Heterodyne PDV on very fast rising shocks

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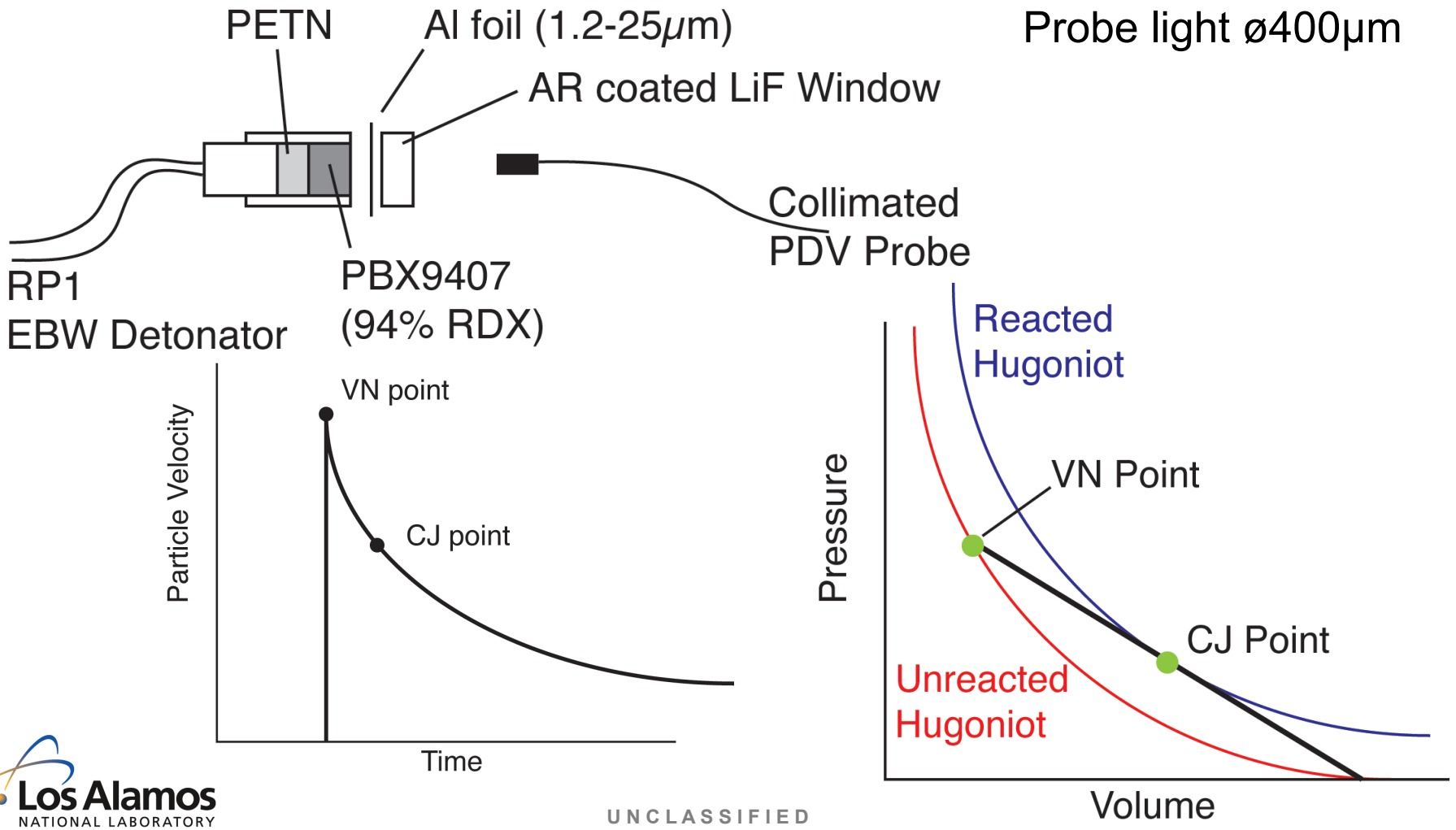
LANL

