Photonic Doppler Velocimetry

FREQUENTLY ASKED QUESTIONS

quantifiphotonics.com

Contents

1 Conventions

Before using the instruments described in this document, take note of the following conventions:

WARNING

Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury. Do not proceed unless the required conditions are met and understood.

CAUTION

Indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury. Do not proceed unless the required conditions are met and understood.

CAUTION

Indicates a potentially hazardous situation which, if not avoided, may result in component damage. Do not proceed unless the required conditions are met and understood.

IMPORTANT

Refers to information about this module that you should not overlook.

NOTE

Indicates some information that requires your attention or some extra information for the current topic.

2 Safety information

Before using the Doppler PXIe or Doppler MATRIQ instruments, ensure that the following safety information has been read and understood.

2.1 Optical laser radiation precautions

WARNING

Do not install or terminate fibers while the light source is active. Care must be taken to ensure that the instrument has been **turned OFF before inspecting the end face(s) of the instrument, or any optical patch cords** connected to this instrument. Never look directly into a live fiber; ensure that your eyes are protected at all times.

CAUTION

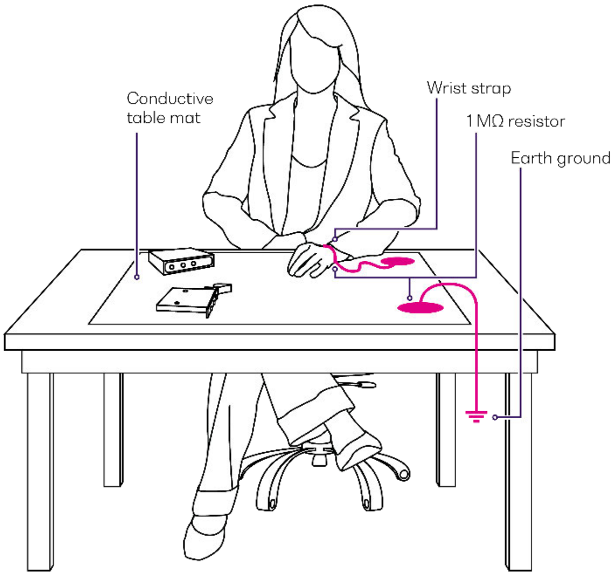
The use of controls, adjustments, and procedures other than those specified herein may result in exposure to hazardous situations involving optical radiation.

2.2 Electrostatic discharge precautions

CAUTION

The Doppler instruments are sensitive to electrostatic discharge (ESD).

Ensure that a wrist strap and grounding table mat is used when unpacking or handling the Doppler instruments. Proper grounding and ESD management practices should always be followed to ensure that no ESD damage is caused to the instrument.



2.3 Electromagnetic compatibility

CAUTION

- For electromagnetic compatibility, this product is a Class A product. It is intended for use in an industrial environment. There may be potential difficulties in ensuring electromagnetic compatibility in other environments, due to conducted as well as radiated disturbances.
- Wherever the ⚠ symbol is printed on the instrument, refer to the instructions provided in the device documentation for related safety information. Ensure that the required conditions are met and understood before using the product.

3 Document overview

3.1 Purpose

This document briefly introduces the Quantifi Photonics' Doppler instruments and provides answers to questions that are frequently asked by users of these instruments.

3.2 Intended readers

The intended readers of this document include Quantifi Photonics' customers and partners. To provide better service to customers and partners, the internal employees of the company, such as people in the Sales team, Support team, and Marketing team, can also refer to this document if they need more information about the Doppler instruments.

With information in this document, you can better understand how the Quantifi Photonics' Doppler instruments work and how they are used in Photonic Doppler Velocimetry (PDV) solutions.

3.3 Related documents

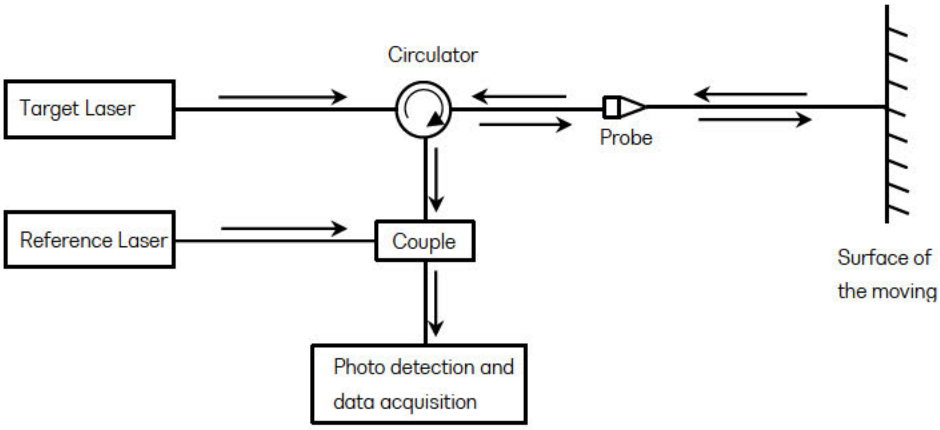
The following documents are related to the Doppler instruments:

