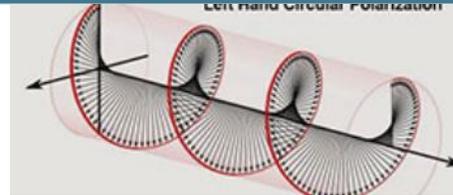
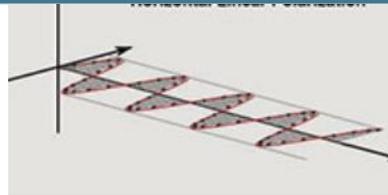
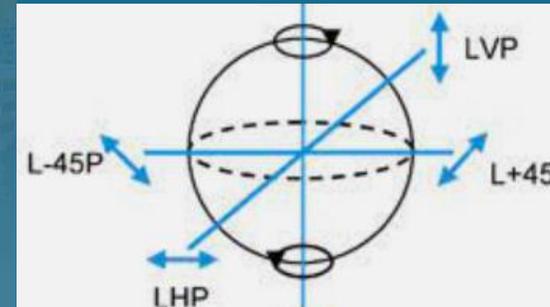




PDV polarization control



Darryl Benally

07FEB2023

Unclassified Unlimited Release (UUR)



Outline



07 FEB 2023

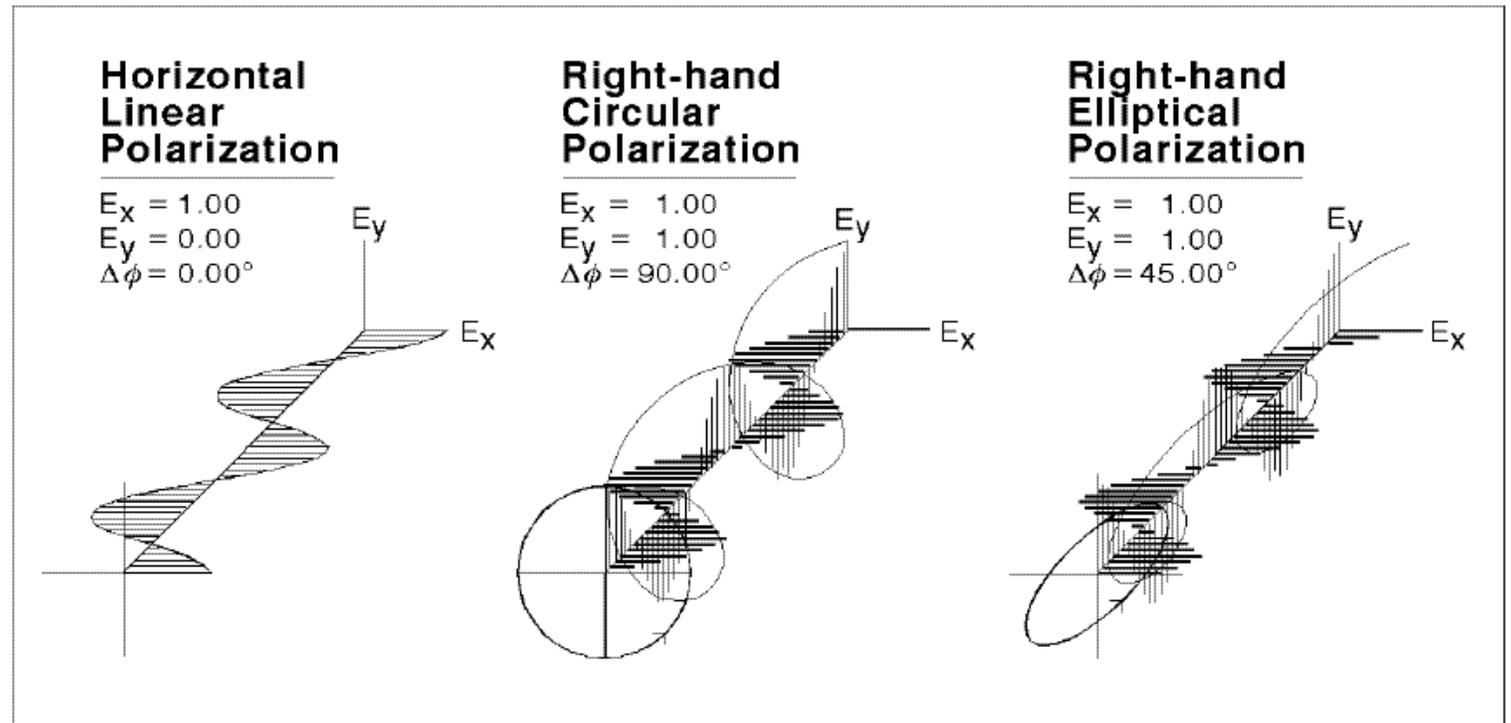
- Motivation
- Device under test
- PDV set ups
 - No polarization control
 - Linear-Linear
 - Circular-Circular
 - No control-Circular
- Conclusions

Motivation and Controlling polarization for a PDV system



- Light from a 1550 nm laser is fundamentally linear polarized.
 - However, the linear polarization is random and every laser activation will have different linear polarization orientation
- The beat frequency will benefit from having a well defined doppler and reference polarization
 - The doppler shifted light will have greater probability in creating the interference pattern with the reference light
 - Thus, beat frequency signal input to photodiode will increase and create a “cleaner” interference pattern

- 4 Distinct set ups
- No polarization control
 - Random linear
 - Random linear
- Linear-Linear
 - Seed laser-linear
 - Reference laser-linear
- Circular-Circular
 - Seed laser-circular
 - Reference laser-circular
- No control-circular
 - Seed laser-random linear
 - Reference laser-circular



Device under Measurement

Velocity measurements were made on metal flyers with reflective tape on the surface to increase doppler shift light return.

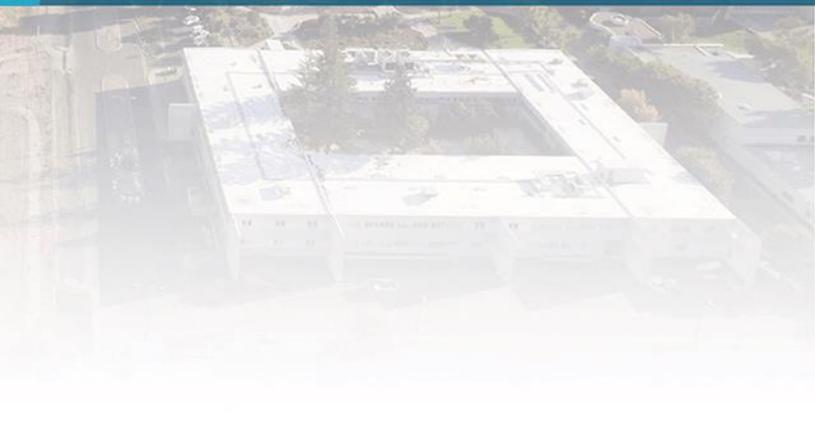
- *Lens Tube*: 1 inch diameter lens tube
- *Probe Mount*: Mount to hold a fiber coupled to GRIN lens
- *Metal Flyer Reflective*: Metal based flyer with 3M 8850 reflective tape to increase doppler shifted light return
- *Porous Disc*: Material to slow the shock wave to lower the potential to destroy the metal flyer
- *Explosive*: High Explosive ~1.27 grams



