Matter in Extreme Conditions at LCLS: EMP Analysis and FLASH Simulation

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Introduction

The Matter in Extreme Conditions End Station allows for the study of high energy density physics through the interaction of matter with high intensity lasers. MEC is a user facility dedicated to meeting the needs of its users. To this end, two such projects were carried out the summer in order to better equip MEC with the capabilities to do so. One focused on diagnosing and analyzing the source of EMP interference within the target chamber, and the second focused on developing the architecture to better simulate experiments ahead of time to predict the results.

Keywords: LCLS, MEC, electromagnetic pulse (EMP), FLASH code

EMP Research

Within the MEC target chamber, an intense laser pulse interacts with solid metal targets, releasing free electrons into the target chamber. The current flow of these electrons radiates an electromagnetic pulse (EMP) throughout the chamber which disrupts the function of various detectors. Though the effect can be minimized with shielding, this solution does not scale well as the laser intensity is upgraded, and a more robust understanding of the phenomenon is desired.

This goal of this project is to analyze the difference in EMP signal for runs where the target is mounted on aluminum cartridges versus polyether ether ketone (PEEK) plastic cartridges. The signal is recorded by two "B-dot" sensors positioned (one vertically and one horizontally) within the target chamber. The EMP spectrum and the background signal on the detectors will be compared in order to investigate the effectiveness of a plastic target holder in reducing EMP.

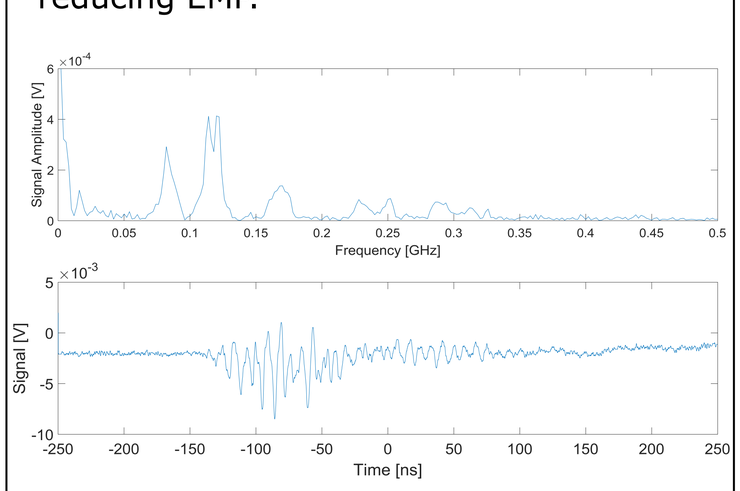

Fig 1. Example EMP signal and Fast-Fourier Transform from an aluminum target holder (Run 164).

