Directional Velocity Measurements Using Frequency-Shifted Reference Leg in a PDV System

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Introduction

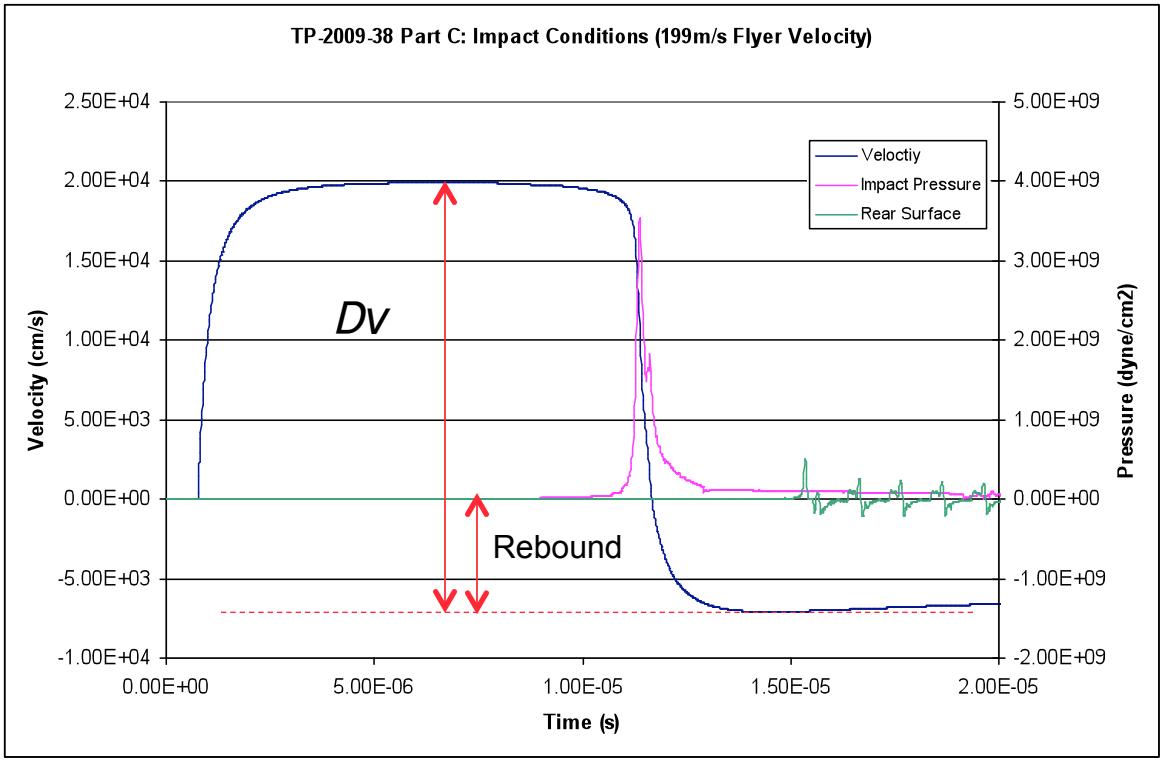
Ed Daykin and Carlos Perez, PDV Workshop 2008, described advantages of using an up-shifted laser frequency in a PDV system in order to provide direction-of-travel information from a single channel PDV record.

The promise of this technique is very attractive for developing a large probe number, direction-sensitive velocimetry system for Sandia's LIHE (Light-Initiated High Explosive) impulse testing facility – potentially very robust and economical.

Should require one oscilloscope channel/probe, and Er-fiber lasers are much less expensive than 532 nm CW lasers of sufficient power to anchor a 10+ probe system.

Up-shifted PDV, PDI and conventional VISAR were tested side-by-side to measure LIHE-driven flyer velocities required to determine the momentum imparted to test objects in a three shot demonstration effort.

Light Initiated High Explosive (LIHE) Impulse Response Testing



Objectives of diagnostic development are to provide a many probe (10+) system that can measure the flyer-delivered impulse over many points of a test structure accurately, easily and economically.

Impulse (momentum transferred/unit area)

$$I = mDv$$

where m = flyer mass/area.

Need to accurately measure both the impact and rebound (negative) velocities in order to obtain the desired *Dv*

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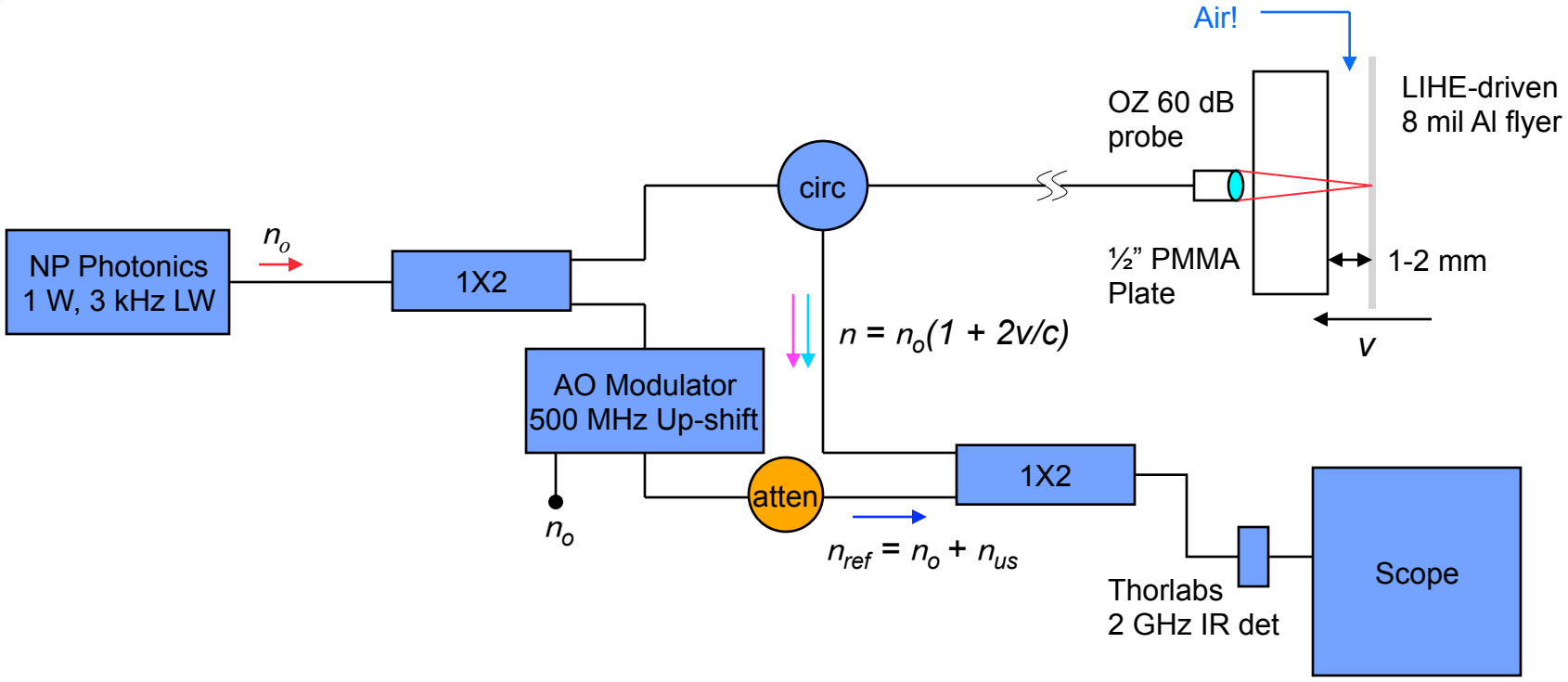
Up-Shifter Concept and Test Schematic



