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

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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.
Objects 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 \( Dv \)
• 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

\[ n_{det} = n_{ref} - n_{targ} \]
\[ n_{det} = n_{us} - 2n_{o}(v/c) \]
\[ v \geq, \leq 0 \]
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
Data & Analysis

500 MHz beat frequency pre-shot

Full record

PDV Vers. 2.1, NSTec LAO

\[ n_{\text{det}} = n_{\text{ref}} - n_{\text{targ}} \]

\[ n_{\text{det}} = n_{\text{us}} - 2n_o(v/c) \]

“Initial” velocity for \( n_{\text{us}} = 500 \) MHz

\[ v_i = ln_{\text{us}}/2 = 387.5 \text{ m/s} \]
To obtain the final velocity profile, $v_f$, from the PDV analysis result, $v_o$,

$$v_f = -(v_o - 387.5 \text{ m/s})$$
Results

PDI data not analyzable

SHOT 38C PDV

SHOT 38C VISAR
Results
Comparison to Normal PDV

Up-shift PDV

One PDI Channel, same shot

Direction of travel is automatic result of technique
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
Single Channel PDI

Laser → 1 → 2 → Radius → 3 → Target

• 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

PDI with Quadrature Recording

Laser → 1 → 2 → Probe → Target

• Target and reference signals mix in 3x3 coupler
• 3x3 coupler output signals have stable $\phi = 120^\circ$ phase difference.
• Symmetric target and reference legs for simple proof-of-principle. Not required for multiple probe system