10/29-91 JS(1)
1/5

SLAC-PUB--5501

DE91 012381

MISALIGNMENT STUDY OF NLC BUNCH COMPRESSOR*

R. P. Rogers, and S. A. Kheifets
Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309 USA

Abstract

Results of computer simulations of the misalignments in the 180°-bend angle second-stage bunch compressor for the NLC are described. The aim of this study was to evaluate alignment and production error tolerances. Three versions of the second stage, differing in their minimum obtainable bunch length (44 μ, 60 μ, and 86 μ) were studied. Simulations included orbit correction produced by errors and misalignments of the compressor elements. The orbit correction itself was done within some error margins. The effects of misalignments on transverse emittance growth were found. Recommendations for alleviating alignment tolerances are discussed.

I. INTRODUCTION

To diminish the effects of chromatic aberrations the NLC bunch compressor is designed to consist of two stages [1]. Small emittances in the horizontal plane, and especially in the vertical plane, are needed to achieve the desired NLC luminosity. Production and alignment errors of the system components should be kept small to preserve the emittances.

In this paper we describe the effects of misalignments on transverse emittance growth in the 180° bend angle second stage bunch compressor. Three versions of the second stage, differing in their minimum obtainable bunch length (44 μ, 60 μ, 86 μ) were studied. The found tolerances for the y-plane appear to be exceedingly tight. Measures for improving alignment tolerances are discussed.

Computer Tools

The design of the NLC bunch compressor and its operation had previously been studied using the **TRANSPORT** [2] and **TURTLE** [3] programs. However, the effects of misalignments and errors can not be studied without inclusion of an appropriate orbit correction (steering). The present study was performed with the help of the program **DIMAD** [4] chosen for its capabilities of an easy and flexible introduction of misalignments and correction.

Correction Scheme

We implemented correction of an orbit produced by randomly chosen errors and misalignments as follows: The first two half-magnets in each cell of the compressor are defined as correctors. These dipole magnets correct the beam x and y positions as read in beam position monitors (BPM) located nine elements downstream of the corrector. The corrector steers by imposing a small x or y displacement of the front end of the magnet. The exit points of the magnets remain fixed. Only one steering was made per run.

Magnets were misaligned around the tangent to the central trajectory at the midpoint of each element. The readings of the BPMs were also assumed to have errors. All error distributions were assumed to be normal cut off at two sigmas (rms). Several different runs were done with the rms displacements of magnets by 0, 25, 50, 75, and 100 μm, respectively, in x, y, and z directions, and with the rms rotations by 0, 25, 50, 75, 100 μrad about x, y, and z axes. For the BPM the corresponding rms reading error equals to 100μm.

Results

One thousand particles were tracked and analyzed per run. The particles were randomly chosen to fill a six-dimensional Gaussian distribution truncated above one sigma. The Table summarizes the results for each version of the compressor. The ratios ϵ/ϵ_0 of the emittance ϵ at the end and ϵ_0 at the beginning of the compressor are tabulated. They were found in the following way.

The beam sigma matrix [2] calculated by DIMAD from the particle distribution resulting from tracking has the form

$$\begin{matrix} \sigma_{11} & r_{12} & r_{13} & r_{14} & r_{15} & r_{16} \\ & \sigma_{22} & r_{23} & r_{24} & r_{25} & r_{26} \\ & & \sigma_{33} & r_{34} & r_{35} & r_{36} \\ & & & \sigma_{44} & r_{45} & r_{46} \\ & & & & \sigma_{55} & r_{56} \\ & & & & & \sigma_{66} \end{matrix} \quad (1)$$

From here the emittance of each projection of the beam ellipsoid was calculated using standard formulae

$$\epsilon_x = \sigma_{11}\sigma_{22} \times \sqrt{1 - r_{12}^2} \quad . \quad (2)$$

$$\epsilon_y = \sigma_{33}\sigma_{44} \times \sqrt{1 - r_{34}^2} \quad . \quad (3)$$

$$\epsilon_\ell = \sigma_{55}\sigma_{66} \times \sqrt{1 - r_{56}^2} \quad . \quad (4)$$

The emittances ϵ_0 were calculated in a similar way from the corresponding sigma matrix at the beginning of the line. The top row of the Table gives the intrinsic emittance growth present in the aligned perfect system. Normalized emittance growth was calculated as follows:

$$\left[\frac{\epsilon/\epsilon_0}{(\epsilon/\epsilon_0)_0} - 1\right] \times 100 \quad . \quad (5)$$

where $(\epsilon/\epsilon_0)_0$ is ϵ/ϵ_0 without misalignments for the version of the compressor being plotted, and ϵ/ϵ_0 is the emittance ratio with misalignments from the Table.