Document	Description
Application Note: Photonic Doppler Velocimetry	Discusses the PDV technology and its applications in the real world.
Doppler Modular Photonic Doppler Velocimetry Spec Sheet	Introduces the key features and specifications of the Doppler PXIe and MATRIQ instruments.
Doppler Modular Photonic Doppler Velocimetry User Manual	Provides instructions for using the Doppler PXIe and MATRIQ instruments and the related software.

4 PDV and Doppler instruments

A Photonic Doppler Velocimetry (PDV) system is a velocity measurement system that uses lasers to detect and calculate the speed of a fast-moving object. PDV systems are usually used in scientific and technical investigations, including shock physics and the study of material behavior at high pressure and high strain rates.

In general, a target laser is sent to a probe via a circulator, and the incident light that is reflected from the surface of the moving object is collected by the probe, and then redirected via the circulator to a coupler, where an external reference laser source provides the unshifted or reference light. This process is illustrated in the diagram below:



For PDV systems, Quantifi Photonics provides almost all the necessary instruments. The Doppler instruments include components like the circulator and the coupler, and the tunable laser source instrument can be used to generate the target and the reference laser. In addition, you can also use an optical-to-electrical (O2E) instrument to convert the optical signal, which can then be displayed on an oscilloscope.

5 Feature questions

This chapter provides answers to questions that are related to the features of PDV systems and Doppler instruments.

5.1 What velocities can be measured with the sampling rate of my oscilloscope?

In a PDV measurement setup, if the laser wavelength is approximately 1550 nm, it works out that 1 GHz of doppler shift in the wavelength of a target moving fast directly towards the probe equates to 775 m/s of velocity. A 6 GHz oscilloscope with 6.4 G sample/s sampling rate has a Nyquist limit of 3.2 GHz, so this equates to roughly an upper limit of 2.480 km/s (3.2*775 m/s), which can be doubled if you place the reference laser relative to the target laser such that the beat frequency shifts through zero, all the way down to -3.2 GHz. This is also called up-shifting, which is further discussed in the question Should my PDV setup be heterodyne or homodyne?.

The calculation can be basically scaled up linearly with the sampling rate of the oscilloscope. For example, an oscilloscope with 8 GHz analog bandwidth and 25 G sample/s sampling rate has a Nyquist limit of 12.5 GHz. Even if the bandwidth is rolled off, there is enough signal to still see the doppler frequency up to about 12 GHz with such an oscilloscope, thus you would have about 9.3 km/s velocity measurements, and if that is doubled, the measurements can reach 18.6 km/s.

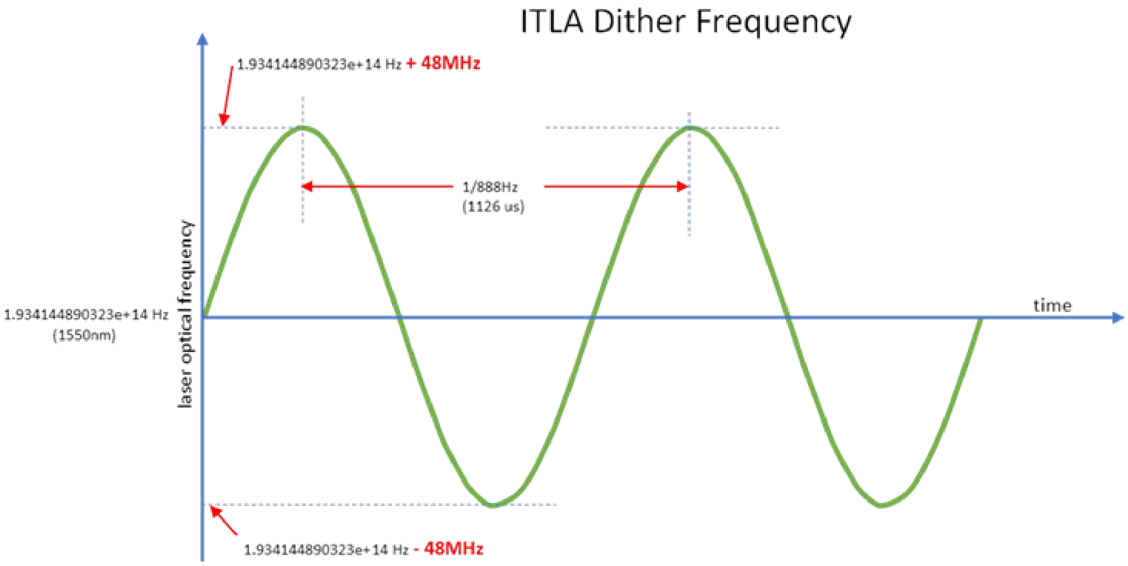
The sampling rate of the oscilloscope in a PDV system basically determines the highest velocity that can be measured. To increase the upper limit of the velocity that can be measured, you can offset the starting frequency in bands so that there are multiple lasers that pick up the signal. In this way, the velocity up to 96 km/s can be measured with an oscilloscope that has 25 G sample/s sampling rate.

