OPTIMIZATION OF HIGHER ORDER MODE DAMPERS IN THE 56 MHz SRF CAVITY FOR RHIC*

Q. Wu# and I. Ben-Zvi, BNL, Upton, NY 11973, U.S.A.

Abstract

A 56 MHz superconducting RF cavity was designed for a luminosity upgrade of the Relativistic Heavy Ion Collider (RHIC), including requirements for Higher Order Mode (HOM) damping. In this paper, we describe our optimization of the damper's performance, and modifications made to its original design. We also show the effects of the damper geometry on the cavity's HOM impedance. To reduce the likelihood of magnetic breakdown, we lowered the magnetic field enhancement at the ports to a value less than the highest field in the cavity. We simulated all monopole and dipole HOMs up to 1GHz with their frequencies, mode configurations, R/Qs, and shunt impedances, verifying that all modes are well-damped with the optimized design and configuration.

INTRODUCTION

The 56 MHz superconducting RF cavity is a quarter-wave resonator designed to have a gap voltage of 2.5 MV. Our plans are to place this beam-driven resonator at a common section of RHIC to provide a storage RF potential for both rings. The large bucket of the cavity will reduce spill due to Intra-Beam Scattering (IBS), and thus increase the luminosity for the detectors. It is very important to damp all the cavity's Higher Order Modes (HOMs) to avoid beam instabilities. The design chosen for the HOM damper is a magnetically coupled loop located at the rear end of the cavity. The loop and its port geometry must be optimized to assure sufficient damping, avoid a large enhancement of the local magnetic field. A high-pass filter is included in the circuit to reduce the power extraction from the fundamental mode

The number of HOM dampers used and their configuration also are important factors for the damping and cooling system. A small loop area will couple out less power from the cavity's fundamental mode, thus reducing the voltage and power dissipation in the damper's filter circuit; however, it might not be sufficient for HOM damping. This problem is resolved by increasing the number of the HOM dampers and carefully choosing their location. Details of the high-pass filter will discussed in another paper [1].

HOM DAMPER AND CHEMICAL PORT

The original design of the HOM dampers 56MHz cavity [2,3] forms the starting point of our optimization. We aim to maintain the following criteria:

- All monopole and dipole HOMs below 1GHz are damped effectively. All other HOMs with a high R/Q are treated similarly.
- The change in the fundamental mode frequency due to the damper is well quantified.
- The HOM dampers can be inserted through the chemical cleaning ports located at the rear of the cavity.
- The field enhancement around the HOM dampers and ports is such that the peak surface-magnetic fields do not exceed the maximum in the rest of the cavity.
- In considering the smallest gap between the port and the damper's loop, we try to avoid an electric discharge.
- Feasibility of fabrication is another consideration.

We simulated the cavity using MICROWAVE STUDIO (MWS) [4]. Figure 1 shows the optimized design of the HOM damper and the inserted configuration.

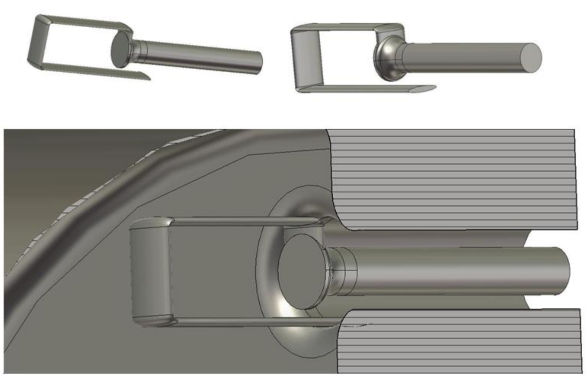

Figure 1: Optimized design of the HOM damper loop.

A rectangular loop was adopted as the final design with an area of 6cm×2.88cm. The width of the loop was set as 2cm and its thickness at 0.3cm. We insert the HOM damper into the cavity via the chemical cleaning port at the high magnetic field end of the cavity. The size of the damper loop was chosen to provide sufficient coupling of the magnetic field, while also allowing its insertion through the 1.6" diameter opening of the port.

