MicroPDV
for
Slapper Detonator Characterization

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PDV Workshop
Livermore Calf
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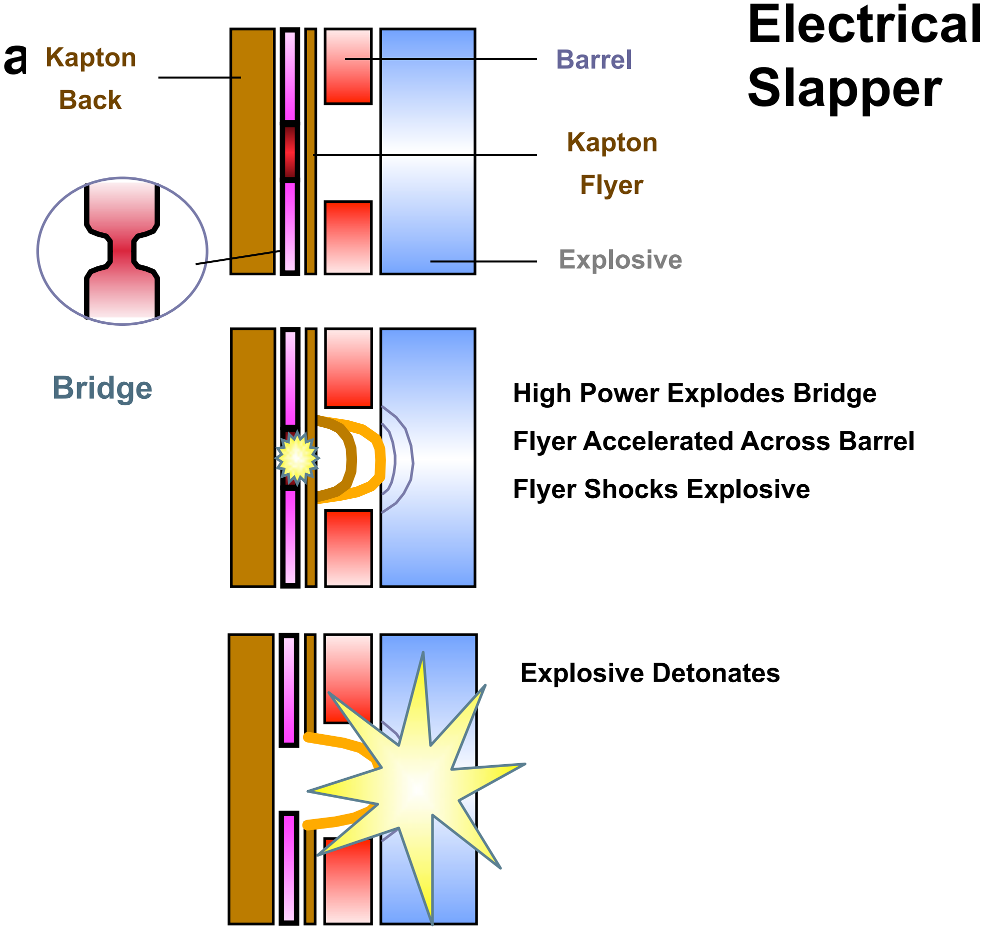
Outline

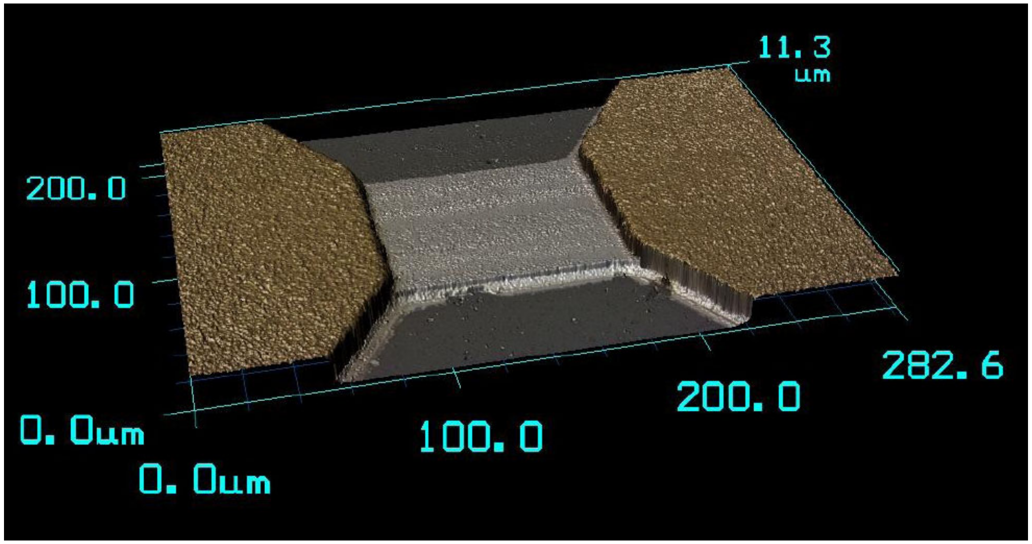
- Slapper Flyer Velocity Problem
- History
- MicroPDV “Probe”
- Data Analysis
- Examples
- Future

