PDV at 532 nm

PDV Workshop, May 2018

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The Plan of the Talk

- Why is using a different frequency for PDV interesting?
- Prototype System and Early Results
- Challenges
- Conclusions

Note: This work has been supported by funding from Laboratory Directed Research and Development at Los Alamos National Lab.

Why is using a different frequency for PDV interesting?

At least four independent reasons:

1. The resolution of PDV is proportional to λ.
2. The scatter from particles is a strong function of the size parameter D/ λ.
3. The diffraction limited spot size is proportional to λ.
4. Higher frequency light can penetrate denser plasmas.

I will review reasons 1 and 2 here.
Confirming reasons 3 and 4 are homework for you.

Possible Applications for Shorter Wavelength PDV

1. Detonator Function Time
2. Grain Selective Measurements
3. Coherent Detection of sub-micron particles (ejecta)
4. Warm Dense Matter

Recent Paper: Chaoqun Jiang, et al., "A 532 nm fiber-optic displacement interferometer for low-velocity impact experiments", Review of Scientific Instruments 89, 023101 (2018).

This paper was published out about 18 months after I submitted my proposal

The resolution of PDV is proportional to λ.

A bit of a review:

Resolution is the ability to separate two different events (time resolution) or two different surfaces (velocity or position resolution).

Time Resolution

Frequency (Fringe Rate) Resolution

For any PDV signal: $\Delta t \, \Delta f > 1/(2\pi)$

This is true for any time waveform.

or $\Delta t \, \Delta v \approx \lambda/(4\pi)$

This is true for any PDV waveform.
Equation #1

"Resolution of Motion"

Velocity Resolution

Resolution of Motion is proportional to λ.

Typical Resolution of Motion:

For many of my 1550 nm PDV experiments we quote:

Δt = 12 ns and **Δv = 12 m/s**

Checking with Equation #1:

$$\Delta t \, \Delta v \approx \lambda/(4\pi)$$

$$(12 \text{ ns})\,(12 \text{ nm/ns}) \approx 1550 \text{ nm}/(4\pi) \checkmark$$

For PDV at 532 nm we could expect:

Δt = 3 ns and **Δv = 12 m/s** or

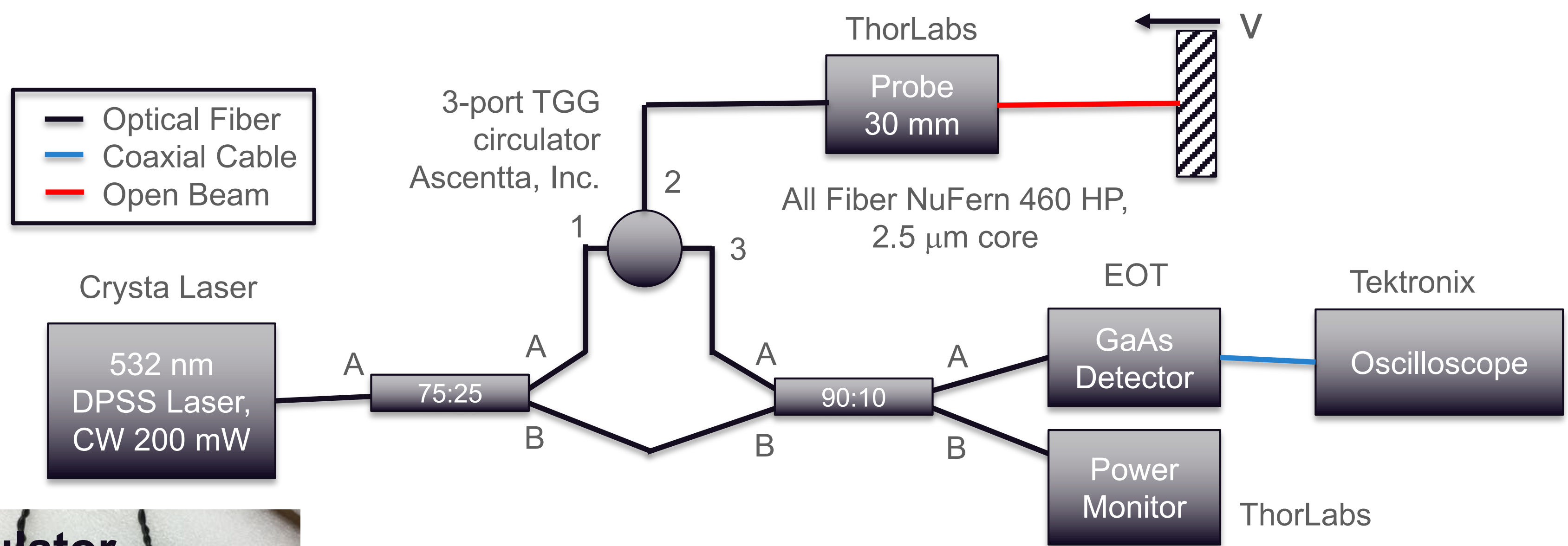
Δt = 12 ns and **Δv = 3 m/s,** for example.

