SLAC-PUB-7934
September 1998

The Dipole Wakefield for a Rounded Damped Detuned Linear Accelerator with Optimised Cell-to-Manifold Coupling

R. M. Jones *et al.*

Presented at the XIXth Linear Accelerator Conference (Linac 98),
8/23/98—8/28/98, Chicago, IL, USA

Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309

Work supported by Department of Energy contract DE–AC03–76SF00515.

THE DIPOLE WAKEFIELD FOR A ROUNDED DAMPED DETUNED LINEAR ACCELERATOR WITH OPTIMISED CELL-TO-MANIFOLD COUPLING

R.M. Jones[†], N.M. Kroll[†‡], R.H. Miller[†], T. Higo[¥], K. Ko, Z. Li[†], R.D. Ruth[†], V. Srinivas[†], and J. W. Wang[†]
†Stanford Linear Accelerator Center, M/S 26, P.O Box 4349, Stanford, CA 94309
‡University of California, San Diego, La Jolla, CA 92093-0319.
¥KEK, National Laboratory for High Energy Physics, 1-1 Oho, Tsukuba-shi, Ibaraki-ken 305, Japan

Abstract

A redesign of the basic cell configuration of the Damped Detuned Structure has been briefly reported in [1] where the cells are referred to as ellipsoidal cavities, and accelerator structures incorporating them are designated DDS 5 and DDS 6. This new structure type has been renamed RDDS 1, and the first of this series, RDDS 1, is presently under design and fabrication. The carefully sculpted cell profile (fabricated on computer controlled lathes at KEK incorporating diamond point machining) provides a 20% increase in shunt impedance which, when combined with other parameters, allows for a dramatic reduction in the RF power required for the NLC (Next Linear Collider). The detuning profile, damping manifold taper, and the cell to manifold coupling contant profile have all been carefully optimised so as to permit decoupling the cells at the ends of the structure from the manifolds while still adequately minimising the transverse wake. The decoupling is required in order to fit adequately matched terminations into the structure. The single structure analysis has been supplemented with studies of wake degradation arising from systematic fabrication errors and wake improvement obtained by combining manifold damping with structure interleaving.

1. Introduction

In the design of the NLC (Next Linear Collider) the heart of the system will consist of 4,752 X-band accelerator structures, each indiviual structure being 1.8025m in length. Any misalignment in the structure, or transverse motion of the structure over time, or beam misalignment from the electrical center of the structure will give rise to a transverse wakefield which will result in the beam being kicked off axis and can lead to a beam break up instability (as originally observed on the Stanford Linear Collider). In order to mitigate these effects, which may seriously degrade the beam emmitance, and hence reduce the luminosity of the beam, the transverse wakefield must be carefully controlled and damped. The method described herein, incorporates both detuning by gently tapering the iris parameters such that they follow an Erf function distribution and, damping the long range wake field, by coupling the wakefield out of the structure to a set of four manifolds which are located along the circumference of the accelerator structure.

In order to obtain the maximum efficiency of interaction, the shunt impedance is required to be maximised. The shunt impedance, R_{sh} is defined in terms of the potential across the structure V and, the power dissipated within the structure, P_d

$$R_{sh} = |V|^2 / P_d$$

In our current design, we maximise the $R_{sh}/Q = |V|^2/(2\omega U_E)$, where ω is the angular resonance frequency and U_E is the energy stored within the electric fields, so that we obtain a value that is 10% larger than that obtained over a set of pillbox cavities and, we enhance the Q value by 10%, both achieved by carefully shaping the contours of the irises and cavities. This together with a larger klystron pulse length, led to our initial design for RDDS with elliptical features having a 30% more efficient source-to-beam, or “wall plug”, efficiency. In this design the average a/λ was approximately 0.171 (a being the radius of a particular iris). However, short range wakefield considerations has led to the iris being widened considerably in order to reduce the wake and, this leads to a 6% degradation in the overall efficiency. In this design the average a/λ is approximately 0.18. Furthermore, our initial design incorporated elliptically shaped cavities and irises. However, driven by mechanical engineering considerations, all shapes have been made circular. This reduces the efficiency by 1% or so, and at the same time it facilitates more rapid verification between the specified design and the fabricated cell.

Here we calculate the wakefield for the accelerator with a 30% improvement in efficiency the elliptical RDDS and, the RDDS with circular cells and cavities, which has an efficiency enhancement of approximately 20%.

