MECHANICAL DESIGN FOR A CORRUGATED PLATE DECHIRPER SYSTEM FOR LCLS

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Abstract

RadiaBeam Systems is developing a novel passive chirp removal system using corrugated plates as studied by Bane and Stupakov. [1] Following on from low-energy experiments at BNL-ATF, [2] RBS will install a much larger and powerful system for removing the chirp from the 3-GeV beams in the LTU section at LCLS. The larger plates will present new challenges in the areas of manufacturing and mechanical control. In this paper we review the requirements for the dimensions of the corrugated plates for proper operation and the infrastructure necessary for precisely placing the plates so as not to adversely disrupt the beam.

INTRODUCTION

Following the successful proof-of-concept dechirper experiment at Brookhaven National Laboratory, [2] RadiaBeam Systems presents here plans for a scaled-up corrugated plate dechirper system for use in the 3-GeV Linac-To-Undulator (LTU) section at Linac Coherent Light Source (LCLS). The system will be designed to completely remove the residual chirp left over from the earlier compression sections. Prior beamlines required up to hundreds of meters of accelerating cavities running off-crest in order to lower the energy spread of the beam bunch enough for use in undulator light sources. The system described in this study will completely remove the chirp from the LCLS beamline with only two two-meter sections

CORRUGATED PLATES

The wakefield of a single electron is approximated by

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

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

$$\lambda = 2\pi\sqrt{\frac{a\delta g}{p}}. \quad (2)$$

The rest of the dimensions (a, δ, g, and p) refer to dimensions of the corrugations, detailed in Table 1 and Fig. 1.

The total wakefield of the bunch forms a linear region over the bunch. The slope of this region determines the dechirping strength, h, is given by

$$h = \left(\frac{\pi^2}{16}\right)\frac{Z_0 cQL}{\pi a^2 l}, \quad (3)$$

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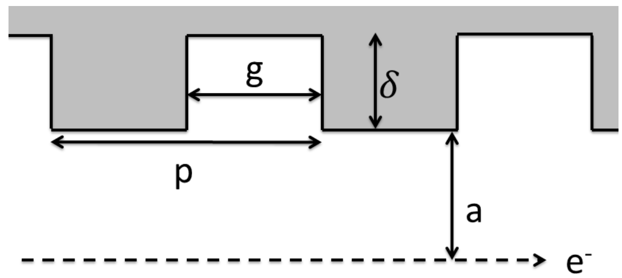

Figure 1: Dimensions of corrugated plates. See Table 1.

Table 1: Corrugated Plate Dimensions

Length	L	4.0	m
Width		12.7	mm
Period	p	0.51	mm
Depth	δ	0.51	mm
Gap	g	0.25	mm
Plate separation	a	1–30	mm
Material		Aluminum	

where Q is the bunch charge, L is the length of the dechirper, and l is the bunch length. More accurate simulations of the wakefield ([3] [4]) show this to be an overestimation by factor of about 1.5, but Equation 3 serves to motivate the dimensions of the corrugated plates.

From Equation 3, the most important dimension in the corrugated plate dechirper is the gap between the plates and the total length. Dechirping power scales proportionally with L and $1/a^2$. Balancing beamline space and the minimum size of the beam determines the overall size constraints. The other dimensions—period, depth, and gap—are only constrained by the wakefield equations to being much smaller than a. [1] Specifically,

$$\delta, p \ll a \qquad h \geq 0.8p \qquad t = p/2. \quad (4)$$

For the LCLS dechirper, a total length of four meters (split into two equal length sections) was chosen to have a design gap ($2a$) of 1.4 mm. [3] A two-section dechirper also allows for cancellation of unwanted transverse quadrupole effects (to be discussed in the Other Considerations section.

The material of the corrugated plates was chosen to be aluminum because of its light weight and easy machinability. As long as the fundamental mode of the wakefield is dominant, the conductivity of the metal is unimportant. [5] To ease manufacturing and installation, the corrugated plates will be made in several section each 0.5 meters long. Numerous simulations have been run to determine the tolerances on manufacturing and they are within range of convention CNC machines with end mills and slit saws. [6]

IN-VACUUM ASSEMBLY

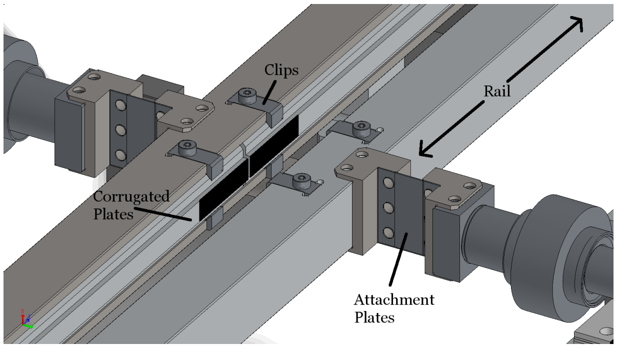

Figure 2: Drawing of the in-vacuum dechirper system.

