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# AN ASSET TEST OF THE CLIC ACCELERATING STRUCTURE

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## *Abstract*

Transverse wakefield suppression in the CLIC (Compact Linear Collider) multibunch accelerating structure, called the TDS (Tapered Damped Structure), is achieved primarily through heavy damping. In order to verify the performance of the TDS design and the validity of the theoretical tools used to model it, a 15 GHz version of the TDS has been constructed and tested in the ASSET facility at SLAC. The test has directly demonstrated transverse wakefield suppression of over a factor 100, with an excellent agreement between the measured and the calculated wakefield.

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Transverse wakefield suppression in the CLIC (Compact Linear Collider) multibunch accelerating structure, called the TDS (Tapered Damped Structure), is achieved primarily through heavy damping. In order to verify the performance of the TDS design and the validity of the theoretical tools used to model it, a 15 GHz version of the TDS has been constructed and tested in the ASSET facility at SLAC. The test has directly demonstrated transverse wakefield suppression of over a factor 100, with an excellent agreement between the measured and the calculated wakefield.

## 1 INTRODUCTION

A common feature for most linear collider designs is that multiple-bunch trains are accelerated during each RF pulse (called multibunching) in order to reach design luminosities ($10^{35}$ cm$^{-2}$ sec$^{-1}$ at 2 TeV for CLIC [1]) in a power efficient way. As a result of multibunching, a major concern for the linear collider designs is bunch train emittance growth. Long-range transverse wakefields induce a bunch-to-bunch coupling of transverse motions. Major efforts in the various linear collider studies have gone into developing accelerating structures in which long range transverse wakefields are suppressed, so as to limit this contribution to emittance growth.

For CLIC, beam dynamics simulations indicate that the single bunch transverse wakefield must be suppressed by a factor 100 in the interval between bunches in the train - 0.67 ns, which corresponds to 20 (30 GHz) accelerating mode cycles - and that the wakefield must continue to decrease for longer times [2].

A structure, called the TDS (Tapered Damped Structure), capable of such a performance has been developed in the context of the CLIC study [3]. Wakefield suppression is achieved primarily through damping. Each cell of the 150-cell TDS is damped by its own set of four individually terminated waveguides. This produces a Q of below 20 for the lowest dipole mode band. The waveguides have a cutoff frequency of 33 GHz which is above the 30 GHz fundamental but below all other higher order modes. Cell and iris diameters are tapered along the length of the structure in order to induce a frequency spread in the dipole bands which is called detuning. Iris dimensions range from 4.5 to 3.5 mm in the TDS. Detuning causes a decoherence of wakefield kicks, further suppressing the transverse wakefield. A cut-away view of the TDS cell and damping waveguide layout is shown in Figure 1.

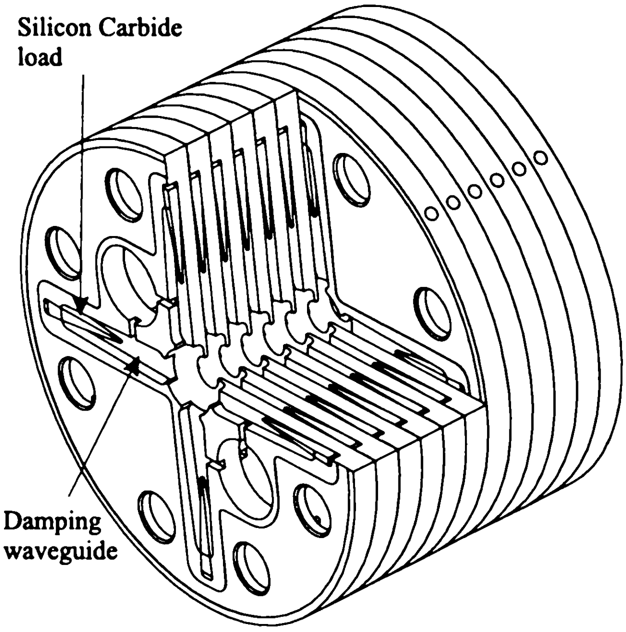

Figure 1: A cross-sectional view of the TDS cell and damping waveguide layout.

A number of theoretical techniques have been developed to compute the time dependent transverse wake of the TDS [3,4,5]. The techniques have been benchmarked with cold model RF measurements that included cell dipole mode quality factors and the reflection coefficient spectrum of the loads [6]. In order to make a definitive verification of the TDS performance and of the theoretical tools used to model it, a test structure has been constructed at CERN and tested in the ASSET facility at SLAC [7].

## 2 ASSET TDS MODEL

The TDS test model prepared for the ASSET measurement is a somewhat simplified version of the 30 GHz CLIC structure. The most important simplification has been to scale the structure up by a factor of two, to 15 GHz in order to increase the minimum iris. This is done in order to avoid creating beam transmission difficulties during testing and particularly during SLAC B-factory operation. The B-factory beam passes through structures installed in the ASSET facility and since opportunities to install and remove the test TDS were limited, the structure had to be made so it could be left installed for an extended period.