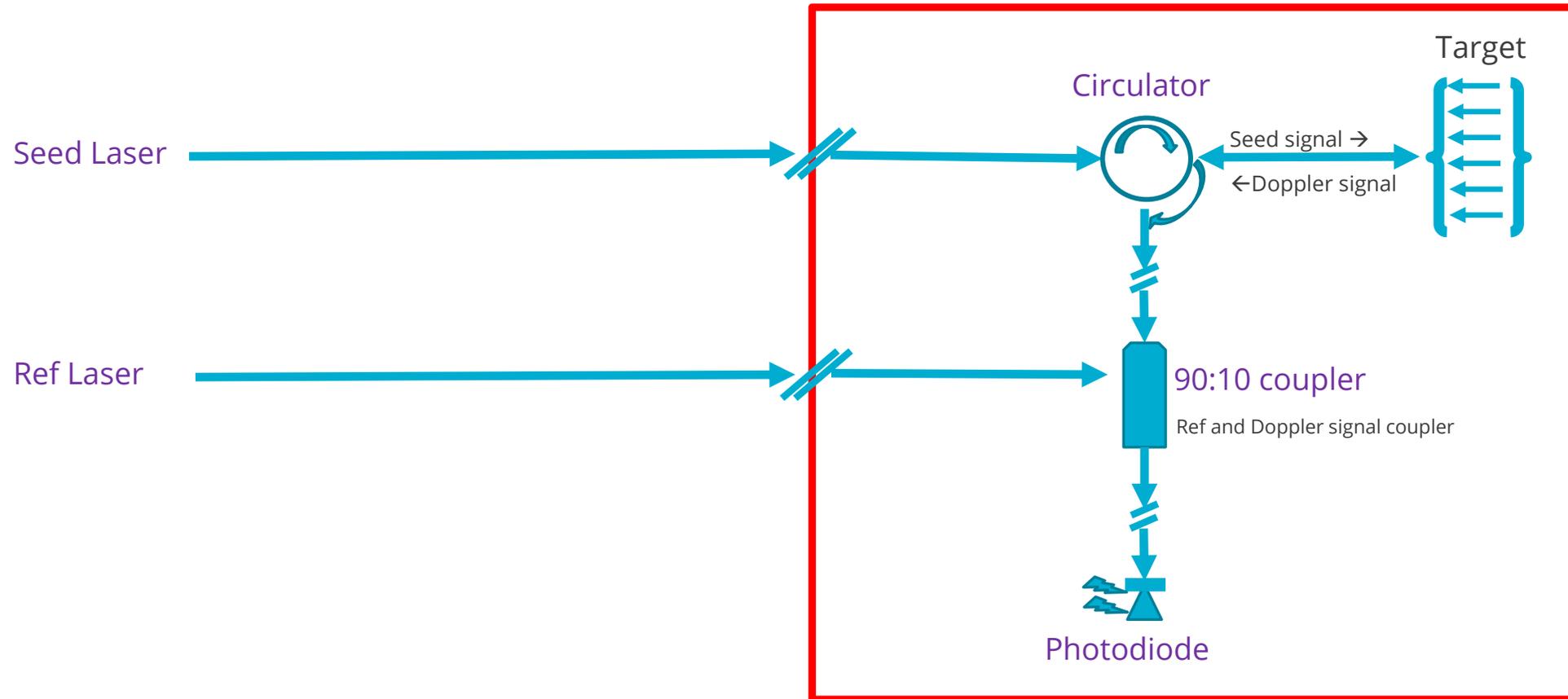


No polarization control

The light from the laser is fundamentally linear and random orientation

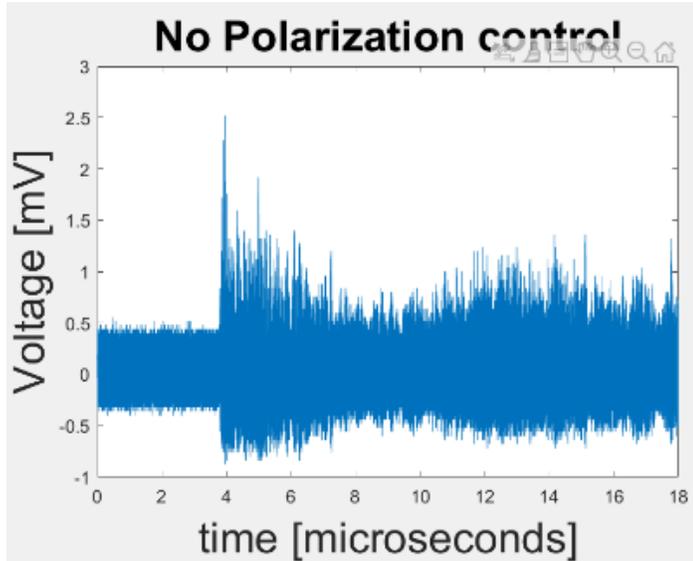


No Polarization control



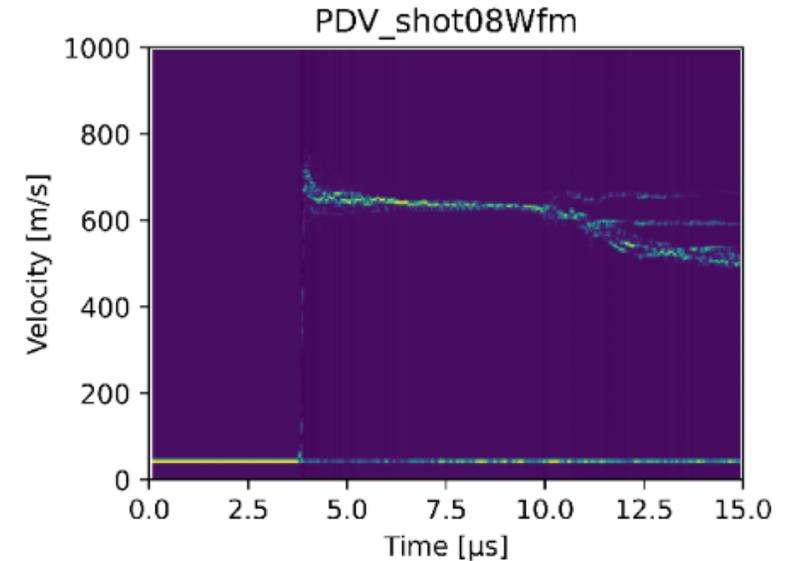
Normal PDV set up

Normal PDV set up

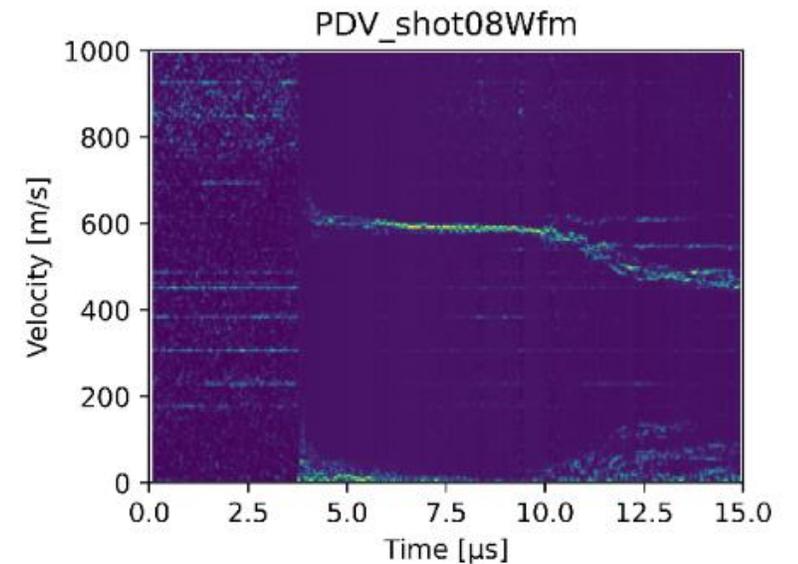


- Beat frequency created during test
- Data from an Oscilloscope
- Vertical Scaling Oscilloscope
 - 20 [mV/Div]

