One & Two Dimensional Diagnostics for Detonators & Boosters

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Diagnostics are needed to understand detonation transfer & HE system design

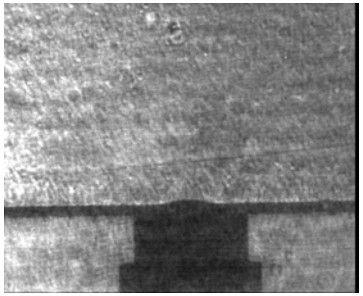
- Every fuze system uses a series of successively larger explosive charges
- This HE transfer problem drives sizing of future munitions, i.e. miniature firing systems are are limited by the size of the explosive train
- Insensitive Munitions requirements only make matters worse

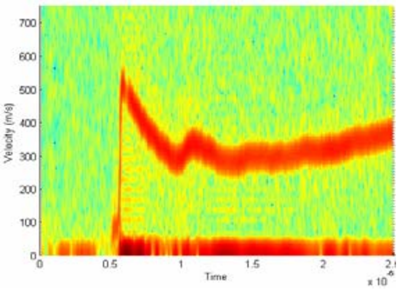
What we know about IHE's

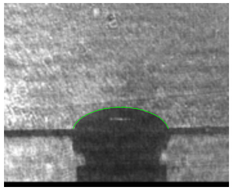
- Difficult to reliably detonate with small initiation systems
- Can experience significant transient effects (accelerating, or decelerating detonation waves & poor corner turning properties
- Area LANL has dubbed "microdetonics"
- HE modeling of transient effects using Detonation Shock Dynamics (DSD)
- Require a better understanding of the transient phenomena to feed HE transfer designs & HE formulations

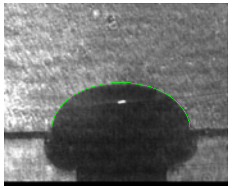
Key to understanding is diagnostics

- Small-Scale Statistically Significant Experiments
  - Phased study of Explosive Train
  - Mini-Wedge Tests for IHEs
- 1-D Experiments & Diagnostic Techniques
  - Comparision to database
  - Photonic Doppler Velocimetry
  - Cutback experiments
- Multi-dimensional Diagnostics
  - Laser Schlieren High Speed Movies
  - Photonic Doppler Velocimetry
  - Streaks, Breakout, and COI
  - Future Diagnostics

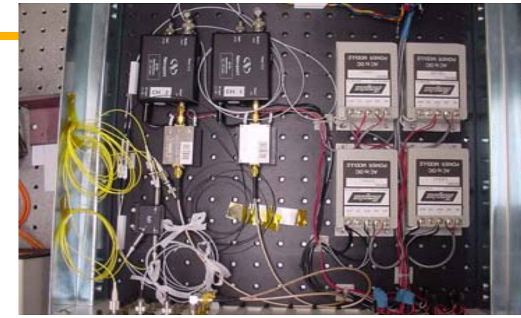




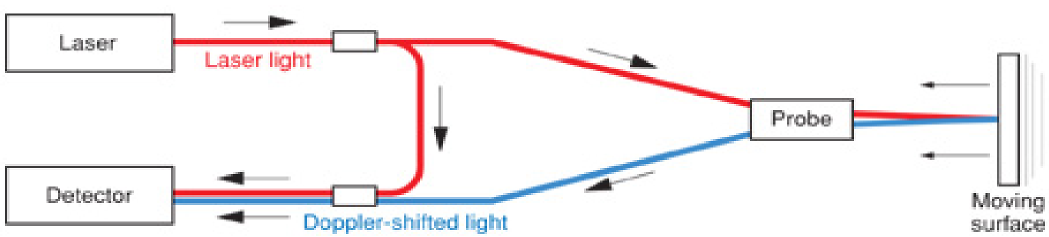




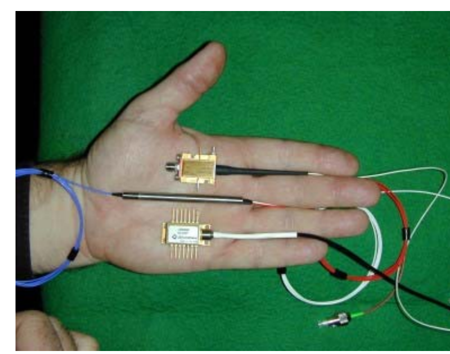
Photonic Doppler Velocimetry (PDV)



- **laser-based radar gun**
- **will replace VISAR as diagnostic**
- **uses IR light (1550nm)**
- **all fiber optic system (no alignments)**
- **determines velocity from Doppler shift of reflected light**
- **similar to VISAR**
- **directly measures the heterodyne beat electronically**
- **velocity range from m/s to km/s**