- With 3 kHz line-width, no need to match leg length
- Up-shift Modulator: Brimrose XXX-XX-YYZ
- Probe: OZ 60 dB, 6.2 mm aperture, 28 mm WD
- Flyer – 8 mil, 1100 Aluminum foil, rough polished

$$n_{det} = n_{ref} - n_{targ}$$

$$n_{det} = n_{us} - 2n_o(v/c)$$

$$v \geq,\leq 0$$

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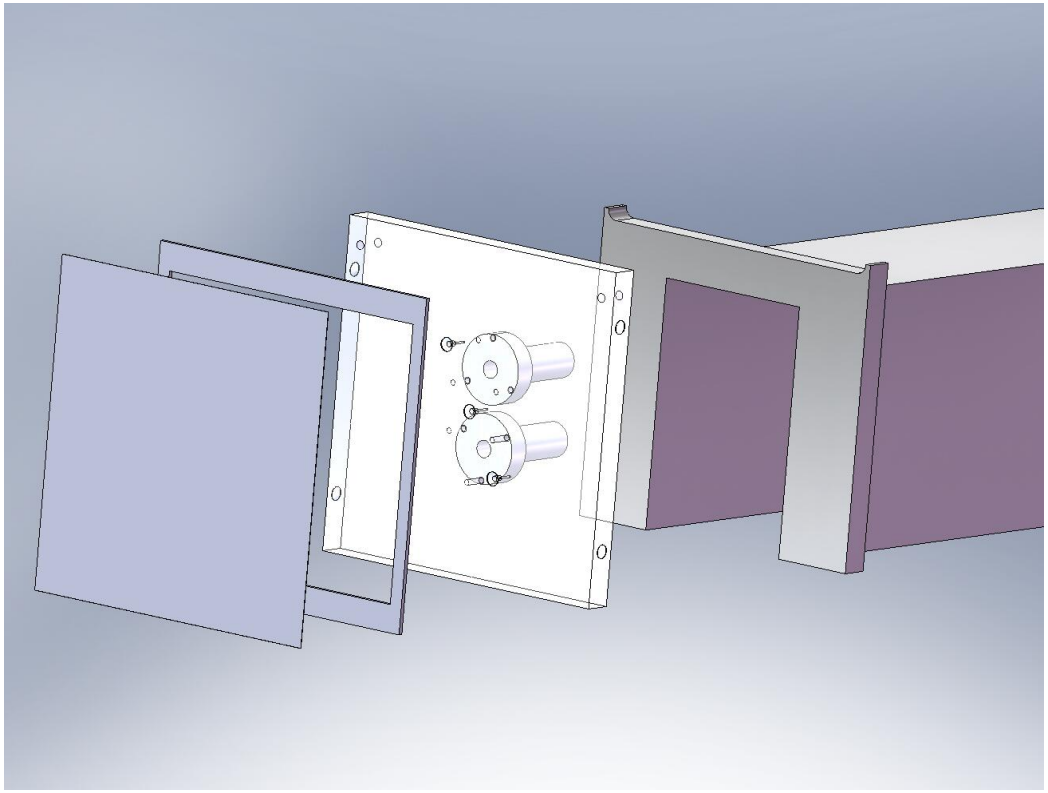
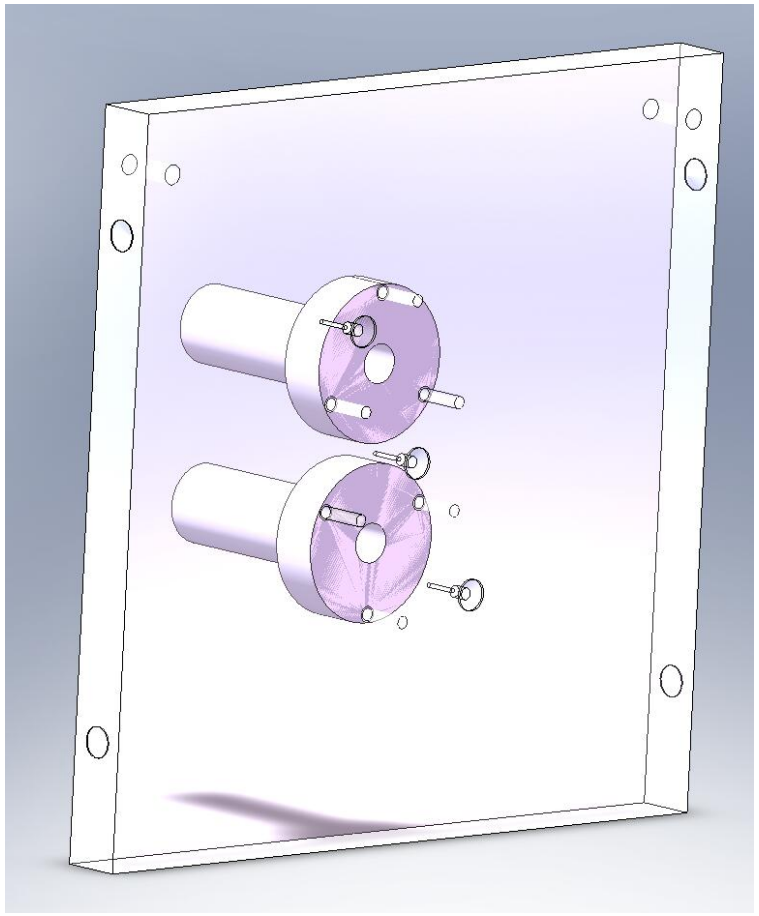
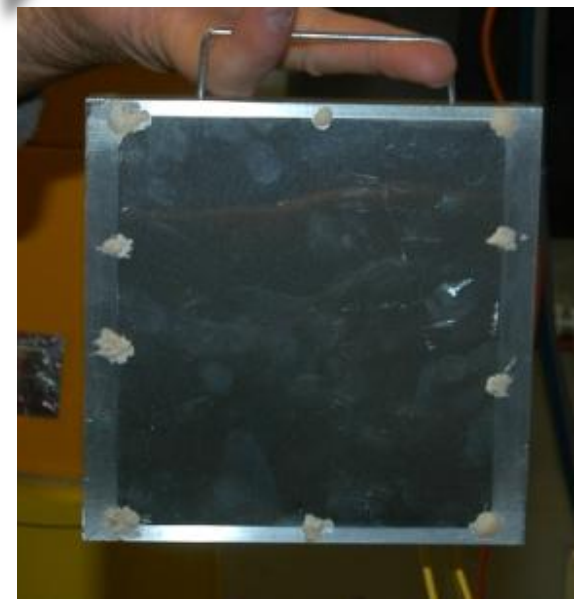
Up-Shift PDV, PDI and VISAR Comparison

