Exploration of Magnetic-Field Generation via Biermann Battery Using the FLASH Code to Model Experiments Performed at UCLA's Phoenix Laboratory

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Department of Physics and Astronomy, University of California, Los Angeles

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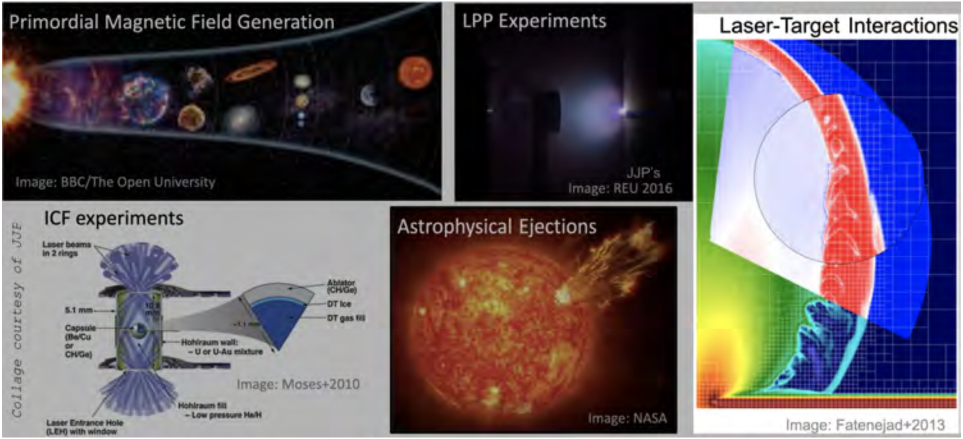
How are magnetic fields generated?

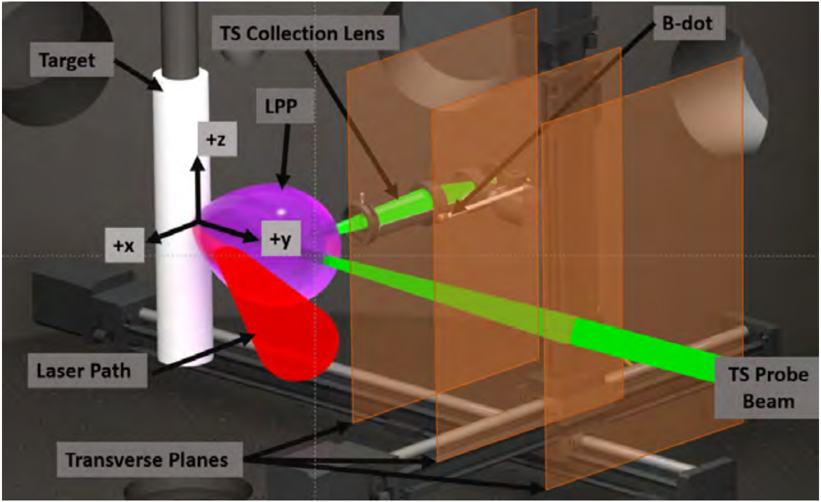


e.g., Biermann Battery (L. Biermann (1950)); $\dot{\vec{B}} \propto \vec{\nabla} T_e \times \vec{\nabla} n_e$

How may laser-target illumination aid us in understanding this?

UCLA's Phoenix Lab has measured Biermann Fields at the centimeter scale!

Figure: Side-on perspective of the UCLA Phoenix Laboratory's experimental set-up using the Peening and Thomson scattering beams (c:JJP)



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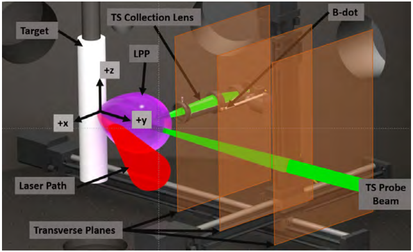

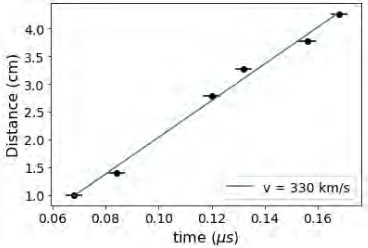

Figure: Distance from the laser spot vs t at which the maximum $\mathbf{B}_\theta$ occurred (black) for $x = -0.7$ cm and $x = 0$ cm. Linear fit (blue line) was applied showing an estimated $v \sim 330$ km/s (c:JJP)

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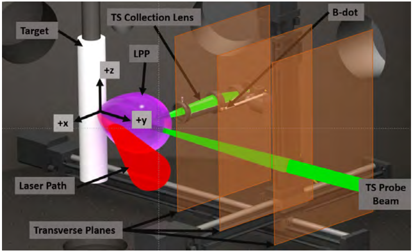

