ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-THPAB147

PRELIMINARY STUDY OF 500 MHz HOM-FREE RF CAVITY*

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Abstract

In this paper, we study the microwave characteristics of 500 MHz HOM-free RF cavity, including the optimization of cavity structure, the simulation design of high-order mode(HOM) absorption structure and the design of coupler. The cavity structure is simulated by CST [1]. The absorption waveguide is designed and optimized. The coupler is designed.

INTRODUCTION

In the accelerator cavity of electron storage ring, the high Q value of high order mode causes the slow attenuation of beam induced field, and the potential beam instability is caused by the coupling of multiple beams in the continuous field. In the past, various measures have been applied to improve the threshold of coupling cluster instability. For example, the hum is detuning by using the tuning rod or changing the cavity temperature; One or more main Homs are damped by using a small band damping antenna; The harmonic damping and decoupling of the adjacent clusters are decoupled by using the high and low harmonic RF systems; The broadband cluster feedback system is used; Single mode cavity, other modes inherent low r/q; Coupling Hom and damping etc. However, all of these methods have their own limitations. The most direct way to avoid the instability of cavity driven coupling cluster is to reduce the Hom impedance to below the threshold. The damping cavity of high order mode (HOM) is an important part of the high brightness synchrotron radiation source to avoid the instability of beam cluster coupling and reduce the quality of synchrotron radiation. The most common use is the broadband damping of HOM cavity of high brightness SR light source: beam tube damping load and waveguide coupler, in which the beam tube damping load is absorbed on the axis, the high-order mode is led out through the large beam tube, and the absorbing material is adopted at both ends; The waveguide coupler is to couple the high-order modes to the outside of the cavity along the radial direction. In the radial direction, according to the distribution of the high-order modes, the waveguide is used to transmit the excited high-order modes to the outside of the cavity, and then the matched load is used to absorb them.

Hefei Advanced Light Facility(HALF) is the fourth generation synchrotron radiation light source based on diffraction limit storage ring (DLR). Its design goal of emittance and brightness is the world's leading. After completion, HALF will be the world's most advanced DLR light source. The high frequency cavity studied in this paper is based on the cavity of BESSY II [2] and used for HALF. Its working frequency is 500 MHz and high-order mode free is required. It is based on waveguide coupler which is the radial transmission matching absorption scheme. The geometric structure design scheme of the cavity is shown in Fig. 1. Based on the cylindrical cavity model, there are three waveguide couplers, one input coupler and one tuning rod.

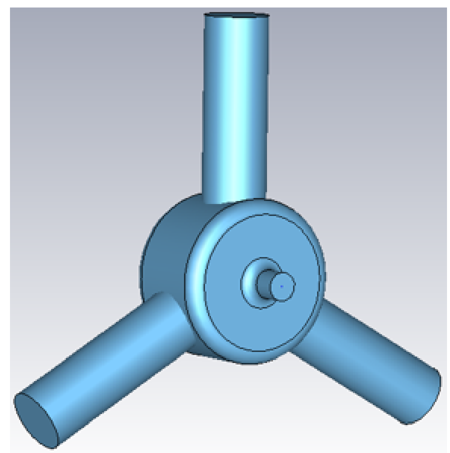

Figure 1: Geometric structure of the HOM-free cavity.

MICROWAVE CHARACTERISTICS OF CAVITY

This section mainly discusses the influence of cavity geometric parameters on microwave characteristics. The cavity parameters are shown in Fig. 2, including beam tube chamfer radius R_o, beam tube radius R_{io}, beam tube length L_{io}, cavity radius R_c, cavity chamfer radius R_{co}, etc. In the following, we will discuss the influence of the above geometric parameters on the microwave parameters.

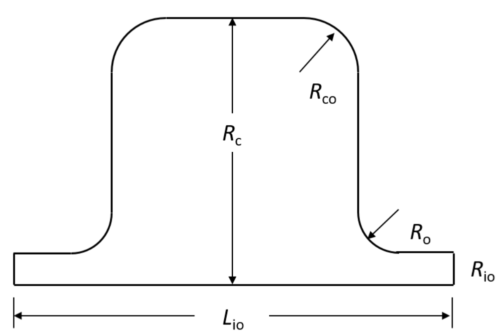

Figure 2: Geometric parameters of the HOM-free cavity.

The chamfering radius of the beam tube has a great influence on the peak surface electric field of the cavity as shown in Fig. 3, the peak surface electric field decreases with the increase of the chamfering radius of the

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beam tube, and its influence on the cavity frequency is $df/dR_o = 0.127$ MHz/mm.