The machined corrugated plates will be attached to 2-meter long aluminum rails which will also serve to keep the plates aligned with each other and the beamline (see Fig. 2. The plates will be held with clips to facilitate installation and replacement in case of damage to one plate. The rail will be attached to support shafts by means of attachment plates that will be slightly flexible to allow for the adjustment of the parallelism of the plates. The entire system will be housed in 6-inch (150-mm) diameter vacuum nipples. The support shafts are attached to flanges mounted on edge-welded bellows for motion feedthrough.

MOTION

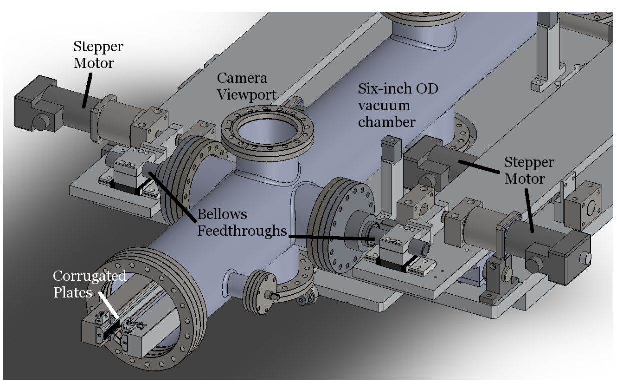

Figure 3: Drawing of dechirper system showing the vacuum chamber than will contain the corrugated plates, stepper motors, and bellows.

The edge-welded bellows are actuated by by NEMA 23 stepper motors, two per rail. The stepper motor nearest the vacuum chamber (middle of Fig. 3) controls the separation of the plate, while the far motor (right of Fig. 3) adjusts the parallelism of the plates. The stepper motors will act through a gear-reducer to lessen the torque required, reduce the linear travel per step, and provide a natural brake in case of power or motor failure. Position feedback will be provided by Daytronic DS2000LC LVDTs, two per rail, with an accuracy of 50 μm. An Aerotech Epaq MR motion controller will control the actuation of two of these dechirper systems. Two cameras mounted on viewports at either end of the vacuum chamber will provide visual assessments of the separation and alignment of the corrugated plates.

OTHER CONSIDERATIONS

One of the consequences of using flat plates instead of the cylindrical geometry as originally proposed in Bane and Stupakov's paper [1] is that additional transverse wakefield components will be generated by the passing beam with magnitude that scales as $1/a^4$. [3] Dipole wakefields, which have a similar effect to transverse deflecting cavities, arise due to the beam being off-center between the plates. This can be mitigated through careful positioning and alignment of the plates during installation and with the motors. Quadrupole wakefields can be greatly reduced in magnitude by operating two dechirpers, one with horizontal actuation (vertically-oriented corrugated plates) as in Figs. 3 and 2, and one with vertical actuation (horizontally-oriented plates). This arrangement is similar to a FODO arrangement of quadrupole magnets and minimizes the effect of the induced quadrupole wakefield.

The beam to be used in the commissioning of the new dechirper system at LCLS is described in Table 2.

Table 2: LCLS Beam Parameters

Beam energy	6.6	GeV
Beam charge	250	pC
Peak current	1.2	kA
Rep rate	120	Hz

In case of beam loss that hits the dechirper plates, the upstream sides of the dechirper rails will be fitted with shields of tungsten or lead.

While an active cooling system will not be necessary for the LCLS system, it will almost certainly be necessary for high-power CW systems like the planned LCLSII. RadiaBeam is studying methods of actively cooling the dechirper plates as they may have to dissipate kilowatts of power.

CONCLUSION

RadiaBeam Systems plans to install this dechirping system at LCLS in August 2015. There, it will undergo a battery of tests to determine its dechirping efficacy as well as its transverse effects on the beams transverse profile, motion, and emittance.

ACKNOWLEDGMENTS

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