- Acceleration curve from the metal flyer
- Velocity upshifted spectrogram on the fundamental heterodyne beat frequency
- The fundamental beat frequency is still seen on the lower portion
 - Meaning, some seed laser light made it through the circulator



- “Ghost” signal created and matches above acceleration curve
- No upshifting
- The doppler shifted light is interfering with the seed laser light within the circulator



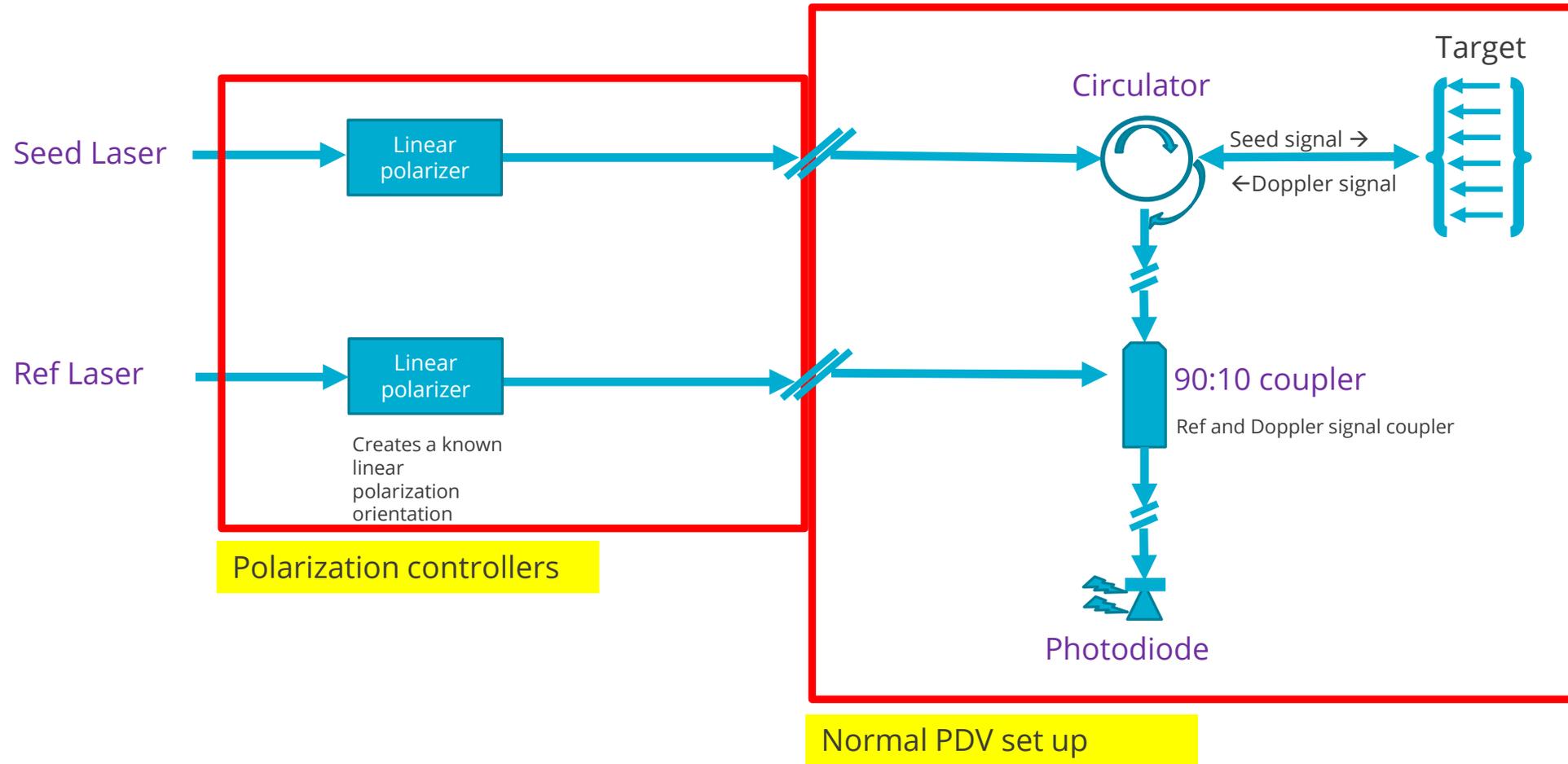


Linear-Linear polarization

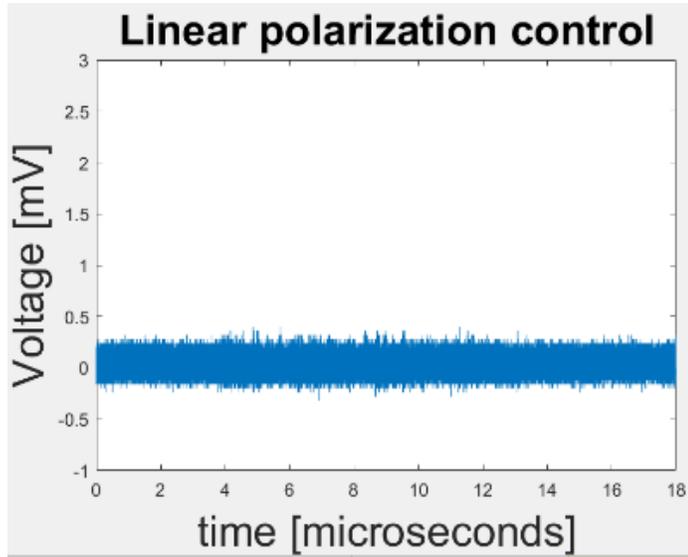
Using only the linear polarizer



Polarization control both making Linear

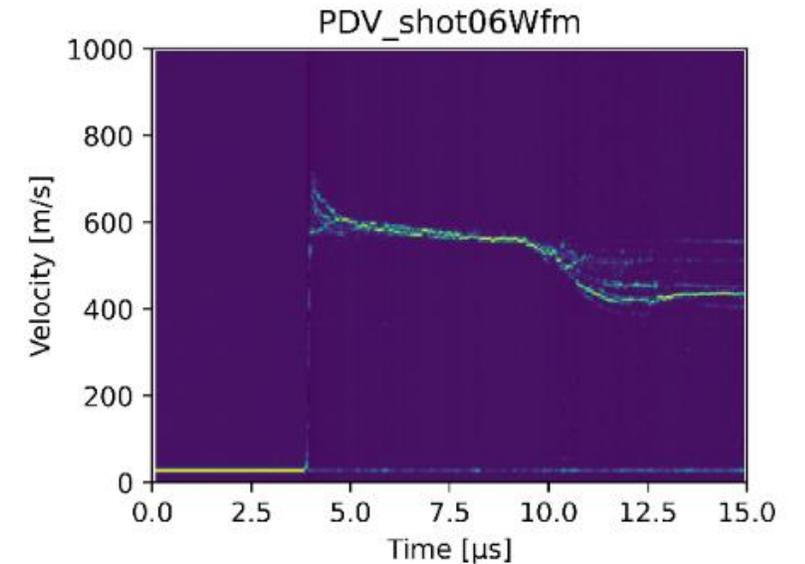


Linearly controlled Polarization without using the $\frac{1}{4}$ wave plate

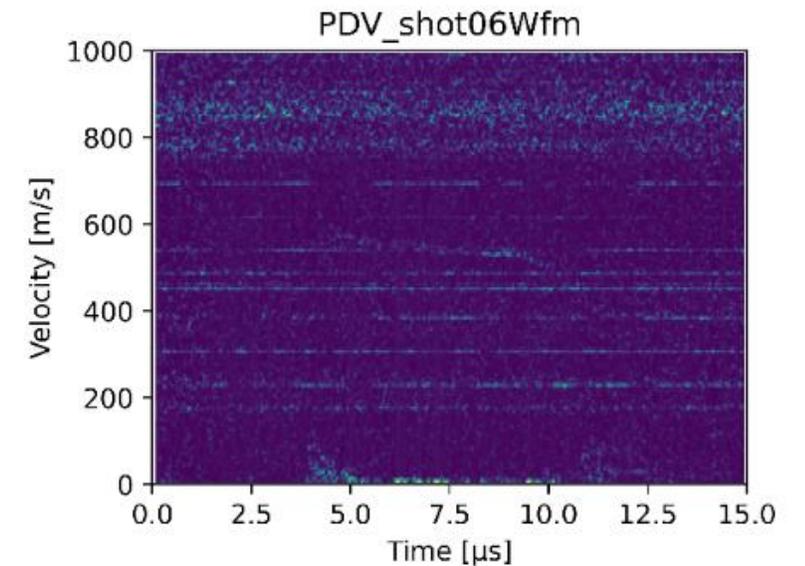