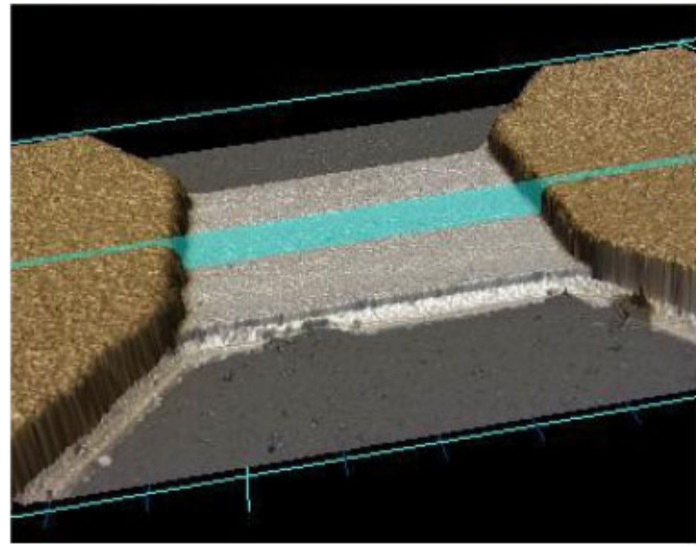
Slapper Detonator Characterization Problem

- **"Slapper" detonators throw a flyer to initiate explosive:**
  - very small (~200 um)
  - clear (typically perylene)
  - Thin (12 to 25 um)
  - Fast (3 – 5 km/s)
- **How do you measure the velocity of these samples?**



Chip Slapper:
Subject for the microPDV system

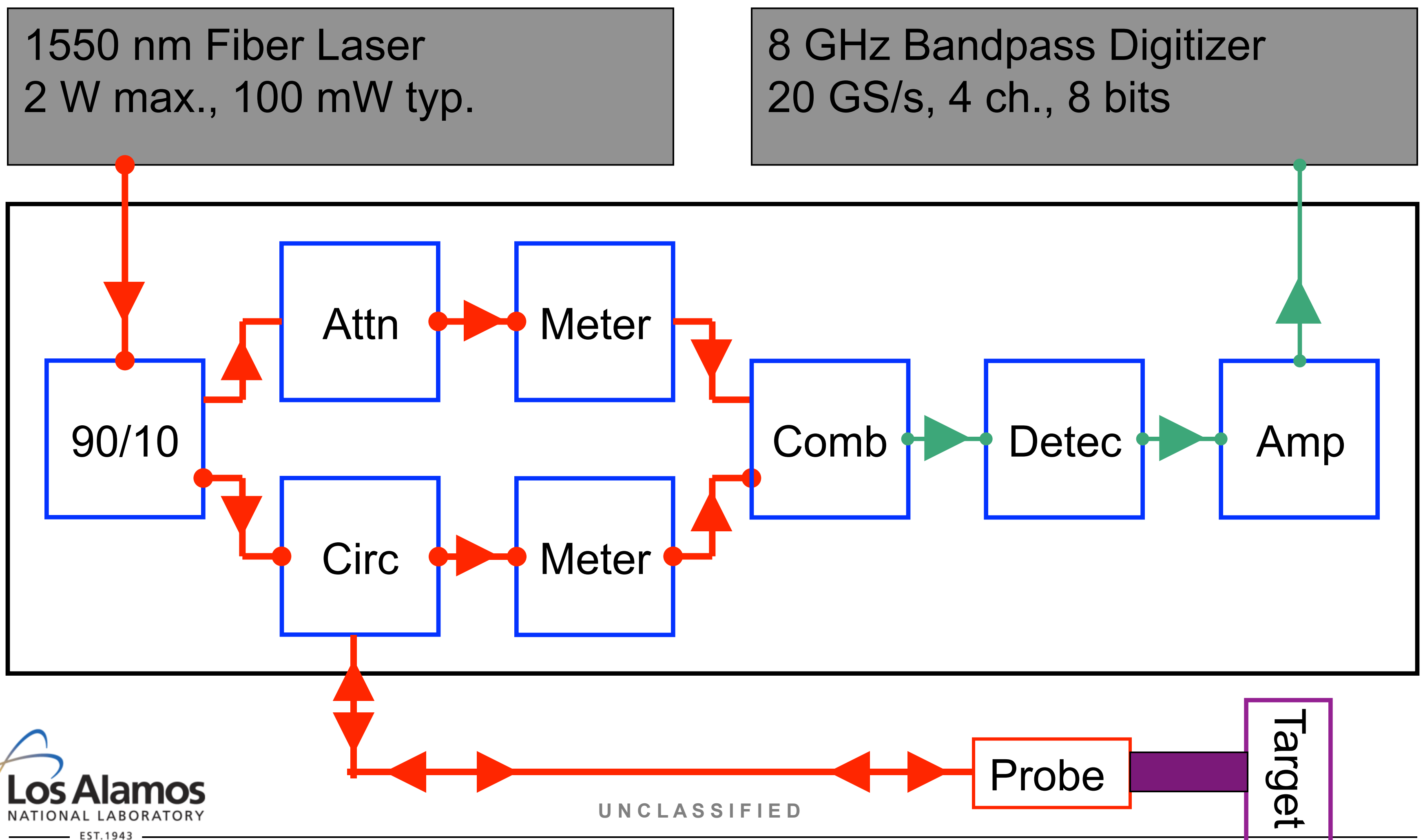




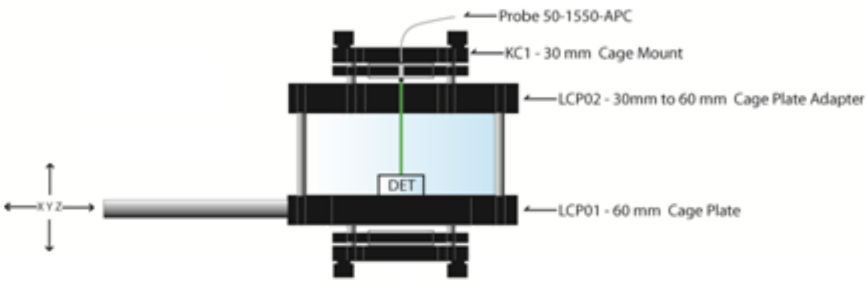
Confocal microscopy (Keyence) applied to chip slappers to characterize bridge surface and surrounding overplating

