Shock accelerated two-dimensional interface

Bradley Motl, John Niederhaus, Jason Oakley,
Devesh Ranjan, Mark Anderson, <u>Riccardo Bonazza</u>
University of Wisconsin-Madison
bonazza@engr.wisc.edu

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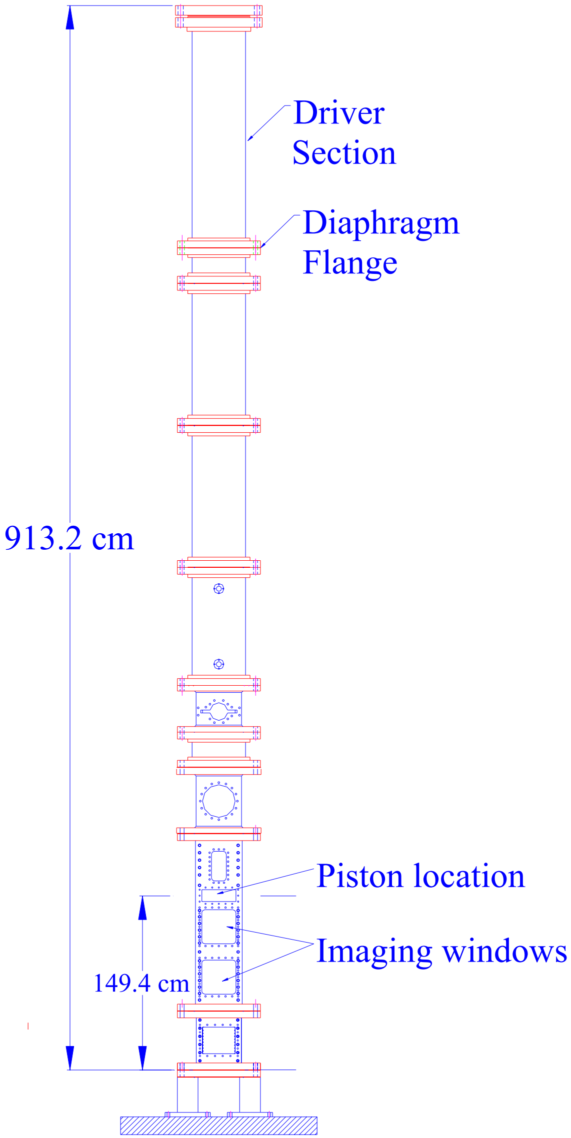
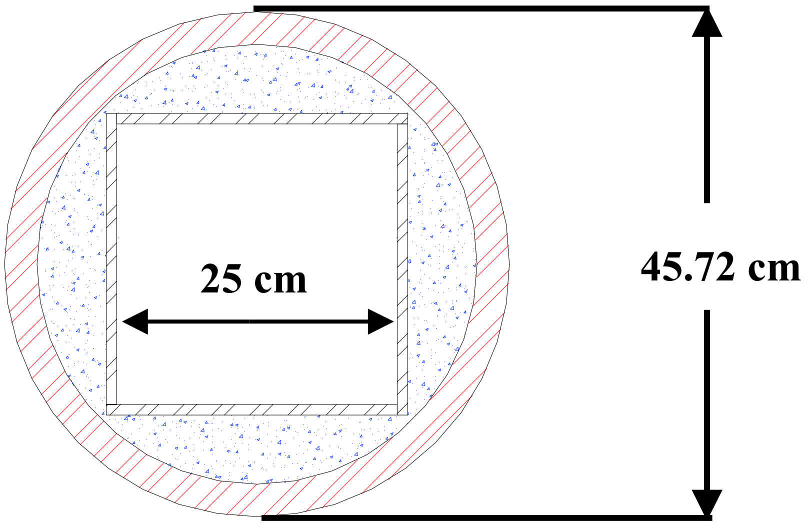
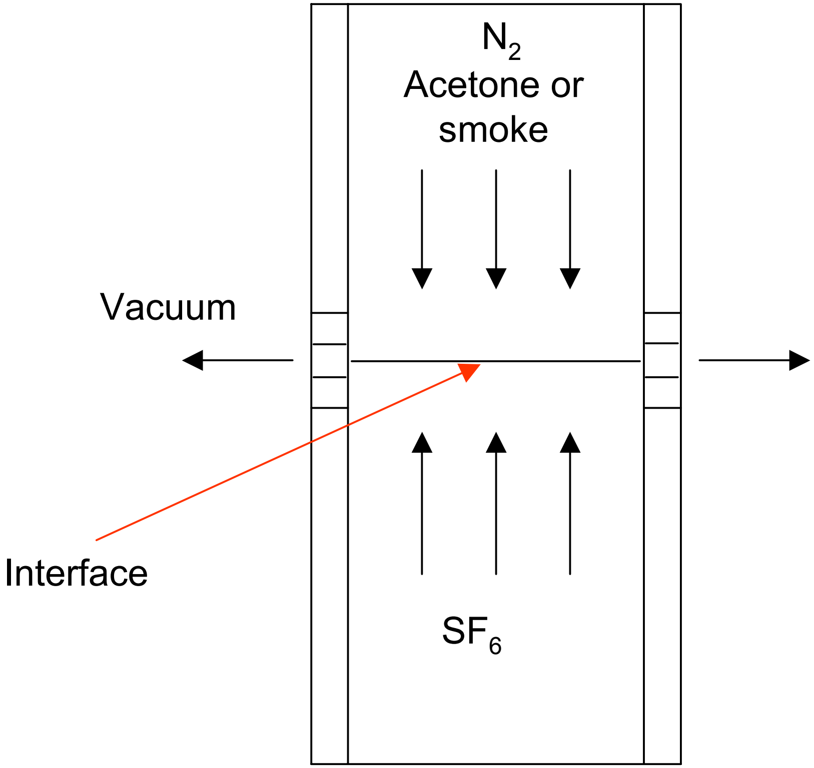
Wisconsin shock tube

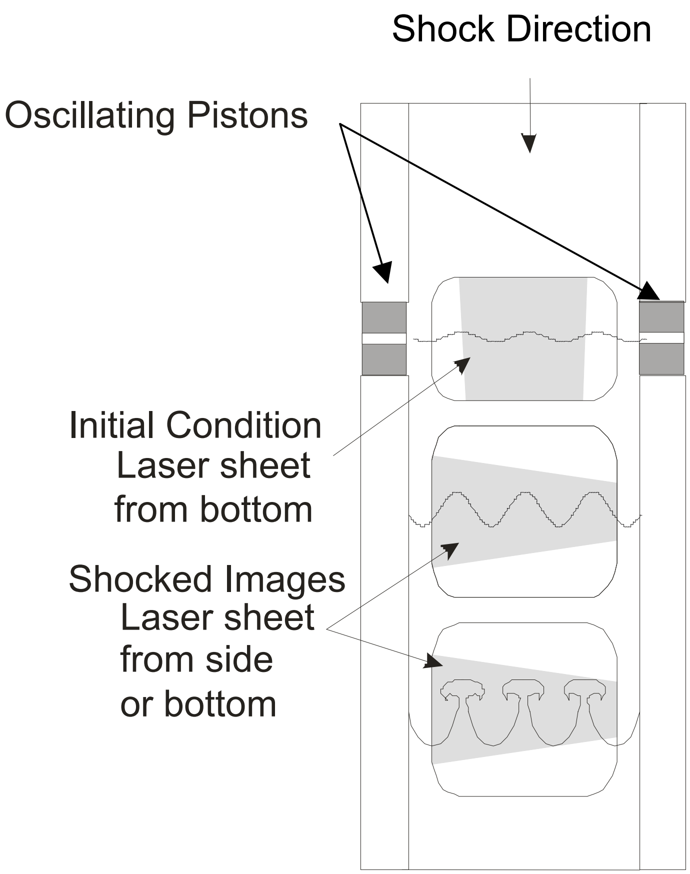


- Vertical
- Large internal cross-section (25 cm square)
- Total length 9.2 m, driver length 2 m
- Pressure load capability: 20 MPa
- Modular driven section