5.2 How low of a velocity can my PDV system measure?

Laser sources that are based on the ITLA multisource agreement usually use a technique known as “dithering” to achieve superior frequency stability. While dithering can help achieve frequency stability, it may cause the phase of the lasers in a heterodyne setup to wander relative to each other, which may lead to uncertainty in terms of relative frequencies. To eliminate the uncertainty and offer greater fidelity, Quantifi Photonics offers a custom operating mode for tunable lasers known as the “Whisper Mode”, in which the dithering function is disabled, and that helps the system to reach the lowest velocity that it can measure.

The industry standard dithering used on ITLA style lasers is essentially a constant periodic shifting of the laser's center frequency up 48 MHz and down 48 MHz from the target tuning frequency.

This periodic shifting is performed in a sinusoidal fashion with a period corresponding to a frequency of 888 Hz, as illustrated below:



In a heterodyne setup with two ITLA lasers "beating" against each other to produce a beat frequency, the dithering function happens simultaneously and asynchronously on two different lasers. Over time, two lasers tuned perfectly to 1550 nm each using this dithering can have a maximum beat frequency of 2 x 48 MHz = 96 MHz relative to each other. Because the two lasers have an asynchronous dithering function, over time the phase of these two beat frequencies slowly wander relative to each other. In this case, unless the dithering is directly measured, you will be faced with an entire uncertainty of relative frequency to each other from 0 Hz to 96 MHz without counting any other sources of phase noise.

In a PDV measurement setup using a real-time oscilloscope in a single-shot triggered event type of capture, you can look directly at the initial conditions just prior to the event to see what the starting relative-beat frequency is to each other. For most PDV experiments, the time windows of capturing events are relatively short (< 10 µs), and thus if you directly measure the exact beat frequency offset at the beginning of the oscilloscope waveform capture, it will only change a small amount over the event.

For example, the 888 Hz dither frequency has a period of 1126 µs, so a 10 µs long oscilloscope trace has a worst-case change in the beat frequency due to the dither alone of (10 us / 1126 us) * (96 MHz) = 0.853 MHz. In a 1550 nm based PDV setup, an object traveling directly towards or away from the optical probe emitting the laser light imposes a Doppler shift of 1 GHz for every 775 m/s velocity. If you do not measure the true starting beat frequency of the two dithering lasers, this amounts to an inherent maximum uncertainty of (96 MHz / 1 GHz) * 775 m/s = 74.4 m/s. If you measure the starting beat frequency at the very start of the oscilloscope PDV capture (before any doppler shift from the target has occurred), the uncertainty over a 10 µs event is reduced to (0.853 MHz / 1 GHz) * 775 m/s = 0.661 m/s.

This example indicates that as the record length of the event increases and as the velocity trying to be measured decreases, the uncertainty grows. To offer greater fidelity in such low velocity and/or long record length events, Quantifi Photonics offers a custom operating mode for the tunable lasers known as the "Whisper Mode", in which the 888 Hz dithering function of each laser is disabled through SCPI format commands.

NOTE
The dithering control feature must be ordered at the time of purchase.

The caveat with disabling the dither function is that the precision tuning of the lasers, which rely on the dithering function to be so precise, slowly wanders and drifts in frequency over time. However, the lasers are still quite precise and stable in their tuning just prior to and immediately after disabling the dither function and entering the Whisper Mode. If the dithering is disabled just prior to capturing the event (10 s of seconds recommended), the inherent error in the measured beat frequency for long events exceeding 10 s of microseconds is reduced to being near the phase noise of the lasers (<100 KHz each), thus an estimate of 2 * 100 KHz = 0.2 MHz corresponds to a Doppler velocity of 0.155 m/s. This is an ideal theoretical limit of the lowest measurable velocity in such a PDV setup, and in actual practice the use of Whisper Mode for long duration events (upwards of 500 µs) with low velocity is likely limited to several meters per second.