EMP Spectrum Analysis

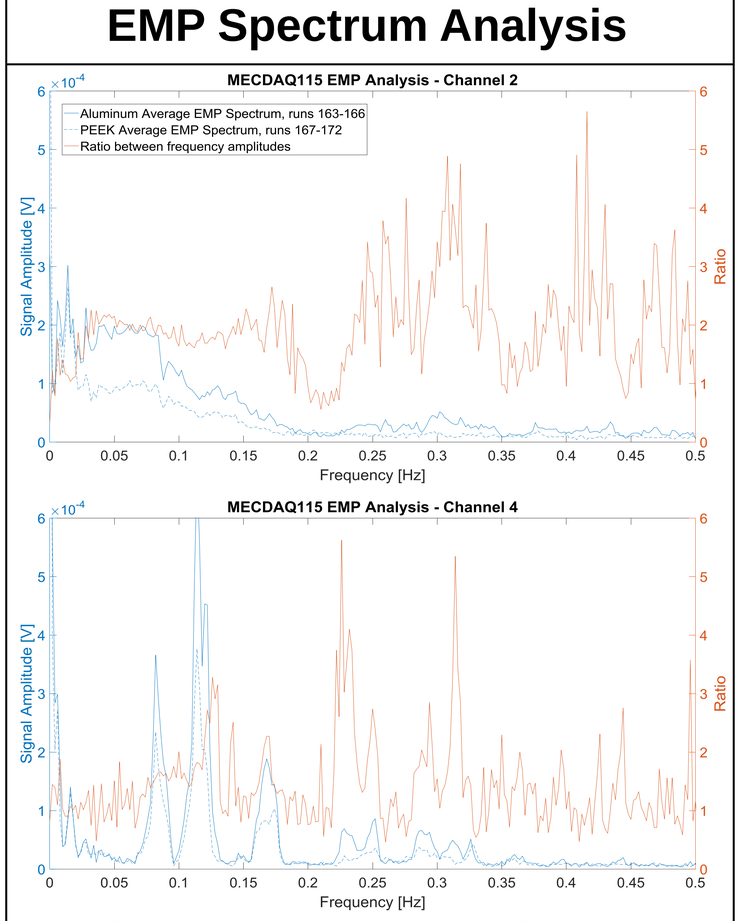

Fig 2. Comparison of signal strengths between aluminum and plastic runs. The signal is significantly reduced on plastic, especially for higher frequencies. We note that the spectrum is more readily apparent in Channel 4, indicating the source is likely a vertical current. We also that the spectrum frequencies correspond to wavelengths comparable to the dimensions of the entire chamber, not just the target holder.

CSPAD Noise Analysis

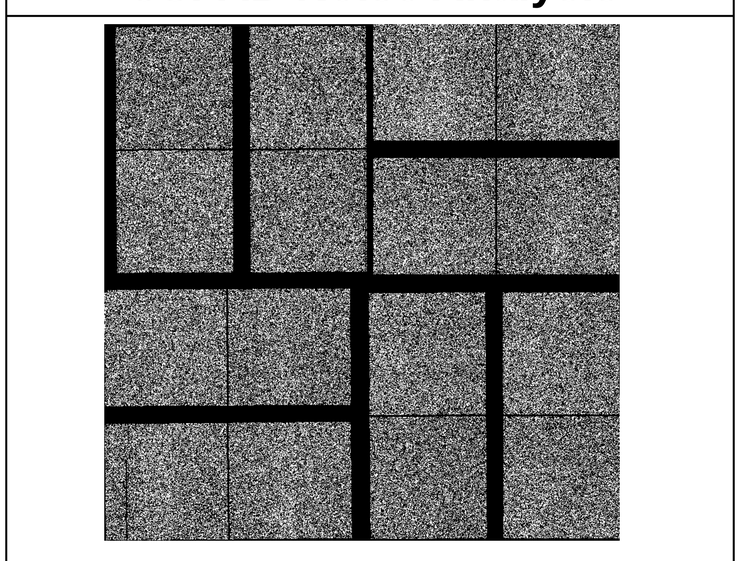

Fig 3. (a) Example CSPAD background noise (b) Histogram of intensities on CSPAD images for various runs. We note a higher slant towards negative values in Plastic runs, indicative of noise present in our aluminum calibration shots.

FLASH Simulations

A secondary project worked on over this summer is the integration of PrOpacEOS generated equation of state (EOS) tables and FLASH code simulation in order to better simulate future experiments run in MEC. Doing so would allow the simulations to be fine tuned, in order to replicate current observations with better accuracy.

Currently, the EOS tables have successfully been converted to a usable format, however they require the simulation parameters to be altered. At this time, a non-trivial simulation using these tables has yet to be run successfully.

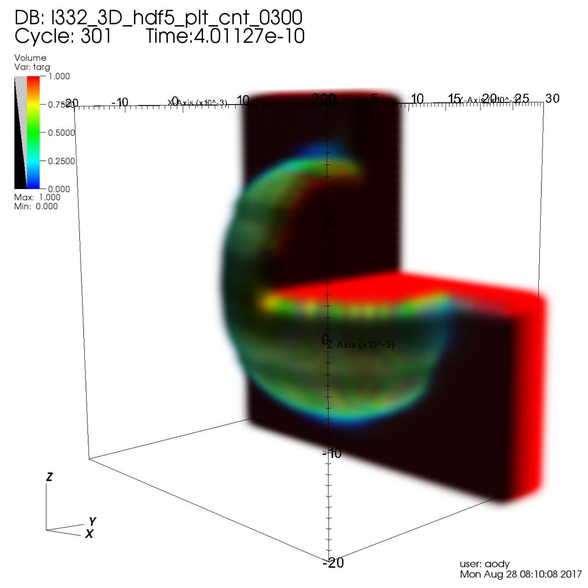

Fig 4. A Visit visualization of a FLASH simulation describing the time evolution of an aluminum target shot by the long pulse laser in MEC.

Conclusions

EMP analysis has successfully shown the need for further diagnostic shots with a more robust sensor array. As well, we have potentially identified a source of the EMP in the target stands due to frequencies observed and the apparent orientation, which we will investigate in future diagnostic shots in the target chamber.

Work on integrating the use of more robust EOS tables with greater tunability in FLASH continues. Though we could not run a successful simulation at the time of writing this poster, we are hopeful that we will have confident simulation based predictions in the coming months.

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