2. Wakefields for Circular & Elliptical RDDS

The wakefield in each 206 cell structure cannot be computed accurately, with a finite difference or finite element code as at present the memory and time requirements required to run the code are prohibitive and thus, we utilise a circuit model [3] and spectral function method [2. The model we use assigns 9 parameters to each cell and this allows the dipole band of the brillioun diagram to be accurately described. The structure geometrical parameters have been designed to vary slowly in an adiabatic manner and thus we interpolate between, 5 cells to obtain the behavior of all 206 cells. The model we use incorporates many features present in the real

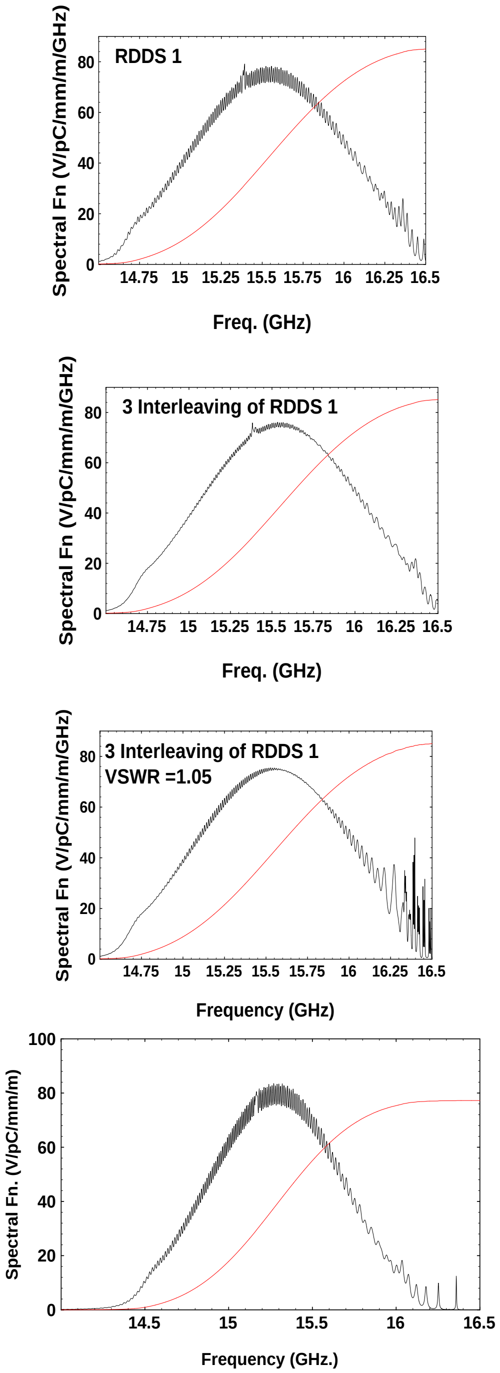

Figure 1: The spectral function and its integral for RDDS 1 for an initial design. The uppermost is the spectral function for a structure with perfectly matched HOM (Higher Order Mode) couplers and all cells coupled. The second is for series of three interleaved structures in which the synchronous frequency of each structure differs form its neighbor by 3.8 MHz. The third curve is for the case of three interleaved structures with six cells decoupled and a HOM load with a VSWR of 1.05. The fourth is for the most up-to-date design, RDDS1 with circular contours.

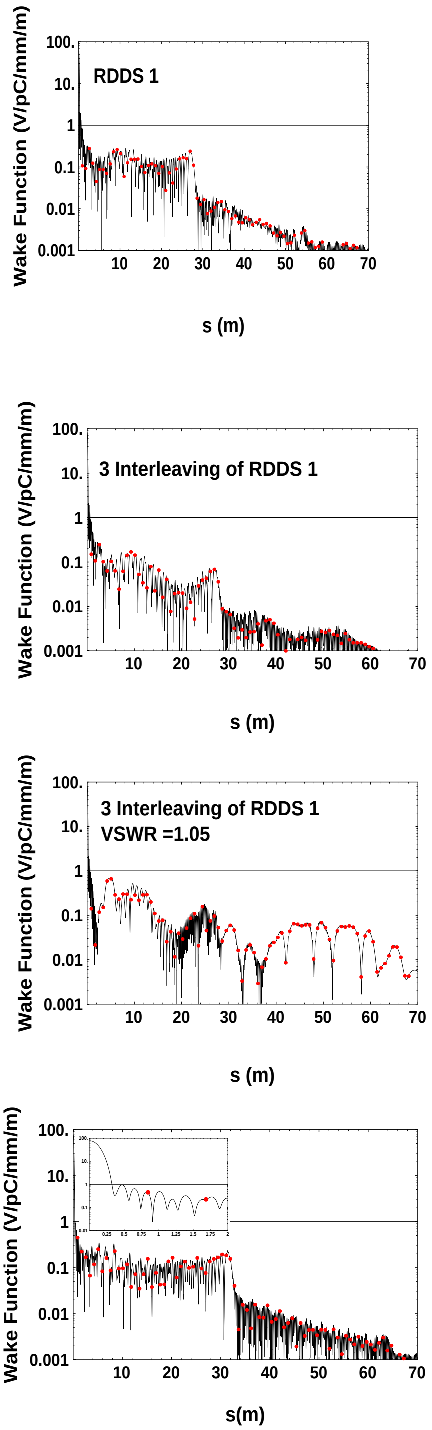

Figure 2: The wake function and its integral for RDDS 1. All wakes are the counterparts of the spectral functions given in fig. 1. The dots are located at the bunch locations. One V/pC/mm/m is indicated as beam emmitance considerations dictate that the transverse wake function, at the bunch locations, may not be larger than this value. The lowermost curve is for RDDS1 with circular features to the irises and cavities. The load has is assumed to have a VSWR = 1.