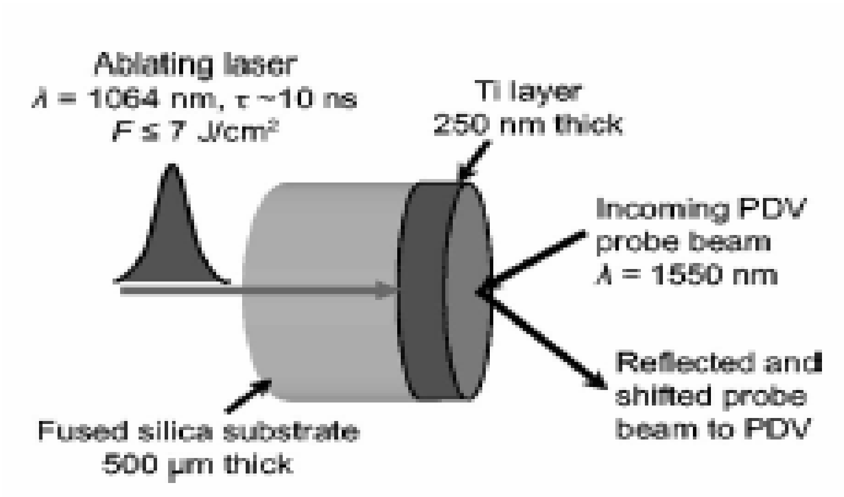
LANL's mini-PDV system



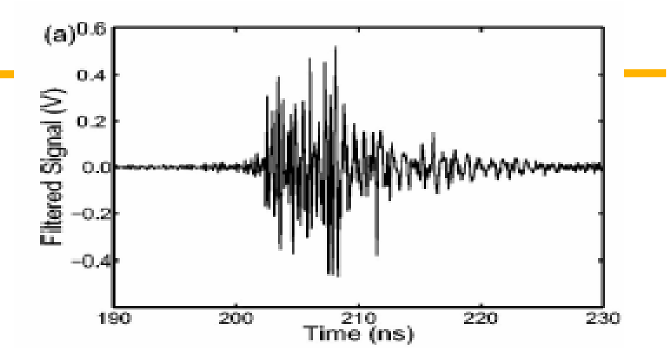
Courtesy of David Holtkamp

Capable of measuring multiple velocities

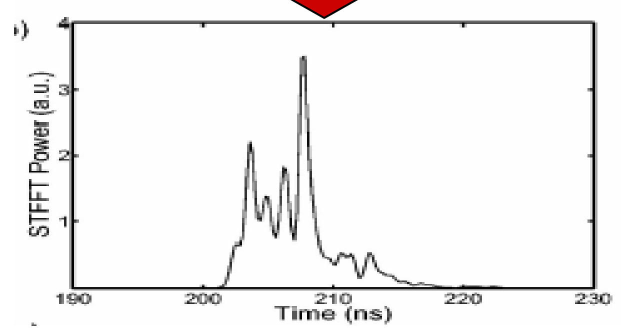
PDV Example: Laser ablated metal



Laser Ablates a thin Ti film

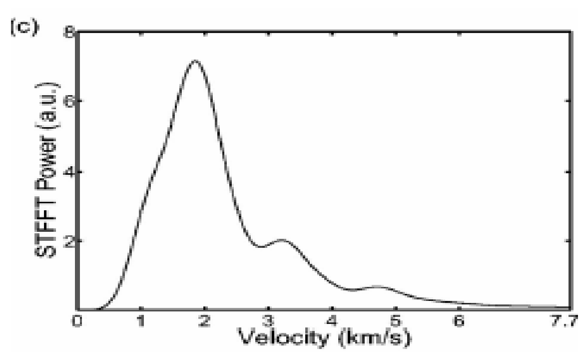


Filtered raw data



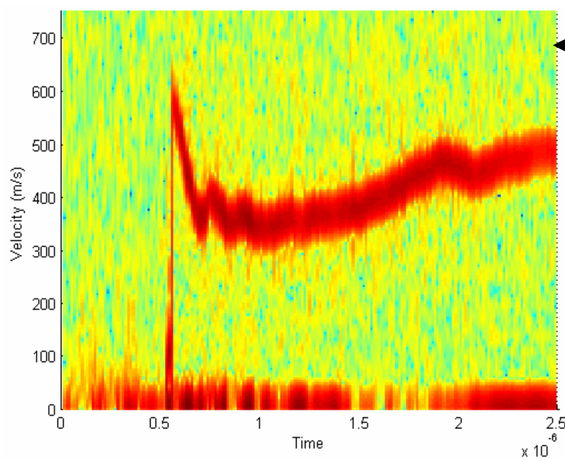
Temporal profile of spectrogram

Velocity data shows Multiple particles Moving at different velocities



A. Valenzuela, et.al., Rev. Sci. Instr. 78, 013101 (2007).

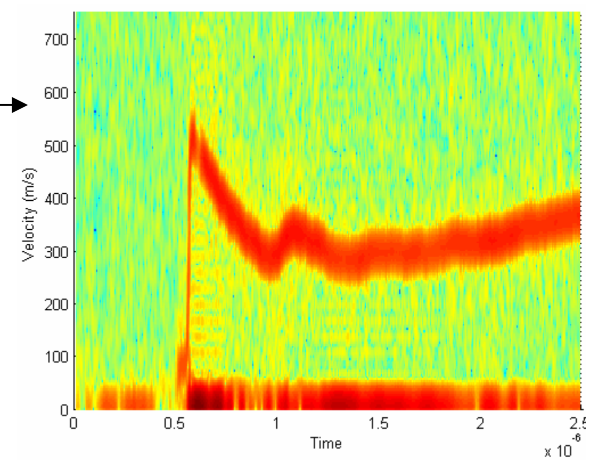
PDV Application Examples