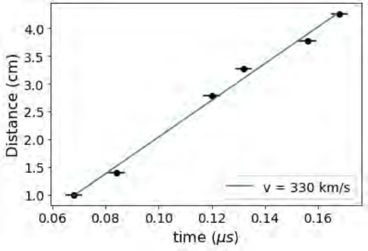

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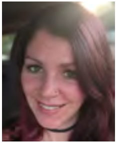

- PhD Candidate **Jessica J. Pilgram (JJP)** (PI: C. Niemann) carried out these experiments!
- She gave this year's HEDSA Student Talk on Sunday!
- **Visit her poster! (NP11.00160) Wednesday, November 10, 2021, 930-1230 in Exhibit Hall A** 👈

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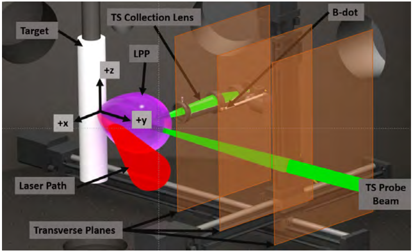

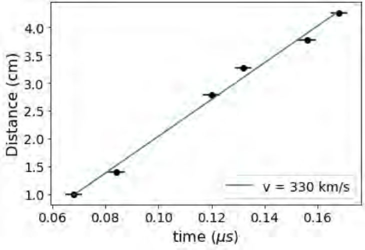

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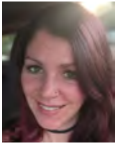

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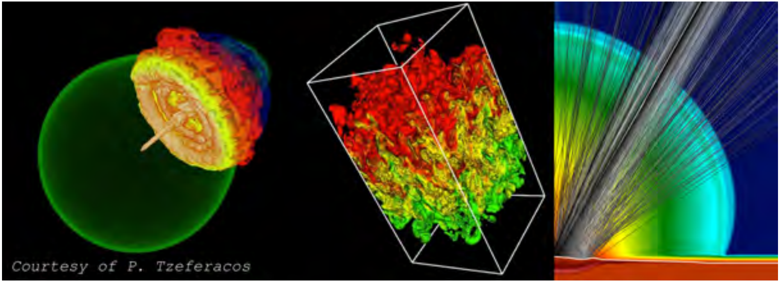
We use FLASH simulations to understand the physical processes!

The FLASH Code

- FLASH is a publicly available, high performance computing (HPC), adaptive mesh refinement (AMR), finite-volume, hydro and MHD code with extended physics capabilities. Supported primarily by the U.S. DOE NNSA. (Fryxell+2000,Tzeferacos+2015)
- FLASH is professionally managed software in continuous development for 20 years: coding standards; version control; daily automated regression testing; extensive documentation; user support; integration of extensive code contributions from external users.

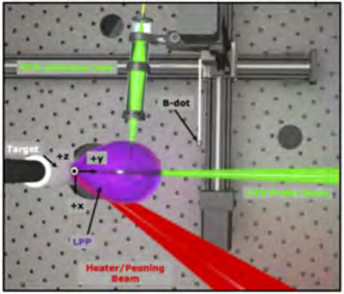
> 3,500 users world wide

>1,200 papers published with FLASH



Visit https://www.flash.rochester.edu & download FLASH today!

How are we using FLASH?



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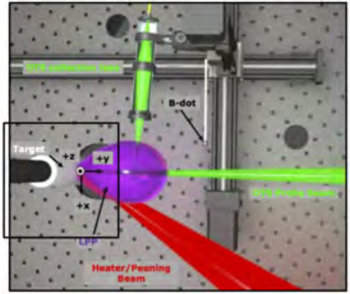

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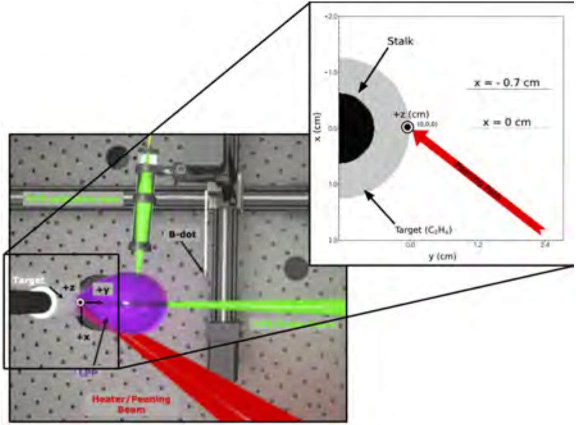