Particle detection with PDV….

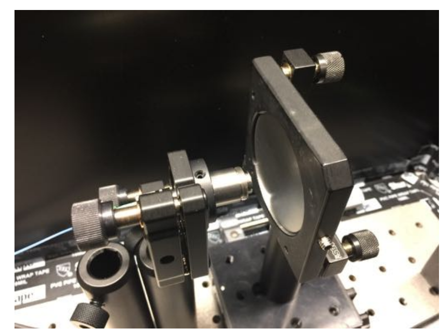
- **First Point: PDV is a coherent detection method and has excellent performance with small signal returns.**
- **Second Point:**
  - The cross Section of a particle in the Rayleigh Regime is proportional to D^6/λ^4
  - The strong dependence on λ, means that you get a big gain when going to shorter wavelengths.
  - The strong dependence on D, suggests a natural way to constrains the distribution of particles sizes.

- **Trivia: Weather Radar is coherent detection of ~1 mm particles (rain drops) with 10 cm light, which can quantify areal mass.**

Prototype System



Probe and Target



Early Results: Tapping the target with a pen

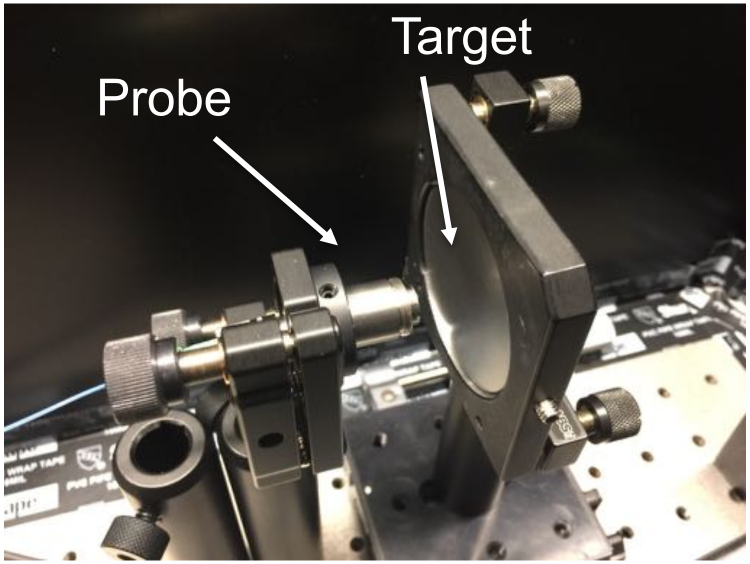
I have no ability in my lab to generate high speed projectiles….. The best I do now is to tap a target surface with a pen. But even this data is instructive….