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

MASTER

Presented at the IEEE Particle Accelerator Conference, San Francisco, CA, May 6-9, 1991

Emittance growth for bunch compressor stage 2						
	86 μ Version		60 μ Version		44 μ Version	
Misalignment	ϵ_x/ϵ_{x0}	ϵ_y/ϵ_{y0}	ϵ_x/ϵ_{x0}	ϵ_y/ϵ_{y0}	ϵ_x/ϵ_{x0}	ϵ_y/ϵ_{y0}
0	1.010	1.001	1.096	1.008	1.688	0.979
dx (μ) 25	1.016	1.000	1.058	1.008	1.455	0.979
50	1.041	1.000	1.061	1.008	1.306	0.979
75	1.083	1.000	1.117	1.008	1.258	0.979
100	1.135	0.997	1.206	1.008	1.306	0.979
dx' (μrad) 25	1.010	1.147	1.096	1.068	1.687	1.047
50	1.010	1.514	1.094	1.269	1.684	1.276
75	1.009	1.994	1.093	1.572	1.678	1.614
100	1.009	2.539	1.088	1.949	1.670	2.029
dy (μ) 25	1.206	4.083	1.600	5.031	2.476	9.174
50	2.874	7.105	5.842	14.059	13.739	35.595
75	6.057	23.265	13.759	37.831	—	—
100	10.448	31.958	—	—	—	—
dy' (μrad) 25	1.009	1.000	1.092	1.008	1.679	0.979
50	1.010	1.001	1.090	1.008	1.672	0.979
75	1.012	1.000	1.088	1.008	1.665	0.979
100	1.014	1.000	1.087	1.008	1.659	0.979
dz (μ) 25	1.010	1.000	1.095	1.008	1.684	0.979
50	1.010	1.001	1.093	1.008	1.681	0.979
75	1.010	1.000	1.092	1.008	1.678	0.979
100	1.011	1.001	1.092	1.008	1.678	0.979
dz' (μrad) 25	1.010	1.009	1.096	1.020	1.688	1.004
50	1.010	1.032	1.096	1.070	1.688	1.075
75	1.010	1.066	1.096	1.168	1.688	1.186
100	1.010	1.114	1.096	1.279	1.688	1.326
$d\delta(10^{-6})$ 25	1.010	1.001	1.099	1.008	1.697	0.979
50	1.011	1.000	1.104	1.008	1.704	0.979
75	1.012	1.001	1.107	1.008	1.714	0.979
100	1.014	1.000	1.112	1.008	1.723	0.979

Figures 1–6 represent the normalized emittance growth (in percent) versus the rms magnitude of the misalignment relative to the aligned system. This removes the effects of the system intrinsic emittance growth, so that only the effects of misalignments on emittances are demonstrated. The points on the plots for the 44 μ version of the compressor stage are marked by squares, the 60 μ version by diamonds, and the 86 μ version by crosses, respectively.

More results can be found in a slightly more extensive version of this paper [5].

CONCLUSION

The results indicate that for all three versions of the compressor both the horizontal and vertical emittances exhibit sensitivity to vertical displacements and horizontal rotations. Acceptable tolerances for such misalignments appear to be on the order of several micrometers for dy and 25 μrad for dx'. For both the 60 μm and 44 μm versions of the compressor particle losses were observed starting at the vertical misalignment level of 50 μm. Other misalignments produced acceptable results up to the 100 μm or μrad level. The horizontal emittance growth seems to improve as misalignments increase. This may be due to coupling between the horizontal and vertical motion.

The alignment tolerances may be improved by using η and β matching in the compressor. Tolerances may also be improved by making use of better steering techniques. Finally, the element parameters in the designs used in the current and previous studies have been chosen with the misalignments not considered. The design of the compressor should be optimized with respect to misalignments.

