Optical diagnostics for flyer characterization

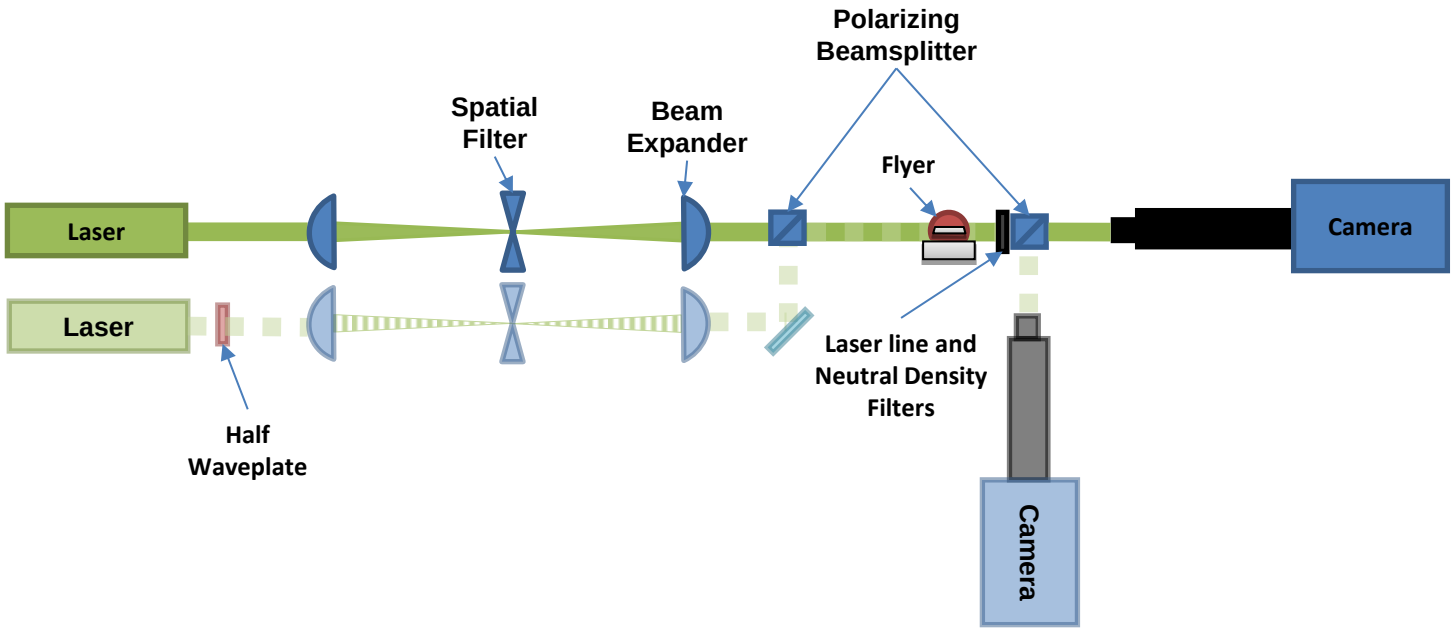
SAND2016-2187C

Joseph Olles

- Holography
  - Setup
  - Images/videos
- PDV
  - SMASH
  - CTH traces -> alignment with experiments
  - My scripts
    - Down/Up- shifting
    - STSF – Short time Sine Fitting
- Fiber streak impact
  - Setup – PDV & Streak
  - Data (HOPEFULLY)

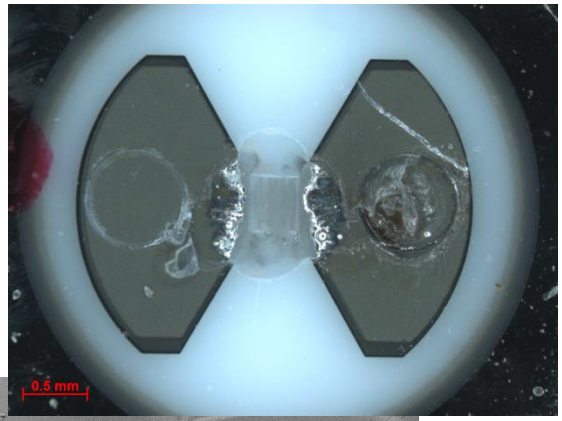
Holography Trial

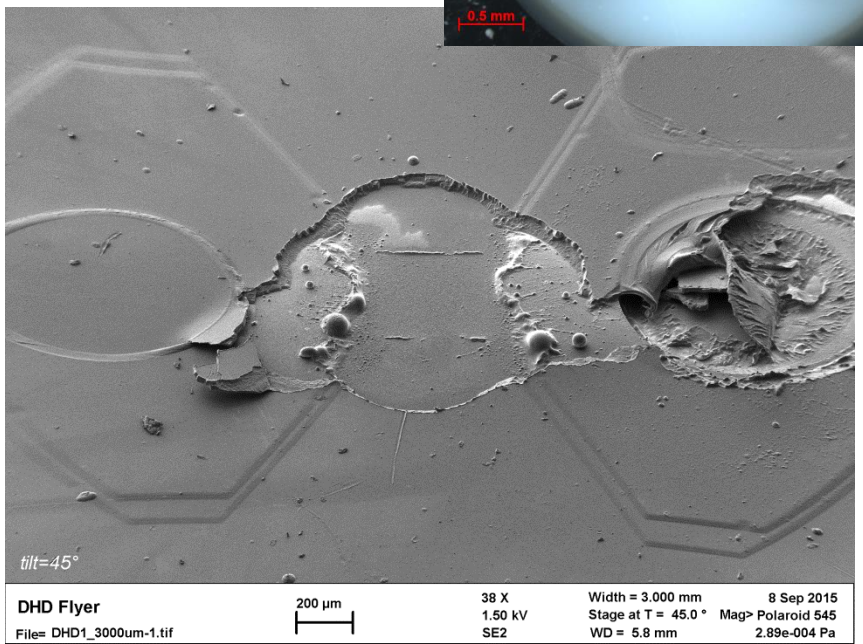
- Planarity of flyer throughout flight
  - Currently investigating an in-line holography technique
  - Polarization with dual laser/cameras can be used for cross-correlation
  - Cameras used microscope objectives → ~1-2 microns/pixel



DHD Flyer

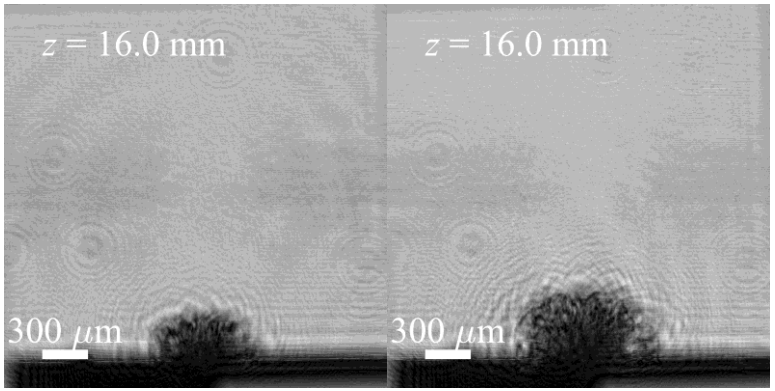
- Used DHD flyer due to ease of optical access
  - RSI EBW fireset used (1-2kV)