All sharp edges are blended to eliminate any enhancement of the local magnetic field. Figure 2 illustrates the magnetic field at the end of the cavity with HOM damper inserted; the maximum field on the damper is 8.4E4 A/m. This value is only 1/3 of the that in our original design, and even lower than the field generated on the cavity's shell, which is 9.5E4 A/m. The peak field at the port's opening is 1.5E5 A/m.

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# qiowu@bnl.gov

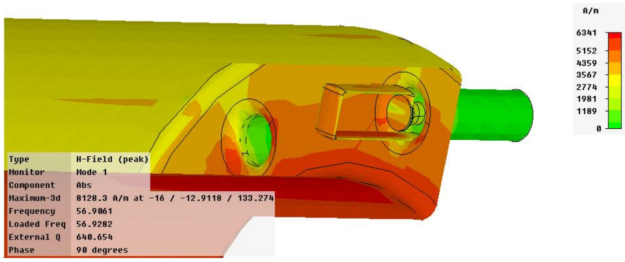

Figure 2: Magnetic field around the HOM damper.

The modified HOM damper maintains the original inner loop's area and thickness, and thus the damping of the HOM modes. We checked this by an MWS simulation, discussed in the next section.

We modified the chemical port detailed geometry to lower the surface magnetic field at its opening; Figure 3 depicts our final design. The field, calculated with the software ANSYS [5], revealed that its peak at the chemical cleaning port declined to the same level as that at the end of the inner cavity.

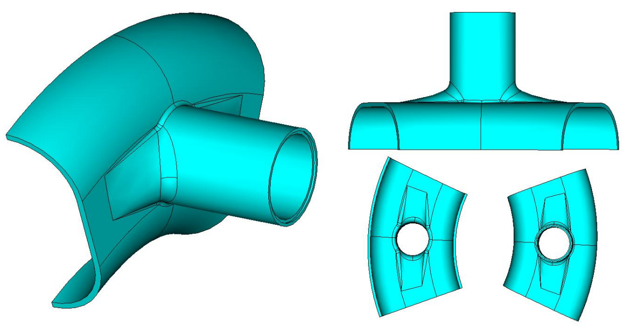

Figure 3: Final design of chemical port.

This design of the chemical port and the HOM damper greatly reduces the risk of magnetic breakdown, and thus quenching of the cavity.

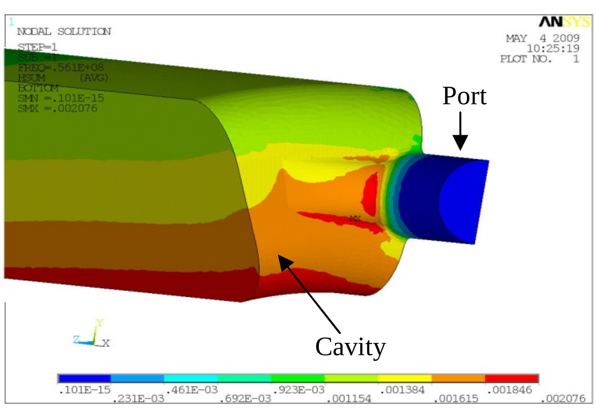

Figure 4: Magnetic field at the chemical port and the rear end of cavity in our final design. The colour scale in the bottom of the picture indicates the field strength with blue as the weakest and red as strongest.

PERFORMANCE OF THE MODIFIED HOM DAMPER

Single Damper

With our optimized HOM damper loop, via simulations, we can proceed to determine the locations and the number of the dampers. Table 1 shows the damping effect of one damper located in the chemical port.

Table 1: MWS simulation of frequencies and Q_Ls in the 56MHz cavity with 1 modified damper for monopole (M), dipole (D), quadrupole (Q), sextupole (S).

Frequency [MHz]	Mode Config.	Q_L
56.182	M	3828
167.53	M	1814
254.38	D	248
260.38	D	6412
276.51	M	1806
314.46	D	2168
377.84	M	2236
393.05	D	1528
474.56	M	2789
525.27	Q	6771
573.20	M	3494
578.64	Q	11802
579.73	D	1207
647.59	Q	3135
670.75	D	2284
677.59	M	2989
722.69	S	75269
727.36	Q	2968
747.10	S	22054
752.41	D	2711
785.44	M	5532
786.73	S	7619
839.02	D	5519
840.13	S	4879
895.97	M	24324
903.22	S	104470
903.98	S	64555
976.50	S	6527
986.44	Q	5407
1002.71	Q	4349
1106.15	M	3282
1122.23	Q	1410
1131.10	M	8651

Table 1 shows that with one damper some frequencies of the HOMs in the 900MHz range are not damped effectively. Because of the size of the HOM damper is limited in this design of the cavity by the accessible radius and location of the chemical port, by using only 1

HOM damper, it would be difficult to achieve desired Q_L for all HOMs. Note that the first mode at 56.182 MHz is the fundamental accelerating mode.

