*S-BAND HOM-DAMPER CALCULATIONS AND EXPERIMENTS**

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I. ABSTRACT

Damper cells for higher order modes are necessary for the S-band linear collider to suppress higher order dipole modes, which are harmful to the beam. It is foreseen to employ two single cell damper stations in the whole 6m-structure. One is posed at cell #25 and the other at cell #106. In order to investigate the effect of a single damper cell within a stack of undamped cells, a 12-cell constant impedance structure loaded by a single wall slotted damper cell was built and analyzed experimentally, numerically and analytically. The goal of the investigations was to optimize the damping effect for the first dipole passband, which contains the (most dangerous) synchronous 11/12π-mode. The first problem is to find the appropriate single damper cell Q-value, which is needed for a certain cell-to-cell coupling to maximize the energy flow into the damper cell. The second problem is to find the optimum tuning position in order to achieve the best over all damping effect for the first dipole passband without disturbing the accelerating mode. Several wall slotted damper cells have been built and examined.

II. INTRODUCTION

In future linear colliders strong higher order mode suppression will be inevitable in order to avoid severe beam break up effects. For S-band linear colliders it is foreseen to suppress higher order modes by detuning [1] and damping [2]. The damper cells are planned to be located at cell #25 and cell #106 of the 6m-section, thus also providing beam position information for the alignment system. The most dangerous higher order modes are known to be trapped within the first twenty cells. But due to the small bandwidth of the first dipole passband (45MHz) which causes very little energy flow due to the small cell-to-cell coupling, damping with a single cell damper is impossible. Therefore damping will be done by coating the iris with lossy material in order to damp every cell. In the chosen geometry the cell-to-cell coupling increases from the front end to the back end of a 6m-structure due to the decreasing iris opening.

III. ANALYTICAL MODEL

The effect of a single damper cell within a channel of undamped cells can be calculated analytically using a simple equivalent circuit model with a serial resistance representing the energy dissipation of the damper cell. For the modes at the outer ends of the passband the dominant change in the field, due to the presence of the damper, turns out to be a phase shift in the argument of the field. With the model described above one can derive the following simple formula for 0- and π-mode:

$$\frac{1}{Q} = K \cdot \sin(\Delta\varphi) \qquad (1)$$

where Q is the Q-value of the simple damper cell, K is the bandwidth of the passband (which represents the cell-to-cell coupling) and Δφ is the phase shift due to the damper. To achieve a damping effect, Δφ has to be a real number. Thus

$$K \cdot Q = \frac{1}{\sin(\Delta\varphi)} \geq 1 \qquad (2)$$

K·Q=1 represents the minimal Q-value, which can be applied. We have shown that the relationship (1) is fulfilled by high accuracy for the 0-mode, for which the single cell Q-value can be measured easily by closing the iris openings of the damper cell with metal surfaces. For π-modes the single cell Q-value could not be derived experimentally, because the iris openings would have to be closed by magnetic walls. Generally speaking the single cell Q-value depends on the mode geometrie.

IV. NUMERICAL MODEL

To investigate the properties of a damper cell in a ci or cg structure one can use a field computation program (eg. MAFIA) or a simplified model of coupled oscillators. The effort for the direct field calculation is rather high, but the effects in the first dipole band of a ci structure only depend on few parameters. Therefore it is appropriate to analyze the effects of these parameters in a coupled oscillator model. Due to the mixing of TM- and TE-like modes, for this band a model with two oscillators per cell was used. For the plain cells there are five degrees of freedom to simulate the dispersion charactersistic and two degrees for

* work supported by DESY/Hamburg

the coupling to the beam. These parameters have been evaluated by single cell calculations with the MAFIA periodic eigenvalue solver. To simulate the effect of a damper, losses are introduced in this model. In the damper cell the Q values of the TM- and TE-oscillators can be tuned and damped individually. Introducing losses in every cell (eg. wall losses) or simulating several dampers does not increase the computational effort. The analysis of damping in complete Linac structures with as much as 200 cells is possible.

