MODE PROPAGATION IN A IRIS TYPE ACCELERATOR SECTION LOADED WITH SINGLE HEAVILY HOM-DAMPED CELLS*

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Abstract

The wakefield effects in accelerator sections for future linear colliders will be reduced either by damping by detuning or by a combination of both. For the DESY/THD linac [1] it is forseen to employ heavily HOM-damped cells to provide a strong coupling to the TE/TM_{11}-dipole passband as well as to the TM/TE_{11}-dipole passband. For our experiments we have used wall-slotted damping cells. This leads to several problems concerning the propagation of fundamental and HOM-modes. Experimental investigations have been done. Results are presented.

1. INTRODUCTION

For the DESY/THD S-Band linac a HOM damping system will be necessary. It is forseen to use a combination of detuning and direct HOM damping by means of some HOM-couplers within an accelerating section. In order to get an optimized damping system it is necessary to investigate how many dampers will be needed, what kind of coupling is appropriate, where to locate them [3], and how strongly needs a single coupler-cell to be damped in order to achieve maximum effect in a section .

As a possible design of a HOM damper system we have investigated a wall slotted iris coupler within a stack of undamped cells. The overall damping effect is determined by the choice of group velocity in the dipole passbands and the geometry of the coupler.

2. EXPERIMENTS

The experiments were done using cups of the proposed DESY/THD geometry. We used cups with the largest iris diameter (31.532mm diam.; i.e. $v_{gr} = 4.1\%c$ in the fundamental mode [2]).

The largest measured structure was a stack of six equal cells. The cups consist of brass (MS58, $\sigma = 1.46 \cdot 10^7 \Omega^{-1} m^{-1}$). They can be tuned by adjusting four tuning screws of 6mm diameter equally spaced around the circumference of the cups, allowing for an independent tuning of both monopole and dipole modes. Tuning was done by successively adjusting the dipole mode under consideration and the fundamental mode (TM_{01}-$2\pi/3$).

First the one-, three-, and six-cell structures were measured without the damping system. After attaching the damping system the achieved quality factors were measured.

* work supported by DESY

For the single cell we reached a loaded Q of about 6 applying a slot of 36mm width and 3mm heigth (compare Fig. 1). The latter geometry was used for all following measurements. Other geometries with lower damping remain to be measured in the near future.

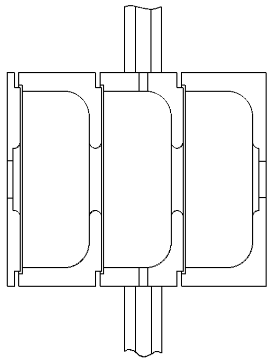

Fig. 1 The damped 3-cell structure

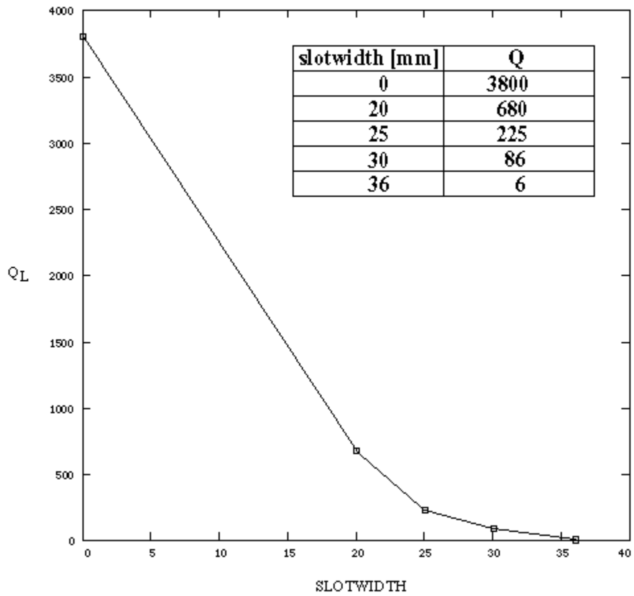

Fig. 2 Damping curve for the waveguide loaded single cell cavity. Rectangular coupling slot, height 3mm.

2.1 Three-cell structure

The measured $r_\perp/Q$ are in good agreement with MAFIA calculations (comp. Table I). In the damped three-cell the TE/TM_{11}-$\pi/3$ was not affected by the damping system. This is due to the fact that this mode has the wrong field geometry in the middle cell to couple to the waveguide. Because the frequency of the middle cell is lowered by the damper this modes shows nearly no field in this cell. Therefore the Q is increased. The other modes are well damped. In comparison to the single cell Q must increase due to the additional stored energy in the undamped cups while the power loss in the damper stays approximately constant. The strong damping of the TE/TM_{11}-$2\pi/3$ mode causes a distortion of fields as can be seen by the lowered $r_\perp/Q$. This is not the case with the TM/TE_{11}-like modes.

