Study of dynamic properties of shock-compressed warm dense matter: hydrodynamic simulations and experiment

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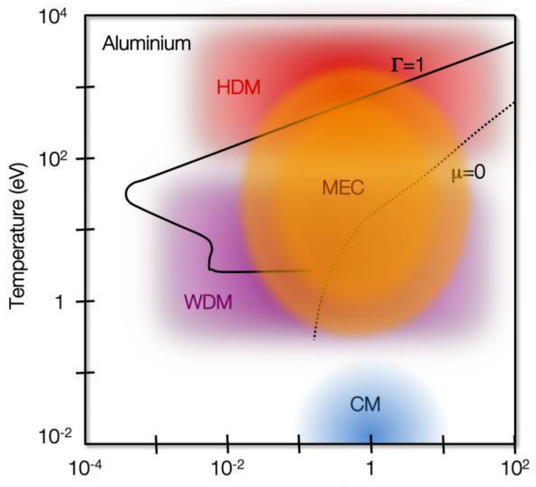
Background: Matter in Extreme Conditions and the Importance of Simulations

Matter in extreme conditions includes matter at high temperature, at high pressure, under large strain, under large fluxes, and in extreme chemical and electromagnetic environments. [1, 2]

Understanding matter in extreme conditions is necessary for:

- Conditions of inertial fusion energy and novel materials
- Planetary formation and modeling of planetary composition
- Astrophysical phenomena

For this project, hydrodynamic simulations using HELIOS software were used to estimate extreme conditions created by nanosecond optical laser at MEC.

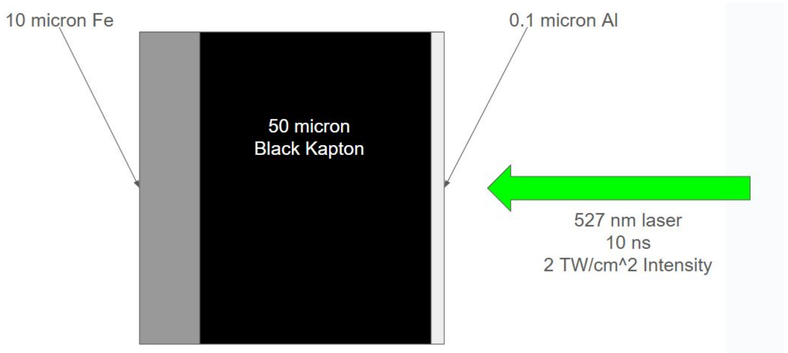


MEC phase space (Courtesy of LCLS) showing the density and pressure of cold matter (CM), warm dense matter (WDM), hot dense matter (HDM), and matter in extreme conditions (MEC).

Simulations helps researchers studying matter in extreme conditions in three ways [3]:

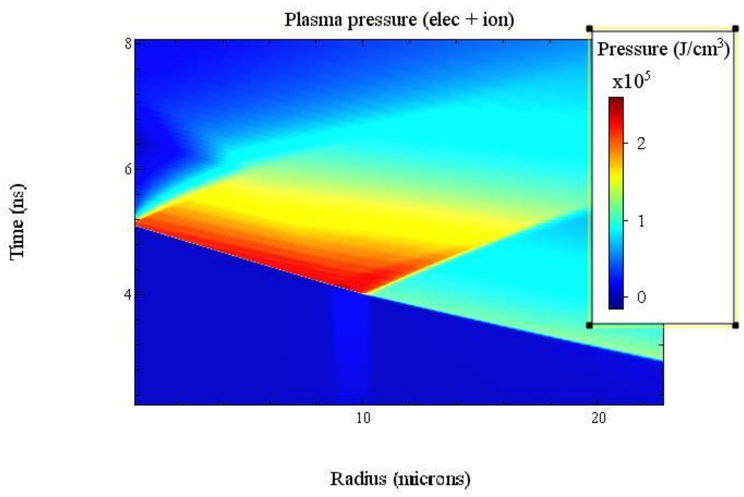
- By analyzing the large amounts of data produced
- By identifying new phenomena and conditions for future experiments
- By comparing the simulated data to experimental data and improving simulations for future use