What's in a name

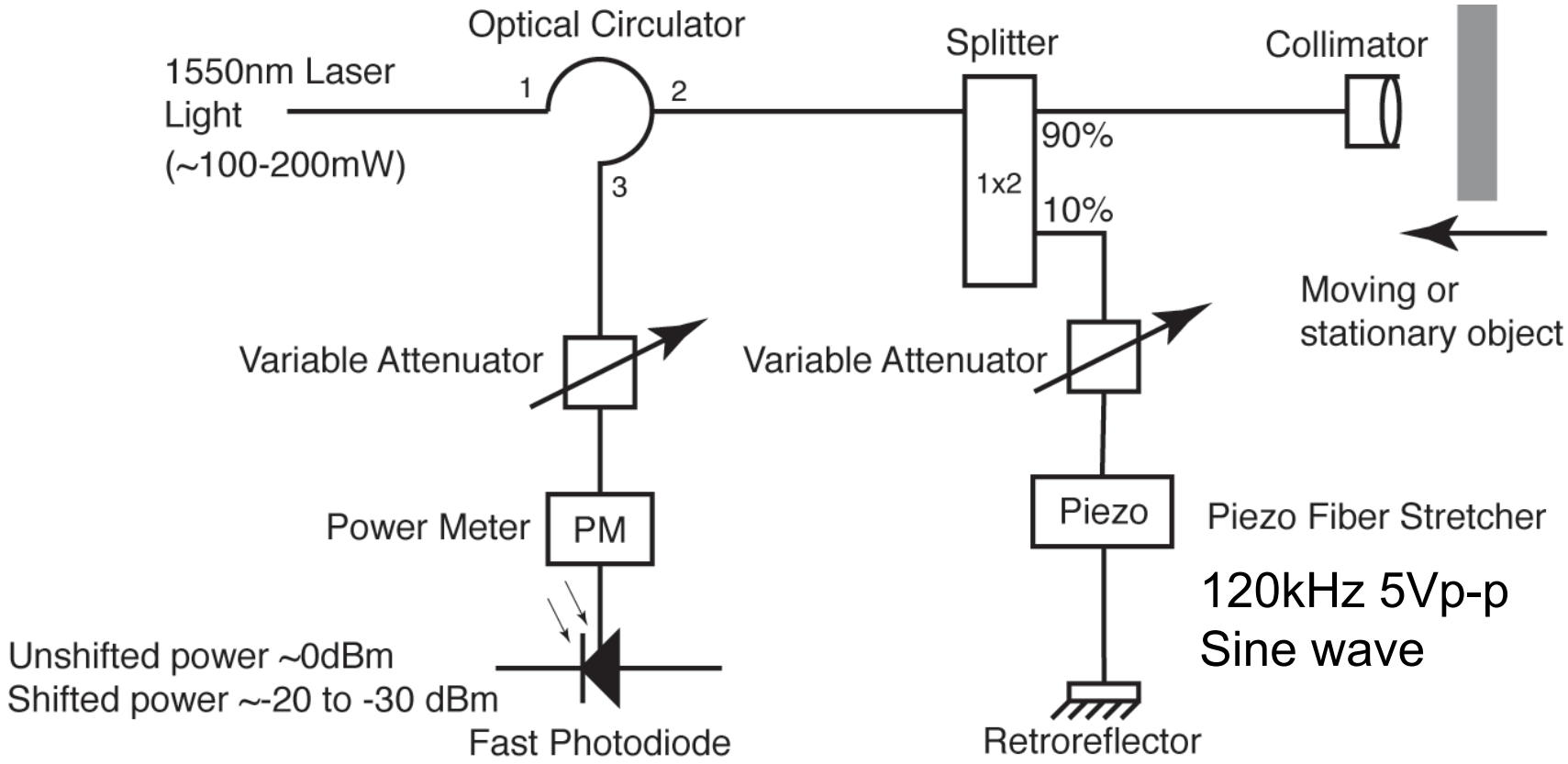
- PDV is a rapidly developing field.
- I call the original system generation 1.
- It is homodyne, that is the reference light and the incident light have the same frequency (no starting fringes).
- People are now developing heterodyne systems (generation 2).
- In these, the reference light and incident light have different starting frequencies, creating reference fringes.
- There are several advantages to this approach, including improved FFT analysis resolution.
- People have moved on to MPDV (multiplexed PDV). This might be generation 3.

