Electromagnetic Pulse Detection Data Analysis

Jennifer Chun[1], Eric Galtier[2], Dimitri Khaghani[2], Meriame Berboucha[2], Florian Condamine[3], Philip Hart[2], Ariel Arnott[2]

1) Department of Computer Science and Mathematics, San Jose State University, San Jose, CA 2) MEC, SLAC National Accelerator Laboratory, Menlo Park, CA 3) Extreme Light Infrastructure Beamlines, Prague, Czech Republic

Introduction and Goals

- Electromagnetic pulses (EMPs): short bursts of electromagnetic signal; byproducts of laser interaction with a target (interaction point)

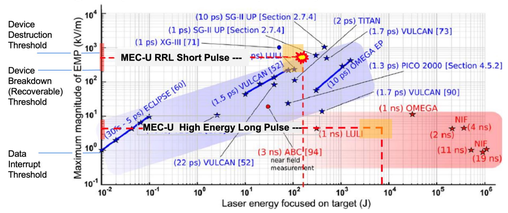


Fig 1: MEC–U plans based on other laser experiments [1]

- EMPs interfere with instrumentation
  - EMP mitigation is crucial for laser experiment data collection
- Main goal: analyze EMP components to assess future EMP mitigation techniques and data collection adjustments for the Matters In Extreme Conditions (MEC) and its upgrade project (MEC-U)

Experimental Setup

- Utilized EMP data from Extreme Light Infrastructure (ELI) Beamlines facility
  - Higher laser energy and EMP strength to current MEC laser

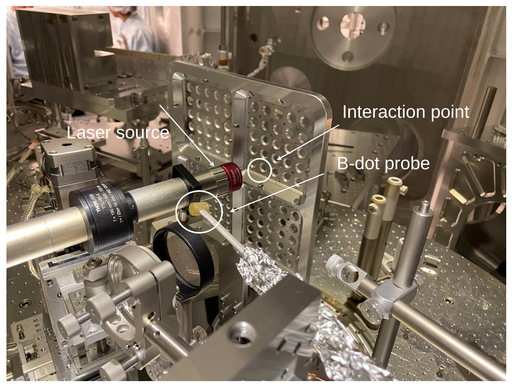


Fig 2: ELI experiment setup w/ B-dot and target holder

- Important B-dot experimental values
  - Area of antenna (A_{eq}): 2e-5 m^2
  - Frequency response: 5.4 GHz

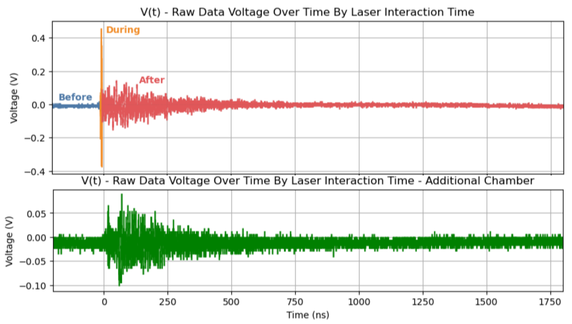
Data Analysis

Time Domain

$$F(\omega) = \int_{t_0}^{t_1} f(t)\, e^{-i\omega t} dt$$

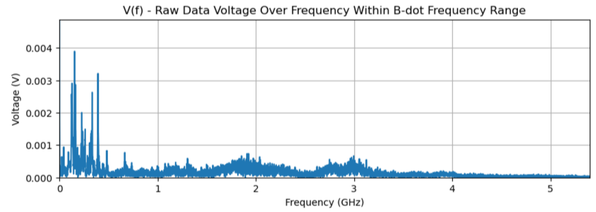
Frequency Domain

V(t) – Raw Voltage Output



Fourier Transform (entire data)

V(f) across Entire Data



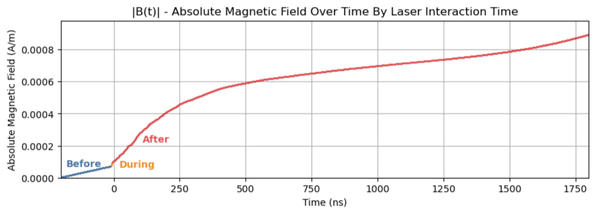
Defined amplitude peaks in the 0 – 1 GHz frequency range
A wide spectrum of notable frequency wavelengths until roughly 3.2 GHz