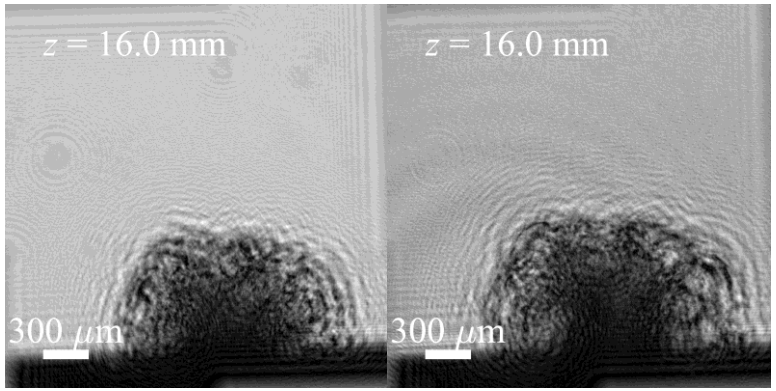




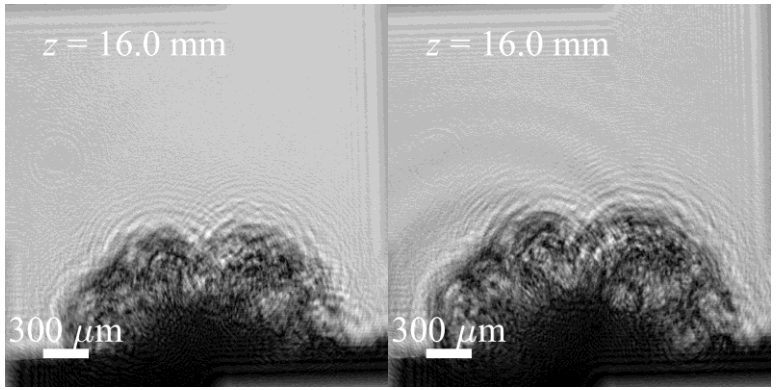
Flyer/Plasma image reconstruction

- 2kV voltage applied
  - Image pairs (30ns delay)
  - Expansion of cloud was between 3500-5000 m/s

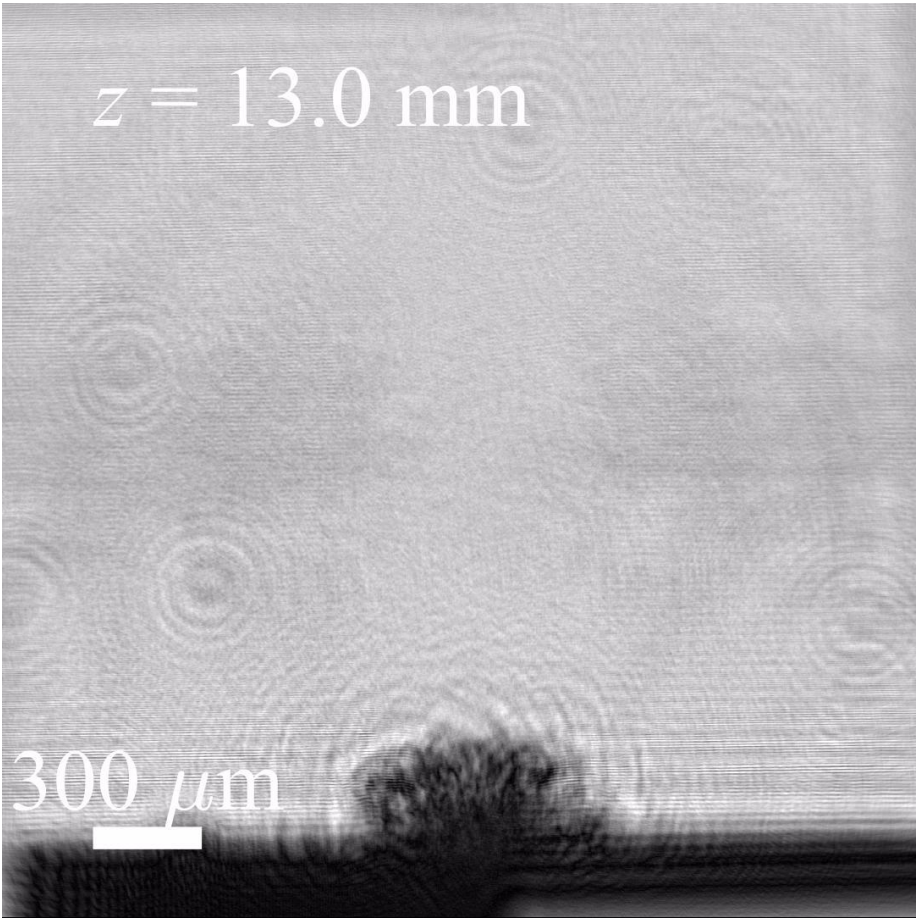




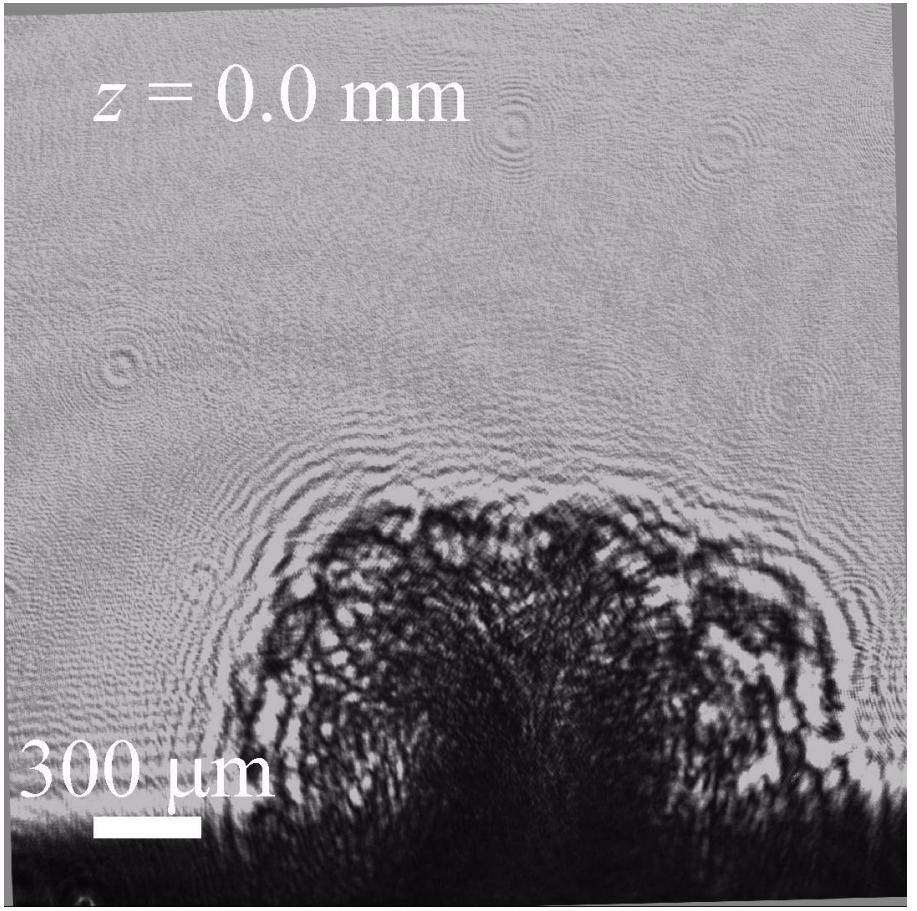
Time after trigger: **600 and 630 ns** **700 and 730 ns**