Table I

Experimental and numerical results for the undamped and damped three-cell structure.

mode	frequency [Ghz]	quality factor Q_0	$r_\perp/Q_0$ [kΩ/m]
Results for the undamped 3-cell structure			
TE/TM_{11}-$2\pi/3$	4.106365	3770	0.8
TE/TM_{11}-$\pi/3$	4.121823	3030	0.6
TM/TE_{11}-0	4.425976	2650	1.1
calculated with MAFIA			
TE/TM_{11}-$2\pi/3$	4.087513	8100	0.98
TM/TE_{11}-0	4.413187	9500	1.0
Results for the damped 3-cell structure			
TE/TM_{11}-$2\pi/3$	4.013031	39	0.3
TE/TM_{11}-$\pi/3$	4.120056	4200	0.5
TM/TE_{11}-0	4.359966	50	1.1

2.2 Six-cell structure

The damping effect on the first dipole passband of the six-cell was very low while the second was affected (Table II). This seems to be a consequence of the very low group velocity in this first passband. Unfortunately the chosen iris opening causes a zero group velocity for the π-like modes (Fig. 5). They have most field energy trapped in the iris, thus nearly no coupling to the wall slots can be expected.

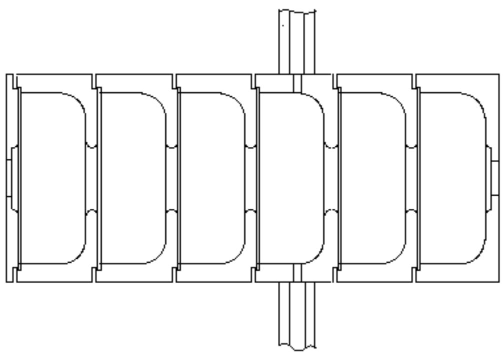

Fig. 3 Damped six-cell structure. Note the location of the damping system.

The second dipole passband was much stronger damped than the first. While a strong coupling to the first modes (TM-0-like) in this passband can be understood it remains unclear why even the last modes showed reasonable coupling. It also seems that the position of the damper within the stack is of some importance. With respect to the first passband we assume that a cross-slotted iris [4] will do better than the present scheme. At least the damping will take place in two or more adjacent cells.

A perturbation measurement on the damped six-cell structure was performed. Around the frequency of the undamped TE/TM_{11}-$5\pi/6$ mode now two peaks appeared. The original mode was separated into longitudinal polarisations A and B. Left of the damper mode A has a very clean TE/TM_{11}-$2\pi/3$ field geometry while on the right we find a π-like mode. Right of the damper mode B is of 0-like type while on the left the type is ambiguous. This can be explained by the effect of the damper on the magnetic field which is necessary to sustain the transversesal electric field in the iris. It is almost completely suppressed and thus the transvesal electric field is nearly zero. This means a short is established in the iris. This result implies that the overall damping could be improved by lowering the damping in the coupler cell.

Table II

Experimental results for the undamped and damped six-cell structure.

mode	frequency [Ghz]	quality factor Q_0	$r_\perp/Q_0$ [kΩ/m]
Results for the undamped 6-cell structure			
1st dipole passband			
TE/TM_{11}-$5\pi/6$	4.108182	5550	0.08
TE/TM_{11}-$3\pi/6$	4.111793	4790	0.26
TE/TM_{11}-$2\pi/6$	4.122301	4680	0.3
TE/TM_{11}-$\pi/6$	4.139517	3950	0.28
TM/TE_{11}-0	4.430500	5510	0.8
⋮	⋮	⋮	⋮
Results for the damped 6-cell structure			
1st dipole passband			
TE/TM_{11}	4.107490	3780	
TE/TM_{11}	4.109889	4440	
TE/TM_{11}	4.119072	3260	
TE/TM_{11}	4.137982	3600	
2nd dipole passband			
TM/TE_{11}	4.421000	500	
TM/TE_{11}	4.482402	400	
TM/TE_{11}	4.631170	480	
TM/TE_{11}	4.876000	110	
⋮	⋮	⋮	

