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THE RECENT RESEARCH OF HOM DAMPER FOR SUPERCONDUCTING CAVITY IN IHEP

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Abstract

For high current accelerator, the efficient higher-order mode (HOM) damping is always an important issue. HOM damper with microwave absorbing material is a key component for high power and broadband HOM damping application. To pursue the high damping efficiency, some ideal material with good microwave absorbing capacity is essential during the RF design and fabrication phase. Sometimes the selection and test of material is the first step and also a long step. This paper will present the recent work on HOM dampers for BEPCII 500MHz cavity and CEPC 650MHz cavity in IHEP.

INTRODUCTION

High Energy Photon Source (HEPS) has been initiated by IHEP in Beijing, which is a 6GeV kilometre-scale light source [1]. In the planned on-axis beam injection scheme, the 499.8MHz ellipsoidal SC cavity will be used as the third-harmonic cavity, which will work with the fundamental 166.6MHz quarter-wave SC cavity [2]. For the high current requirement of HEPS, the HOM damper located on the beam pipe is essential in the 499.8MHz SRF system. Since the same frequency, the design and experience of BEPCII 500MHz SRF system will be used in this project. The research on 500MHz HOM damper (the HOM damper used for 500MHz cavity) has been developed for the 500MHz spare cavity in IHEP several years ago. Based on this successful experience, this paper will describe the recent work on 500MHz HOM damper, about RF design optimization to lower the fabrication cost and absorbing capacity research of ferrite, and so on.

To explore the magic Higgs Boson for high energy physics, the R&D of Circular Electron-Positron Collider (CEPC) has been promoted by IHEP in the collaboration with some other institutes and university. CEPC will be a 120GeV 100 km ring collider with high luminosity. The 650MHz 2cell ellipsoidal SC cavity is adopted as the main accelerating cell in the storage ring [3]. Due to the short bunch length, the HOM spectrum is extremely wide. The beam pipe HOM damper will be used to suppress the HOM power from 1.5GHz to 20GHz, which is above the cut-off frequency of beam pipe [4]. For the broadband absorbing requirement, some new materials need to be explored. At the latter part of this paper, the recent design and exploration of 650MHz HOM damper will be reported.

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500MHz DAMPER OPTIMIZATION

The research on 500MHz HOM damper has a long history, since the typical design of Cornell CESR type and KEKB type [5]. Years ago, the 500MHz damper has been developed successfully for the spare cavity in IHEP, the prototype is shown in Fig. 1. This IHEP type damper used ferrite as its RF absorbing material. The ferrite on the inner surface of damper is arc-shaped, which can fit the cylinder shape with 8 pieces. This damper had an excellent absorbing efficiency, which is higher than 50% around 1GHz.

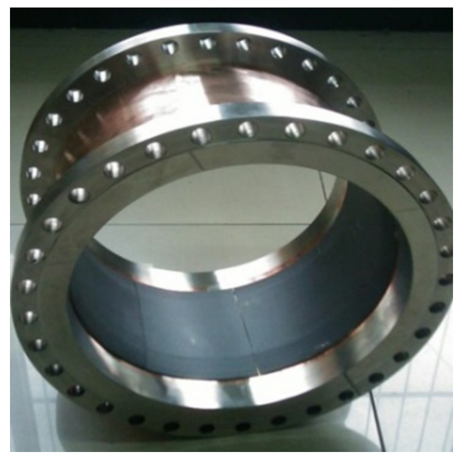

Figure 1: IHEP 500MHz HOM damper for spare cavity.

Due to the arc-shaped ferrite, the material preparation and the brazing technology is too difficult to lower the yield of damper. As a consequence, the development cost is expensive. For the economic consideration, it is an attractive job to optimize the RF design of damper to make a balance between the absorbing efficiency and fabrication cost.

The direction of optimization is to make the shape of ferrite more convenient for processing. Naturally, the first choice is ferrite sheet. As we know, it will increase the reflection of RF power on the contact section, that using the polygon to fit the circle. So the ferrite size and some other feature should be optimized to realize impedance matching, in order to decrease the reflection coefficient. As a result, the absorbing efficiency of damper will not change too much, sometimes even better. The optimized RF structure of damper is shown in Fig. 2.