The actual specifications of the HOMs performance are the shunt impedance R values, obtained from the product of Q_L and R/Q for each mode.

Therefore, to assure damping of all modes, we must increase the number of the HOM dampers and properly distribute their locations. The R/Q and shunt impedance of each mode must be calculated to quantify each mode's tolerance, and so improve the efficiency of damping.

Multiple Dampers

Due to the limitations of the number of insertion ports, four is the maximum number of HOM dampers we can use. To provide coupling to orthogonal quadrupole HOMs, the four dampers must be placed asymmetrically, as shown in Fig. 5.

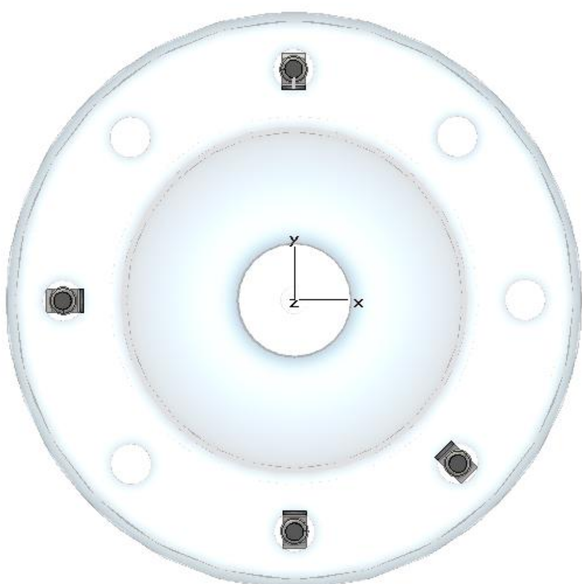

Figure 5: Rear view of the cavity with 4 HOM dampers inserted in asymmetrical ports.

Table 2 details the modes in the geometry given in Fig. 5. The loaded Qs for all monopole and dipole modes are smaller than 8000. Those loaded Qs for all quadrupoles are smaller than 5E4. All R/Q for HOMs are < 33Ω. This configuration assures that the higher order modes are very well damped, and the damping meets the requirements for the cavity.

ACKNOWLEDGEMENT

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Table 2: MWS simulation of frequencies, mode configurations, and R/Qs in the 56MHz cavity with four modified dampers inserted in asymmetrical chemical ports. (M, monopole; D, dipole; S, sextupole; and. Q, quadrupole)

Frequency [MHz]	Mode Config.	R/Q [Ω]	Q_L
56.231	M	80.53	940
167.456	M	32.34	438
260.445	D	22.18	3817
278.583	M	25.4	428
314.605	D	16.58	760
378.767	M	27.77	514
393.22	D	19.17	543
475.135	M	22.63	621
484.371	D	19.73	1115
490.072	Q	0.000874	7334
524.115	Q	0.00056	2205
573.46	M	12.91	744
577.852	Q	0.081	1390
579.53	D	19.68	1102
646.969	Q	0.0016	990
647.105	Q	0.00211	3758
670.053	D	19.30	1683
677.37	M	6.63	838
721.767	S	4.91E-05	56720
726.747	Q	0.00106	953
746.283	S	0.000477	15679
747.159	S	0.00046	9811
750.743	D	21.44	2224
751.081	D	22.43	1099
784.496	M	3.74	1510
786.022	S	0.0555	4880
813.048	Q	0.00123	1287
835.634	D	6.86	2315
838.906	S	0.00236	0.64
892.829	M	2.63	7458
902.098	Q	0.000988	5122
903.064	S	0.000843	12132
932.277	D	2.68	4584

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[4] CST Microwave Studio Suite 2008.

[5] ANSYS v11.0.