Section 6.6 describes what typical PDV users can see when they perform a Fourier transform on the waveform that contains the doppler shifted beat frequency not only from the reflections off the parts of the Device Under Test (DUT) that travels at high velocity, but also from the reflections from parts of the DUT and the surrounding area that are not moving. The Fourier transform shows a baseline result that is from this zero-velocity part of the reflections. These baseline zero-velocity results are very useful for measuring low velocity events in experiments in which the dithering function is enabled. By always subtracting the finite velocity event from whatever the baseline zero-velocity event produces in the Fourier transform from the time domain waveform, you can subtract the dithering error from the results and thus measure relatively slow velocity events without disabling the dithering function.

5.3 What O2E converter bandwidth do I need for my oscilloscope?

In a PDV measurement setup, the bandwidth of the O2E converter and the bandwidth of the oscilloscope combine to determine the system performance.

For linear systems, engineers often estimate the risetime with the following formula:

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risetime ~= 0.35/bandwidth
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For example, the risetime of an O2E converter with the bandwidth of 25 GHz is 14 ps (`0.35/25 GHz`), and the risetime of an oscilloscope with the bandwidth of 40 GHz is 8.75 ps (`0.35/40 GHz`).

You can use the following formula to calculate the system risetime based on the bandwidth of the O2E converter and the bandwidth of the oscilloscope:

$$system\ ristime = \sqrt{(O2E\ converter\ risetime)^2 + (oscilloscope\ risetime)^2}$$

NOTE

These formulas are only for 10% to 90% risetimes, not the 20% to 80% risetimes.
The conversions are only useful in linear or Gaussian-type systems, not non-linear or clipped systems.

Continue with the example above, the system risetime of a 25 GHz O2E converter and a 40 GHz oscilloscope is 16.5 ps:

$$\sqrt{(14\,ps)^2 + (8.75\,ps)^2} = 16.5\,ps$$

And the system bandwidth of this combination is 21.2 GHz (`0.35/16.5 ps`).

If you use high performance oscilloscope, you must choose high performance O2E converters to match it. Otherwise, you might have performance issues. The bandwidth of the O2E converters from Quantifi Photonics is usually 20 GHz, and that makes those converters a good choice for high performance PDV measurement systems.

For example, the O2E-1101-PXIe provides 20 GHz of bandwidth while delivering an impressive 900 V/W conversion gain with a built-in low-noise linear transimpedance amplifier, and the low noise (`40 pW /sqrt(Hz)`) amplifier in the converter gives similar noise floor performance despite having almost double the bandwidth compared to other traditional 12 GHz converters used in PDV applications.

5.4 What type of tunable laser sources should I choose?

Many PDV users prefer high-resolution tunable laser sources because they can do the tuning up to 1 pm. The tunable laser sources from Quantifi Photonics use the Micro Integrable Tunable Laser Assemblies (μITLA) technology, thus they can achieve that resolution. To achieve that, the μITLA type laser sources use a double etalon type structure, which when moving from one wavelength to another would in fact have a lot of mode-hopping going on during the tuning, and that is why it is standard to essentially turn the laser off during such movement. When a new wavelength is defined, the laser source reduces power (essentially off), moves the tuning over a few seconds, and when at the right location, it turns back on at the new wavelength.

In addition, the dithering function is also used to ensure tuning stability and precision. Basically, there is a sinusoidal low frequency dithering that essentially moves the instantaneous linewidth (<100 KHz) +/- 48 MHz from the center wavelength at a rate of 888 Hz. For interferometric sensitive experiments, this dithering control option is popular.

5.5 What are the mode-hopping and laser-tuning characteristics of the Quantifi Photonics tunable laser source instruments?

The tunable laser source instruments from Quantifi Photonics use the Micro Integrable Tunable Laser Assemblies (µITLA) technology for tunable lasers. In addition, these instruments use the standard dithering method for frequency stability. As an optional feature, the dithering function can be turned on and off, which is useful for ultimate narrow linewidth applications.

> **NOTE**
> The dithering control feature must be ordered at the time of purchase.

To achieve the precision in tuning, the µITLA type laser sources use a double etalon type structure, which when moving from wavelength A to wavelength B would have a lot of mode-hopping going on during the tuning. For that reason, the laser is automatically turned off during such movement. When you define a new wavelength, the laser reduces power (essentially off), moves the tuning over many seconds, and when in the right location, it turns back on at the new wavelength.