Tantalum

3mm PETN ←

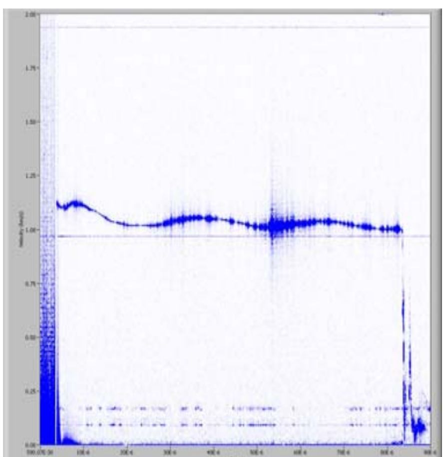
6mm PETN →

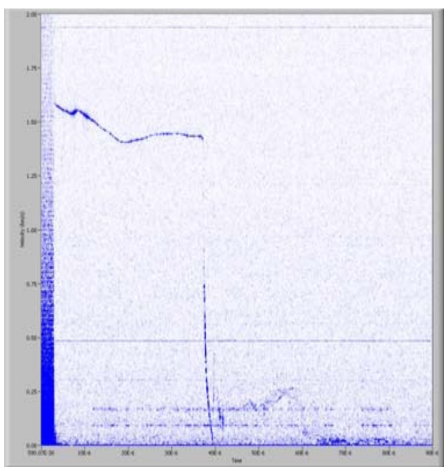


Aluminum

← Thick Flyer

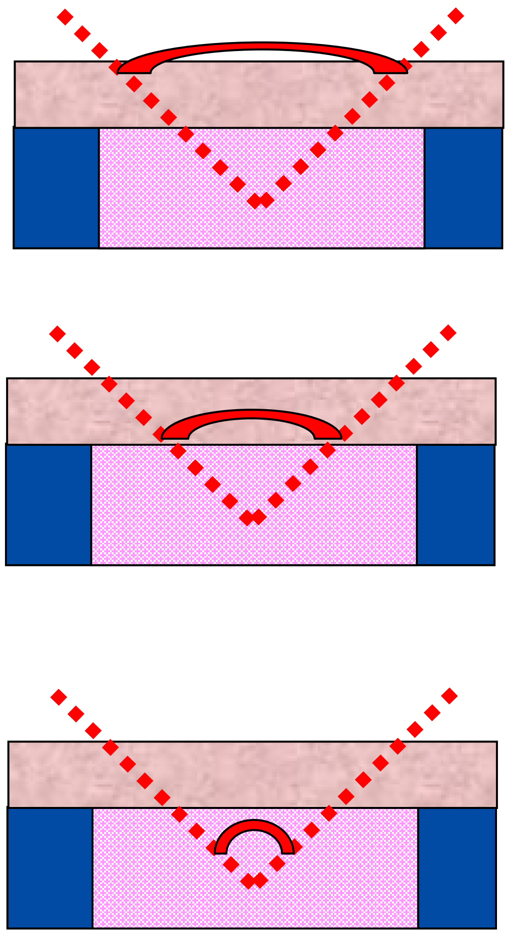
Thin Flyer →





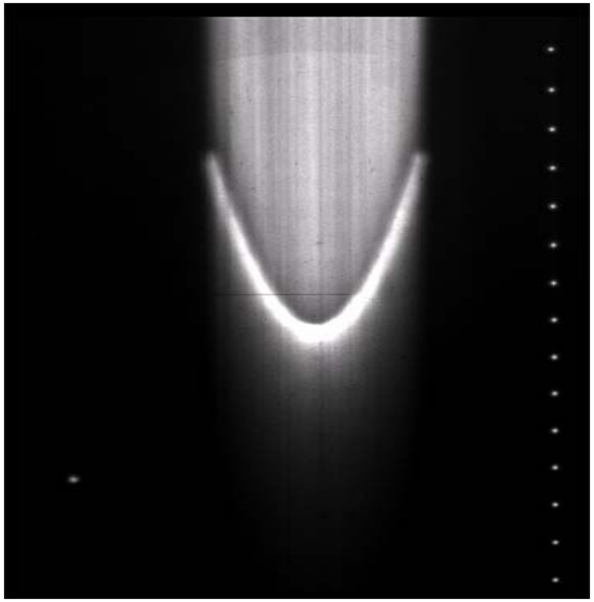
Apparent Center of Initiation as a Metric

- Explosive breakout observed by streak camera
- Image fit to a curve
- Assume a Huygens-like propagation
  (not bad idea for detonator HE)
- Work equations backwards to determine
  apparent "point" of initiation
- Provides a distance from surface
- Quantitative measure of waveshape
- May or may not be related to actual COI

