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<i>Title:</i>	MicroPDV for Slapper Detonator Characterization
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## Abstract

MicroPDV (photonic Doppler velocimetry) is described. The history of the technique and the current setup is described. The software features such as channel combining and distance extraction are also described. Finally, examples of the data are shown.

# MicroPDV for Slapper Detonator Characterization

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PDV Workshop  
Livermore Calf  
Nov 2, 2011



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Slide 1

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# Outline

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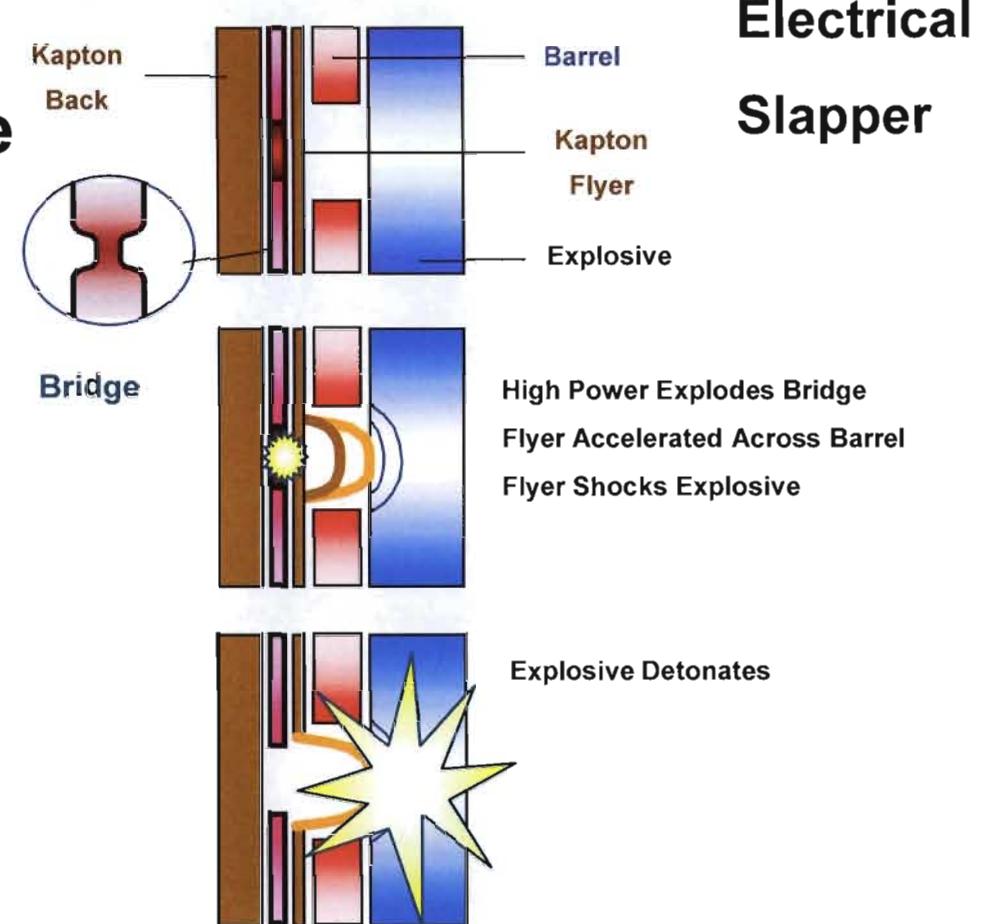
- **Slapper Flyer Velocity Problem**
- **History**
- **MicroPDV “Probe”**
- **Data Analysis**
- **Examples**
- **Future**

# Slapper Detonator Characterization Problem

- **“Slapper” detonators throw a flyer to initiate explosive:**

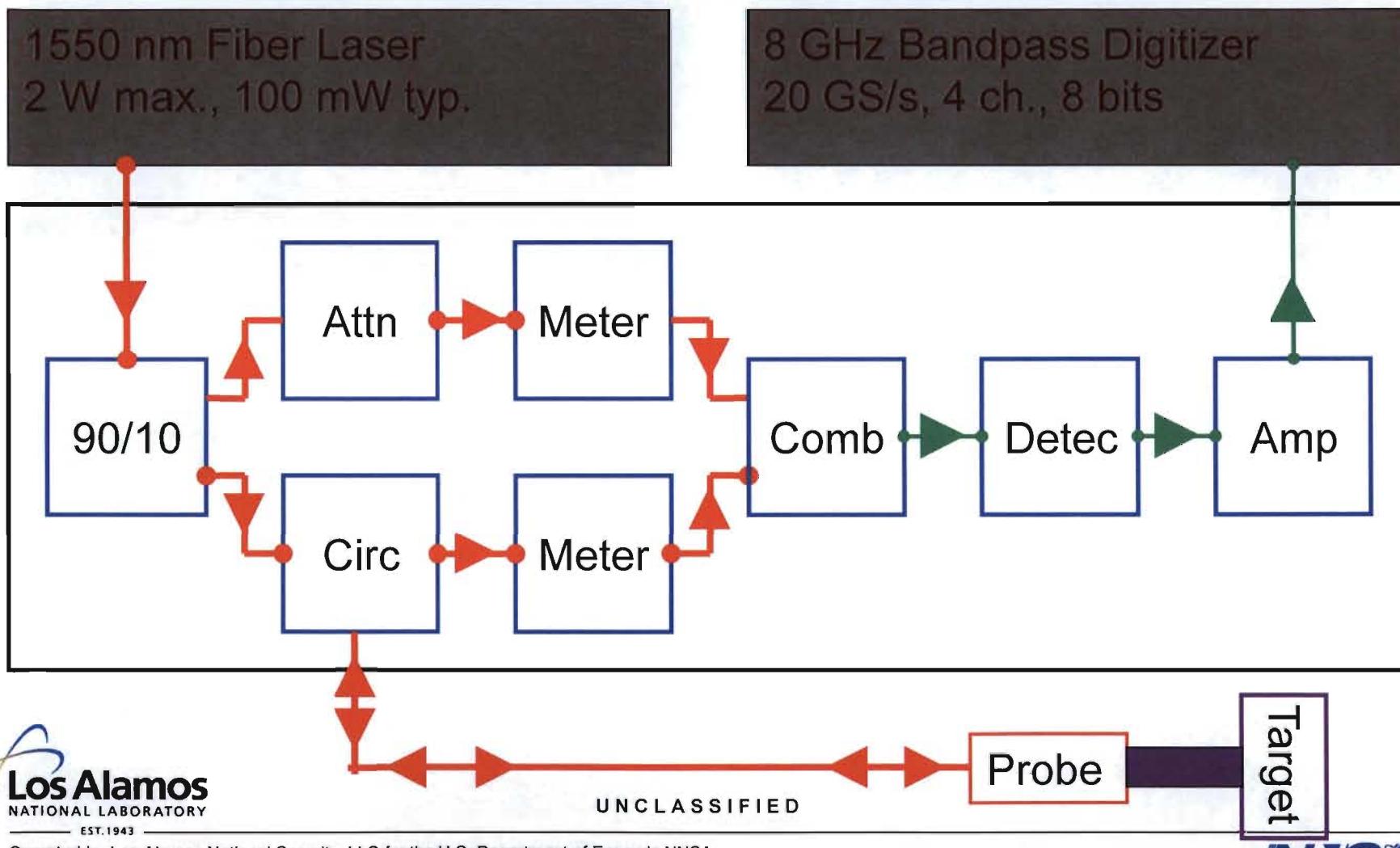
- very small (~200  $\mu\text{m}$ )
- clear (typically perylene)
- Thin (~25  $\mu\text{m}$ )
- Fast (3 – 5 km/s)

