DESIGN OF THE FUNDAMENTAL MODE DAMPER AND THE HOM DAMPERS FOR THE 56 MHZ SRF CAVITY*

E. M. Choi‡ , H. Hahn, and I. Ben-Zvi, BNL, Upton, NY 11973, U.S.A.

Abstract

A 56 MHz Superconducting RF cavity is under development for the Relativistic Heavy Ion Collider (RHIC) aiming at luminosity enhancement. The 56 MHz SRF cavity can adiabatically rebucket the beam from the 28 MHz accelerating cavities, provide shorter bunches and significantly enhance the luminosity. The 56 MHz SRF cavity will be turned on at store, therefore, the fundamental mode should be damped while the beam is injected and accelerated. The feature requires a fundamental mode damper (FD). The mechanical design of the FD is challenging since the fundamental mode damper has to be physically withdrawn while the cavity is turned on. This motion introduces a frequency change of the cavity. Since for stability the cavity frequency must be kept below the beam frequency in this phase, we chose a judicious axial placement of the FD to minimize the frequency shift. Various studies of the FD were done with prototype cavity tests and numerical simulations. The engineering issues were addressed. Higher-order mode (HOM) dampers are necessary for stable operation of RHIC with the 56 MHz SRF cavity. The physics study of the HOM dampers will be presented in the paper. Based on the stability criteria of the cavity, the HOMs are properly damped by having two HOM dampers. The fundamental mode is filtered out by a 5 element high pass filter. The HOMs were identified and the external Q factors were obtained from tests of the prototype cavity and compared to simulations with the CST Microwave Studio® program [1].

INTRODUCTION

The 56 MHz Superconducting RF (SRF) cavity designed for the Relativistic Heavy Ion Collider (RHIC) is a Quarter Wave Resonator (QWR) in order to make it sufficiently compact.

Unlike low β QWR resonators, the beam path is along the axis of symmetry of the cavity. Since this cavity is beam-driven , it must be turned on or off by extremely heavy variable damping of the fundamental mode. The cavity has to be damped while the beam is injected and accelerated, and the damping removed at beam store. The Higher-order mode (HOM) dampers are needed at all times for the stable operation of the storage ring. Interestingly enough, the QWR mode spectrum simplifies the design of the HOM dampers, since there is a large gap between the frequency of the fundamental mode and the lowest HOM. The fundamental mode damper and the HOM dampers are discussed in the following sections.

Table 1: The 56 MHz SRF Cavity Parameters

Frequency	**56.298 MHz**
Voltage	2.5 MV
Superconducting surface resistance	10 nOhm
Power dissipated to LHe (4.2 K)	42 W
Q factor	1.8E9
Stored energy	221 J
R/Q	79.9

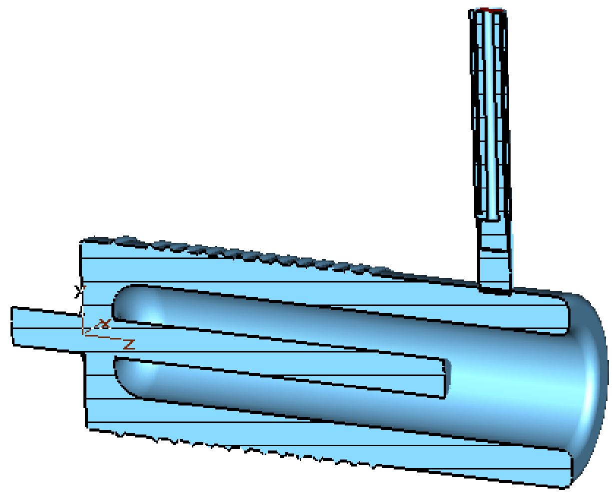

Figure 1: The 56 MHz SRF cavity shape in CST MicroWave Studio (MWS) simulation. The fundamental damper port is in the picture.

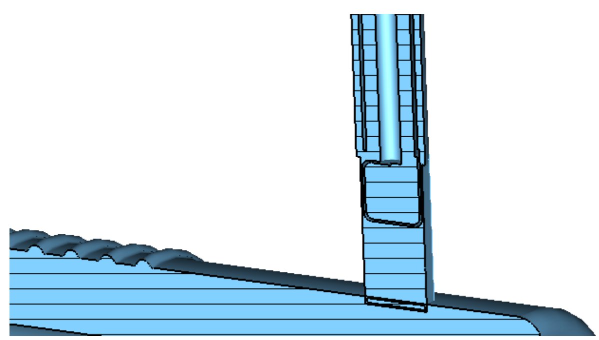

Figure 2: The enlarged fundamental mode damper picture. The fundamental mode damper is recessed by 10 cm from the cavity surface. The rectangular waveguide shape opening is extended and followed by a circular open port.

