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NNSA Laboratory Directed Research & Development

Innovation Advancing Nuclear Security

Photonic Doppler Velocimetry Multiplexing Techniques: Evaluation of Photonic Technologies

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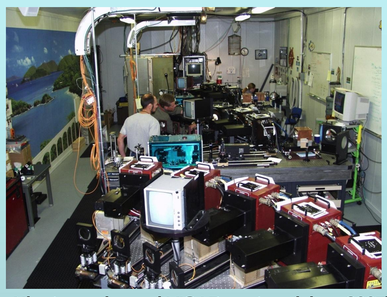
What is the challenge?

- **Capability**. Enable future stockpile stewardship experimental efforts that require large data channel counts (~100) by leveraging existing diagnostic techniques and commercial technologies to expand and enhance optical velocimetry capabilities.
- **Physics**. Determine whether frequency multiplexing and heterodyne techniques could expand upon Photonic Doppler Velocimetry (PDV) measurements of surface velocity.
- **Economy**. Develop economical methods to record high-fidelity optical velocimetry data via frequency and time division multiplexing coupled with commercially available telecom technologies and components.
- **Operations and Logistics**. Develop an 'experimenter friendly' diagnostic capability: portable, robust, and operable within a laser safe environment.

Fabry-Perot and VISAR velocimetry—capable but expensive

… requires extensive expertise, time, hardware cost and facility resources (care & feeding)

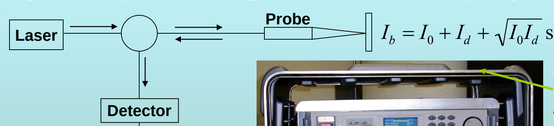


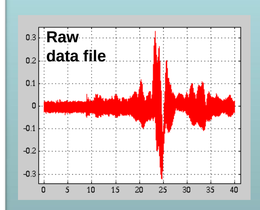
Nineteen-channel VISAR system (circa 2007)

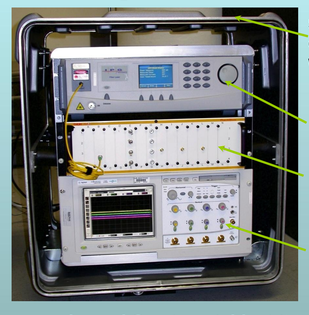
Fifteen channels of Fabry-Perot Velocimetry at NTS/U1a (circa 2003)

PDV was developed as a relatively simple, portable and inexpensive diagnostic methodology

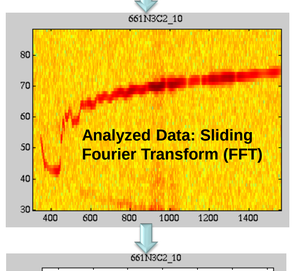
Concept: Generate a beat signal using fiber mixing of un-Doppler-shifted light with Doppler-shifted light and measure beat frequency