- **How do you measure the velocity of these samples?**

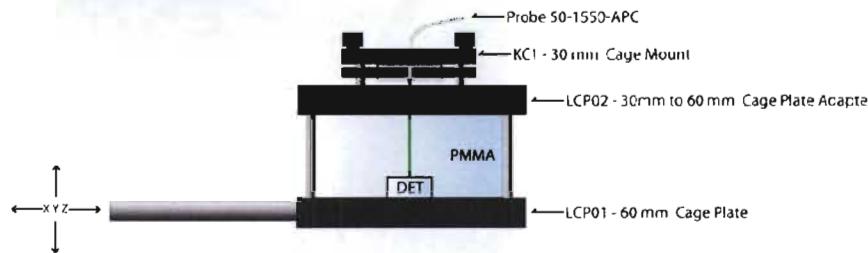
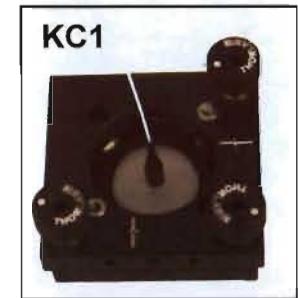


## History:

### 2005 LANL W-6 Adjustable Balance PDV Design

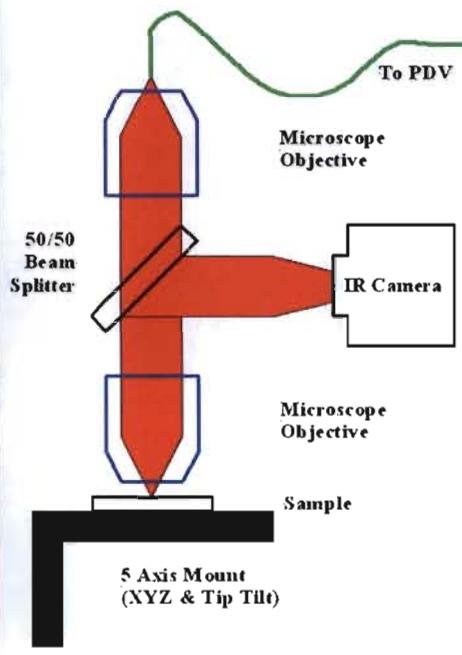


# History: First Probe and Alignment setups



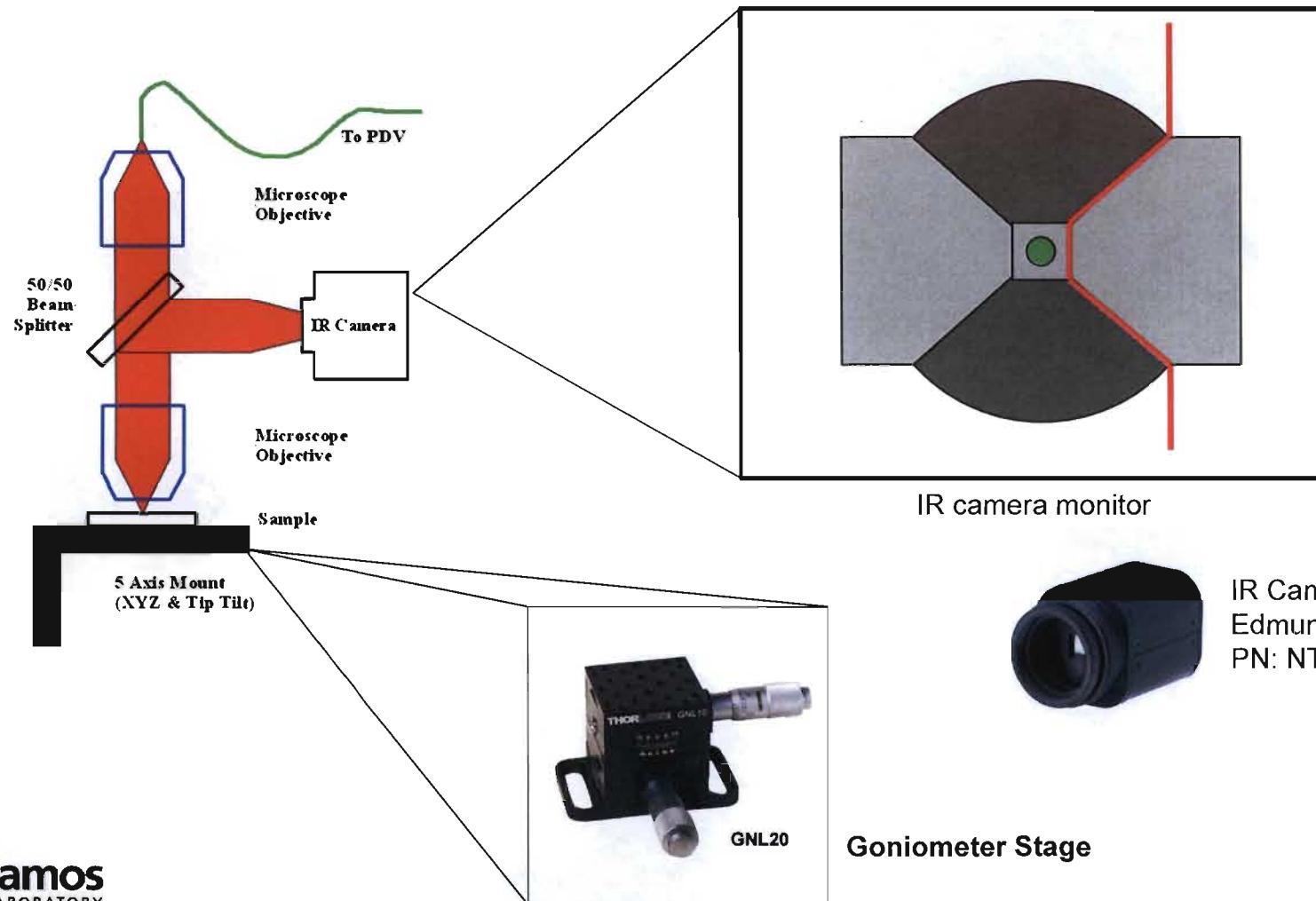
- **First try:**
  - Collimated probes
  - One tip-tilt stage
  - Alignment very difficult
  - At best 50/50 data return
- **Other attempts**
  - Tried two tip/tilt stages
  - Tried visible alignment laser
  - Tried IR visualizing tools
  - Tried disposable probes mounted to chip
- **Other labs tried several attempts as well**
  - LLNL had a long range microscope and visible laser (had to misalign in a reproducible way)
  - SNL had some similar approaches

# The Micro-PDV Solution: Combine IR microscope and PDV probe



- PDV and IR Microscope System
- Allow very precise positioning of PDV probe beam on small targets (EFI Bridges, etc.)