3 Gold				3 Gold
1.5 Copper	3 Gold		3 Gold	1.5 Copper
0.05 Titanium	1.5 Copper		1.5 Copper	0.05 Titanium
8 Gold	0.05 Titanium	0.05 Titanium	0.05 Titanium	8 Gold
	2.75 Aluminum	2.75 Aluminum	2.75 Aluminum	
0.3 Palladium				0.3 Palladium
0.2 Titanium	0.1 Titanium	0.1 Titanium	0.1 Titanium	0.2 Titanium
		CERAMIC		
0.2 Titanium				0.2 Titanium
0.3 Palladium				0.3 Palladium
8 Gold				8 Gold
3 Gold				3 Gold

History:
2005 LANL W-6 Adjustable Balance PDV Design

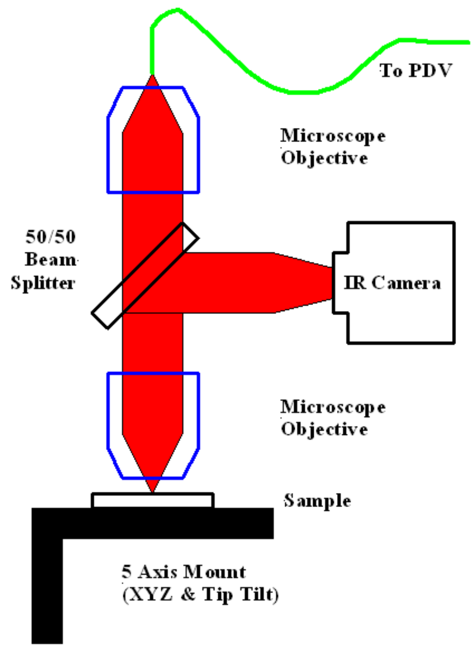


History:
First Probe and Alignment setups



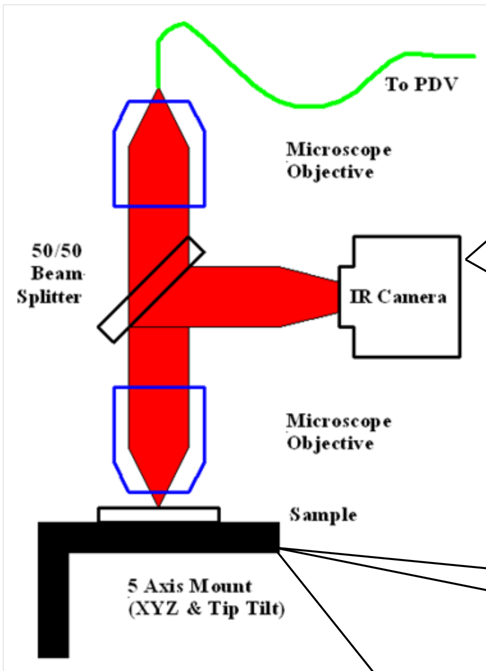
- **First try:**
  - Collimated probes
  - One tip-tilt stage
  - Alignment very difficult
  - At best 50/50 data return
- **Other attempts**
  - Tried two tip/tilt stages
  - Tried visible alignment laser
  - Tried IR visualizing tools
  - Tried disposable probes mounted to chip
- **Other labs tried 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

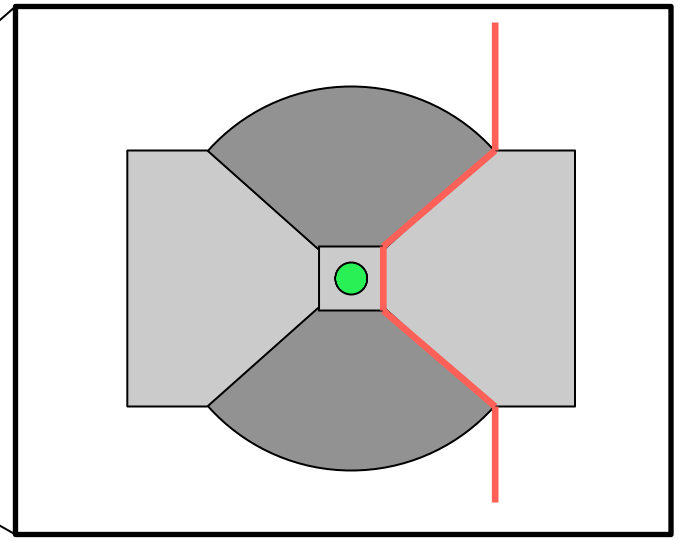
The Micro-PDV Solution:
Combine IR microscope and PDV probe



