RF Measurements on Cu Model of the Superstructure for the TESLA Linear Collider

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Abstract

Here we present results we have obtained on a Cu model of the superstructure [1,2] made of four 7-cell sub-units with non-resonant coupling. The proposed superstructure will allow to feed 28 cells with only one input coupler, overcoming the difficulties in the field flatness control and in the HOM damping, known from experiences with multicell structures coupled resonantly. A short description of the proposed layout is given. The field flatness adjustment, HOM damping scheme, transient measurements and input coupler matching are discussed in detail.

1 INTRODUCTION

The superstructure, a chain of four non resonantly coupled 7-cell cavities, increases the fill factor in the machine and increases the number of cells fed by one input coupler by a factor of 3. These make the superstructure to be an option promising a cost reduction and an improvement in the performance of the collider. The length of the interconnection between cavities is chosen to be half of the wave length, ($\lambda/2$). When the number of cells in one cavity is an odd number, the π-0 mode (π cell to cell phase advance and 0 structure to structure phase advance) can be used for the acceleration. The chosen coupling method is the main difference from the standard multicell cavities (20 cells Darmstadt, 28 cells HEPL). This method leaves enough space to put HOM couplers between the cavities for the damping of dangerous parasitic modes and to put pickup probes to control the field flatness. It will be partially corrected even during the operation since each cavity (i.e. sub-unit) will be housed in an individual LHe vessel and thus can be equipped with a tuner. Therefore, in the superstructure the field flatness and the HOM damping can be handled still at the sub-unit level, contrary to other approaches.

In order to verify the computations for the superstructure, a Cu model of the superstructure has been built; see Fig. 1. The parameters of this model are given in Table 1. In the following first RF measurements on the Cu model of the cavity chain are discussed.

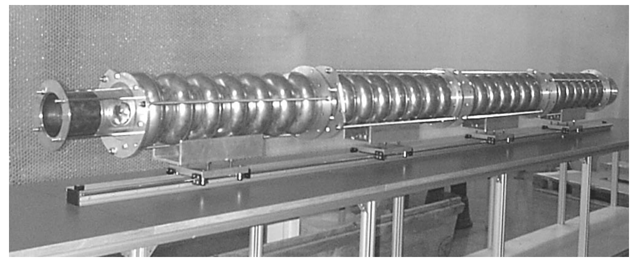

Figure 1: Cu model of the superstructure.

Table 1: Parameters of Cu model of the superstructure

Parameter	
number of cells, M x N	4 x 7
number of HOM / input couplers	5 / 1
radius of mid / end iris [mm]	35 / 57
fill factor	0.875
k_{cc}, cell-to-cell coupling	0.019
k_{ss}, cavity-to-cavity coupling	$3.6 \cdot 10^{-4}$
field instability factor, N^2/k_{cc} [10^3]	2.6
(R/Q)/length [Ω/m]	906
Q_0	≈ 27000

2 FUNDAMENTAL MODE

The copper model of the superstructure allows to check the tuning and field profile adjustment for the fundamental mode, the transient state in individual cells and the coupling of the FM coupler.

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2.1 Field Flatness

The π-0 mode will be used for the acceleration of the beam in the superstructure. Before assembly, each of the four 7-cell Cu cavities has been tuned individually for flat field profile and the chosen frequency of the π-0 mode. The field flatness was almost 98%. After the cavity chain of the superstructure has been assembled, the field profile of the π-0 mode was measured for the whole chain with help of a bead-pull technique. A typical bead pull result is shown in Fig. 2a, obtained after small frequency corrections of the individual cavities. The expected field profile for a superconducting state ($Q_{ext}=2.5\cdot10^6$) can be calculated from this measurement. For the bead pull measurement of Fig. 2a, the corresponding field profile for a superconducting superstructure is given in Fig. 2b. The measurements on the copper model of the superstructure have demonstrated, that the field flatness can be expected to be about 95% for a superconducting state.