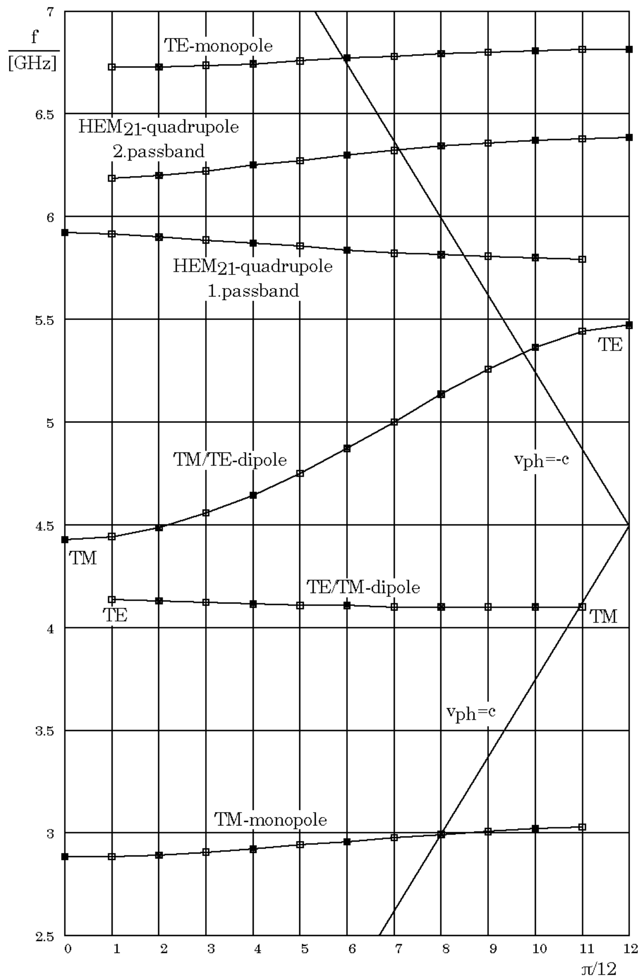

Fig. 4 Brillouin diagram for the chosen cup geometry. TE/TM passband starts with a TE-like and stops with a TM-like mode, TM/TE vice versa.

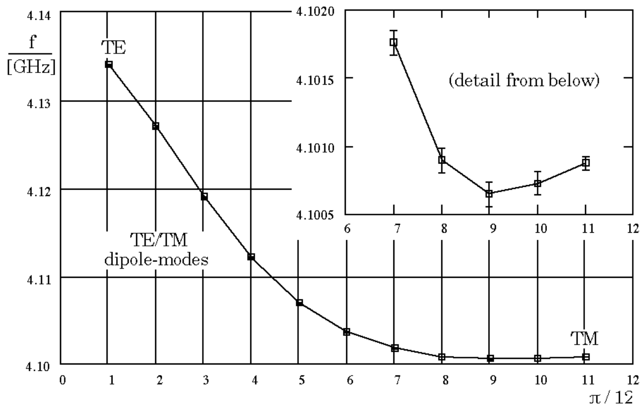

Fig. 5 The TE/TM_{11}-dipole passband in more detail. Between the 8th and the 10th mode coupling changes from magnetic to electric.

3. Conclusions

It is quite simple to damp a single cell down to very low Q values. The difficulty increases with the number of additional undamped cells. This holds particularly for passbands with very low group velocity. In this case the effect of a strong damper is only to separate the section into two nearly independently resonating subsections.

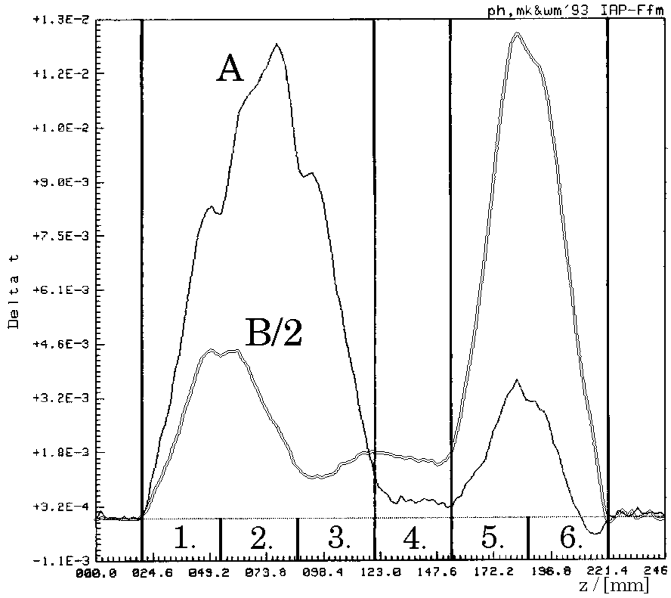

Fig. 6 Perturbation measurement of the longitudinal electric field strength on the damped six-cell structure, measured around the undamped TE/TM-5π/6 mode. The damper is located in cell #4. The original mode has separated into two longitudinal polarisations A and B. B is plotted with half of the measured amplitude. Δt is the difference of transmitted power with and without bead and thus proportional to E_z^2 [4].

The investigated iris geometry represents the first twenty cells of a DESY/THD accelerator section. If one wants to damp the first HOM passband within this region one must increase group velocity considerably. One must avoid iris openings which lead to a compensation between electric and magnetic coupling in the passband. Since the DESY/THD linac is a constant gradient structure the choice is to increase the iris opening in order to get a forward coupling passband with considerable group velocity.

4. References

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