Experimental setup





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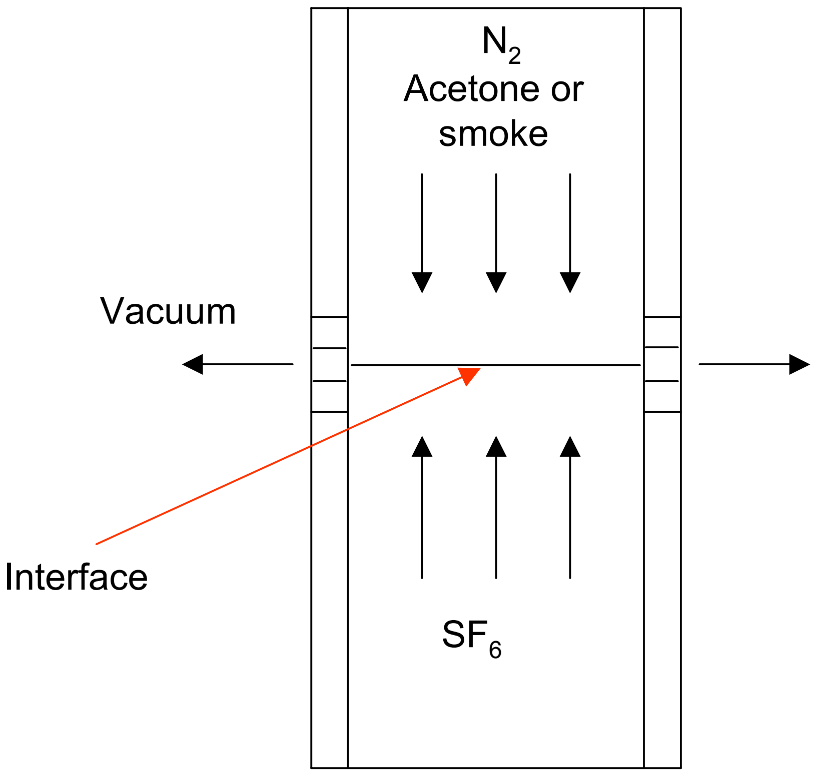

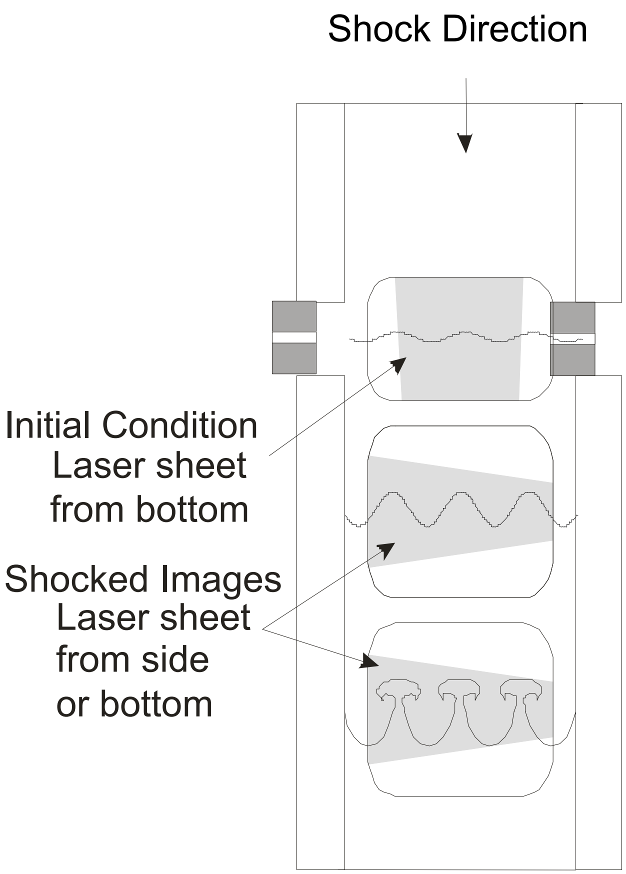

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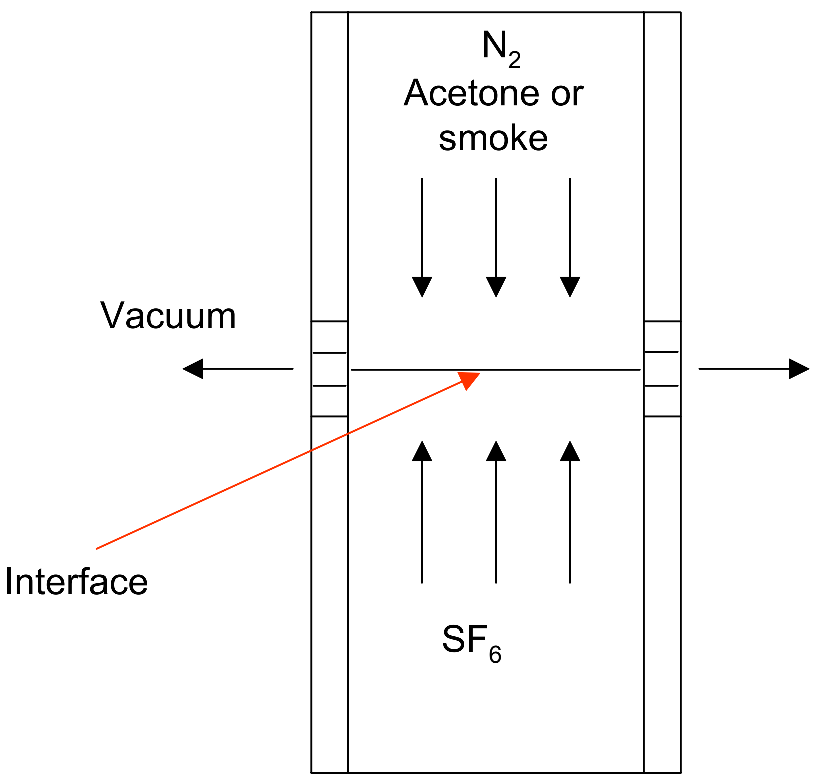

