OPTIMIZATION OF CLIC TRANSFER STRUCTURE (CTS) DESIGN TO MEET NEW DRIVE BEAM PARAMETERS

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I. INTRODUCTION

In the original CTS design [1] the 2.8 mm-wide slit, joining the cylindrical beam chamber to the teeth-loaded rectangular waveguides provided a sufficient coupling for the 160 nC drive-beam bunches to deposit 40 MW of 30 GHz power in the waveguides. The drive-beam generation studies have recently evolved towards schemes which envisage an increased number of bunches at reduced charge per bunch [2]. In order to cope with the reduced beam intensity while maintaining the correct power output level, the CTS design has been modified to increase the beam coupling parameter. Moreover, the new CLIC Test Facility (CTF2) requires transfer structures with even higher beam coupling because of the reduced bunch frequency (3 GHz) [3]. Additional modifications to the original design were required by manufacturing, which imposed the presence of round lips at the slit edges [4]. We have simulated the new CTS by means of MAFIA in order to explore the range of variation of the coupling parameter with slit aperture, and optimized the design to meet the requirements of both the new drive beam and the CTF2. We report here the results of the simulation studies.

II. CTS COUPLING FACTORS FOR CLIC AND CTF2

In the reference scheme for CLIC, the drive beam is formed by four trains of 22 bunchlets each, separated in time by 2.84 ns. The Gaussian bunchlets have σ = 1 mm, a 30 nC charge, and a spacing of one 30 GHz period. After the traversal of one bunchlet train, the CTS received the energy

$$U = (R/Q) q^2 F^2(\sigma)\omega/2 \quad (\mathrm{VAs}) \qquad (1)$$

where R/Q is the mode coupling factor, q = 660 nC is the charge in one train, F(σ) = 0.82 is a function of the bunch length, and ω = 2 πf is the angular frequency of the coupled mode. The energy U is induced in one burst during the traversal of the bunchlet train and discharges uniformly during 2.84 ns at the rate imposed by the mode group velocity of 0.3*c*. Just before the CTS discharges completely, the next bunchlet train traverses the structure and again fills it with energy. The CTS thus acts as a pulse stretcher and delivers a uniform power pulse 11.4 ns long to fill two CLIC Accelerating Structures (CASs), one from each waveguide. The power needed to fill the two CASs is 90 MW, which requires 4U = 1.02 VAs, and R/Q = 9.4 Ω/structure or R'/Q = 23.0 Ω/m, as the CTS is 41 cm long.

The main goal of the CTF2 experiment is to use one CTS to provide 50 MW power pulses to one CAS by combining the two waveguide outputs. In this case the drive beam will be formed by a continuous train of bunchlets separated by a 3 GHz period or 333.3 ps. The charge which traverses one CTS during 2.84 ns will initially be limited in CTF2 to 200 nC, so that solving Eq. (1) for R/Q and substituting U = dP with P = 50 MW and d = 2.84 ns we get for the CTS coupling parameter the value

$$R/Q = 56.7\ \Omega/\text{structure or } R'/Q = 138.0\ \Omega/\text{m}.$$

III. THE NEW CTS GEOMETRY

Figure 1 shows a six-cell section of the CTS as simulated by MAFIA [5].

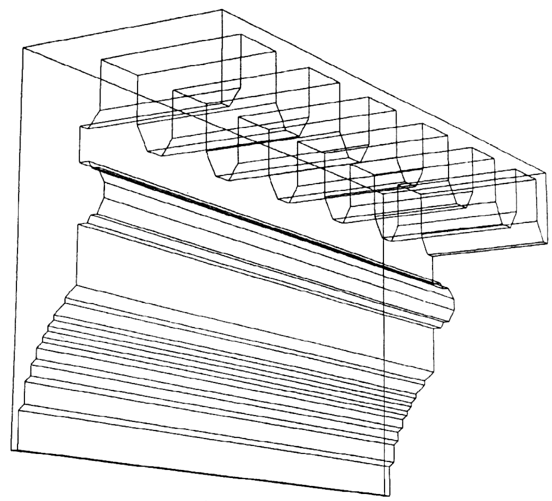

Figure 1: Six cells of CTS as simulated by MAFIA (upper left corner shown).

We notice the presence of the rounded lips, which mark the separation of the beam chamber from the teeth-loaded wave-guides. The main geometrical parameters of the CTS are:

Beam chamber radius	6.000 mm
Waveguide width	8.600 mm
Slit aperture*	3.0 to 7.000 mm
Lip radius	0.800 mm
Waveguide height	3.000 mm
Teeth spacing	3.332 mm
Teeth height	2.000 mm
Teeth thickness	1.667 mm
CTS length	410.0 mm

**may vary to change the coupling*

The maximum aperture between the lips' edges is given by the waveguide width minus twice the lip radius, or 8.6 – 1.6 = 7.0 mm. We have explored the variation of the main RF parameters with slit aperture increasing from 3.0 to 7.0 mm while keeping all other parameters constant. Table 1 summarizes the results obtained.