- Very small spot size (~ 10 micron)
- 5 Axis mount allows optimal alignment of sample to PDV probe
- Using to characterize initiation events (EFI flyer, EBW bridge burst, DOI Ablation, etc.)

# microPDV: Visualize PDV spot on sample



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# MicroPDV Design Tricks

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## ■ Microscope Objective

- We have had mixed success with microscope objectives
- Extremely clear images with some
- Very high back reflections with others
- Large number of optics, and no control over AR coatings or plano-faces

## ■ IR Camera

- Cheap solution has served us well.
- CCD camera with scintillation coating from Edmunds scientific

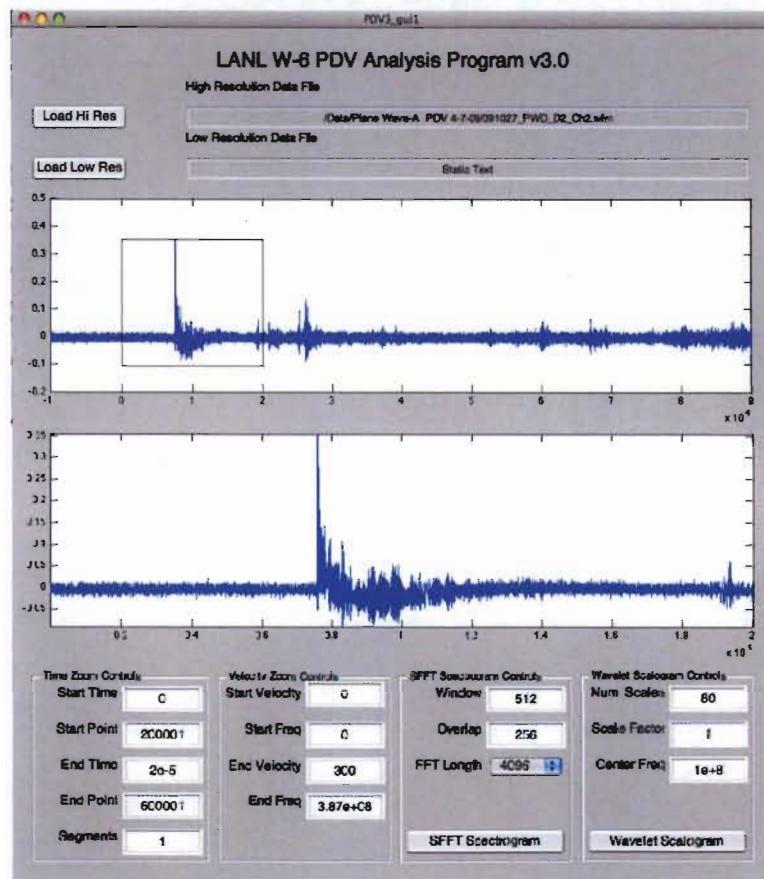
## ■ Beam Splitter

- Thick substrate, 10% beam splitter has given best results

## ■ Tip/Tilt is very important

- Perfectly Normal does not give PDV results (flash?, too much spectral reflectance? Etc.)
- Slight tilt to off normal gives better result

