FURTHER ANALYSIS OF CORRUGATED PLATE DECHIRPER EXPERIMENT AT BNL-ATF

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Abstract

RadiaBeam Systems successfully completed testing of a proof-of-concept corrugated plate dechirper at the Brookhaven National Laboratory Accelerator Test Facility. [1] Such passive devices should prove indispensable for the efficient operation of future XFEL facilities. These experiments demonstrated a narrowing of the energy spectrum in chirped beam bunches at 57.6 MeV. In this paper, we compare these results with results from Elegant simulations of the BNL-ATF beam. We also compare GdfidL simulations of the wakefield with the analytic results of Bane and Stupakov. [2]

GdfidL WAKEFIELD SIMULATION

The analytic equation for the wakefield [2] used to determine the dimensions of the corrugated plates is given by convolving the bunch charge density with the single electron wakefield:

$$W(z) = \frac{\pi^2}{16}\frac{Z_0 c}{\pi a^2} cos\left(\frac{2\pi z}{\lambda}\right), \tag{1}$$

where Z_0 is the impedance of free space (377 Ω), c is the speed of light, z is the bunch longitudinal coordinate, λ is the wavelength of the wakefield given by

$$\lambda = 2\pi\sqrt{\frac{a\delta g}{p}}. \tag{2}$$

The other variables describe the dimensions of the corrugated plates and are listed in Table 1.

To check the accuracy of the analytic equations used in designing the plates, a numerical simulation of the wakefield was run using the program GdfidL. A 500-pC, 1-ps beam bunch with Gaussian longitudinal profile was simulated passing through the corrugated structure defined in Table 1 and the resulting wakefield calculated. A comparison between these two calculations is seen in Fig. 1. The GdfidL simulation reports a wakefield about 64% the magnitude of the analytic equations inside the electron bunch. This factor will be used in simulating the effect of the bunch's wakefield as it passes through the corrugated structure. Note that this factor matches field-matching simulations performed by SLAC with $F\left(\frac{h}{a}=1, \frac{p}{a}=1\right)$. [3]

ELEGANT SIMULATION

Using the beam simulation software package Elegant, a bunch was propagated through ATF's beamline to the chamber housing the dechirper. Bane and Stupakov's analytic

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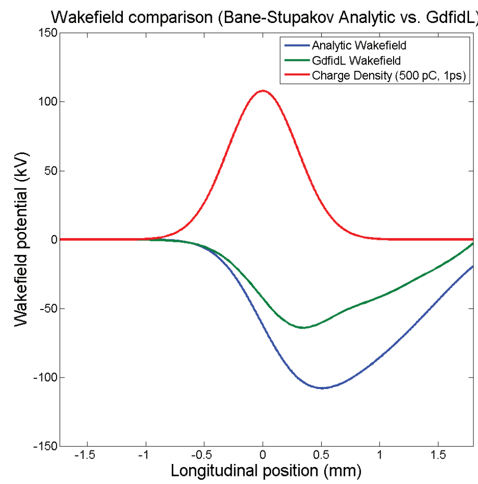

Figure 1: Comparison of the wakefield given by the analytic equations [2] and GdfidL simulations. The bunch charge density is also plotted for longitudinal position reference.

expression of the wakefield with the correction factor determined by the GdfidL simulation was directly applied to the bunch to determine the total dechirping power. Representative phase space plots at various plate gaps are shown in Fig. 2.

Table 1: Corrugated Plate Dimensions

Length	L	181	mm
Width		38.1	mm
Period	p	1.15	mm
Depth	δ	1.15	mm
Gap	g	0.77	mm
Plate separation	a	1–30	mm
Material		Aluminum	

Table 2: BNL ATF Beam Parameters

Beam energy	E	57.6	MeV
Bunch charge	Q	340	pC
Initial chirp		400	keV/mm
Transverse beam size		100	microns
Pulse length (full width)	l	3.4	ps
Longitudinal profile		Rectangular	

