PDV at 532 nm

PDV Workshop, May 2018

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LA-UR 18-24003
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 $\lambda$.
2. The scatter from particles is a strong function of the size parameter $D/\lambda$.
3. The diffraction limited spot size is proportional to $\lambda$.
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


This paper was published out about 18 months after I submitted my proposal.
The resolution of PDV is proportional to $\lambda$.

A bit of a review:

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

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

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

Time Resolution  Frequency (Fringe Rate) Resolution

Velocity Resolution

"Resolution of Motion"

This is true for any time waveform.

This is true for any PDV waveform. Equation #1
Resolution of Motion is proportional to $\lambda$.

Typical Resolution of Motion:
For many of my 1550 nm PDV experiments we quote:
\[ \Delta t = 12 \text{ ns and } \Delta v = 12 \text{ m/s} \]

Checking with Equation #1:
\[ \Delta t \Delta v \approx \frac{\lambda}{4\pi} \]
\[ (12 \text{ ns}) (12 \text{ nm/ns}) \approx 1550 \text{ nm}/(4\pi) \checkmark \]

For PDV at 532 nm we could expect:
\[ \Delta t = 3 \text{ ns and } \Delta v = 12 \text{ m/s} \text{ or} \]
\[ \Delta t = 12 \text{ ns and } \Delta v = 3 \text{ m/s}, \text{ for example.} \]
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 $D^6/\lambda^4$
  – The strong dependence on $\lambda$, means that you get a big gain when going to shorter wavelengths.
  – The strong dependence on $D$, suggests a natural way to constrain 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

532 nm DPSS Laser, CW 200 mW

3-port TGG circulator
Ascentta, Inc.

75:25 Power Monitor

GaAs Detector

90:10 Oscilloscope Probe

30 mm

ThorLabs

EOT

All Fiber NuFern 460 HP, 2.5 µm core

Circulator

Optical Fiber
Coaxial Cable
Open Beam

Benchtop Setup

Probe and Target

ThorLabs

Tektronix

Oscilloscope
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

188 kHz Fringe Rate

0.003 m/s

~200 Hz vibration
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.