BETTER RF CAVITIES FOR HERA/PETRA

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Abstract

This paper deals with the design criteria of the HERA/PETRA RF accelerating cavities in terms of their improvement. Particular care was given to the existing cavity geometry modification in order to increase its shunt impedance and to minimize the electron resonance discharge probability.

The possibilities of damping higher order cavity modes are investigated.

1 INTRODUCTION

Usually, the design principles of an accelerating structure are as follows:

- Because of the desired beam emittance and the required beam current (supposed to be quite low and high, respectevly), the impedances for HOM's must be minimized as small as possible;
- A simple cavity structure is desirable for easy fabrication. Consequently cavity-cooling mechanism is refined and phenomena induced by the bunched beam in the cavity must be understandable;
- The high shunt impedance of an accelerating mode generally conflicts with minimizing HOM impedances. Thus the accelerating shunt impedance is to be set as high as possible in order to suppress an excessive thermal load in the cavity and stabilize an operation;
- A cavity geometry should minimize the possibility of resonant discharges (multipacting).

We tried to follow them in our task.

2 EXISTING HERA/PETRA CAVITY SIMULATION

Some parameters of HERA RF system are presented in Table **??**.

Table 1: Some HERA/PETRA cavities parameters

RF Frequency	52.0	MHz
RF Peak Voltage	150	kV
Cavity Length	1.49	m
Cavity Tank Radius	549.5	mm
Accelerating Gap	262	mm

The working HERA/PETRA cavity may be considered as back-to-back half-wave resonators loaded by intermidiate cylinder supported on a post at the zero-field symmetry point (TM-010 mode). The cavities were fabricated from aluminum alloy 6061-T6.

To simulate this cavity 3D MAFIA codes have been used.

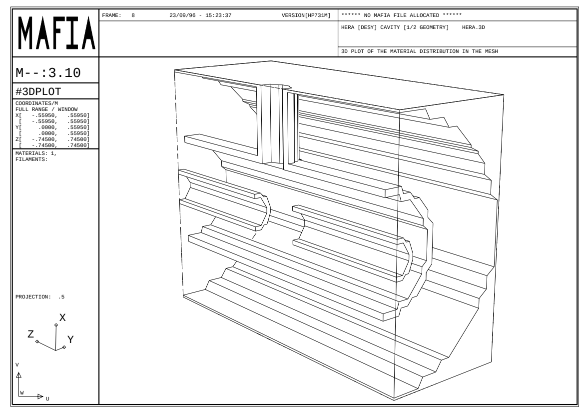

Figure 1: HERA RF Cavity.

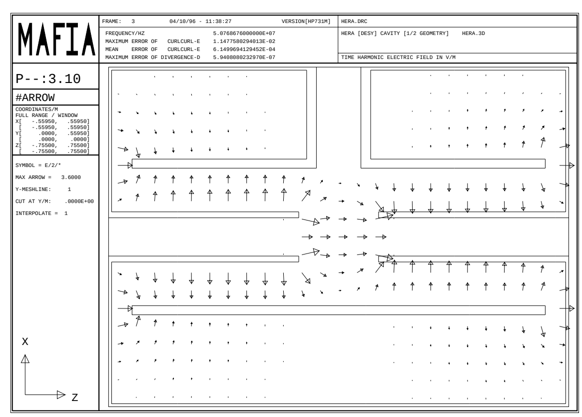

Figure 2: Electrical Field Distribution in HERA Cavity.

On Fig. **??** a half part of the cavity geometry is shown as it was generated by a mesh generator. The results of MAFIA simulation are presented in Table **??**. The modes 2 and 4 are essentially the fundamental and its second harmonic. The modes 1 and 3 are the first and second harmonics of the transvers mode.

Here we see the following existing cavity disadvantages:

- Low fundamental mode shunt impedance value for such cavity dimensions which is resulted from a complex structure;
- Because of a big inner surface, small gaps and a complex structure there is a very high possibility of resonant discharges (multipacting) (Fig. **??**);

- Z - symmetry plane results in more higher order modes;
- Aluminum cavity walls (mainly oxide layer) substantially reduces the shunt impedance value and increases a probability for multypactor.

