ADVANCED DAMPED DETUNED STRUCTURE DEVELOPMENT AT SLAC

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Abstract

The first damped detuned accelerator structure, DDS 1, has been built, tested in the ASSET experiment, and installed in the NLCTA. The planning and construction of a series of further structures, incorporating some modifications, is under way. DDS 2, 3, and 4 all incorporate the same basic design as DDS 1. The manifold design for the last 5 % of the downstream end of the structure has been modified to accommodate improvements in the manifold loads. Calculations based on the spectral function method indicate, on average, a factor two or better reduction in the long range wake. Modest modifications in the distribution of geometrical detuning parameters along the structure which, according to calculations based on spectral function theory, significantly improve the short range wake will be incorporated in DDS 3 and 4. The basic cell configuration will be redesigned in DDS 5 with the intention of improving shunt impedance as well as incorporating further improvements in the wake.

1 INTRODUCTION

The NLC Accelerator Structures group at SLAC is engaged in three simultaneous processes: 1) optimizing the design of NLC Accelerator Structures, 2) learning how to fabricate them within satisfactory dimensional tolerances including the straightness tolerance, and 3) manufacturing structures for the NLC Test Accelerator. The schedule realities of these three goals have led to a process of making incremental changes in the design which were compatible with the fabrication schedule. The NLC beam parameters have evolved, going from a pulse train of 10 bunches with 1.4 ns spacing to 90 bunches with a 1.4 ns spacing, and now will change to 82 bunches with a 2.8 ns spacing.

2 DETUNING

The first two NLC developmental accelerator sections were the Mark 1 and Mark 2, detuned sections which were identical in design except for minor dimensional corrections. All of the NLC structures discussed here are 1.8 meters long with 206 cells (including the couplers) and are designed to operate with a $2\pi/3$ phase advance per cell in the accelerating mode. The dipole modes in the Mark 1 and 2 structures were undamped, except for copper losses. These structures were designed to be approximately constant gradient with the dipole mode frequencies adjusted to have a gaussian density distribution by varying the iris radius a, and the disk thickness t. The resulting gaussian density distribution of the lowest dipole band had σ_f = 2.5% about a center frequency of 15 MHz. The full frequency spread was 10% with the gaussian distribution truncated at +/-2σ_f. The effect of the gaussian detuning of the Mark 1 was measured by Adolphsen [1]. The measurements showed that the wake fields fell by a factor of about 70 to below 1 Volt/pC/mm/m by the time that a second bunch arrived 1.4 ns after the drive bunch. To get an equivalent fall off in 1.4 ns with damping would require a Q of 12 for the dipole modes. However, while the Gaussian distribution is very effective in achieving a destructive interference which produces a rapid fall off at short times, because there are a finite number (206) of discrete modes, they begin to constructively interfere again after times inversely proportional to the separation between modes. The build up of the wake field due to this reappearance of constructive interference can be seen in the wakefield plot for the detuned (DT) structure at the top of Fig. 2.

3 DAMPED DETUNED STRUCTURES

DDS 1 was the first of our manifold damped detuned structures. DDS 1,2,3, and 4 have 4 rounded rectangular damping manifolds arranged at 90 degree intervals in azimuth around the accelerator cells. Each manifold is a single mode, TE_{10}, waveguide with its wide dimension in the radial direction, so that the E fields are in the azimuthal direction. The small dimension of the manifolds is 5 mm along its full length. The wide dimension (radial direction) of the manifolds tapers from 11 mm at the input end of the structure to 9.8 mm at the output end. Each manifold couples to every cell except the first 3 (counting the couplers) at each end by means of a rectangular coupling hole which is 5 mm in the azimuthal direction and about 7 mm long. The coupling is controlled by tapering the wide dimension of the manifolds and by controlling the distance of the manifolds from the outer wall of the accelerator cells. In DDS 1 through 4, the coupling was chosen in an attempt to achieve a loaded Q of about 1000 for all the modes in the lowest dipole band which interact strongly with the beam. The loaded Q of 1000 was chosen to produce a damping time of 20 ns. We didn't realize that only the more widely spaced modes which contribute to the early rise in the wakefields need a Q of 1000. The Q of each mode should be such that the bandwidth of the mode is