The dithering function is mainly used to ensure stable tuning. Basically, there is a sinusoidal low frequency dithering that essentially moves the instantaneous linewidth. The instantaneous linewidth is lower than 100 KHz and it is moved +/-48 MHz from its programmed center frequency. The dithering function is used to ensure that the lasers are tuned without using an external cavity that is larger and thus not as tunable, and it can be useful for interferometric sensitive experiments.

For ultimate narrow linewidth applications, the tunable laser source instruments from Quantifi Photonics can be upgraded with a feature to disable this dithering, which turns off the +/-48 MHz dithering and gives you the raw linewidth (<100 KHz).

5.6 Why is the PDV frequency shift twice what the Doppler equation predicts?

Based on PDV page on Wikipedia, the "velocity of the moving surface (ν^*) is a function of the source wavelength (λ_0) and the signal frequency ($\bar{f}$)": $\nu^* = \frac{\lambda_0}{2} * \bar{f}$

Based on this equation, if a 193.4 THz wave is mixed with a 193.40032 THz wave, the result is a beat frequency of 320 MHz. While that corresponds to reflecting off an object moving at 500 m/s, the calculation result based on the equation is 225 m/s if the source wavelength is 1550 nm and the signal frequency is 320 MHz.

That does not mean the calculation is incorrect. The difference is caused by the fact that there are two doppler shifts. At first, the target object observes the target laser frequency coming from the doppler probe output, with a single doppler shift corresponding to its relative orthogonal velocity to the target laser's emission from a probe or collimator, and that is the doppler shift that the listener at the target observes. Once it reflects off the target, there is a second doppler shift in what the observer sees from the laser source side as well. That is the reflected light coming from the moving object straight towards you, and that is the reason that you get twice the doppler shift in the reflection.

5.7 In the O2E PXIe spec sheet, what do the “wavelength” and “calibrated wavelength” specifications mean?

The “wavelength” specification indicates a nominal useful wavelength range, which is the typical range in which the responsivity is >~40%. In reality, the instruments can operate slightly below and above this range.

The “calibrated wavelength” specification is a list of the wavelengths for which the built-in power meter function is calibrated for accuracy.

5.8 What is the longest delay we can fit in PXIe slots?

Quantifi Photonics offers fiber delay modules with increments of 4.893 μs, which is approximately about 1 km worth of single-mode fiber delay. If you require longer delays, connect these modules serially to introduce incremental delay. For example, you can get N*4.893 μs delay with N modules.

If you wish to have more varieties and longer delays than this approach can offer, contact us by sending an email to support@quantifiphotonics.com to discuss your custom fiber delay requirements. Solutions like using stand-alone mechanical enclosures instead of active PXIe slots can be considered.

6 Configuration questions

This chapter provides answers to questions that are related to the configuration of PDV systems and Doppler instruments.

6.1 To set up a demonstration PDV system, what modules do I need?

For a typical demonstration PDV system, the following modules are required:

- National Instruments® (NI) PXIe chassis 1078 or any chassis with the controller and more than 3 slots
- NI PXIe-8821 controller with NI MAX, and the driver installed for NI Digitizer 5186 or 5185
- Quantifi Photonics Laser-1001-2-FA-PXIE
- Quantifi Photonics Doppler-1001-1-FA-PXIE
- Quantifi Photonics O2E-1101-1-FA-PXIE
- NI Digitizer PXIe-5186 (5 G bandwidth) or PXIe-5185 (3 G bandwidth)

NOTE
For demonstration purposes, the laser source is used instead of an actual probe.

6.2 For a demonstration PDV system, how do I set up the modules?

NOTE
This setup uses the modules listed in the section To set up a demonstration PDV system, what modules do I need?.

1. Connect one channel of the laser source to the “ref in” port on the Doppler instrument.
2. Connect the other channel of the laser source to the “probe in/out” port on the Doppler instrument.
3. Connect the “signal out” port on the Doppler module to the input port on the O2E instrument.
4. Connect the “RF output” port on the O2E module to the oscilloscope.
5. Follow instructions in the user manual to install the drivers for the laser source, the Doppler instrument, and the O2E instrument.
6. Open CohesionUI and configure the following settings:

   WARNING
   Do not turn on the laser until everything has been set up. Otherwise, the photodetector inside the O2E instrument may be damaged.

   a. Set the frequency of one laser source channel to 193.414 THz, and the frequency of the other channel to 193.416 THz. This leads to a 2 GHz difference between the two laser channels.
   b. Set the output constant power of the Doppler instrument to 0 dBm. The damage threshold of the O2E instrument is 4 dBm.
7. Turn on the laser source, check the optical power from the O2E instrument. You should see some peak at 2 GHz on the oscilloscope.

