The role of radiation in a shock-driven shear flow

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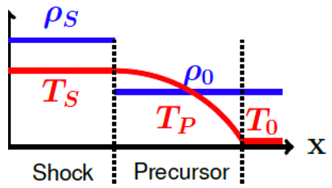
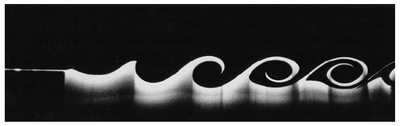
Introduction

- The effect of radiation on shear flow and instabilities in a HED flow is not well known. This study combines the Shock-Shear campaign [1,2] with high radiative fluxes to determine the effect on perturbation growth.
- **Objective:** Validate radiative shock shear simulation via one- and two-dimensional simulations. Investigate the assignment of spectral opacity groups to predict the state of the plasma upstream.

Radiative Shockwaves: When the radiative energy flux is on the order of shocked material energy flux, post-shocked material can emit radiation ahead of the shock and form a radiative precursor [3]. Radiative shocks are often seen in ICF and laboratory astrophysics.

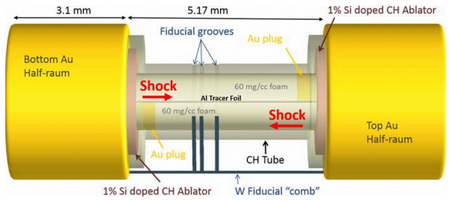


Kelvin-Helmholtz instability: Velocity shear causes a perturbed interface to grow into a roll-up structure and contributes to turbulent mixing.

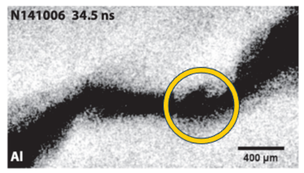


Experimental demonstration of Kelvin-Helmholtz in the classical fluid regime [4].

Shock Shear Campaign [1,2]: The Kelvin Helmholtz instability was studied in the HED regime using counter propagating shock waves in an ablation-driven target. This campaign used a low drive (~220 eV) to drive the shocks, so radiative effects were not considered.



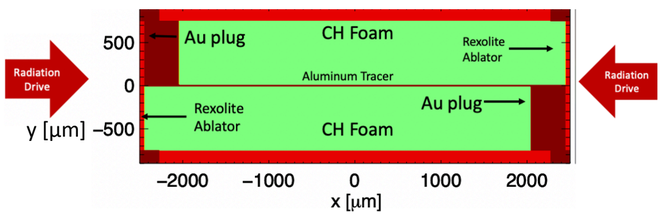
Shock-Shear campaign target design [1].



Radiograph of KH rollup [2].

Methodology

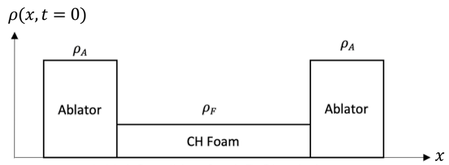
- CRASH radiation hydrodynamics code with flux-limited multigroup diffusion [5] is used to study the shock-shear evolution.
- The radiation drive temperature was increased from **220 eV (low drive)** to **300 eV (high drive)** to study radiative effects.
- CRASH uses multigroup opacities from the PrOpacEos database.



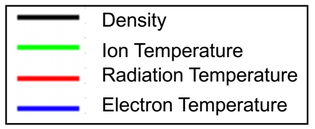
Initial condition for 2-D simulation resembling the shock-shear campaign target.

Results: 1-D Simulation

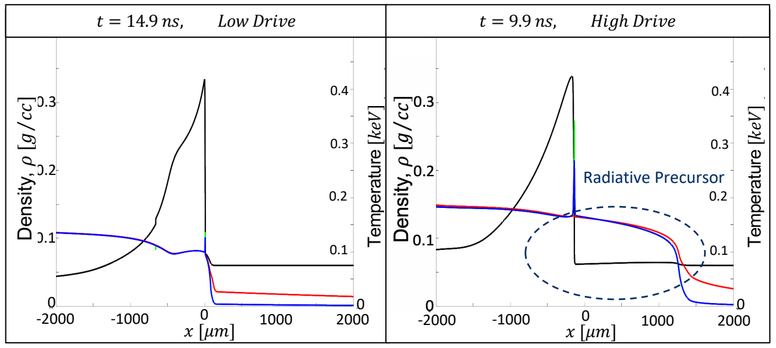
- Material density, ion temperature, electron temperature, and radiation temperature are used to investigate the state.
- A radiative precursor is observed for the high drive scenario.