- **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





IR camera monitor

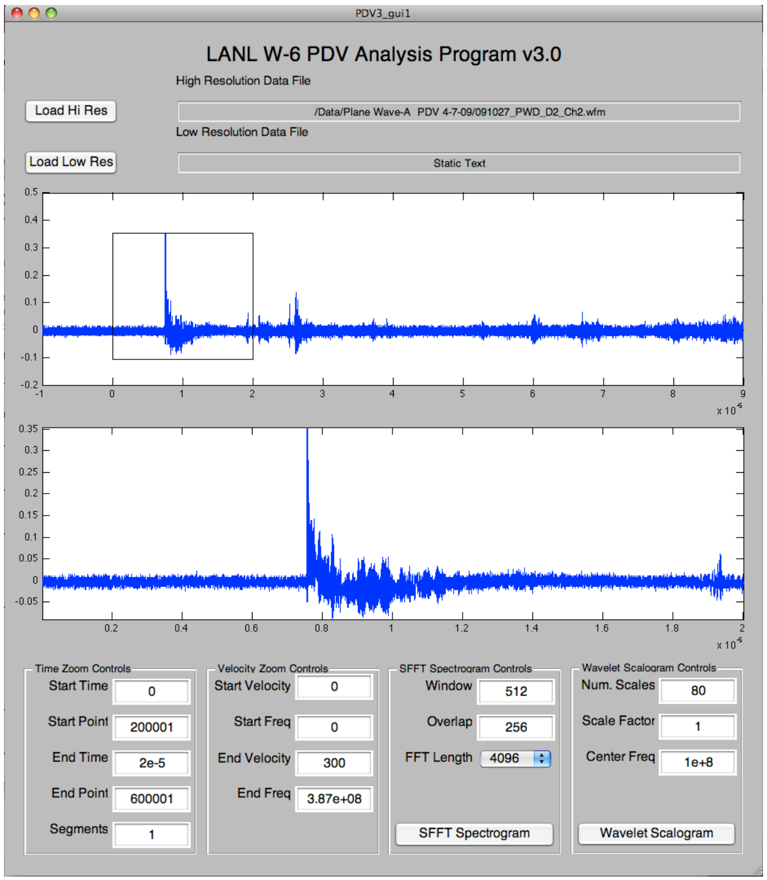
Goniometer Stage

IR Camera:
Edmund Optics
PN: NT56-567

MicroPDV Design Tricks

- **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

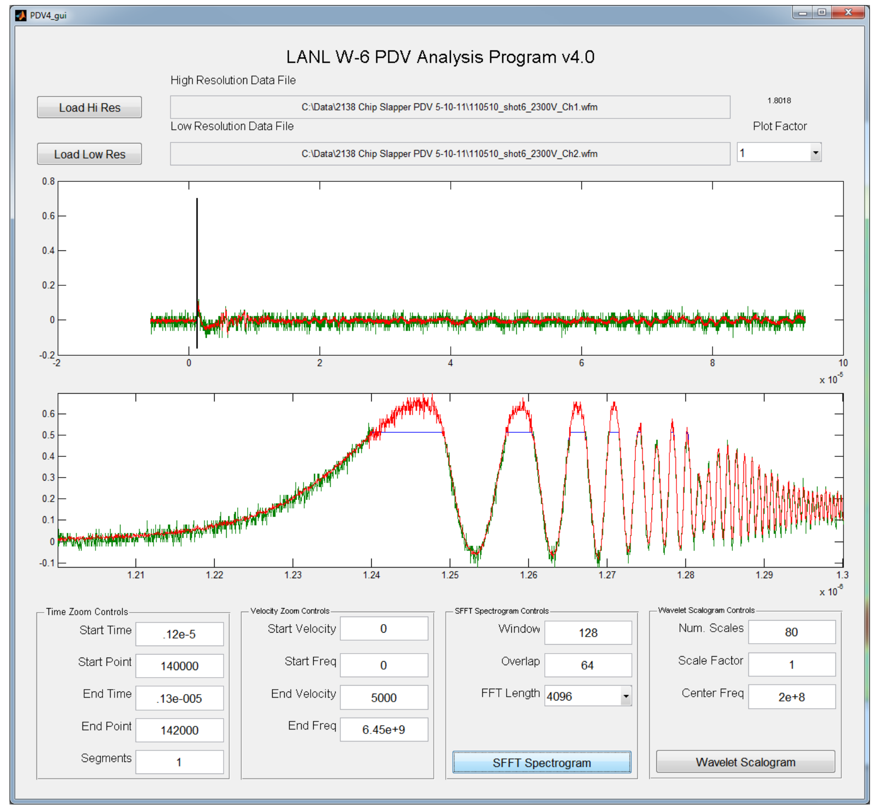
PDV Software



- 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)

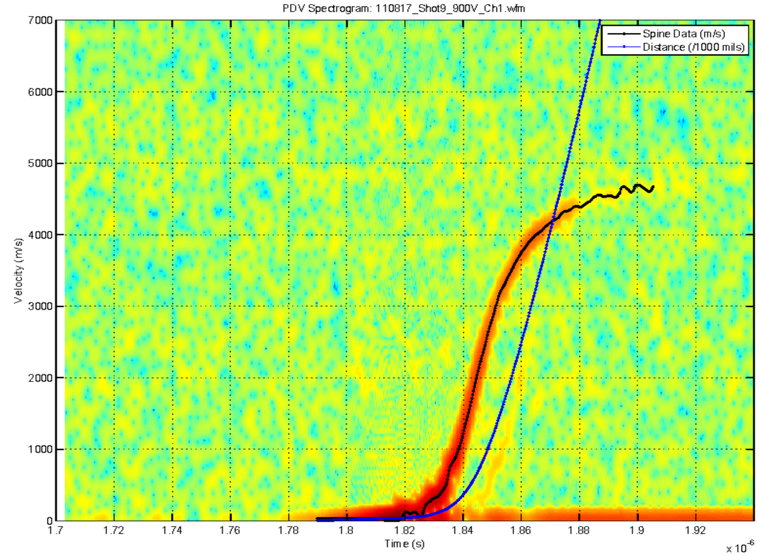
Software:
Combine Two Resolution Data Files

- **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**

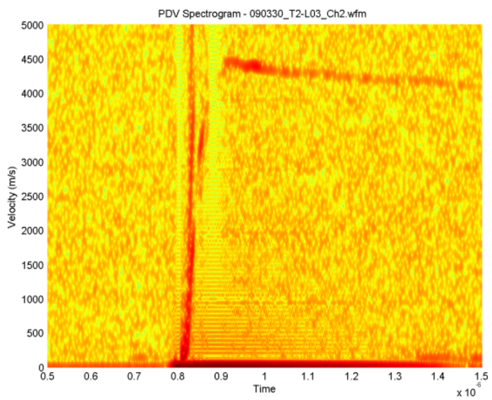


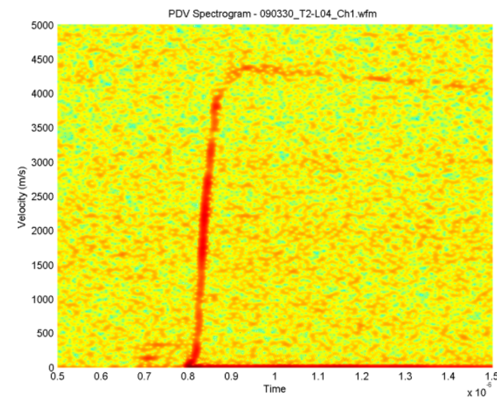
Software:
Extract V vs. T Plot, and Integrate to D vs. T Plot

