Kelvin-Helmholtz Modeling Using the CRASH Code

E. M. Rutter, R P. Drake, M. J. Grosskopf, G. Malamud, E. C. Harding, K. I. Gasior, C. C. Kuranz

Abstract

The Center for Radiative Shock Hydrodynamics (CRASH) at the University of Michigan has developed an AMR, Eulerian radiation-hydrodynamics code, CRASH, which can model laser-driven experiments. One of these experiments we performed previously on the OMEGA Laser at LLE was designed to produce and observe the Kelvin-Helmholtz instability. The target design included low-density CRF foam layered on top of polyamide-imide plastic, with a sinusoidal perturbation on the interface and with the assembled materials encased in beryllium. The results of a series of CRASH simulations of these Kelvin-Helmholtz instability experiments are presented. These results will be compared to the experimental observations.

Motivation

Kelvin-Helmholtz instabilities arise from a velocity differences across the interface of two fluids, ie how wind over water can cause waves. We are interested because:

- KH instabilities arise in many astrophysical phenomena such as supernovae
- Well-studied system for which many experiments have been performed, but not in the laser setting
- Opportunity to test the CRASH code on experimental setups very different than our nominal radiative shock-tubes for which we possess experimental data

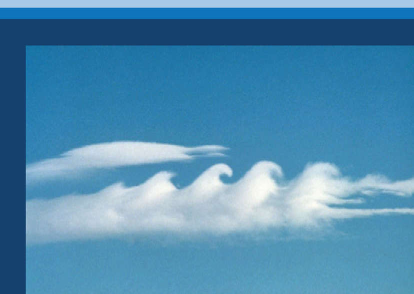
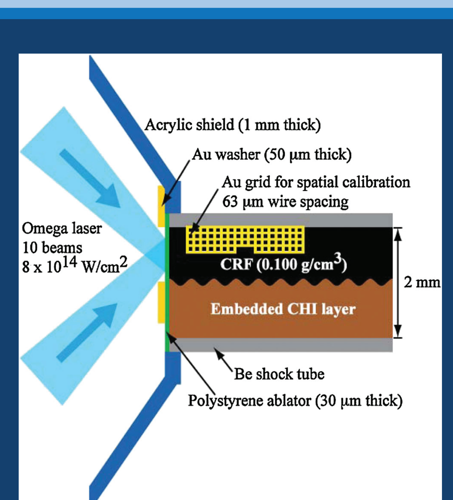


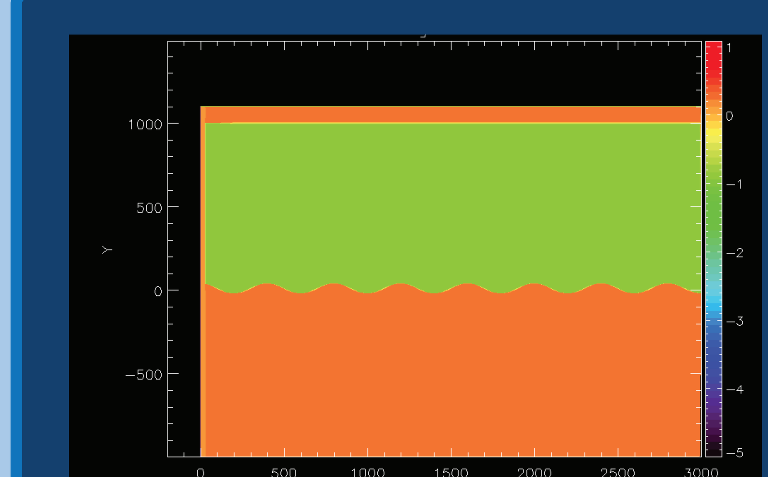
Photo Credit: Brooks Martner, NOAA/ETL

Example of Kelvin-Helmholtz instsability in cloud formations

Introduction to Laser-Driven Kelvin-Helmholtz Experiments



Schematic of the Kelvin-Helmholtz experimental target geometry (1)



