

IMPLEMENTATION OF A CORRUGATED-PLATE DECHIRPING SYSTEM FOR GeV ELECTRON BEAM AT LCLS

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Abstract

A new corrugated-plate Dechirper was recently installed in the LCLS and underwent commissioning tests to gauge its efficacy in shaping the longitudinal phase space of bunches entering the FEL. Here, we describe in detail the completed four-meter LCLS Dechirper system along with a narrative of its construction. We detail the various challenges and lessons learned in the manufacturing and assembly of this first-of-its-kind device. An outlook on future designs is presented.

OPERATIONAL SUMMARY

The dechirper uses corrugated conducting plates to shape an electron bunch's wakefield to passively remove the linear energy chirp leftover from bunch compression chicanes. Unlike prior chirp-removal strategies like running RF accelerating structures off-crest and utilizing the wakefields from bare beam pipe, this device requires no input power and requires only a few meters to perform the electron bunch adjustment. Theory and previous devices and experiments have been extensively covered in the literature [1–3].

DESIGN REQUIREMENTS

The design of the corrugated-plate dechirper is primarily driven by three considerations:

1. Providing enough dechirping power to remove and reverse the chirp of the beam to control the FEL bandwidth,
2. Minimizing transverse dipole and quadrupole effects that spoil emittance,
3. Preventing interception of the beam by the corrugated plates.

Because the amount of chirp removed is proportional to the length and inversely proportional to the square of the gap, the first consideration requires a long total length and a small gap. The deleterious transverse effects in the latter two points are inversely proportional to the cube of the gap, requiring a larger gap to maintain beam quality. The quadrupole effects can be further mitigated by combining two dechirper modules—one with the plates above and below the beam and the other with plates to the left and right, an arrangement reminiscent of a FODO quadrupole cell. After in-depth discussions with SLAC, the parameters for operational efficacy (listed in Table 1 and shown in Fig. 1) and machine protection and beam quality maintenance (listed

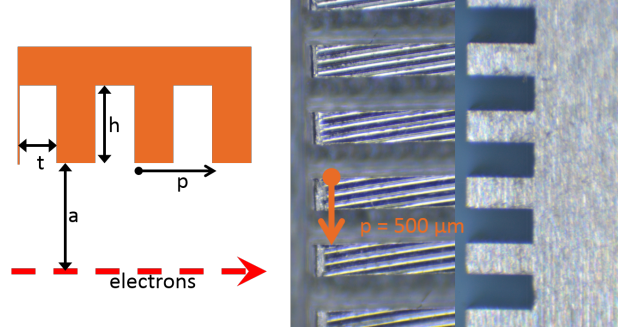


Figure 1: (left) Diagram of corrugated plate parameters. (right) Magnified view of corrugations

in Table 2) were set. In depth discussions of these issues are discussed in SLAC internal reports [4].

Table 1: Corrugated Plate Dechirper Parameters

Parameter	Symbol	Value
Number of modules		2
Length of corrugation jaws	L	2.02 m
Gap range	$2a$	1–25 mm
Chirp-removal gap	$2a_0$	1.4 mm
Corrugation period	p	500 μm
Slit thickness	t	250 μm

Table 2: Corrugated Dechirper Plate Tolerances

Parameter	Value
Corrugation tip flatness	50 μm
Position accuracy	10 μm

NOTABLE CONSTRUCTION ISSUES ENCOUNTERED

The corrugated blocks were manufactured in 50-cm sections to make it easier to meet the flatness requirements and to save time in case a section of corrugations was damaged during machining, cleaning, installation or transport. The length was chosen to be short enough to minimize bending due to machining and to maximize unattended machining time. Each block was inspected by RadiaBeam's own CMM individually for corrugation tip flatness and overall flatness to direct shimming during installation onto the I-beam strong-

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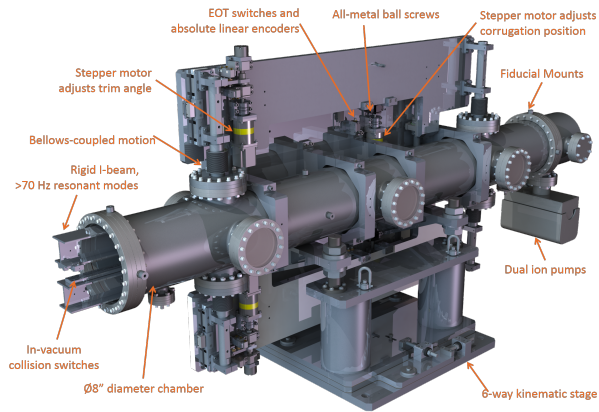


Figure 2: CAD rendering of vertically actuated dechirper. LVDTs were added after construction and installation and are not shown here.