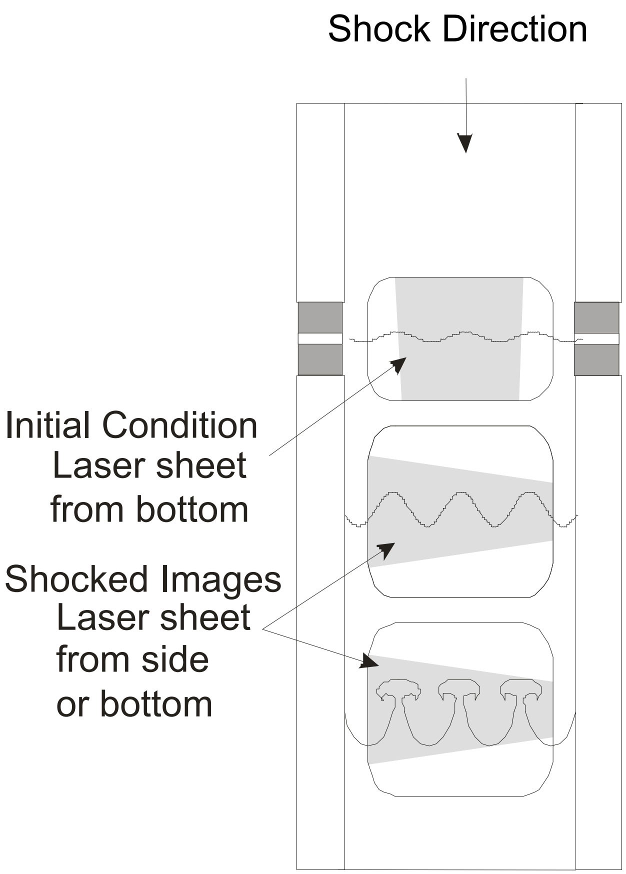

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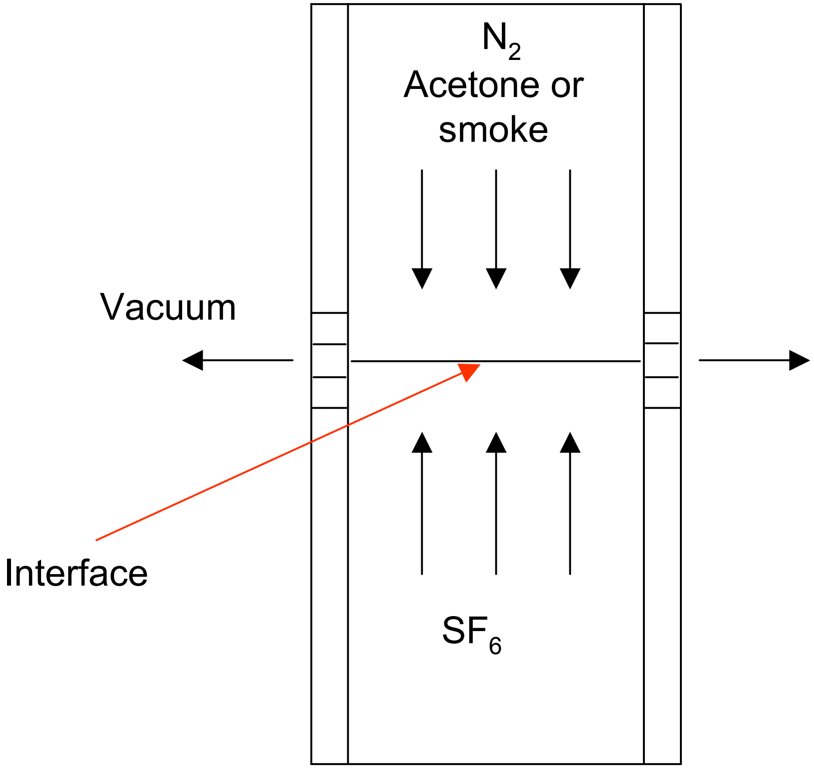

