Design of the Bunch-Length Monitors for the new Superconducting LCLS Linac

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Abstract

The LCLS x-ray free-electron laser at SLAC uses the third km of the original 3-km copper linac. We are now installing LCLS-II, a superconducting linac that replaces the first km. Two undulators, for hard and soft x rays, will be driven by bunches from either linac. One of the solutions developed at SLAC involves a pyroelectric detector, which converts the infrared emitted by the electron bunch into voltage by measuring fast changes in the temperature of the detecting crystal. Not only are the pyrodetectors used at SLAC but also a method with gap diodes. The radial electric field produced by the bunches leaks through a ceramic gap in the beampipe and is collected by a horn antenna and conveyed through a one millimeter waveguide. The waveguides act as a filter, only passing shorter wavelengths and a zero-bias Schottky diode measures the power. In both methods, a portion of the spectral energy emitted by the bunch is intercepted. After normalizing to differentiate between bunches of the same length with different charge, the detected signal is sensitive to only changes in bunch length. This poster discusses the mechanics and optics behind the LCLS-II bunch length monitors' operations and plans for collaboration.

Background

- This paper describes the physics requirements and implications for instrumenting the single-shot relative bunch length monitors (BLM) based on coherent edge radiation (CER) at the end of the LCLS-II bunch compressor chicanes.
- It also describes the physics requirements and implications for instrumenting single-shot, diode-based relative bunch-length monitors (BLEN) based on radiation picked up from a ceramic break in the vacuum pipe and coupled to a GHz detection diode. [2] [3]

Pyroelectric Detector

- A mirror with a long, vertical slot for the electron beam will be insertable into the beamline to reflect the upstream coherent edge radiation (CER) from the fourth bend magnet (B4) out of the vacuum chamber.
- The CER will then be sent up into the optics box containing the diagnostic. Once in the optics box, the CER will be guided by a couple of off-axis parabolic mirrors.
- Then it will pass 4 insertable filters followed by a beam splitter. It is meant to image the CER onto two identical pyroelectric detector elements.
- There are two pyroelectric detectors for redundancy in the event of a single element failure. Detectors will include preamplifiers with remotely selectable gain.