Table 1

Slit (mm)	f (GHz)	Q	R'/Q (Ω/m)	E_w/E_t (%)	$\hat{W}'_z$ *(V/pC/m)*
3.0	28.85	2651	2.40	99.70	0.95
4.0	29.95	3143	14.42	98.60	2.65
5.0	30.94	3538	89.61	94.67	7.25
6.0	30.88	3832	149.75	92.44	12.34
7.0	30.35	4025	178.20	88.95	19.10

The fifth column in the table gives the ratio of the energy of the mode in the waveguides over the total mode energy. This is an important parameter as it determines the efficiency of the power extraction from the beam. The sixth column shows the peak value of the longitudinal wake potential for a Gaussian bunch with σ = 1 mm traversing 1 m of structure, computed using the time domain module T3320 of MAFIA.

IV. OPTIMIZATION OF THE CTS FOR THE CLIC REFERENCE SCHEME

From the results shown in Table 1 it appears that a slit aperture of about 4.2 mm would provide the required CTS coupling of 23 Ω/m for the reference scheme, albeit at the expense of relatively high losses, as shown by the low Q value. We have preferred to keep a wider slit aperture and to search for the required coupling parameter value by increasing the waveguide height. The search has been successful and the results are:

Slit aperture:	5.8 mm
Waveguide height:	4.0 mm
Mode frequency:	29.993 GHz
Q factor:	3942
R'/Q:	25.1 Ω/m
E_w/E_t:	97.6%
W'_z:	4.6 V/pC/m
v_g/c:	0.29

The frequency is not exactly at the nominal value but is well within the tolerance imposed by our mesh resolution.

V. OPTIMIZATION OF THE CTS FOR CTF2

The solution to the CTF2 requirement (R'/Q=138 Ω/m) was found by lowering the waveguide height (to increase the coupling parameter) and by increasing the teeth height (to lower the coupled mode frequency). The results were:

Slit aperture:	7.0 mm
Waveguide height:	2.6 mm
Teeth height:	2.11 mm
Mode frequency:	30.016 GHz
Q factor:	3786.0
R'/Q:	146.0 Ω/m
E_w/E_t:	90.2%
W'_z:	28.1 V/pC/m
v_g/c:	0.27

The shape of the longitudinal wake excited by one bunch traversal of a 12-cell section of CTS shows that the bunch interacts mainly with a single mode (Fig. 2).

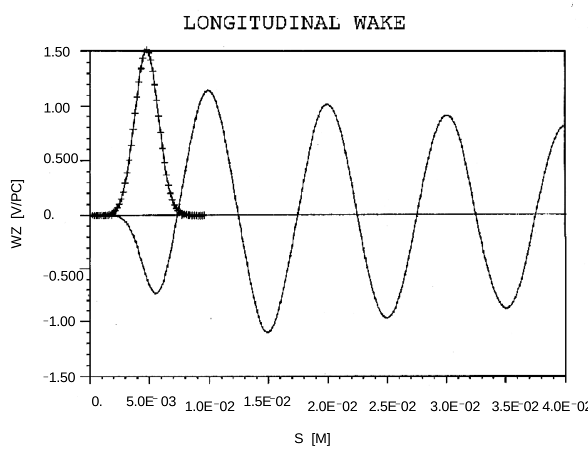

Figure 2: Longitudinal wake.

It is therefore possible to compare the peak value of the longitudinal wake with the coupling factor of the synchronous 2π/3 mode by means of the relation

$$(R'/Q)\omega e^{-1/2(\omega\sigma/c)^2} = \hat{W}'_z \ .$$

The result for the left-hand side is 22.60 V/pC/m, which compares fairly well with the value of 28.1 V/pC/m for the peak of the longitudinal wake.

VI. CONCLUSION

With our simulation study we have shown that it is possible to increase the CTS beam coupling over a wide range without destroying the chosen mode for power transfer. We have found the frequency and coupling factor characteristics as a function of the slit aperture and have optimized the geometry to meet the requirements imposed by the drive beam properties in both the reference CLIC scheme and the CTF2 experiment. We have shown that a higher beam coupling brings stronger wakefields and a less favourable mode energy distribution between the wave-guides and the beam chamber. This last drawback may, however, be overcome by means of an optimal design of the output waveguide couplers, which recuperate part of the energy in the beam chamber.

VII. REFERENCES

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