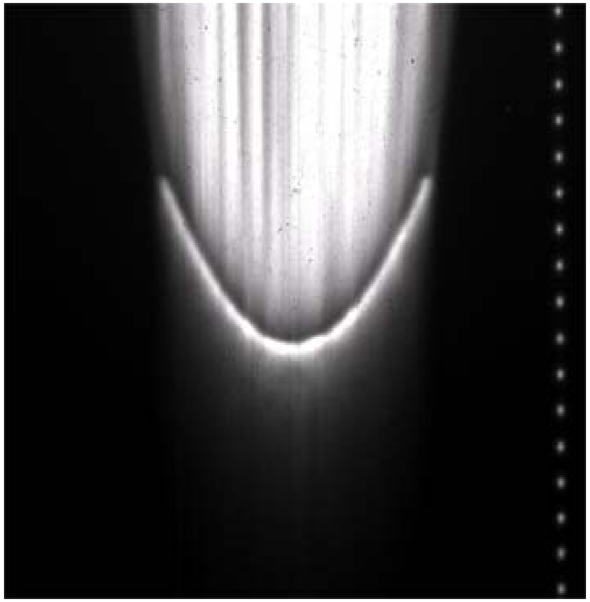


Quantitative Measurements Of Wave Shapes Offers A Gauge Of Similarity

EBW



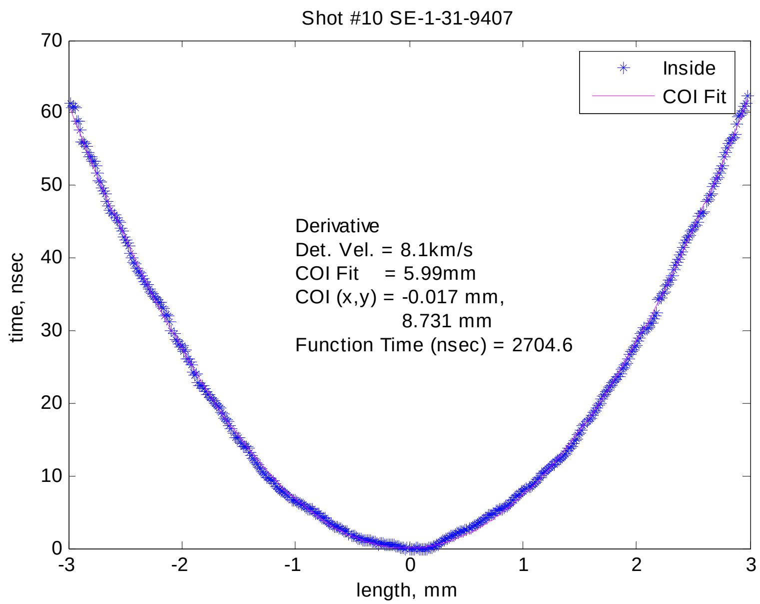
Laser Det.