900 and 930 ns

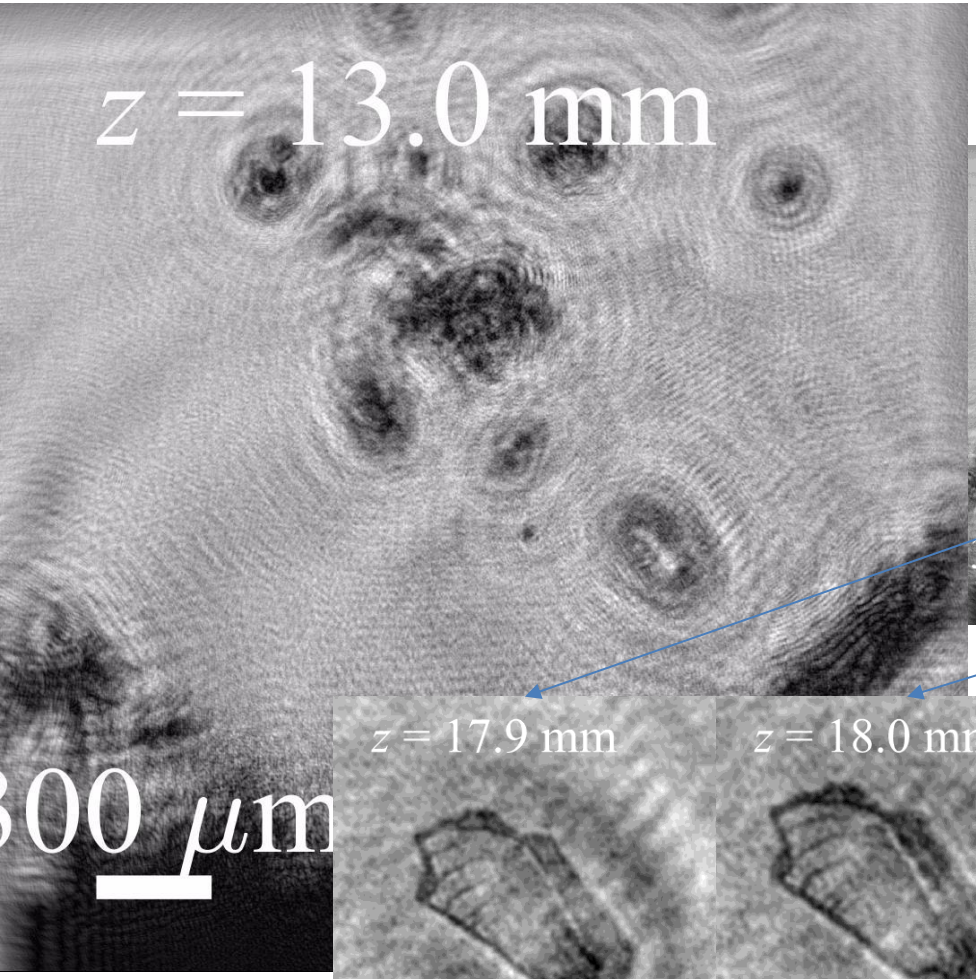


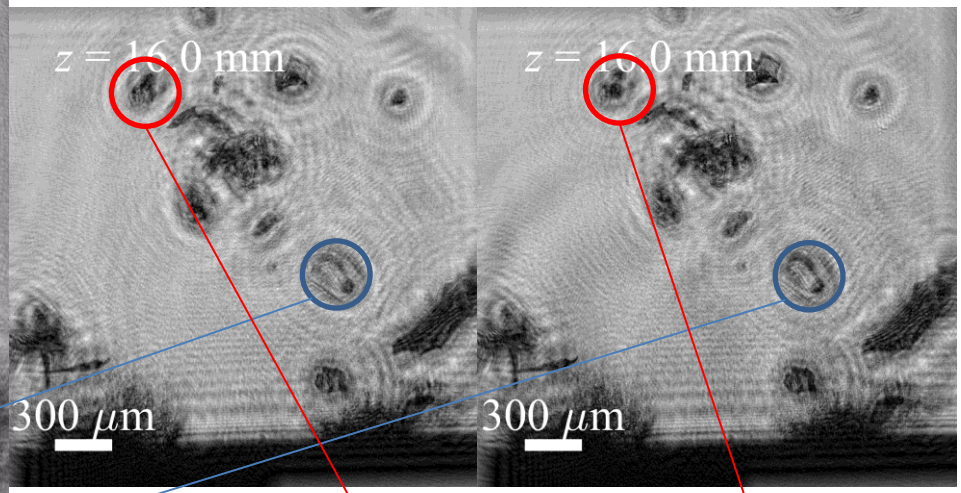
600ns delay



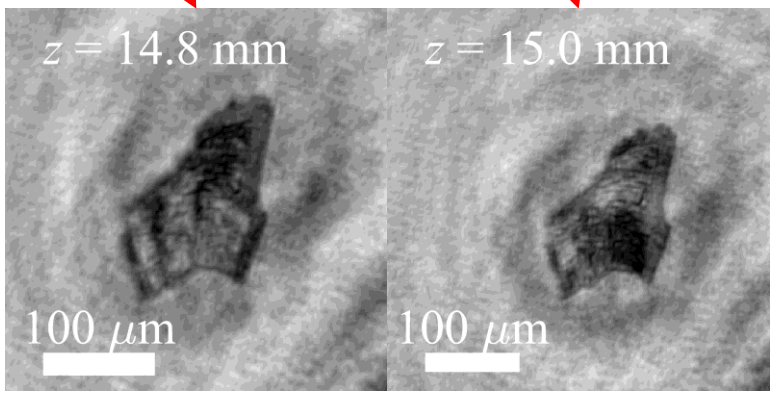
700ns delay

- Late time images (microseconds after trigger)
  - Refocused to 16mm (most paricles are in focus)
  - Resolution shows striations in plastic (brittle failure)
  - Particles traveling 300-500 m/s



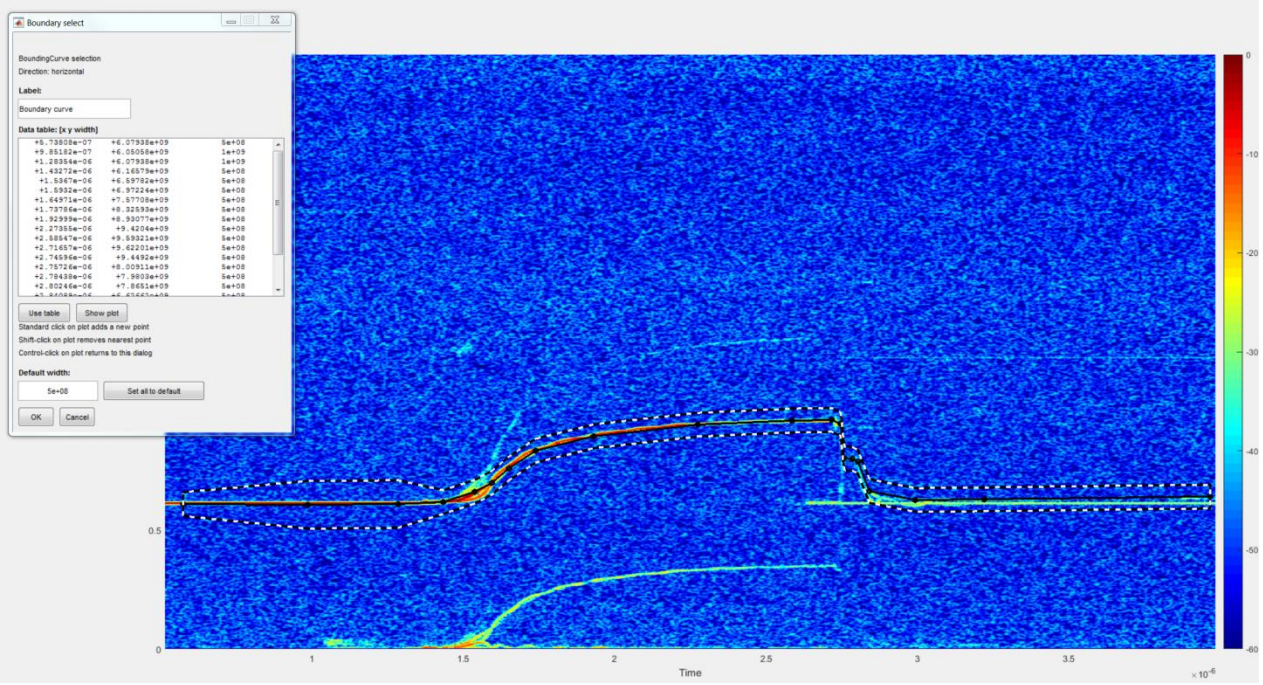


10,250 and 10,280 ns



SMASH Toolbox

- **S**andia **M**atlab **A**nalysi**S** **H**ierarchy (**SMASH**) toolbox
  - Open source code (not private files like SIRHEN)
  - No toolboxes needed (authors write code for ftns)
  - Object Oriented Programming (OOP)