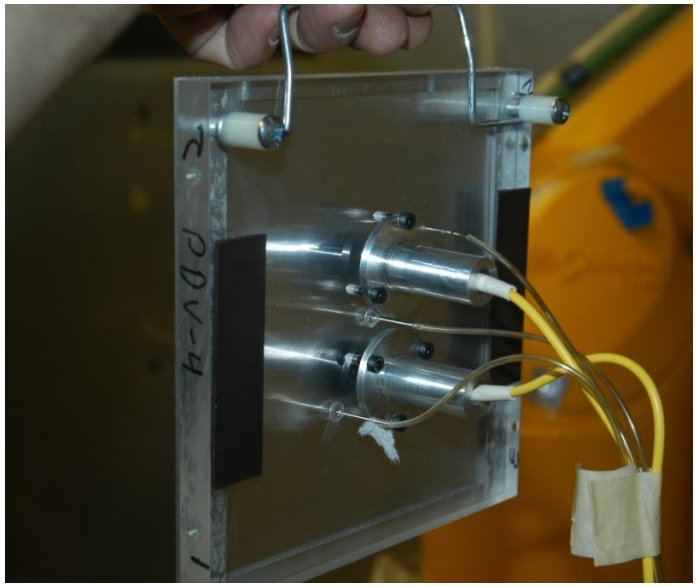
The up-shift PDV was fielded along with 3-phase Photonic Displacement Interferometer (PDI) and conventional VISAR at 532 nm as a head-to-head test for deciding future diagnostic direction at SNL's LIHE facility