6.3 Why are two laser sources needed in a typical PDV system?

In general, it is recommended that you implement a wavelength-agile PDV setup in which the target laser and the reference laser are from independent tunable laser sources. In such a setup, you can offset the starting beat frequency for each channel at any desired values. By selecting pre-shot beat frequencies (the difference between the target and reference laser frequency of a given channel), you can distance the multiple channels far enough apart in the optical spectrum so that the stray reflection picked up on one channel from another (crosstalk) is rejected due to the wavelength gap between these channel settings.

6.4 Should my PDV setup be heterodyne or homodyne?

In general, the heterodyne method is highly recommended.

Compared with the heterodyne method, the homodyne has several disadvantages. First of all, if you split a single narrow linewidth laser and use it for both the target signal and the reference oscillator, the beat frequency being “0 Hz” for “0 velocity”, which means that the oscilloscope beat frequency starts at near 0 Hz before the velocity event being probed creates a large enough Doppler shift for the transform of the waveform to discern what the beat frequency is. The initial condition of “0 Hz” can be difficult for the time domain waveform to capture.

Secondly, for multi-channel systems, the homodyne method also has its disadvantages. If you implement a multi-channel PDV system by using high-power lasers and splitting them multiple times to provide the reference laser to each channel, the following drawbacks may affect your system:

- The high-power lasers, such as 2 W, are above the normal laser safety limits for class 1M lasers and may cause safety concerns.
- By using the same laser for multiple channels, you are limited to the variety and spacing of the initial beat frequencies that can be established between the target and reference laser mixing of each channel at the O2E converter.
- If you reuse the reference (and/or target) laser by splitting it for multiple channels, you are confined to having to use a different oscilloscope channel for each channel in order to record the history of the beat frequencies. In addition, if the target laser is split from a single laser source or is at a static frequency, all channels have similar beat frequencies, which can make it very difficult to discern each different probe reflection.
- Reusing the same laser (and thus the same wavelengths) for multiple channels means that crosstalk of the reflections from one channel to the next cannot be separated or discerned accurately.

On the contrary, the heterodyne method has quite a few advantages.

First, using two separate narrow linewidth lasers for the target and the reference allows you to intentionally offset the beat frequency to a higher value near the bandwidth and sampling limit of the oscilloscope used to capture the beat frequency waveform from the O2E converter. By tuning the frequency of the target laser to a point that is lower than that of the reference laser, the resulting beat frequency from a high velocity event reflecting the target increases the frequency of the target reflection. The beat frequency that the O2E converter and the oscilloscope can discern within their combined bandwidth and sampling rate limit is essentially twice, because as the target velocity increases, the beat frequency moves from an initial high value, towards 0 Hz, and then go through and past 0 Hz as it increases until the maximum bandwidth-sample-rate limit is reached on the other side. This up-shifting offsetting method effectively doubles the maximum velocity event that can be measured by the PDV system without increasing the cost of the oscilloscope or O2E solution.

Secondly, by using independent, tunable lasers sources in the C-band and L-band, you have the flexibility to assign each target and reference pair of lasers to the typical ITU grid channels associated with the ITU-T G.694.1 standard, and that allows common accessories such as DWDM optical Mux and Demux passive components to combine and separate multiple PDV channels on a single fiber at the same time. With this, you can literally space the reflections of each channel away from each other in time and thus allows a single oscilloscope channel to capture multiple channels.

Finally, if you use dedicated tunable lasers for each target and reference laser combined with the inline power meters and attenuators inside the Doppler instrument, you can optimize the relative mixing levels of the reflected signals for each channel. Channels may have very different amounts of reflection to one another, and thus having an easy to use power monitoring capability in real time for all target reflection powers as well as all reference laser powers prior to mixing is extremely important for ease and consistency of setup prior to a shot/shock event in PDV experiments.

6.5 Are there any reflection issues in a PDV system if foil or stainless steel is used?

Yes. There would be some reflection issues. If these types of material are used in a PDV target setup, the amount of reflection off them results in ample reflection.

PDV systems use the coherent mixing of the lasers and they are quite sensitive. This is especially true when an amplified O2E converter is used before the oscilloscope with conversion gains. Reflections with return losses as low as 50 dB from the target are easily discernable on the recorded beat frequency with the ~15 dBm reference laser and the accompanying pair of VOA and power meter paths inside the Doppler instrument. For example, users who implemented PDV setups for foil targets routinely found they needed to attenuate the reference laser at least 20 dB to keep the O2E converter and oscilloscope in the operating dynamic range and not saturate.