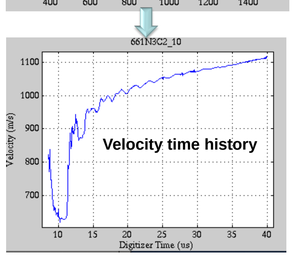




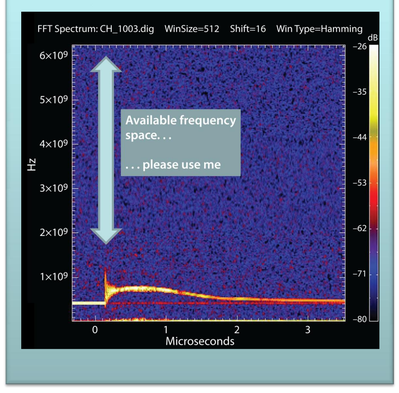


Four-channel Gen 1 portable PDV system



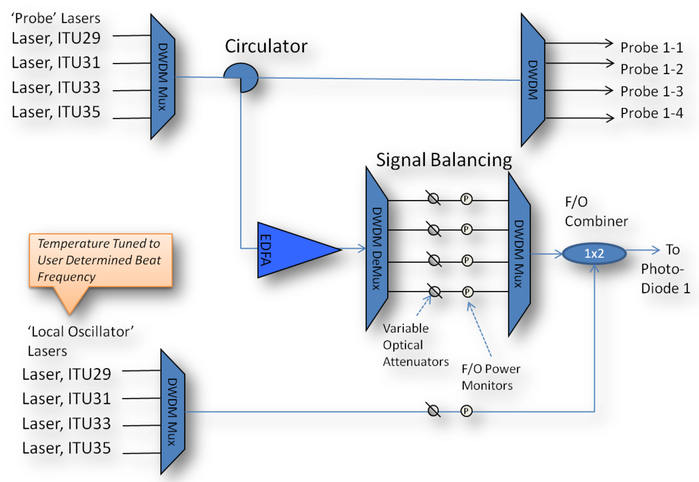


Motivation for multiplexed PDV: Make use of available digitizer bandwidth and memory

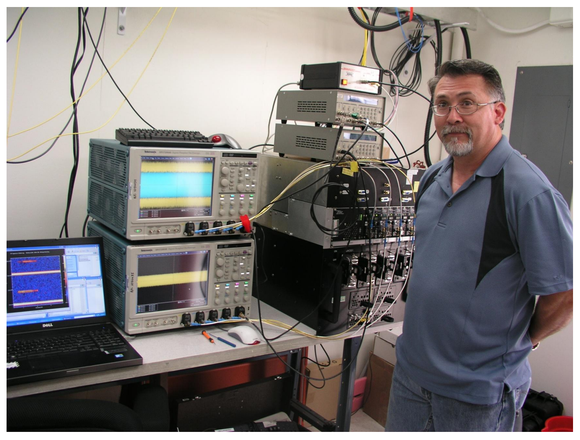


What have we learned so far?

- **Successfully fielded demonstration MPDV system.** We have assembled and successfully tested an MPDV demonstration system on shock-driven experiments.
- **Photonic Technologies**. We've evaluated and are leveraging telecom components–optical amplifiers, wavelength multiplexers, and seed lasers–to provide an economical, compact and rugged approach to system architecture.
- **Wavelength Division Multiplexing & Fourier Analysis**. FFT data analysis is a robust method capable of discriminating simultaneous data traces (combined via wavelength division multiplexing) recorded onto a single digitizer channel and also allows for approximately 35 dB of dynamic range (optical signal in the frequency domain.)



The MPDV: Conceptual MPDV system architecture for 4x frequency multiplexing heterodyne interferometry.

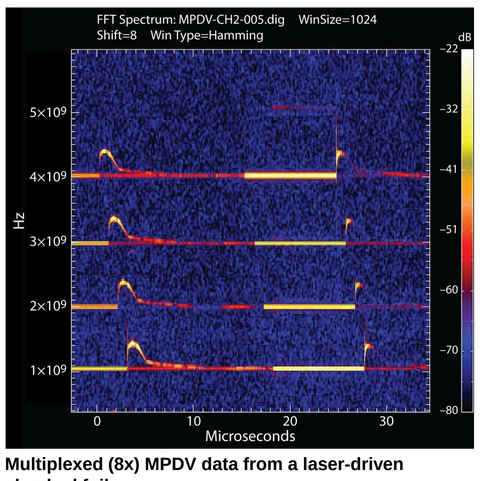


Demonstration MPDV 28-channel system (including digitizers) fielded at NSTec's 10-gram test chamber located at the Special Technologies Lab (C. Perez in foreground).

What is our innovation?

