.8%, and it is affordable. The Q_L is 2273 calculated by the S_{21} and its bandwidth at -3 dB. It approximates to the design result. The measurement result is shown in Fig. 10.

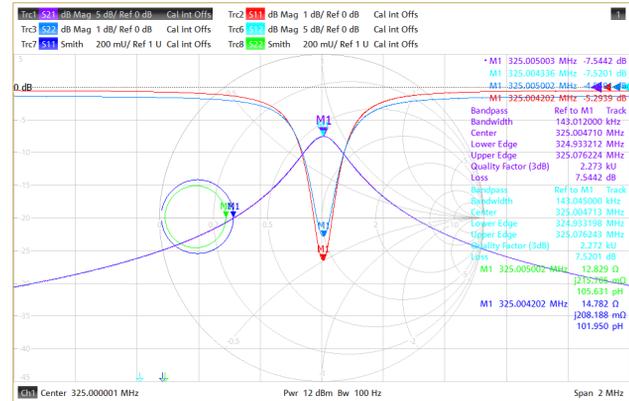


Figure 10: Measurement results from the vector network analyzers.

CONCLUSION

A power-conditioning cavity for the coaxial power couplers is designed by CST Microwave Studio software. After the parameter measurement of the coaxial power couplers and the manufacture of the cavity, the vacuum leakage detection and RF performance measurement were implemented. The sealed vacuum effect is very satisfactory. The measured results of the S-parameter measurement are different with the design value, but it is acceptable for the power-conditioning process. It's maybe that the tolerance of the coaxial coupler installing ports was too big to make the RF connection between the couplers and cavity close enough. The Q factor is approximated to the simulating result. In the near future, the power-conditioning stand will be structured. The RF power will be inputted to one of the couplers with 6 1/8-inch coaxial transmission line from the 4616 RF power source. Another coupler will be connected dummy load. If the power conditioning for the former is completed, the exchange between two couplers will be executed for the next power-conditioning process.

REFERENCES

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- [3] <http://www.cst.com>.