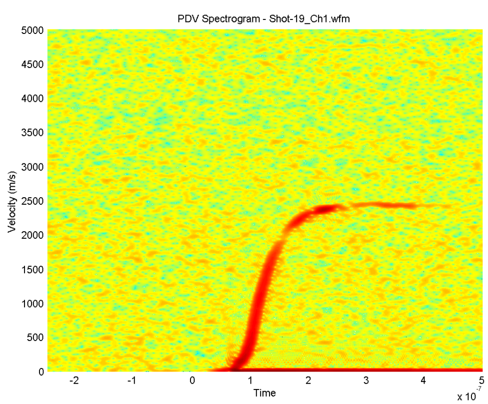
- **Extract Velocity by fitting a Gaussian to the FFT power spectrum at each time step.**
- **Smoothes the jagged noise on the top of the velocity.**
- **Use center of Gaussian as velocity at that time step.**
- **Use Gaussian parameters from previous time step as seed for each new time step**
- **Also 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**

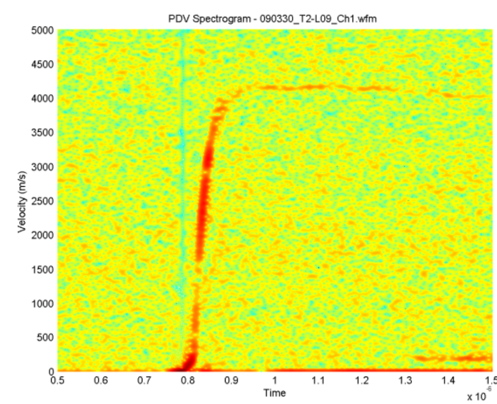