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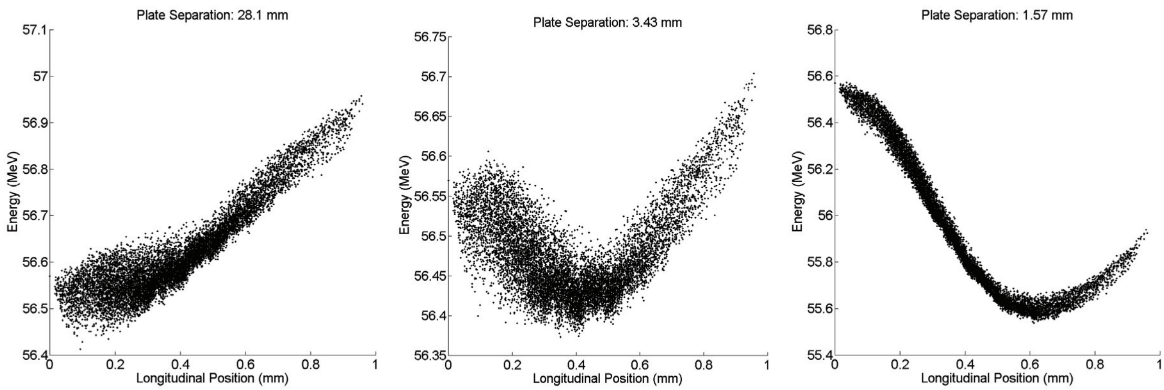

Figure 2: Longitudinal phase space plots at various plate gaps as simulated in Elegant. Note that the smallest gap causes an overdechirp that results in a larger energy spread.

BROOKHAVEN LAB EXPERIMENT RESULTS

To demonstrate the efficacy of a passive corrugated plate system, RadiaBeam Systems installed an 18 cm long test piece in the BNL ATF and ran beam through it with properties given in Table 2. The dimensions of the corrugated plates are given in Table 1 and illustrated in Fig. 3.

The experiment consisted of running the beam through the corrugated plates at various gaps while measuring the energy spread of the bunch with a downstream dipole spectrometer. The dechirping power, defined as the difference in energy spread before and after the dechirper divided by the bunch length, was calculated and plotted in Fig. 4 along with the predicted dechirping power calculated from the Elegant simulations.

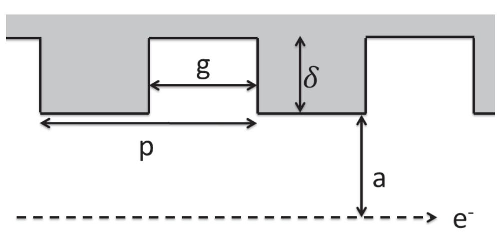

Figure 3: Dimensions of corrugated plates. See Table 1.

CONCLUSION

RadiaBeam Systems has successfully demonstrated a prototype dechirping system that requires no power or RF input. The simple device made of machined aluminum reduced and even reversed the longitudinal energy chirp of the BNL ATF beam. The agreement between the measurements and simulations in this experiment is an encouraging sign that scaling this system up to meters in length for GeV-energy systems such as LCLS, SwissFEL, PAL-XFEL, and many others.

In light of the success of this experiment, RadiaBeam Systems is currently designing a larger, multi-module dechirper for installation at LCLS. [4] The corrugated structures will be two meters long and there will be two sections: one with horizontal plates and one with vertical plates. The differing orientations will limit the unwanted quadrupole focusing effects seen in simulations. [3]

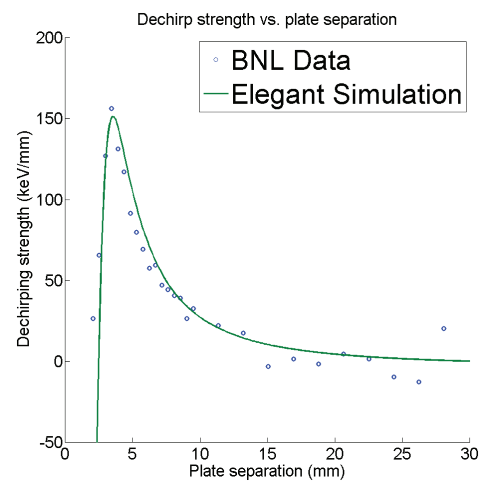

Figure 4: Comparison of measured and theoretical dechirping power of corrugated plates.

ACKNOWLEDGMENTS

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