Table 2: 3D HERA/PETRA Cavity Simulation.

mode	f/MHz	Q	R_{sh}/Ohm
1	30.648050	15185	2101
2	50.804836	25467	2841781
3	111.214553	25828	28402
4	137.515625	26646	1985710
5	162.594528	34812	28444
6	187.964111	36654	17680
7	195.989883	33475	3652
8	235.453430	50070	492604
9	240.907730	40634	388
10	282.909118	49957	9567

3 BETTER HERA CAVITY

3.1 Accelerating Structure Modification

The main reason of nearly all problems in the existing HERA cavities as we could see from above is the intermidiate cylinder. It reduces gaps which results in a wave impedance reduction which in its turn reduces shunt impedance. That's why the first suggestion on an accelerating structure modification is to consider the cavity without this cylinder. This would also help to reduce the possibility of multypactor.

Another disadvantage is an existence of z-symmetry plane which not only increases the higher order mode number but also lifts the fundamental frequency up (for the fixed cavity tank dimensions).

Finally, if we make changes to eliminate these disadvantages we get a simplified cavity which is essentially well known one gap quarter wave length cavity and its fundamental frequency is defined by the cavity length and an accelerating gap capacitance. In all changes we keep the cavity tank radius, an accelerating gap size and beam pipe dimensions the same. And as soon as this new cavity is a quarter wave length rather than half wave length a fundamental frequency of a new cavity is not very far from a required 52 MHz (56.33 MHz). To get a proper frequency in this cavity it is sufficient to modify sligtly an accelerating gap geometry – to make the electrodes bigger on 60 mm then the beam pipe outer radius.

Now we have more simple structure with much higher shunt impedance than before. Further structure modifications should be related to the multypactor minimization. Starting with an idea that a completely spherical structure is free from multypactor let's make our cavity more round. The suggestion and results of such cavity simulations are in Table **??** and on Fig. **??**.

Table 3: Simple HERA/PETRA Cavity.

mode	f/MHz	Q	R_{sh}/Ohm
1	52.151126	33014	4574552
2	155.941635	55060	2846867
3	179.858795	74806	1654
4	234.054168	56862	1984153
5	246.854187	86124	3358
6	283.446258	77554	1
7	302.748230	60196	74252
8	320.968811	58708	38240
9	332.116394	88448	1
10	333.923797	97283	5989

3.2 HOM Damping

For higher order mode damping let's start with a simplest possibility like an inductive nonresonant loop. From electric and magnetic field distribution consideration a loop should be oriented in XY-plane (parallel to a fundamental mode magnetic field). At the same time to damp succesfully higher harmonics of fundamental it should be placed in the zero-magnetic field point of a second harmonic (Fig. **??**).

The shunting simulation can be done by an electrical conductivity change of a small part of the loop line where it connects to the ground. Since we don't know which conductivity corresponds to the shunting resistor value the simulation was done for the series of the conductivity values and the results are shown on Fig. **??**.

The existing HOM damping resonance inductive loop design can be used here, too.

A more progressive method of HOM damping is a connection of an additional cavity to the main one close to the gap [**?**]. These cavities are coupled via a capacitive gap of an additional cavity. A frequency of this cavity should be higher than the fundamental frequency of the main cavity and lower than the first HOM frequency. Depending on the coupling value the damping strength will be different.

Now to damp higher order modes the HOM cavity gap

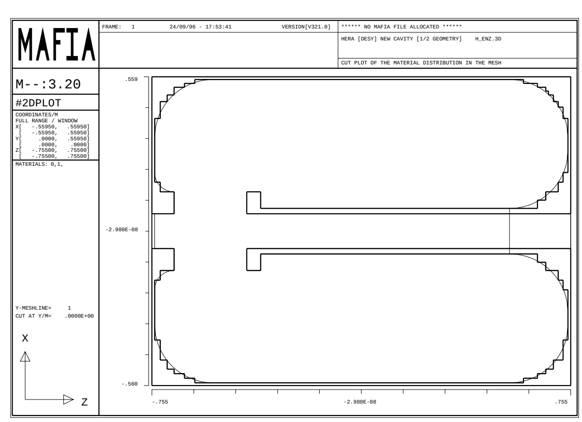

Figure 3: Simple HERA Cavity.

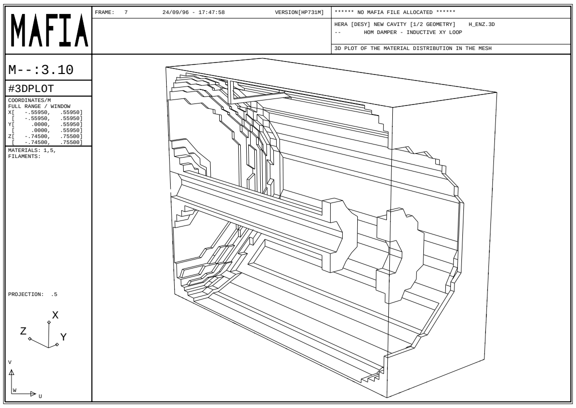

Figure 4: Cavity With HOM Damping Inductive Loop.