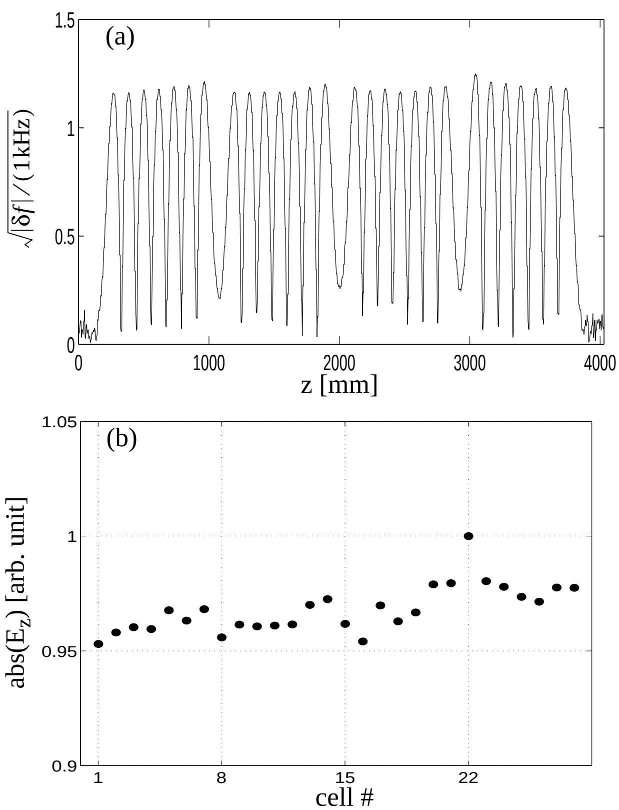

Figure 2:
(a) Bead pull result on the Cu model of the superstructure: π-0 mode after small frequency corrections of the individual cavities (input antenna cell 1, output antenna cell 28);
(b) Corresponding calculated field profile for a superconducting state.

2.2 Field Profile for HPP

By proper tuning of the 7-cell structures, half of the input power can be transferred to the structure to be processed. As example Fig. 3 shows a bead pull measurement after tuning the Cu model of the superstructure for processing of cavity #2.

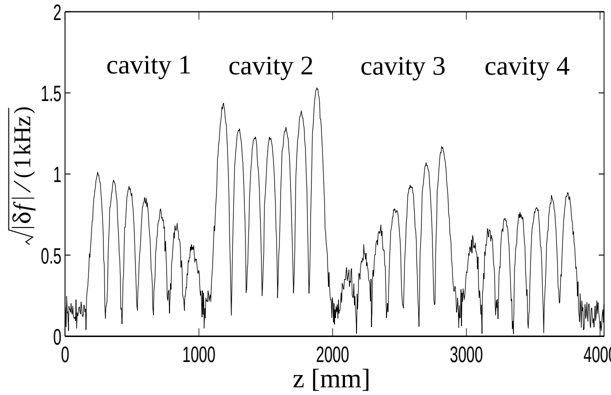

Figure 3: Bead pull result on the Cu model of the superstructure: π-0 mode, tuned for processing of cavity #2 (cavity #1 detuned by +25 kHz and cavity #2 detuned by -200 kHz).

2.3 Transient State

The transient state of each cell of the superstructure has been computed with help of HOMDYN code [3]. This was done for a superconducting Nb-superstructure as well as for a Cu-model. In order to confirm the reliability of the mathematical model, the computed transients have been compared to the measured ones [4]; see Fig. 4 for cell #28 of the Cu model. The measured and calculated rise and delay times are in good agreement. The small differences in the substructure of the transients result from variation of the cell to cell coupling and differences between the cavities. On the other hand the calculations are based on ideal cavities without variations. Even when the π-0 mode frequency of all sub-units is the same, the variations causes differences in the frequencies of the other modes. Theses differences in frequency make the sub-units of the superstructure uncoupled for some modes.

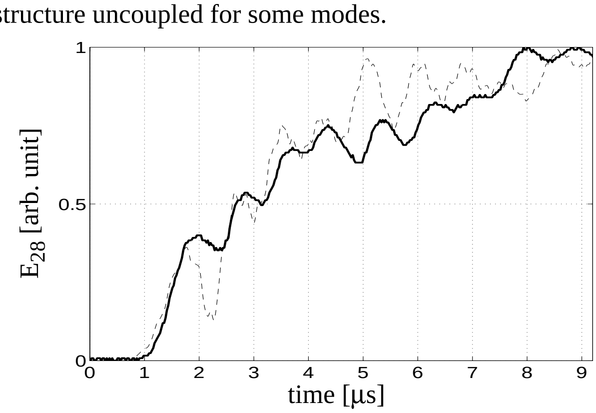

Figure 4: Transient in cell #28: measured on the Cu model of the superstructure (bold line) and computed (dashed line). The step on the input power for cell #1 starts at 0 µs.

