Introduction

Develop diagnostic for computer control and high current beams based on edge radiation

• Ideal for computer control: single shot, beam isn’t interrupted
• Ideal for high current beams: diagnostic not destroyed by high currents
• We generate edge radiation all the time in bunch compressors, every accelerator has bend magnets
  • Can combine different sources, i.e. transition+edge, diffraction+diffraction
• Theoretically sensitive to beam divergence and energy spread

![Diagram showing edge radiation setup with filter, camera, and wavelength spectrum graphs](attachment:image.png)
How the diagnostic works

Intensity pattern includes information from emittance and energy spread

\[
\frac{d^2I}{d\Omega d\omega} = (E_1 + E_2)(E_1 + E_2)^* \\
= |E_1|^2 + |E_2|^2 + 2E_1E_2^* 
\]
Current Progress

Develop hardware capabilities in stages

- Windows are most challenging to install, they require engineering + fabrication + downtime
  - Currently examining BC20
- Cameras + optics are somewhat easier to install
  - Cameras in DL, BC11
  - Cameras in BC14 do not last long
  - Bring over rad fets? Shielding?
- Simulations, machine learning implementation, moving to real time all happen contemporaneously
Demonstration that emittance measurement works

- Emittance, alpha, beta are measured just upstream of the dogleg
- An average measurement, integrating over many shots
- Variations not captured
- Neural Network is trained to determine the beam sizes at the three locations from the images
- Neural Network then determines the emittance on each shot
  - The red Xs are single shot determination of emittance

\[ \text{Emittance} [\text{um}] \]
\[ \text{ML + Edge Radiation} \]

\[ \text{Emittance} [\text{um}] \]
\[ \text{Traditional} \]
\[ x \quad \text{ML + Edge Radiation} \]

\[ \text{Traditional Diagnostic} \]

Compare to emittance measure via OTR foil

\[ \sigma_{A,11} \quad \sigma_{B,22} \quad \sigma_{C,22} \]

\[ \sigma_{A,11} \quad \sigma_{B,22} \quad \sigma_{C,22} \]
• Goal is to get to fast analysis that can, on a shot-by-shot basis, determine “this beam is different from that beam”
• Enables experimenters to discriminate between shots
  • i.e. threshold used to calculate emittance using other techniques
• Online tuning friendly
  • Control applied to move to “better”, or hold better over time
• Work on concrete challenge of pushing analysis live
Use machine learning + differential simulations to get detailed and quantitative

- Analytic solutions do not exist for any beam distribution, but simulations are well benchmarked

- Developed differential GPU code to generate beam distributions from radiation patterns (submission soon)

- Shot-by-shot data shows wide variation in interference intensity and location
  - Potential wealth of information
Future Plans + Next Shifts

Develop a diagnostic that uses machine learning to do machine control (and more machine learning)

- Understand method to separate beams quasi-quantitatively
  - Deploy functions for the DAQ that users can use during experiments
- Develop plan for diagnostics in S14 and S20 - high current!
- Generate beam parameters and distributions from single cameras
  - Need to be confident that changes to interference are a beam effect
- Develop plan for experiments at LCLS-II
  - There is a dogleg that looks perfect in the BSY

Next shifts:
- Interference vs laser heater energy (3 nC)
- Iterate on optics and camera choices to improve signal-to-noise