Quartz-Wedge Achromatic Depolarizers

- ▶ **Randomizes the Polarization of a Linearly Polarized Input Beam**
- ▶ **Effective with Monochromatic and Broadband Light**
- ▶ **Available with AR Coatings**

DPU-25-A | DPU-25-C | DPU-25 | DPU-25-B

DPU-25-A Depolarizer
Mounted in an SM1 Lens Tube

Related Items

Features

- Optic Axis Alignment Not Required
- Ideal for Broadband Light Sources and Large Diameter (>6 mm) Monochromatic Beams
- Air-Gap Design Allows for use with High-Power Beams
- Available Uncoated (190 - 2500 nm) or with One of Three AR Coatings
  - 350 - 700 nm (-A Coating)
  - 650 - 1050 nm (-B Coating)
  - 1050 - 1700 nm (-C Coating)

General Specifications	
Substrate	Quartz Crystal
Coatings	Uncoated (190 - 2500 nm) -A Coating (350 - 700 nm) -B Coating (650 - 1050 nm) -C Coating (1050 - 1700 nm)
Outer Diameter	1" (25.4 mm)
Thickness	7.35 mm (0.289")
Clear Aperture	>Ø21.59 mm
Surface Flatness	λ/10 @ 633 nm
Surface Quality	10-5 Scratch-Dig

Thorlabs' Quartz-Wedge Achromatic Depolarizers convert a polarized beam of light into a pseudo-random polarized beam of light. The term pseudo-random is used since the transmitted beam doesn't become unpolarized; instead the polarization of the beam is randomized. Linearly polarized light from a monochromatic source that is transmitted through a quartz-wedge depolarizer will have a polarization that varies spatially. Linearly polarized light from a broadband source that is transmitted through a quartz-wedge depolarizer will have a polarization that varies spatially as well as with wavelength. While the DPU-25 is designed for use with linearly polarized light (as shown in the *Tutorial* tab), it will also produce pseudo-random polarization if the input is elliptically or circularly polarized. Quartz-wedge polarizers will work with light incident on either side of the optic.

Zemax Files

Click on the red Document icon next to the item numbers below to access the Zemax file download. Our entire Zemax Catalog is also available.

Design

These achromatic depolarizers consist of two crystal quartz wedges, one of which is twice as thick as the other, that are separated by a thin metal ring. The assembly is held together by epoxy that has been applied only to the outside edge (i.e., the clear aperture is free from epoxy), which results in an optic with a high damage threshold. These depolarizers are available uncoated for use in the 190 - 2500 nm range or with one of three antireflection coatings deposited on all four surfaces (i.e., both sides of the two crystal quartz wedges). Choose from AR coatings for the 350 - 700 nm (-A coating), 650 - 1050 nm (-B coating), or 1050 - 1700 nm (-C coating) range.

The optic axis of each wedge is perpendicular to the flat for that wedge. The orientation angle between the optic axes of the two quartz crystal wedges is 45°. The unique design of the quartz-wedge depolarizers eliminates the need to orient the optic axes of the depolarizer at any specific angle, which is especially useful if the depolarizer is used in an application where the initial polarization of the light is unknown or varies with time.

The thickness of these optics prevents them from being mounted in our LMR1 optic mount. However, they can be mounted inside an SM1-threaded (1.035"-40) lens tube for integration into a lens tube system or post mounting via an LMR1 mount, as shown in the image at the top of the page.

Free-Space Applications

Although the quartz-wedge depolarizers can convert a polarized monochromatic or broadband source into a pseudo-random polarization, depolarization of narrowband (monochromatic) light sources can only be achieved if the incident beam is greater than 6 mm in diameter. This minimum beam diameter is needed for monochromatic sources because randomization of the output beam's polarization is achieved by producing a spatial variation in the beam's polarization (see the *Tutorial* tab). Thorlabs also offers liquid crystal polymer depolarizers that use a patterned retarder to effectively depolarize beams as small as Ø0.5 mm (see the *Quartz vs. LCP* tab for details).

Depolarization of a broadband source does not have the same beam diameter restrictions as found with the narrowband or monochromatic source. This is because the polarization of the output beam will be randomized as a result of the wavelength-dependent retardation of the light transmitted through the quartz crystal wedges, in addition to the spatial variation in the polarization of the output beam.