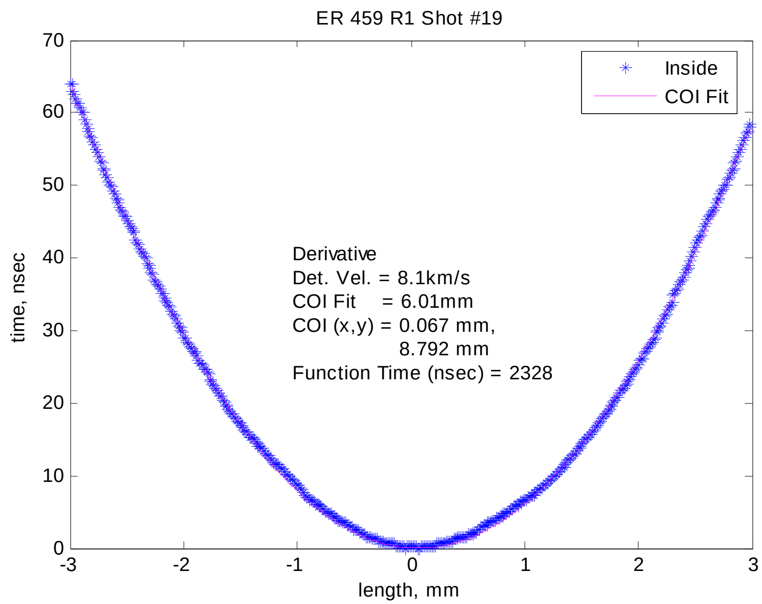
Output WaveShapes are very similar

***Time/Distance Scales are not equivalent**

Fits to the Apparent Center of Initiation provide Metric of Equivalency



EBW Detonator



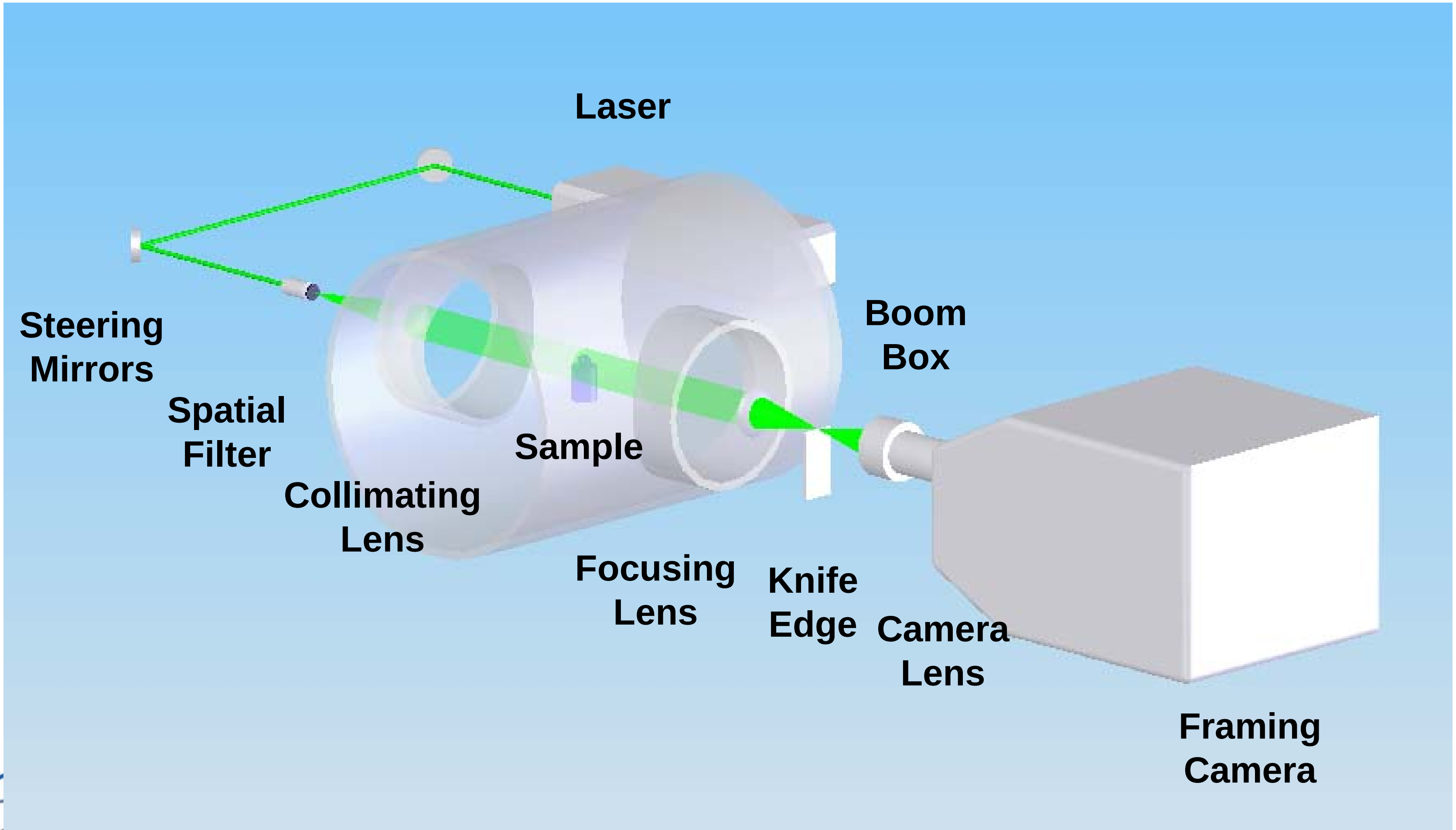
WorkHorse Detonator

Average Center of Initiation	
SE-1 (EBW)	**WorkHorse (Laser)**
8.10 mm	**8.58 mm**

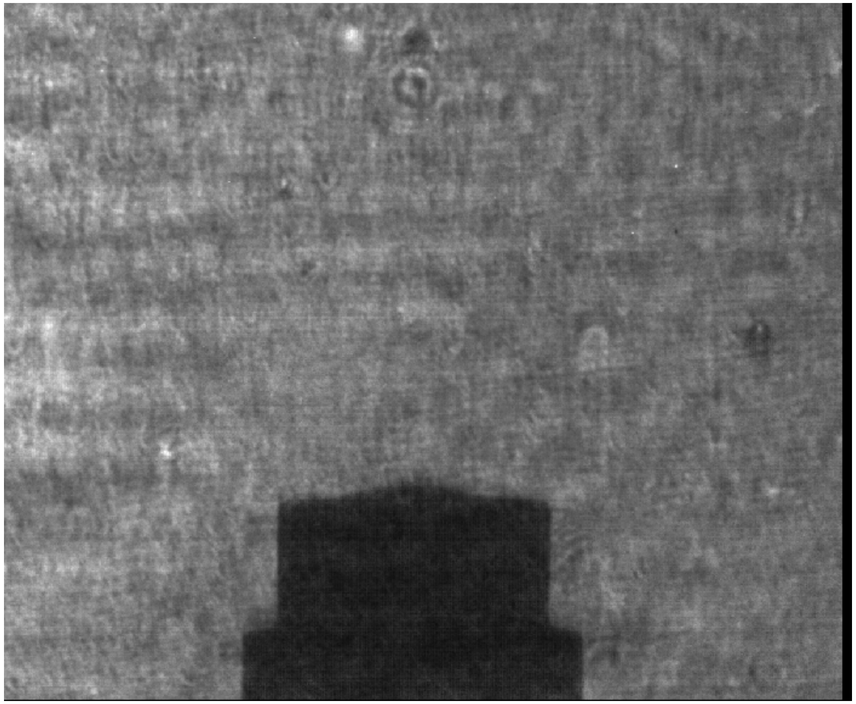
Need for Multi-Dimensional Data

- It is not enough to determine the pressure drive in 1-D
- Next stage explosive sees all of the input
- Requires 2-D flow characterization
- LANL attempted different techniques to characterize the true flow fields