V. EXPERIMENTS

The slotwidth of the damping cell was varied from 24mm up to 30mm. The slot was of 3mm height. The damper cell (see Fig. 1) was made of brass (Ms58, $\sigma=1.46\cdot10^7\ \Omega^{-1}m^{-1}$) with an inner diameter of 81.6mm and an iris opening of 27.8mm. In order to tune the damped cell with respect to the accelerating mode and the dipole modes of the first dipole passband to some extent independently, six tuning screws (A and B) can be moved into the cell. The waveguides are made of aluminium, they are of 40mm width (3.75GHz cut off frequency) and 9mm height.

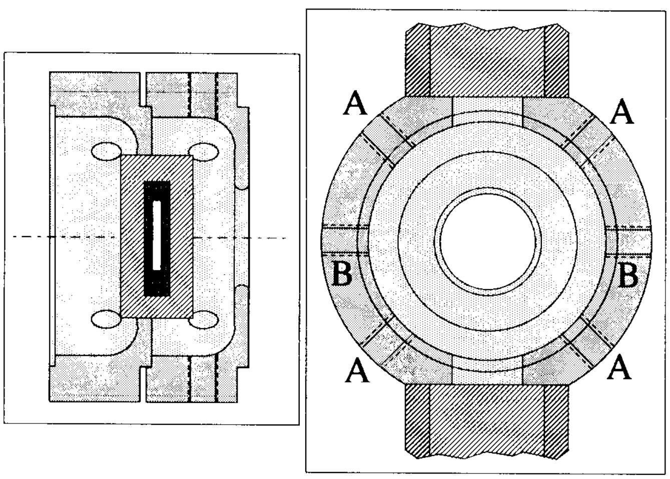

Figure 1: Damper cell with two waveguides.

This damping system was investigated alone, closed with metal plates as shown in figure 2, which shows the dependence of the single cell Q-value upon the slotwidth:

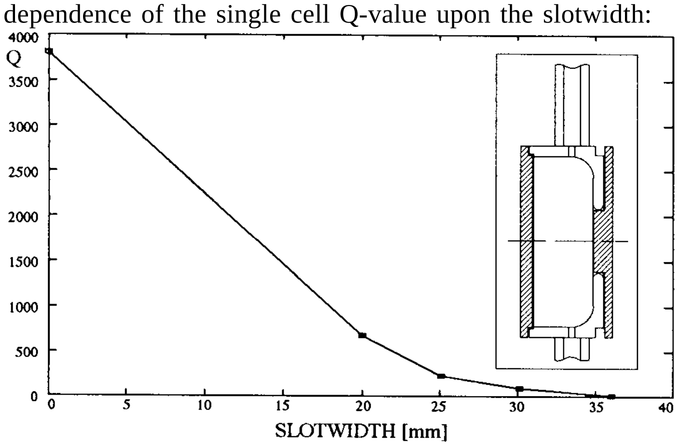

Figure 2: Single damper cell Q-value versus slotwidth.

Then the damper cell was emploid in the 12-cell structure (bandwidth of the first dipole passband is 200MHz) at cell #4 as shown in figure 3:

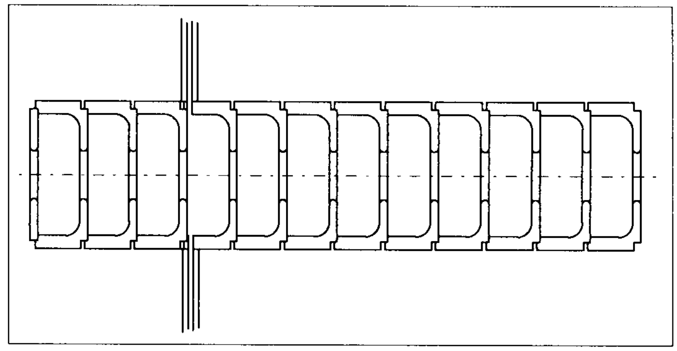

Figure 3: Damped 12-cell structure.

