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PRELIMINARY RESEARCH OF HOM FOR 100 MHz SUPERCONDUCTING CAVITY IN THE PRE-RESEARCH PROJECT OF HALS*

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Abstract

A 100 MHz QWR superconducting cavity is researched in the pre-research project of Hefei Advanced Light Source (HALS). Higher order modes (HOM) damping is a big challenge for synchrotron radiation light source. In this paper, we first apply the novel choke mode structure to the 100 MHz QWR (quarter wave resonator) cavity in order to damp the HOM. We identify the main harmful higher order modes. The HOMs in the QWR cavity are suppressed by optimizing the choke dimensions. The broadband HOM impedance spectrum of the cavity was also evaluated by calculating the beam induced wake potential in time domain. The results show that choke mode structure has a good HOM damping effect on the QWR cavity.

INTRODUCTION

A new synchrotron radiation light source conception was brought forward by National Synchrotron Radiation Laboratory, which was named Hefei Advanced Light Source (HALS) [1]. RF cavity research and HOM damping are important in the pre-research project of HALS. A QWR superconducting cavity may be used in the HALS storage ring for the compact structure and the physical calculation results of the QWR cavity in the pre-research project of HALS were provided in reference [2].

There are three main types of HOM coupler based on different transmission lines and coupling circuits: beam pipe absorbers, rectangular waveguide HOM couplers and loop/antenna HOM couplers to a coaxial line. The QWR cavity has a wide separation of the lowest HOM from the fundamental mode, which has the advantage for HOM damping. The damping loops strongly coupled the HOMs with high-pass filters protecting the fundamental mode in the 56 MHz QWR superconducting cavity for the RHIC [3]. A hybrid HOM damping scheme was proposed for the 166.6 MHz HEPS QWR superconducting accelerating cavity [4]. An absorber installed in the enlarge beam pipe to damped the HOMs above beam pipe cutoff frequency while a petal-shaped coaxial structure extracts the other HOMs.

Tsumoru Shintake first proposed the choke mode cavity [5]. The choke mode structure can provide a strong HOM damping. A choke-mode damped structure designed for CLIC main linac has good damping effect [6]. In this paper, the choke mode structure is proposed to apply on the QWR cavity in pre-research project of HALS to damp the HOM.

The beam current of HALS storage ring is up to 500 mA, HOMs induced by beam need to be strongly damped because HOM will result in some severe beam instabilities. We investigate the HOMs distribution in the 100 MHz QWR cavity and identify the main harmful HOMs. A novel choke mode structure for the QWR cavity was designed to damp the HOM. The novel choke mode structure is composed of a coaxial line, a radial line choke and the ferrite load. The location of the ferrite material was optimized to absorb the HOMs effectively. Wakefield simulation was performed to get the broadband impedance spectrum of the 100 MHz QWR cavity with the choke mode structure and to evaluate the damping effect of the choke mode structure.

HOM PERFORMANCE FOR THE QWR CAVITY

The size of the QWR cavity was optimized to get good RF parameters. Table 1 shows the RF parameters of the 100 MHz superconducting cavity, where Ep/Eacc (Bp/Eacc) is the ratio of the peak electric (magnetic) field at the cavity wall to the accelerating field, R/Q is the ratio of shunt impedance to the quality factor and G is the geometry factor. The electric field distributions for the fundamental mode and the first HOM are shown in Fig. 1 and Fig. 2 respectively. The frequency of the first HOM is 252 MHz which has a large separation from the fundamental mode. The first HOM is dipole mode and we evaluate the dipole shunt impedance at 10 mm off-axis. We also calculate HOMs below 1GHz and identify the mode configurations. Table 2 lists the details of the main harmful HOMs in the 100 MHz QWR cavity.