Digitally Up/Down-Shifting

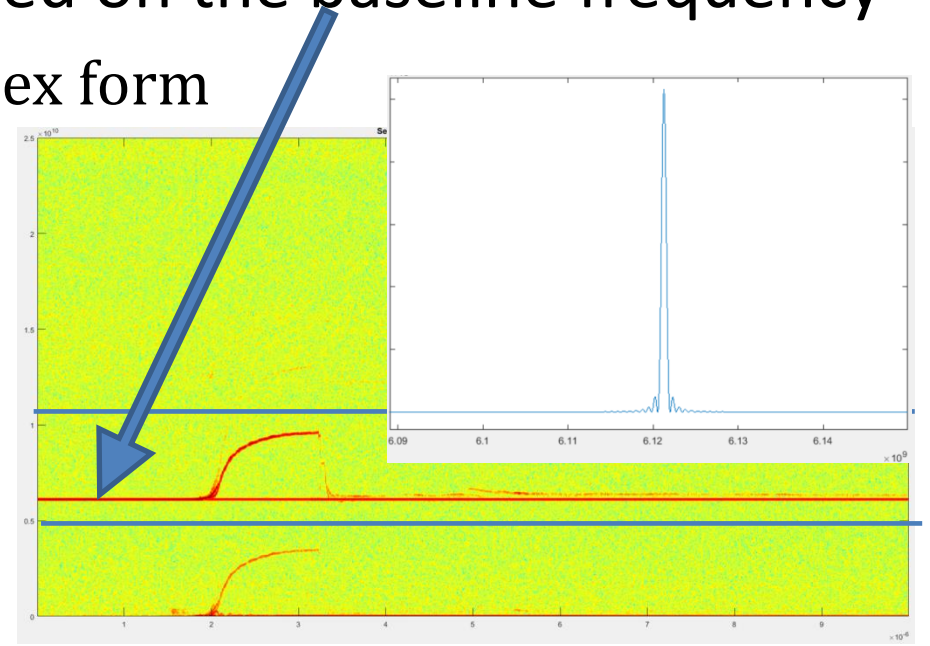
- Visual aid to pick out start of motion or impact
- Downshifting – Upshifted PDV signal
  - Goes back to Standard PDV without the 0Hz noise
- Upshifting – Standard PDV signal
  - Digitally brings signal up, aids in *fft* analysis