Shock generation system



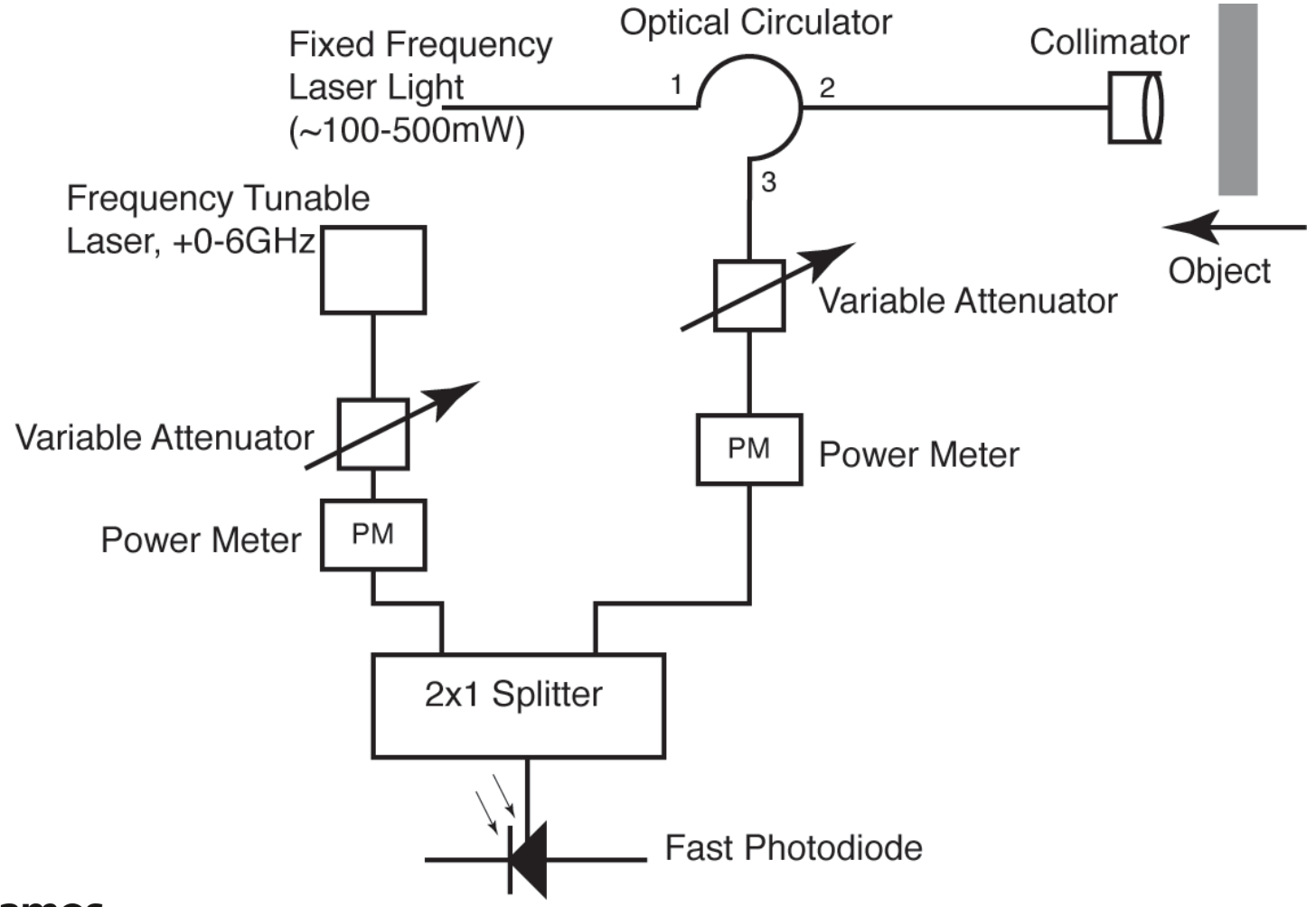
Implementations

Generation 1 fiber stretcher diagram

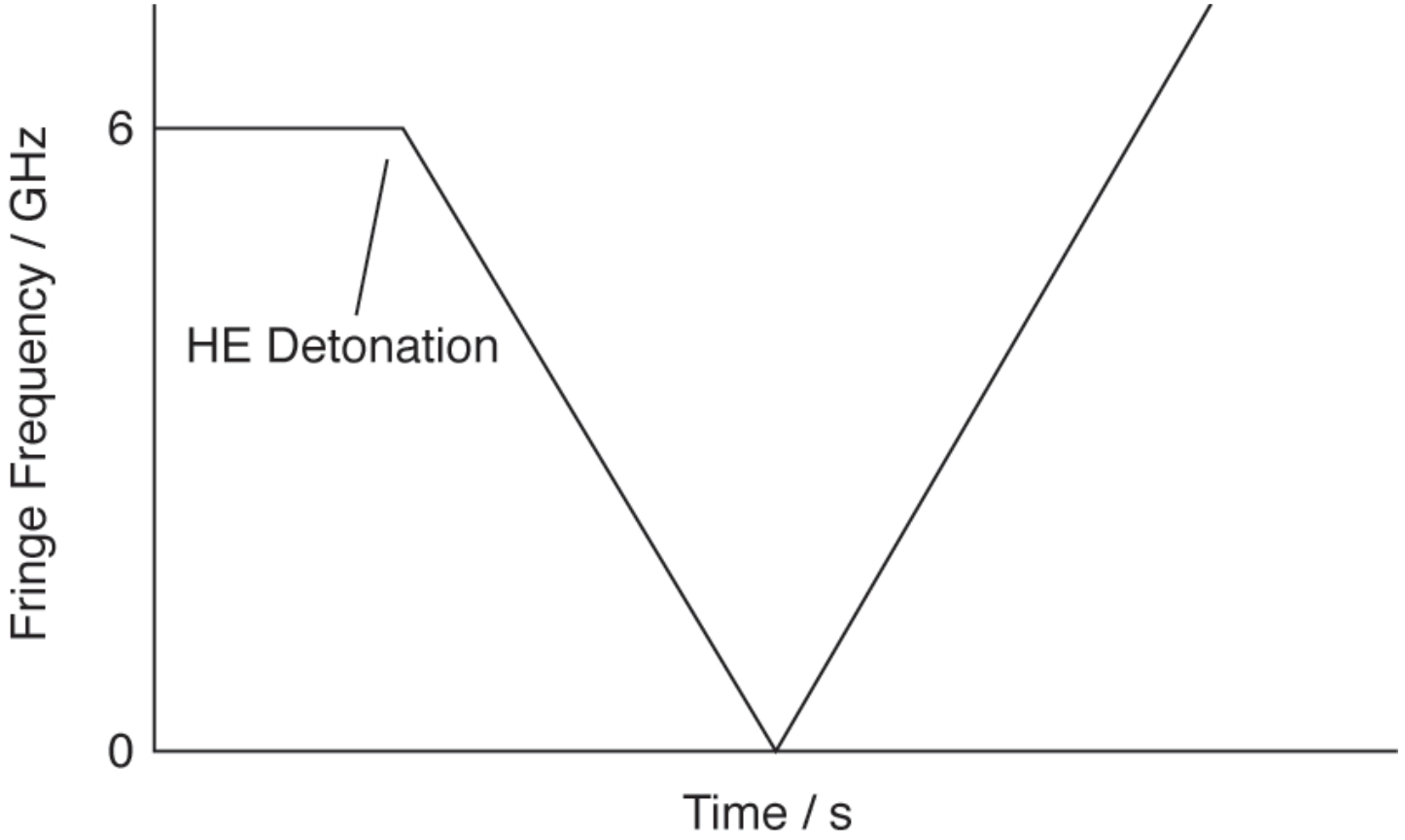


12m of fiber tightly wrapped around a periodically expanding core

Matched Lasers

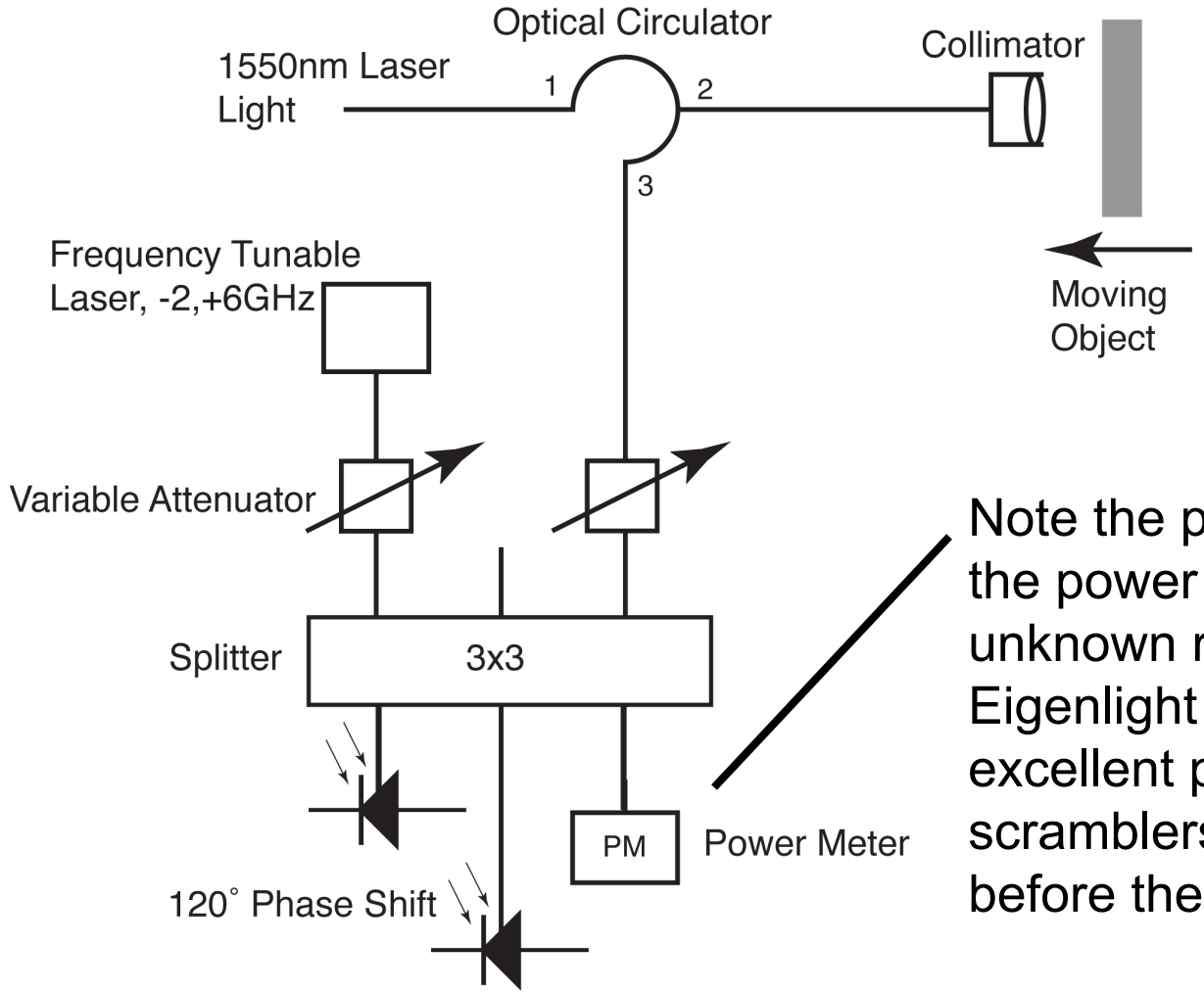


Frequency Offset