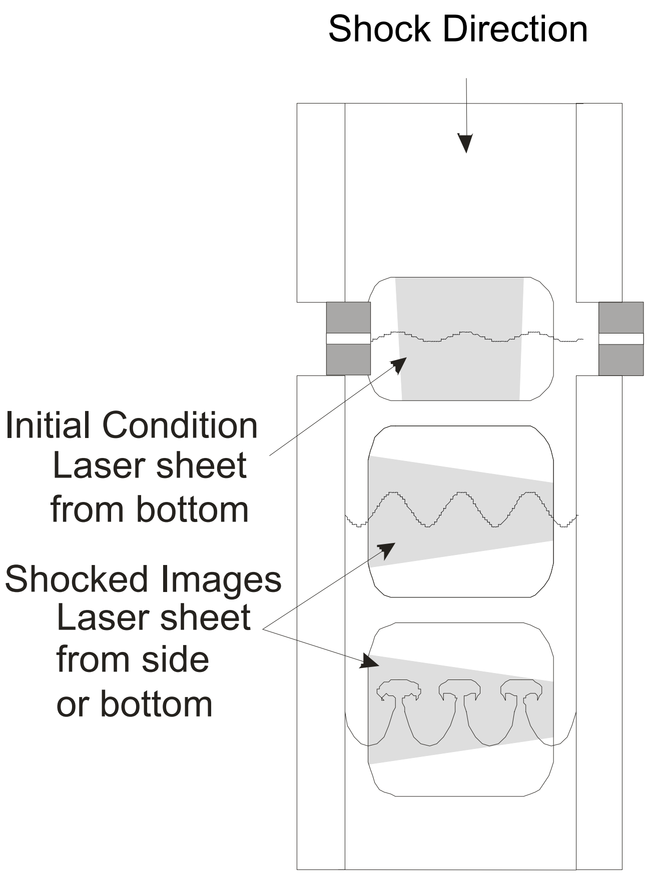

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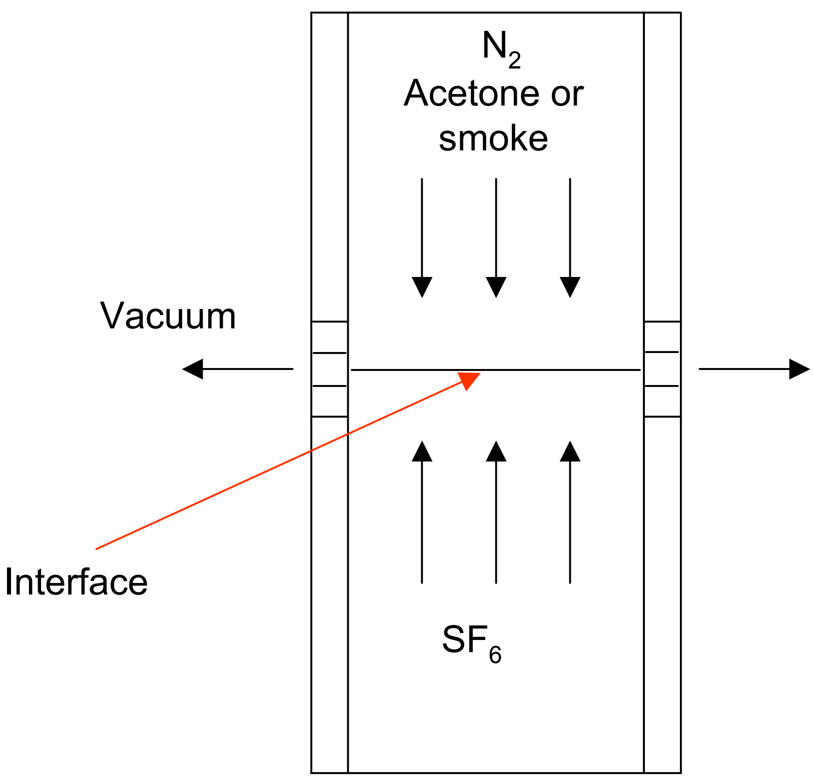
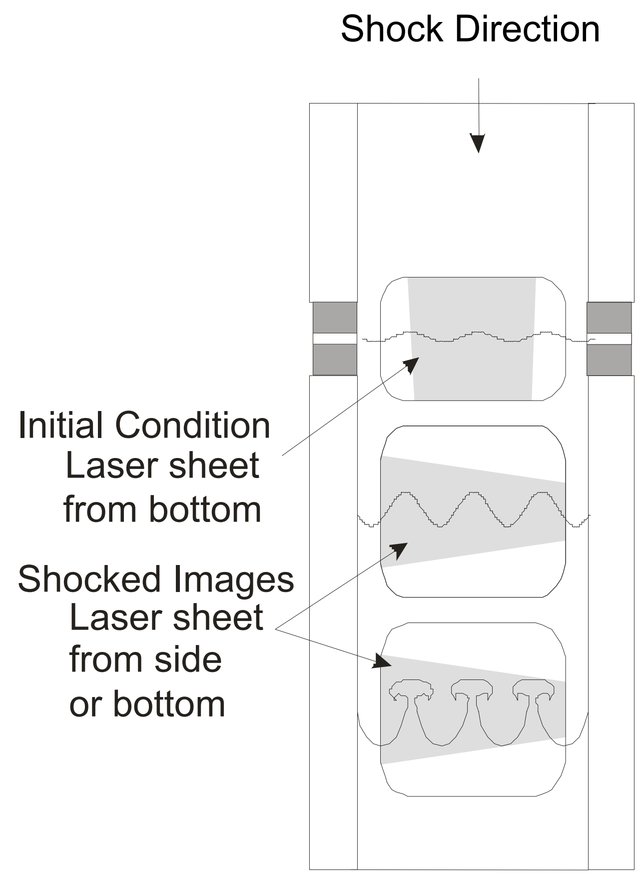
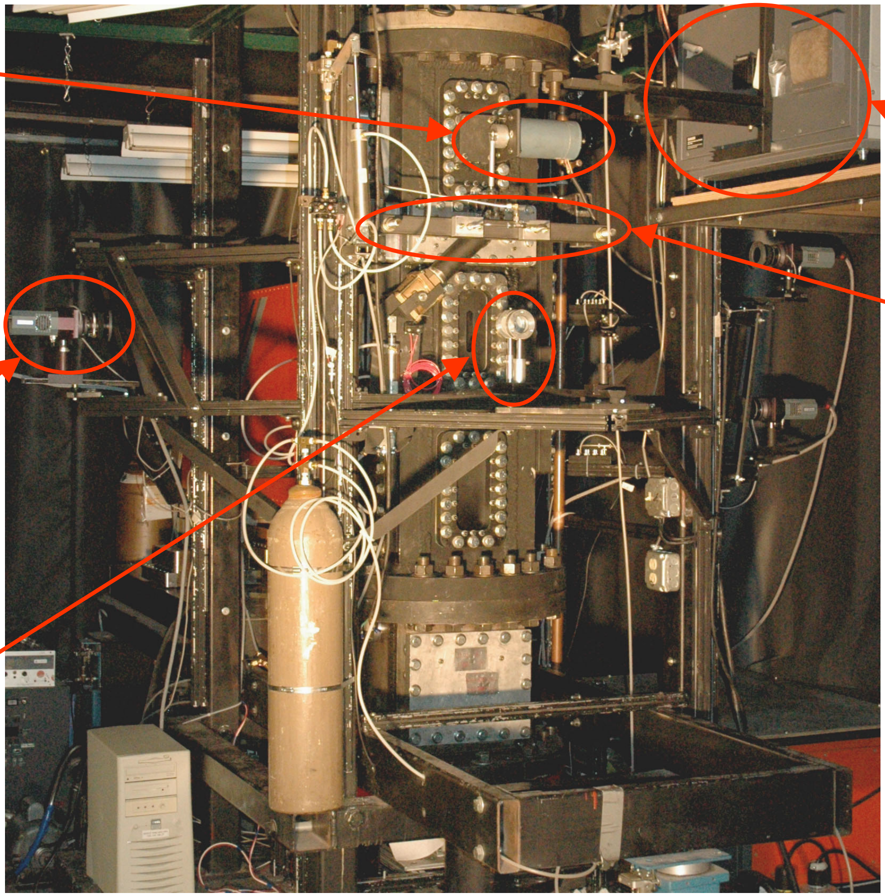




TEST SECTION

Stepper motor



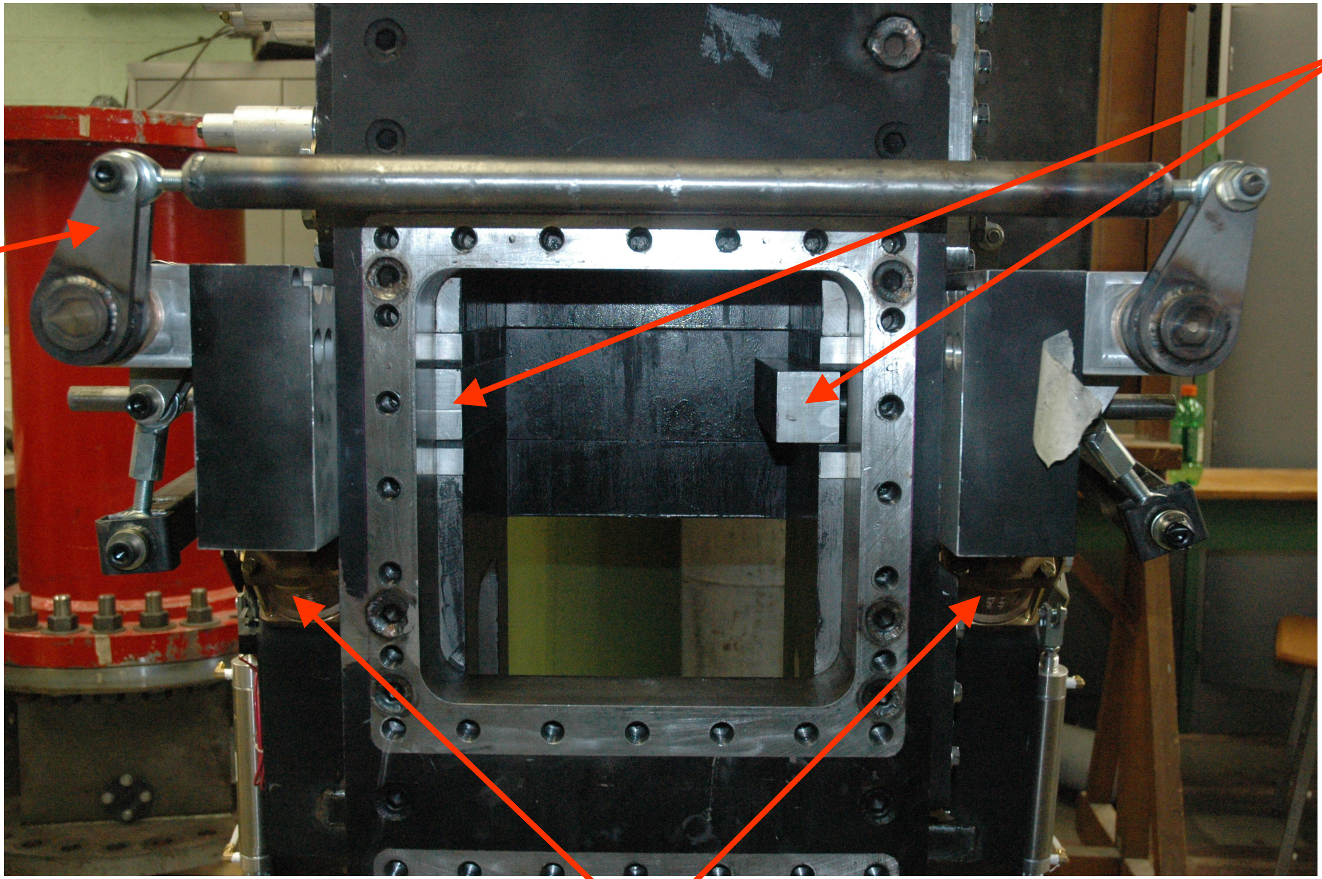
Excimer Laser
λ = 248 nm
E ≈ 550 mJ / pulse

