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Measurements on Heavily HOM Damped Accelerator Cavities*

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Abstract

Field strength measurements in accelerator cavities, heavily damped with respect to higher order modes (HOM), are presented. From the results coupling (damping) factors and thus Q_l of the damped resonator can be derived. Measurements are done using a pillbox resonator and a two-cell structure.

1. INTRODUCTION

Wake field effects in accelerator cavities for future linear colliders are mainly due to HEM_{11}- and to some extent to HEM_{21}-modes. To reduce their beam perturbing capability wall-slits are well suited to couple those modes into loads [1,2]. Because only the effect of the fields on the particles is of interest we attempted to determine them directly. This is done with the antenna [4] and nonresonant perturbation technique [5]. Based upon TM_{11}-measurements on a pillbox we now intended to expand experiments to a two-cell structure and, additionally, we looked for the TM_{21}-mode in the pillbox.

2. THEORY

2.1 Measurement methods

Comparing fields in the undamped (u) and damped (d) case one finds with the antenna method [4]

$$\frac{\Delta P_i}{P_{iu}}+1=\frac{P_{ext}}{P_{dd}}+1=\frac{E_u^2}{E_d^2}=K+1 \qquad (1)$$

P_{dd} is the power dissipated in the cavity, K+1 is the damping coefficient. Of course the damping coefficient links the values Q_0 of the undamped and Q_L of the damped structure under the premise that the field distribution of the mode remains unchanged by the damping system:

$$Q_l=\frac{Q_0}{1+K}=Q_0\frac{E_d^2}{E_u^2} \qquad (2)$$

The nonresonant perturbation technique allows the measurement of fields both electric and magnetic in an arbitrary cavity by observing the change of the complex reflection coefficient Γ at the input port while a bead is pulled through the structure [5,6]. For our puposes a dielectric rod is well suited. To find ω_d the frequency region of interest has to be scanned for the highest value of $|\Delta\Gamma_d|$.

$$\frac{E_u^2}{E_d^2}=\frac{\omega_d Q_0\left(1-|\Gamma_u|^2\right)\frac{f_0^2-f^2}{f^2}}{2\omega_u|\Gamma_d|^2}=k+1 \qquad (3)$$

Herein f_0 and f denote the (undamped) resonances before and after inserting the rod.

2.2 Transversal Shuntimpedance

A particle traversing a dipole- or quadrupole-type cavity field (say) off the beam axis will experience a deflecting force. The transversal shuntimpedance per unit length can be ex-

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pressed as [3]

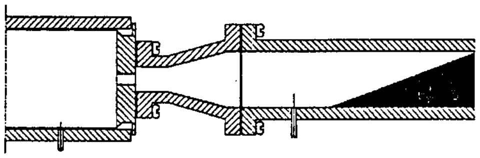
$$r_\perp = \frac{\left\{\frac{1}{k}\left(\frac{\partial}{\partial y}E_z\right)\right\}^2}{dP/dz} \qquad (4)$$

Using a calibrated bead $r_\perp$ can be obtained from the longitudinal r taken at an off-axis position where $\omega y = c$, y being the axis offset.

3. MEASUREMENTS

3.1 Experimental procedure

A pillbox resonator and a two-cell structure have been built. The cavities are made of brass ($\sigma = 1.46 \times 10^7\ \Omega^{-1}\mathrm{m}^{-1}$). In order to damp the dipole- and quadrupole-modes the cavity walls are slotted (6mm X 60mm). Cavity and waveguides (20mm X 60mm) are connected by matching sections, both consisting of aluminum. Their cutoff is at 2.498 GHz. This is well above the fundamental mode of the pillbox (2.049 GHz). For details see Fig. 1 and 2. Another point of interest is the choice of coupling position and kind. An antenna located at one of the waveguides proved to be the best decision since it can be made large enough to provide sufficiently high field levels but does not perturb the field geometry of the mode in the resonator.



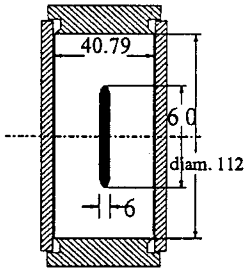


Fig. 1) Pillbox with one half of the damping-system. For the two-cell structure identical couplers are used. From the upper picture the choice of antenna position can be seen.

First the coupling slots were closed and the properties of the undamped cavities were measured, especially the transversal shuntimpedance $R_\perp$ of the TM_{110}- resp TM_{210}-mode of the pillbox and of the HEM_{11}-π-mode of the two-cell. Measurements were done with dielectric rods ($\varepsilon_r = 9.2$) of 0.5 mm diameter.

After attaching the damping system the measurements were repeated. The diameter of the rod had to be increased to 2mm since the field strength had decreased strongly.