- **Initializing** 2D Cartesian geometry of target with laser-facing side in *xy*-plane
- (maximum) 20 J laser modeled with a triangle wave with a peak power of 1.3×10^9 **W at** 7.5 **ns for a** 15 **ns duration pulse**
- Note closest corresponding **planes of measurement** $x = -0.7$ cm and $x = 0$ cm
- Biermann source on for whole simulation (`Full BB`) and only for laser duration (`LOBB`)

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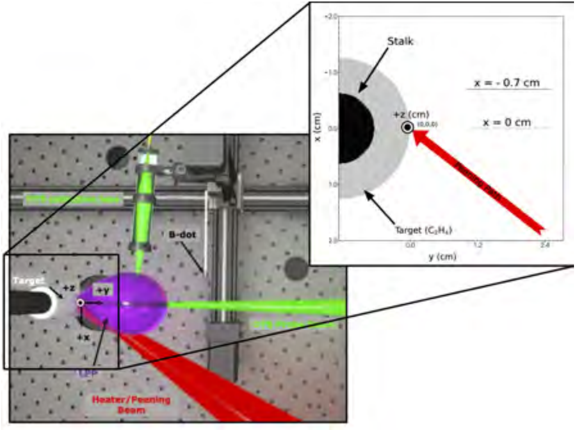

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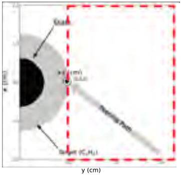
Goals:

- Elucidate upon the laser produced plasma's material properties
- Calibrate, and determine the Peening laser's intensity
- Validate the Biermann source-term implementation in the FLASH code



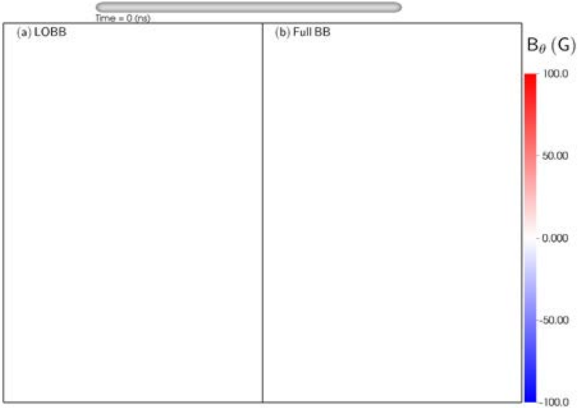
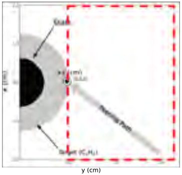


Figure: An animation of the magnetic field evolution from a Peening laser produced plasma (LPP); Biermann battery term is calculated (a) for the duration (15 ns) of the laser's pulse only (`LOBB`) and (b) for the full (`Full BB`) simulation duration (400 ns).



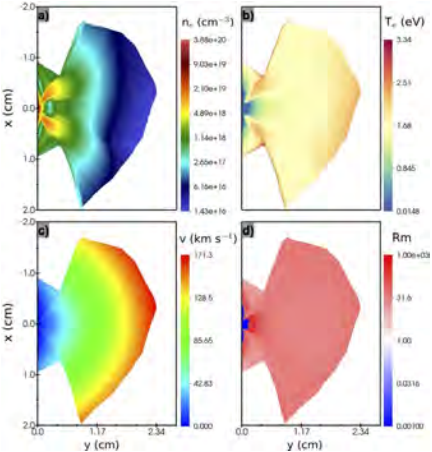


Figure: For $t = 150$ ns (a) the electron density in cm^{-3}, (b) the electron temperature in eV, (c) the plasma's velocity in kms^{-1} and finally (d) the Magnetic Reynolds number

Calibrated 2D simulations are being performed to match v ***of the fields, their values, as well as the plasma properties***

Concluding Remarks

- The DOE Center of Excellence **Center for Matter Under Extreme Conditions** has provided a great infrastructure for student led collaborations such as this one!
- The goal of this work is to understand the physics that occurred in JJP's experiments using validated FLASH simulations
  - The magnetic field topology
  - The material properties of the laser produced plasma
  - and the laser's intensity!
- High fidelity 3D FLASH simulations will be used to understand what is physically happening in the experiment
- Calibrated 2D FLASH simulations are underway; with experimental results, be used to validate the Biermann implementation in the code by using their experimentally obtained values $(n_e,\ T_e,\ v,\ B_\theta)$
- **Visit Jess' poster! (NP11.00160) Wednesday, November 10, 2021, 9:30-12:30 in Exhibit Hall A**

Thank you for your time and attention! 👋