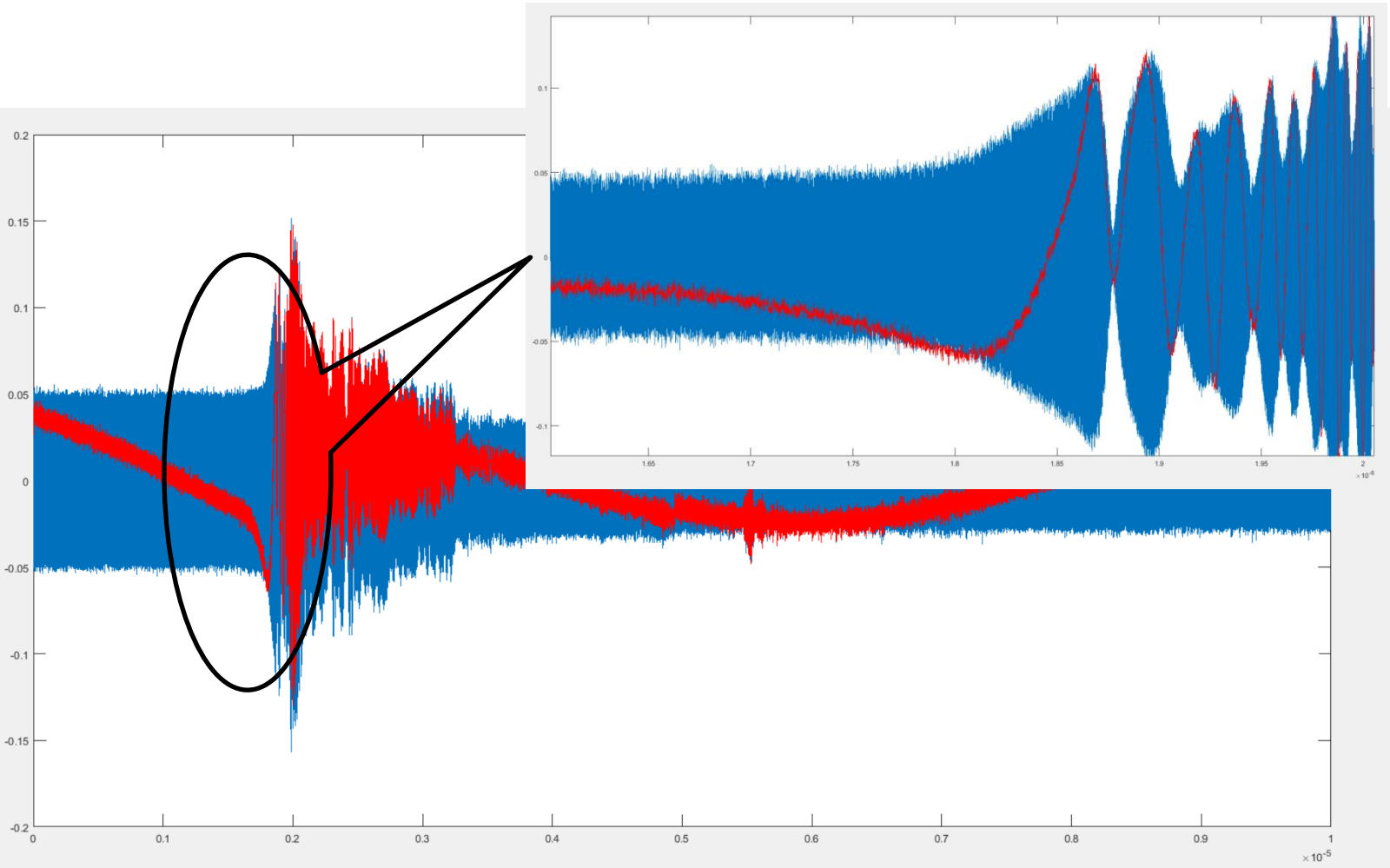
Up/Down-shifting

$$X_k = \sum_{n=0}^{N-1} x_n \cdot e^{-i 2\pi k n / N}$$

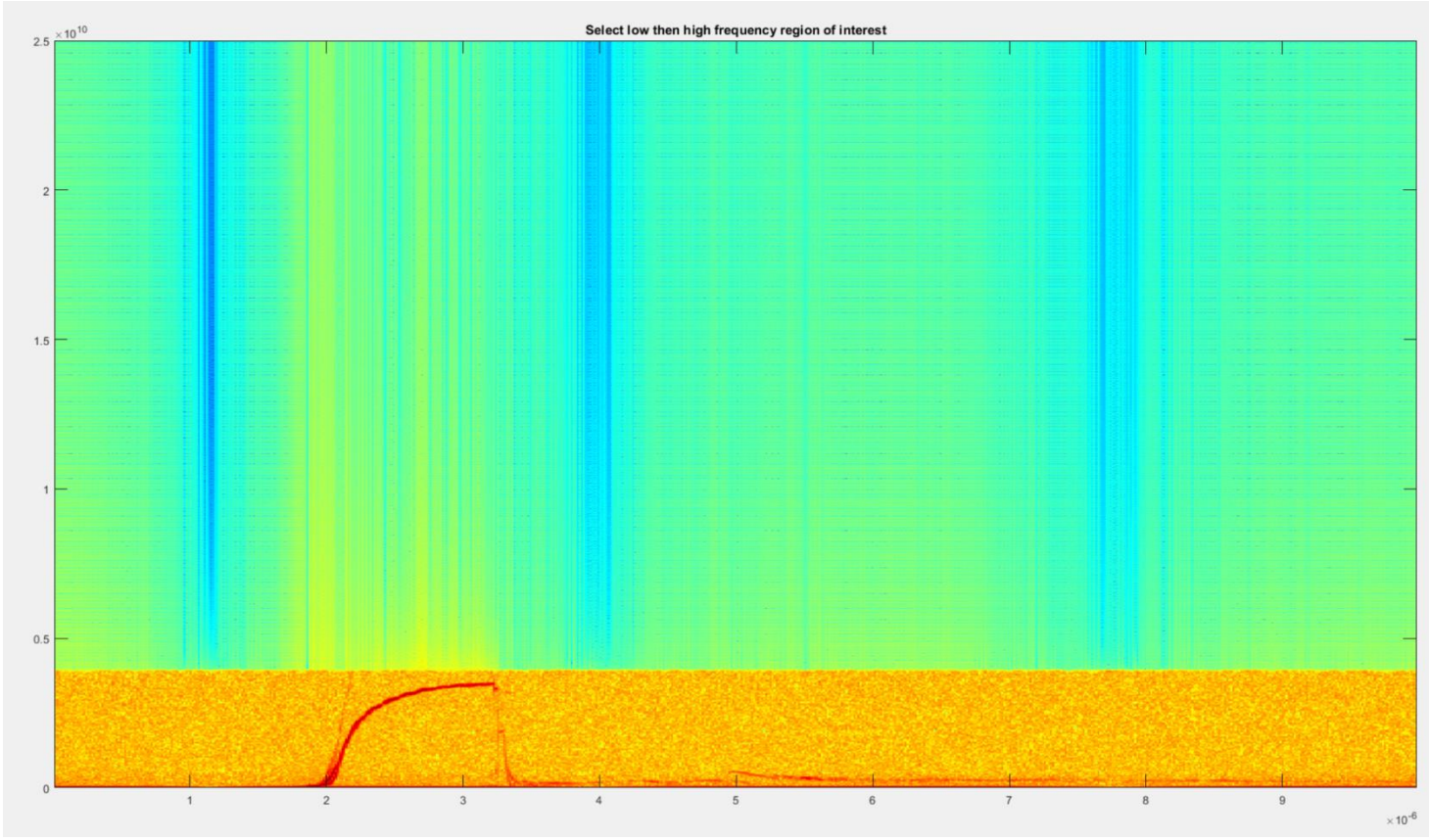
$$x_n = \frac{1}{N} \sum_{k=0}^{N-1} X_k \cdot e^{i 2\pi k n / N}$$

- Fourier transform
- Since PDV signal is frequency varying sinusoid, you can add or remove frequency to it
  - In this case I shift based on the baseline frequency
    - *fft* → *ifft* gives complex form
    - $z = re^{i(\varphi - \varphi_{Baseline})t}$

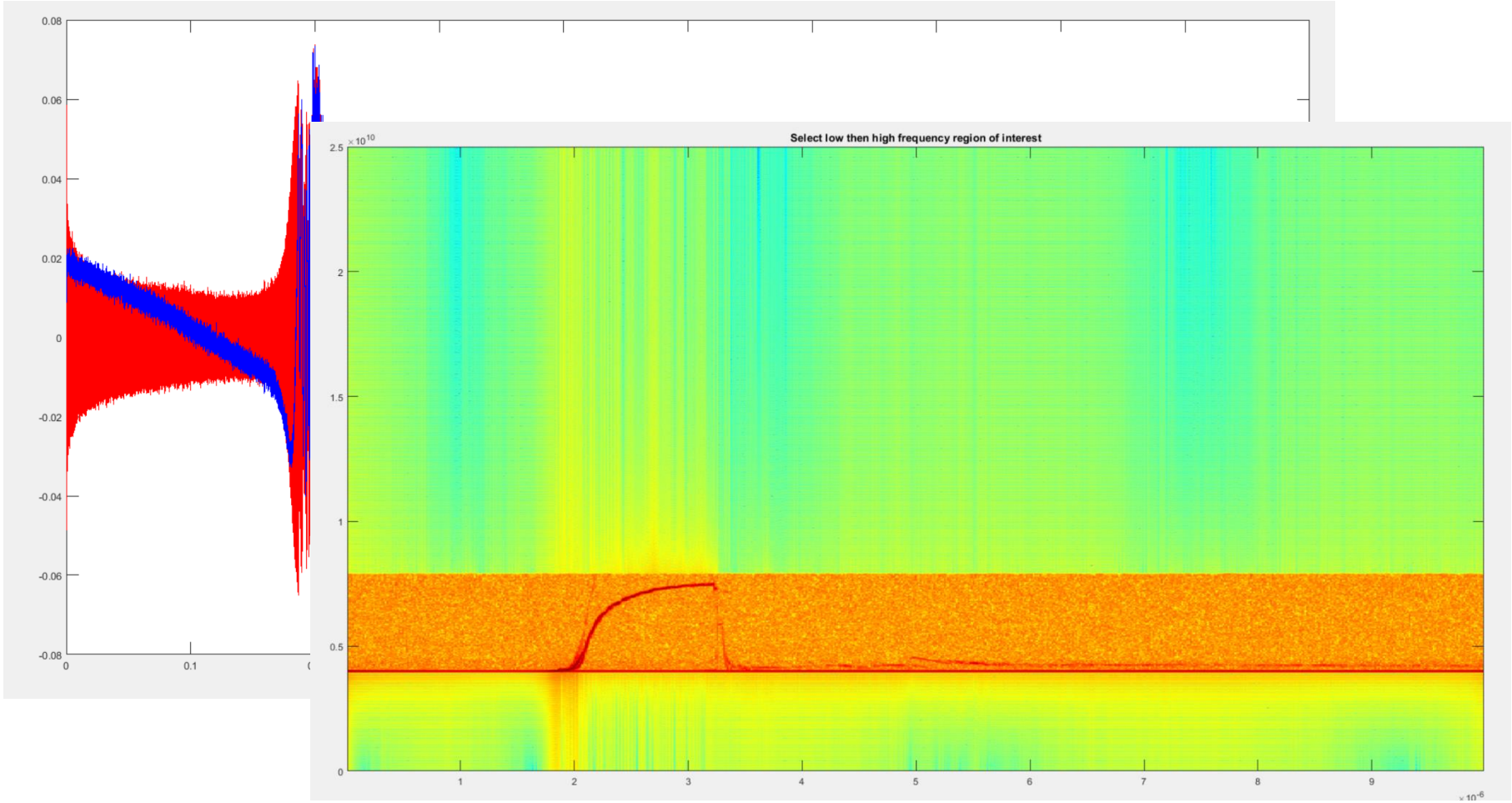



0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
×10^-5
0.1
0.05
0
-0.05
-0.1
1.65
1.7
1.75
1.8
1.85
1.9
1.95
2
×10^-6