microPDV Spectrograms

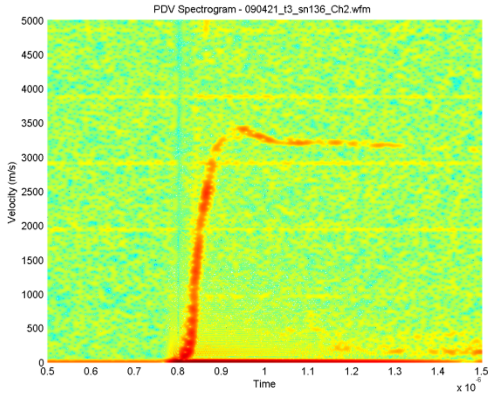


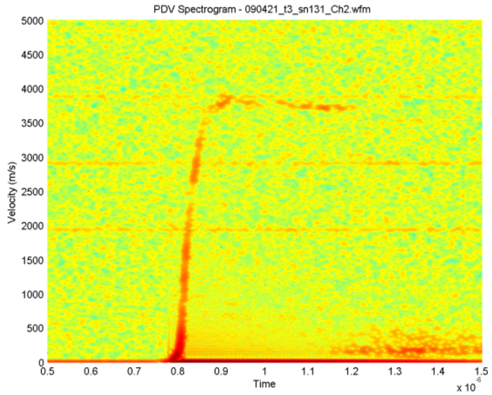


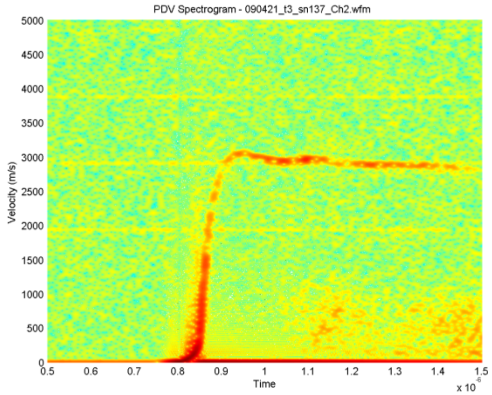


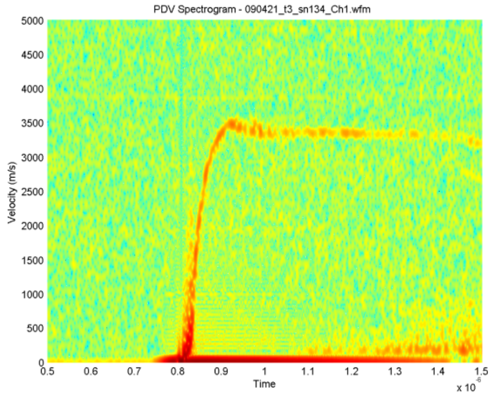


Typical Tanner Shots with Micro-PDV

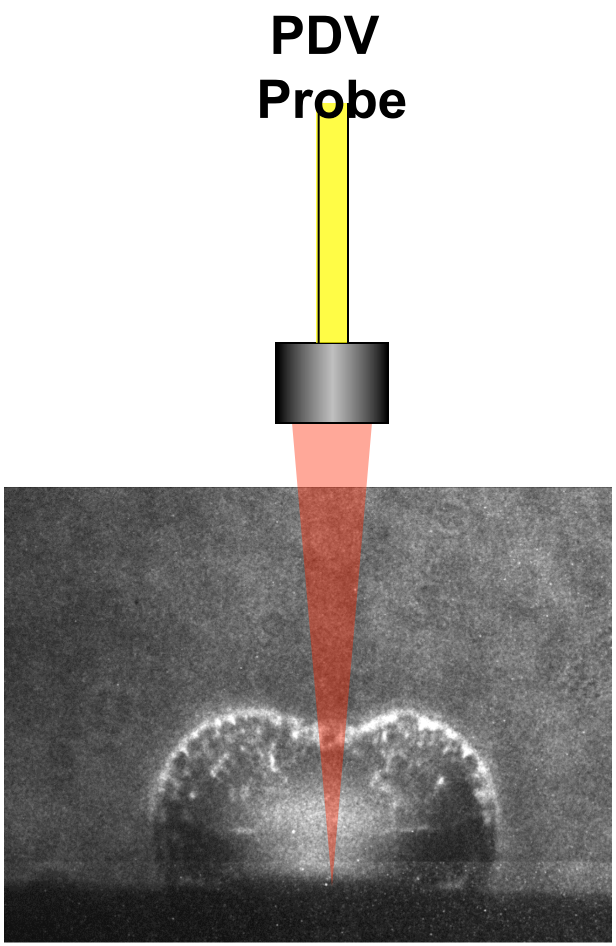


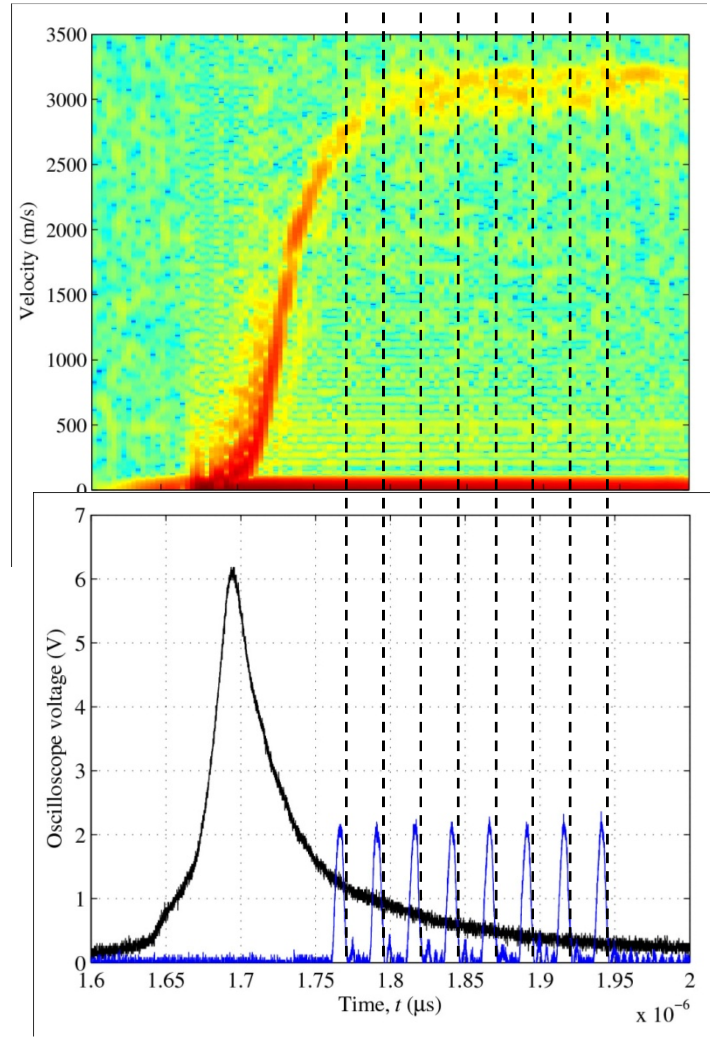






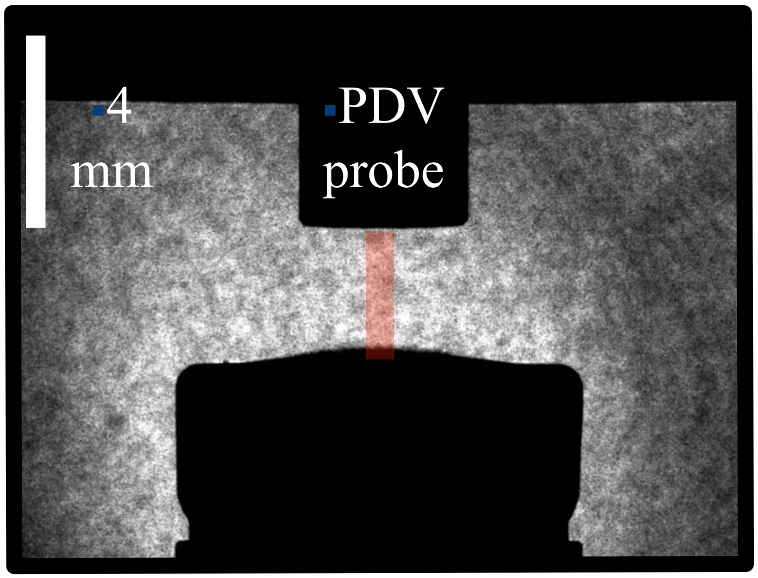
Simultaneous Schlieren/PDV on Chip Slapper