Here the wraparound really helps. It halves the required bandwidth (Total BW=17.4GHz for SiO2 fiber in 9501)

Triature System



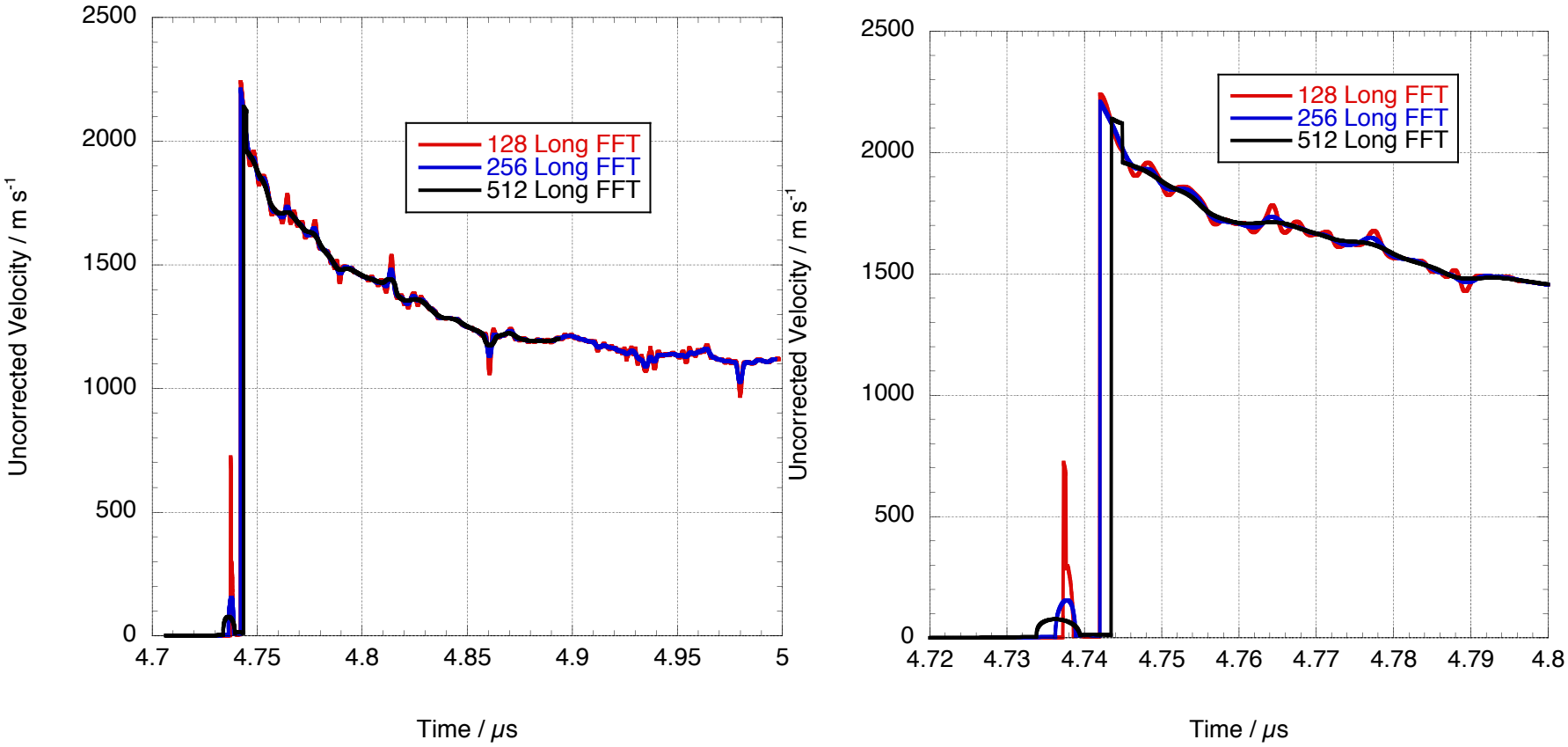
Note the position of the power meter. For unknown reasons, the Eigenlight devices are excellent phase scramblers if placed before the detector!