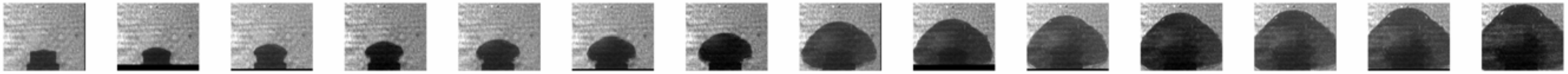
Laser Schlieren Experimental Setup



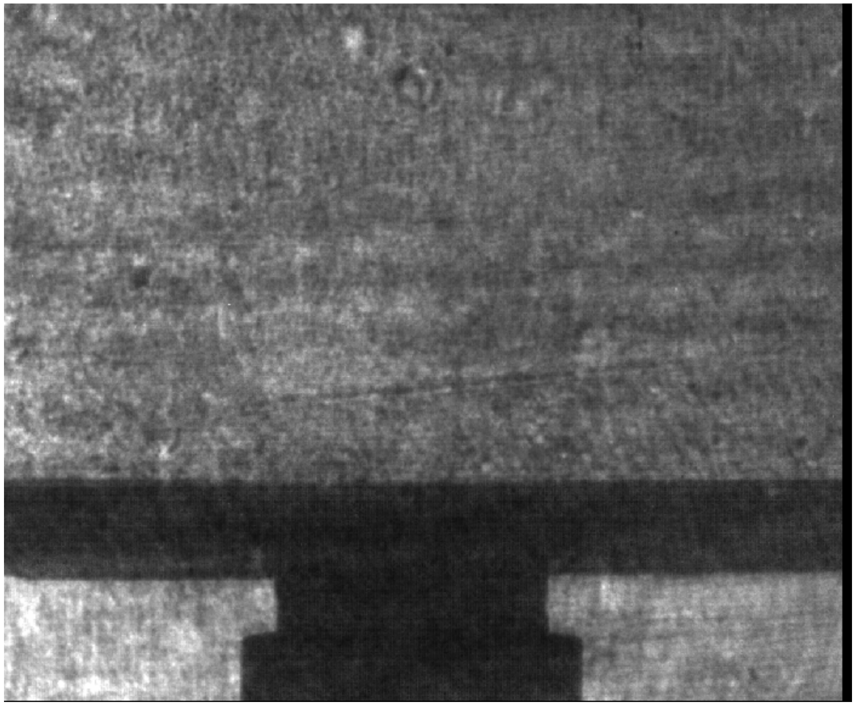
ER-462 into Air



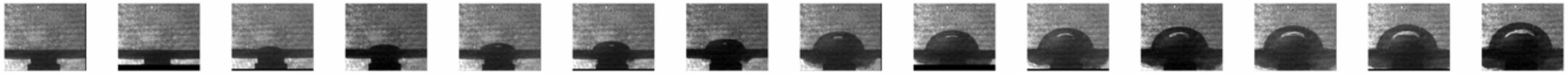
- No witness material
- Hard Fire of ER-462
- 20 ns exposures
- 200 ns interframe
- 3.61 km/s shock velocity



ER-462 (DOI) into PDMS



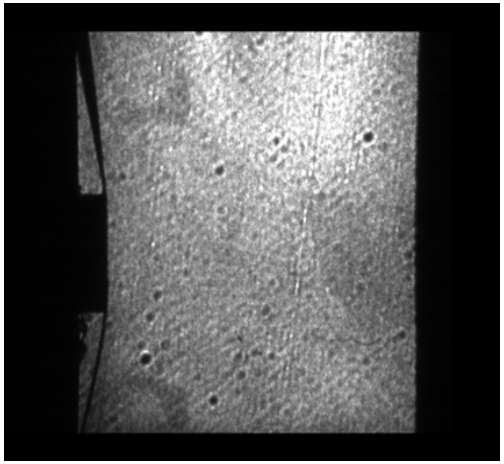
- PDMS is soft plastic witness material
- Hard Fire of ER-462
- 20 ns exposures
- 200 ns interframe
- 2.21 km/s shock velocity

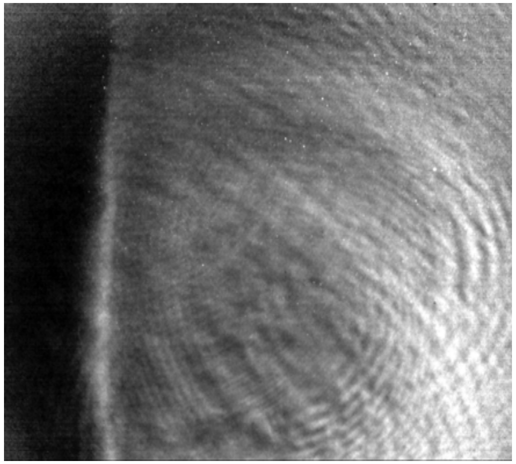


Schlieren System has Wide Applicability

Large field of view (~ 30 mm)

Long interframe time (~15 us)



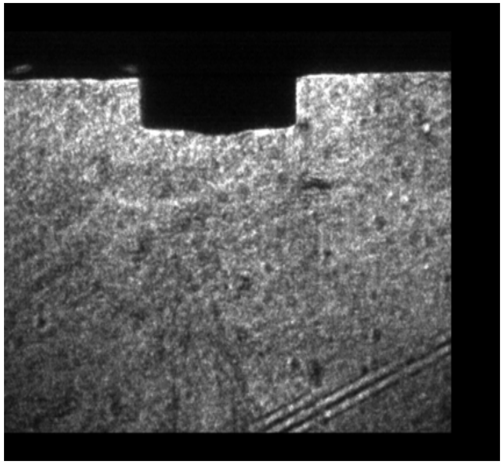


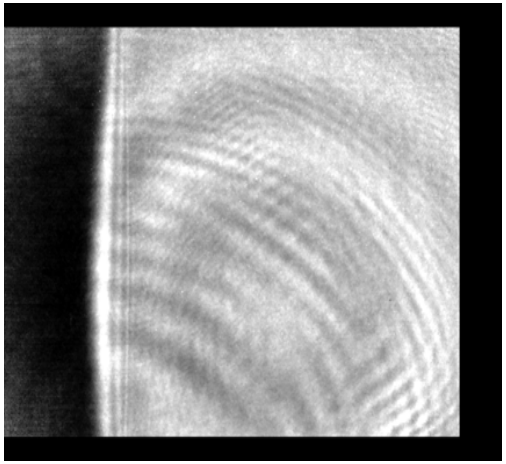
Small field of view (~2.5 mm)

Intermediate Interframe time (~150ns)

Large field of view (~ 30 mm)

Short interframe time (~50 ns)