The pseudo-random polarization generated by these depolarizers may be more suitable than linearly polarized light for polarization-sensitive devices and experiments, such as Raman Amplification and reduction of polarization-dependent losses. Because of their effectiveness over a wide spectral range, with both narrow- and broadband sources, the quartz-wedge depolarizers have been used with favorable results in applications involving polarization-sensitive spectrometers and LCD test systems. In addition, the depolarizer's design eliminates the need to align the optic with respect to the orientation of the linear polarization axis of the incident beam, making them highly adaptable to varying input polarizations.

Click to Enlarge
Edge-on View of the Quartz-Wedge Depolarizer

Fiber Applications

Thorlabs' quartz-wedge achromatic depolarizers are not recommended for applications where the depolarized beam is going to be coupled into a single mode optical fiber. Consider the output beam as two superimposed beams. Since the optic axes of the two wedges are not aligned, there will be a non-zero divergence/offset of the propagation vectors of the two output beams due to the birefringence of the quartz crystal. If the diverging/offset beams are then focused onto the tip of a fiber, each beam will be imaged at a slightly different position. As a result, optimizing the coupling of light into the fiber can result in the preferential coupling of one beam over the other and the polarization of each individual beam is not completely randomized. The PL100S and DPC5500-T are fiber based polarization controllers that have a depolarization mode, which rapidly varies the output polarization in time.

Other Depolarizers

These depolarizers and our Liquid Crystal Polymer (LCP) Depolarizers each offer distinct advantages depending on your application. The depolarizers featured here have a much better surface quality and a high damage threshold due to their use of a quartz substrate and air-gap design, which makes them suitable for high-power applications. The LCP depolarizers use a patterned retarder design that can effectively depolarizers monochromatic beams down to Ø0.5 mm, while the quartz depolarizers typically require input beam diameters of at least 6 mm. The patterned retarder design used in the LCP depolarizers is also less sensitive to the angle of incidence. See the *Quartz vs. LCP* tab for a more detailed performance comparison.

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			DPU-25	Quartz-Wedge Achromatic Depolarizer, Ø25.4 mm, Uncoated Quartz Crystal	$535.81	√	Today
			DPU-25-A	Quartz-Wedge Achromatic Depolarizer, Ø25.4 mm, AR Coating: 350 - 700 nm	$650.25	√	Today
			DPU-25-B	Quartz-Wedge Achromatic Depolarizer, Ø25.4 mm, AR Coating: 650 - 1050 nm	$650.25	√	Today
			DPU-25-C	Quartz-Wedge Achromatic Depolarizer, Ø25.4 mm, AR Coating: 1050 - 1700 nm	$650.25	√	Today

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Additional Polarizers

Linear Film Polarizers	Polarizing Beamsplitters	Glan-Thompson Polarizers	CO_2 Laser Brewster Polarizer
Economy Film Polarizers with Windows	Circular Polarizer	Double Glan-Taylor Polarizer	Variable Beamsplitter / Attenuator
Wire Grid Polarizers on Glass Substrates	Glan-Laser α-BBO Polarizers	Rutile TiO_2 Polarizers	UV Fused Silica Brewster Windows
Holographic Wire Grid Polarizers	Glan-Laser Calcite Polarizers	Calcite Beam Displacers	FiberBench Polarization Modules
MIR Wire Grid Polarizers on Silicon Substrates	Glan-Taylor Polarizers	Yttrium Orthovanadate Beam Displacers	Quartz-Wedge Depolarizers
Dichroic Film Polarizer	Glan-Taylor and Glan-Laser Mounts	Wollaston Polarizer	Microretarder Depolarizer Array

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Quartz-Wedge Achromatic Depolarizers

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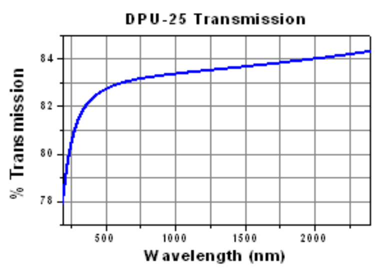
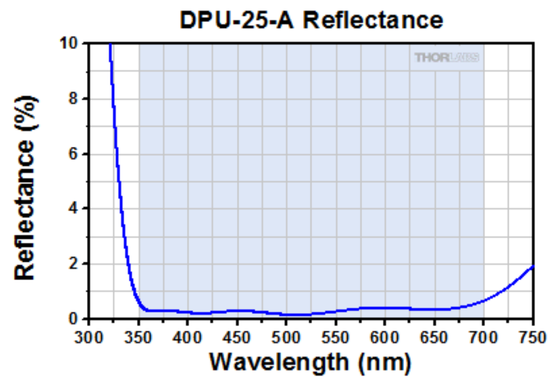
The DPU-25 is also available from stock with three different AR coatings. As the plots below show, the AR coating significantly reduces surface reflections, and since these depolarizers are made from two quartz crystal wedges, the AR coating minimizes the reflections at four surfaces. For example, the loss due to surface reflections at 1400 nm for the uncoated DPU-25 is approximately 15%. However, the AR coating on the DPU-25-C reduces the loss due to reflections to approximately 2%.