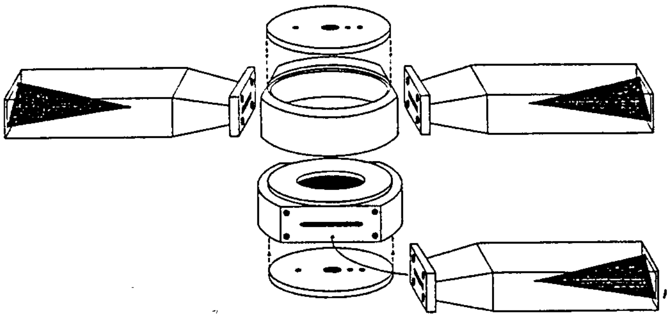


Fig. 2) Sketch of two-cell structure and damping system

3.2 Results

Table 1. shows the results for the HEM_{11}-π-mode in the two-cell. The phase velocity of the undamped mode is 1.08c and thus the transittime-factor is 0.83.

Table 1.
Results HEM_{11}-π-mode (two-cell)

		f_0 [GHz]	Q_0	$R_\perp$ [kΩ]	$r_\perp$ [MΩ/m]
non-damped	MAFIA	3.496	11840	400	4.6
	exp.	3.47	7840	372	4.3
damped	exp.	3.44	20-25	1.13	0.013

Table 2.
Results for the TM_{210}-mode (pillbox)

	f_0 [GHz]	Q_0	$R_\perp$[kΩ]	$r_\perp/Q$[kΩ/m]
theory	4.37	11800	46.5	0.1
exp.	4.33	6320	47	0.18

The results for the undamped case are in good areement with MAFIA- results. In case of damping the transversal shunt-impedance is reduced by a factor of k+1=330. The maximum value of k+1 corresponds to a Q of 20. Measurements on a pillbox-cavity have shown that this gives the correct Q [7].

Table 2. and the following figures show the results for the TM_{210}-mode in the

pillbox.

Again in the undamped case we find good agreement between analytical estimates and experiment.

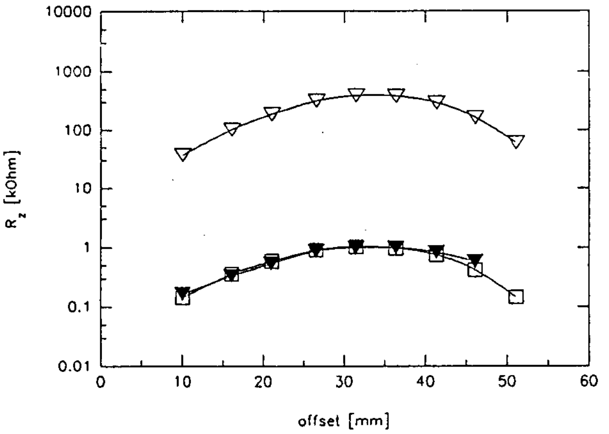


Fig. 3) Longitudinal shuntimpedance R_z against off-axis position for TM_{210}-mode (pillbox). The squares represent data taken with a long (k_w=0.28) antenna, triangles represent a short one (k_w=0.02).

From the results one can derive the transversal shuntimpedance per unit length:

$$r_\perp = 3.56\frac{k\Omega}{m}$$

leading to a damping factor of

$$\frac{r_{\perp u}}{r_{\perp d}} = \frac{1.152 M\Omega/m}{3.56 k\Omega/m} \approx 324 = k+1$$

Looking for the damping-factor k+1 versus off-axis position one finds the following curve:

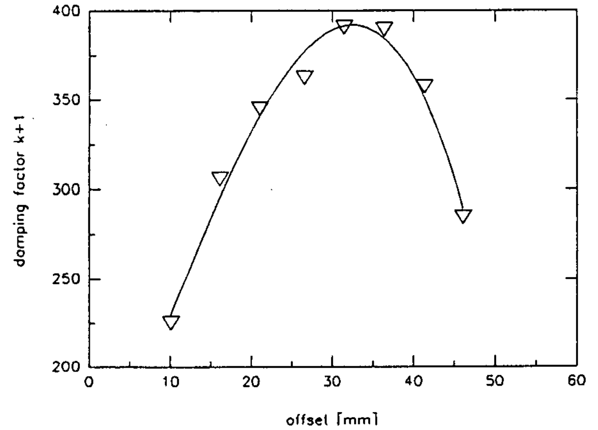


Fig. 4) Damping-factor against off-axis position, Maximum is taken to determine reduction of Q [7]. Data refer to k_w=0.02

The Q of this mode is reduced by a factor of 380.

The coupling-slots cause a reduction of the shuntimpedance of the fundamental mode of 25% for the two-cell structure and 18% for the pillbox.

4. DISCUSSION

For the two-cell structure the effectiveness of the damping system is somewhat lower than for a pillbox [7]. This is due to the fact that damping works only for one polarisation in a single cell. Heading for only one polarisation one can of course achieve a higher (k+1>500, Q<20) damping factor than in the pillbox case.

For the undamped pillbox the TM_{210}-mode has a transversal shuntimpedance of nearly 1/200 of the TM_{110}-mode [7]. MAFIA calculations of the two-cell structure have shown that the HEM_{21}-π-mode has a transversal shuntimpedance of about 50kΩ which is almost identical to the pillbox value. Thus this mode seems to be of little influence on particle dynamics in an S-band collider.

5. REFERENCES

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