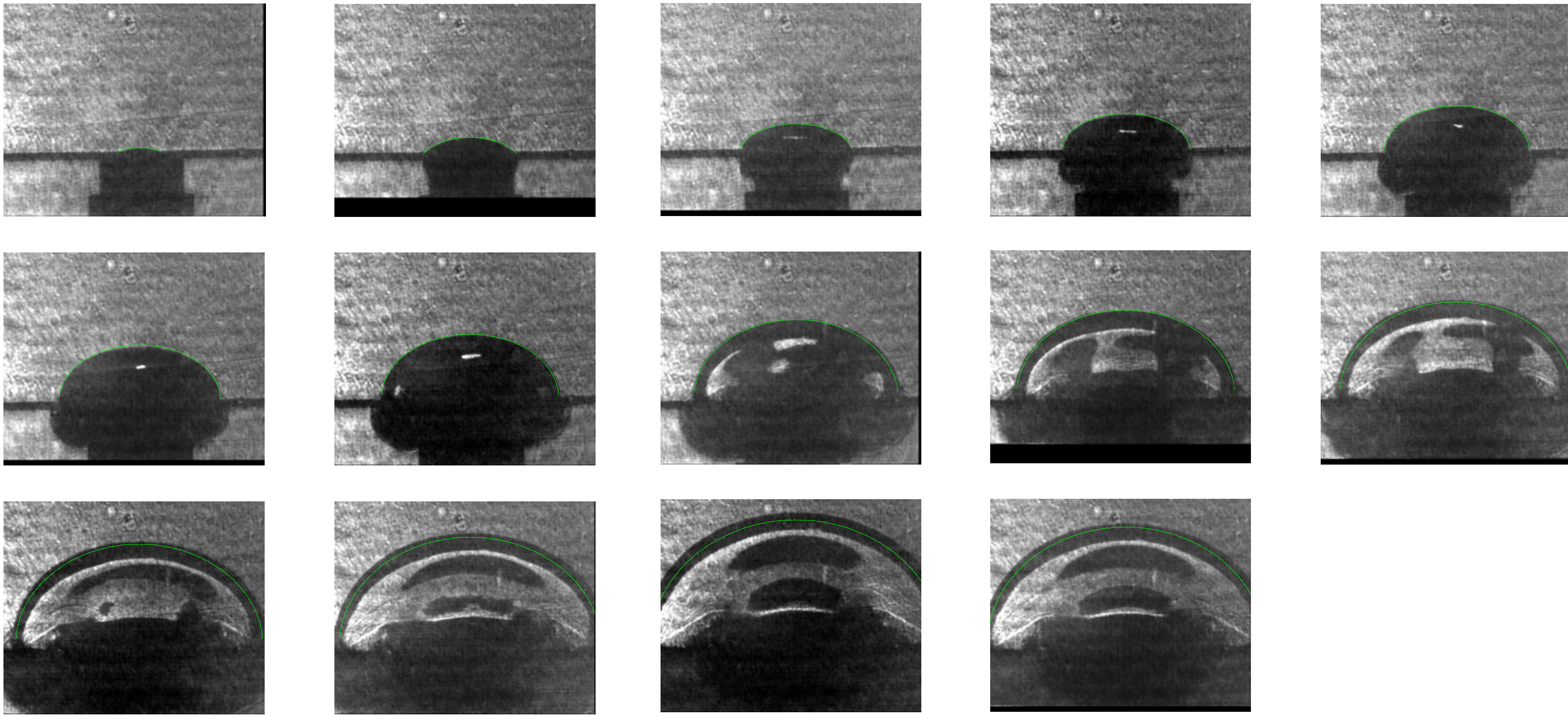




Small field of view (~2.5 mm)

Very Short Interframe time (~5ns)

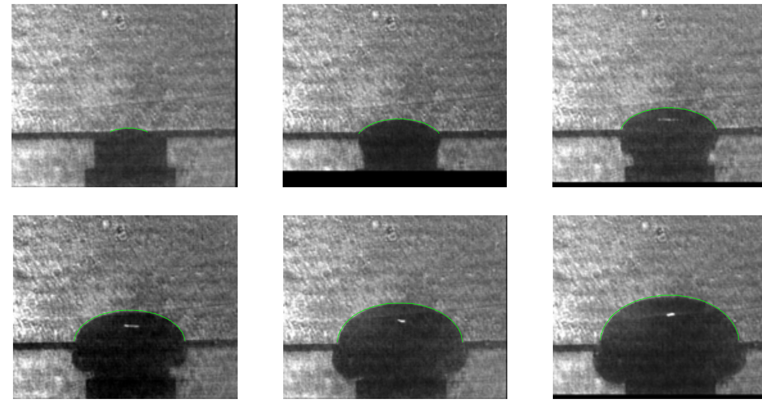
Use EPIC to infer the pressure output from detonator creating the shock profile