EMP output is comprised of 3 notable sections
Signal is a result of probe orientation

$$\left|\vec{B}(t)\right| = \frac{1}{A_{eq}} \int_{t_0}^{t_1} |V(t)|\, dt$$

Fourier Transform (by section and in expected frequency range)

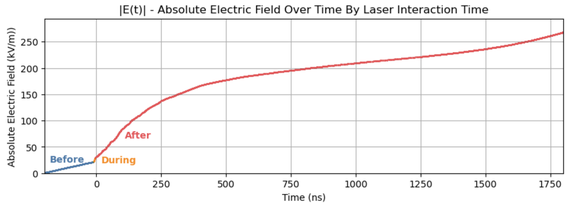
|B(t)| – Absolute Magnetic Field



Length of time of a section is more important to magnetic field than the average amplitude
Output not approaching a limit value

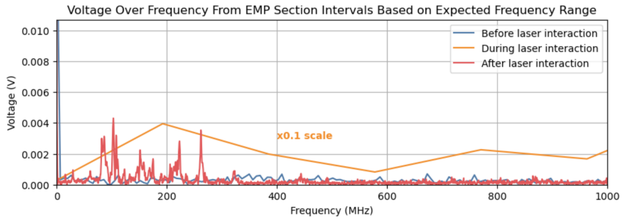
$$\left|\vec{E}(t)\right| = c\left|\vec{B}(t)\right|$$

|E(t)| – Absolute Electric Field



Current E(t) is currently not deconvoluted to account for equipment setup attenuation

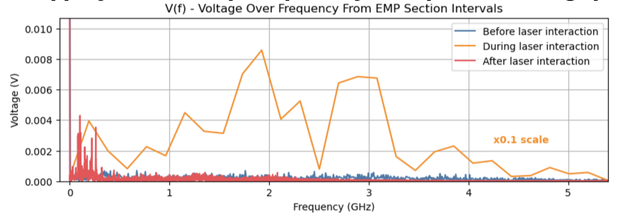
V(f) by Section (Predicted 1000 MHz Range)



Each section of EMP output has distinct frequency ranges and amplitudes
"During" section doesn't have many distinct frequency values within chosen range

Zooming out to frequency response range of 5.4 GHz

V(f) by Section (Frequency Response Range)



"During" section covers wide frequency range, most notable range up to 3.2 GHz

Takeaways

- Distinctly different areas within EMP data
  - Long-lasting "after" section responsible for strong electric field
    - Break down EMP into smaller components for proper analysis
- Direct correlation btwn laser strength and EMP output's time and frequency range
  - MEC's 1800 ns and 1000 MHz ranges exceeded by ELI data's ranges
    - Take more data points of EMP

Next Steps

- Deconvolute magnetic & electric field using known experiment equipment factors (wires, distance from target, etc.)
- Benchmark deconvoluted data with recorded ELI EMP measurements
- Utilize electromagnetic field simulation software to verify calculations
  - Modeling software instrumental in MEC-U development

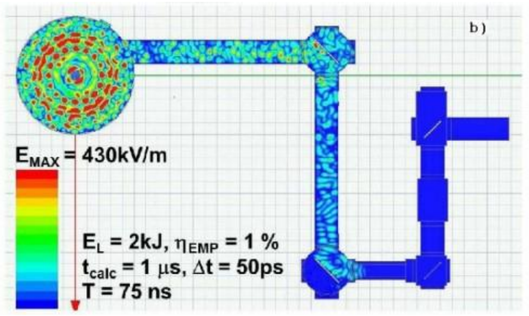


Fig 3: Electric field snapshot, example of how EM simulation software could work [1]

Acknowledgments

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References

[1] Consoli, Fabrizio, et al. "Laser produced electromagnetic pulses: Generation, detection and mitigation." *High Power Laser Science and Engineering*, vol. 8, 2020, https://doi.org/10.1017/hpl.2020.13.