- Beat frequency created during test
- Data from an Oscilloscope
- Vertical Scaling Oscilloscope
 - 20 [mV/Div]

- Acceleration curve from the metal flyer
- Velocity upshifted spectrogram on the fundamental heterodyne beat frequency
- The fundamental beat frequency was not seen on the lower portion



- “Ghost” signal greatly diminished by controlling the polarization
- No upshifting
- Indicating higher probability the doppler shift and reference light interfering more efficiently



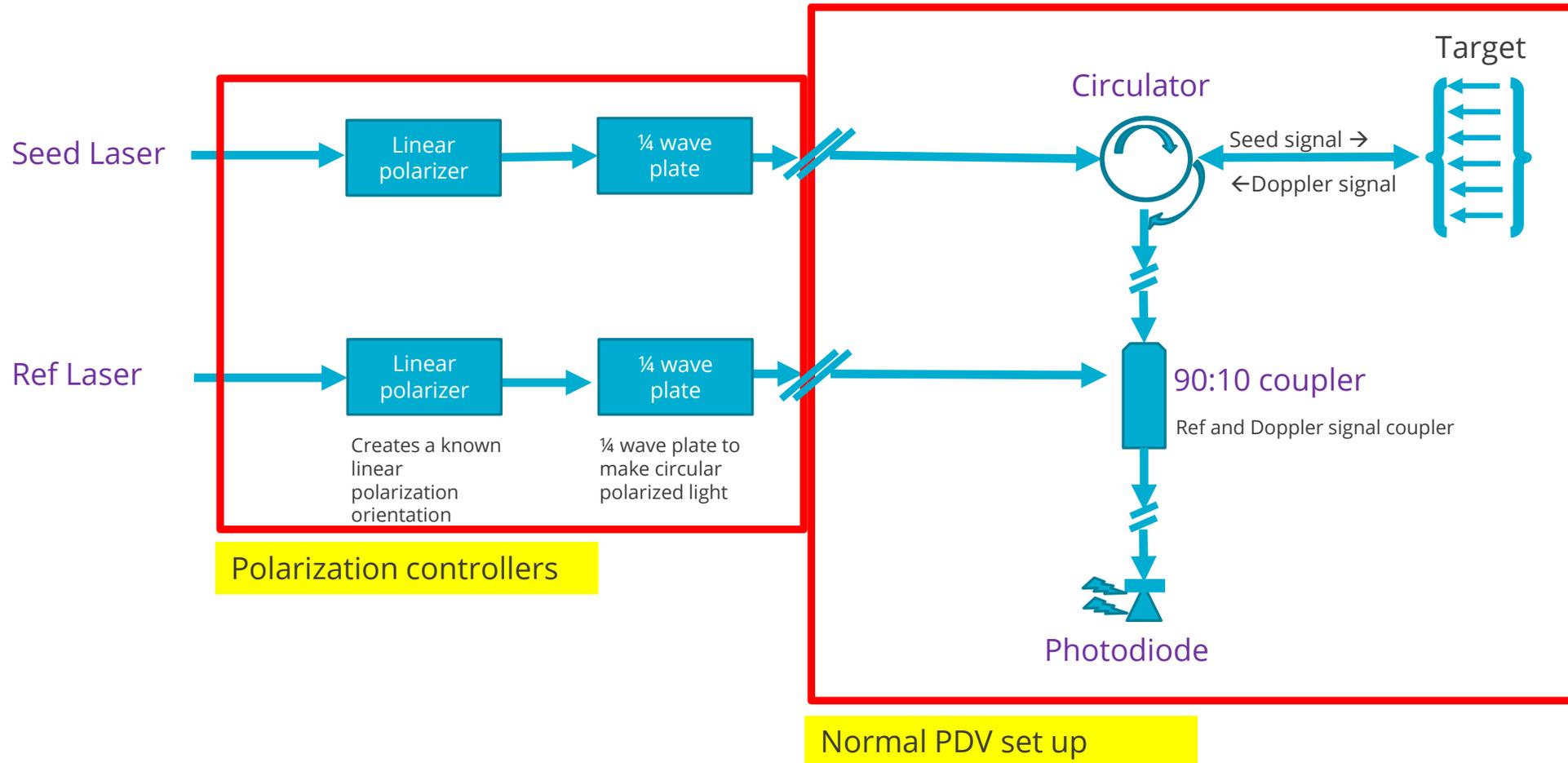


Circular-Circular polarization

Using the $\frac{1}{4}$ wave plate for circular polarization

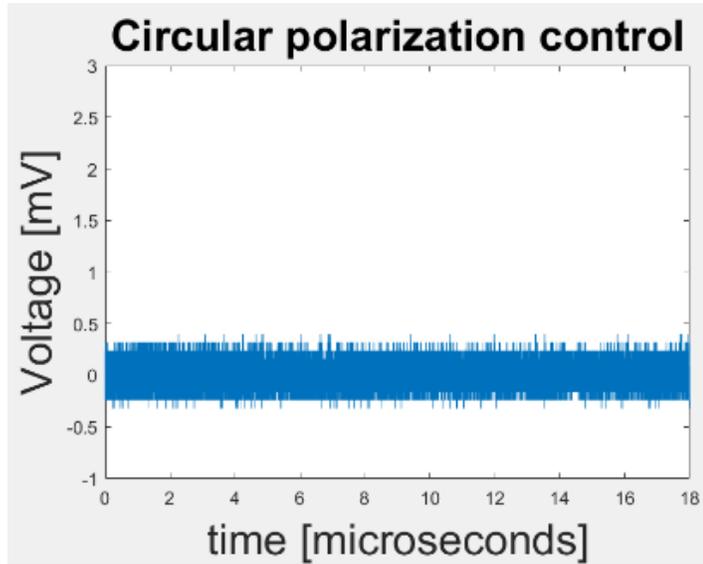


Polarization control both making Circular



Circular Polarization Results.