Figure 3: Both dechirper modules as installed in the SLAC LCLS. Between the two modules is a quadrupole magnet.

back. The corrugated blocks were then cleaned and mounted onto the strongback (Fig. 2).

The original design for the strongback onto which the corrugated blocks would be mounted consisted of a trough that would hold the blocks and while the vertical sides would provide collision protection at the same time. However, LCLS vibrational requirements necessitated that the strongback be much lighter and stiffer to bring the resonant vibration mode above 60 Hz. The new strongback design, which is installed in the dechirper, is an aluminum I-beam with tight tolerances on flatness and small raised portions where the corrugated blocks are fixed. Empty space is left beneath most of the blocks to prevent trapped gas from creating virtual leaks once the chamber is pumped down. In the case of the rails being brought too close together and the corrugations colliding, a hard stop is installed at the ends of each rail which extend a small distance above the corrugation tips. These will collide before the more delicate corrugations.

The design of the dechirper began in April 2014 and lasted through December 2014 culminating with the Final Design Review. This included a manufacturing study during the summer of 2014 to determine the most efficient way (both in terms of time and cost) to manufacture the fine features of the corrugations. The horizontal module was delivered to SLAC in early August 2015 and, after final acceptance, was installed in late August. The vertical module was delivered in late August and installed in early September.

DISCOVERIES DURING INSTALLATION AND COMMISSIONING

Installation of the two dechirper modules in the SLAC LCLS is shown in Fig. 3. The corrugated plates were examined with SLAC's coordinate measuring machine (CMM) in order to measure overall flatness, corrugation tip height consistency, and motion accuracy. It was found that only removing shims was required for the corrugated blocks to meet the flatness requirements of no more than 50 μm of height variation over the 2 m length of the dechirping rails.

The position feedback system was found to be inadequate due to stiction issues when moving both ends of the rail with a single motor. This was addressed by adding four LVDT position monitors to the shaft furthest from the gap-adjusting motor.

In experiments with the dechirper, SLAC LCLS has found other ways to use the dechirper:

- Closing the gap between the rails to smaller than the nominal gap reverses and increases the chirp to allow FEL bandwidth control [5].
- Running the beam off-center through the dechirper makes it act as a passive streaker [6].
- Combining transverse kicks and longitudinal phase space adjustments can produce two-color output from FELs [7].

FUTURE ITERATIONS

Plans are already underway for future dechirpers at LCLSII and other labs worldwide. Many lessons have been learned which will be put to use in the design of future dechirpers.

The reason a single motor is used to actuate both ends of a corrugated block rail is that it was considered desirable to be able to adjust the gap between the rails and the angle between the rails independently. However, it was observed during commissioning that it is difficult to keep the motion of the end of the rail farthest from the motor moving smoothly as a slight torque would jam the bearings against the motion rails. For future dechirpers, RadiaBeam is considering placing motors at each end of the rail (despite this requiring two-motor coordinated motion for gap adjustment) or a more constrained rail system (which risks worse jams due to over-constraint). Furthermore, position feedback encoders should be directly attached to the shafts which attach to the jaws in-vacuum to provide the most direct indication of the position of the rail ends.

To avoid delays due to adjustments, it will be necessary to confirm the tolerances of the corrugated blocks and rails as a fully assembled system, instead of separate pieces, as it was found that the assembly process can have a large effect

on the flatness error stackup. To better maintain flatness, shorter corrugation blocks will be designed since these will bend less during machining.

Future dechirpers will also have the following features as needed:

- Beam position monitors affixed to the ends of the rails to aid in beam-based alignment
- A single-rail version for passive streaking comparable to an RF deflecting cavity
- Water cooling for high-power MHz-class beams
- Improved position monitoring with 10- μ m accuracy

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