Analysis Window: 164 μs

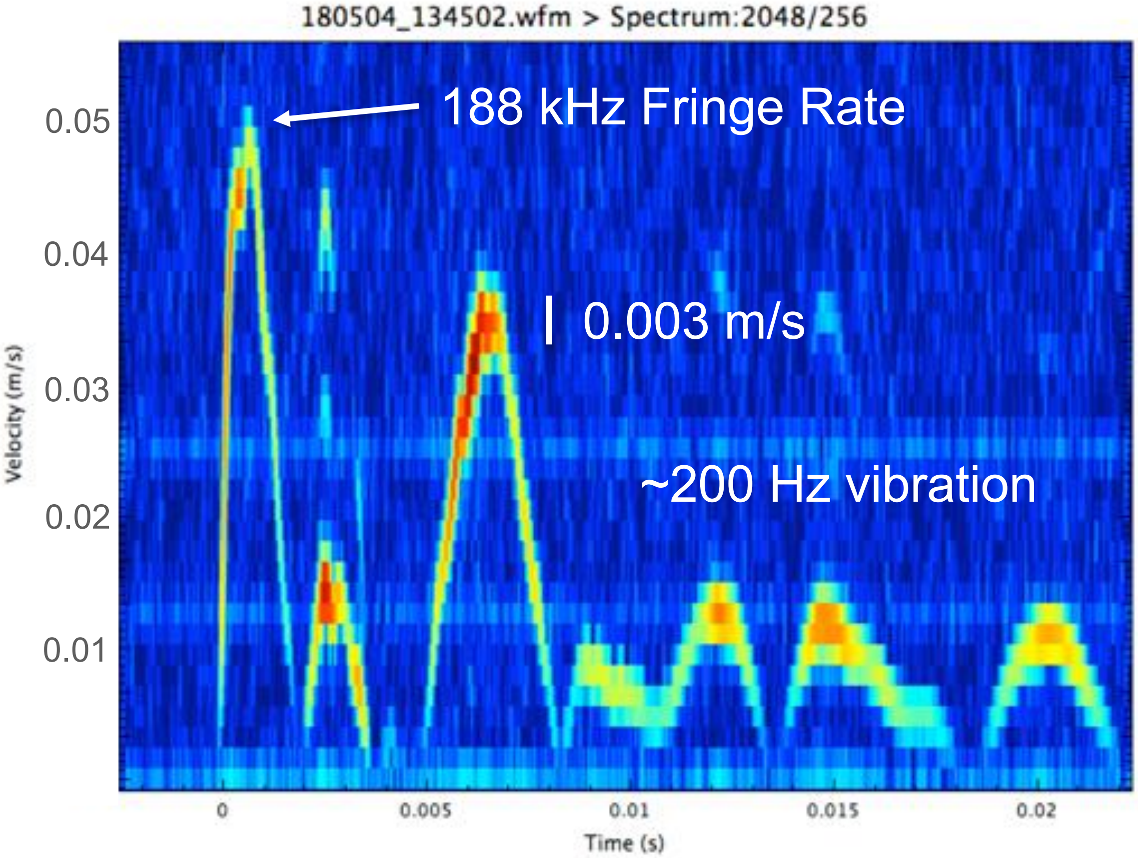
- Equation 1 predicts a velocity resolution of .9 mm/s or 3 mm/s for 95% containment of the signal. This checks out!

I can get a 30 dB signal with about -30 dB light return.

- My sensitivity is about -50 dB (with a 10 dB signal requirement).