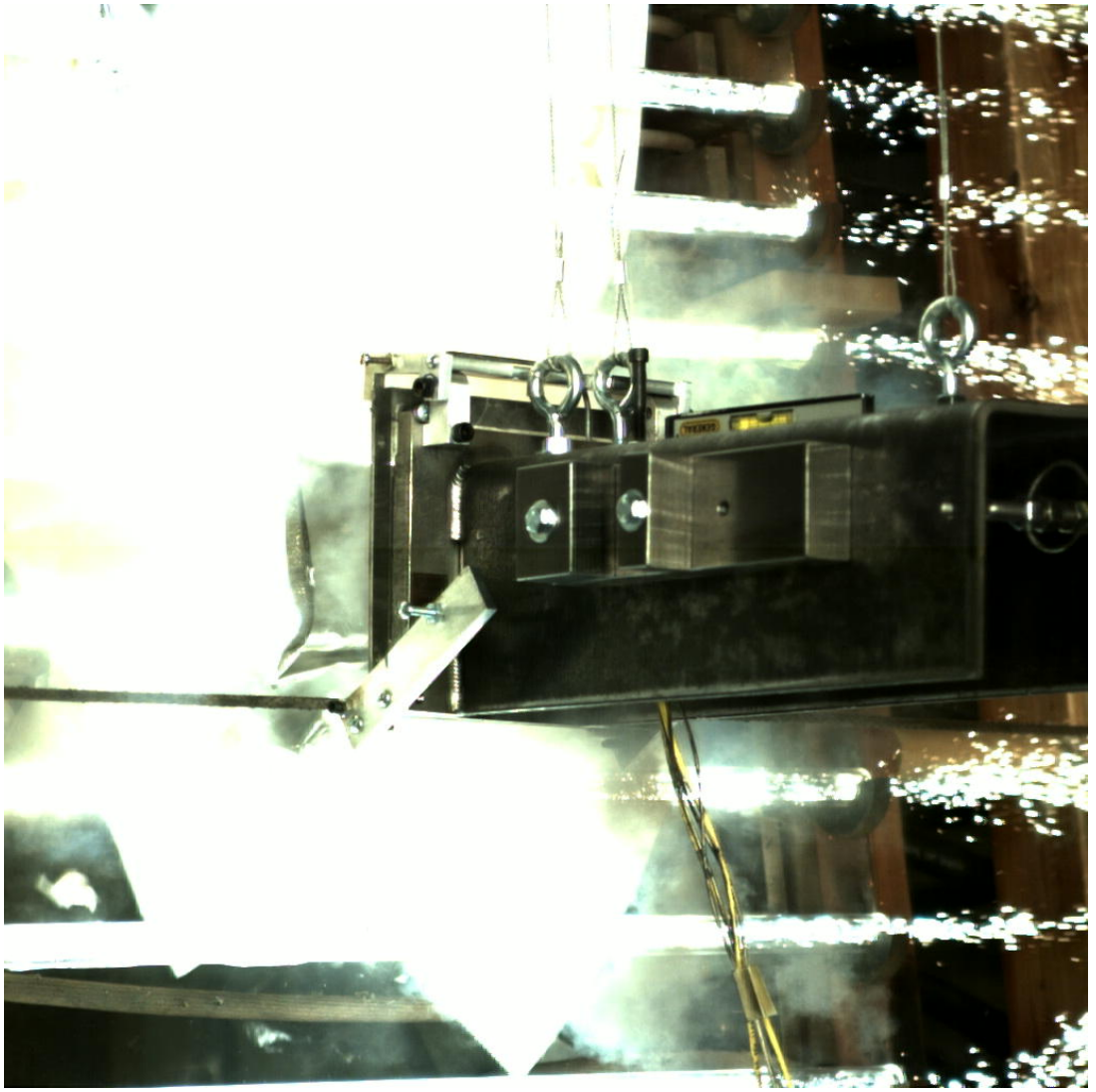




Flyer & Target Hardware







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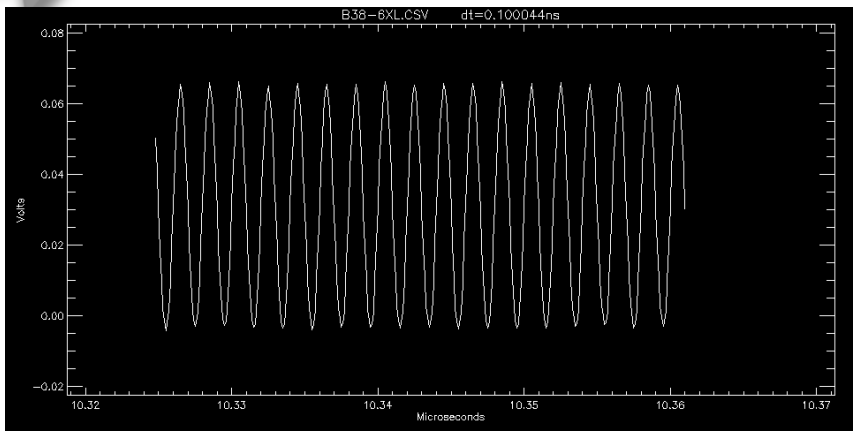
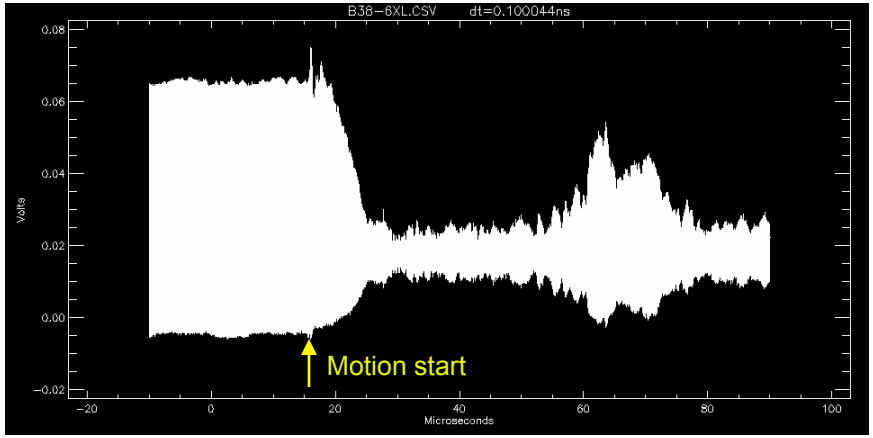
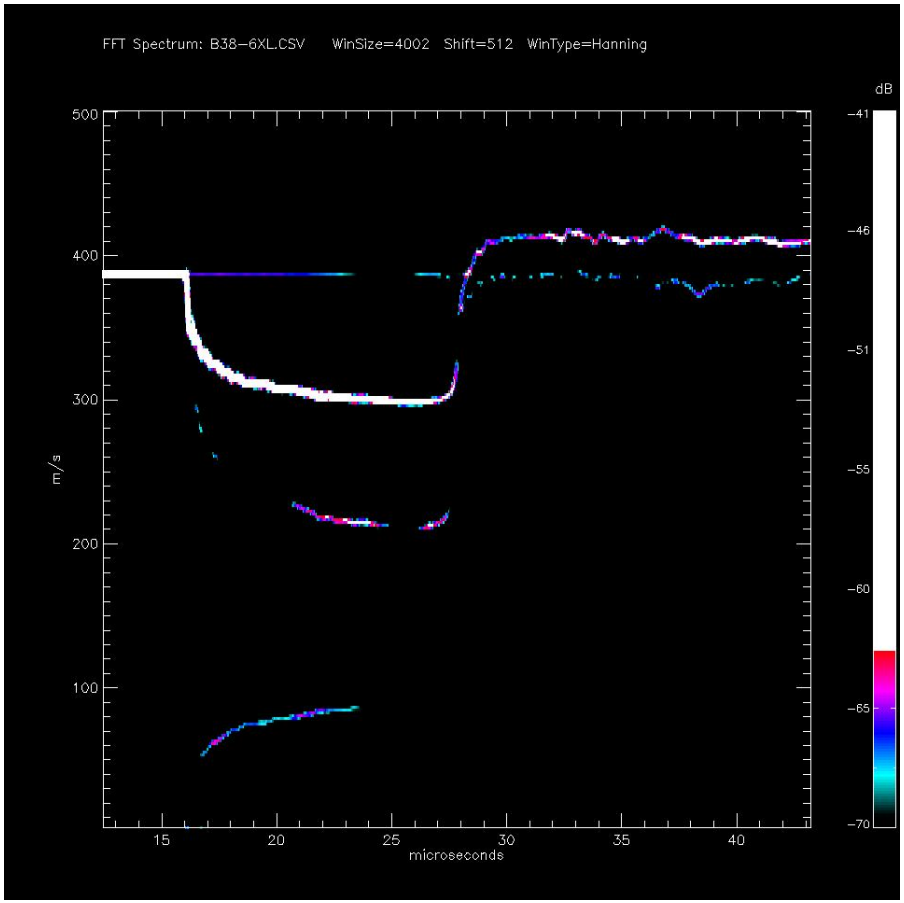
Data & Analysis