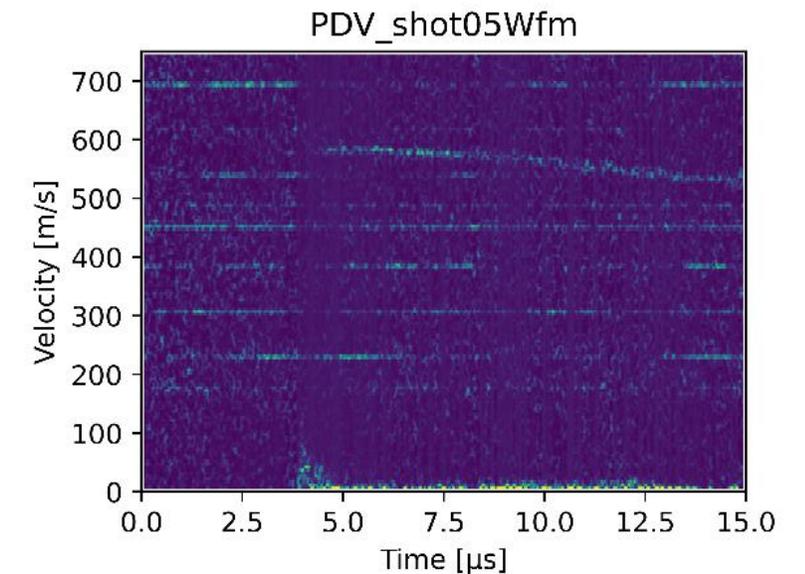
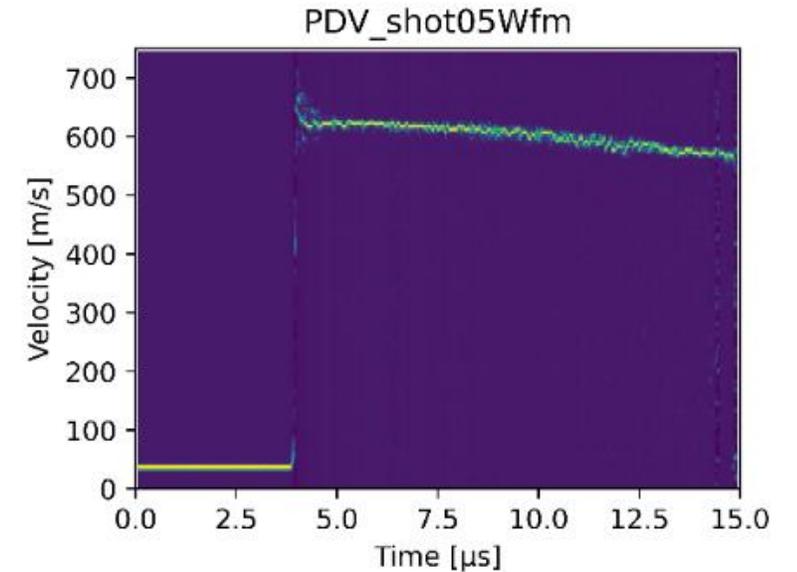
Interconnections are shown in slide 4



- Beat frequency created during test
- Data from an Oscilloscope
- Vertical Scaling Oscilloscope
 - 20 [mV/Div]

- Acceleration curve from the metal flyer
- Velocity upshifted spectrogram on the fundamental heterodyne beat frequency
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- “Ghost” signal greatly diminished by controlling the polarization
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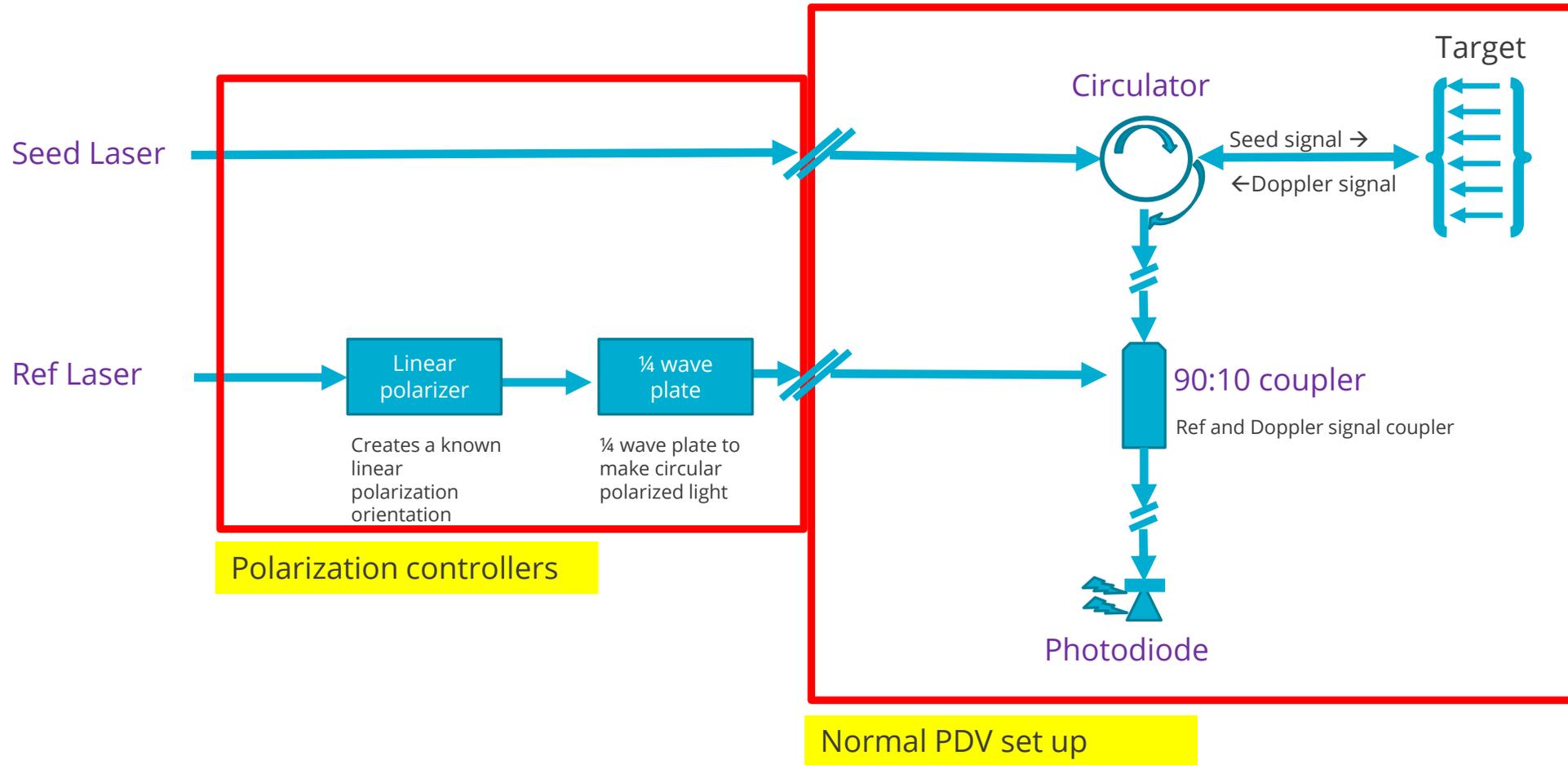


