THE DESIGN OF THE HOM-DAMPING CELLS FOR THE S-BAND LINEAR COLLIDER *

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Abstract

Damping cells for the higher order modes are necessary for the S-band linear collider to minimize BBU (Beam-Break-Up). The construction of the damper cells has to take into account the different field geometries of the higher order modes. So two different types of dampers have been designed: a wall slotted an an iris slotted cell. In order to optimize the two types of damping cells with respect to damping strength, impedance matching between coupling system and waveguide dampers and between damping cell and undamped cells and the tuning system, damping cells of both types have been built and examinated.

Introduction

In future linear colliders strong HOM suppression will be inevitable in order to avoid severe BBU effects on the beam. This can be done either by detuning [1] or damping [2]. For the S-band linear collider it is foreseen to have a combination of both techniques. The damper cells are planed to be located at the beginning and at the end of a 6m section thus also providing beam position information for the alignment system. From calculations the most dangerous HOM's are known to be trapped within the first 20 cells. The group velocity of the $2\pi/3$-TM_{01}-mode of the cell-geometry examined is 4.1% c thus the 1st dipole passband is very narrow (45MHz). Whereas it is not too difficult to strongly damp a single cell, multicell structures show a more complex behaviour. From calculations [4] it can be predicted which damping strength can be expected employing a single damper cell and which are the limitations.

Experiments

Wall slotted coupler. The first type of damping system examined is the wall slotted cell (see Fig. 1). The slot was of 30mm width and 3mm height. All cells were made of brass (Ms58, $\sigma=1.46\cdot10^7\ \Omega^{-1}m^{-1}$). In order to tune the damped cell back to the undamped frequency six tuning screws could be moved into the cell from the outside. The waveguides are made of Al, they are of 40mm width and 9mm height [5]. This damping system was investigated alone (closed with metal plates at both ends) and as cell #6 in a 12-cell structure (see Fig. 2):

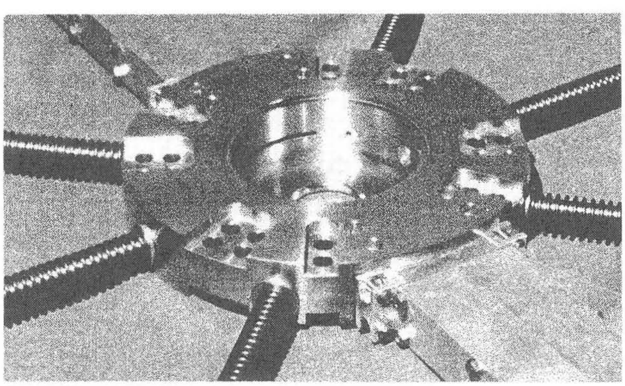

Fig. 1: The wall slotted damping cell.

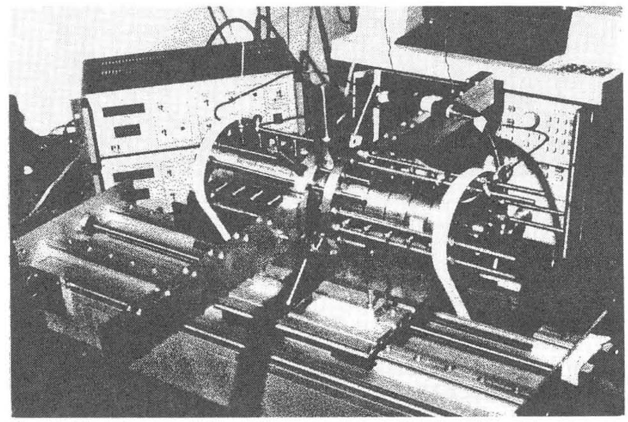

Fig. 2: The damped 12-cell structure on the test bench.