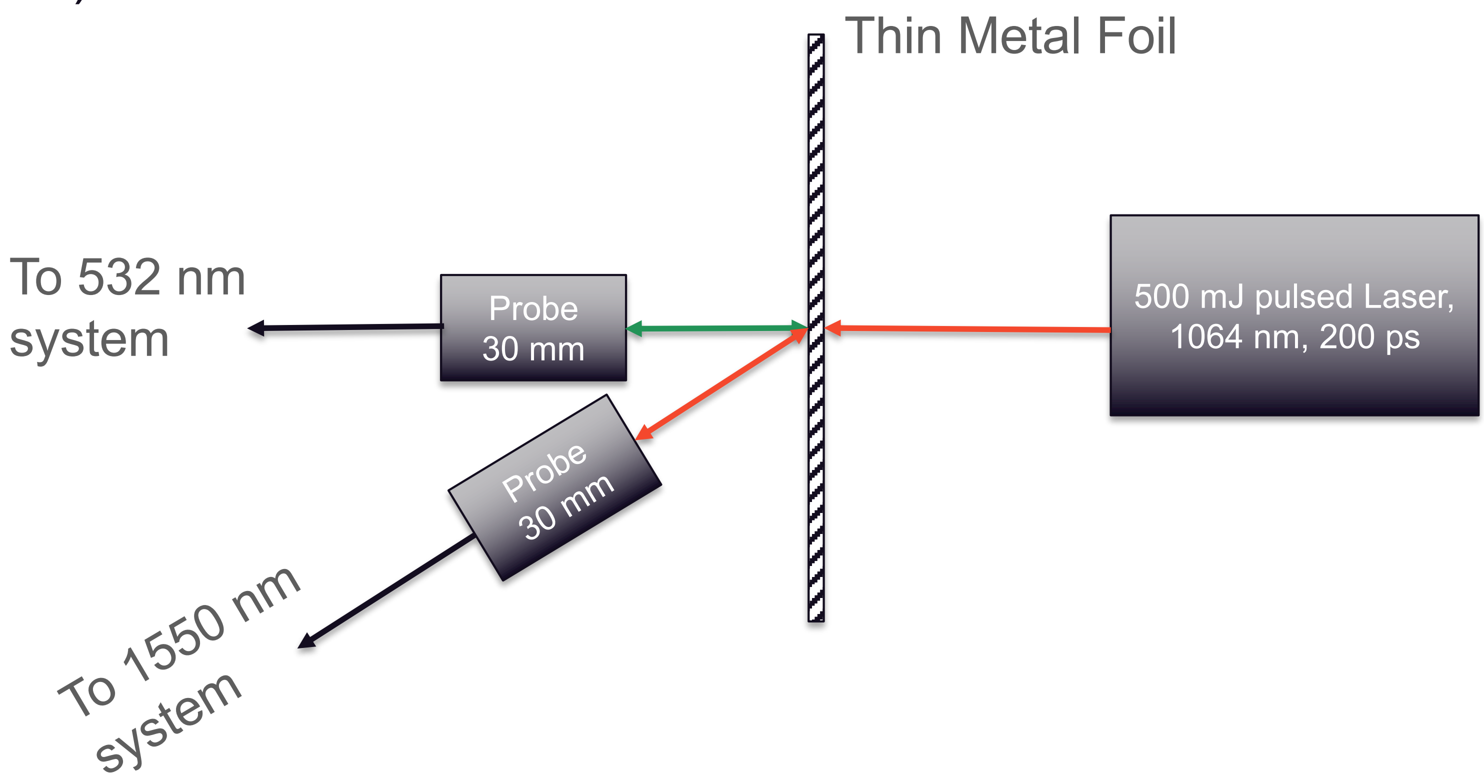


532 nm PDV data, 50 mW on target, -30 dB return



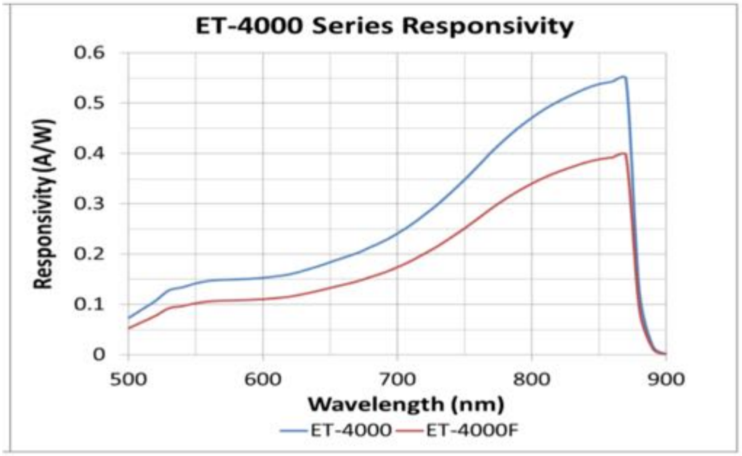
Next Step: Laser Driven Metal Foil

- MSTS LAO has agreed to let me conduct tests with their laser drive system
- Expect velocities of 500 m/s or greater with a 200 ps, 500 mJ pulse
- Can perform 10+ shots a day
- Will confirm Resolution and Sensitivity Performance (can compare with 1550 PDV).



Some Challenges

- Coupling of laser into 2.5 micron core not trivial.
- Greater attenuation in fiber (2-3 dB for a 50 m downlead, Nufern 460-HP).
- Less isolation (22 dB) and directivity (40 dB) and greater insertion loss (2.8 dB one-way) in Circulator (Ascentta, Inc.)
- Power density in core is high (~10 dB more than 1550 nm)
- **Sensitivity of detector (8 dB less A/W)**
- BW of Detector (Commercially available detectors >10GHz are rare), limits max velocity to <3 km/s.
- Laser Classification: 3B at >5 mW.



Conclusions

PDV at higher frequencies has several interesting attributes.

– Resolution of Motion, Sub-micron particle detection, Diffraction limited spot size, Higher critical density in plasmas.

– Niche applications are intriguing….

But there are challenges

– Perhaps sensitivity is the biggest concern – ~15 dB less sensitivity than 1550 nm PDV (could increase sensitivity by removing circulator).

Early benchtop results have demonstrated a useful sensitivity

– Next steps are experiments with a laser driven foil.

– Then repackaging and exploring applications for characterizing detonators, measuring particle size, and possibly studying WDM at DARHT.