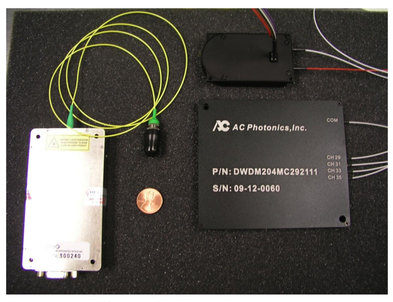
- **Frequency and time-division multiplexing in optical velocimetry**. Developed diagnostic system architecture for a Multiplexed PDV (MPDV) that incorporates frequency and time-division multiplexing into existing PDV methodology to provide increased channel count. Current MPDV design increases number of data records per digitizer channel 8x, and also operates as a laser-safe (Class 3a) system.
- **Increased velocity range**. Applied heterodyne interferometry to allow for direction-of-travel determination and enable high-velocity measurements (>10 km/s) via optical downshifting.
- **Portable, economical, and rugged.** Leveraged commercially available, inexpensive and robust components originally developed for telecom applications. Proposed MPDV architectures employ only commercially available, fiber-coupled hardware.

MPDV Data Multiplexes in Frequency and Time

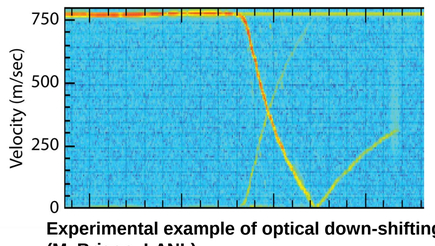


Multiplexed (8x) MPDV data from a laser-driven shocked foil.

Evaluation of Photonic Technologies



Commercially available telecom components: seed laser, EDFA optical amplifier, and dense wavelength division multiplexer.

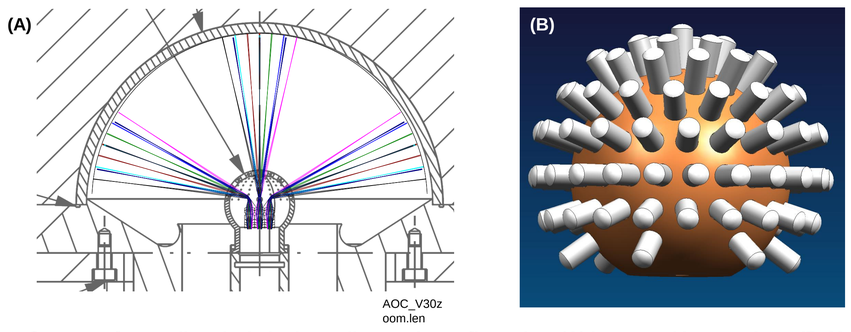


Experimental example of optical down-shifting (M. Briggs, LANL).

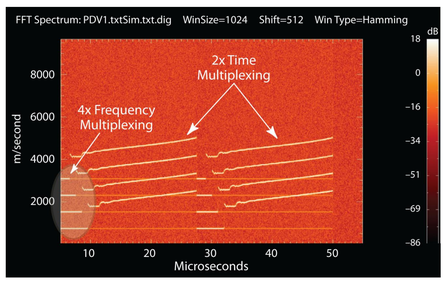
Why is this important for our nation?

The MPDV addresses the need to provide enhanced diagnostic capabilities for experimental programs within Science-Based Stockpile Stewardship.

- **Large channel count experiments.** We anticipate employing MPDV systems on the Scaled Initiative experimental series, as well as other efforts.
- **High-velocity experiments**. Pulsed power experiments, both within facilities and explosively driven, can leverage MPDV optical down-shifting to measure velocities ~2x greater than the conventional PDV velocity limitation.



Concepts for an all-optical pin dome diagnostic configuration: (A) integrated lens package (R. Malone, 2011 NSTec), and (B) discrete probes (D. Holtkamp et al., 2007 LANL)



Simulation of eight data records (probes) multiplexed and recorded onto a single digitizer channel, i.e., 8x multiplexing.

Future Work

- **Expanded time and frequency multiplexing investigations: coherency and polarization effects**
- **System Engineering: develop MPDV suitable to large channel count, high-value experiments.**
- **Diagnostic methods for high-velocity applications.**
- **Analysis methods to improve time resolution.**

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National Nuclear Security Administration

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