For the single damping cell the reduction of the shunt impedances compared with the undamped single cell was measured (see Table 1):

TABLE 1
Damping Effect for the Single Wall Slotted Cell

	undamped		damped	
TM_{010}	f_0	= 2.813 GHz	f_0	= 2.789 GHz
	Q_0	= 3717	Q_0	= 5020
	r_S/Q_0	= 8.89 kΩ/m	r_S/Q_0	= 8.98 kΩ/m
TM_{110}	f_0	= 4.469 GHz	f_0	= 4.235 GHz
	Q_0	= 3243	Q_0	= 5.5
	$r_\perp/Q_0$	= 1.63(10) kΩ/m	$r_\perp/Q_0$	= 1.64(16) kΩ/m

If we take into account that the Q-value of the monopole modes was only affected by the reassembling and estimate the same effect for the dipole modes the damping strength is 796, coupling from the damping cell into the waveguide dampers is very good. But if we mount the damping cell in a 12-cell structure (as shown in Fig. 2) damping heavily decreases. In the next figures the transmission for the first dipole passband (see Fig. 3) and the second dipole passband (see Fig. 4) is shown. On top the undamped and below the damped case is shown. Only the first few modes of the second passband are influenced significantly, whereas the first passband is not damped at all. This behaviour was predicted by theoretical work, which gives the maximum possible damping effect [4].

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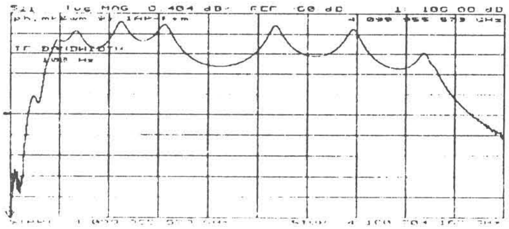

Fig. 3: First dipole passband in the 12-cell structure.

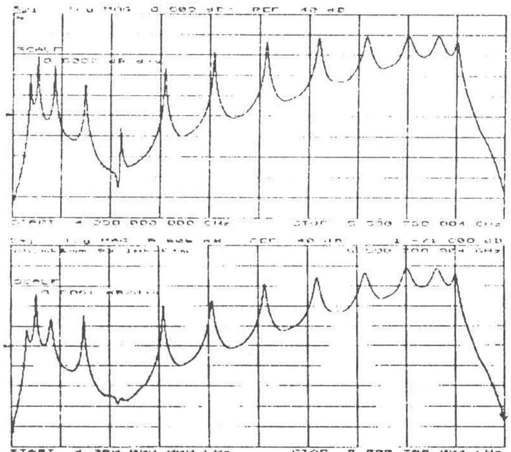

Fig. 4: Second dipole passband in the 12-cell structure.

The following two tables show the Q-values for the first (see Table 2) and second dipole passband (see Table 3):

TABLE 2
Q-Values for the first Dipole Passband

Mode	Frequency undamped [GHz]	Frequency damped [GHz]	Quality factor undamped	Quality factor damped	Coupling factor
1	4.1025	4.1024	6240	6060	1.03
2	4.1039	4.1038	-	-	-
3	4.1050	4.1049	4970	4990	-
4	4.1071	4.1068	4730	4350	1.09
5	4.1116	4.1114	4650	4480	1.04
6	4.1165	4.1159	4490	3890	1.15
7	4.1273	4.1271	4400	4360	1.00
8	4.1355	4.1351	4380	4020	1.09
9	4.1427	4.1425	4090	3850	1.06
10	4.1440	4.1435	-	-	-

TABLE 3
Q-Values for the second Dipole Passband

Mode	Frequency undamped [GHz]	Frequency damped [GHz]	Quality factor undamped	Quality factor damped	Coupling factor
1	4.4243	4.4206	5050	960	5.26
2	4.4434	4.4430	5890	4810	1.22
3	4.4857	4.4799	4100	910	4.50
4	4.5610	4.5605	3520	3050	1.15
5	4.7561	4.7550	5500	2430	2.26
6	4.8755	4.8729	4370	740	5.90
7	5.0034	5.0019	3480	1300	2.68
8	5.1310	5.1299	2160	990	2.20
9	5.2486	5.2480	1340	770	1.74
10	5.3512	5.3509	905	750	1.21
11	5.4262	5.4258	840	680	1.24
12	5.4718	5.4712	570	500	1.14

Cross slotted iris coupler. The second coupler examined is a cross slotted iris [3]. This type of coupler is especially sensitive to modes whose E-field change sign in the iris. Again the coupler was made of brass, the iris slots are of 5mm height, towards the waveguides the wall was opened by a slot of 5mm height and 40mm width.