The scaling was limited to a factor of two in order to maintain a sufficiently strong transverse wakefield kick from the structure, which decreases with the cube of the frequency. The smallest kick which can be measured in ASSET is about 0.1 V/(pC·mm), although the exact value is influenced by the available driving positron bunch charge. The factor two scaling results in an initial wakefield kick of 120 V/(pC·mm), and thus makes possible direct measurement of suppression factors of up to 1000.

The second simplification was to assemble the structure by bolting rather than by brazing. This simplification has a negligible influence on the heavily damped dipole modes which have with loaded quality factors less than 20. Quality factors achieved in un-damped bolted cells are lower than in un-damped are easily over 200 to 300. The disks were made from aluminium in order to ease machining, reduce cost and reduce weight. The bolted stack of plates was mounted in a vacuum tank and the cells were pumped via the damping waveguides.

A close-up view of the ASSET TDS cell and damping waveguides is shown in Figure 2. Figure 3 shows he structure being assembled.

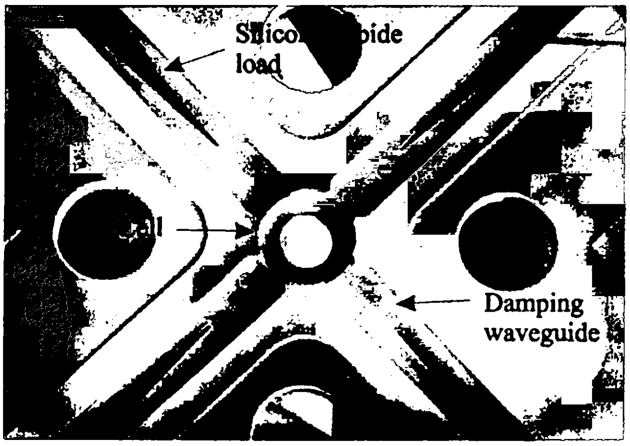

Figure 2: Close-up view of the TDS cell, with the four damping waveguides and silicon carbide loads.

Another difference between the 30 GHz TDS and the 15 GHz ASSET test structure is in the load. Since the complex permittivity of silicon carbide is a function of frequency [6], a load had to be specially designed for the test structure. The reflection coefficient spectrum of the load is shown in figure 4 and does not differ significantly from the load designed for 30 GHz structure.

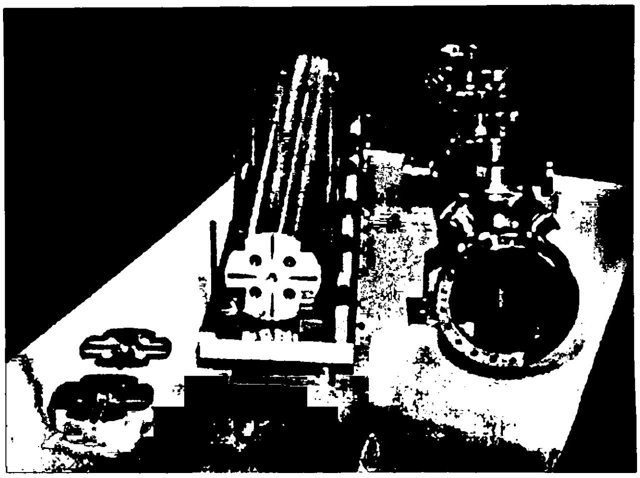

Figure 3: The structure being assembled.

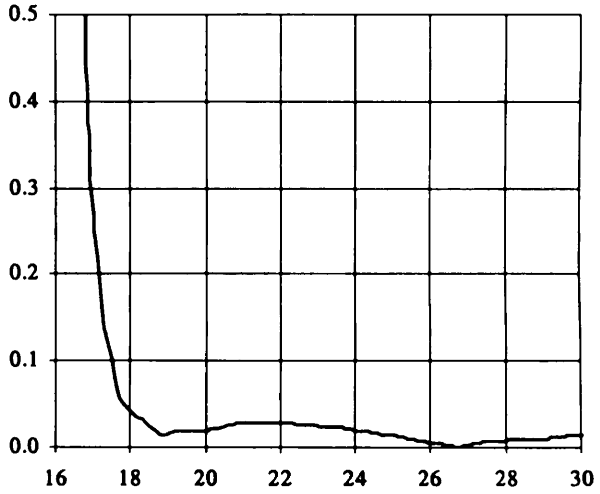

Figure 4: Measured load reflection coefficient magnitude spectra. These values were used to compute the wake.