Click to Enlarge
Theoretical transmission as a function of wavelength through an uncoated DPU-25 depolarizer.



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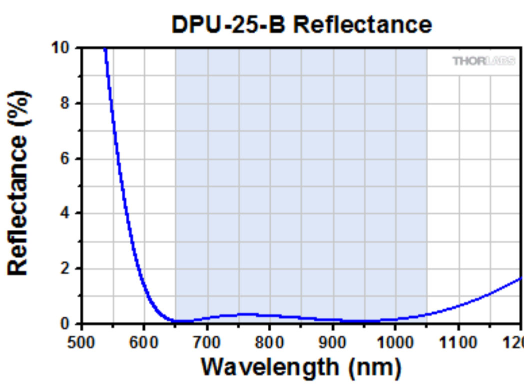
Theoretical percent reflectance as a function of wavelength for the AR-coated surfaces of the DPU-25-A depolarizer.



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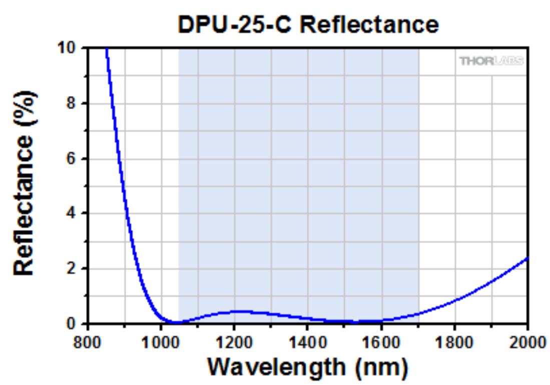
Theoretical percent reflectance as a function of wavelength for the AR-coated surfaces of the DPU-25-B depolarizer.



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Theoretical percent reflectance as a function of wavelength for the AR-coated surfaces of the DPU-25-C depolarizer.

Click Here to download reflectance data for all three AR coatings available.

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DPU-25-A


DPU-25


DPU-25-B


DPU-25-C


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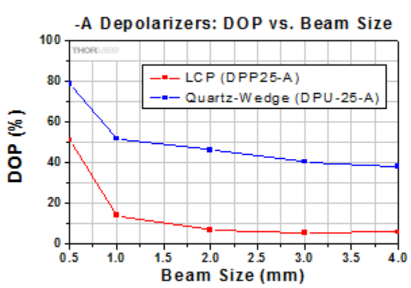
The following plots compare the degree of polarization (DOP) that can be achieved using the liquid crystal polymer (LCP) patterned depolarizers and our quartz-wedge depolarizers. Compared to the quartz wedge depolarizers, the LCP patterned depolarizers show greater performance stability with changing angle of incidence and can effectively depolarize smaller beam sizes, which is especially useful for laser applications. In contrast, the quartz-wedge depolarizers have a higher surface quality and damage threshold. They also provide better performance for depolarizing elliptically and circularly polarized light.

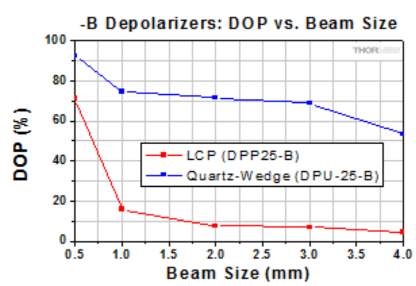
Depolarizer Comparison Table

Depolarizer Type	LCP Patterned Retarder	Quartz-Wedge Design
Effective Beam Size	Down to Ø0.5 mm	Down to Ø6 mm
Surface Quality	60-40 Scratch-Dig	10-5 Scratch Dig
Thickness	3.2 mm (0.13")	7.35 mm (0.289")
Available Wavelengths	350 - 700 nm (AR Coated) 650 - 1050 nm (AR Coated) 1050 - 1700 nm (AR Coated)	190 - 2500 nm (Uncoated) 350 - 700 nm (AR Coated) 650 - 1050 nm (AR Coated) 1050 - 1700 nm (AR Coated)

Degree of Polarization vs. Beam Size



Click to Enlarge
The DPP25-A is an LCP depolarizer and the DPU-25-A is one of Thorlabs' quartz-wedge depolarizers. This test was performed using a 532 nm CPS532 laser diode module (1 nm FWHM bandwidth).