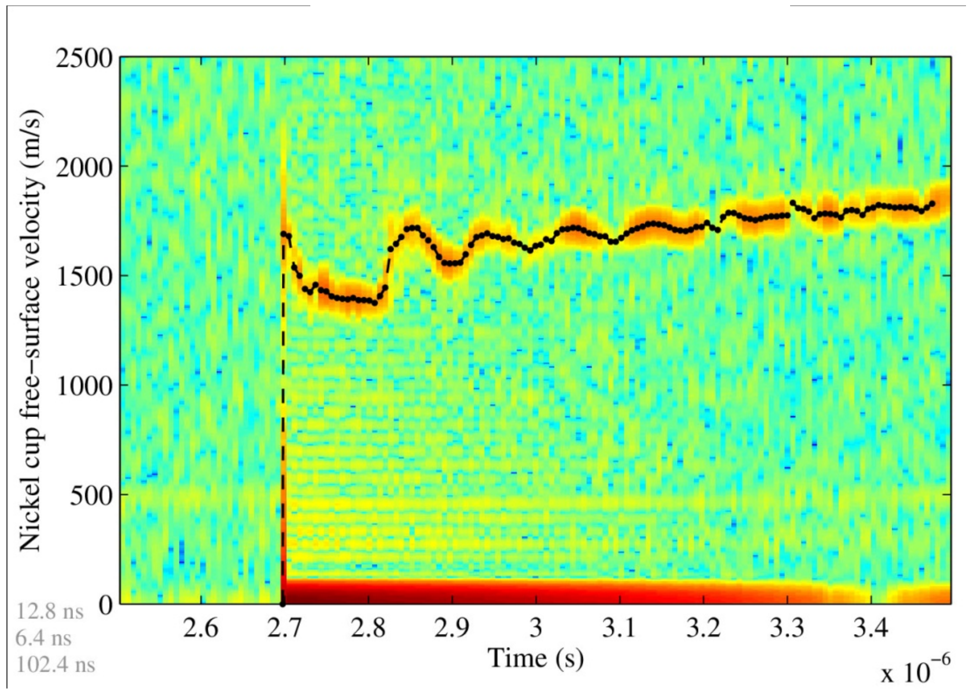
Detonator Output into Air

▪Ultra-high speed imaging



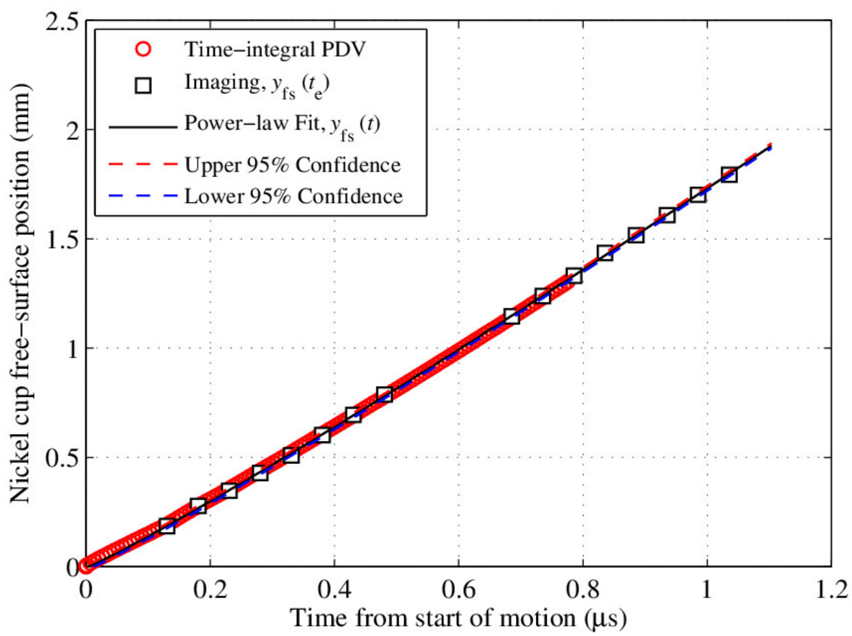
▪5 ns exposure, 50 ns inter-framing

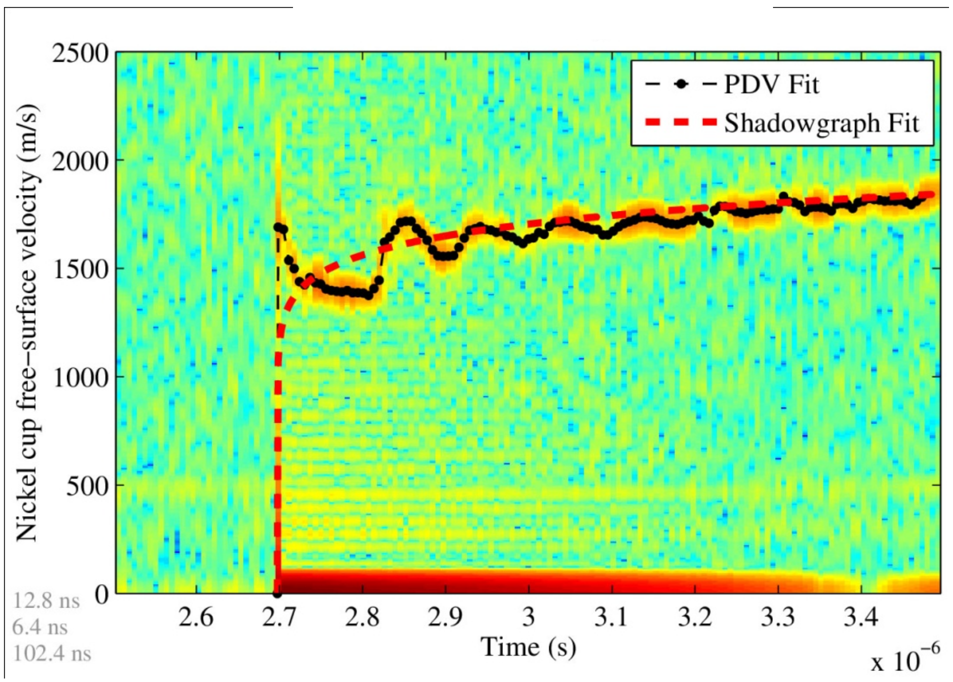
▪Centerline PDV



▪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





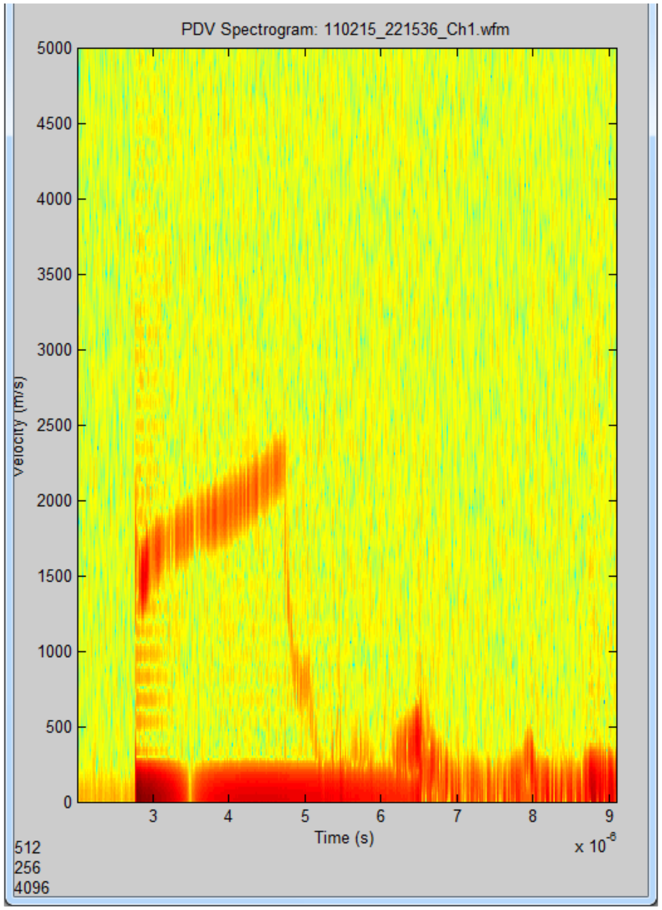
- Excellent agreement is observed that supports the use of simultaneous ultra-fast time-resolved imaging and PDV techniques to validate the reduced data resulting from each method.