Phase unwrapping

- Phase unwrapping of the triature data required (easy).
- Synthetic quadrature data created from a single channel with the aid of the Hilbert transform (unwrapping is easy).
- Numerical differentiation of the resulting displacement data required to obtain velocity (hard).
- Various differentiation methods tried. Rick Gustavsen's idea of least squares fitting a straight line between N displacement points was the simplest and worked best for these data.
- N=+/-10 works well. At 40G samples s^{-1}, that is a fit over 0.525ns of data. 21 point FFT anyone?
- As Rick found, moving to a polynomial line fit showed no improvement. Why?

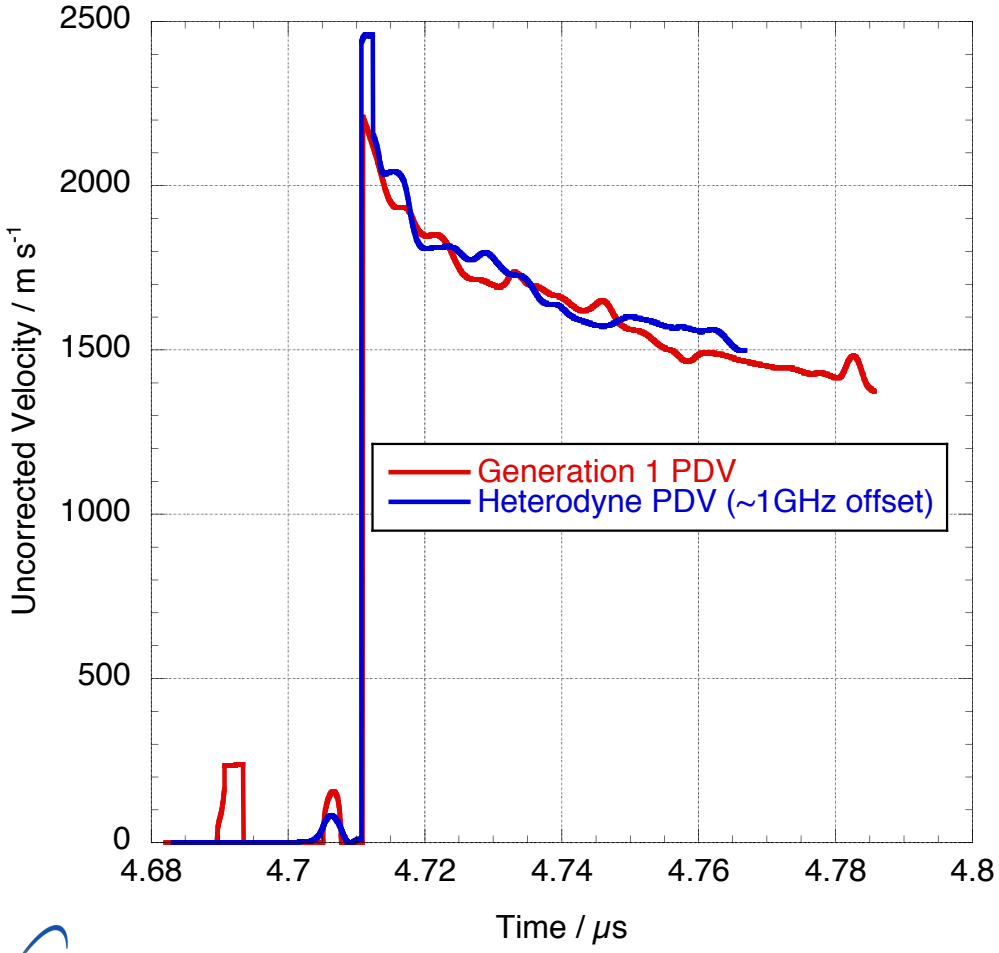
Results

Traditional FFT extraction, length comparison



All with x32 padding and short time advances (1/256-1/128 window lengths)

Generation 1 vs. Generation 2 (heterodyne)

