A theoretical approach for shock strengthening in high-energy-density laser compression experiments

Michael Wadas¹, Griffin Cearley¹, Jon Eggert², Marius Millot², and Eric Johnsen¹
¹Mechanical Engineering, Univ. of Michigan, Ann Arbor, MI. ²Lawrence Livermore Nat. Lab, Livermore, CA.

Introduction

- Details of many planetary interior compositions remain unknown.
- Simulations predict superionic ice in Jovian planets, but accessing these conditions experimentally is challenging [1-3].
- Objective: develop a method for extending experimental access to extreme conditions found in planetary interiors.

Method of Analysis

- The MoC reduces PDEs to ODEs along specific paths, enabling solutions to 1D nonlinear hydrodynamics.
- The Riemann problem describes a system after diaphragm release.
- The analysis leverages the MoC with a boundary condition from the Riemann problem. A calorically perfect gas is assumed.

Results: Single Step

- An intermediate step enables a stronger shock in the target material than without the step until reflected waves weaken it.
- Optimal shock strengthening occurs when the step density is the geometric mean of the densities of the left and right materials.

Results: Multiple Steps

- Incorporating multiple steps can further strengthen the shock.
- Exponential density profiles optimize shock strengthening.

Method

- The MoC is a theoretical approach for shock strengthening in high-energy-density laser compression experiments.
- Density steps can be used to locally strengthen shock waves.
- For one step, a density $\rho_s = \sqrt{\rho_L \rho_R}$ maximizes the shock strength.
- Exponential density profiles yield optimal shock strengthening, enabling access to new experimental states of matter.

Conclusions and Acknowledgement

- A semianalytical method was developed to explore shock strengthening in anvil-based laser compression experiments.
- Density steps can be used to locally strengthen shock waves.
- For one step, a density $\rho_s = \sqrt{\rho_L \rho_R}$ maximizes the shock strength.
- Exponential density profiles optimize shock strengthening, enabling access to new experimental states of matter.

References:


This work is supported by the Lawrence Livermore National Laboratory (LLNL) under subcontract B637249 and was performed under the auspices of the U.S. Department of Energy (DOE) by the LLNL under Contract No. DE-AC52-07NA27344 with partial support provided by LDRD 19-ERD-031. Furthermore, this work was performed as part of the U.S. DOE National Nuclear Security Administration Stewardship Science Graduate Fellowship Program under grant DE-NA000396G.