2.4 Input Coupler Matching

To minimize the effort, a DESY TTF III type coaxial coupler will be used as input coupler to feed the Nb-prototype of the superstructure. The coupler is placed 45 mm axial apart from the end cell. The Cu model of the superstructure has been used to measure and adjust the coupling of the accelerating mode to the FM coupler. $Q_{ext}=2.5\cdot10^6$ is required for a reflection free operation. The measurement on the copper model shows that this Q_{ext} is reached at a penetration depth of about 6 mm for the antenna tip into the beam tube; see Fig. 5. This penetration depth is similar to the one of the FM coupler for the 9-cell structures. Therefore a DESY TTF III type coupler can be used for the Nb-prototype of the superstructure without modification.

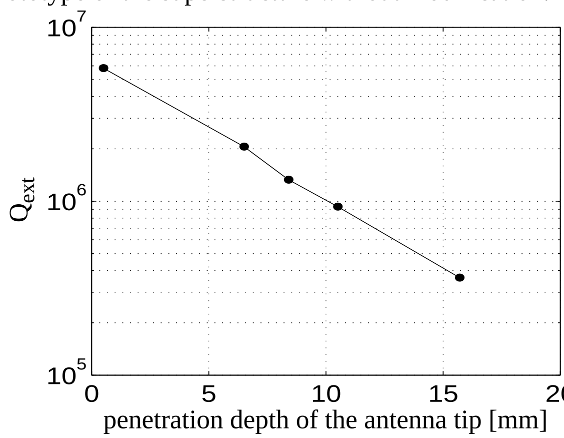

Figure 5: Measured Q_{ext} values of the input coupler at different penetration depths of the antenna tip into the beam tube (accelerating mode, FM coupler is placed 45 mm apart from cell #1).

3 HOM DAMPING

The interconnecting tubes allow to put HOM couplers between the four 7-cell cavities for damping of dangerous parasitic modes. Therefore the superstructure will be equipped with five HOM couplers: three at the interconnection tubes and two at the both end tubes of the chain. In this way each inner coupler can damp modes from two neighbouring cavities.

The Cu model is used to prove, that such a damping scheme can fulfil the requirements on damping for the TESLA collider. First computations of the Beam Blow-Up (BBU) showed, that high impedance transversal modes should be damped to the level of $Q_{ext}<1.5\cdot10^5$ [5]. For the monopole modes the peak power capability of cables and feedthroughs limits $Q_{ext}<4\cdot10^4$.

For all modes of the TE111, TM110, TM011 and TE221 passband the field profile has been measured on the Cu model and compared to MAFIA calculations. As an example, Fig. 6 shows the measured and the calculated field profile for a dipole mode with high R/Q and Fig. 7 the same for a monopole mode.

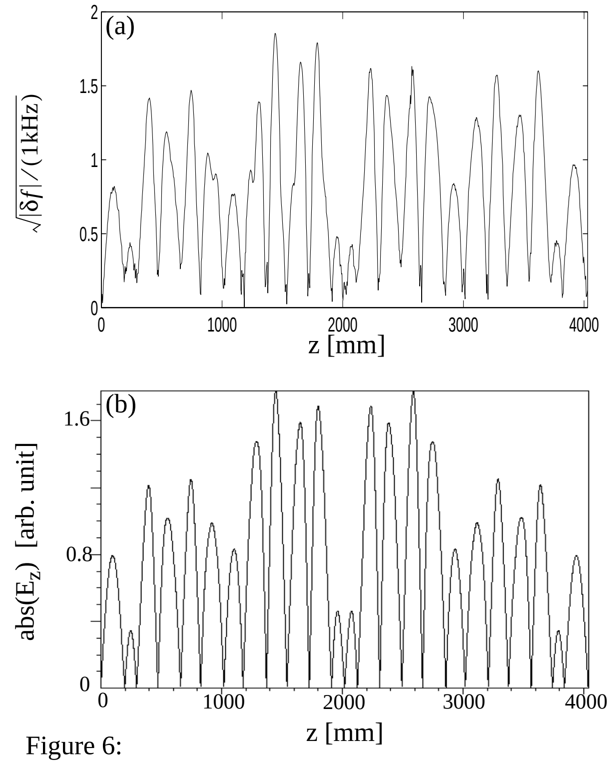

Figure 6:
(a) Bead pull result on the Cu model of the superstructure for one polarisation of the dipole mode TE111, 24;
(b) MAFIA calculation of the field profile for TE111, mode 24.