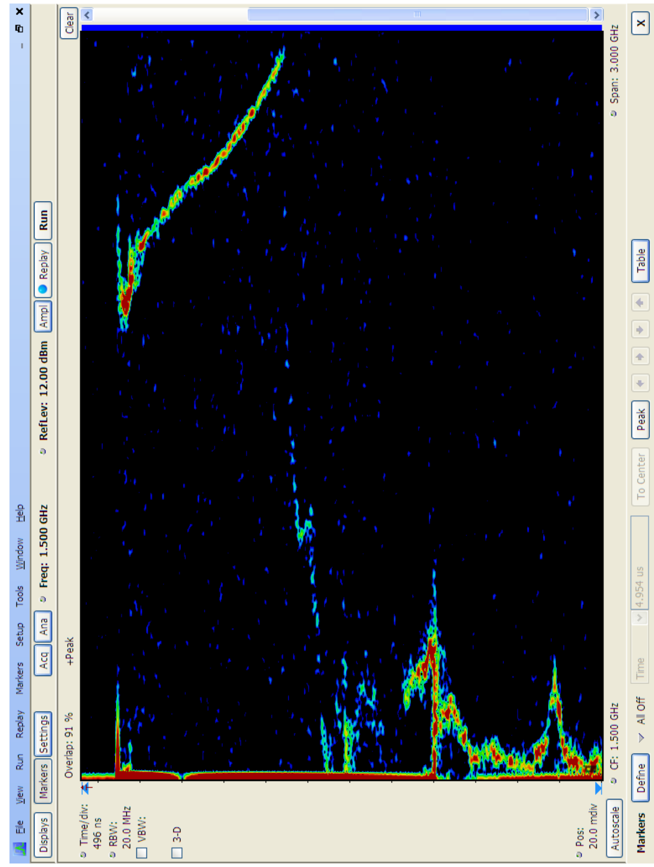
Conclusions

- **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**

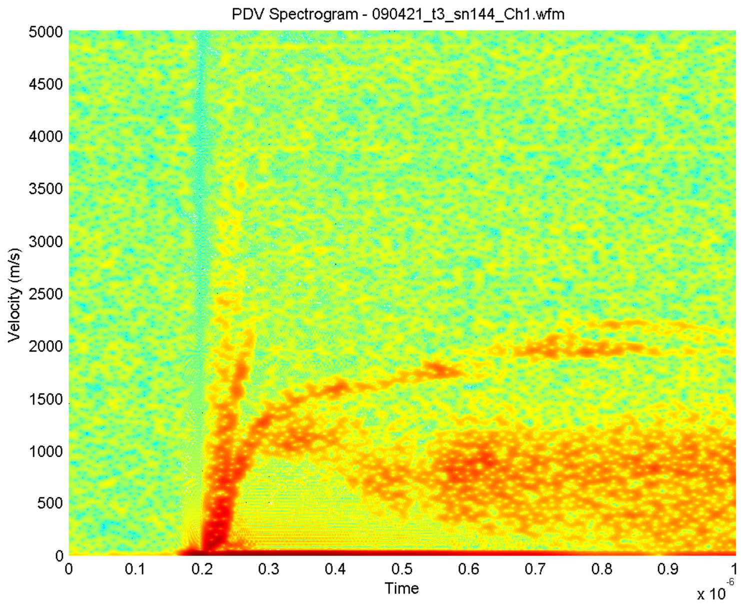
Questions:

- **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 transfrom**
  - 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


PDV Spectrogram: 110215_221536_Ch1.wfm
Velocity (m/s)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
3
4
5
6
7
8
9
Time (s)
x 10^-6
512
256
4096



What happened here?



- Perhaps as many an 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