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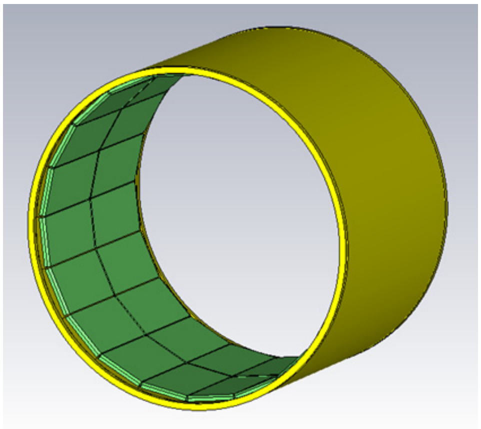


Figure 2: The optimized RF structure of damper.

The simulation results of the optimized structure compared with the arc-shaped structure are shown in Fig. 3. The curves in Fig. 3 indicate the absorbing efficiency from 0.6~1.6GHz for the TM01 circular waveguide mode. The absorbing efficiency of optimized structure reaches 86% around 1GHz, that is even higher than the 78% of old structure. On the other hand, profiting from the use of ferrite sheet, the fabrication cost can be reduced nearly 50% due to the more convenient material preparation and processing.

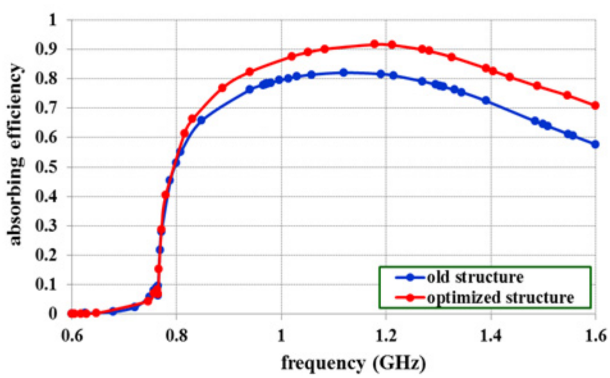
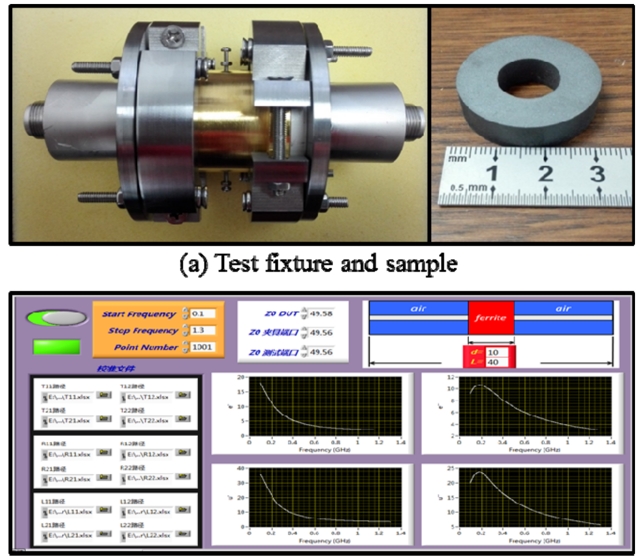


Figure 3: The absorbing efficiency simulation data using CST MWS [6].

MATERIAL TEST

The permittivity (ε) and permeability (μ) are important parameters for absorbing material in the damper simulation. A test system used for measuring ε and μ of dielectric material has been built. This test system includes a special fixture to hold material sample, the TRL calibration method to eliminate the fixture influence, and the data processing code to get the credible value, as shown in Fig. 4. Cooperating with the VNA, the system can calculate the ε and μ through the measured S parameter.

The property of our ferrite has been tested by this system. The measurement data of ε and μ is shown in Fig. 5. The ε' of ferrite is nearly a constant about 12.5, but the ε'' is almost 0 in the frequency range. Since the ferrite mainly absorbs the H field, the measured μ'' is large, which means the strong RF absorbing capability in this band.



(a) Test fixture and sample

(b) Data processing program

Figure 4: The absorbing material test system.