The resulting transverse wakefield computed using the double-band circuit model [4] appears in Figures 5 and 6. Total wakefields from the structure are presented in this paper although per meter values are the same since the 150 cell, 15 GHz structure is exactly 1 m long. For reference, the CLIC bunch spacing scaled to 15 GHz is 1.33 ns.

## 3 MEASUREMENTS AND RESULTS

The structure was measured in ASSET during one night-time break in B-factory operation. The principles and procedures for the measurement of the transverse wakefield were the same as for previous measurements of SLAC X-band structures [7]. The now well established measurement process proceeded without incident.

Plots on two different time-scales of the measured transverse wakefields in the vertical plane are shown in Figures 5 and 6.

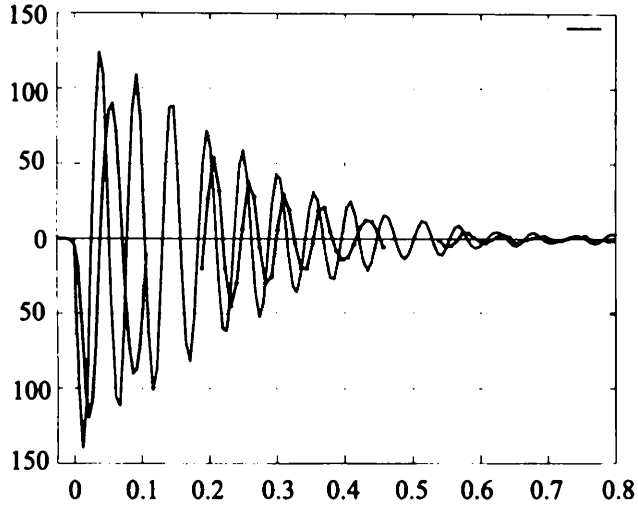

Figure 5: Measured (dark) and computed (light) transverse wakefield in units of V/(pC·mm) against time in units of ns.

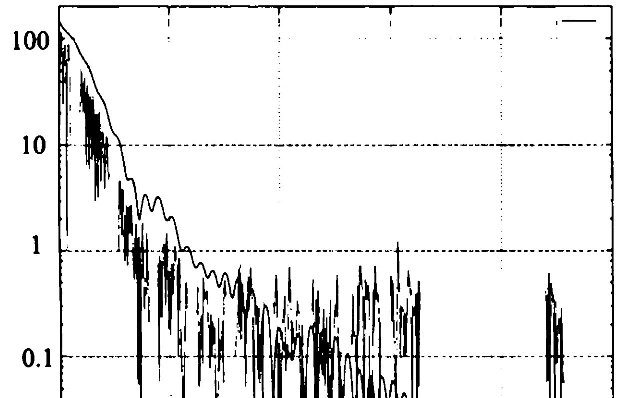

Figure 6: Log plot of the measured (dark) and computed (light) transverse wakefields in units of V/(pC·mm) against time in units of ns.

The agreement between the measured and computed wake is excellent and represents a direct verification of the performance of the design and of the accuracy of techniques used to model it.

The only unexpected feature of the data was a 7.6 GHz component of the wake that emerged after the wake had fallen below about 0.2 V/(pC·mm). The close-up on data where the signal appears is shown in Figure 7. Since the component occurred at a frequency well below the fundamental mode of the structure, it was clear the signal had its origin in a feature of the experimental set-up rather than in the structure itself. A quick a posteriori analysis of the set-up and a MAFIA 2-D run identified the vacuum chamber to beam pipe transitions as the offending components. The transitions had a narrow circular gap that behaved as a high-Q coaxial resonator. The computation matched the observed signal in both frequency and in kick amplitude. A new sliding-fit transition has been manufactured and will be installed if scheduling allows.

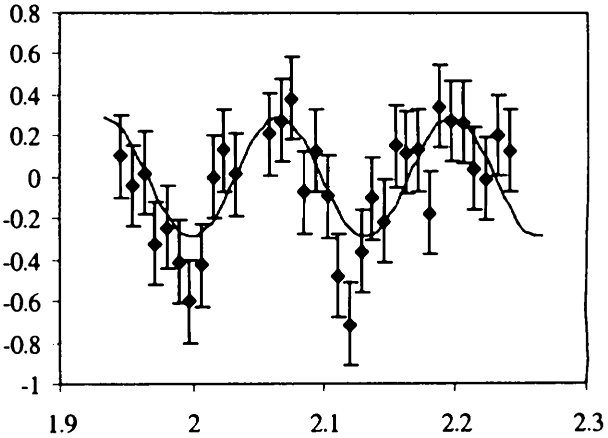

Figure 7: Close-up view of the measured wakefield around 2.1 ns in units of V/(pC·mm) against time in units of ns. A 2.9 V/(pC·mm) 7.6 GHz wake is superimposed on the data.

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