*Work supported by Work supported by Brookhaven Science Associates, LLC under Contract No. DE-AC02-98CH10886 with the U.S. Department of Energy.
‡Eunmi Choi [choi.eunmi@gmail.com]

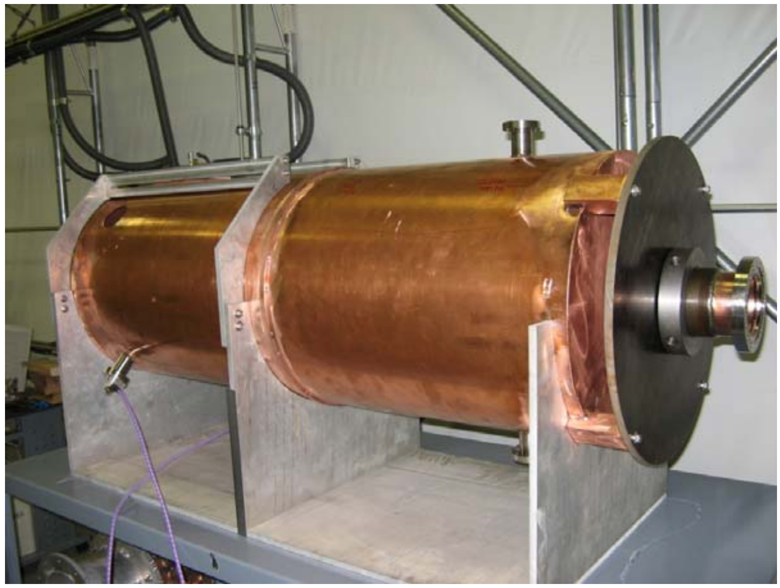

Figure 3: The prototype copper cavity.

THE FUNDAMENTAL MODE DAMPER

As explained above, the fundamental mode damper is essential for the operation of the cavity in the storage ring.

Fig. 1 shows the cavity shape with a port for the FD from the MWS simulation. The port has a rectangular shape for the damper loop that is 8 cm by 8 cm with a width of 4 cm. The fundamental mode damper loop will be made of copper for the production cavity because it will be withdrawn while the cavity is at high field. Fig. 2 is the enlarged picture of the fundamental mode damper. As seen in Fig. 2, the FD will be guided through a rectangular waveguide, whose size is just determined by the FD loop size with a certain margin.

Fig. 3 is a picture of the prototype copper cavity for the test. It allows the tests of the FD and all necessary components.

Fig. 4 shows the external Q factors as a function of the FD location. The FD is recessed out of the cavity, where the recessed distance 0 represents the cavity surface in Fig. 4. In order to compare the exact values, the MWS simulation model was built such that the cavity has a rectangular opening attached to the circular port. One should note that the external Q factor of the FD of the production cavity at 10 cm recessed distance is 8×10^{10}, which is much larger than that of the prototype cavity shown in Fig. 4.

THE HOM DAMPERS

The old version of the HOM damper was designed and tested as reported in [2]. It was to be located at the outer shell of the cavity. However, it turned out that a 1 GHz monopole mode which has to be suppressed for stability was not damped effectively due to the damper's location. A combined study of prototype cavity measurements and simulations shows that the HOM damper has to be located at the shorted-end of the cavity (the strongest magnetic field region) to effectively damp out all HOMs. The ports for the chemical cleaning, which are located at this region will provide convenient openings for the HOM dampers.

New HOM damper ports have been designed with a new size of the HOM damper loop which is determined by the damping properties of the HOMs and accommodated to the allowable openings for the chemical cleaning ports. The rectangular HOM damper loop size is 6 cm by 2.88 cm with a 2 cm width. The simulated frequencies and Q values from two different codes are presented in Table 2.

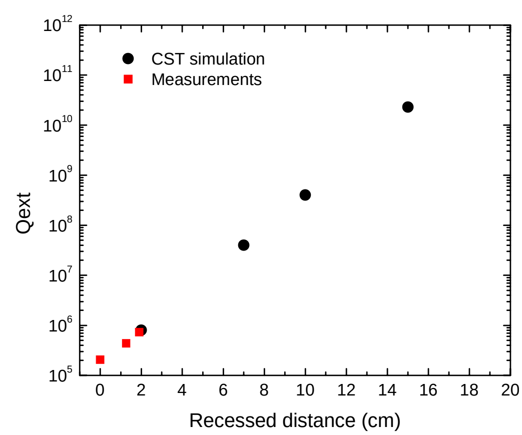

Figure 4: The external Q as a function of the fundamental mode damper location (the damper is recessed with respect to the cavity surface). Black dots represent the MWS simulation, and red squares represent the prototype measurement.