Piston

1024 x 1024
CCD Array

Laser sheet
forming optics

PISTON ASSEMBLY



Piston cam assembly

5.08 cm wide pistons

Back pressure exhaust ports

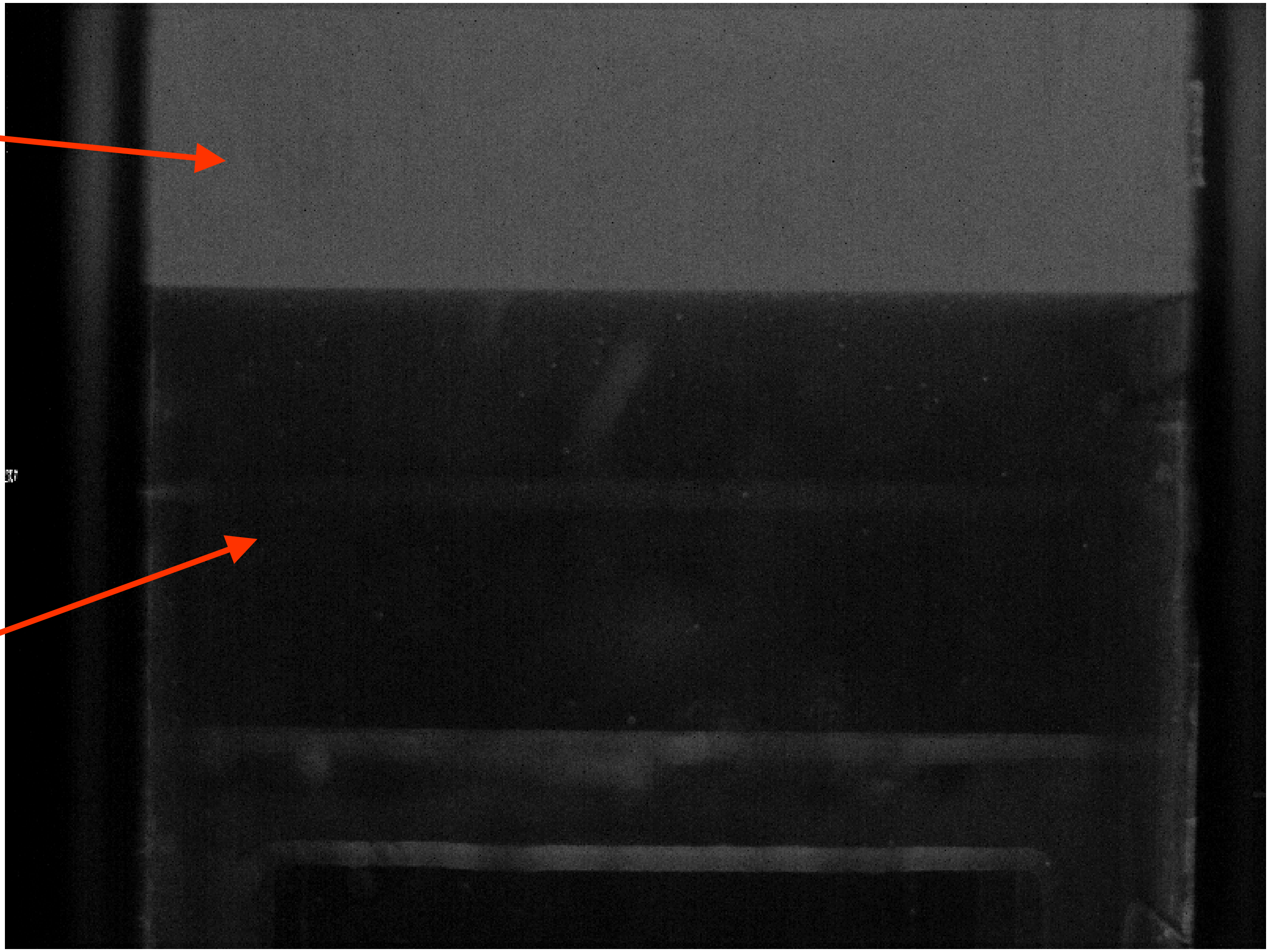
Experimental parameters

	A	B	C
Light gas	N_2	N_2	N_2
Heavy gas	SF_6	SF_6	SF_6
Tracer	acetone	acetone	smoke
M (initial)	1.26	1.26	2.05
A (pre)	0.643	0.643	0.678
A (post)	0.672	0.672	0.771
η (pre)	0.78 - 0.81 cm	0.52 - 0.82 cm	0.64 - 0.97 cm
η (post)	0.57 - 0.58 cm	0.39 - 0.58 cm	0.37 - 0.57 cm
λ	9.4 cm	17.9 cm	16.8 cm
k	0.670 cm^{-1}	0.351 cm^{-1}	0.374 cm^{-1}