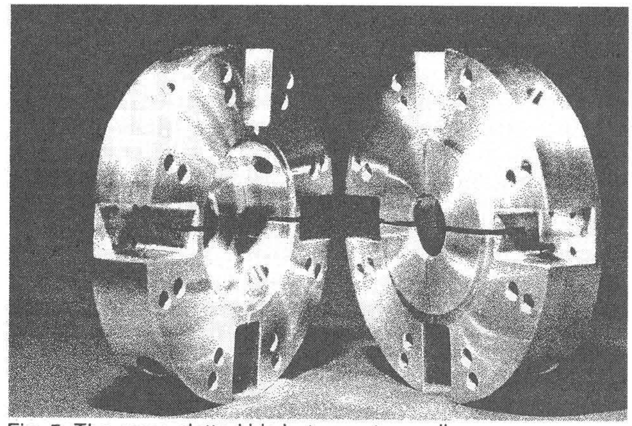

Fig. 5: The cross slotted iris between two cells.

At first the undamped structure was tuned with respect to the 0-mode of the fundamental passband. The $2\pi/3$-mode is then tuned as well (see Fig. 6).

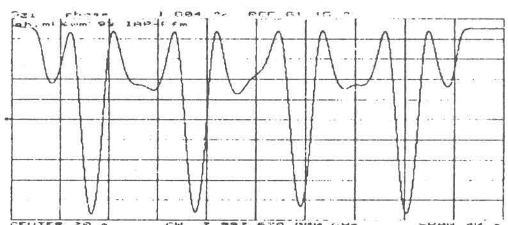

Fig. 6: TM01-$2\pi/3$-accelerating-mode.

Again it can be observed that the first dipole passband is hardly affected at all. In comparison to the wall slot coupler every second mode in the second passband is strongly damped (see Fig. 7 and 8).

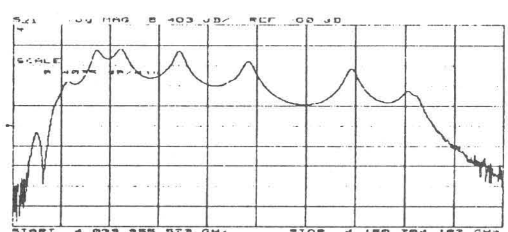

Fig. 7: First dipole passband in the 12-cell structure

Again the Q-values for all modes of the two dipole passbands were measured in the undamped and damped case. The resulting coupling factors are shown in Table 4 and 5.

As can be seen in the first dipole passband the strongly damped iris causes some modes to "break" apart. Fig. 9 shows the example of modes #4 and #5, where the modes are transformed into two independently resonating ones.

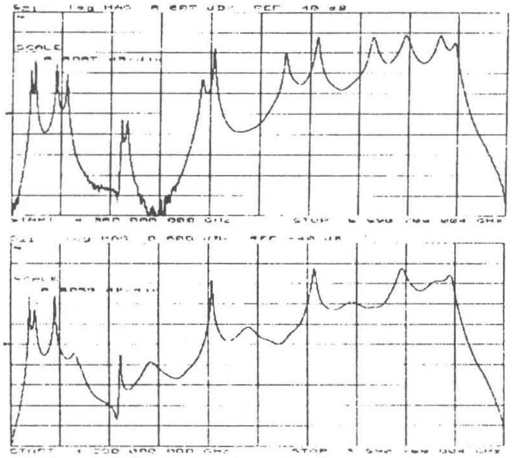

Fig. 8: Second dipole passband in the 12-cell structure.