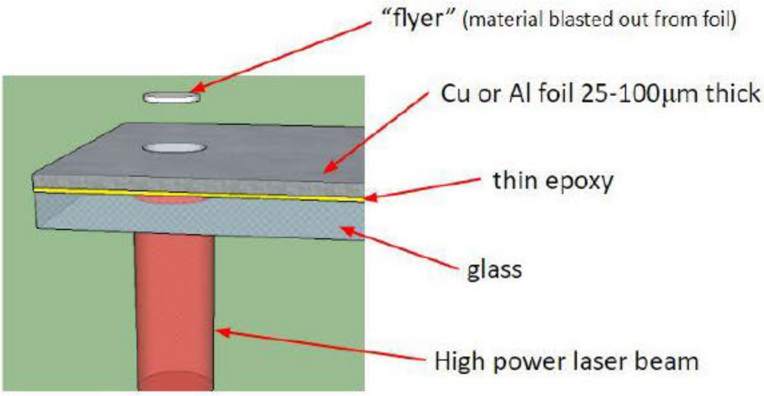
6.6 What factors do I need to consider when I choose a collimator or a probe for my PDV system?

Targets in PDV systems can come in a large variety of sizes, shapes, tilts, reflectivity, surface conditions, and distances travelled during the event, and all of these can affect the optimum choice of the probe for the experiment.

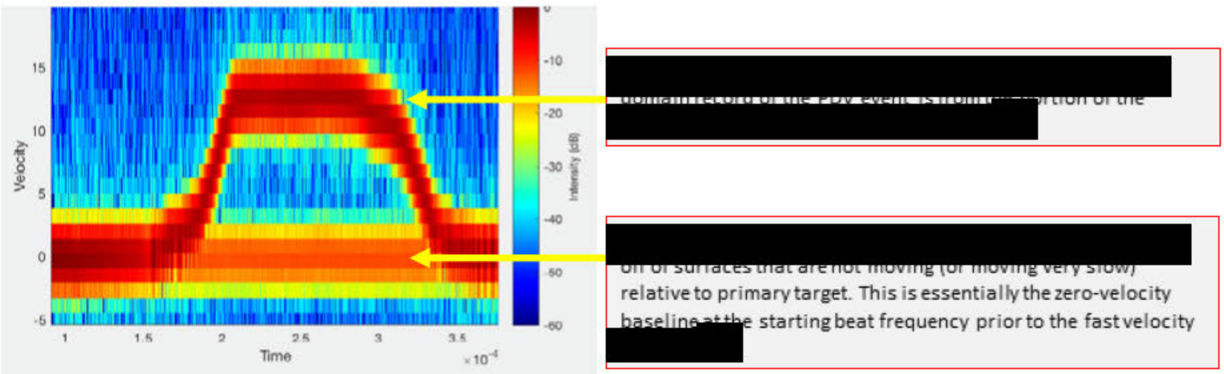
In general, you can consider the following factors when you choose a collimator or a probe:

Factor	Consideration
Probe type	Is a focusing probe or a collimator the best to use?
Target properties	Is the target surface tilted? Is the surface of the target initially reflective or very diffuse?
Test requirements	When using a focusing probe, what stand-off distance is best to use? How close to the target do the probes need to be and how many of them will there be? What is the best spot-size for a focusing probe to use?
Wavelength of light	What wavelength of light will you be transmitting through the fiber?
Type of fiber	Do you need multimode, single mode, or polarization maintaining fiber?
Fiber cladding size	What fiber core/cladding size do you prefer?
Size of the collimated beam	For the collimator, what size of the collimated beam do you need?
Spot size and working distance of the focuser	If you need a focuser, what spot size and working distance do you need?
Collimator housing diameter	What is the maximum diameter collimator housing that you can use?
Type of lenses	Do you prefer GRIN lenses, aspheric lenses achromat lenses, or plano convex / biconvex lenses?
Return loss	How low a return loss do you require?
Patchcord	How long should the patchcord be, in meters?
Fiber connector type	Do you need a connector on the other end of the fiber? If so, what type?
Cable type	What type of cabling do you need?