No control-Circular polarization

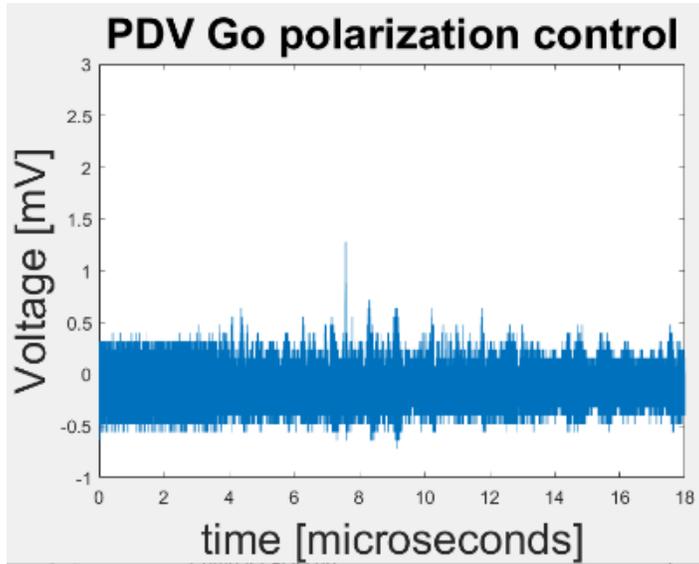
Reference laser light only gets the polarization control



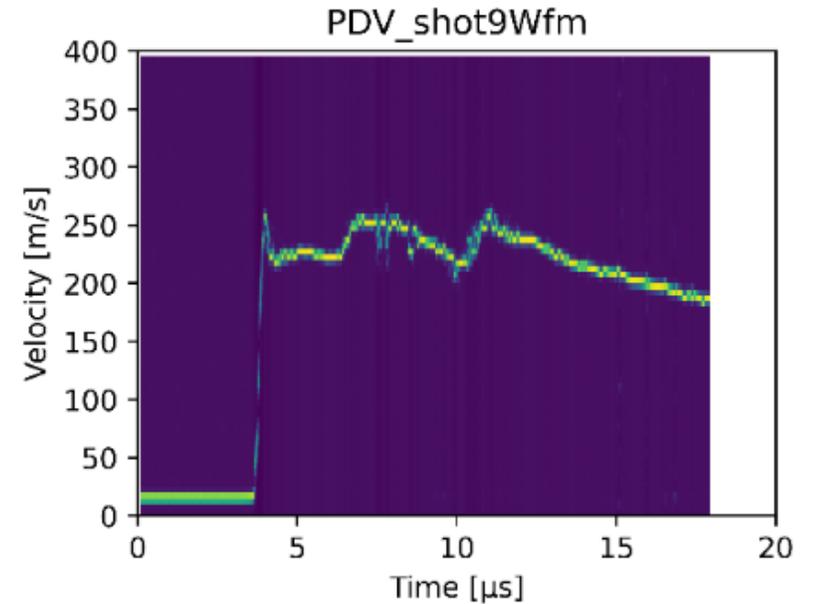
Polarization control for reference light only



Circular Polarization on Reference, ONLY

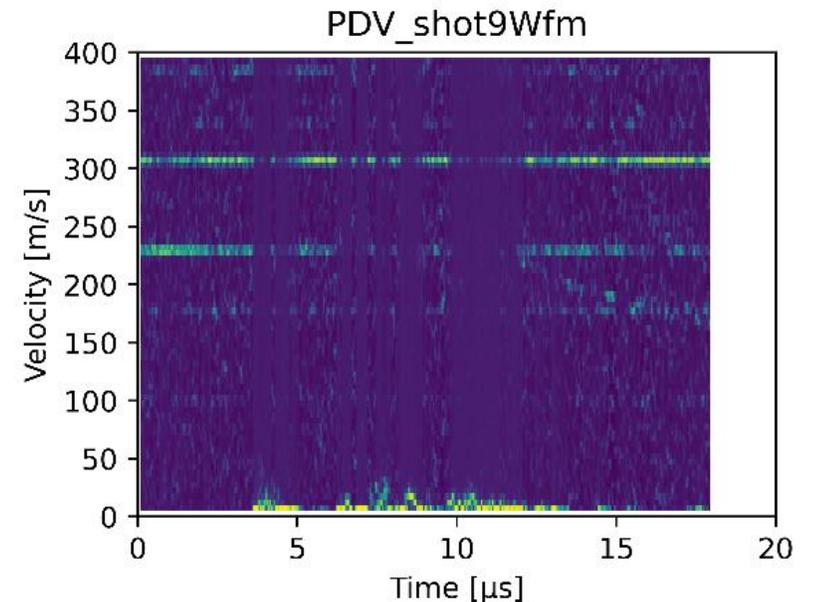


- Acceleration curve from the metal flyer
- Velocity upshifted spectrogram on the fundamental heterodyne beat frequency
- The fundamental beat frequency was not seen on the lower portion



- Beat frequency created during test
- Data from an Oscilloscope
- Vertical Scaling on Oscilloscope
 - 20 [mV/Div]

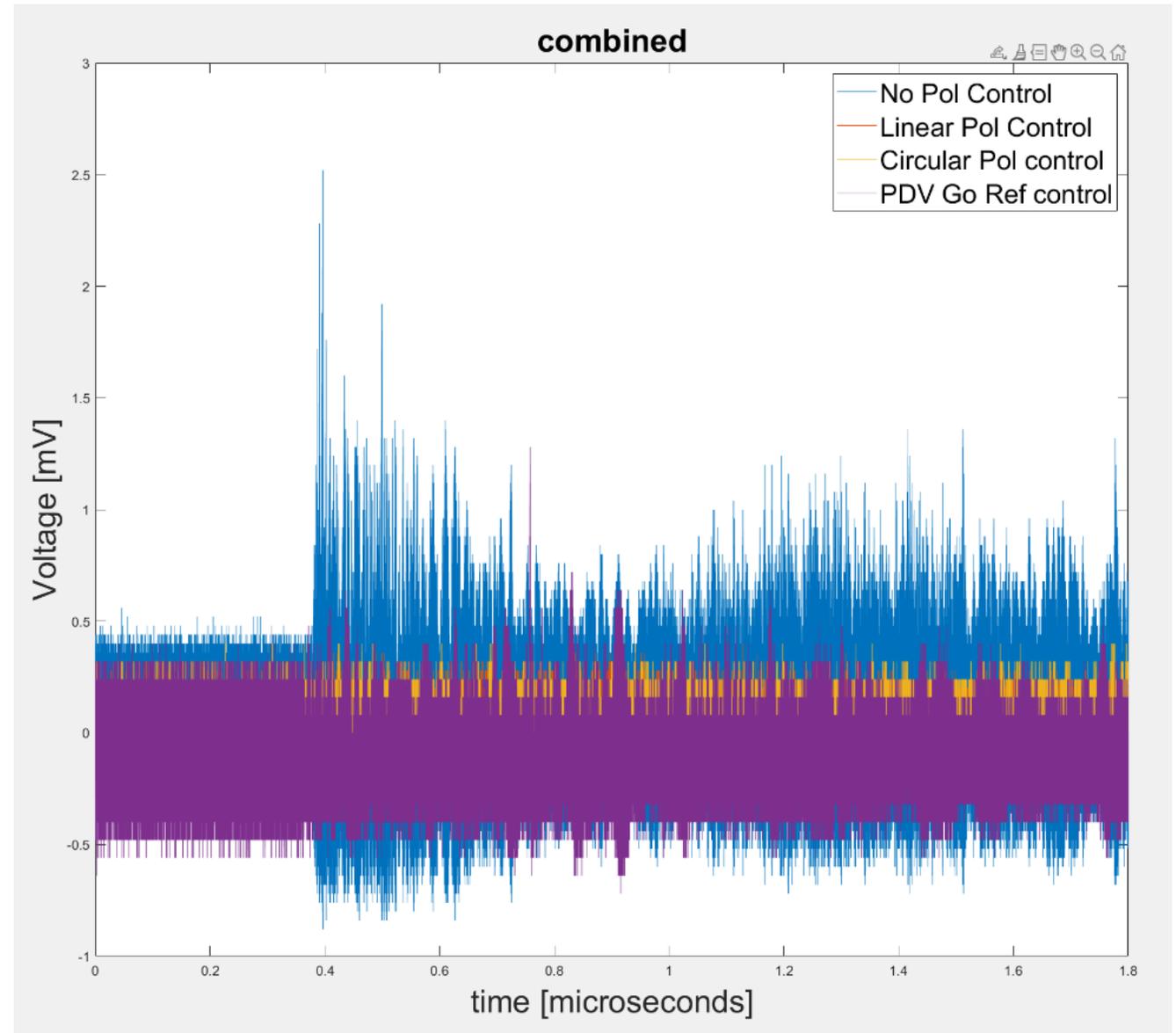
- “Ghost” signal greatly diminished by only controlling the reference laser light polarization
- No upshifting
- Indicating higher probability the doppler shift and reference light interfering more efficiently