Density profile of initial CRASH set-up of KH target

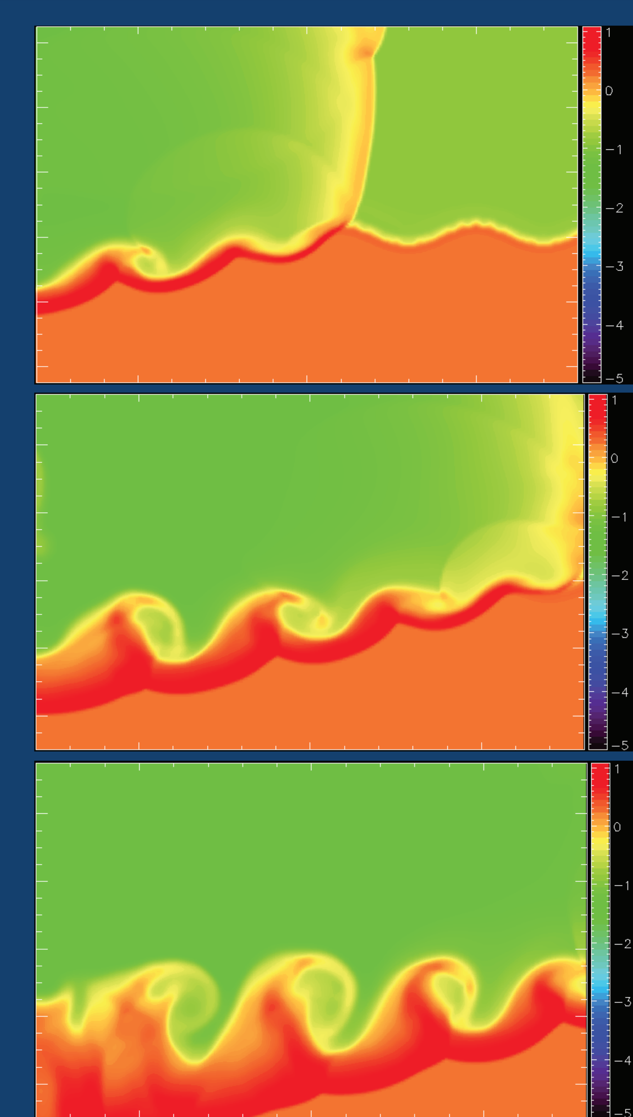
Experiments performed on the OMEGA laser feature:

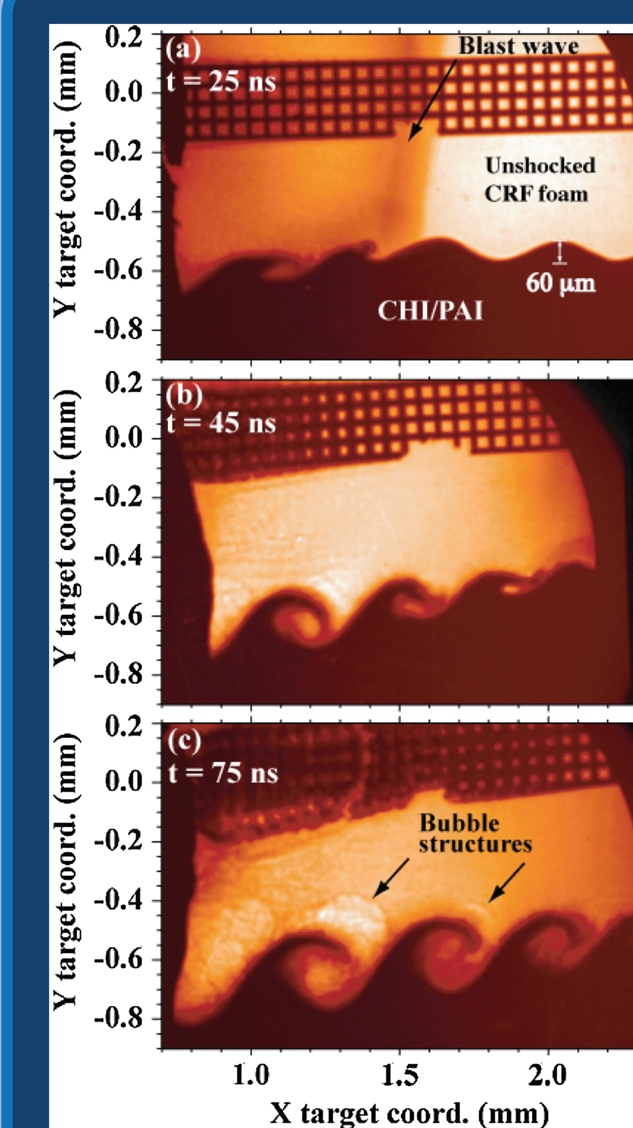
- 30 um Plastic ablator
- Layered plastic and low-density carbon foam separated by sinusoidal perturbations with 400 micron wavlength and 60 micron amplitude
- Rectangular beryllium encasement
- Gold washers and acrylic shielding to assist with diagnostics
- Diagnostics included radiography images
- Irradiated by 4300 J of laser energy in a 1ns pulse
- Observed structure in radiographic images at several distinct times