THE NEW HOM FILTER

Based on the successful prototype cavity measurements with the first HOM filter, a new HOM filter has been redesigned. The new HOM filter is more compact than the first HOM filter in physical size.

Table 2: The Simulated HOM Frequencies and Q Factors

Omega3P	MWS	Omega3P	MWS	Omega3P	MWS
Frequency (MHz)	Frequency (MHz)	Qext	Qext	R/Q	R/Q
56.263	56.241	3485	4255	80.0	78.9
167.865	167.790	1694	1818	32.3	30
276.205	276.147	1704	1614	27.5	23.2
378.447	378.393	2073	1780	27.9	22.6
475.459	475.393	2520	2040	21.7	21.4
574.779	574.724	3127	2580	13	15.8
680.133	680.038	2802	2520	6.7	9.8
789.259	789.042	4108	3800	3.5	6.2
899.415	899.121	37142	50400	2.8	4.9
1009.34	1008.66	4577	5726	2.8	6.5
1112.72	1112.01	5401	4900	14.9	23.4
1138.59	1137.91	10663	11060	17.7	11.6

Table 3: The Required Frequencies and Q Factors of Monopoles Calculated by Nathan Towne [3]

Frequency (MHz)	Q
56.16	
167.563	2000
275.731	
377.863	25000
474.9	7000
574.3	5000
679.8	25000
788.8	100000
898.2	
1008	10000
1112	
1139	

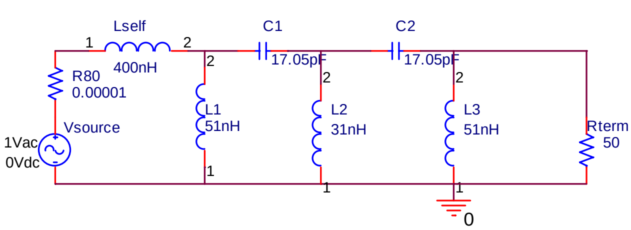

Figure 5: A new HOM filter circuit model.

Fig. 5 shows the new HOM filter circuit schematic for the PSPICE [4] simulation. Lself represents the HOM damper loop which is estimated to be a self inductance of 400 nH. It is a 5 element high pass filter. The HOM filter model was simulated in the MWS. The result of the MWS simulation is shown in Fig. 6. The fundamental mode at 56 MHz is rejected at about -60 dB.

Table 3 shows the required HOM frequencies and Q factors of monopoles determined by stability calculations done by Nathan Towne [3]. The simulated results meet the stability condition given by Table 3. The experimental measurements were done with the prototype cavity.

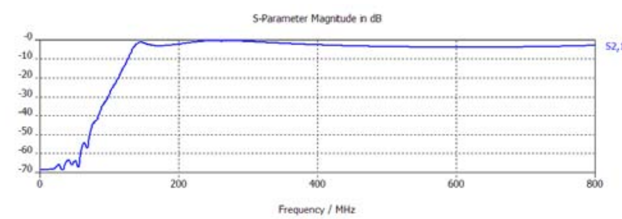

Figure 6: The MWS simulation result of the HOM filter.

CONCLUSIONS

The fundamental and HOM dampers for a 56 MHz superconducting QWR intended as a storage cavity in the Relativistic Heavy Ion Collider were investigated through computer simulations and prototype cavity tests. The fundamental mode damper loop and its port dimensions were determined. The higher-order mode dampers were located at the high magnetic field region of the cavity. The HOM dampers with the high pass filter were tested in the prototype cavity and compared to the simulations. The simulations and measurements are in agreement and the performance of the dampers meets the cavity's specifications.

REFERENCES

[1] http://www.cst.com/Content/Products/MWS/Overview.aspx.
[2] E. M. Choi, and H. Hahn, "Higher-order mode damper study of the 56 MHz SRF cavity", C-A/AP/319, 2008.
[3] http://www.bnl.gov/cad/ecooling/docs/PDF/56_MHz/56_MHz_Towne-CHHCStability.pdf.
[4] http://www.orcad.com/.