- Downshifted ~6.121GHz

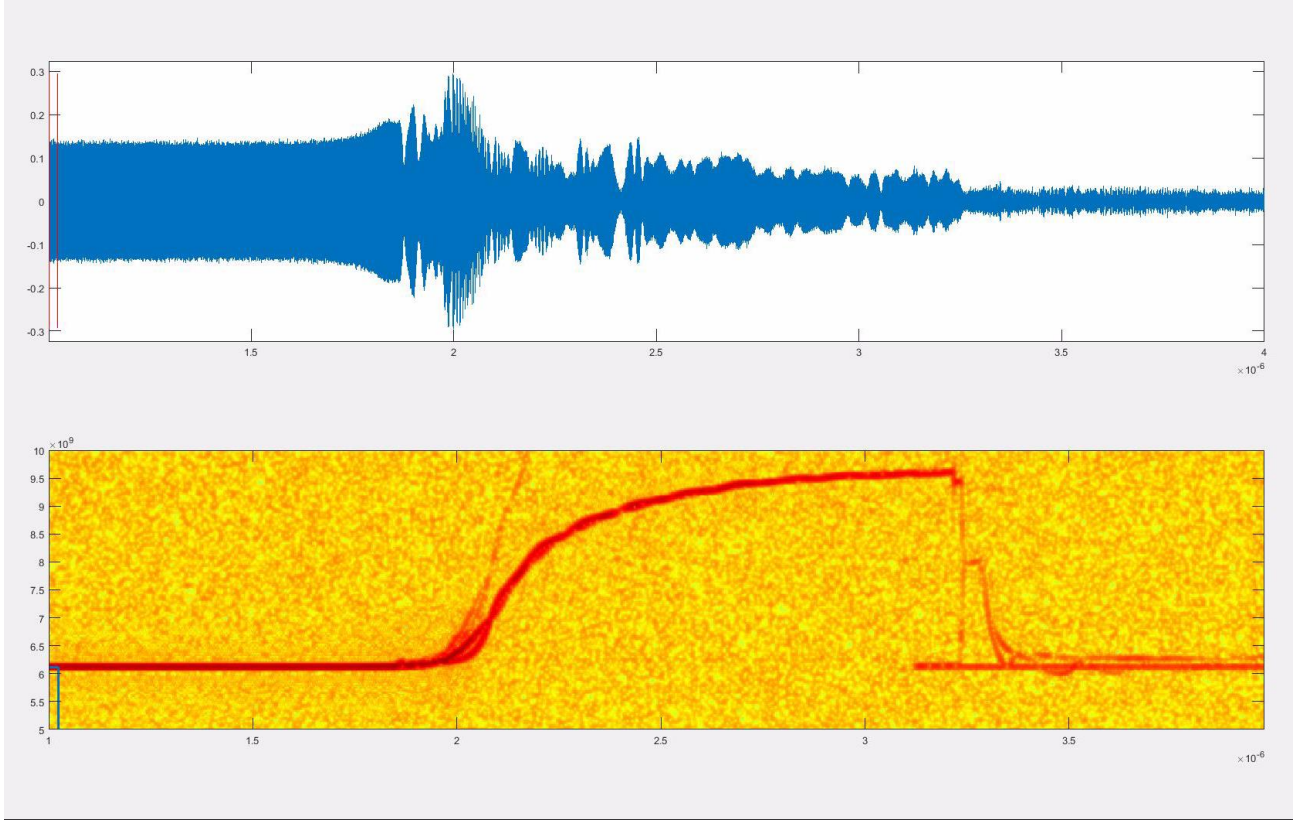


- Or add an upshift… (4GHz here)



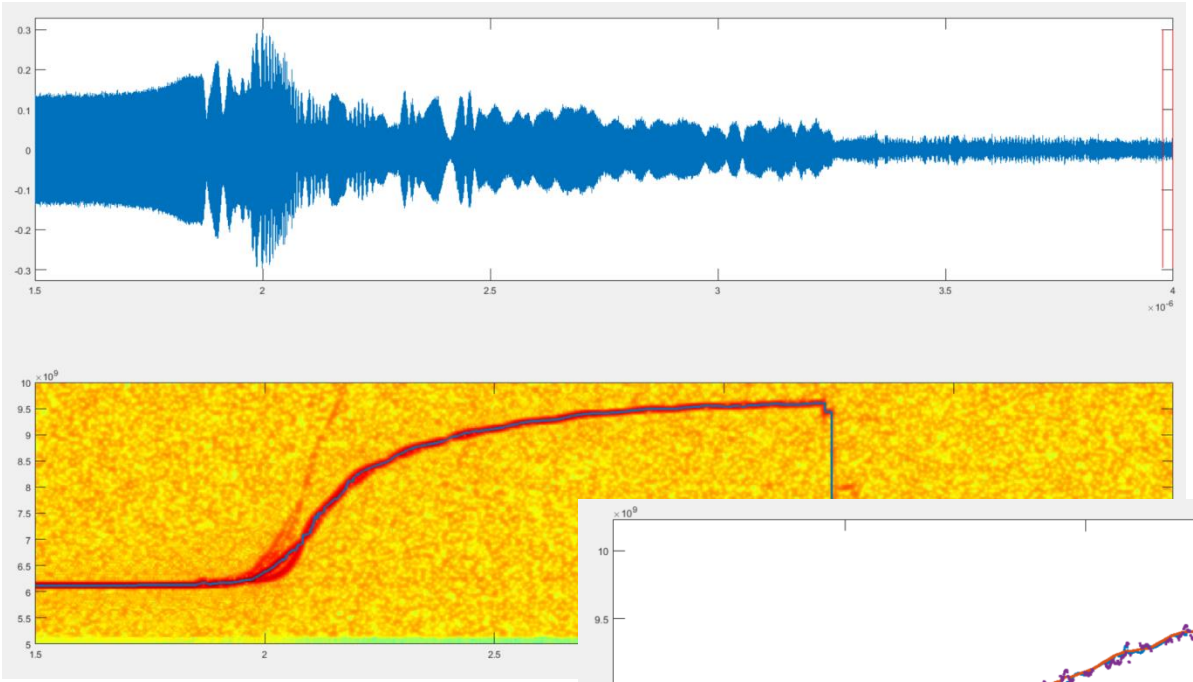
STSF – Short Time Sine Fitting

- Take a cleaned (filtered) signal
  - Frequency bandpass & remove baseline from ROI

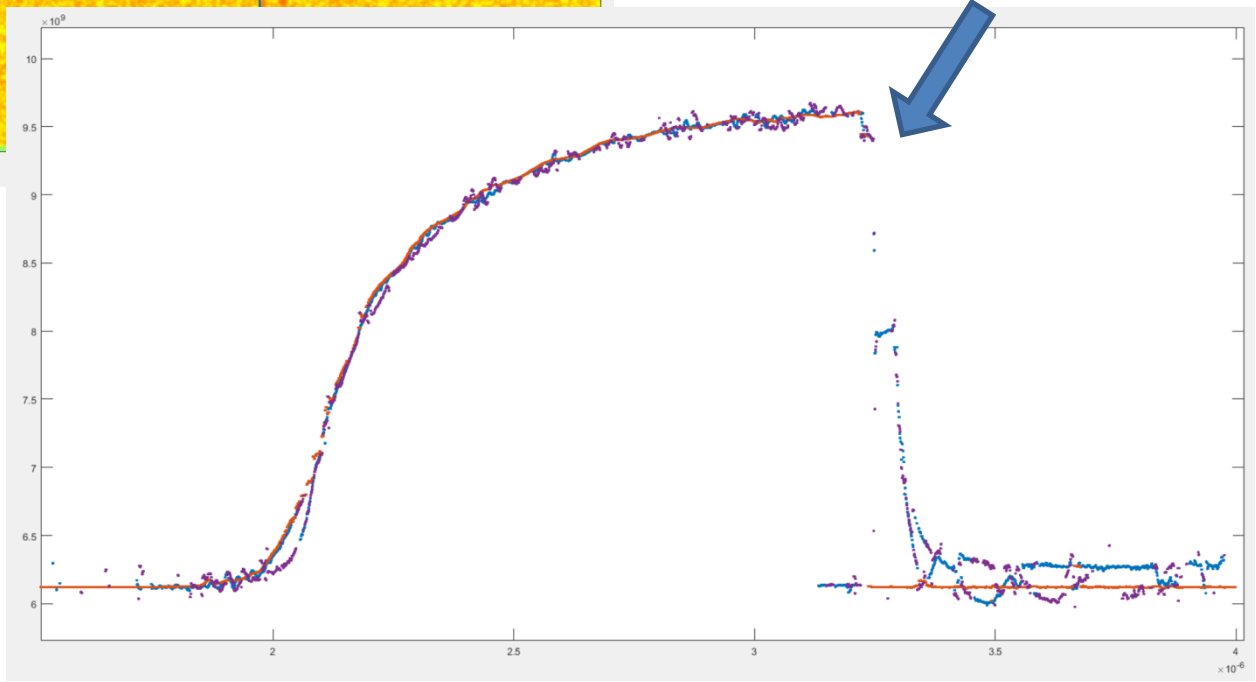


- Fit a sine curve to a subset of points based on the strongest frequency in that subset
- Subtract that sine curve from the raw data and step in time (freq. and ampl.)