Initial Condition for 1-D Simulation



1-D Simulation Legend



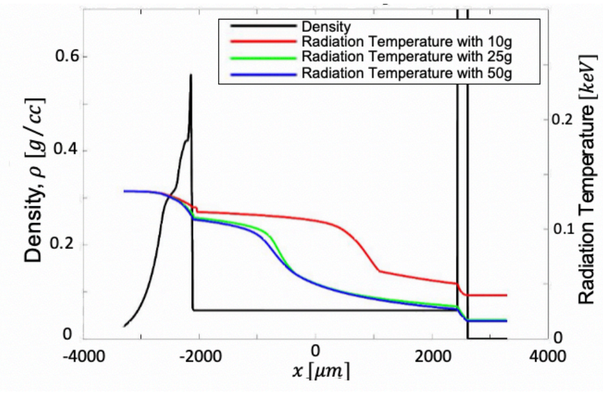
1-D simulation evolution for the low and high drive cases.

Results: Upstream State and Opacity

- Multigroup opacities are defined by,

$$\kappa_{MG} = \frac{\int_{\nu_1}^{\nu_2} \kappa_\nu B_\nu d\nu}{\int_{\nu_1}^{\nu_2} B_\nu d\nu}.$$

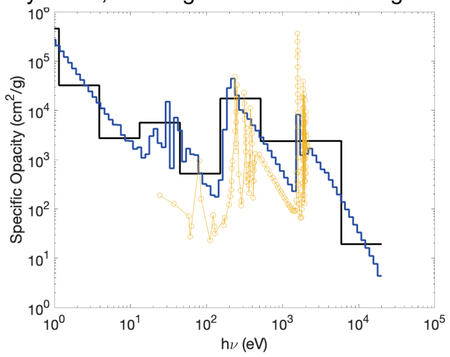
- The state upstream of the shock is highly dependent on the number of photon energy groups representing the opacity.
- As the number of groups increase, the radiative precursor converges.



Effect of the number of photon groups on radiative precursor structure

Results: Upstream State and Opacity II

Two factors are responsible for the convergence of the precursor. As the number of groups increases,
(1) the true spectral opacity is better represented and
(2) fewer high-energy photons (60keV-200keV) are assigned a low opacity value, causing less free-streaming due to the flux-limiter.

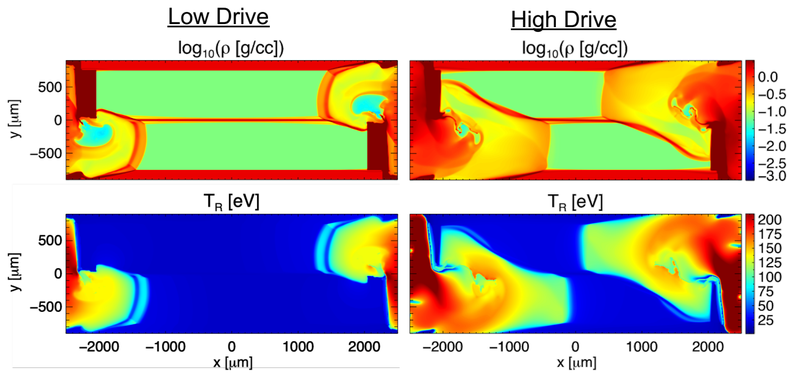


Black = **10 groups** Propaceos Database used in CRASH simulations
Blue = **100 groups** Propaceos Database
Yellow = Los Alamos National Lab Database [6]

Specific opacity versus photon energy for Aluminum at T = 40 eV, n_e=10^{19} cm^{-3}

Results: 2-D Simulation

- Early time (before shock crossing) simulations are used for verification.
- The radiative precursor is observed in the high drive simulation.



Density (top) and radiation temperature (bottom) contours for low and high drive.

Conclusion and Future Work

- The state ahead of the radiative shock is highly dependent on the plasma opacity.
- Sufficient resolution in frequency space is essential to predict the plasma state upstream
- Future work includes focus on perturbation growth driven by the radiative shockwave.

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