Due to the RF limitation of the transfer connector, the coaxial fixture is suitable for 0~9GHz measurement. For the test in X and Ku band, the waveguide fixture is more convenient. So the upgrade work for the test system is in progress. Some new types of waveguide fixture are in processing, and the code has been modified to handle the calculation in high frequency.

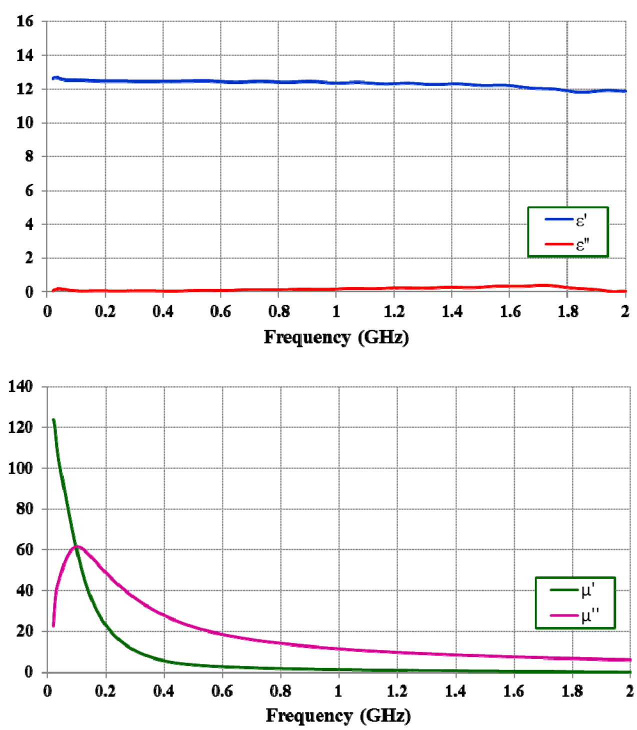


Figure 5: The measured ε and μ of ferrite.

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BRAZING EXPERIMENT

Brazing is the key technology for the damper fabrication. Based on the ferrite sheet, two kinds of brazing experiment has been finished.

The first experiment is aimed to check that, after the high temperature brazing whether the property of ferrite will change or not. The value of key parameter μ'' before and after high temperature heating are shown in Fig. 6. The value of μ'' did not change obviously, so the chosen brazing temperature is suitable for our ferrite.

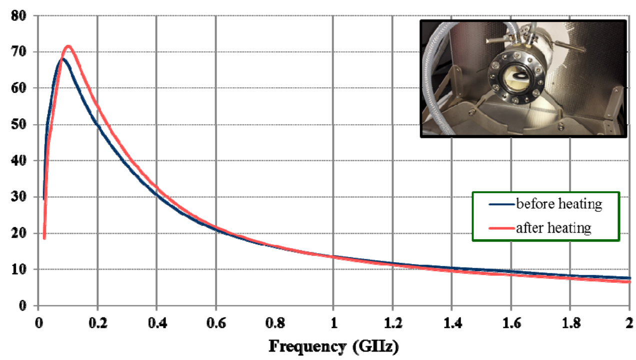

Figure 6: The value of μ'' before and after brazing.

The second experiment is trying to braze the ferrite sheet on the copper plate. It took a long time to solve the problem of nonuniform combination and ferrite fragmentation. The picture of failing and successful brazing is shown in Fig. 7.

(a) failure

(b) success

Figure 7: The ferrite and copper brazing results.

650MHz HOM DAMPER DESIGN

For CEPC 650MHz cavity, the HOM damper will absorb the power from 1.5GHz to 20GHz. Only one type of absorbing material will not fulfil the operation in this broadband. A kind of AlN+SiC composite material is selected for the high band. This composite is mainly used to absorb E field. The picture of composite is shown in Figure. 8. This composite is more compact and has good thermal conductivity.

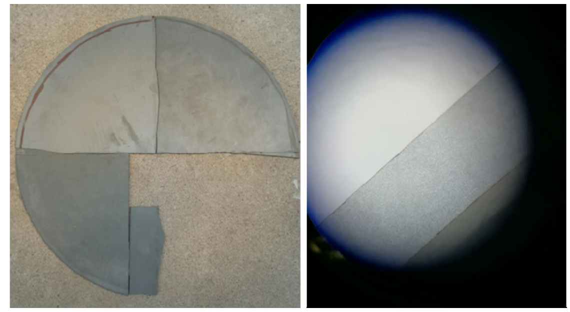

Figure 8: The AlN+SiC composite used for high band.