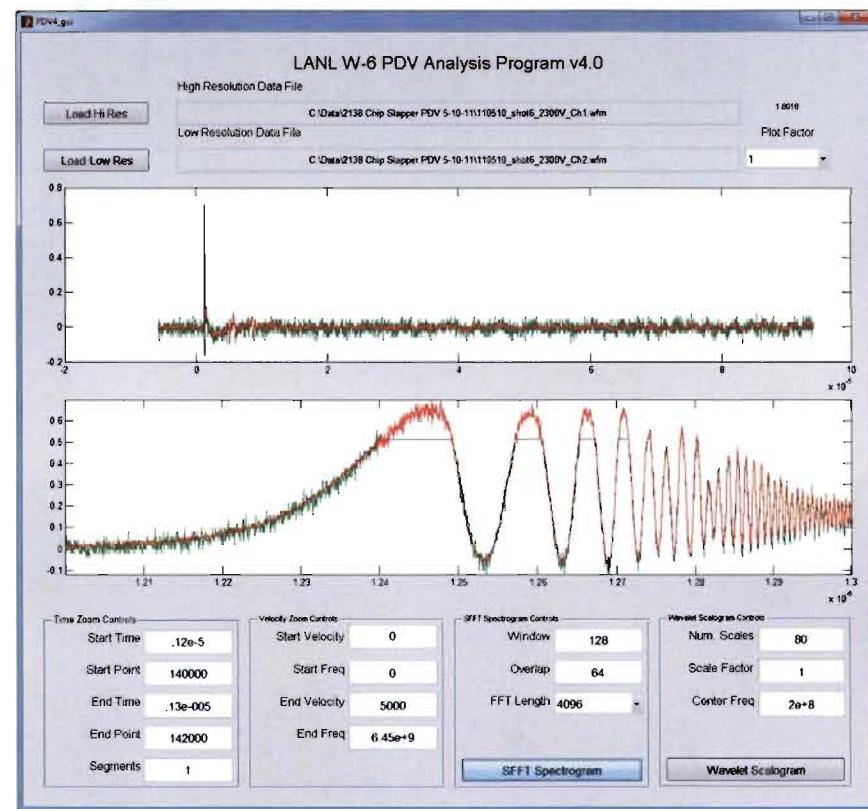
# PDV Software



- Combines two channels (high and low res) into one hybrid channel
- Has standard SFFT analysis, and our implementation of the Indian Head segmented SFFT analysis
- Has an option to extract a spline either forwards or backwards and save to Matlab desktop
- Requires MatLab, and currently reads either CSV (huge data files) or Tek .wfm files for our scope.
- Two implementations of Wavelets (MatLab's new toolbox and an inhouse implementation)

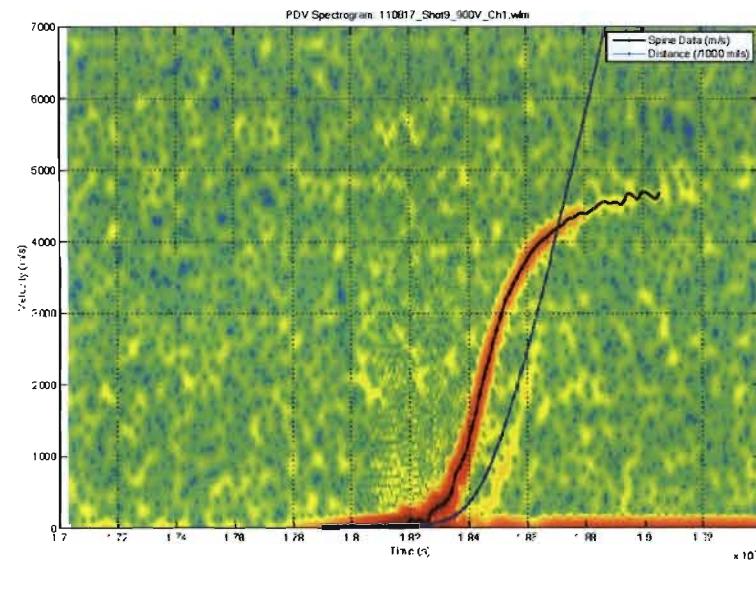
# Software: Combine Two Resolution Data Files

- We usually collect data on two channels, with one set to 10x voltage resolution
  - Low Resolution for period of high reflectivity (launch for our work)
  - High Resolution for period of low reflectivity (flight for our work)
- Software combines both traces into one “hybrid” trace
- One approach to dealing with changing reflectivity during experiment