After tuning, the end cells represent electrical boundary conditions, so that the stack shows a proper 0-mode in the TM-monopole passband. In the case of strong damping, the tuning was performed by additional metal pieces, which were attached to the inner wall without affecting the coupling slot geometry. The way of independent tuning was to first tune the 0-mode of the second dipole passband with tuning screws A, which affect monopoles as well as dipoles and then tuning the monopole modes with tuning screws B, which mainly affect the monopole modes. The mode geometry was controlled by bead measurements, using a dielectric bead.

VI. COMPARISON OF NUMERICAL AND EXPERIMENTAL RESULTS

The damping effect of the first dipole passband is shown in figure 4:

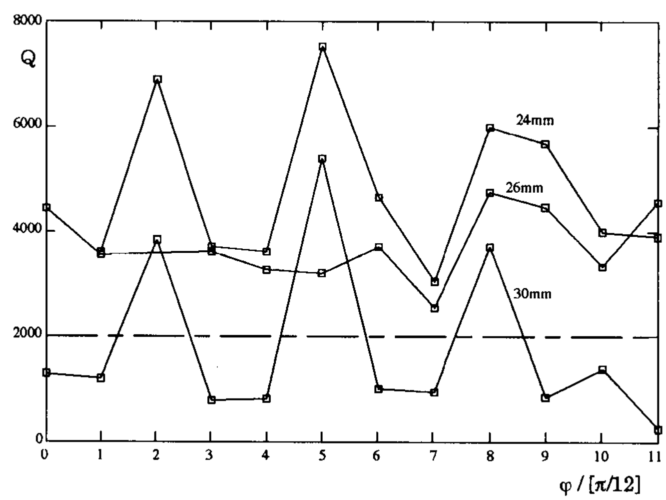

Figure 4: Measured Q-values of the first dipole passband.

The damping effect increases with increasing the slot width. Most of the twelve modes were damped well below 2,000. The three remaining modes show nearly no longitudinal electric field strength at the damper position. The same plot was calculated numerically by the equivalent circuit model nearly resembling the experimental results (see Fig. 5).

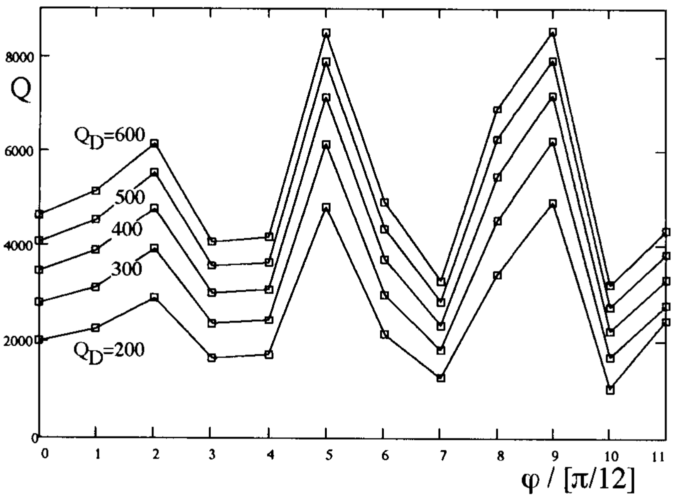

Figure 5: Calculated Q-values of the first dipole passband.

The best overall damping effect was not found in the tuning position where all modes resembles the undamped mode geometry. Exemplary the tuning behaviour of the damping effect was examined for the 11/12π-dipole mode. Tuning the damper cell frequency for this mode to lower frequencies lead to an energy concentration in the neighborhood of the damper cell, maximizing the damping effect (see Fig. 6).