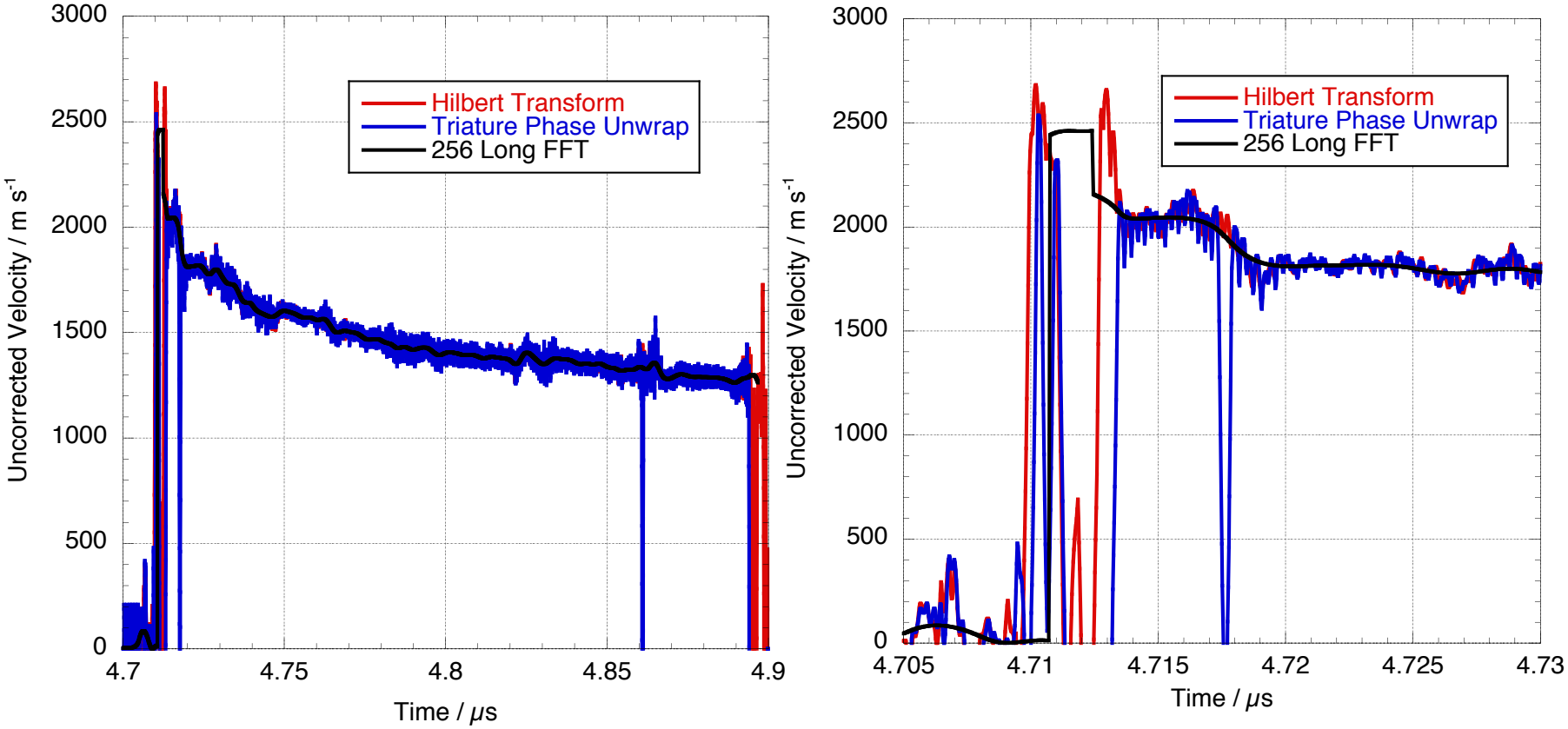


Transform lengths 256, x32 padding, 1/128 advancement.

Two probes on the same experiment.

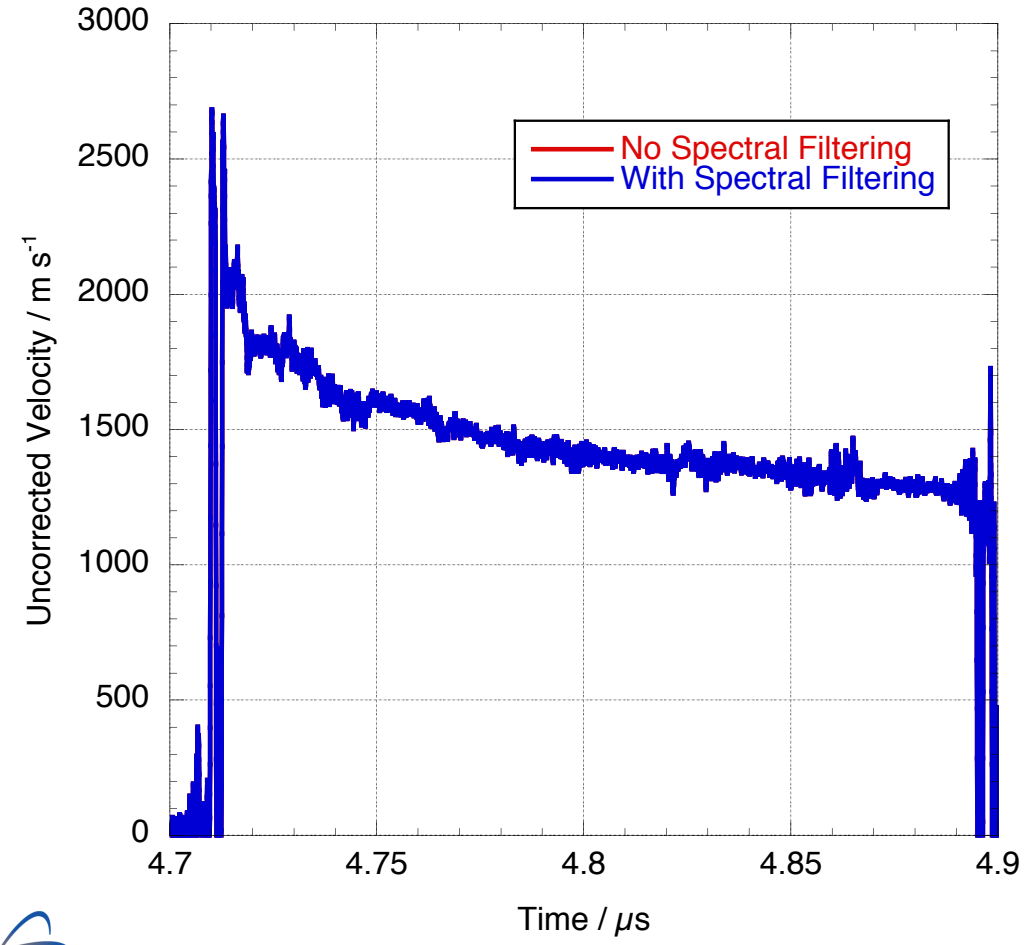
Gen. 1 PDV misses the VN point, but agrees at later times.

FFT vs. Hilbert Transform vs. Triature



All from the same data. 1.2μm Al foil. Triature is slightly noisier than the Hilbert transform method. Why?

