STUDY OF HOM COUPLERS ON AN 800MHz PROTOTYPE CAVITY

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Abstract

On an 800MHz two-cell prototype superconducting cavity, we study the different designs of the HOM coupler that can meet the high damping requirements for both longitudinal and transverse modes. The results of measurements on an aluminium model as well as MAFIA simulations are presented. This project is supported by National Natural Science Foundation of China.

1 INTRODUCTION

One of the major sources of beam impedance in accelerators is the higher-order modes (HOMs) of the RF cavities. So HOM damping is required for removing beam induced power from the cavity in order to avoid beam instabilities. In order to study the HOMs in RF cavities, an aluminium two-cell prototype of the future superconducting cavities was built by IHEP (Institute of High Energy Physics). On this cavity, we have made a series of tests, involving HOMs measurement, HOMs absorbing, HOMs coupler, and so on. Figure 1 shows the outline of the cavity.

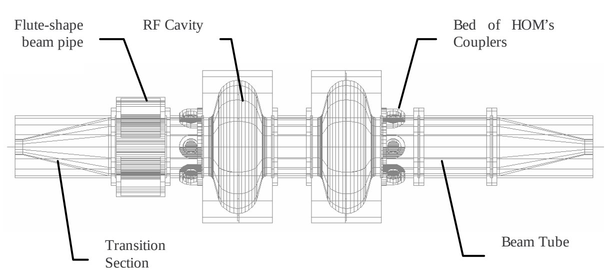

Fig. 1: Layout of A two-cell prototype cavity

During the process of designing HOM couplers to provide the damping desired for operation in accelerators, some of the considerations must come into play. Here we have made two varieties of coaxial HOM couplers, which are HERA type and LEP-II type. These types of HOM couplers have been developed for years. But in China, it is the first try. The following figure shows the schematic drawing of this structure.

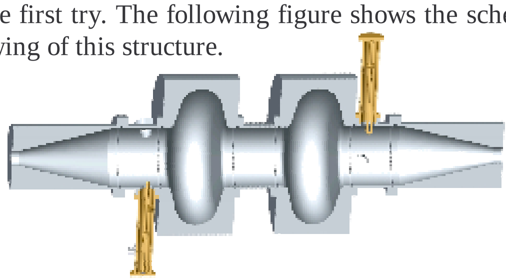

Fig.2: The rendered schematic drawing

After presenting some of the design aspects, we give a brief report on the performance of each coupler type. The results show that the models we have made are not well optimized yet. So we have a lot of things to do on the next stage of our research.

During the design of the HOM couplers, MAFIA code is used to simulate the HOMs in the prototype cavity and the bead-pull technique is used to get R/Q values.

2 GENERAL DESCRIPTIONS OF THE HOM COUPLER DESIGN

2.1 Preliminary design considerations

It is usually preferable to put HOM couplers on the beam tube, outside the end cells even though the fields are not as strong as inside the cell. This ensures that the couplers do not disturb the cell geometry. We also wish to avoid reopening the possibility of low field multipacting in the favourably shaped superconducting cells.

The first step in designing HOM couplers is to identify the monopole and dipole HOM modes and to carry out field calculations using codes such as URMEL and MAFIA. The first harmful modes are those with high R/Q_0. Generally, we focus on modes up to the cut-off frequency of the beam tube. However, it is also important to examine modes above the cut-off frequency to ensure that there are no “trapped” modes. If trapped modes with high R/Q_0 are found, modifying of the cell shapes may be necessary.

In order to adequately damp both polarizations of the dipole modes, at least two HOM couplers per cavity are desirable. The presence of a single will break the multipole mode degeneracy. If beam instability from quadrupole modes is a concern, a 90° angle between the two couplers should be avoided so that quadrupole modes can still be intercepted without additional couplers. However, the quadrupole modes have lower R/Q_0 than the dipole modes and are not generally a concern for beam instabilities.

HOM couplers have been developed in both the waveguide and the coaxial varieties. Waveguide couplers are more often found in higher-frequency (i.e., 1000 and 1500 MHz) cavities. The coaxial variety is preferred for the lower frequency (350-500 MHz) cavities because these couplers are more compact. On the other hand, the filter needed to reject the fundamental mode in a coaxial coupler must be designed and tuned carefully to allow Q_e high enough for the accelerating mode.

2.2 HERA type coupler

HERA type couplers construct a compensating transformer network based on the use of two inductive stubs, as shown in Figure 3, along with the equivalent circuit. With two inductive hollow posts, this approach turns out to be an excellent method to provide cooling to the coupler antenna as well as stub supports for the centre conductor. As usual, a series resonant filter, L_fC_f can be added parallel to L_2 to suppress the fundamental mode.