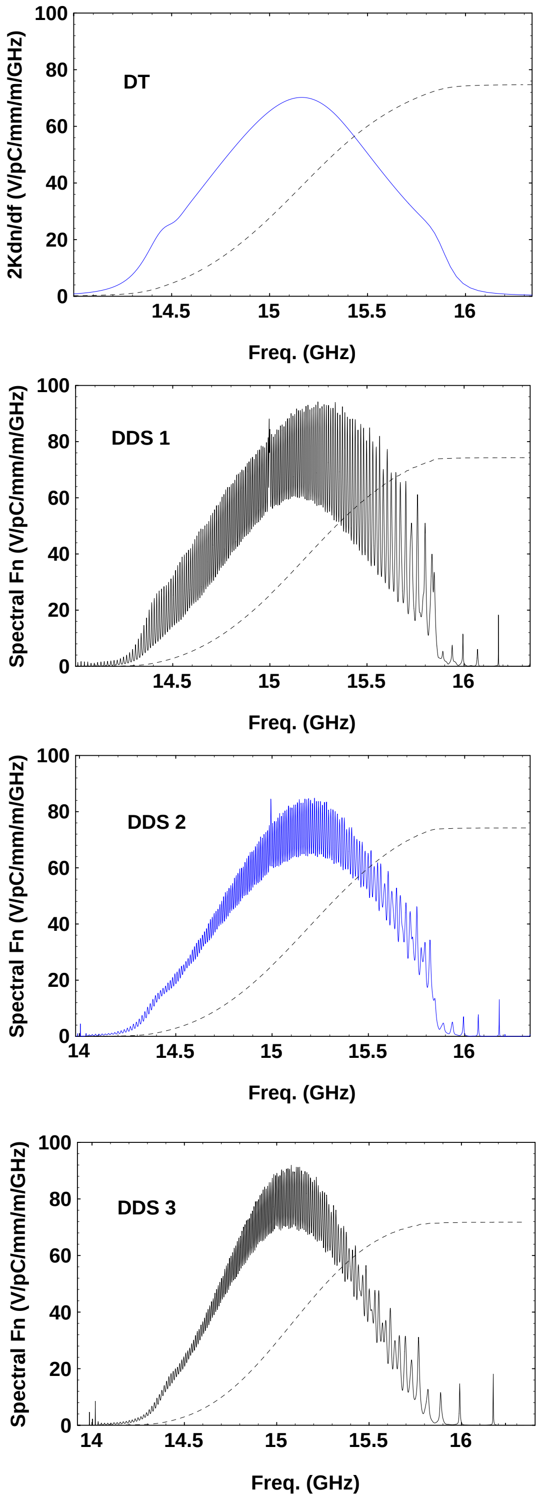

Fig 1: Shown uppermost is twice the kick factor weighted density function (2Kdf/df) for the DT (damped detuned) structure. The succeeding curves are of the spectral function for DDS 1, DDS 2 and DDS 3 The significant improvement in the matching to the HOM loads for DDS 2 reduces the amplitude of the oscillations of the spectral function. DDS 3 uses similar HOM couplers and loads as DDS 2 but the cells have been redistributed using a recently developed mapping function method . The integral is dashed.