Overlapping all Oscilloscope displays



- Interference pattern intensity on the photodiode on each set up



Conclusion



Externally controlling the polarization does help in spectrogram and oscilloscope signal quality

- Polarization controls provide a predictable and efficient means to provide a quality light signal for the interference pattern on the photodiode
- These controls can help in providing better light in low light intensity applications
 - Prevent damage to device when high intensity light is used

Polarization controls do add some complexity to the single probe PDV set up

- Linear polarizers are easy to integrate as they are set up for in-line fiber optic connections
- $\frac{1}{4}$ wave plate used in making circular polarizations adds the most complexity
 - The optics are external wave plates that require fiber optic to air to fiber optic light transfer
 - Specially made in-fiber optic $\frac{1}{4}$ wave plate polarization can be made and are custom

Additional

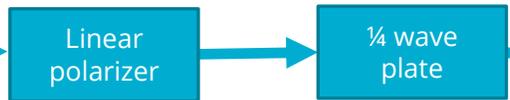


This slide and the following slides were not presented at the PDV workshop in Feb 2023
They provide more detail about the orientation system and process



Below is the schematic of the fiber optic cables, shown in arrows

Seed Laser



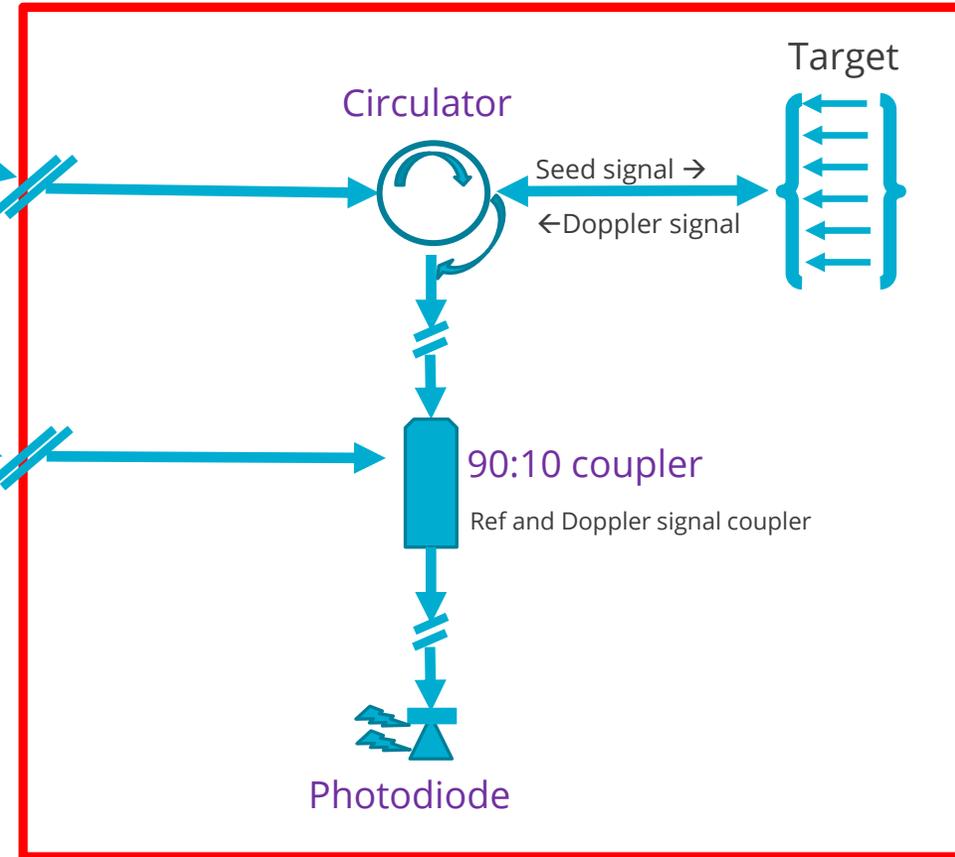
Creates a known linear polarization orientation

1/4 wave plate to make circular polarized light

Polarization controllers



The polarization control is made by using dual polarizers. The first one is a linear polarizer and the second is 1/4 wave plate to change the outgoing light from the linear polarizer to a circular polarization. The light can be made left or right circular,

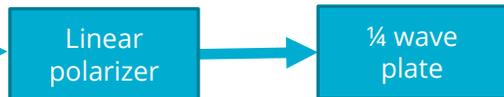


Normal PDV set up

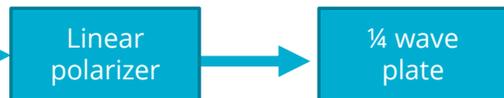
Plate orientation for circular polarization