Table 1: RF Parameters of the 100 MHz Superconducting QWR Cavity

Parameter	Value
Frequency	100 MHz
R/Q	124.63 Ω
Ep/Eacc	2.26
Bp/Eacc	5.01 mT/(MV/m)
G	50.65 Ω

CHOKE MODE STRUCTURE DESIGN

We modify the original design of the choke mode structure in reference [5]. The electromagnetic modes are extracted by

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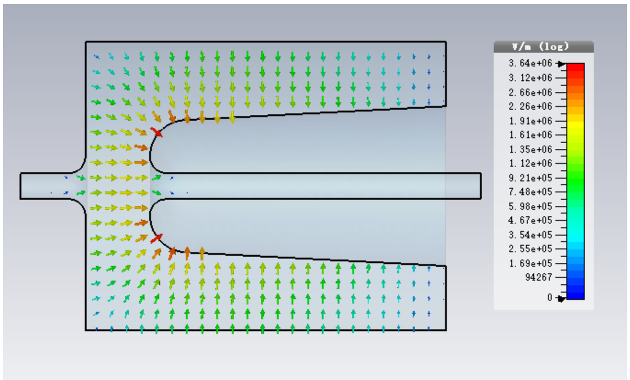

Figure 1: Electric field distribution for the fundamental mode.

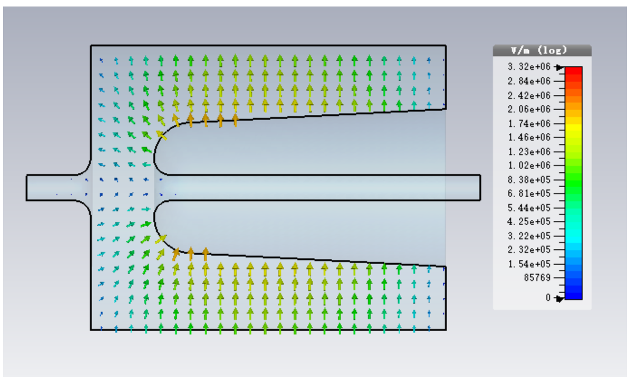

Figure 2: Electric field distribution for the first HOM mode.

Table 2: Main Harmful HOMs in the QWR Cavity (M: monopole; D: dipole)

Frequency (MHz)	Mode Configuration	R/Q (Ω)
100	M	124.6344
252	D	0.0448
267.9	M	84.8393
387.3	D	0.1265
407.5	M	58.2906
533.4	D	0.5689
559.9	M	13.6753
615.9	D	0.3645
731.6	M	0.1952
792.5	M	125.7825
863.5	D	0.0041
896.9	M	5.1035
903.3	D	0.6274
910.2	M	11.7336
920.5	D	0.0397
962.4	D	0.0437
966.6	D	1.0482
968.4	M	8.6511

coaxial line and the fundamental mode is reflected by radial line choke. Figure 3 shows the QWR cavity with choke mode structure. The QWR cavity is slotted with a narrow annulus ring. The choke mode structure is connected to the QWR cavity. The outer diameter of the coaxial line is equal to the diameter of the QWR cavity, which can provide strong coupling. The electromagnetic fields in the QWR cavity are coupled to the coaxial line and propagated to the ferrite load. The design of the choke mode structure is to ensure more HOMs can be propagated to the load and the fundamental mode can be well reflected. The simulation results show that the S21 parameters are sensitive to dimensions of the choke mode structure, especially the length of the radial line choke. Figure 4 show the S21 parameter with different length of the radial line choke. The choke mode structure was optimized to achieve a well reflection of the 100 MHz fundamental mode. The optimizing result is shown in Fig.5. The 100 MHz fundamental mode is reflected with a S21 parameter of –26.922dB and most of the harmful HOMs can be effectively propagated to the load.

Ferrite absorber was used to absorb the HOM power. The ferrite absorber was carefully designed to absorb more HOM power. Ferrite cylinders are inserted in the gap between inner and outer conductor of the coaxial line. The other ferrite is placed in the end of the coaxial line.

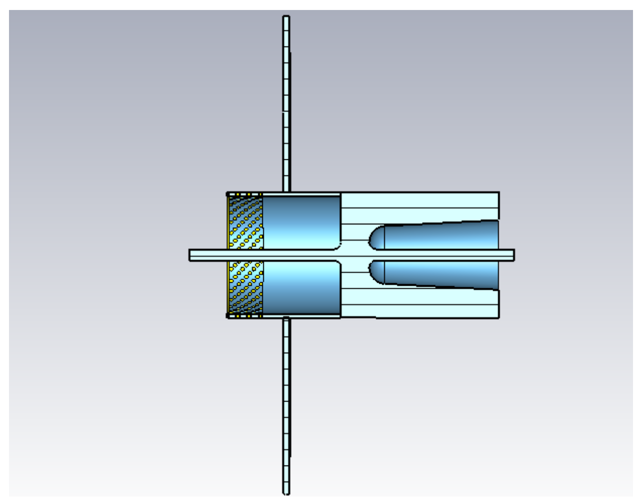

Figure 3: QWR cavity with choke mode structure.