Initial condition

N_2 seeded with smoke

SF_6

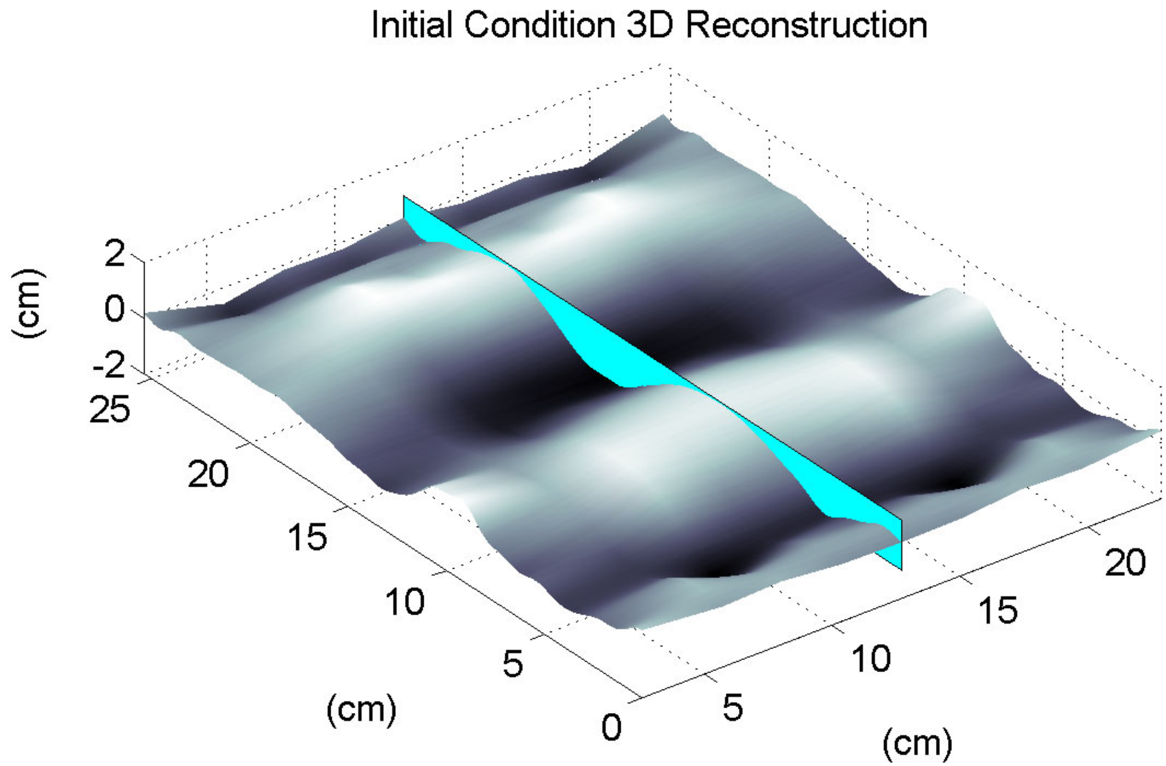


Pistons oscillate at 2.1 Hz (0.476 second period),

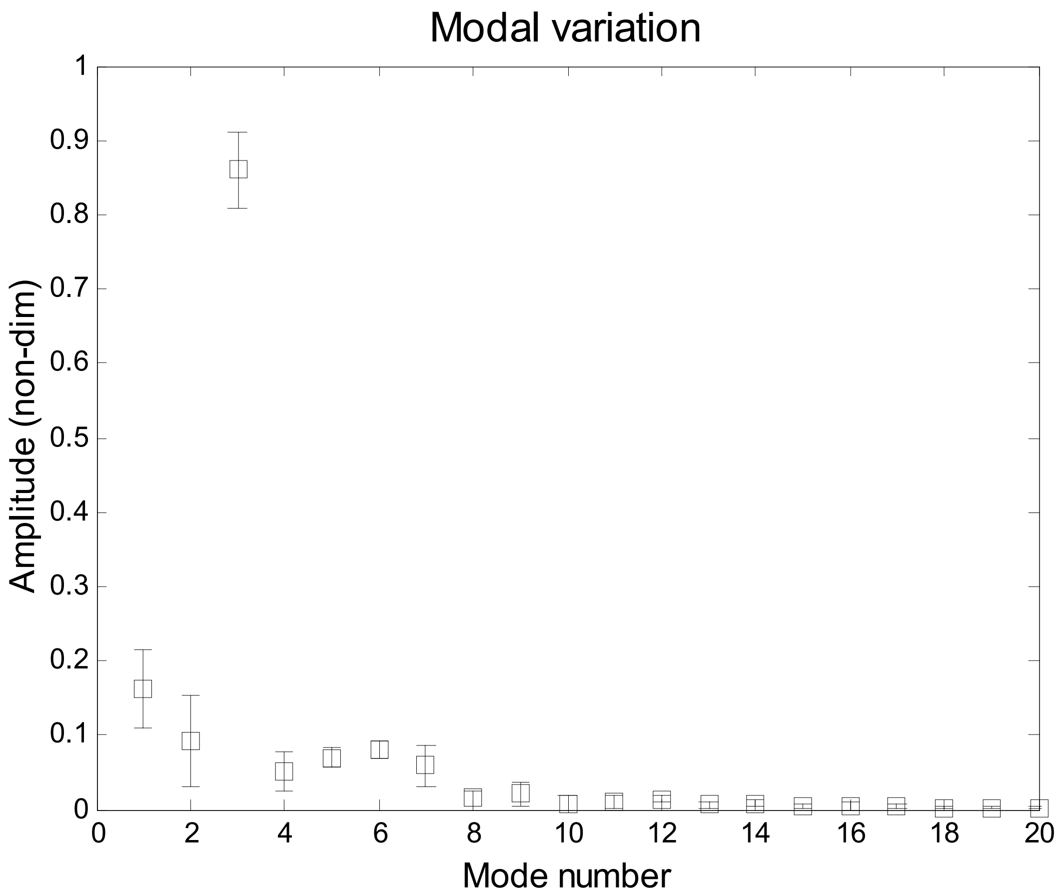
for 3 revolutions.

Initial condition

Pistons oscillating at 1.9 Hz



Initial condition modal content (6 test sample)

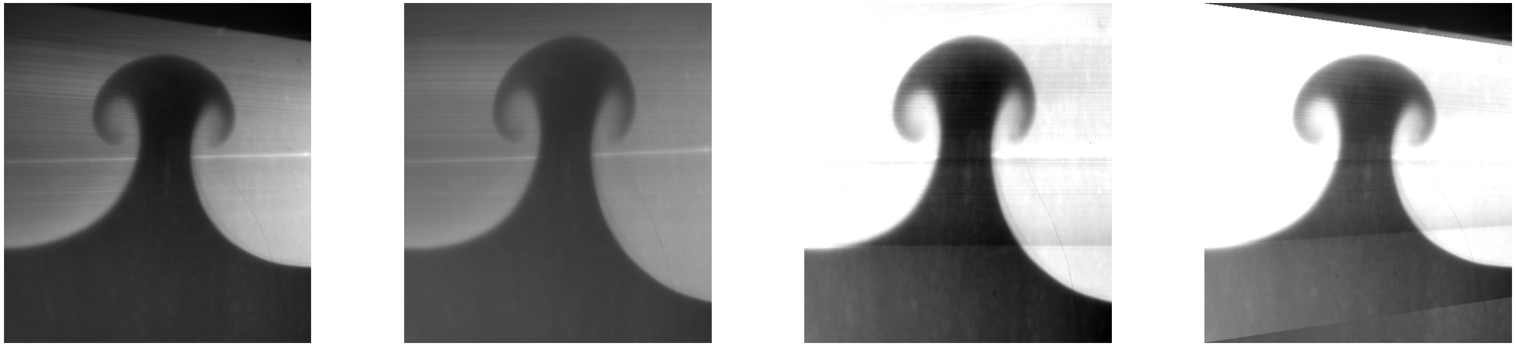


a) Raw image

b) Mapped image

c) Mapped image corrected using Beer's Law

d) Re-mapped corrected image



a b c d

Computational setup

2D hydrodynamic code – Raptor (LLNL)

a) solves the multi-fluid compressible Euler equations, with an ideal gas law equation of state

b) a shock-capturing scheme and higher-order Godunov solver is used to handle shock propagation accurately and suppress spurious oscillations

c) fixed (Eulerian) grid in 2-D Cartesian geometry, 512 grid points in the transverse dimension

d) two levels of adaptive mesh refinement (AMR) on the fluid interface

e) initial condition is characterized using a Fourier transform

f) the interface is smeared vertically using a hyperbolic tangent distribution fitted to the diffusion characteristics of the experimental interface

Non-dimensional parameters

Following Jacobs & Krivets, Physics of Fluids 17, 034105 (2005)

Non – dimensional amplitude = $ka - ka_0 = \eta$

where k is the wave number, a_0 is the initial amplitude and a is the amplitude

Non – dimensional time = $k\dot{a}_0 t = \tau$

where $\dot{a}_0$ is the post shock growth rate, and t is time

In the analysis presented, the approximation $\dot{a}_0 \approx ka_0 A \Delta V$ is utilized,