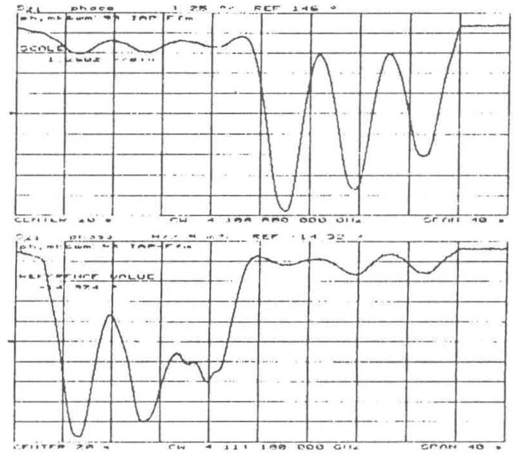

Fig. 9: A separated mode in the 12-cell structure

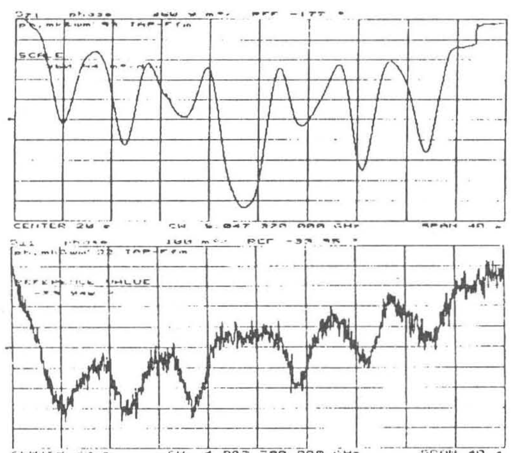

Fig. 10: Example of a strongly damped mode.

TABLE 4
Q-Values for the first Dipole Passband

Mode	Frequency undamped [GHz]	Frequency damped [GHz]	Quality factor undamped	Quality factor damped	Coupling factor
1	4.1025	4.1024	4650	3950	1.18
2	4.1043	4.1043	-	-	-
3	4.1057	4.1056	5350	4950	1.08
4	4.1088	4.1087	3960	3880	1.02
5	4.1113	4.1112	4110	3550	1.16
6	4.1174	4.1173	4620	4170	1.11
7	4.1246	4.1245	4730	2760	1.71
8	4.1351	4.1350	4290	3930	1.09
9	4.1409	4.1408	2690	2030	1.33
10	4.1417	4.1418	5256	-	-

TABLE 5
Q-Values for the second Dipole Passband

Mode	Frequency undamped [GHz]	Frequency damped [GHz]	Quality factor undamped	Quality factor damped	Coupling factor
1	4.4273	4.4272	6660	6350	1.05
2	4.4378	4.4411	5940	1440	4.13
3	4.4899	4.4897	5650	5410	1.04
4	4.5163	4.5381	3090	300	10.16
5	4.6503	4.6501	6210	5930	1.05
6	4.8459	4.7252	830	140	5.89
7	4.8745	4.8740	4680	4490	1.04
8	5.0473	4.9628	1440	130	11.39
9	5.1249	5.1240	2290	1960	1.17
10	5.2619	5.2166	1230	100	11.97
11	5.3413	5.3392	1100	830	1.33
12	5.4268	5.4269	1350	200	6.80
13	5.4620	5.4583	3110	1250	2.49

The cross slotted iris affects only modes with E-field at this iris. Because it was mounted in the middle of the 12-cell structure every second mode was damped. An example is shown in Fig. 10.

Conclusion

The damping effect on the second passband was relativly high. A combination of both damping systems would complete the damping effect on the second passband. The damping effect on the first passband was rather poor. Obviously we have chosen a Q-value for the damping system which was too low with respect to the bandwidth. The bandwidth is of the order of 10^{-2}. Increasing the Q-value of the damping cell in the order of 150 would probably provide better results in this passband. But that would lead to a quality factor for the whole structure which is unwanted high. A structure with higher group velocity would be the better choice.

References

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