Hilbert spectral filter comparison

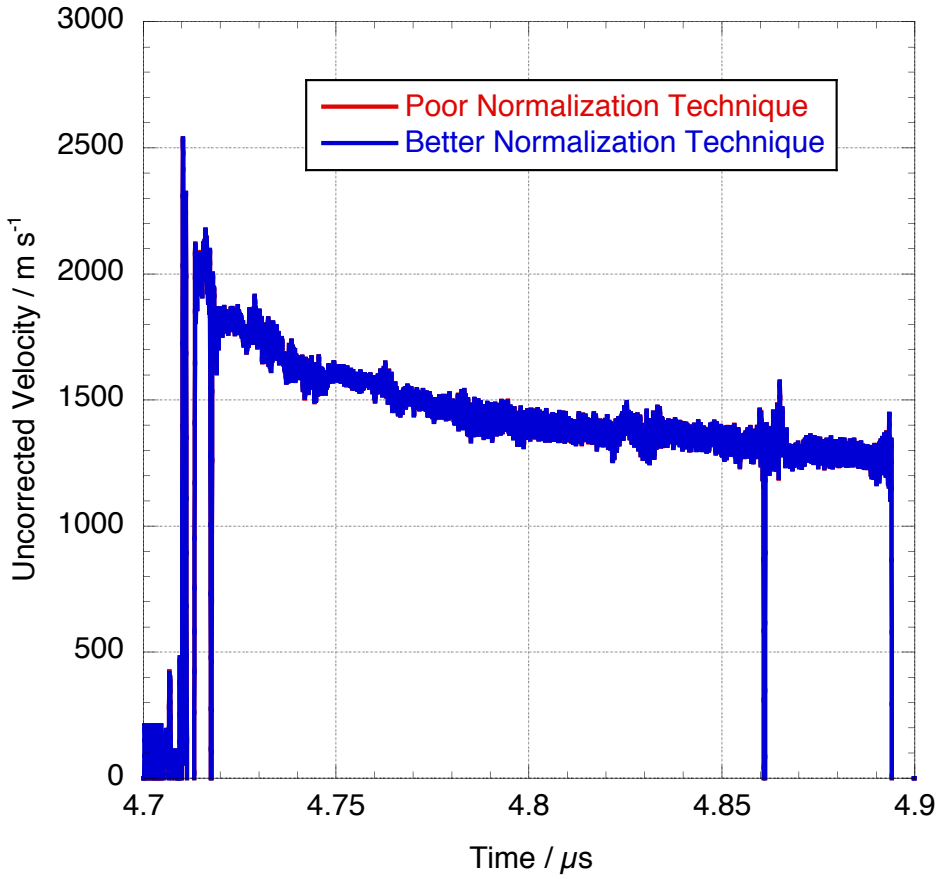


Hilbert transform done with and without low & high pass filtering of the input data prior to processing.

No apparent effect.

1.2μm Al foil

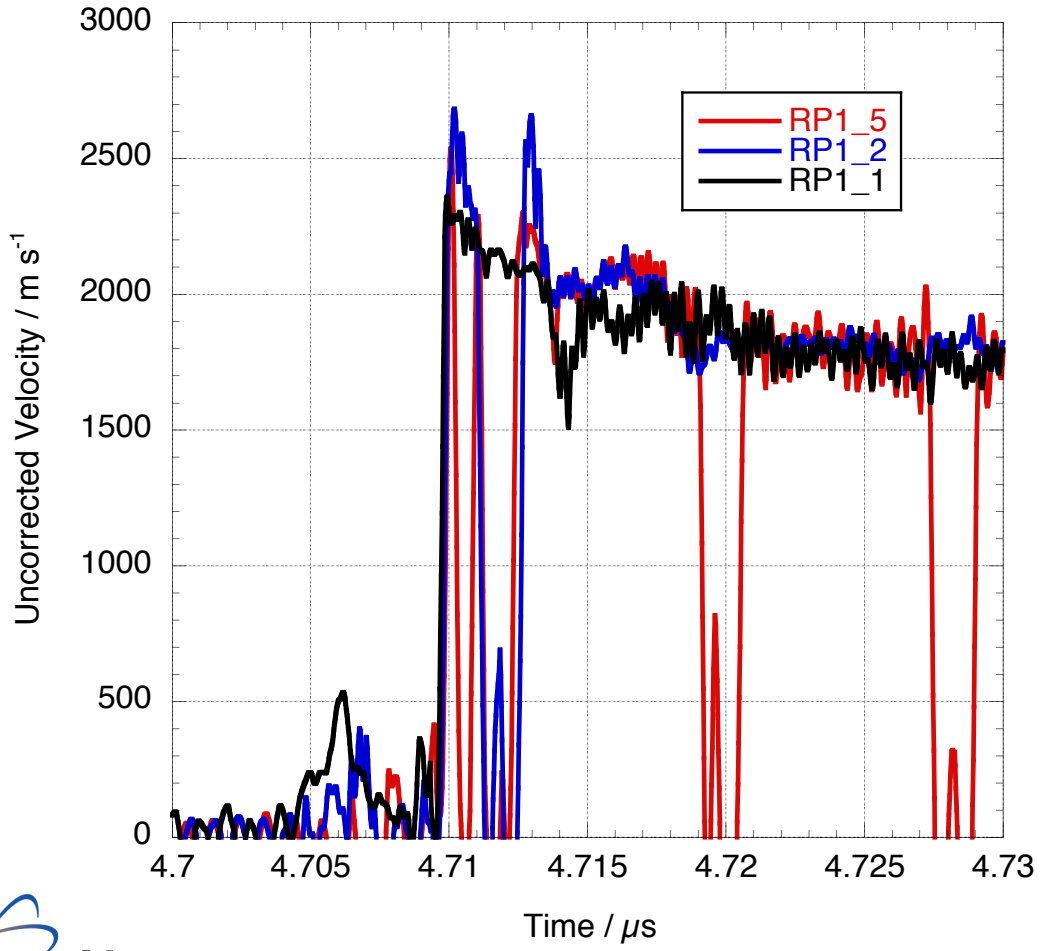
Triature normalization comparison



It has been previously observed that amplitude normalization of the two triature/quadrature waves can be important to accuracy. Here, simple subtraction of the mean (dc correction) is compared with a more sophisticated normalization of the data (piecewise gain normalization).