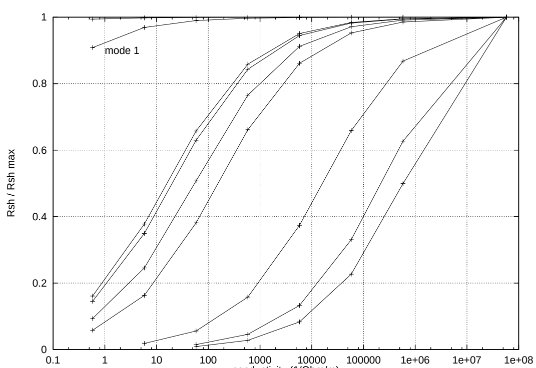

Figure 5: HOM Damping with Inductive Loop.

should be shunted (Fig. **??**). We used the same procedure as before for shunting simulation by MAFIA. The results of such structure simulation are on Fig. **??**. Further development of this HOM damping structure is an optimization of the number and places of shunting points on the damping cavity gap. At the same time the shunting might be done not directly but through a high frequency filter to minimize more a fundamental mode damping [**?**].

In order to reduce more the coupling at the fundamental frequency by this type of damper a new concept of damping HOM in the KAON booster cavity by employing a high-pass filter is proposed on TRIUMF [**?**]. This high-pass filter can be applied to a suggested quarter wave length cavity.

4 CONCLUSIONS

- A proposed quarter wave length one gap accelerating cavity has much simpler structure than existing HERA/PETRA cavities which is easer to fabricate;
- Bigger gaps between inner conductor and cavity tank walls will result in multipactor possibility decrease;
- Because of a structure simplification the shunt impedance of the proposed cavity is much higher (4.57 MOhm instead of 2.84 MOhm);
- Two options for HOM damping have been considered

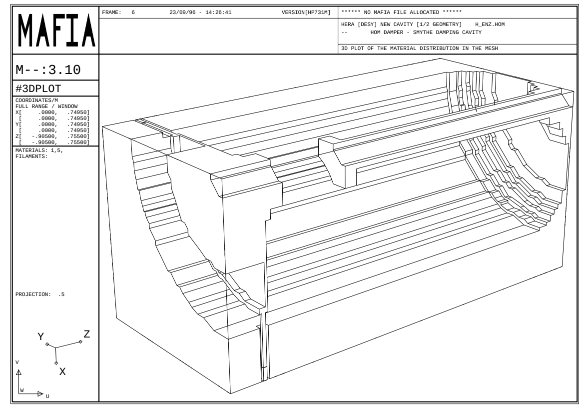

Figure 6: Smythe's HOM Damping Cavity (1/4 of geometry is shown).

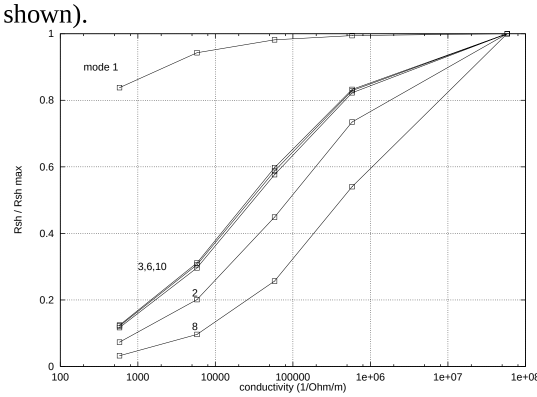

Figure 7: HOM Damping Cavity with Smythe's Cavity.

which can be developed to a higher efficiency;
- All MAFIA calculations have been done for copper cavity walls. In the case of real cavity design to replace the existing cavities one should definitely think to build a cavity with copper walls. It will increase more the shunt resistance to compare with existing and drastically improve a situation with multypactor.

5 REFERENCES

[1] W. R. Smythe, "Proton Synchrotron RF Cavity Mode Damper Tests", IEEE PAC, 643 (1991).

[2] L. Walling et al., "Broadband Higher-Order Mode (HOM) Damper for SSC LEB Ferrite-Tuned Cavity", IEEE PAC, 1083 (1993).

[3] A. K. Mitra, "Higher Order Mode Dampers for the KAON Booster Cavity", IEEE PAC, 974 (1993).