Next Linear Collider Test Accelerator Optics for Test of W-Band Structure

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Abstract

In this note we present a beam-optics configuration for the proposed test of the W-Band planar structure in the Next Linear Collider Test Accelerator. An optimal configuration must permit the beam to pass through the structure with adequate clearances, and should also be compatible with the standard tuning procedures of the NLCTA; furthermore, the optics should allow tuning of the beam for the W-Band experiment, and require a minimal restructuring of the NLCTA itself. The optics devised satisfies all these requirements at 340 MeV, and requires only 1 additional quadrupole and no additional power supplies relative to the present arrangement of the beamline.

1 Introduction

Microwave acceleration of electron bunches at W-Band frequencies is an area of recent interest at SLAC. Most notably, D. H. Whittum has proposed a test of a 91 GHz structure in the Next Linear Collider Test Accelerator, in which the beam is bunched at 11.424 GHz: the beam will act as a subharmonic driver for the structure, allowing tests of the behavior of such devices at high power [1].

At 90 GHz, RF wavelengths are on the order of millimeters. The W-Band structure is similarly scaled: most critically, the full aperture of the structure through which the beam must pass is 1.4 mm $\times$ 6 mm. This is tighter than any existing aperture in the NLCTA, and in the standard optics in use at present no point in the NLCTA has a beam small enough to pass through the W-Band apparatus.

A pre-requisite for the W-Band test, then, is to devise an optics which permits the insertion of an aperture as described above. The required properties of the optics are as follows:

- At some point in the line, the beam must pass through a waist which is small enough to clear the W-Band's aperture; a minimum of 2σ stay-clear in all directions is required
- The optics must also permit the beam to pass through the existing X-Band linac in the NLCTA, at least as cleanly as it presently does
- The new optics must be at least as amenable to tuning as the present optics; in particular, the flattening of the bunch-to-bunch energy profile that is done on a regular basis in the NLCTA must still be possible in the new optics
- The new optics can have no more than one additional quadrupole installed, since this is the number of spares available; furthermore, since no spare power supply channels will fit into the existing racks, no additional power supplies can be required.

In this note, we present an optical configuration of the NLCTA which satisfies all of the requirements above.

2 NLCTA Standard Optics

Figure 1 shows the betatron functions of the NLCTA's standard optics. The beam enters at $z = 0$ with an energy of approximately 60 MeV; passes through an isochronous chicane and a match into the X-Band linac; enters the linac at $z = 13$ meters; is accelerated to approximately 340 MeV by 4 RF structures from $z = 13$ meters to $z = 23$ meters; and, finally, is matched via a pair of triplets into a spectrometer consisting of a single bend and a short drift, terminating at the dump profile monitor at $z = 39$ meters. In order to obtain the best possible $\beta : \eta$ ratio, the beam size at the dump screen should be minimized in x. Furthermore,

Figure 1: Design NLCTA Optics.

the spectrometer match contains a ramped vertical kicker, which spreads out the NLCTA's 120 nanosecond bunch-train in the vertical. In order to optimize the time-resolution, the beam size at the dump screen should also be minimized in y.

The optimization of the energy profile is critical to the W-Band experiment as well as to the NLCTA experimental program. Because the W-Band apparatus introduces additional beam loading, the present experimental concept requires that the NLCTA be tuned conventionally with the W-Band apparatus removed from the beam path; once the tuning is complete, the apparatus shall be moved onto the beam line via a remote- controlled translation stage and tuning for the W-Band experiments shall begin. Therefore, the beam size should remain small on the dump screen in x and y in the optics used for W-Band tuning, and the beam size in the spectrometer matching region should provide high-β regions to allow tuning of the beam size on the dump screen.

3 NLCTA Optics for W-Band Experiment

Figure 2 shows the optics proposed for the W-Band experiment. The W-Band apparatus is located at approximately $z = 28.3$ meters, some 50 centimeters downstream from the downstream face of QD 1760. In this optics, the waist at the apparatus has $\beta_x = 0.116$ meters, $\beta_y = 1.34$ meters. For somewhat conservative assumptions about the emittance and beam energy available ($\gamma\epsilon_x = \gamma\epsilon_y = 1.0 \times 10^{-4}\mathrm{m} \cdot \mathrm{rad}, E = 340\mathrm{MeV}$), the RMS beam size at the apparatus is $130\mu \times 450\mu$, with the horizontal being the smaller dimension (*i.e.*,

Figure 2: NLCTA Optics for W-Band experiment.

a skinny spot rather than a flat spot). For a W-Band structure mounted with its long axis in the vertical, the stay-clears are better than $\pm 5\sigma$ in each direction.

In order to achieve these conditions, the following changes have been made from the standard optics:

- Quads QD 1550, QF 1650, and QD 1760 have been altered in strength
- A new quadrupole, QF WB, has been added immediately downstream of QD 1760; QD 1760 and QF WB constitute a D-F focusing doublet for the apparatus
- QD 2010 is not powered, and its cables are moved to power QF WB
- QF 1810, QD 1870, QF 1920, QF2030, and QD 2050 have been altered in strength to recover the desired spectrometer optics.

Table 1 summarizes the changes in quad strengths between the standard optics and the optics for W-Band experiments.

While high fields are required in quads 1760 and WB, the values shown in Table 1 are well within the maximum values. Consequently, the W-Band experiment can be run with beam energies up to 385 MeV without exceeding a quadrupole limit.

Table 1: Quad Strengths in Standard and W-Band optics, 340 MeV. Strengths are integrated-gradient (BDES), in kilogauss.

Quad	Standard strength	W-Band strength	Max strength
1550	-3.14	-4.33	-73.5
1650	3.14	5.59	73.5
1760	-1.98	-40.7	-73.5
WB	0	62.9	≈ 73
1810	9.42	20.8	72.8
1870	-11.7	-13.2	-71.3
1920	18.2	17.3	71.3
2010	-8.01	0	-71.3
2030	14.7	12.2	71.2
2050	-10.7	-10.8	-71.4

One area of concern for such strong-focusing solutions is chromatic dilution: is the bandwidth of the doublet adequate for the anticipated energy spread of the beam? The solution above was tested via the second-order particle tracking facility of the program DIMAD. The initial RMS energy spread was set to 1%, and the phases of the RF cavities in the linac were set to give an extracted RMS energy spread of 0.4%. These represent somewhat conservative estimates, since the extracted FWHM energy spread is usually around 0.3%. When tracked, the beam size increased to 150μ in the horizontal and 460μ in the vertical, from a "linear beam size" (beam size counting only linear optics in the propagation) of $130\mu \times 450\mu$.

References

[1] D. Whittum, "Subharmonic Drive Experiment Without Resonant Ring." SLAC ARDB Technical Note 114 (1997).