Simulation

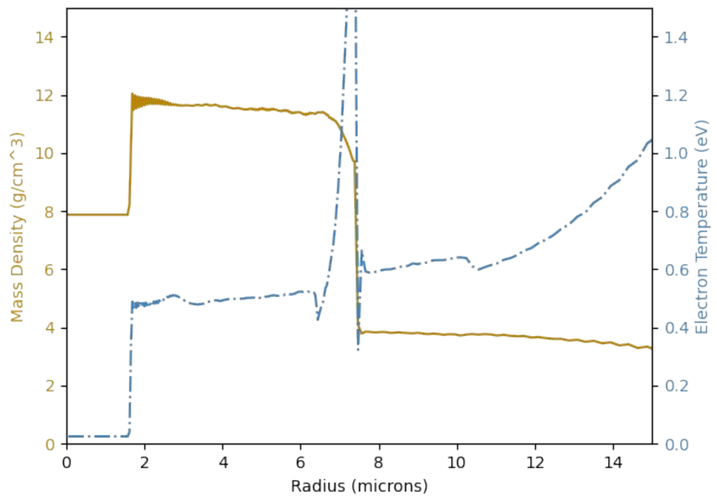


Sample and laser specifics used in the simulation, which are set to match the expected experimental conditions of the MEC1008539 (July 10-15, PI-Nagler) experiment.

For this project, the HELIOS simulation software was used to simulate the conditions of the experiment, MEC1008539. Physical parameters of density, pressure, and temperature, were collected with respect to both sample radius and time to be analyzed in preparation of the experiment.



Simulated plasma pressure of the iron portion of the sample with respect to radius and time, showing shock propagation.



Simulated mass density and temperature of the iron portion of the sample at 5 ns, which can be compared to experimental data.

Experiment: Temperature Measurements in Shocked Iron

The data from the simulation showed that optimal data collection would happen around 5 ns into the laser pulse and gave estimates of what measurements would look like.

As a part of this project, we assisted with the setup and data collection for the MEC1008539 experiment, which we had previously simulated. While data analysis has not yet been complete, preliminary analysis shows optimal data collection around 7-9 ns, indicating a difference from the simulation.

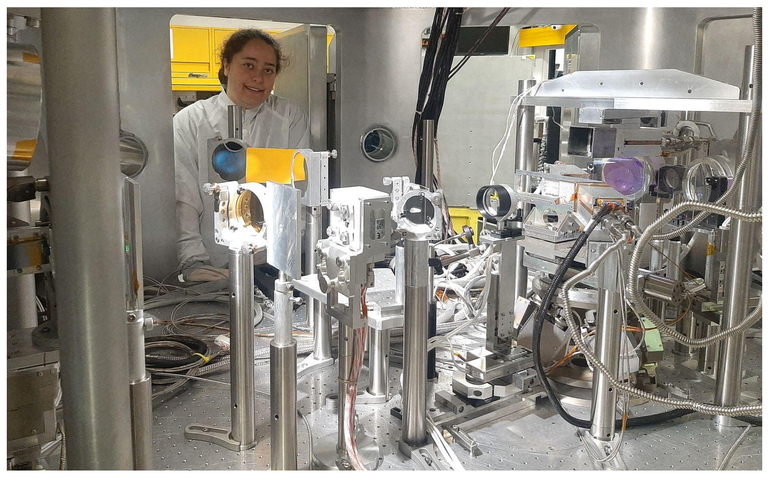


Photo of MEC1108539 experiment set-up (Courtesy of H. J. Lee).

Conclusion

This project simulated a matter in extreme conditions experiment and the dynamic evolution of the matter. It also provided basis for comparison to the experiment, which likely has differing data.

Future Research

Future work on this project includes comparing the simulated data to the experimental data and using the conclusions from this comparison to adapt the use of the HELIOS simulation software to better predict the results of future experiments.

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