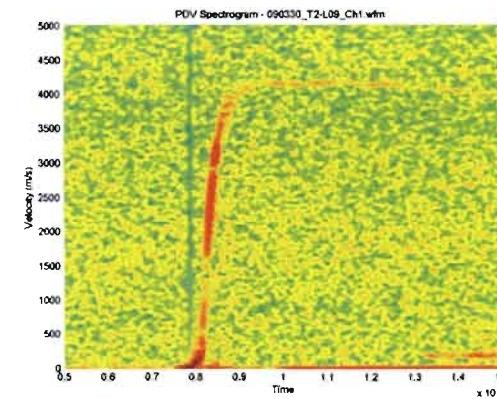
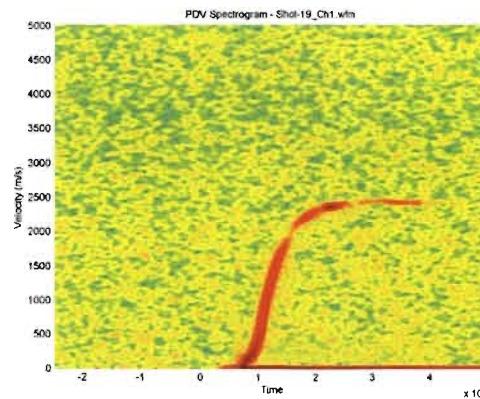
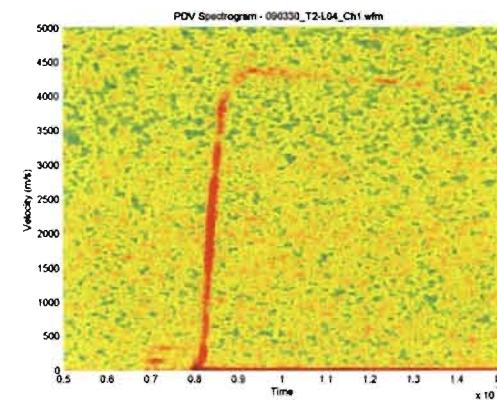
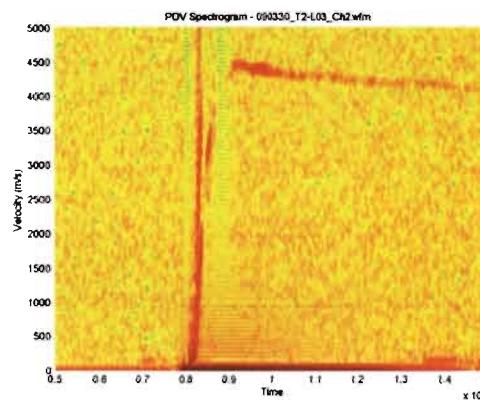


# Software: Extract V vs. T Plot, and Integrate to D vs. T Plot

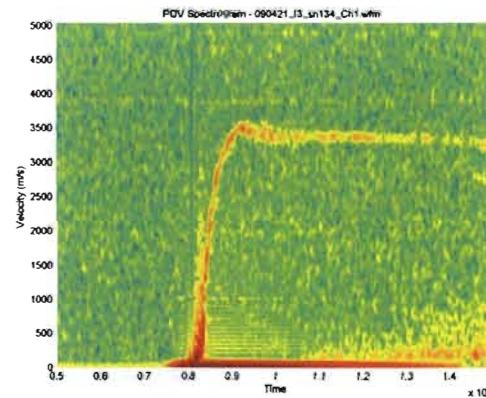
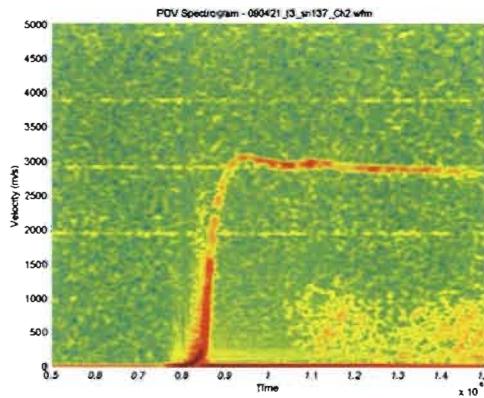
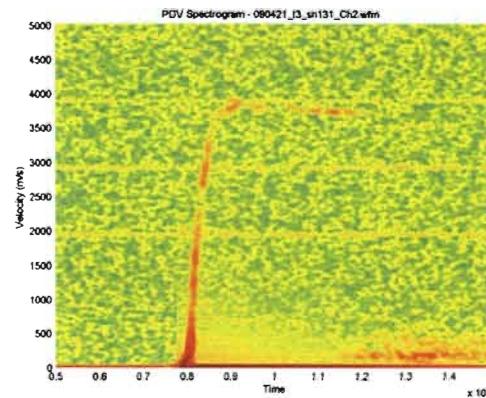
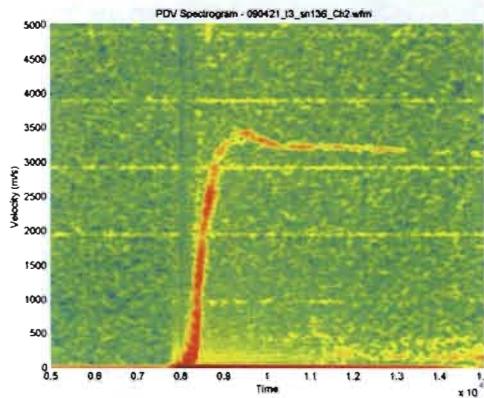
- Extract Velocity by fitting a Gaussian to the FFT power spectrum at each time step.
- Smoothes the jagged noise on the top of the velocity.
- Use center of Gaussian as velocity at that time step.
- Use Gaussian parameters from previous time step as seed for each new time step
- Also extract gaussian width, which might contain additional information about signal quality, sample condition, etc.
- Integrate V vs. T plot to get D vs. T Plot