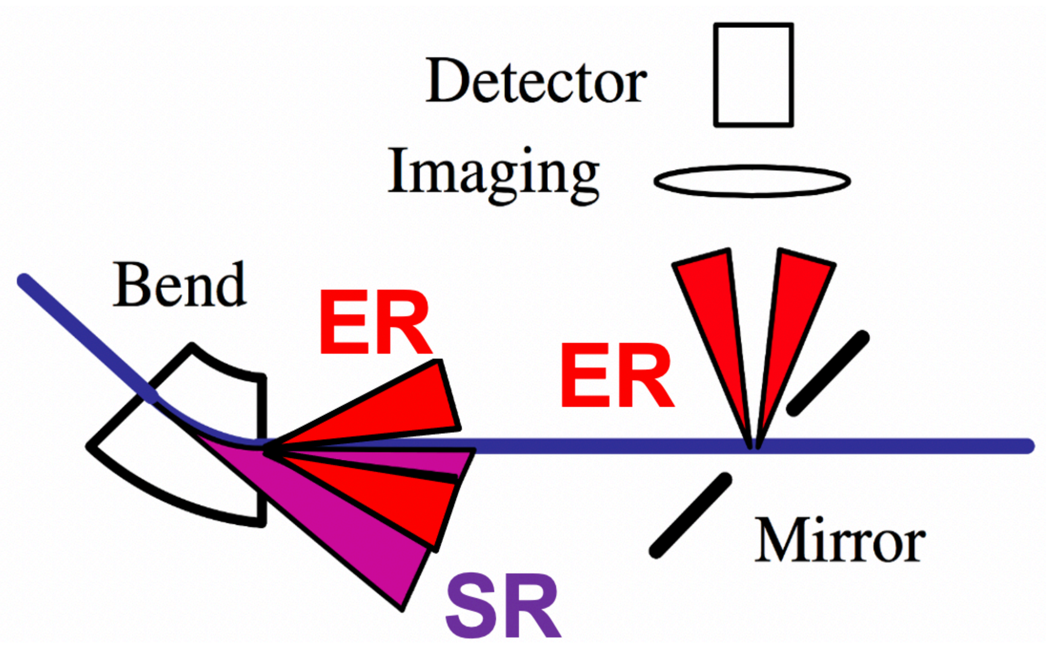

Figure 1: Diagram of the Capture of Edge Radiation

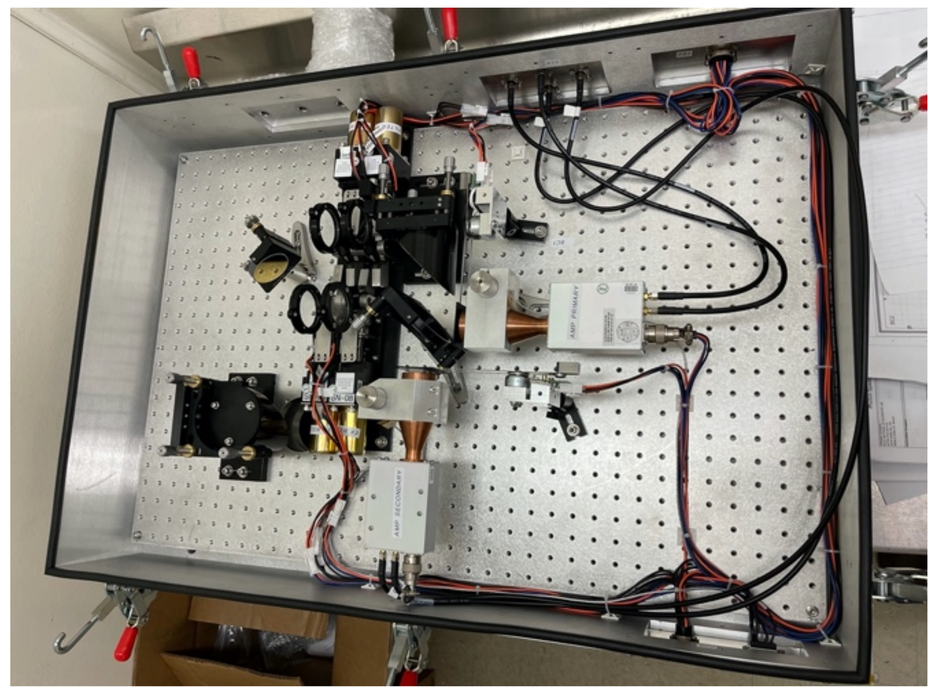

Figure 2: Picture of the completed Optics Box

Ceramic Gap-Diode

- As the electron travels in the +z direction along the beamline, it radial emits an electric field in the r direction for all theta.
- The beam then traverses a ceramic break in the vacuum pipe. The ceramic gap is covered in circular apertures in a metal shield.
- Two sets of diametrically opposed, pyramidal, high-frequency (GHz-THz) RF horns are placed outside the ceramic gap in the vacuum pipe. These horns pick up signal from the electron bunches by shrinking to the size of the waveguide.
- The waveguides elongate and attenuate pulses, filters out wavelengths of RF that are unsatisfactory, and are finally measured by high-frequency, Schottky-diode detectors. The diode measures the power, and the power can be interpreted as a bunch length.
- Lastly, like the pyroelectric detector method, the power readings must be normalized to differentiate between bunches of the same length but different charge.
- Summing the two opposing horns reduces sensitivity to an off-axis beam. With proper selection of the frequency of the diodes and waveguides, this sum is inversely proportional to the electron bunch duration.