500 MHz beat frequency pre-shot



Full record



PDV Vers. 2.1, NSTec LAO

$n_{det} = n_{ref} - n_{targ}$

$n_{det} = n_{us} - 2n_o(v/c)$

"Initial" velocity for n_{us} *= 500 MHz*

$v_i = ln_{us}/2 = 387.5$ *m/s*

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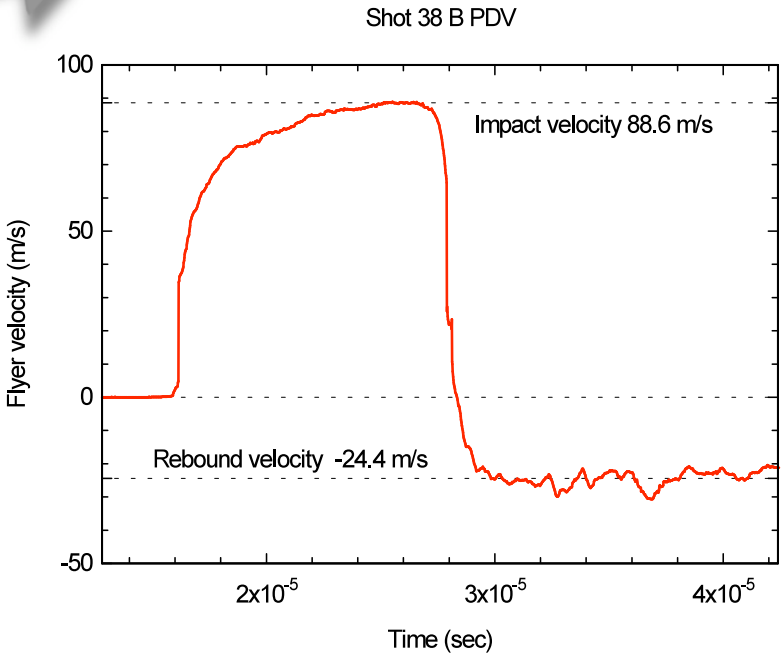
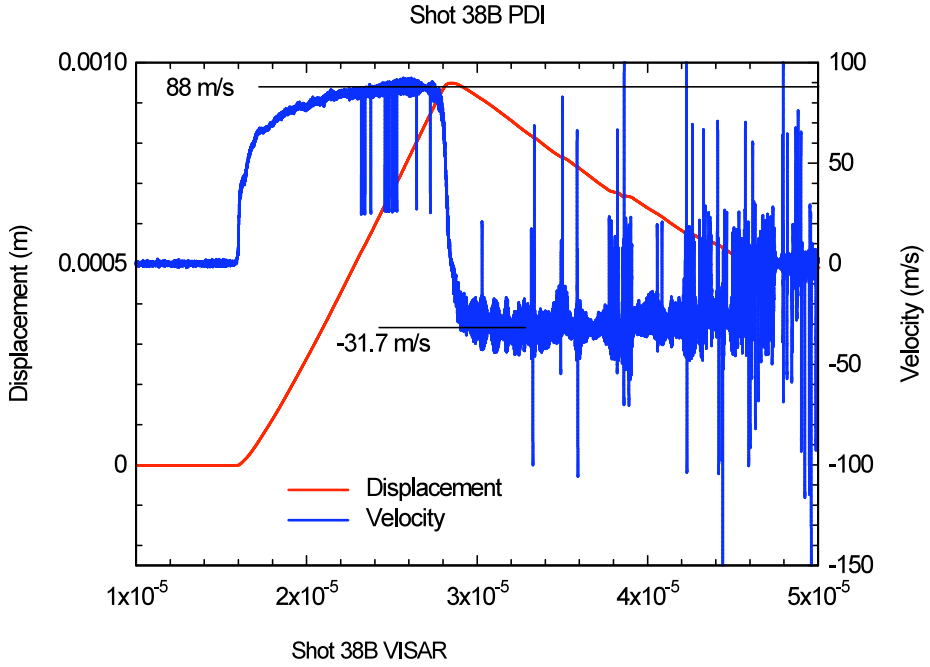
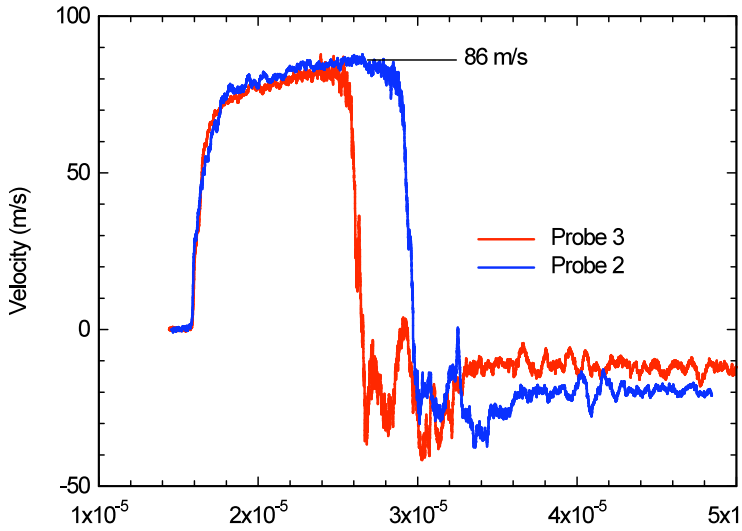
Results





To obtain the final velocity profile, v_f, from the PDV analysis result, v_o,

$$v_f = -(v_o - 387.5\ m/s)$$



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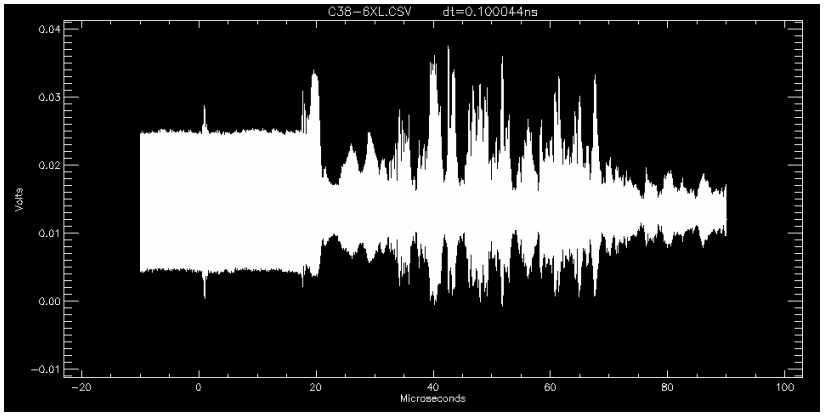
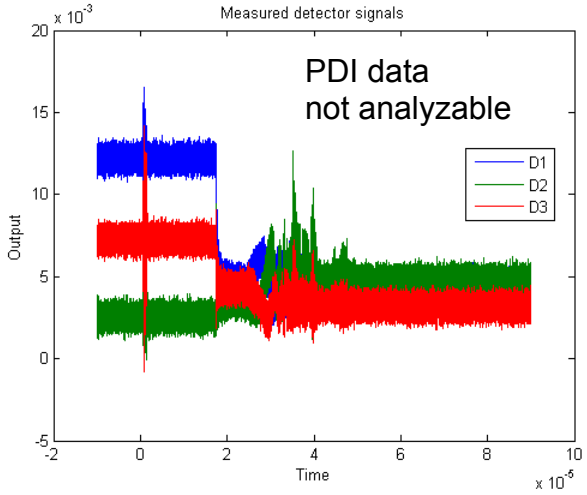
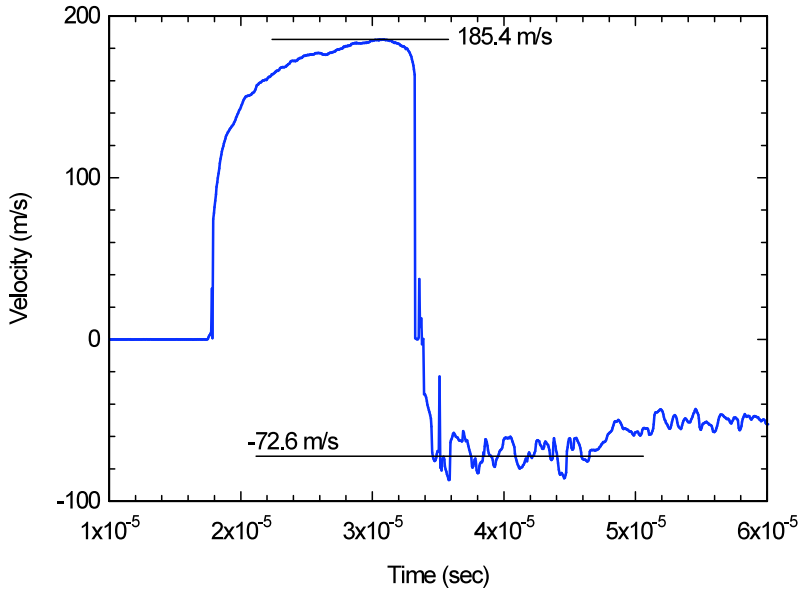
Results