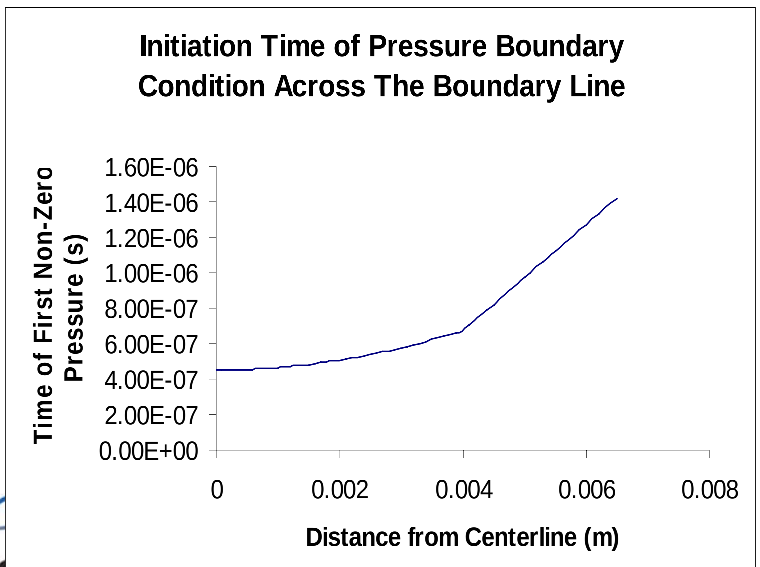


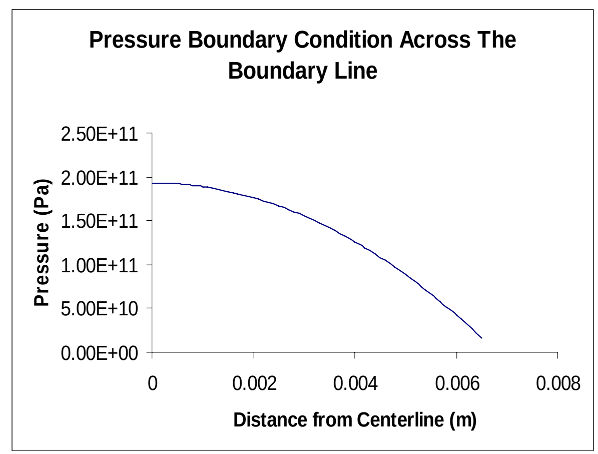
- Use EPIC to find 'likely' boundary condition on experiment
- Working the problem in reverse
- Verify detonation model parameters for detonator explosives (PETN, HNS-IV, …)

Use EPIC to find Temporal-Spatial Pressure Profile

- **Use EPIC to find ‘likely’ boundary condition on experiment**
- **This allows us to infer the pressure output profile for tested detonators**
- **Verify detonation model parameters for detonator explosives (PETN, HNS-IV)**



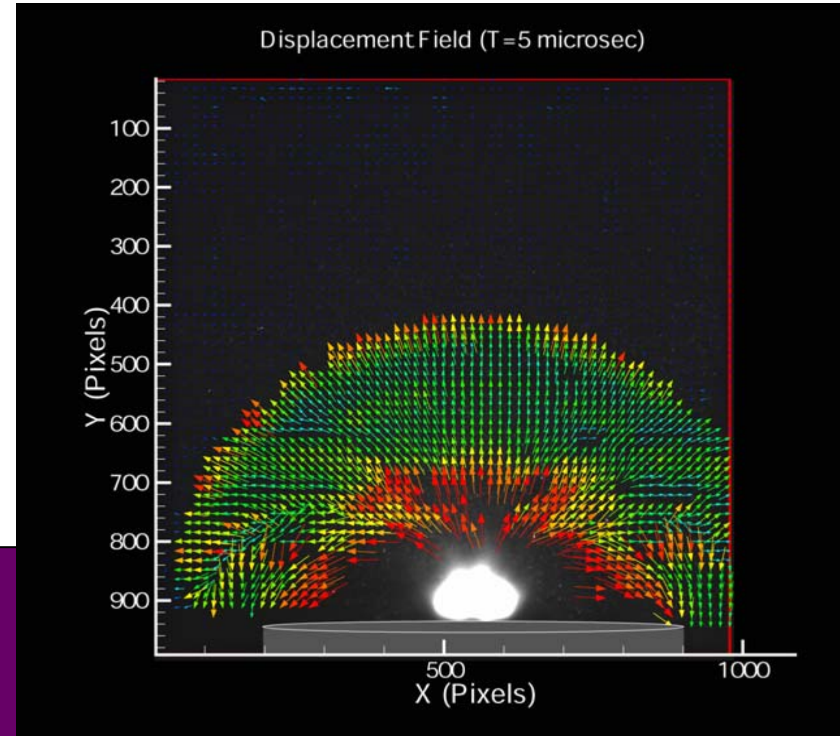


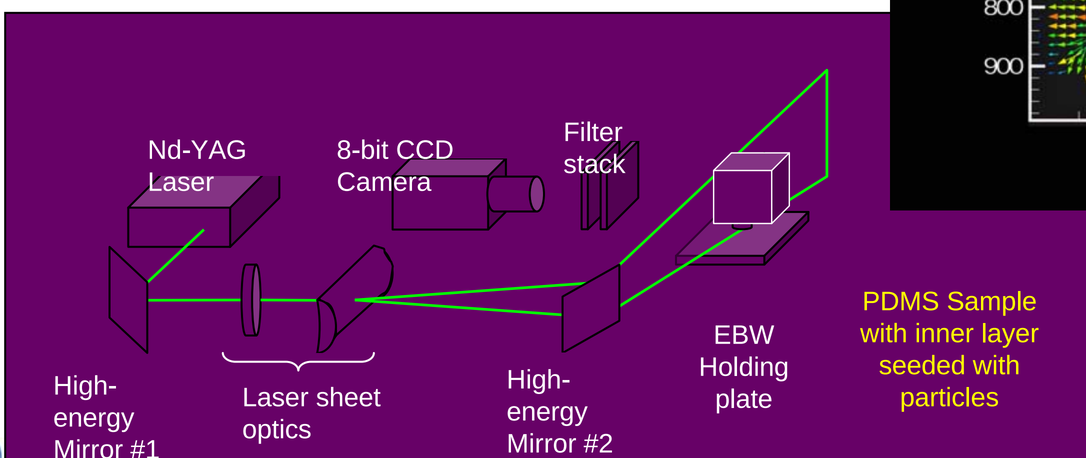


PIV Measurements Show 2-D HE Flows

GOAL – quantify 2-D flow

- **Particle Imaging Velocimetry**
- **Embedded particles**
- **Current testing at ASU on EBWs & EFIs**





Summary

- LANL working to develop diagnostics for 1-D and 2-D flow of energy from various stages of detonator-booster explosives
- Presented several techniques
- Attempting to make Schlieren & PIV techniques feed hydrocode data (not just pretty pictures)
- Better understanding is the key to working the existing IHE transient detonation problems