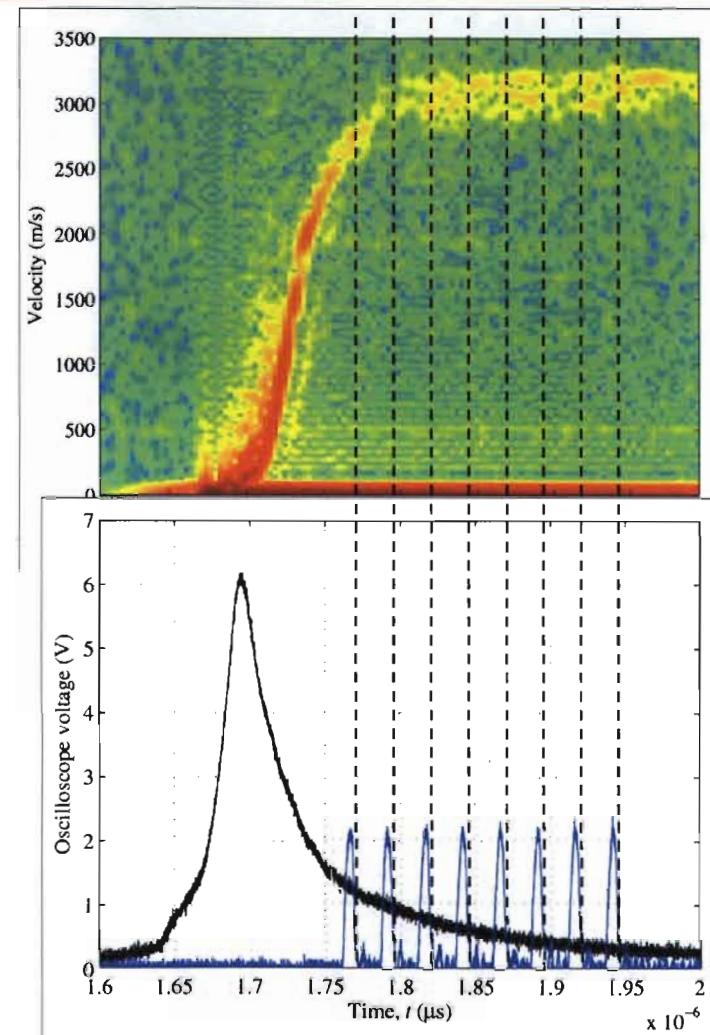
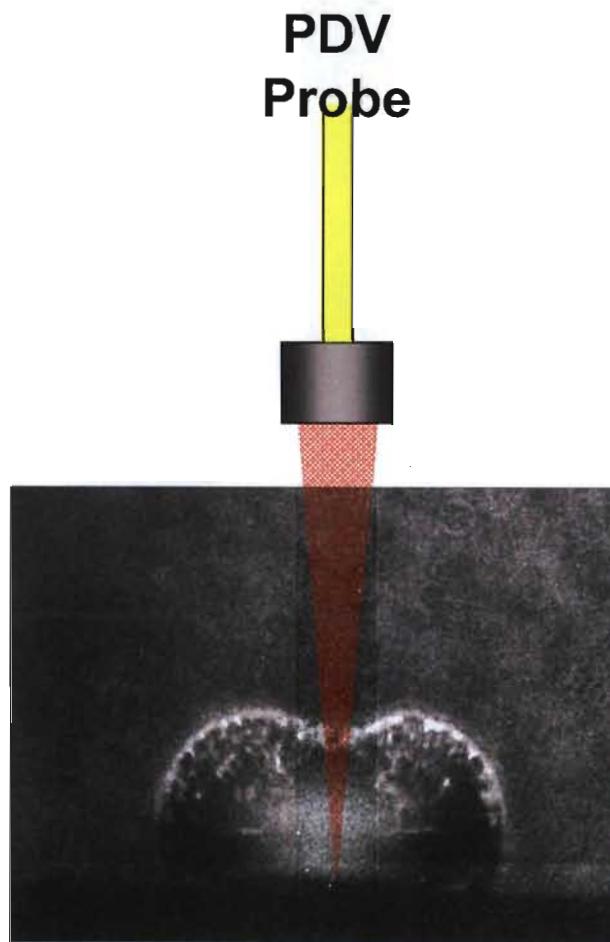
# microPDV Spectrograms