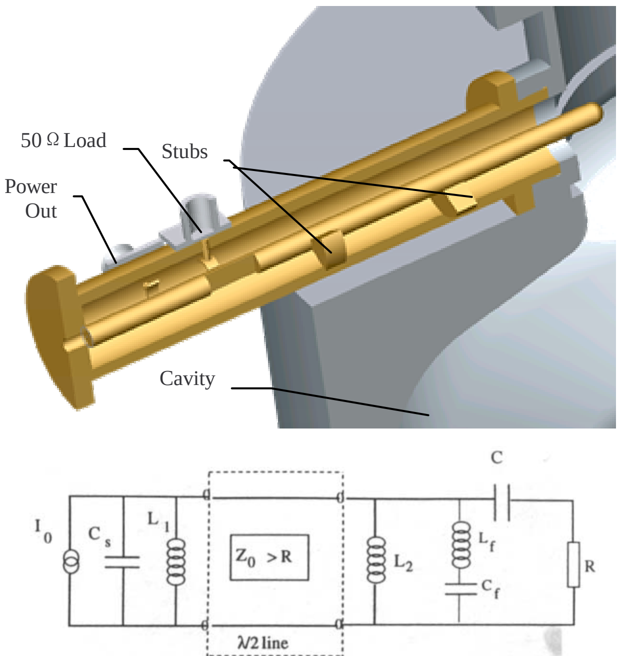

Fig. 3: Rendered layout and equivalent circuit of the HERA type coupler

As part of the modelling process, the frequency-dependent transmission properties of the evolving HOM coupler were measured with an arrangement such as shown in the following Figure 4. Here the coupler is mounted onto the beam tube with a Coca-Cola bottle full of water inside. A network analyzer is used to measure the output port, where the load would normally be connected.

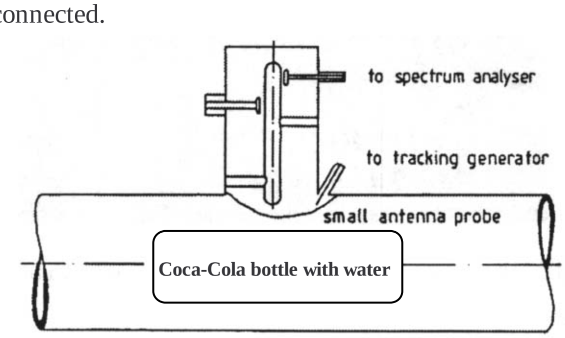

Fig. 4: Measurement setup for evaluating the HOM coupler sensitivity curves

As an example, Figure 5 shows the power transmission through the transforming network. Recent results show the coupler is not successfully aligned with the dangerous HOM's. So the structure needs further optimization.

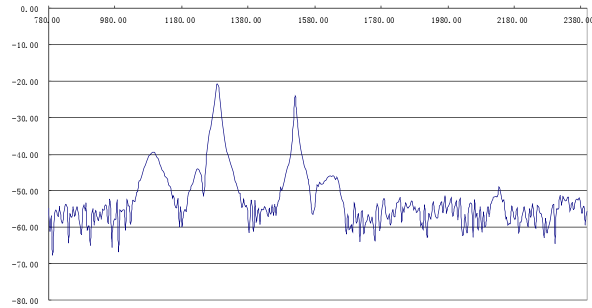

Fig. 5: Power transmission curve for the HERA type HOM coupler. (P_{out} *(f)* curve)

2.3 LEPII type coupler

As a variation of the two-stub design, LEPII type coupler is studied. A capacitor is added in series with L_1 in the circuit of Figure 6 to serve as the filter. If the capacitance is achieved via a piece of open-circuit transmission line, the cavity end of the coupler resembles a fishing hook. When properly oriented, this type of LC series resonator filter naturally forms a loop that couples to the magnetic field of the TE dipole mode, but not to the magnetic field of the fundamental mode. The coupling to the load is via the capacitive gap, as shown in Figure 6, too.

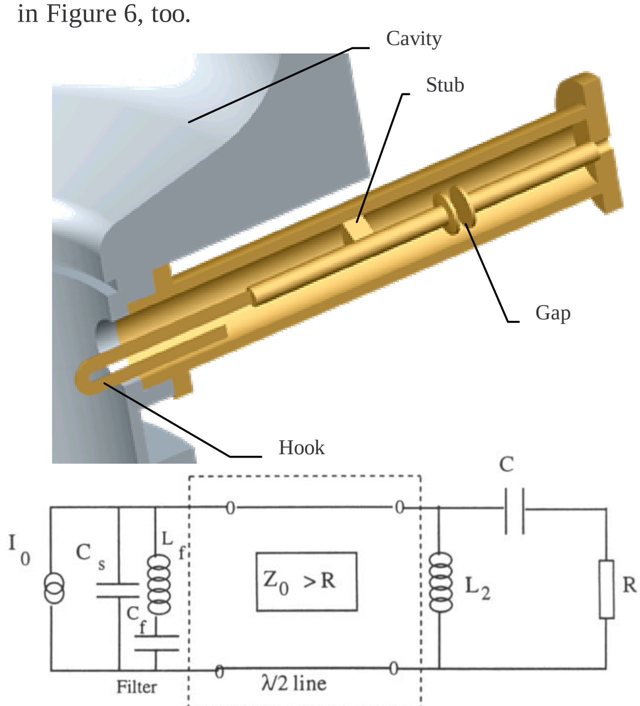

Fig.6: Rendered layout and equivalent circuit of the LEPII type coupler

Using the same arrangement as the HERA type coupler, we got the broad resonances due to the transforming network, as shown in Figure 7. The results also show the coupler needs further optimization.