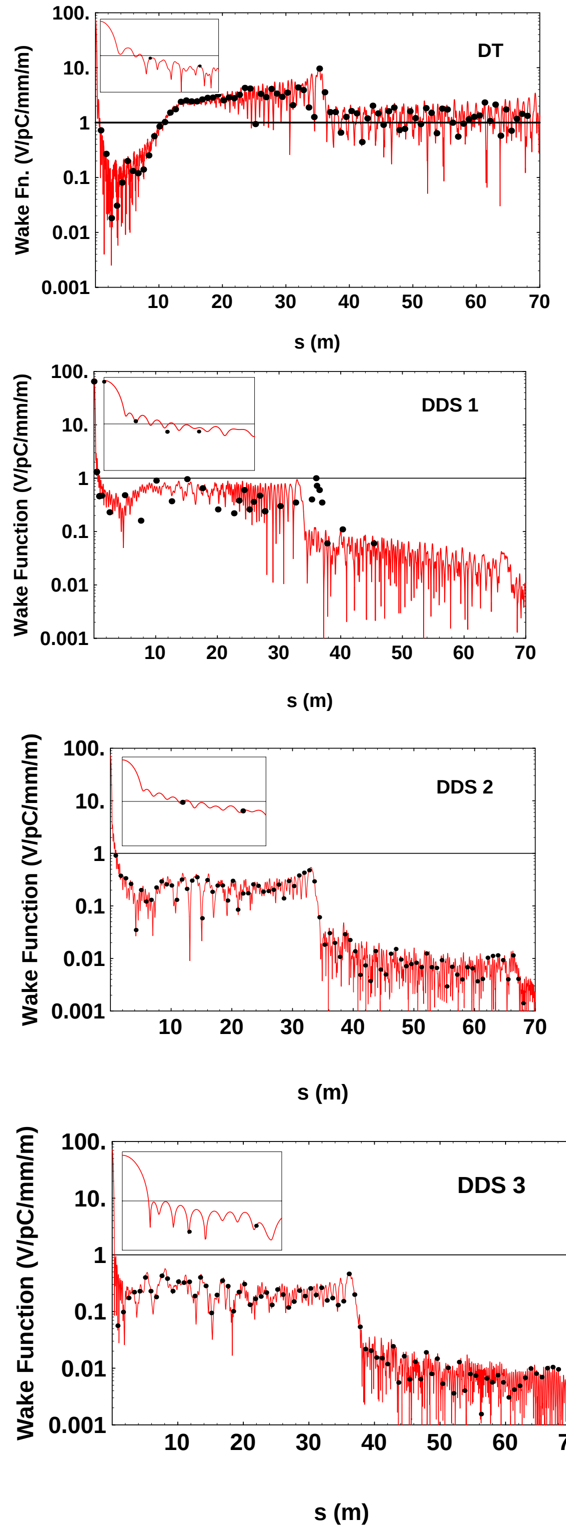

Fig 2: Shown uppermost is the wake function for the DT structure. The succeeding curves are of the wake function for DDS 1 (HOM couplers included and ASSET data points), DDS 2 and DDS 3. The dots in DDS 2 and DDS 3 indicate the position of the 82 bunches placed 2.8 ns apart. The long range wake for DDS 1 is improved over the DT structure by an order of magnitude or more, the medium and long range wake for DDS 2 by a factor of 3 over DDS 1, with further improvement of the short range wake for DDS 3.

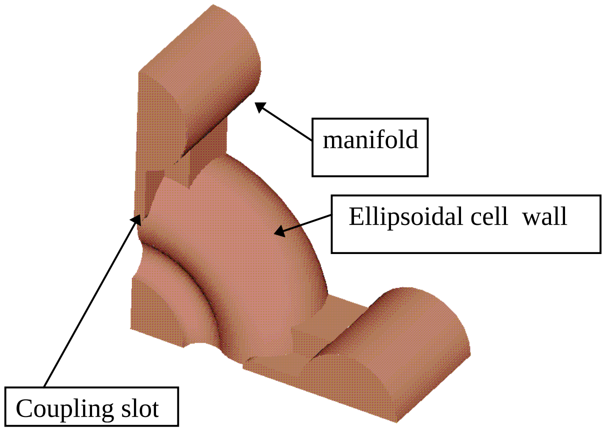

Fig 3: Interior of 1/4 of improved Ellipsoidal Cell.