# Typical Tanner Shots with Micro-PDV

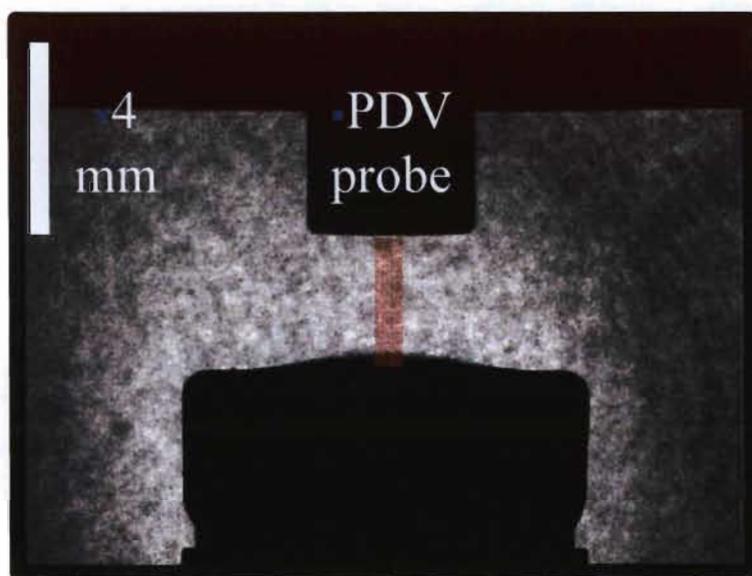


# Simultaneous Schlieren/PDV on Chip Slapper



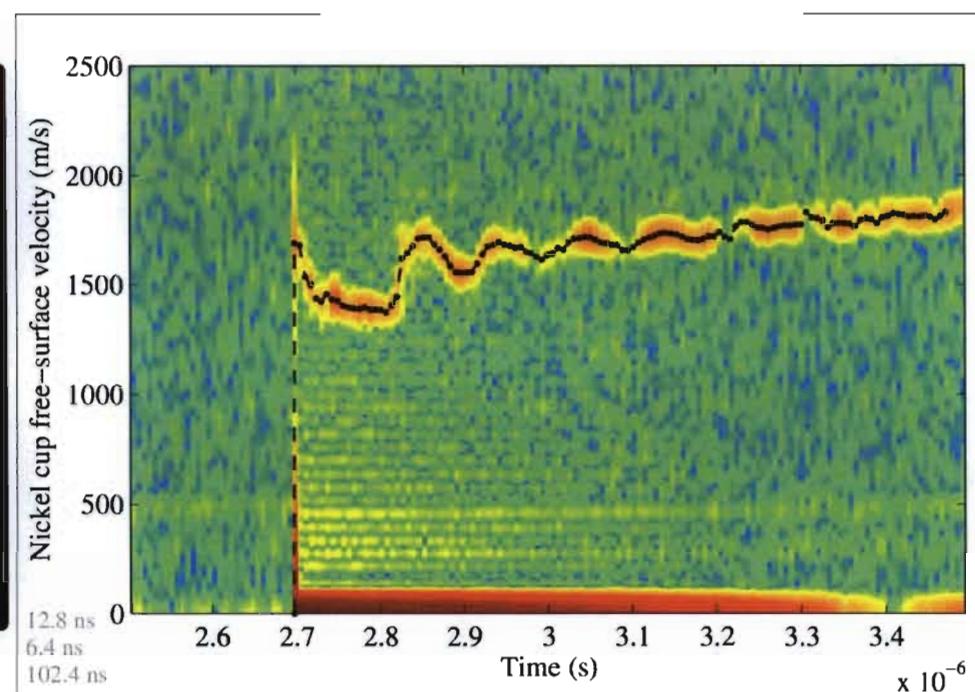
# Detonator Output into Air

- Ultra-high speed imaging



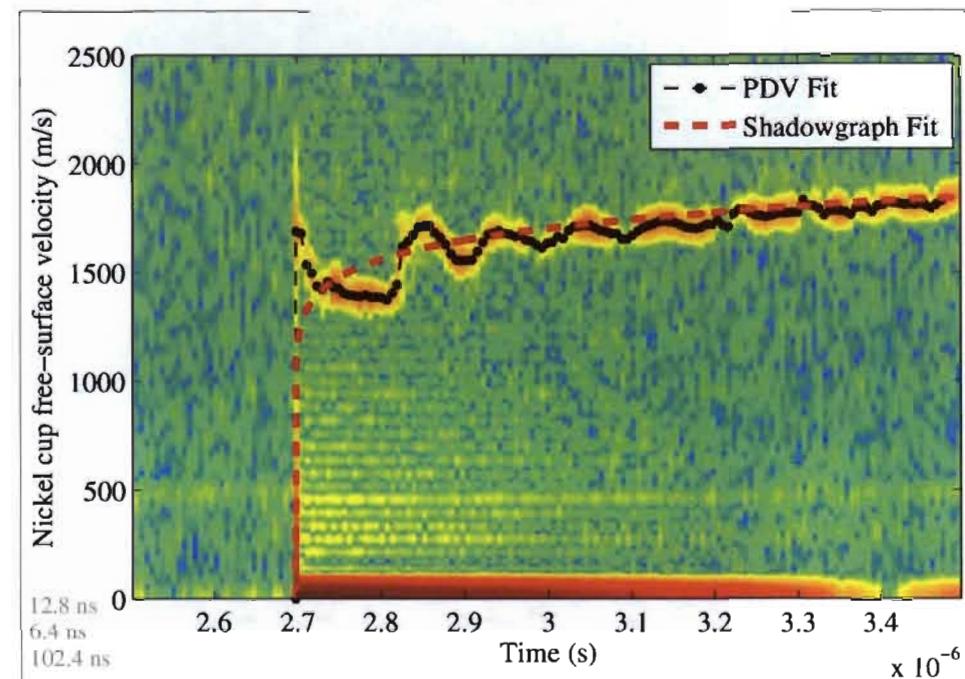
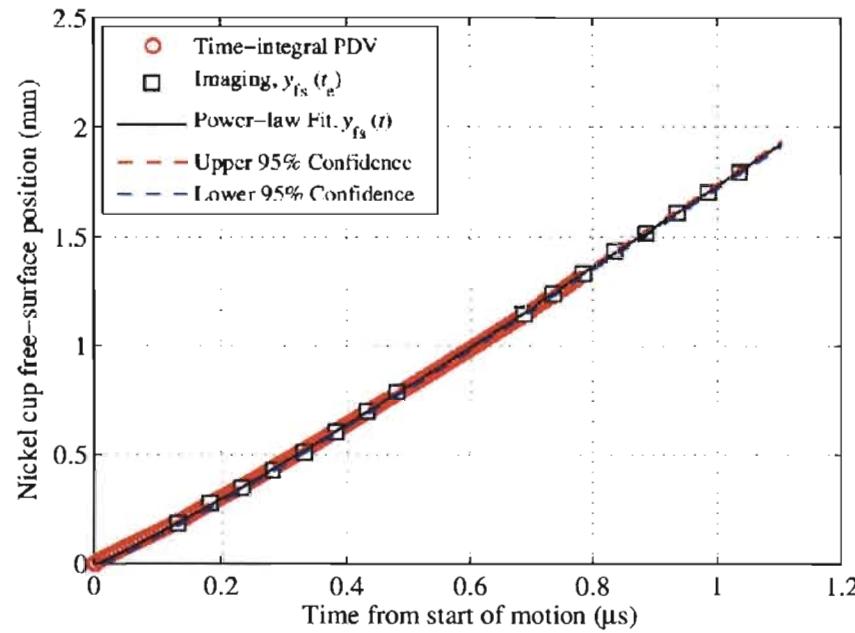
- 5 ns exposure, 50 ns inter-framing

- Centerline PDV



- A Gaussian fitting method is employed to find the peaks of the measured velocity data for each FFT window

## Detonator Output into Air – Centerline Results



- Excellent agreement is observed that supports the use of simultaneous ultra-fast time-resolved imaging and PDV techniques to validate the reduced data resulting from each method.