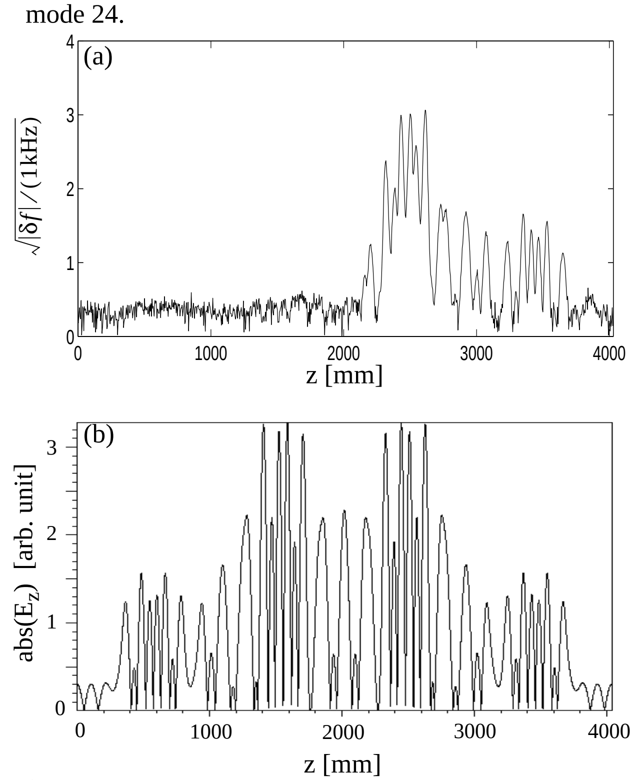

Figure 7:
(a) Bead pull result on the Cu model of the superstructure for the monopole mode TM011, 29;
(b) MAFIA calculation of the field profile for TM011, mode 29.

As mentioned before, differences in frequency make the sub-units of a superstructure uncoupled for some modes. For the monopole mode of Fig. 7, the cavities #3 and #4 are uncoupled from the structures #1 and #2.

The cavities for the Nb-prototype of the superstructure will be connected by flanges [6]. The remaining space between the cavities will allow to attach to the interconnection HOM couplers based on a 40 mm coaxial line or less. In order to make a fast construction of a Nb-prototype possible (the first beam test should be in January 2001), the existing 40 mm TTF HOM coupler [7] was tested on the Cu model of the superstructure. After first measurements the length of the antenna tip of the coupler was lengthened by 5 mm in order to increase the damping to the most dangerous modes; see Fig. 8.

Figure 8: Cu model of the HOM coupler for the Nb-prototype of the superstructure. This coupler is based on the 40 mm TTF HOM coupler for the 9-cell cavities. The length of the tip is increased by 5 mm to fulfil the requirements on damping.

Each mode of the TE111, TM110, TM011 and TE221 passband with higher R/Q was checked. All modes have been measured for four different angular positions of the HOM couplers, as summarized in Table 2.

Table 2: Angular positions of the HOM couplers.

	coupler #1	coupler #2	coupler #3	coupler #4	coupler #5
1st meas.	0 deg	90 deg	0 deg	90 deg	0 deg
2nd meas.	0 deg	90 deg	180 deg	270 deg	0 deg
3rd meas.	0 deg	120 deg	0 deg	120 deg	0 deg
4th meas.	0 deg	120 deg	240 deg	0 deg	120 deg

From the measured Q_{ext} the impedance of a mode is calculated: $Z = R/Q \cdot Q_{ext}$ (R/Q computed by MAFIA). The results we have obtained with the modified 40 mm TTF HOM coupler are shown in Fig. 9 to 11 for the dipole modes and Fig. 12 for the monopole modes.