No significant differences.

Repeat experiment comparison



RP1_1: 25μm foil

RP1_2 & _5: 1.2μm foil

Note the drop out (low signal intensity) just after the VN point in both 1.2μm foils. This has been seen before in HE driven LiF windows. What causes it?

Summary

Summary

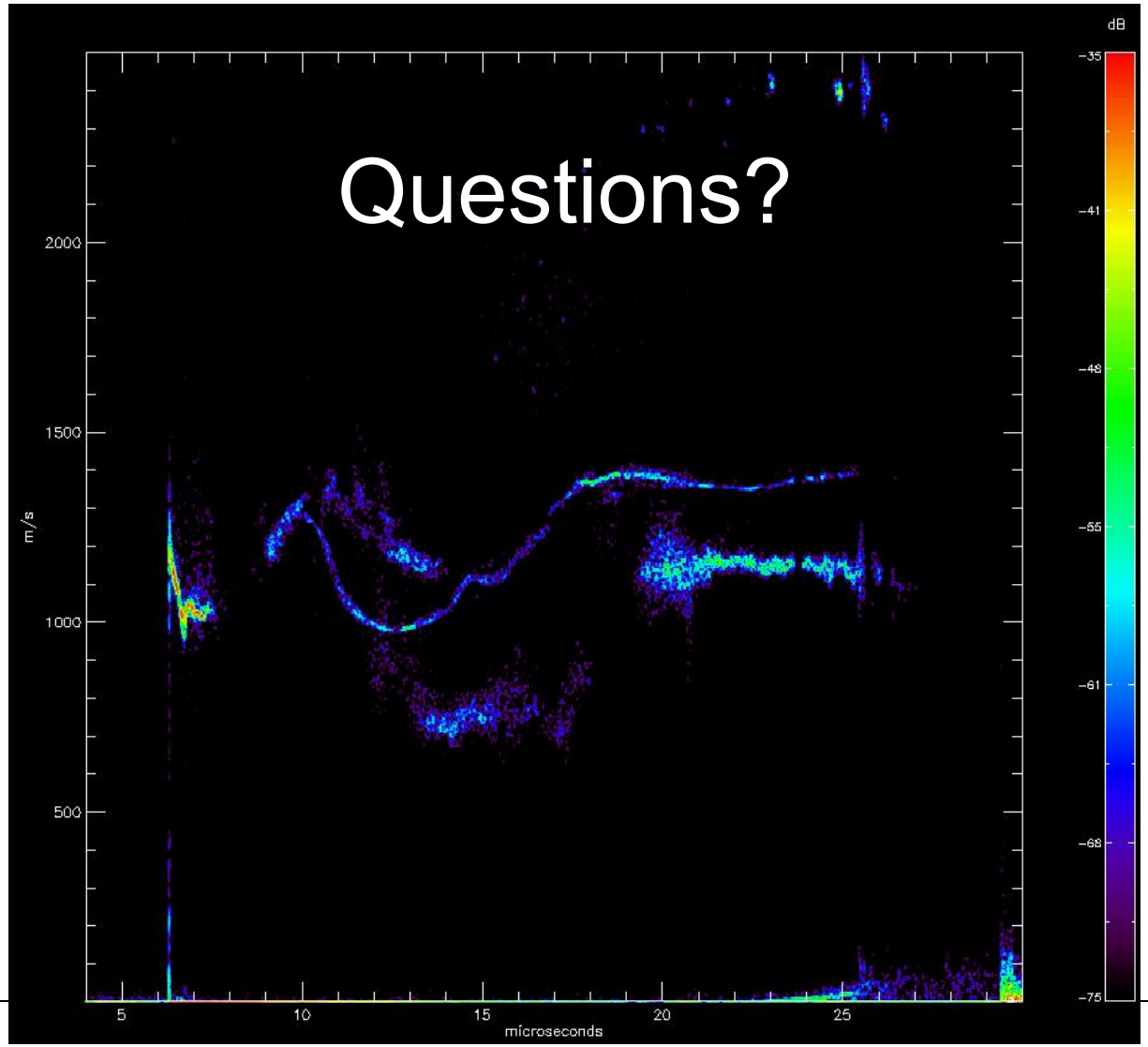
- In these experiments, generation 1 PDV is worse at capturing short transitory events than Heterodyne PDV using the FFT method.
- In my experiment, phase unwrapping is better at capturing very short events than FFT methods.
- Triature is not worth the additional infrastructure over Hilbert methods. If anything, triature it may be slightly inferior.
- Fancy data corrections/normalizations are sometimes not useful.
- Thicker window foils attenuate the VN point.
- HE breakout into LiF exhibits a ‘dark zone’ shortly after the VN point.

Future ideas

Ideas for the future

- Borrow a 100G samples s^{-1} ‘scope to examine the difference in temporal resolution available over a 40G samples s^{-1} device.
- Investigate collimated vs. focusing PDV probes (HE crystal size effects?).
- Compare my acousto-optical frequency modulator system against the laser system.
- Investigate the effects of foil thickness (0.65 to 25 μm).
- Look at the reaction zone in various explosives.
- Change the window impedance (TPX to Sapphire) to investigate the effect on reaction zone length and rate.
- (Imperial college showed at the last APS that the 1550nm correction factor for PMMA windows is indeed 1.0 and I have asked them to look at TPX.)

$10 to whomever can draw this HE driven geometry



Questions