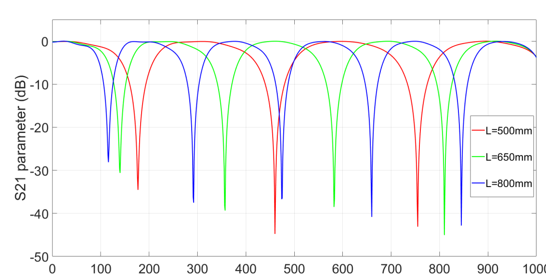

Figure 4: S21 parameter of the choke mode structure with different length of the radial line.

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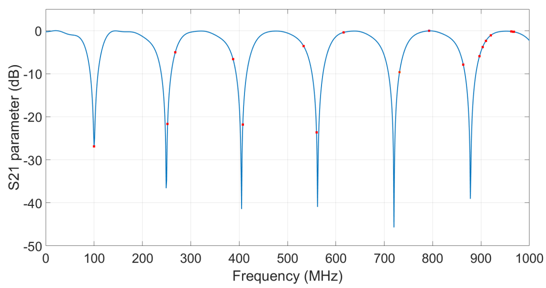

Figure 5: S21 parameter of the optimize choke mode structure.

WAKEFIELD SIMULATION

To evaluate the damping effect of the choke mode structure, we have carried out the wakefield simulations with CST Particle Studio [7] and compared the results with or without the ferrite load. The wake potential and impedance results are shown in Fig.6 and Fig.7. The calculated impedance is not equal to the shunt impedance of the cavity due to the truncation of the wakefield calculation. After adding the ferrite load, the impedance of HOM are reduced to a very low value while the impedance of the fundamental mode has almost no change. Wakefield simulation results show that the HOM power can be absorbed by the ferrite load. Meanwhile, the fundamental mode can be reflected by the radial line choke and the fundamental mode power is prevented from being absorbed by the ferrite load.

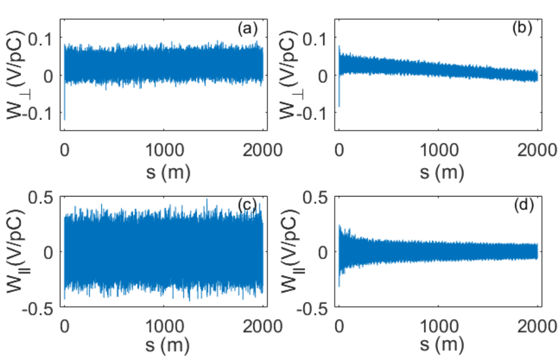

Figure 6: Wake potential. (a): transverse wake potential in X direction without ferrite load; (b): transverse wake potential in X direction with ferrite load; (c): longitudinal wake potential without ferrite load; (b): longitudinal wake potential with ferrite load.

SUMMARY

We have investigated the HOM performance for the 100 MHz QWR superconducting cavity and designed a choke mode structure. Wakefield simulation results also show that the new-type choke mode structure can provide strong HOM damping. Fundamental mode is not affected by the ferrite load due to the reflection of the radial line choke. The deeply work is in progress.

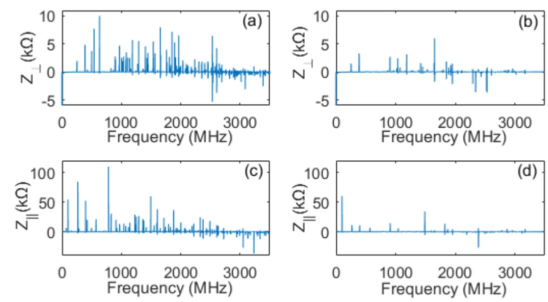

Figure 7: Wake impedance. (a): transverse wake impedance in X direction without ferrite load; (b): transverse wake impedance in X direction with ferrite load; (c): longitudinal wake impedance without ferrite load; (b): longitudinal wake impedance with ferrite load.

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