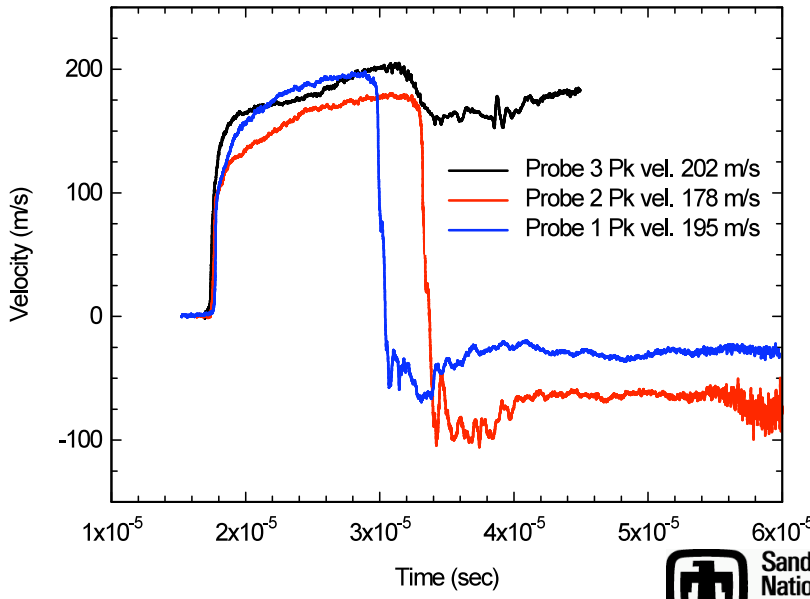




SHOT 38C PDV



SHOT 38C VISAR



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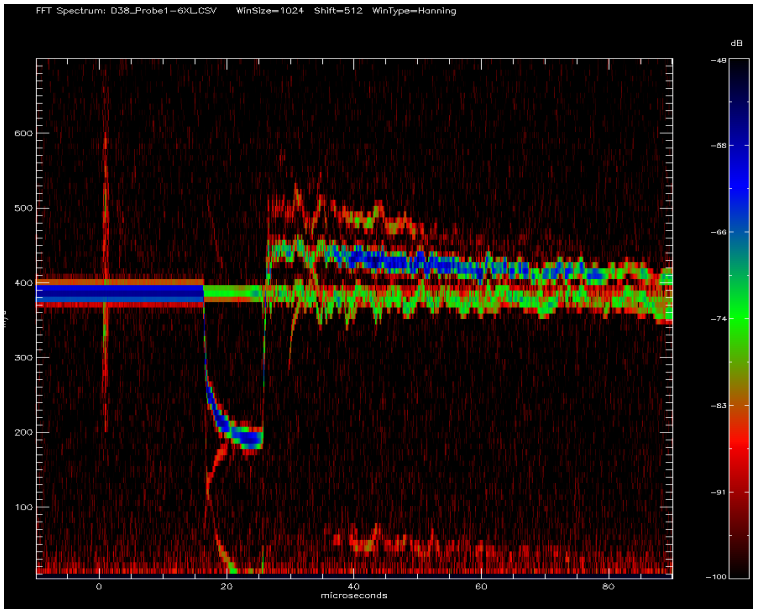
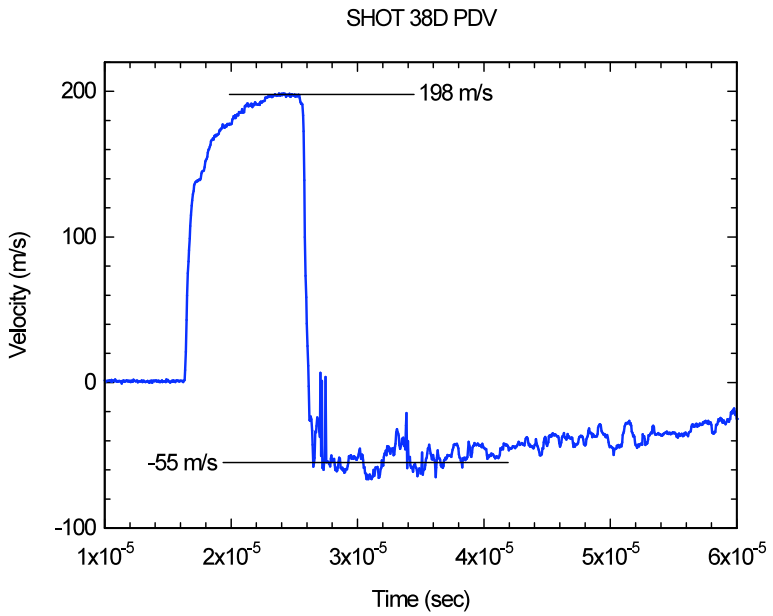
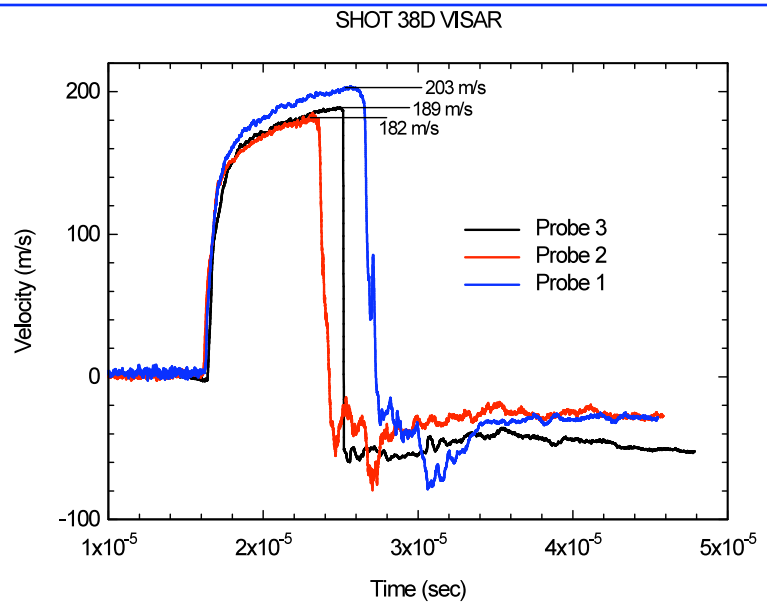
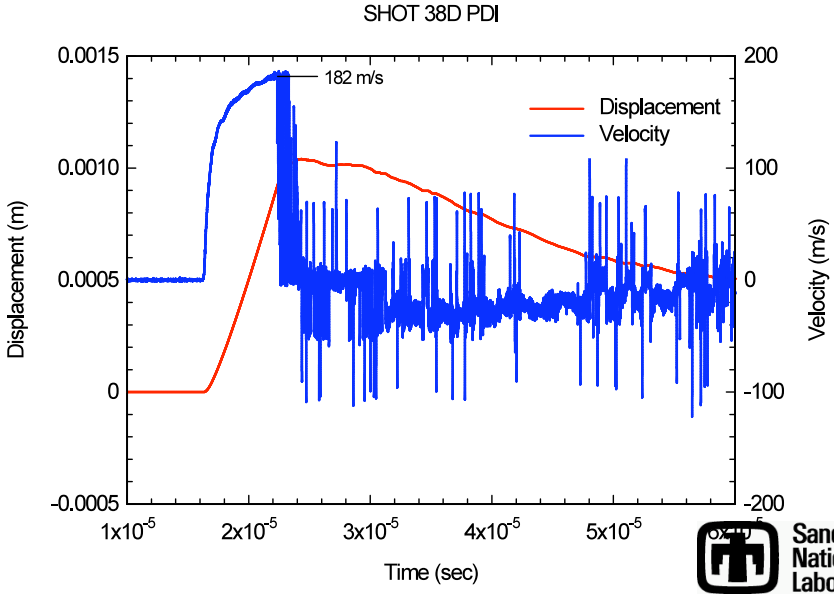
Results