Simuations in CRASH feature:

- 2D and 3D Eulerian radiation-hydrodynamics code
- Multigroup radiation and tabular equation of state

Simulation and Experimental Results

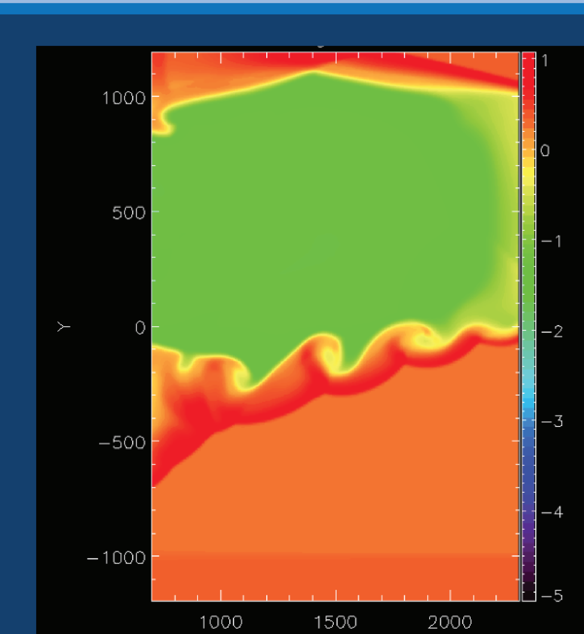


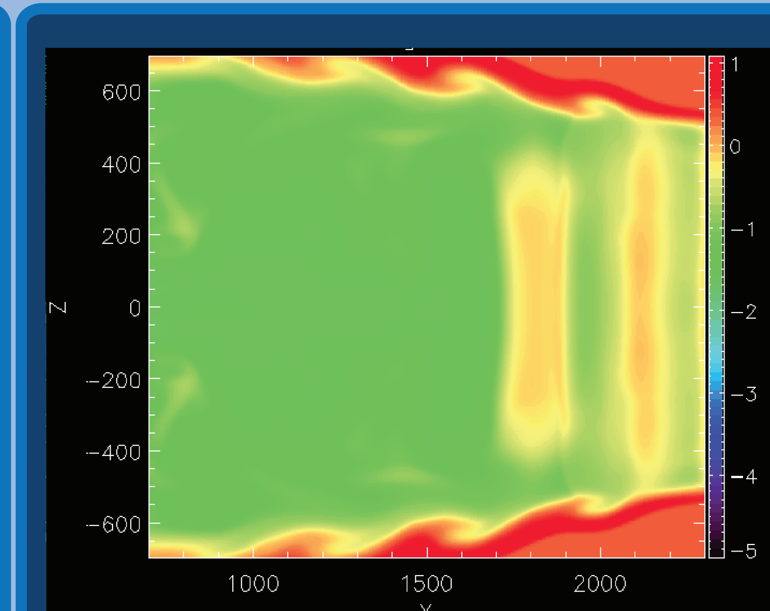


CRASH simulations of the KH experiment density profiles (left) compared to radiographs from actual experiment (right) at corresponding times (1)

These simulations of the Kelvin-Helmholtz experiments show promising qualitative results. In order to more accurately model the simulation, and laser power, it is necessary to expand this simulation into three dimensions.

