Investigation of the Richtmyer-Meshkov instability

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Technical report for the period January 2007 - December 2007

1 Introduction

The present research program is centered on the experimental and numerical study of the hydrodynamics of shock-accelerated spherical density inhomogeneities. These flows are part of a broader category of shock-induced mixing flows that play a critical role in the implosion of D-T pellets in laser-driven ICF experiments.

The value of our work is both in the physics that can be learned from our experiments and calculations and in the validation that comes from comparing the experiments with the numerical results.

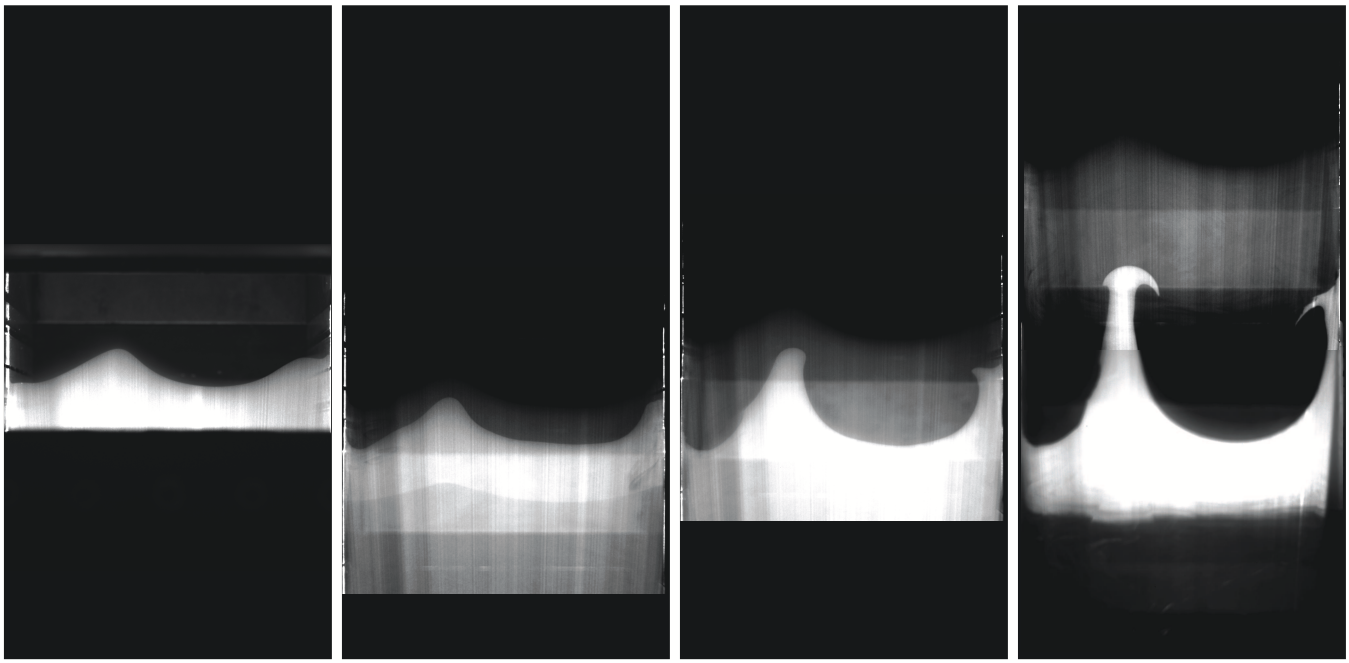
2 Accomplishments

The main accomplishment for 2007 was the completion of John Niederhaus' and Devesh Ranjan's Ph.D. programs and their respective hirings by Sandia National Laboratory as a staff member and Los Alamos National Laboratory as a postdoc.