0	shot A006	Atmosphere	Polycast PMMA	n/a	n/a	E-Gun	200mil, 5 mil thick kapton	20	Nitro gen	14.5	19	PDV, V, I	-12	-4.3	Yes	No voltage measurements as they are clipping too bad on previous shots. Good PDV data



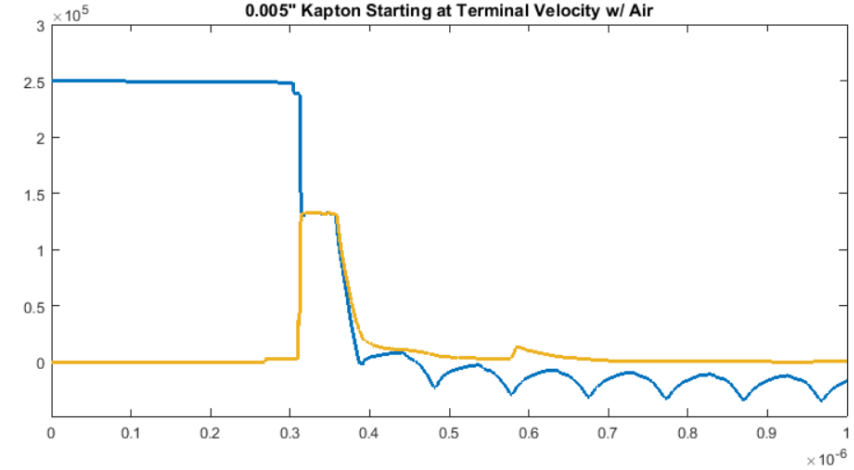
- Fit a sine curve to a subset of points based on the strongest frequency in that subset
- Subtract that sine curve from the raw data and step in time
- This was ran 3X

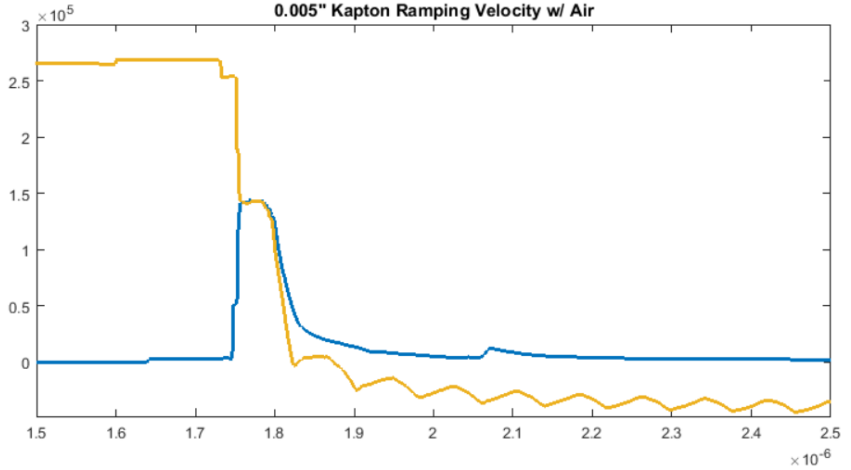


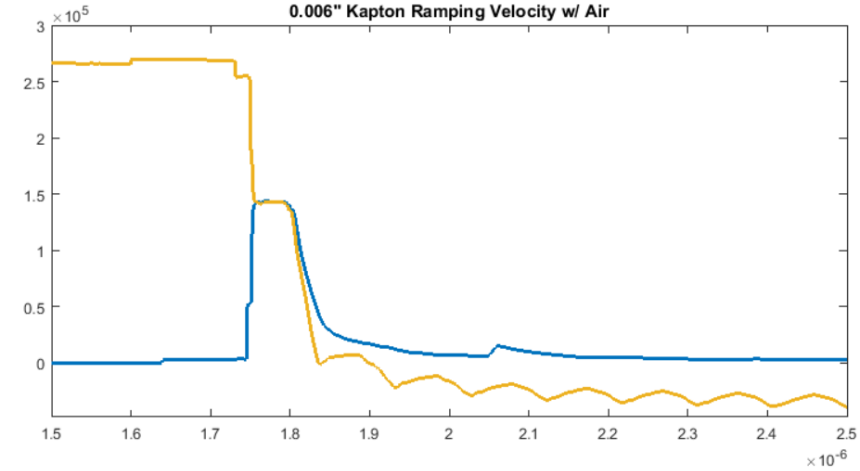
Comparison to CTH

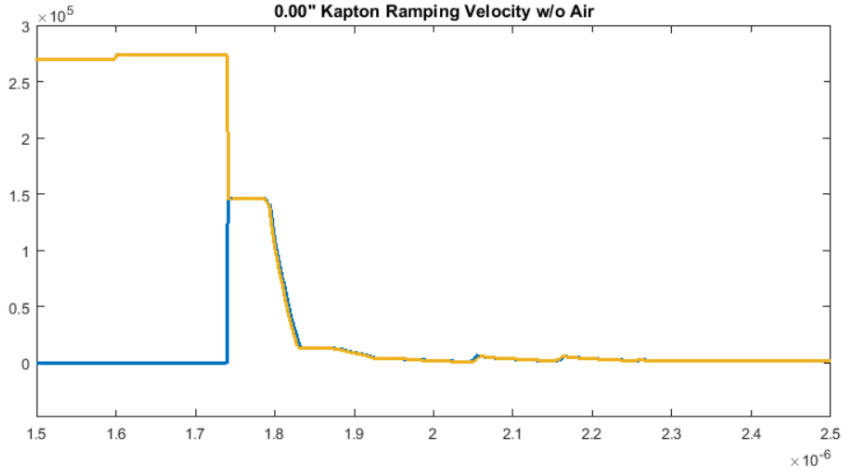
- Bow shock
  - Decrease in flyer velocity prior to impact
  - Window increase in interface velocity
- Pulse duration of flyer into window
- Release shock in the window and flyer velocity decay