## Conclusions

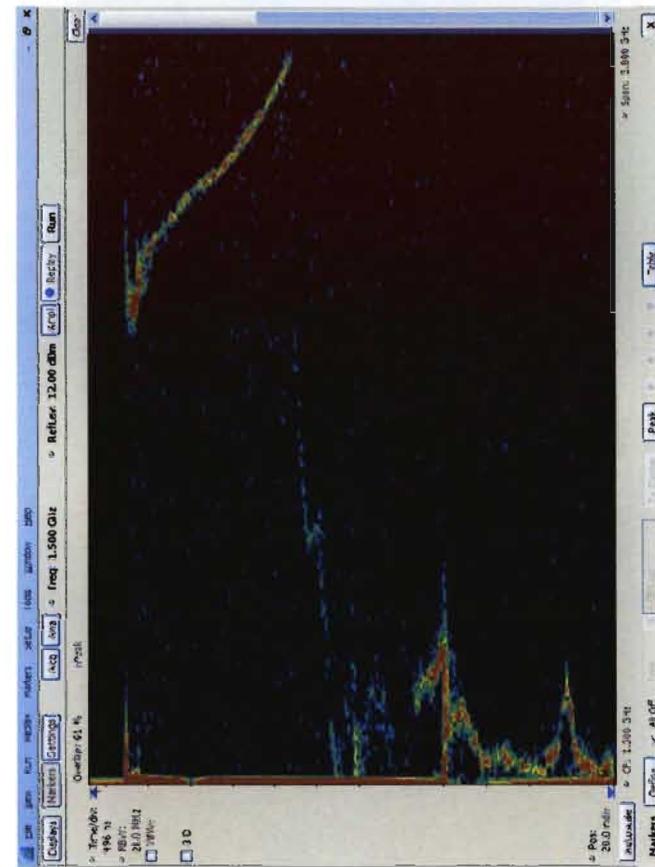
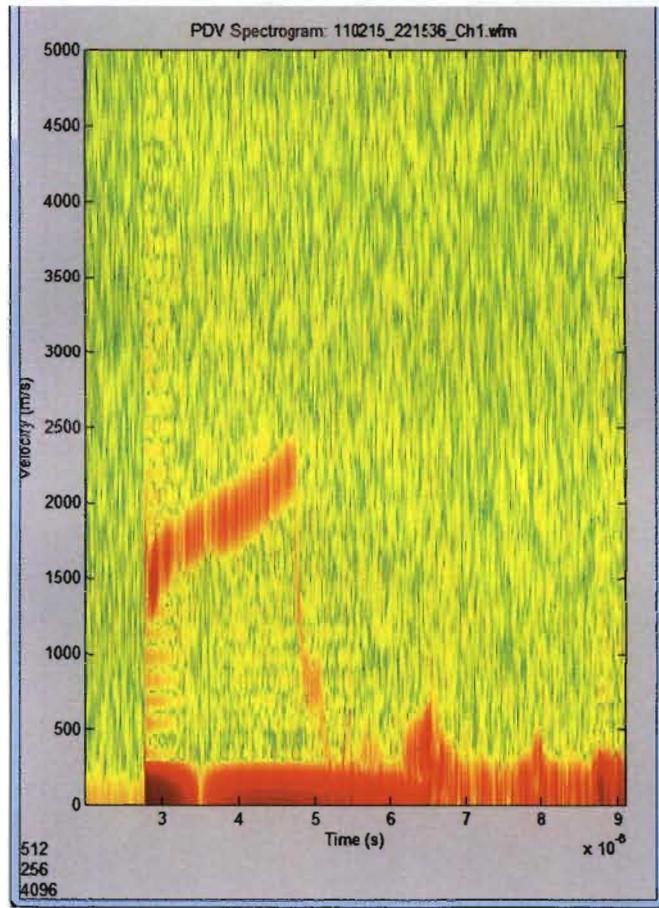
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- MicroPDV combines IR microscope for small focused spot size and positioning and PDV signal light recovery
- Effective for small fast clear subjects
- Concept could be applied to other subjects as well

## Questions:

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- **Need “long working distance” (1 m?) PDV probe design.**
  - Anyone have some success, I would appreciate tips/tricks/suggestions
- **Velocity vs. Time to Distance vs. Time transform**
  - Probably not possible (path integral vs. state integral)
  - Transform “image”
- **Z-Chirp Transform?**
  - From discussions with Tektronix, they suggest a “Z-Chirp Transform”, which is somehow optimized for single shot



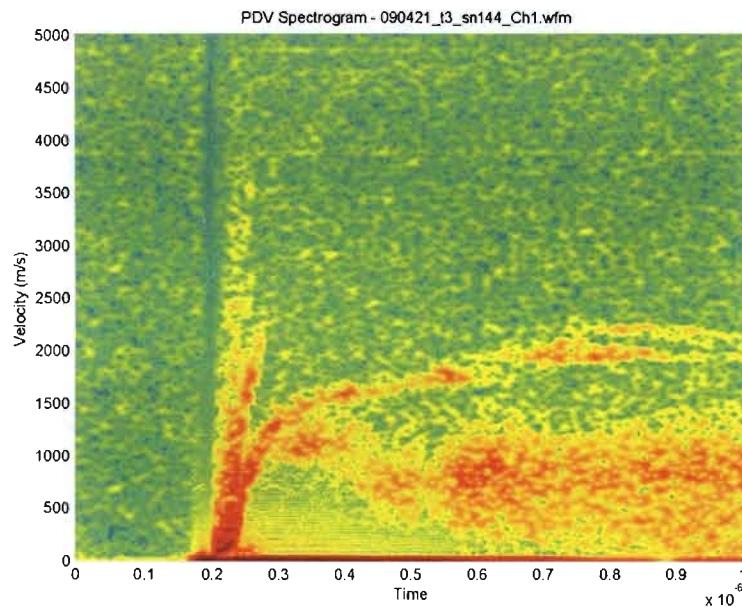
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# What happened here?



- Perhaps as many as 4 different “flyers” in this shot
- A fast accelerating flyer that we lose quickly
- A medium accelerating flyer that eventually breaks into two pieces
- A cluster of slower material that rapidly decelerates