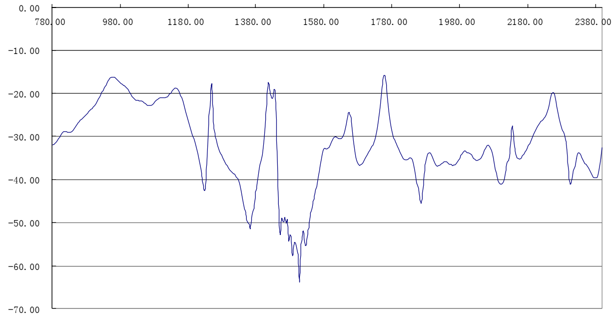

Fig. 7: Power transmission curve for the LEPII type HOM coupler. (Pout *(f)* curve)

3 MEASURMENTS OF HOM DAMPING

Before the measurements of HOM damping, we got the first harmful HOMs by MAFIA code simulations. The following table gives the results.

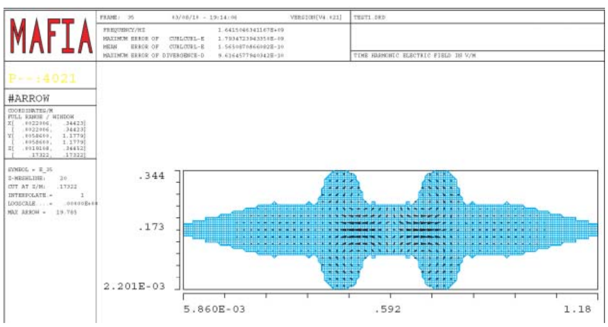

Fig 8: One of the Calculated Double-cell Cavity Modes

Table 1: First harmful HOMs calculated by MAFIA

Modes	f/GHz	R/Q (Ohm)	Q_0 (Cu)
Dipole	1.014943	8.6	34450
Dipole	1.041562	45.1	40436
Dipole	1.089830	58.5	47385
Dipole	1.328849	15.3	36324
Dipole	1.468013	87.1	40436
Monopole	1.641505	10.8	39550
Dipole	1.898951	16.6	34397
Monopole	1.981041	7.8	40239
Monopole	2.150952	3.7	37958
Monopole	2.259609	8.7	41093

Damping measurements for individual HOMs were made with the two-cell aluminium cavity at room temperature. Table 2 and 3 give the results for the two coupler types. The results show that the two types of coupler have worked in some sense. However, both of them need further optimizations to get more acceptable results.

Table 2: Measured HOM Damping with HERA Type Coupler

Modes	f (GHz)	R/Q (Ohm)	Q_E
Dipole	1.029441	5.6	10229
Dipole	1.048450	38.5	8512
Dipole	1.097164	27.9	11057
Dipole	1.345027	14.0	6933
Dipole	1.468013	89.4	5890
Monopole	1.668500	9.1	7730
Dipole	1.910883	13.5	6102
Monopole	1.999460	7.5	8026
Monopole	2.237904	4.4	7155
Monopole	2.306859	7.9	6098

Table 3: Measured HOM Damping with LEPII Type Coupler

Modes	f (GHz)	R/Q (Ohm)	Q_E
Dipole	1.029732	5.1	7842
Dipole	1.048159	40.0	7922
Dipole	1.097071	25.9	9954
Dipole	1.345438	15.7	7730
Dipole	1.468694	88.3	3316
Monopole	1.668370	9.8	6503
Dipole	1.910437	11.1	6779
Monopole	1.999115	7.7	7596
Monopole	2.238056	4.1	7325
Monopole	2.306375	8.5	4756

4 CONCLUSIONS

Two types of coaxial HOM couplers were made to study the HOM damping on an 800 MHz two-cell aluminium prototype cavity. MAFIA code is used to simulate the HOMs in the prototype cavity and the bead-pull technique is used to get R/Q values. The results of power transmission tests and HOM damping show that further optimizations of the couplers are needed.

REFERENCES

[1] Hasan Padamsee, Jens Knobloch, Tom Hays, “RF Superconductivity for Accelerators”, John Wiley & Sons INC, 1998.

[2] E. Haebel, J. Sekutowicz, “Higher Order Mode Coupler Studies at Desy”, DESY M-86-06, July 1986

[3] Mosnier et al., “HOM DAMPING IN SOLEIL SUPERCONDUCTING CAVITY”, SOLEIL, Gif / Yvette (France), 1997

[4] Olaf Naumann, “Dampfung hoherer moden in den supraleitenden Resonatoren des LHC-Protonesnspeicherrings”, Berlin/Genf, 1995