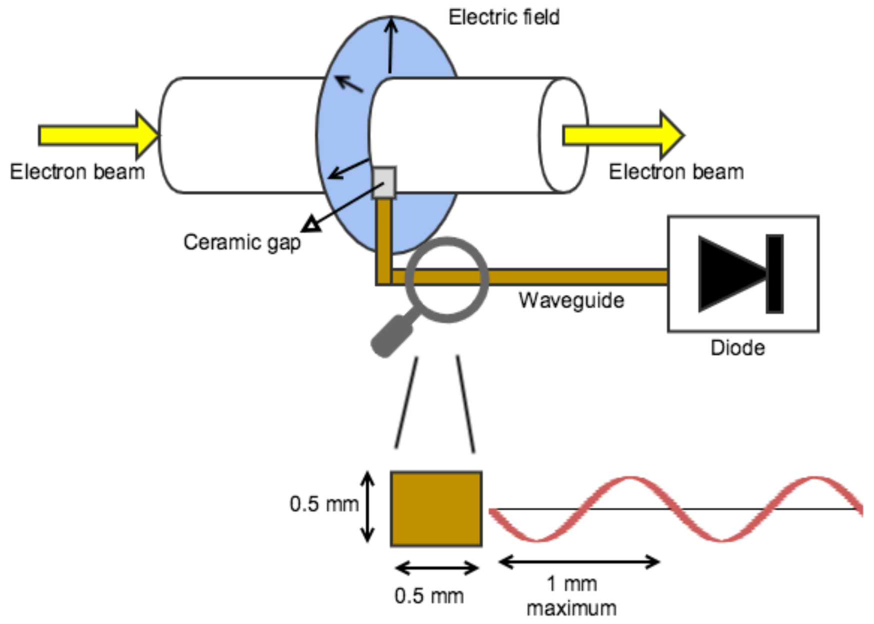

Figure 3: Diagram of Gap Diode Bunch Length Monitor Mechanism

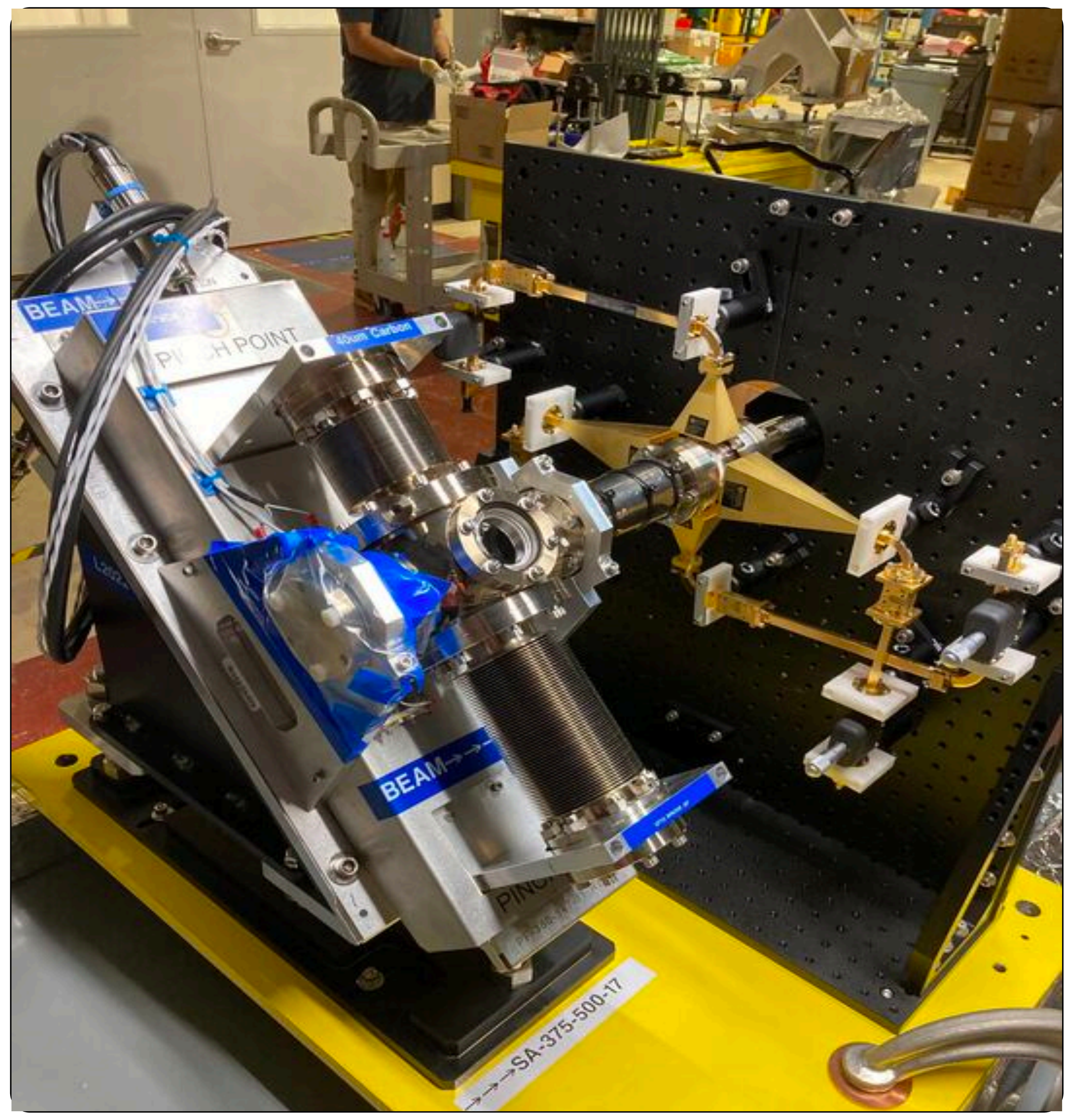

Figure 4: Picture of Gap Diode BLM Mechanism on optical breadboard

Conclusions

- Both pyroelectric detector method and the ceramic gap-diode method for the superconducting LCLS-II solve the problem of needing a single-shot monitor with longitudinal feedback. Both have already been constructed and await use when the LCLS-II is commissioned.

References

[1] H. Loos, T. Borden, P. Emma, J. C. Frisch, and J. Wu, "Relative Bunch Length Monitor for the Linac Coherent Light Source (LCLS) using Coherent Edge Radiation", in *Proc. 22nd Particle Accelerator Conf. (PAC'07)*, Albuquerque, NM, USA, Jun. 2007, paper FRPMS071, pp. 4189-4191.
[2] T. Maxwell, J. Chan, T. Raubenheimer, D. Schultz (2021) "Single-shot CSR Relative Bunch Length Monitor Requirements". *Unpublished draft.*
[3] A. Fisher, T. Maxwell, J. Chan, P. Emma, D. Schultz (2021) "Gap Diode Bunch Length Monitor Requirements". *Unpublished draft.*