Polarization Analysis of the LCLS Beam in the Soft X-Ray

SLAC NATIONAL ACCELERATOR LABORATORY

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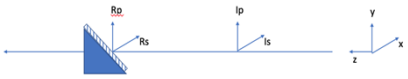
Introduction

The purpose of this project was to determine the degree of linear polarization of the FEL radiation. During this project, I also used and learned about many useful data analysis techniques and tools.

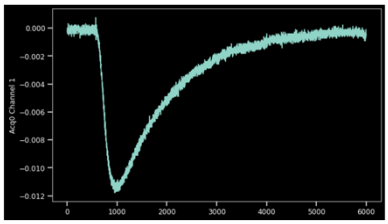
Research

The FEL radiation hits the multilayer, angled at 45 degrees, is reflected in the x and y direction, and is measured by a diode. The multilayer is rotated around the beam axis (z axis). Below is a diagram of the set up of the experiment.

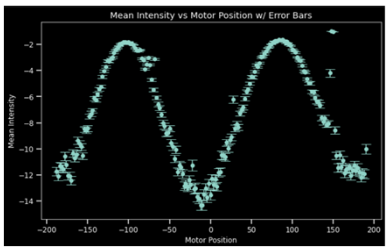


I used Jupyter Notebook as a Python IDE. Python packages that I used included NumPy and Matplotlib.

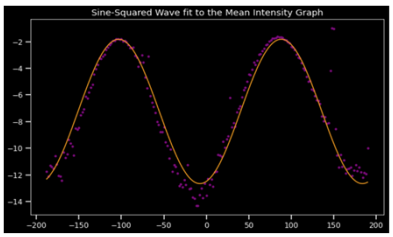
Initially, the readings from the diode resembled the waveform below.



For each shot the waveform was integrated. These integrated sums were averaged for each motor position to get the mean intensity for each motor position. Graphing the mean intensity for each motor position yielded a graph like the following.



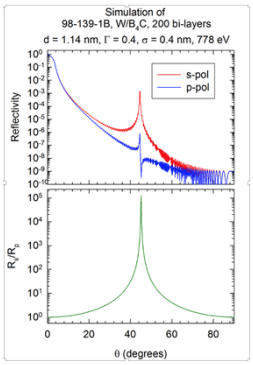
The data was fitted with a sine squared curve to the graph, and then extracted the maximum and minimum values with the maximum corresponding to $I_{0°}$ and the minimum corresponding to $I_{90°}$, in the following equation. This was done using the Python package lmfit.



To calculate the degree of linear polarization of the FEL, the given equation was used.

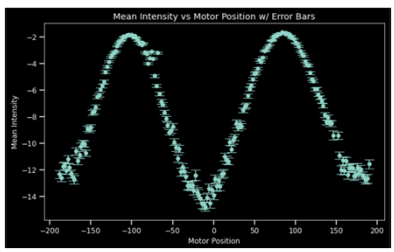
$$P_L = \frac{(R_S+R_P)(I_{0°}-I_{90°})}{(I_{0°}+I_{90°})(R_S-R_P)}$$

The CXRO calculator[1] was used to find the value of the constants Rs and Rp using the given energy of the laser, the material of the multilayer, and the angle of incidence of the laser with the multilayer. The peaks of s-pol and p-pol were used for Rs and Rp respectively.



From this point onward, we worked on improving the results and accounting for other factors. Previously, it was estimated the degree of linear polarization of the FEL would be close to 98 percent. The degree of linear polarization was closer to 85 percent.

As seen in the mean intensity graph from before, there were outliers. To reduce noise and outliers, the shots used to calculate the mean intensity were filtered based on a threshold set by the GMD intensity data. With this method, the mean intensity graph had fewer outliers and was smoother, also resulting in a higher degree of linear polarization.



Further Work

Further work on this project would include eliminating noise from the data and accounting for other factors. For instance, there were other filters interacting with the FEL, which affected the calculated degree of linear polarization. Below is a list of items that were beginning of be addressed.

- Accounting for the Co filter that had also interacted with the FEL
- Normalizing the mean intensity through the GMD intensity data or through other means
- Error propagation for the degree of linear polarization
- Background correction

Extra

- Spoke with Chantal Mustoe and Yue Wang about their experiences and projects involving Machine Learning
- Volunteered at the SAGE Summer Camp
- Attended talks by speakers, including Andy Aquila and Susan Wojcicki
- Participated in HXR commissioning of LCLS

Conclusions

During this project, we created a method for analyzing polarization data. From the preliminary data analysis, we were able to calculate the degree of linear polarization without accounting for other factors. Personally, I was able to learn a great deal about the tools and procedures for data analysis in Python.

Acknowledgments

I owe a great deal to Stefan Moeller for mentoring me this summer. This opportunity introduced me to the research happening at LCLS and improved my Python skills. Additionally, I'm grateful for Vincent Esposito, Silke Nelson, and Matt Seaberg for setting up access to the necessary environment and data for this project and for guiding me through learning Python. It's been a pleasure to have mentors like you all and it's impossible for me to express how much I've gained through your mentorship.

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[1]https://henke.lbl.gov/optical_constants/multi2.html

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