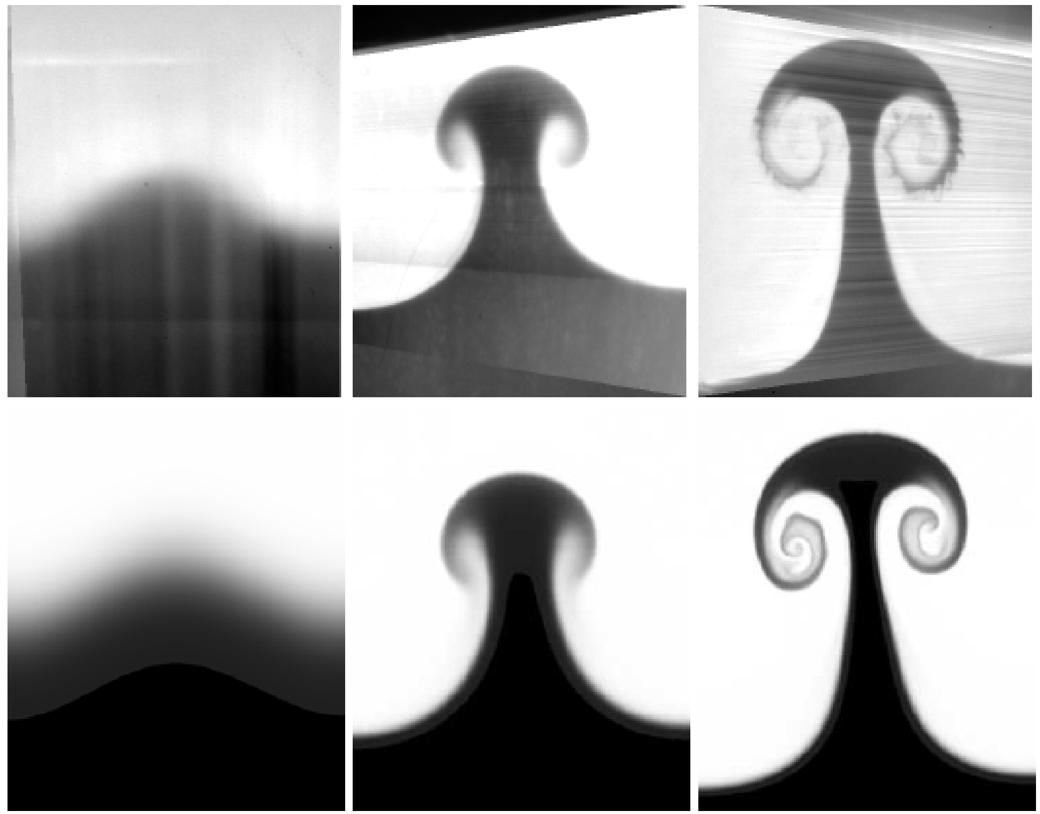
where A is the post shock Atwood number and ΔV is the velocity change of the interface due to impulsive acceleration of the shock wave