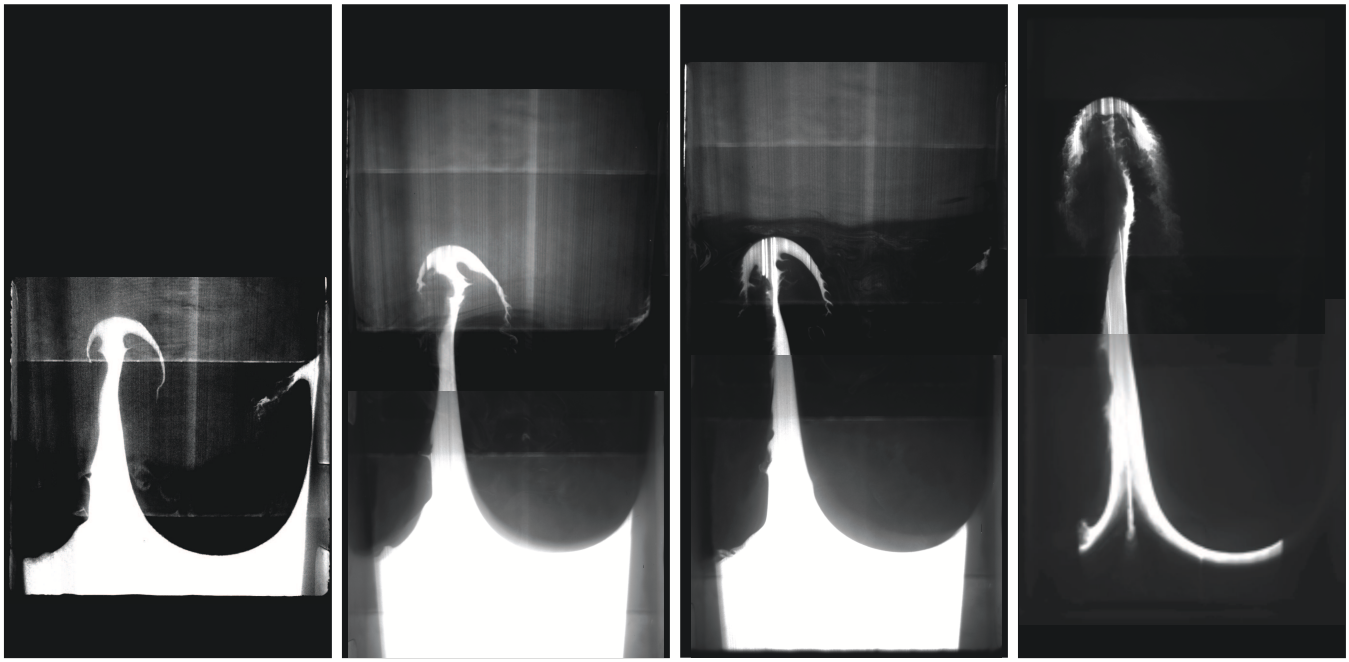
A comprehensive campaign for the study of shock-acelerated bubbles (including extensive shock tube experiments and calculations based on the *Raptor* code) was thus completed. Two papers summarizing the entire research were submitted in 2007: one appeared in January 2008; the other one is in press.

The study of shock-accelerated two-dimensional interfaces continued with experimental series for very high Atwood number ($A = 0.96$, using a He/SF_6 interface) at three different Mach numbers (1.13 ad 1.42, and 1.95). Sample images for the experiments at $M = 1.13$ sre shown in Fig. 1.

The experimental data are currently being analyzed and compared to existing analytical models. At present, the data seem to be better described by models proposed by Mikaelian and Dimonte & Schneider than by one proposed by Sadot *et al.*, as shown in Fig. 2.



(a) (b) (c) (d)



(e) (f) (g) (h)

Figure 1: Laboratory experiments on a shocked He-SF_6, nearly sinusoidal interface. $A = 0.96$, M=1.13. Planar Mie scattering. (a) $t = 0.00$ ms; (b) $t = 0.36$ ms; (c) $t = 1.02$ ms; (d) $t = 2.67$ ms; (e) $t = 4.52$ ms; (f) $t = 6.24$ ms; (g) $t = 7.04$ ms; (h) $t = 9.62$ ms.