Seed Laser



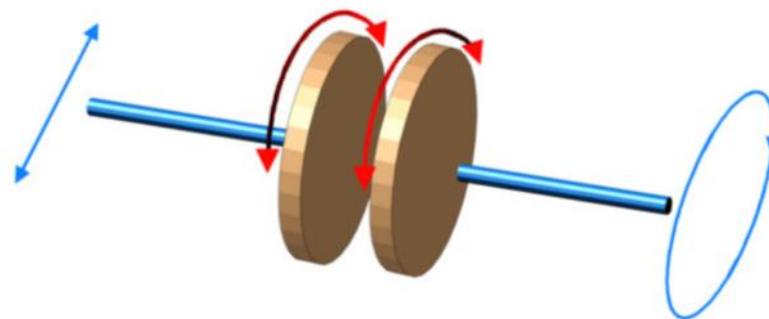
Ref Laser



Creates a known linear polarization orientation

1/4 wave plate to make circular polarized light

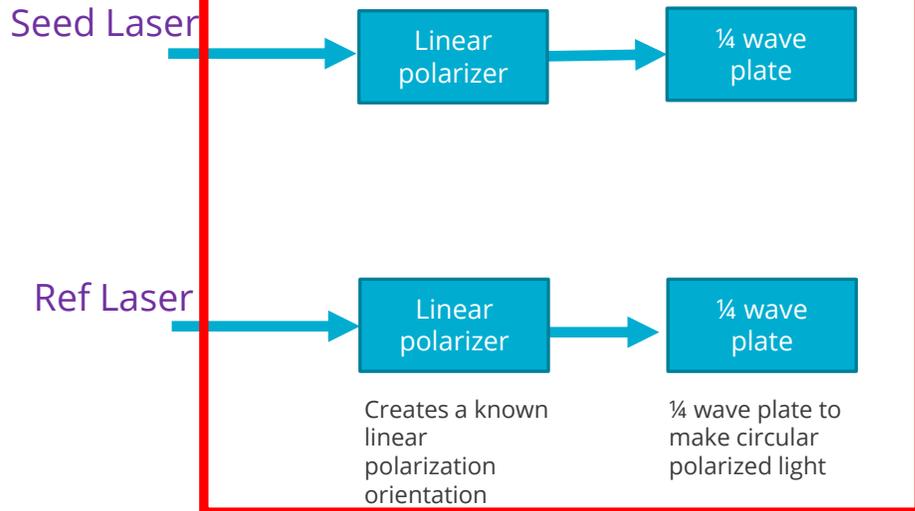
Polarization controllers



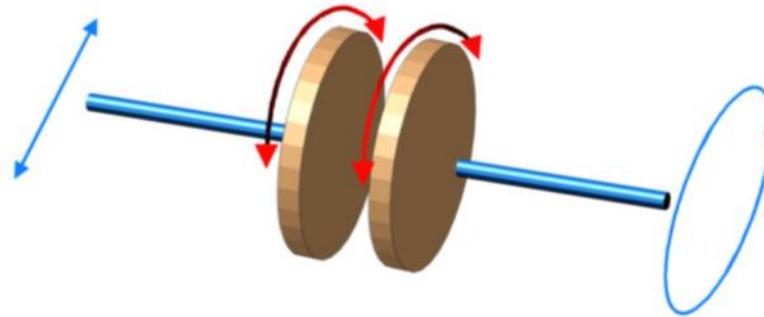
The ability to change the polarization was provided by rotating two plates. One represents the linear polarizer and the other 1/4 wave plate.

This was also chosen over bending fiber optic cables because the dual plate configuration does not strain the fiber optic cables.

Verifying circular polarization



Polarization controllers



Rotating Linear Polarizer Modules



- ▶ [Nanoparticle Film Polarizers](#)
- ▶ >10 000:1 Extinction Ratio
- ▶ 360° Continuous Rotation
- ▶ Engraved Scale with 2° Incre
- ▶ Ø2.5 mm Clear Aperture for F
- ▶ Ø4.0 mm Clear Aperture for F
- ▶ Custom Mounts are Available

The label FiberBench Rotating L

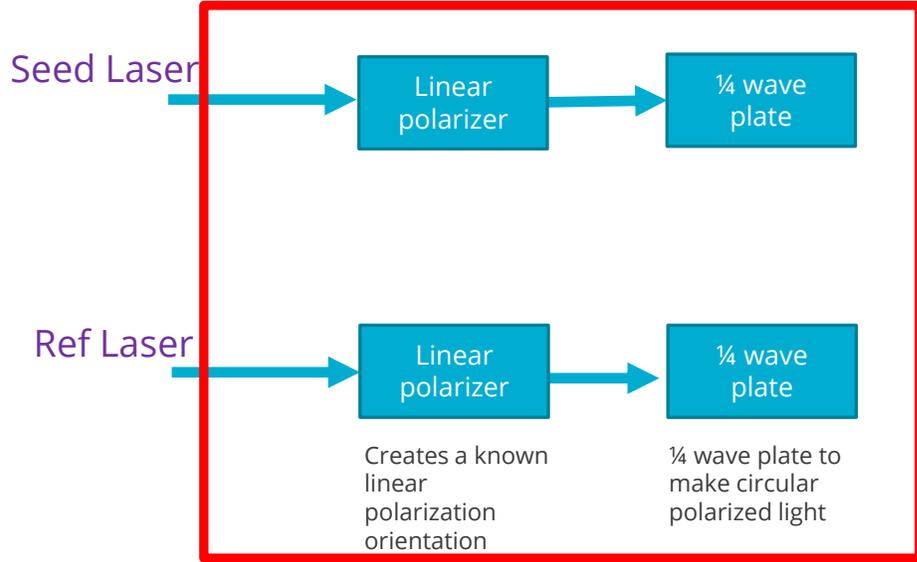
The output light was coupled to another linear polarizer. The plate was used to verify circular polarization.

After the light is passed through all 3 plates, the light intensity was monitored on a light card. The light card converts the 1550 nm light into green visible light.

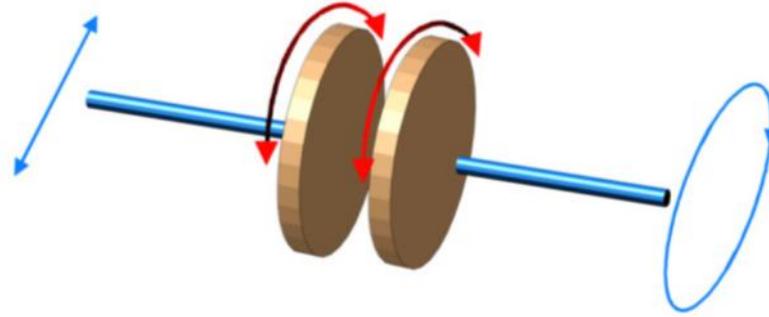
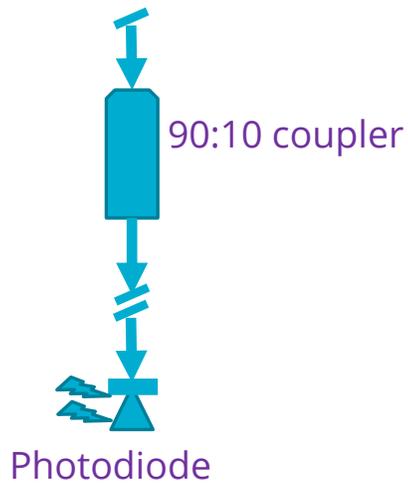
If the light exiting from the first two plates is truly circular polarized then enters the rotating linear polarizer module. The light intensity seen on the light card will not change as the rotating linear polarizer is rotated 360 degrees.

This provides a low key and easy way to verify that the light exiting the linear polarizer and $\frac{1}{4}$ wave plate is circular polarized (CP).

Verifying circular polarization



Polarization controllers



Rotating Linear Polarizer Modules



- ▶ Nanoparticle Film Polarizers
- ▶ >10 000:1 Extinction Ratio
- ▶ 360° Continuous Rotation
- ▶ Engraved Scale with 2° Incre
- ▶ Ø2.5 mm Clear Aperture for F
- ▶ Ø4.0 mm Clear Aperture for F
- ▶ Custom Mounts are Available

Seed laser fiber optic connection

The reason for the CP in the seen laser connection is to provide the most efficient polarization coupling into the circulator. This is due to the circulator relying on polarization for proper operation and efficient light transfer.

Ref laser fiber optic connection

The doppler shifted signal and reference laser light are combined into a single fiber optic for transmission to the photodiode. The interference pattern that creates the "beat frequency" is made on the photodiode.

In doing so, the inference pattern between the CP reference light and the linear polarized (LP) will provide a uniform intensity on the photodiode regardless of the doppler shifted signal's LP orientation.

Interference pattern on photodiode

The inference pattern created from a ref CP and doppler LP light increases the amplitude efficiency making low intensity doppler shifted light easier to sense on the PD.

If both the ref and doppler light are LP, the highest intensity will only happen when the both LPs are parallel and intensity will decrease as the LPs are shifted closer perpendicular orientation.

Why is this important, the electrical voltage signal that is converted from the photodiode is proportional to the light intensity. Higher coupling efficiency throughout the PDV system will provide the highest intensity to the photodiode for a more precise electrical signal provided to an oscilloscope.