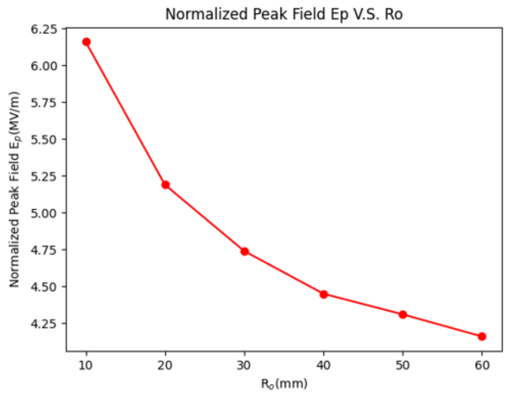

Figure 3: Peak surface electric field VS R_o.

The influence of beam tube radius R_{io} and beam tube length L_{io} on the microwave parameters of the cavity is relatively small, but it should be noted that both of them affect the microwave cut-off, so we should make a compromise to prevent the leakage of the main mode microwave.

The cavity radius R_c mainly affects the working frequency, $df/dR_c = 2.12$ MHz / mm. At the same time, adjusting the cavity radius is also a common way to adjust the microwave frequency.

As shown in Fig. 4, the shunt impedance increases with the increase of cavity chamfer radius R_{co}. At the same time, its influence on the working frequency is nonlinear, as shown in Fig. 5.

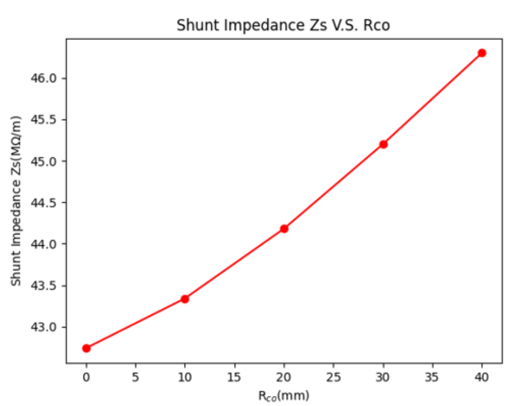

Figure 4: Shunt impedance Z_s field VS R_o.

HOM TRANSMISSION

The transmission of the cavity HOM through the circular waveguide to the outside is the key to realize HOM free. Meanwhile, the working frequency of the main mode of the cavity is required to be below the cut-off frequency in the circular waveguide. Therefore, in the design of the circular waveguide, the frequency of the first HOM must be greater than the cut-off frequency of the circular waveguide, which will determine whether all HOMs can be transmitted to the outside of the cavity through the circular waveguide.

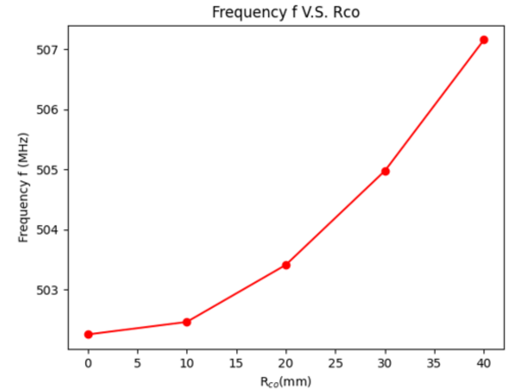

Figure 5: Working frequency f VS R_o.

We simulate and calculate the cutoff wavelength of circular waveguide with different radius, as shown in the Fig. 6, select the appropriate radius, and the cutoff frequency meets the conditions: greater than the cavity working frequency, less than the first Hom frequency.

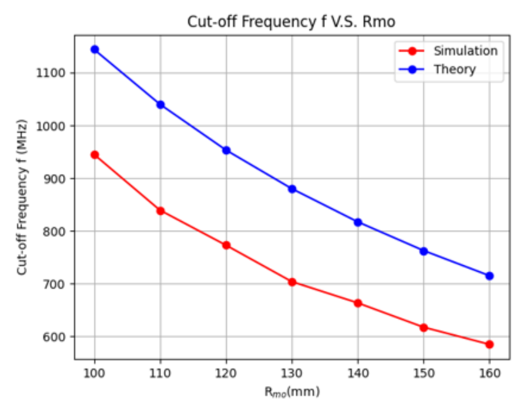

Figure 6: Cutoff frequency f VS R_o.