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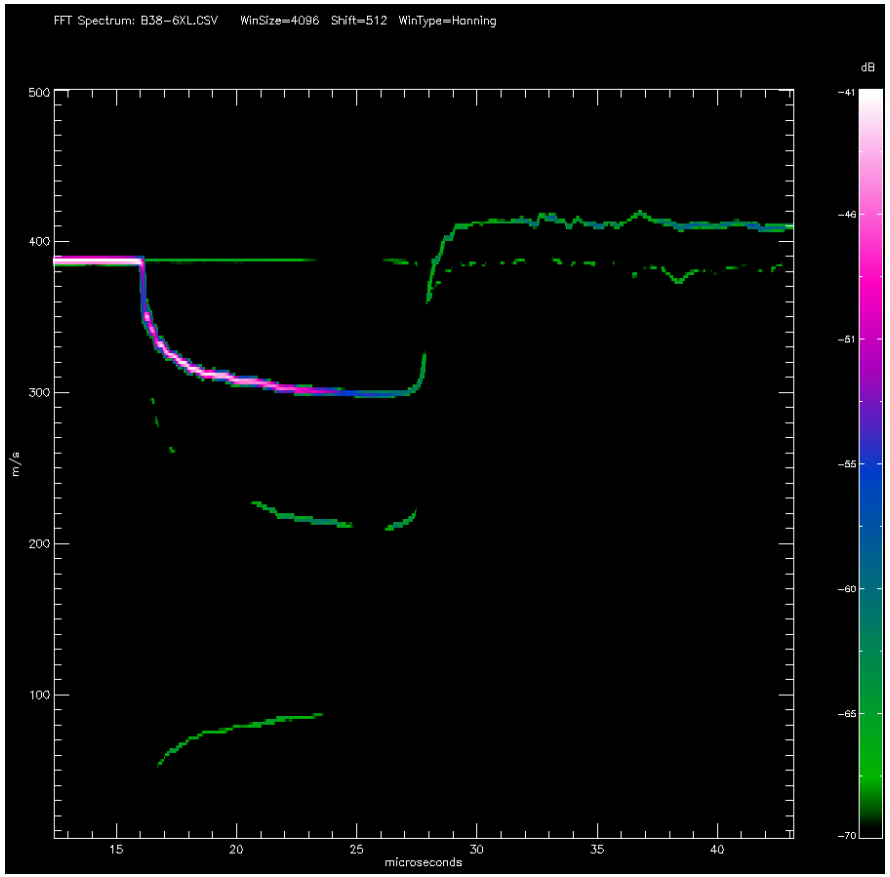
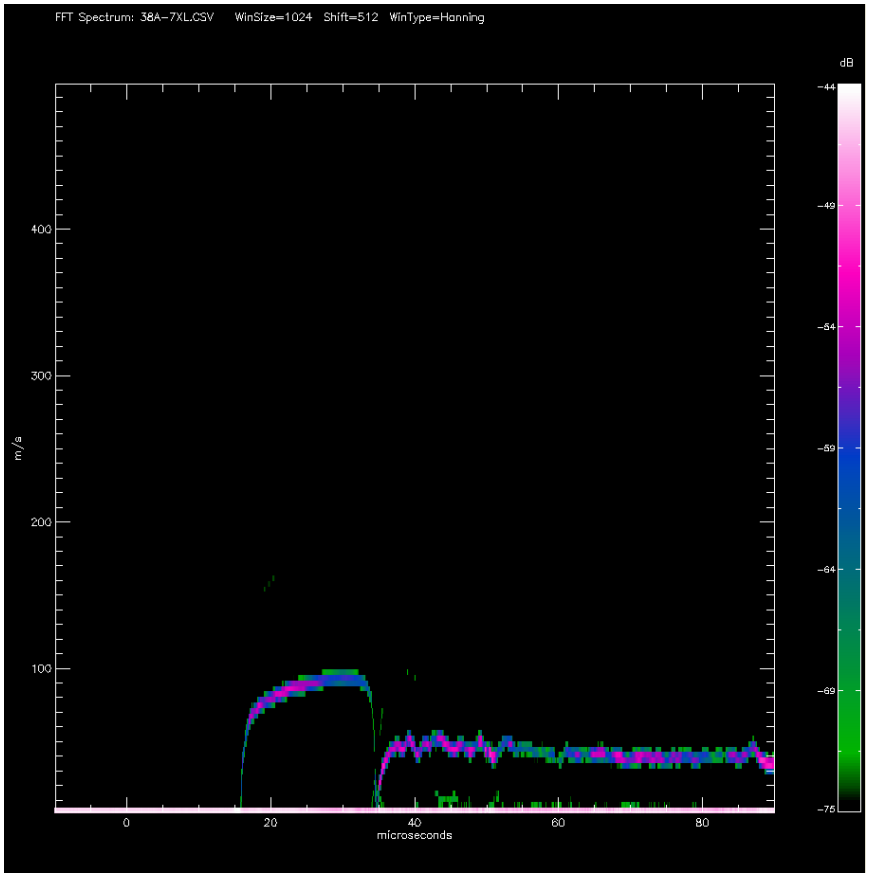
Comparison to Normal PDV