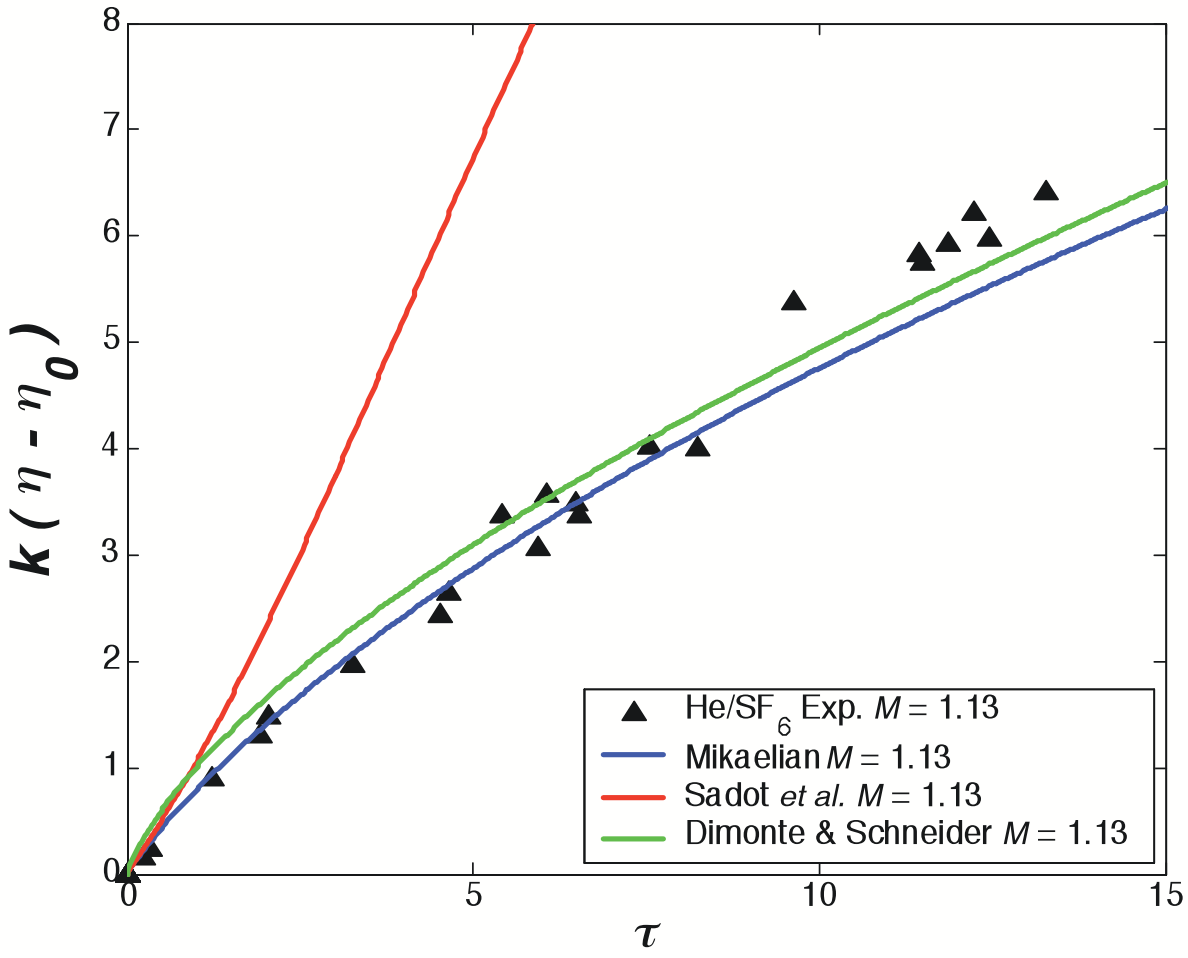


Figure 2: Comparison of experimental data to analytical models. Dimensionless time $\tau = k\dot{\eta}_0 t$.

Numerical simulations at the same conditions are presently being performed using the *Raptor* code. A manuscript is already in preparation for submission to Physics of Fluids.

The entire campaign will be completed this year with four more series: N_2/SF_6 at $M = 2.9$; varigon/Ar at $M = 1.3$, $M = 2.0$ and $M = 2.9$ (varigon is a mixture of 50% He and 50% Ar, yielding an Atwood number of 0.29 when paired with argon).

3 Publications and presentations

Two **journal articles** were submitted and accepted for publication:

D. Ranjan, J. Niederhaus, J. Oakley, M. Anderson, R. Bonazza, and J. Greenough, Shock-bubble interactions: features of divergent refraction geometry observed in experiments and simulations, accepted for publication in *Phys. Fluids*, 2008

Niederhaus J., Greenough J., Oakley J., Ranjan D., Anderson M., Bonazza R., A computational parameter study for the three-dimensional shock-bubble interaction, *JFM* **594**, 85-124, 2008

One journal article was published:

Ranjan D., Niederhaus J., Motl B., Anderson M., Oakley J., Bonazza R., Experimental Investigation of Primary and Secondary Features in High-Mach-Number Shock-Bubble Interaction *Phys. Rev. Lett.* **98**, 024502, 2007

Our work was presented at three **conferences**:

1) The 26th International Symposium on Shock Waves, Goettingen (Germany), 7/15-20/2007. Two papers appearing in the proceedings:

Niederhaus J., Ranjan D., Oakley J., Greenough J., and Bonazza R., Computations in 3D for shock-induced distortion of a light spherical gas inhomogeneity

and

Ranjan D., Niederhaus J., Oakley J., Anderson M., and Bonazza R., Experimental investigation of shock-induced distortion of a light spherical gas inhomogeneity

2) The 1st International Conference on Turbulent Mixing and Beyond, Trieste (Italy), 8/18-26/2007. Two conference papers under review for publication in Physica Scripta:

Niederhaus J., Greenough J., Oakley J., and Bonazza R., Vorticity evolution in two- and three-dimensional simulations for shock-bubble interactions

and

Ranjan D., Niederhaus J., Oakley J., Anderson M., Greenough J. and Bonazza R., Experimental and numerical investigation of shock-induced distortion of a spherical gas inhomogeneity

3) The 60th Annual Meeting of the Division of Fluid Dynamics of he American Physical Society, Salt Lake City, UT, 11/ 18-20/2007.

4 Personnel

Faculty and staff involved in and supported by the program include:

Prof. Riccardo Bonazza, Department of Engineering Physics; supported for 3.25 months

Dr. Jason Oakley, Assistant Scientist, Dept. Engineering Physics; supported for 2 months

Mr. Paul Brooks, Instrumentation Specialist, Dept. Engineering Physics; supported for 4 months

Graduate students supported by and fully involved in the program in the past year include:

Mr. Brad Motl (USA; pursuing a PH.D. degree); supported for 5 months

Mr. John Niederhaus (USA; pursuing a Ph.D. degree); supported for 2 months

Mr. Devesh Ranjan (India; pursuing a Ph.D. degree); supported for 5 months

Mr. Jeremy White (USA; pursuing a Ph.D. degree); supported for 5 months

Mr. Adam Sweet (USA; pursuing a Master's Degree); supported for one month.

Five **undergraduate students** were also involved in and supported by the program at various levels and for different lengths of time.