COUPLER

Coupler is the key element to feed microwave power into the cavity. In this paper, coaxial line and coupling ring are used. In the process of coaxial line design, we need to pay attention to the following three aspects: high order mode, power limitation, attenuation and characteristic impedance. The coupling coefficient of the coupler depends on the size of the coupling ring. At the same time, for the convenience of later processing and tuning, after the size of the coupling ring is determined, the angle between the coupling ring surface and the beam direction section along the cavity is used to tune the coupling coefficient of the cavity. Different coupling ring radii correspond to S11 parameters and Polar plot, as shown in Figs. 7 and 8. It can be seen from the above Figs. 7 and 8 that with the increase of coupling ring

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radius, the changes of S11 parameters are in the order of under coupling, matching and over coupling.

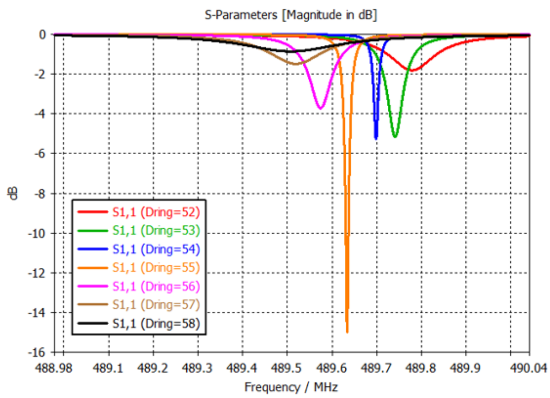

Figure 7: S11 parameters VS coupling ring radius.

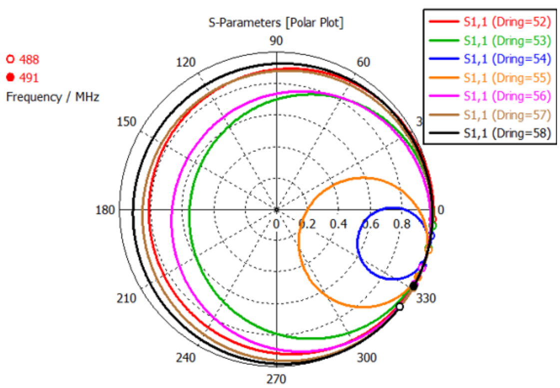

Figure 8: Polar plot VS coupling ring radius.

After the microwave power is fed into the coaxial line, the 3D electromagnetic field distribution of the main mode TM010 in the cavity is shown in Fig. 9.

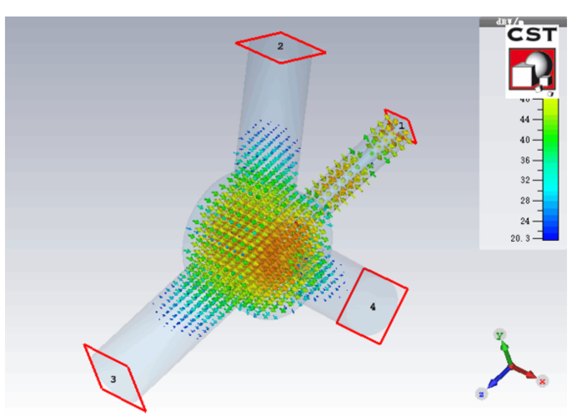

Figure 9: 3D electromagnetic field distribution.

TUNING ROD

Because of the large size of the cavity, the change of the radius of the cavity has little effect on the working frequency of the cavity. In order to process tuning and adjust the frequency of the cavity in operation, an external tuning rod is adopted to regulate the working frequency of the cavity. The tuning ability of tuning rod is influenced by the radius R_t of tuning rod and the length H_{pt} deep into the cavity as shown in Fig. 10.

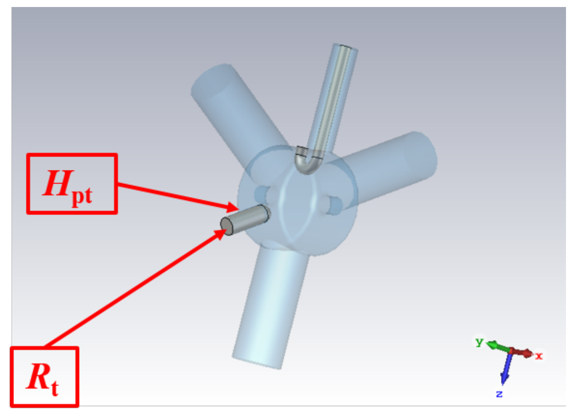

Figure 10: Tuning rod.

CONCLUSION

In this paper, the influence of cavity geometry parameters on microwave parameters, the design of circular waveguide transmission Hom and coupler are studied by simulation, and the design scheme of HOM free in the cavity is basically realized.

ACKNOWLEDGEMENTS

The author sincerely thanks Faya Wang, Yuanji Pei for constant encouragement and discussing. We appreciate the support from National Natural Science Foundation of China (U1832135 and 11805199).

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