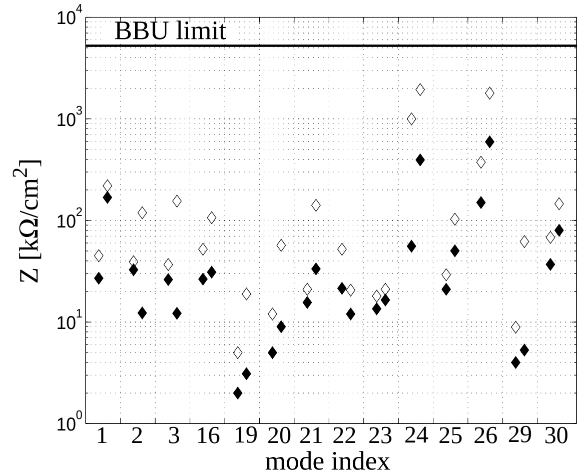

Figure 9: Measured impedance values for dipole modes of the TE 111 passband with higher R/Q. For each mode the damping of both polarisations have been measured at four different angular positions of the HOM couplers (see Table 2): (♦) lowest value of these measurements for one polarisation of a mode, (◇) highest value.

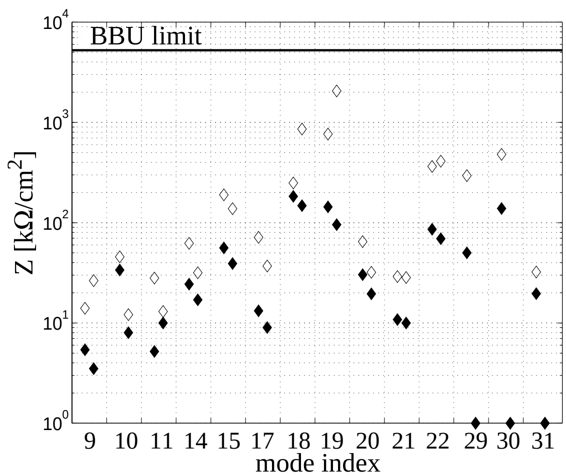

Figure 10: Same as Fig. 9, but for dipole modes of the TM 110 passband with higher R/Q.

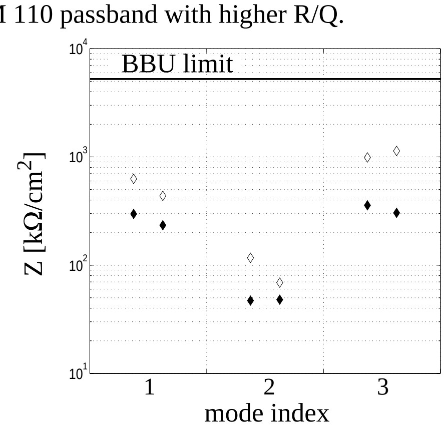

Figure 11: Same as Fig. 9, but for three dipole modes of the TE 221 passband with higher R/Q.

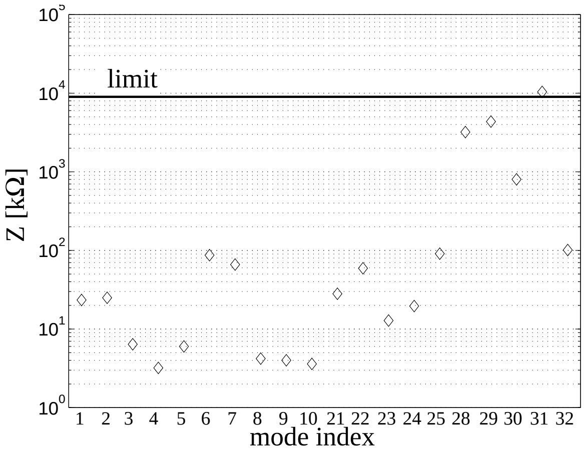

Figure 12: Measured impedance values for monopole modes of the TM 011 passband with high R/Q.

The achieved damping is very good for many modes with respect to the BBU limit. Only for some of them Z is near to the limit. The measurements done so far do not enable to conclude, which of the four arrangements of the HOM couplers is superior.

4 OUTLOOK

The final design of the superstructure will allow to use HOM couplers with 60 mm diameter to have more margin in the HOM damping. The model of this coupler is under preparation and will be tested in the near future.

However, the Cu model of the superstructure does not allow to prove finally the numerical simulation of the bunch-to-bunch energy spread. Therefore a Nb prototype will be build and tested with beam in the TTF linac [6].

5 ACKNOWLEDGEMENT

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6 REFERENCES

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