According to the data from company, the absorbing efficiency in C and X band has been preliminarily simulated. As shown in Fig. 9, the absorbing efficiency (the red curve) is greater than 50% in the whole band. Base on this composite, the performance of damper will be better by further optimizing the RF structure.

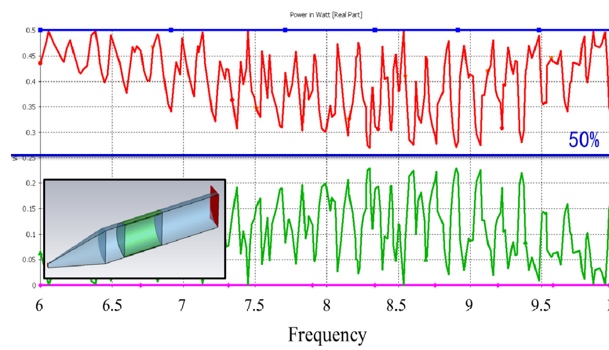

Figure 9: The preliminary simulation of absorbing efficiency using AlN+SiC composite.

Normally the integral simulation of "cavity + damper + taper" model should be carried out, to check the real situation of HOM damping. For narrow band, the eigen mode simulation is an effective way to estimate the HOM damping by calculating the Q_L of the system. An example for TM111 mode damping result is shown in Fig. 10. The system QL is 56.7, that means a good damping for this mode. But for broadband case, it is hard to do simulation for each mode, especially in the high frequency band. To calculate the HOM impedance directly by wakefield in time domain will be a more efficient method for broadband estimation.

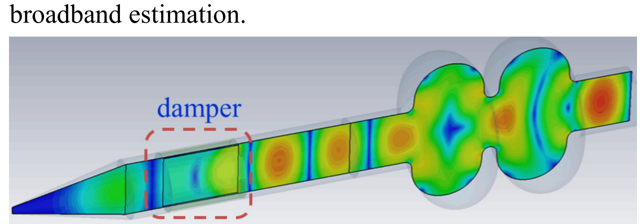

Figure 10: The simulation result of TM111 mode for "cavity + damper + taper" system, QL=56.7.

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SUMMARY

Base on the mature ferrite, the RF structure of 500MHz damper has been optimized to lower the fabrication cost. The brazing experiment of ferrite is finished. The fabrication of damper is in progress.

A test system has been built to measure the ε and μ of absorbing material. Due to the limitation of fixture connector, now this system can work below 6GHz. This system will be updated 18GHz by modifying the fixture and data processing code.

The preliminary design of 650MHz damper is under way. The AlN+SiC composite is selected for high frequency band microwave absorbing. The ε and μ of composite will be tested up to 18GHz, which will be used to further optimize the damper RF structure to increase the absorbing efficiency.

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REFERENCES

[1] G. Xu, "Progress of the Lattice Design and Physics Studies Studies on the High Energy Photon Source", in *Proc. IPAC2017*, Copenhagen, Denmark, 2017, paper WEPAB052, pp, 2697-2699.

[2] P. Zhang, "A 166.6 MHz Superconducting RF System for the HEPS Storage Ring", in *Proc. IPAC2017*, 2017, Copenhagen, Denmark, 2017, paper MOPVA079, pp. 1049 -1051.

[3] J. Zhai, "CEPC SRF System Design and Challenges", presented at SRF2017, 2017, Lanzhou, China, paper TUXAA01, this conference.

[4] H. Zheng, "HOM Simulations and Damping Scheme for CEPC Cavities", in *Proc. IPAC17*, Copenhagen, Denmark, 2017, paper MOPVA080, pp. 1052-1054.

[5] R. Eichhorn, "Higher Order Mode Absorbers for High Current ERL Applications", in *Proc. SRF2015*, Whistler, BC, Canada, paper THPRI111, pp. 4037-4039.

[6] *CST Microwave Studio*®, Ver. 2017, CST AG, Darmstadt, Germany.