structure as fabricated, viz., the non-perfect terminations of the manifolds in the higher mode loads and, the details of the coupling of the cells to the manifold (the modal composition of the accelerator is mainly TE at the low energy end and, it becomes progressively more TM towards the higher end of the structure). The spectrum function for a single elliptical structure is calculated and the coupling of the manifold to the structure is carefully optimised. The result of a final optimisation for the design with an a/λ = 0.171 is shown in Fig.1 for perfectly matched HOM couplers (higher order mode) and the wakefield corresponding to this spectral function is shown in Fig. 2. By interleaving the structures with structures whose central frequency is slightly shifted from their neighbours the wakefield is forced to decohere successively more so than a single structure. In Fig. 1 the spectral function is shown for three structures whose central dipole synchronous cell frequencies differ by 3.8 MHz from their neighbours, both with matched terminations to higher mode couplers and with terminations with a VSWR of 1.05 and with six cells decoupled either end of the accelerator structure.

The magnitude of the oscillations imposed on the spectral function is seen to be significantly reduced, particularly in the upper end of the spectral function. And, the wakefield is seen to be 3 times smaller in the region 0 to 30 m or so. Furthermore, the system is considerably stablised with respect to oscillations in the spectral function, on decoupling the last few cells. The last lowermost curve in Fig. 1 corresponds to the present RDDS with circularly shaped irises and cells. The spectral function corresponding to this latest design, is shown lowermost in Fig. 1. In this design, all ellipses have an eccentricity of 1 and the VSWR =1 of all loads in this preliminary realisation.

3. Effect of Systematic Errors on the Wakefield

In the fabrication of the RDDS cells systematic, or repeatable errors, in the machining of the cells us likely to occur and in this section we consider the effect of such errors on the transverse wakefield. We consider a specific case, viz, a sinusoidal perturbation of amplitude 2MHz in the synchronous frequencies, in the central region of the structure (cells 75 through 125). The spectral function, illustrated in Fig. 5 is seen to be significantly modulated in the central region.

However, this significant modulation has little effect on the long-range wake function (Fig. 6). Although, for the first few bunches the wake field is slightly enhanced, it is a very small effect. We also consider random errors and, for a Gaussian spread in the synchronous frequencies with a σ of 10^{-4} (corresponding to approximately 1.5 MHz) the wakefield is largely unaffected.

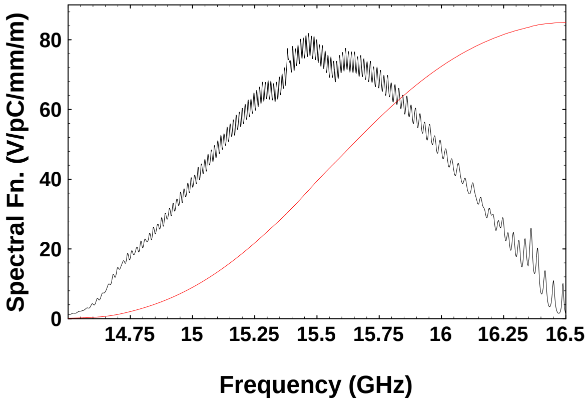

Figure 3: Spectral function for RDDS1 with all cells coupled and a perfectly matched HOM coupler. A systematic error in the fabrication is assumed to occur leading to a sinusoidal perturbation in the cell dimensions and the synchronous frequencies. The synchronous frequency perturbation has amplitude of 2 MHz.

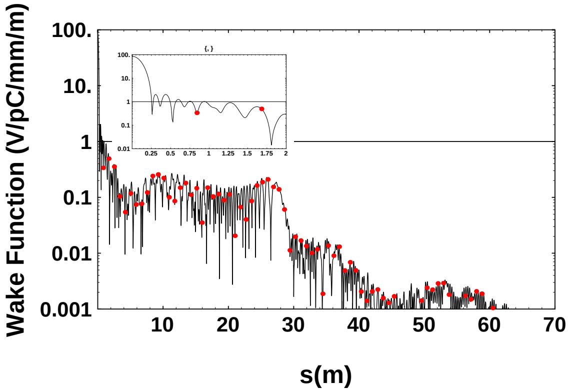

Figure 4: Wake function including the effects of a systematic fabrication error which results in a sinusiodal deviation in the synchronous frequency in the middle of the frequency band of the structure. Shown inset is the short-range wake in the range 0 to 2m.

4. Acknowledgments

This work is supported by Department of Energy grant number DE-FG03-93ER40759‡ and DE-AC03-76SF00515†.

5. References

[1] R.M. Jones., N.M. Kroll, R.H. Miller, R. Ruth and J.W. Wang, Advanced Damped Detuned Structure Development at SLAC, Proc. Particle Accelerator Conference, Vancouver, Canada, 1997. http://www.cern.ch/accelconf

[2] R.M. Jones., N.M. Kroll and R.H. Miller, A Spectral Function Method Applied To The Calculation Of The SLAC Damped Detuned Structure. Proc. Intl. Linac Conf. Geneva Switzerland, 1996 (SLAC-PUB 7287).