CTH simulations

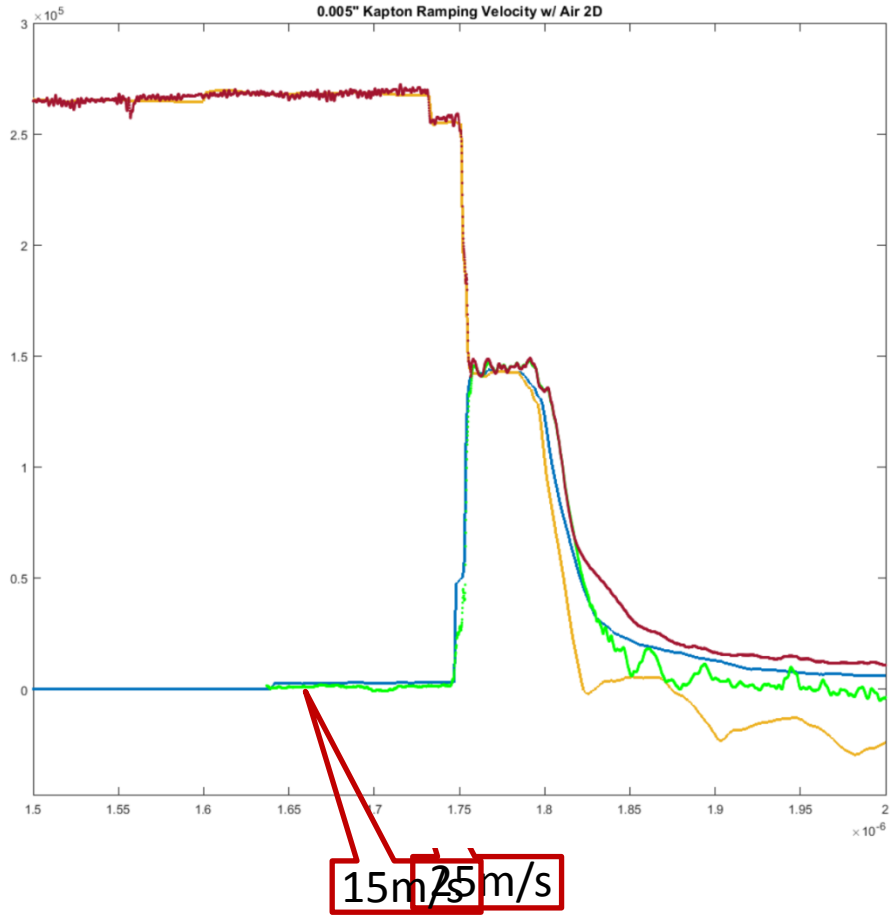


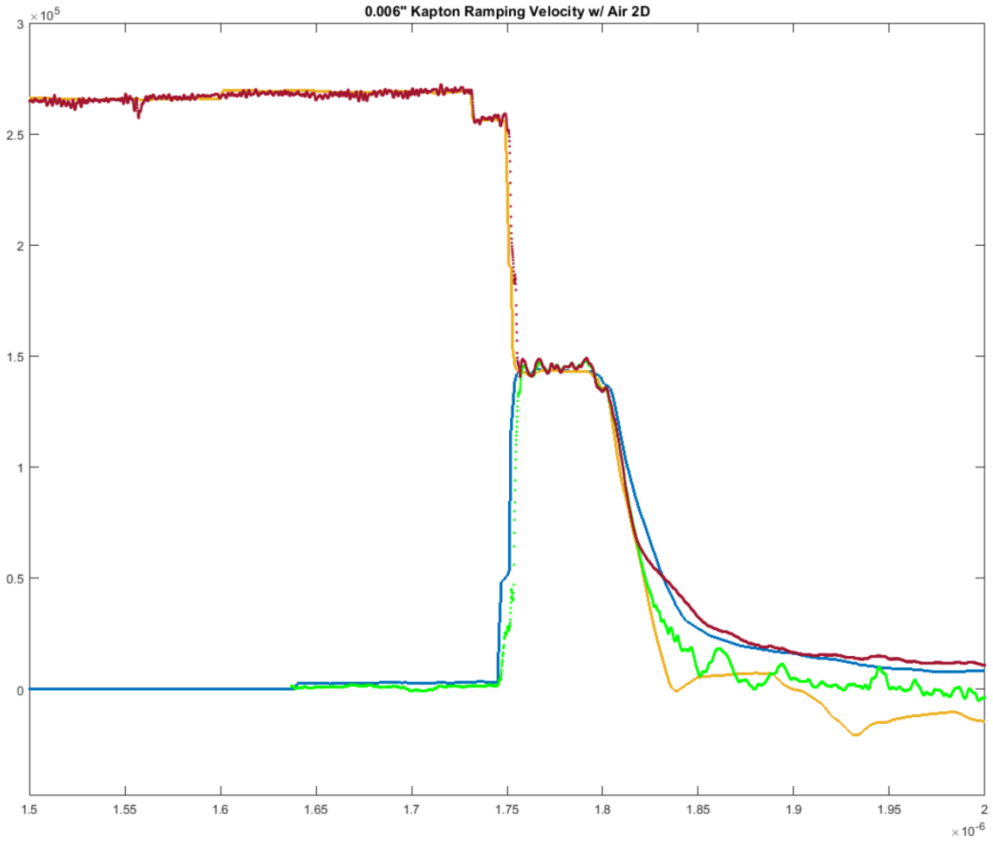






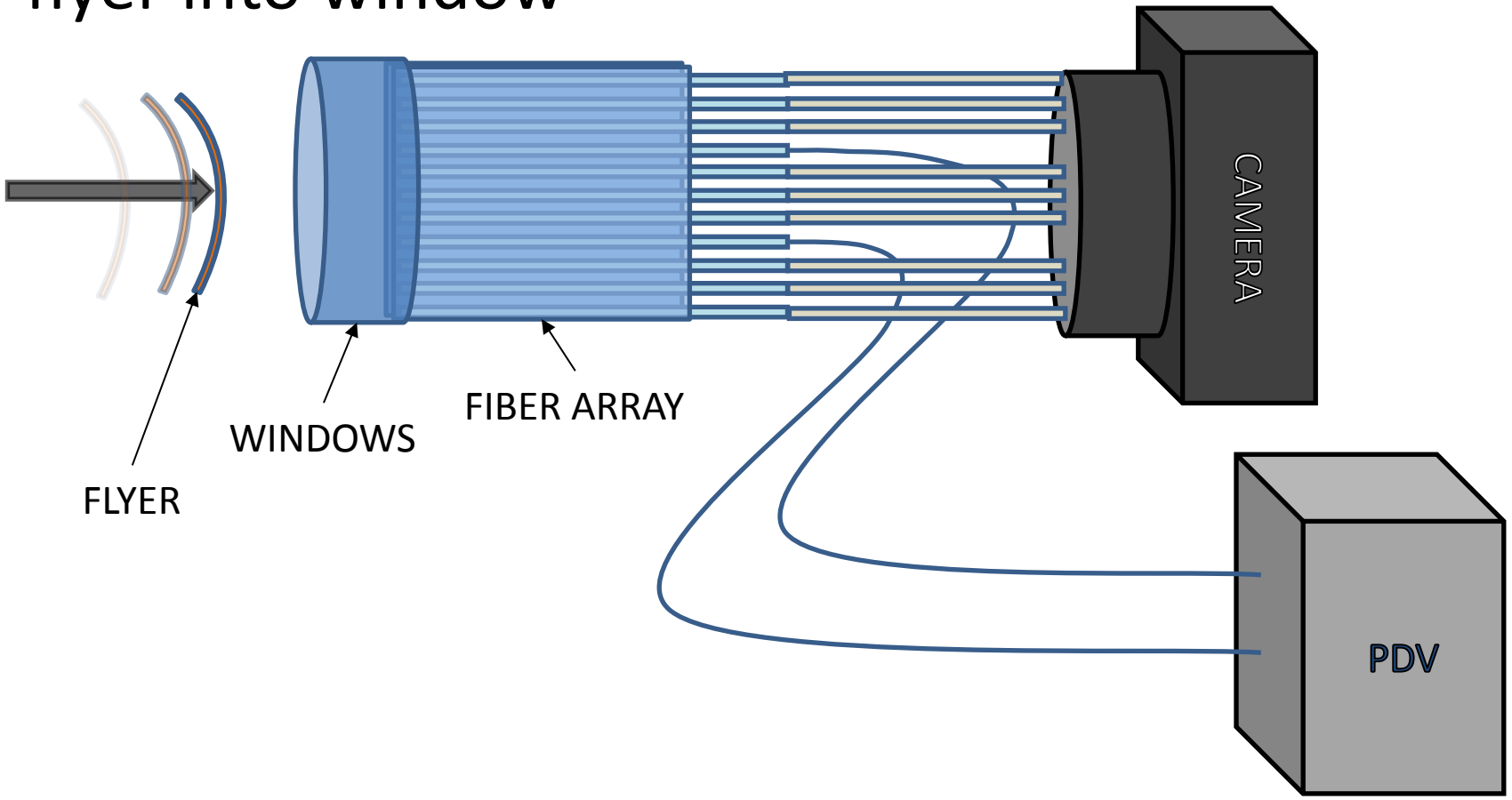
CTH 2D Comparison





Multipoint Velocity and Impact

- Bare fiber PDV and streak camera image of flyer into window



Fiber Arrays

- Spacing of 9/125 um fibers is ~127um