Up-shift PDV



One PDI Channel, same shot



Direction of travel is automatic result of technique

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Conclusion

The up-shifted reference PDV system was demonstrated to work very well in this first attempt at fielding – a fairly difficult first try.

This method appears to be more forgiving of poor and varying return signal than PDI using the same probes – a result of extracting frequency rather than interference phase

Optimizing probe configuration should pay off with even easier set-up and more robust signal quality

Economics relative to conventional VISAR is self-evident for a large probe number system – single scope channel per probe vs 3 for PDI and 2-4 for VISAR

A 10+ probe system is presently under development at Sandia's LIHE facility

Backup Slides

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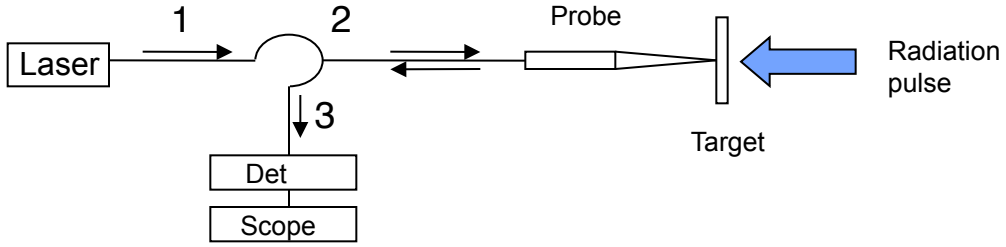
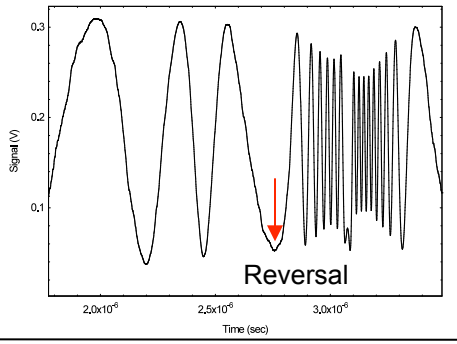
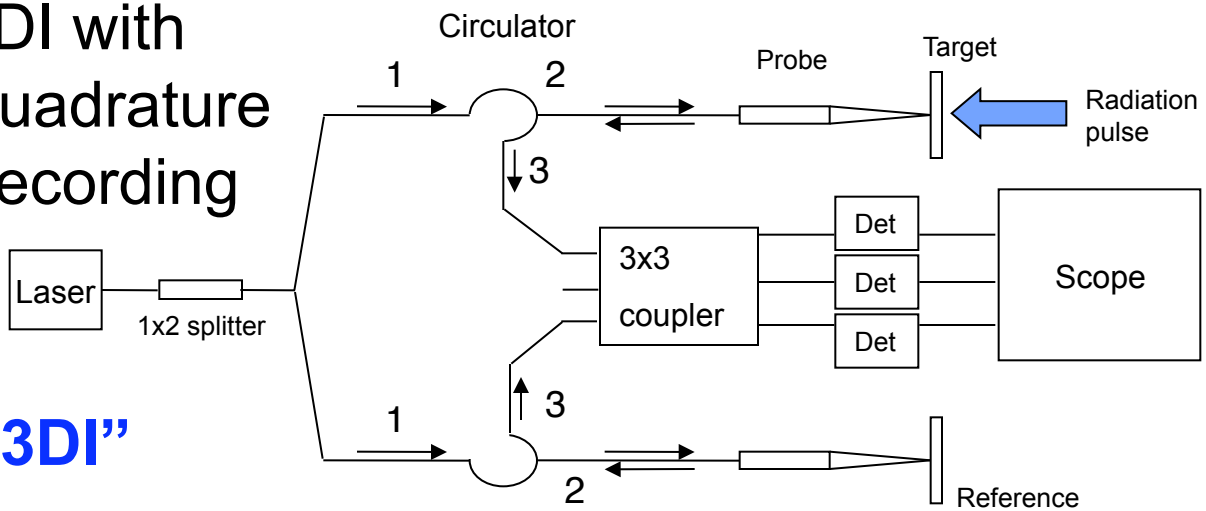
Single Channel PDI



Signal

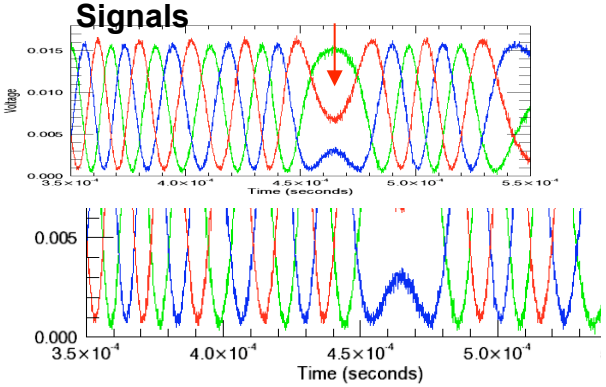


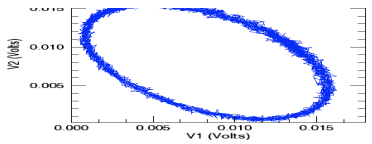
PDI with Quadrature Recording



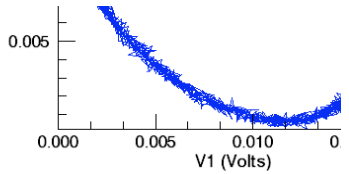
"3DI"

Reversal **Signals**





2 Ch Lissajous



- Target and reference signals mix in 3x3 coupler
- 3x3 coupler output signals have stable φ = 120° phase difference.
- Symmetric target and reference legs for simple proof-of-principle. Not required for multiple probe system
- Analysis of Lissajous (2 ch) enables automated displacement analysis for arbitrarily long records (up to 1 Mpoints to date)
- Reduces uncertainty in displacement analysis-Unambiguous direction, numerically

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