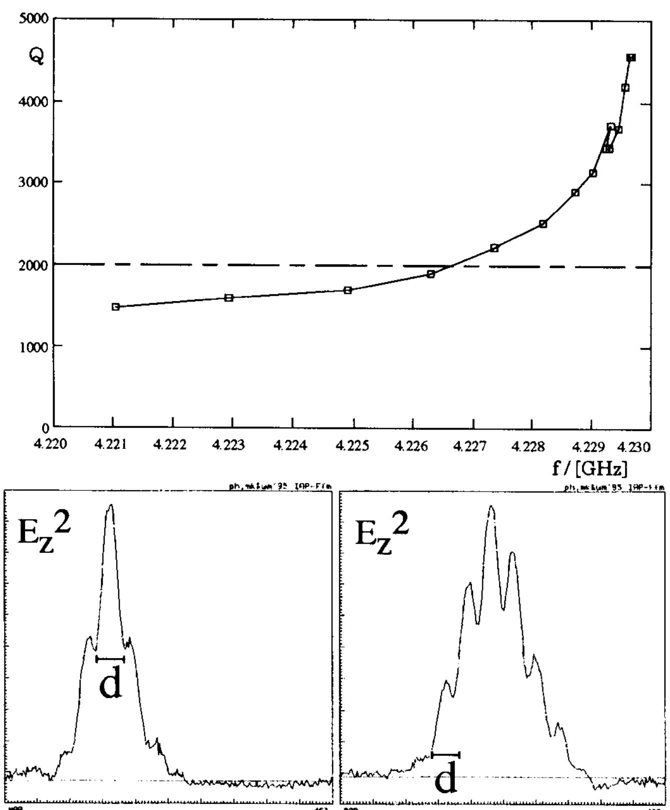

Figure 6: Measured Q-value of the 11/12π-dipole-mode and related field distributions.

This effect can be shown also numerically (see Fig. 7).

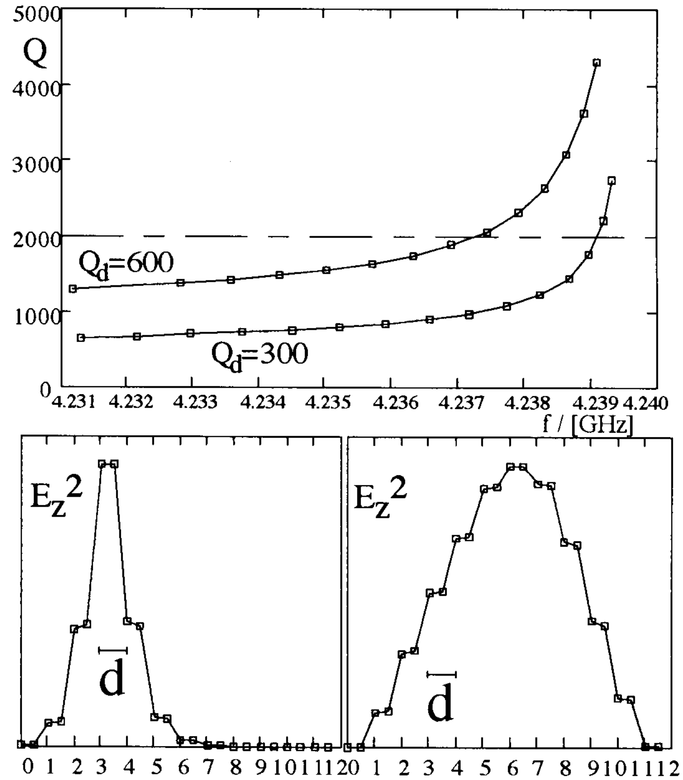

Figure 7: Calculated Q-value of the 11/12π-dipole-mode and related field distributions.

VII. REFERENCES

[1] K. Balewsky et al.: DESY and TH-Darmstadt: Status report of a 500 GeV S-Band linear collider study”, DESY 91-153, 1991, D-22603 Hamburg, Notkestraße 85, pp. 1-39

[2] R. Ruth: The status of the NLC”, 3rd Int. Workshop on Linear Colliders, LC’91, Vol. 1, Protvino 1991, pp. 141-175