3-Dimensional Simulations of the Kelvin -Helmholtz Experiment





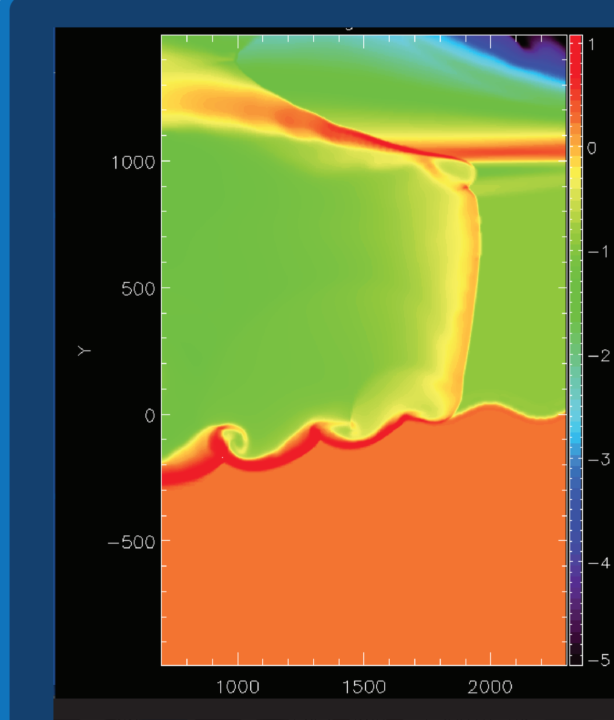
CRASH simulations of the KH experiment in 3 Dimensions with orthogonal views at 75 ns. Note the roll-ups occurring from the beryllium walls blowing in

3D simulations indicate important interactions between the blast wave and the beryllium encasement. What effect does this introduce into the instability? Further simulations without an encasement could provide crucial details missing in the 2D simulation

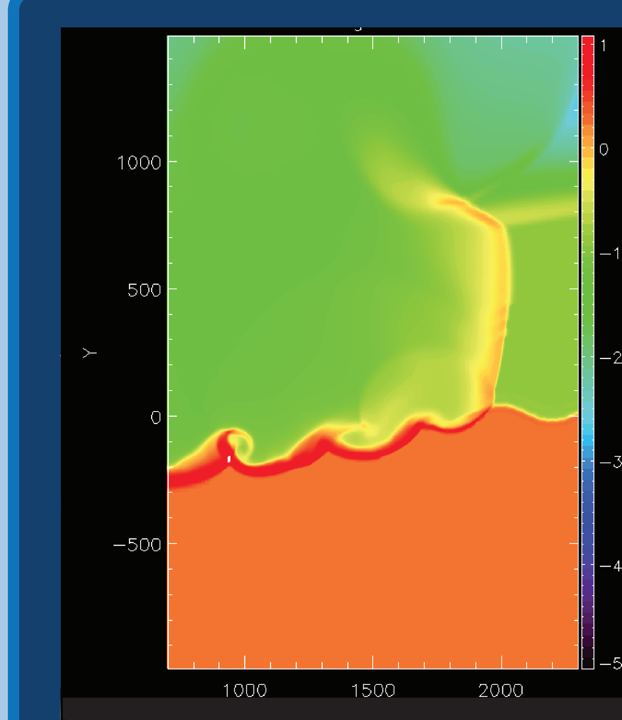
Design of Upcoming Experiments

Initial experiments proved changes need to be made before more experimentaion

- Since machining of beryllium encasement is too difficult and expensive, a suitable alternative must be found
  - Plastic tube
  - No tube



Kelvin-Helmholtz density profiles at 25 ns but with a thin plastic tube instead of beryllium. Note there is not much structurally different from previous simulation



Kelvin-Helmholtz density profiles at 25 ns but with no tube, opening up into vaccuam. The roll-ups still occur even if there is no containment.

Simulations using substitute materials appear to engender the same Kelvin-Helmholtz roll-ups, effective cutting costs of both staff time and money. Further simulations could assist in predicting effects.

Conclusions & Further Directions

CRASH is a code that is still being developed. As such, it is important to exercise the code to simulate a variety of experiments different from our nominal one. The Kelvin-Helmholtz experiments have been performed at the OMEGA laser and we possess the data. CRASH has proved to simulate this experiments well, offering a slightly easier method of target fabrication. The next steps include further analysis and to continue simulating possible future experiments.

Acknowledgements and References

This work is funded by the Predictive Sciences Academic Alliances Program in NNSA-ASC via grant DEFC52- 08NA28616, by the NNSA-DS and SC-OFES Joint Program in High-Energy-Density Laboratory Plasmas, grant number DE-FG52-09NA29548, and by the National Laser User Facility Program, grant number DE-FG52-09NA29034

(1) E. C. Harding, J. F. Hansen, O. A. Hurricane, R. P. Drake, H. F. Robey, C. C. Kuranz, B. A. Remington, M. J. Bono, M. J. Grosskopf, and R. S. Gillespie, Phys. Rev. Lett. 103, 045005 (2009)