REFERENCES

[1] S. A. Kheifets, R. D. Ruth, and T. H. Figuth "Bunch Compressor for the TLC," Stanford Linear Accelerator Center preprint SLAC-PUB-5034 (1989).

[2] K. L. Brown et al., "TRANSPORT—a Computer Program for Designing Charged Particle Beam Transport Systems," Stanford Linear Accelerator Center Report SLAC-91 Rev. 2, UC-28 (1977).

[3] D. C. Carey et al., "Decay TURTLE," Stanford Linear Accelerator Center Report SLAC-246, UC-28 (1982).

[4] R. V. Servranckx et al., "Users Guide to the Program DIMAD," Stanford Linear Accelerator Center Report SLAC-285, UC-28 (1985).

[5] R. P. Rogers and S. A. Kheifets, "Misalignment Study of NLC Bunch Compressor," Stanford Linear Accelerator Center preprint SLAC-PUB-5501 (1991).

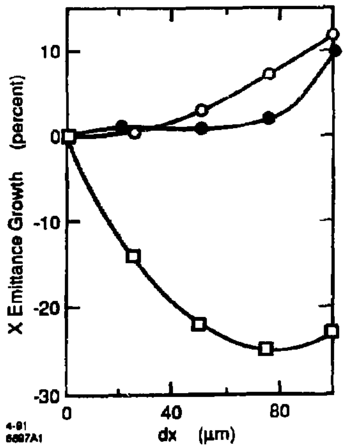

Fig. 1

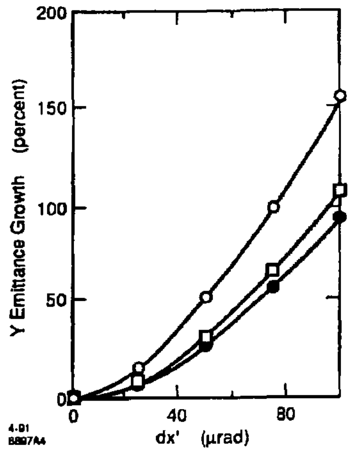

Fig. 2

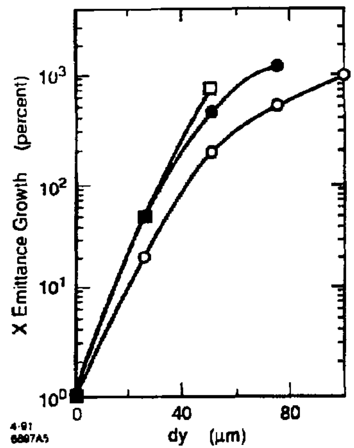

Fig. 3

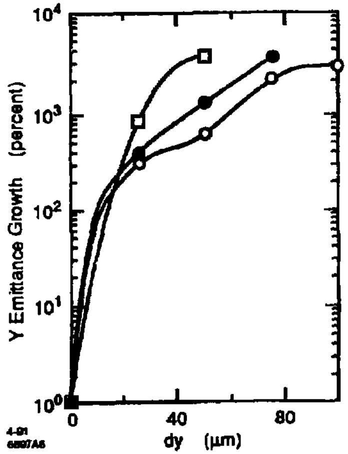

Fig. 4

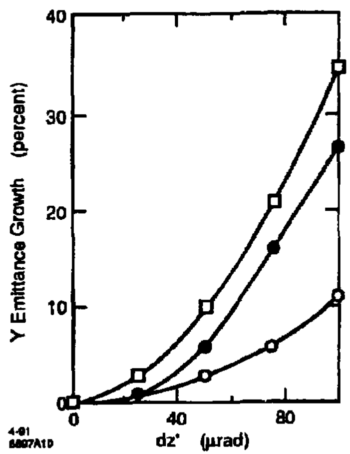

Fig. 5

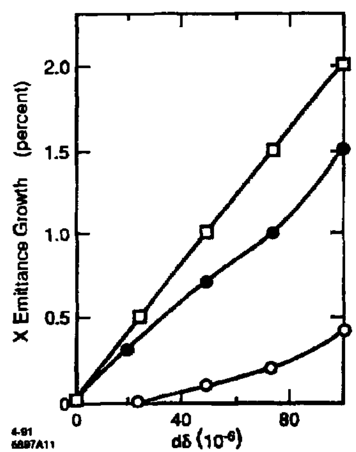

Fig. 6