Results: *M = 1.26*

M = 1.26, 2.6 Hz driving frequency, λ= 90 mm, a_{0-} = 6.11 mm

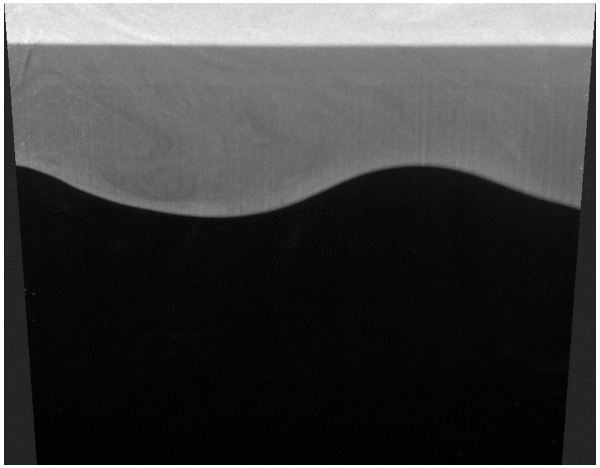
Experiment

RAPTOR

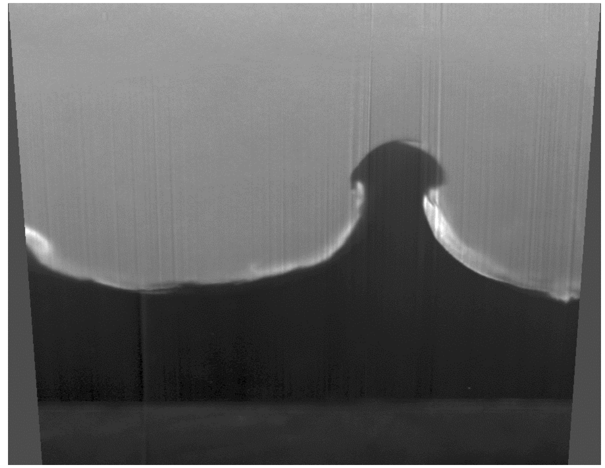


τ = 0.00 τ = 4.66 τ = 8.79

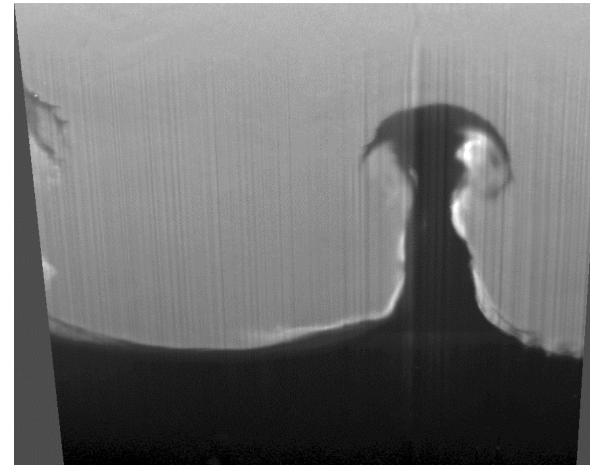
Results: $M = 2.05$



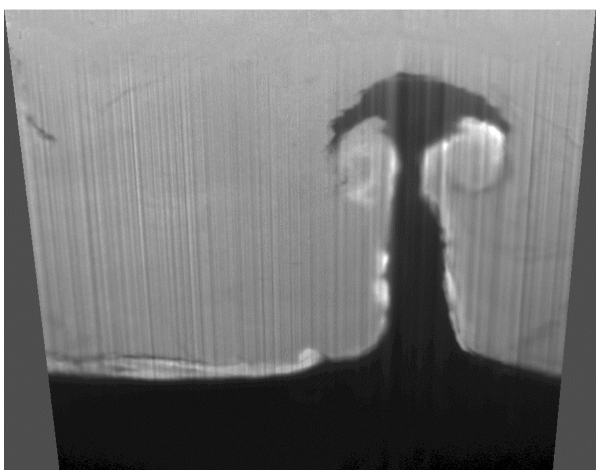
$\tau = 0.00$



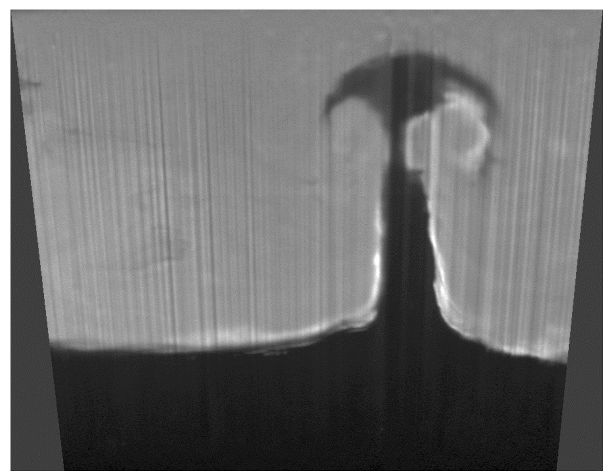
$\tau = 1.54$



$\tau = 3.29$

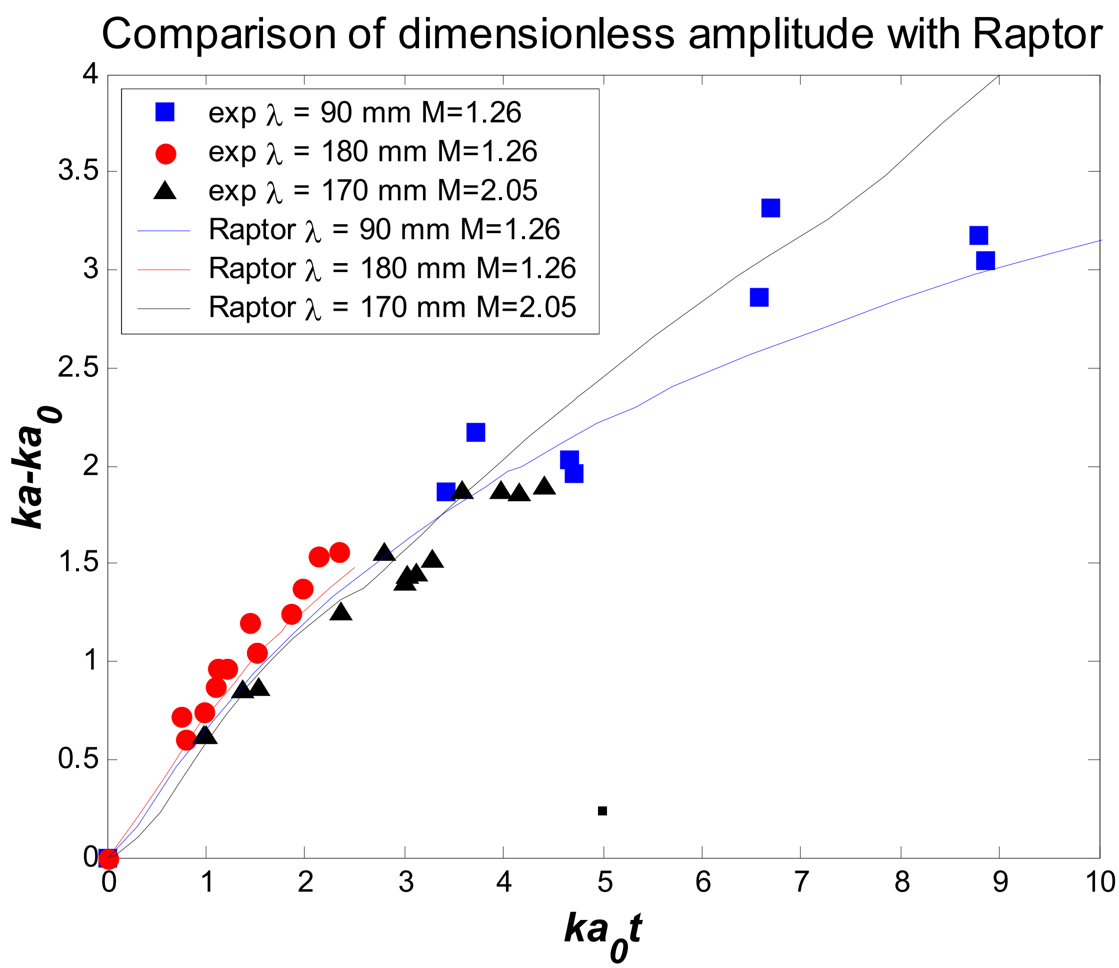


$\tau = 3.98$



$\tau = 4.16$

Comparison with Raptor results



1) Sadot et al., Phy Rev Lett Vol. 80 Number 8 (1998)

$$a(t) = [\frac{\dot{a}_0}{(4E - D^2)^{\frac{1}{2}}}(2 - \frac{BD}{E})] \times \tan^{-1}[\frac{2Et + D}{(4E - D^2)^{\frac{1}{2}}}] + \frac{\dot{a}_0 B}{2E}\ln(1 + Dt + Et^2) + K$$

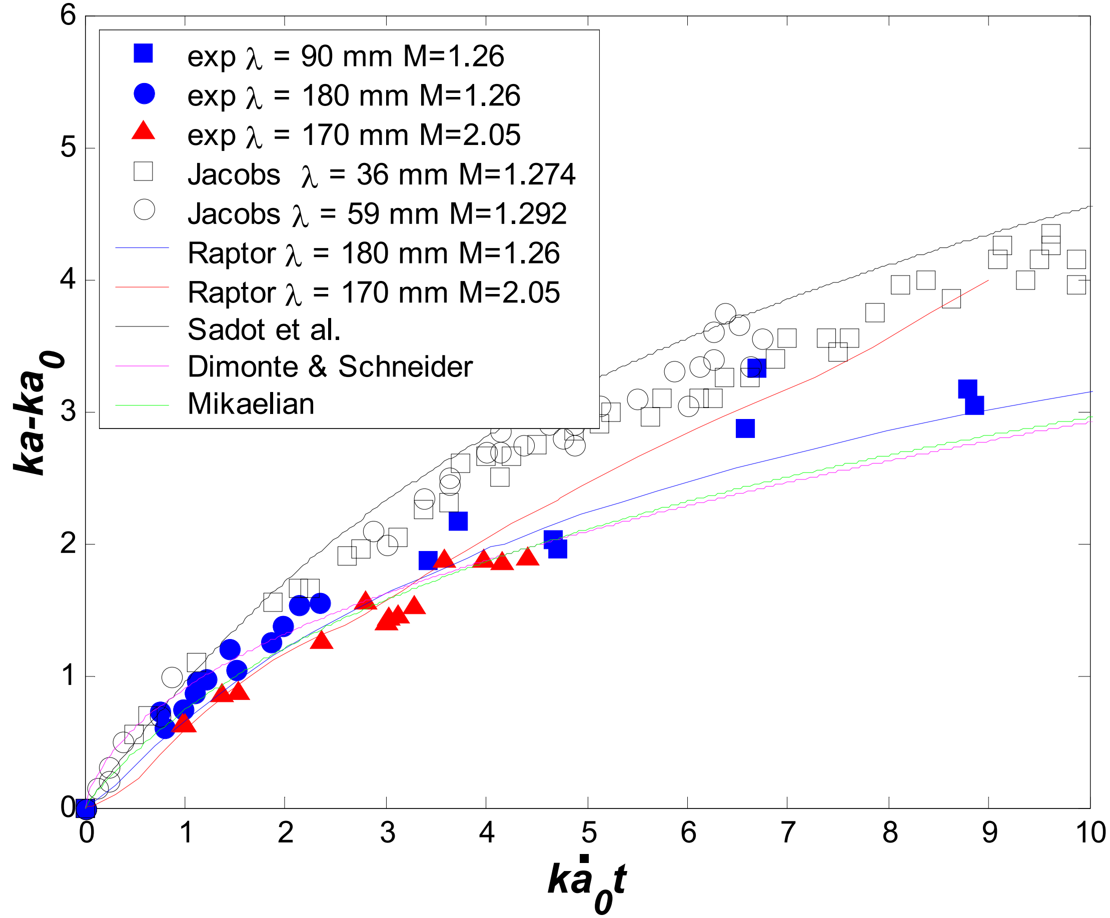
2) Mikaelian, Physical Review E 67, 026319 (2003)

$$a(t) = a_0 + \frac{3 + A}{3(1 + A)k}\ln(1 + 3\dot{a}_0 kt\frac{1 + A}{3 + A})$$

3) Dimonte & Schneider, Physics of Fluids Vol. 12 Number 2 (2000)

$$a(t) = a_0 \tau_i^{\theta_i}$$ where $$\tau_i = \frac{V_{i0}(t - t_0)}{\theta_i a_0} + 1$$

Comparison of dimensionless amplitude with several models



*Jacobs data taken from Figure 7 of J.W. Jacobs & V.V. Krivets Physics of Fluids 17, 034105 (2005) paper.

Conclusions

1) Oscillating piston technique suitable for setup of 2D initial conditions

2) Same geometrical features as in low *M* experiments at much earlier dimensionless times

3) Satisfactory agreement between the experiment and Raptor at M = 1.26 and M = 2.05 at early times (but intermediate *M* expts. suggest saturation while code doesn't)

4) Satisfactory agreement with Mikaelian and Dimonte & Schneider models at M = 1.26 and M = 2.05 (but intermediate *M* expts. suggest saturation while models don't)

5) Is current normalization missing compressibility effects? (more in bubble epxts. and corresponding calculations)