A general guideline is that you can use a relatively narrow collimator with the beam size of 1.8 mm. However, smaller spot sizes might be needed in cases such as the flyer plate tests. In such tests, high powered pulsed lasers are used to rapidly heat an absorbing surface, which in turn explodes through a thin metal foil surface that can produce velocity events of approximately several kilometres per second. The small portion of foil that gets blasted out from the sudden laser burst is called a "flyer plate", as illustrated below:



If the flyer plate diameter is roughly 0.5 mm, you should consider using a focusing probe that has about 0.5 mm or less in spot size depending on where the probe is positioned relative to the target. If you use a larger spot-size focusing probe or a collimated probe, a large portion of the reflected light will be from the surrounding foil area, which is relatively slow or not moving. Such reflected light has little or no doppler shift, and thus a large portion of the light coupled back to the mixer preceding the O2E detector will have near-zero velocity, and in such case the eventual Fourier transform of the signal from the O2E converter into the digitizer will have a zero-velocity baseline in the result simultaneously as the other components that are at higher velocities, as illustrated below:



Ideally, most of the reflected light should come from the portion of experiment that moves at high velocity, and hence a spot-size of 0.5 mm or smaller is needed in this example. In addition, if the flyer plate tilts slightly and it is not perpendicular to the probe, a focused probe with the spot size that is smaller than 0.5 mm is better, because as the flyer plate tilts slightly, much of the light can still be coupled back into the probe.

6.7 How do I protect the Doppler instrument from high-power laser at 1064 nm in my PDV system?

To protect the Doppler instrument from high-power lasers, consider the following options:

- Put a band-pass filter in the free space between the target and the probe. It will reduce your signal a bit.
- Use a relevant high-power laser line mirror. This is usually very effective.

6.8 How much does the µITLA tunable laser drift?

As described in the question How low of a velocity can a PDV system measure?, the linewidth that is lower than 100 KHz is an instantaneous value for the Laser 1000 Series PXIe of laser sources, and the dithering function is used to keep the laser stabilized at its intended target. That is to say, the center wavelength of the laser changes +/-48 MHz following a sinusoidal pattern with a period corresponding to 888 Hz. Without this dithering, the laser can and will slowly wander, especially if the temperature changes.

For certain applications where this dither is a blocking issue, Quantifi Photonics allows you to optionally turn the dithering feature off. However, if you request either a wavelength change or power change, the dithering is automatically turned back on and remains so until the laser reaches its new target wavelength and/or power. Then you have to manually turn the dithering off again. With the dithering function turned off, the resolution of setting the Laser 1000 Series PXIe tunable lasers is limited to 1 picometer (125 MHz).

> **NOTE**
> To ensure the laser stability, the dithering function must be enabled. The dithering control feature must be ordered at the time of purchase.

6.9 Where can I buy a collimator for my PDV system?

Contact Quantifi Photonics for suggestions.

6.10 Where can I buy used oscilloscopes and other test and measurement equipment?

Contact Quantifi Photonics for suggestions.

7 Application questions

This chapter provides answers to questions that are related to the application of PDV systems and Doppler instruments.

7.1 How is PDV used in distance measurement?

Lidar sensors often use a simple time-of-flight approach, in which the sensor sends out a pulse of laser and measures how long it takes for the laser to return. This is usually used in distance measurement.

On top of this, Frequency-modulated Continuous-wave (FMCW) lidars send out a continuous laser beam with a steadily changing frequency. When the laser bounces and returns, the sensor optically combines the inbound and outgoing laser. The distance can then be measured precisely based on the frequency difference between the two beams. Because distance measurements depend on the difference between two constantly changing frequencies, FMCW beams are more immune to interference.

In terms of measuring moving objects, FMCW lidars usually measure the doppler shift in the returning reflections, so that both the distance and the velocity can be detected in a single pulse event.

With the PDV instruments from Quantifi Photonics, such as the tunable laser sources, the Doppler instrument, and the O2E instrument, you can easily set up a PDV distance measurement system.

8 Technical support

8.1 Contacting the Technical Support Group

To obtain after-sales service or technical support for this product, contact Quantifi Photonics.

The Technical Support Group is available to take your calls Monday to Friday, 9:00 a.m. to 5:00 p.m. (New Zealand Time).

Technical Support Group
Tel: +64 9 478 4849
support@quantifiphotonics.com

To accelerate the process, please have information such as the product name and the serial number (see the product identification label), as well as a description of your problem, close at hand.

8.2 Transportation

Maintain a temperature range within specifications when transporting the unit. **Transportation damage can occur from improper handling.**

The following steps are recommended to minimize the possibility of damage:

- Pack the module in its original packing material when shipping.
- Avoid high humidity or large temperature fluctuations.
- Keep the module out of direct sunlight.
- Avoid unnecessary shocks and vibrations.

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