roughly equal to its frequency separation from it nearest neighbors. This transforms the impedance distribution from 200 delta functions to a fairly smooth gaussian in the frequency domain. Since the mode density varies continuously across the distribution, the Q of the modes should also vary. There were two more significant problems in the design of DDS 1: 1) The manifold terminations were not well matched; 2) the coupling changed the gaussian distribution somewhat and exacerbated the effect of the truncation of the gaussian, particularly at about 15.8 Ghz. This is apparent in the spectral function [2] for DDS 1 and 2 in Fig 1, and causes an increase in the wakefields for the first few meters for DDS 1 and 2 as seen in Fig 2. The terminations for the manifolds DDS 1,2,3, and 4 consist of H plane mitered bends to bring the manifolds out from the structure followed by H plane radiused bends, tapers up to WR-62 rectanqular waveguide, alumina windows and commercial waveguide loads. The VSWR of mitered bends at the output end rose to about 2.0 at the low frequency end of the band, and the VSWR of the windows used on DDS1 rose to 2.0 at the high frequency end.

For DDS 2 the mitered bend on the output end was redesigned and new windows were purchased so that the VSWR is about 1.1 across the center 1 GHz of the band, and rises to 1.2 at the band edges. The improvement in the calculated spectral function and a resultant improvement of a factor of about 3 in the wakefield from about 7 to about 35 meters from DDS 1 to DDS 2 is evident in Fig 1 and 2.

For DDS 3 and 4 the gaussian distribution has been modified to reduce the effect of the truncation at +/- 5%. Using the same range of cell parameters as in DDS 1 and 2, the density distribution has been changed to obtain a symmetric kick factor weighted gaussian density function, Kdn/df with $\sigma_f = 2.125\%$ truncated at +/- 2.35 σ_f. As can be seen in Fig 1 & 2, this significantly reduces the truncation step at the high frequency end of the spectral function and hence significantly lowers the wakefield for the first few meters.

4 DDS 5 AND 6: ELLIPSOIDAL CAVITIES

In the fall of 1996 a program was started to improve the efficiency of the RF system of NLC. The changes in the cell design which raise the shunt impedance about 20% and the related changes in the RF system and its parameters which combined give a 33% reduction in the RF power required for NLC are described in Ref [3] and [4], respectively. The conceptual shape of the interior of the new ellipsoidal cavities is depicted in Figure 3. The round TE_{11} manifolds were chosen because they are easier to fabricate, and improve the vacuum conductance. The outer surface of the cells is an ellipsoid of revolution rather than a right circular cylinder as in DDS 1,2,3 & 4. The ellipsoidal outer surface gives about a 10% improvement in shunt impedance by increasing the Q. The rest of the improvement comes from shaping the disk with a gentle ellipsoidal bulge near the beam hole. The ellipsoidal outer surface significantly reduces the coupling produced by a hole between the manifold and the cavity, so we have added a thin (1.5mm) radial slot in the disk to enhance the coupling. This slot interupts the azimuthal currents in the TM_{11} like dipole mode producing a displacement current across the slot which couples strongly to the TE_{11} mode in the manifold. The slots in the disk will not extend further than 3.5 mm in from the cell maximum diameter, which is roughly half the distance to the beam hole and is also close to the thinest part of the disk, the surface electric fields are well down from their maximum. This slot depth gives a cell to manifold coupling which is about 60% stronger than the couplings for previous structures.

The long range behavior of the wake function could be improved substantially more by improving the match of the terminations. For this reason, and to simplify the mechanical design, internal loads will be considered for future DDS designs.

5 ACKNOWLEDGEMENTS

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REFERENCES

[1] C.Adolphsen *et al.* Phys. Rev. Lett. **74**:2475, 1995.
[2] R.M.Jones *et al.*, ‘A Spectral Function Method ...’ SLAC Pub 7287, Proc. Linac96, Geneva, 1996.
[3] V.Srinivas *et al.*, ‘Optimizing Cell Contours...’, Paper 3W13, this conf.
[4] R.M.Jones, P.B.Wilson, Paper 3W12,This conf.