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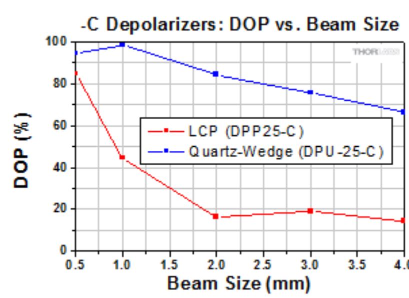
The DPP25-B is an LCP depolarizer and the DPU-25-B is one of Thorlabs' quartz-wedge depolarizers. This test was performed using a 780 nm CPS192 laser diode module (1 nm FWHM bandwidth).



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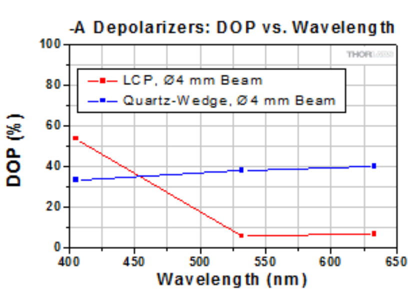
The DPP25-C is an LCP depolarizer and the DPU-25-C is one of Thorlabs' quartz-wedge depolarizers. This test was performed using a 1310 nm MCLS1-1310 laser diode module (1 nm FWHM bandwidth).

Degree of Polarization vs. Wavelength



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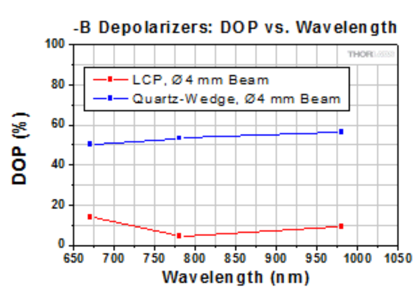
The DPP25-A is an LCP depolarizer and the DPU-25-A is one of Thorlabs' quartz-wedge depolarizers. This test was performed at three wavelengths using three different lasers



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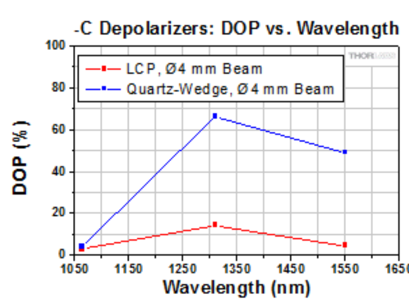
The DPP25-B is an LCP depolarizer and the DPU-25-B is one of Thorlabs' quartz-wedge depolarizers. This test was performed at three wavelengths using three different lasers



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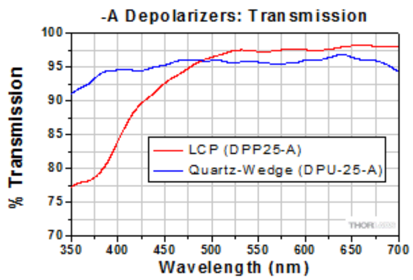
The DPP25-C is an LCP depolarizer and the DPU-25-C is one of Thorlabs' quartz-wedge depolarizers. This test was performed

with a Ø4 mm beam size: 405 nm (CPS405, 1 nm FWHM bandwidth), 532 nm (CPS532, 1 nm FWHM bandwidth), and 633 nm (HRS015, <10 pm FWHM bandwidth).

with a Ø4 mm beam size: 670 nm (CPS186, 1 nm FWHM bandwidth), 780 nm (CPS192, 1 nm FWHM bandwidth), and 980 nm (CPS980, 1 nm FWHM bandwidth).

performed at three wavelengths using three different lasers with a Ø4 mm beam size: 1064 nm (1.5 nm FWHM bandwidth), 1310 nm (MCLS1-1310, 1 nm FWHM bandwidth), and 1550 nm (TLS001-1550, 1 nm FWHM bandwidth).

Depolarizer Transmission



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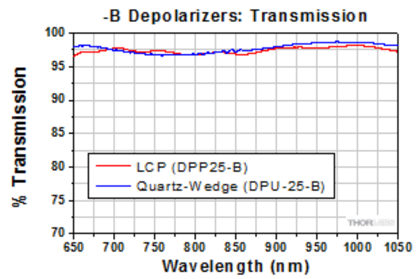
The DPP25-A is an LCP depolarizer and the DPU-25-A is one of Thorlabs' quartz-wedge depolarizers.



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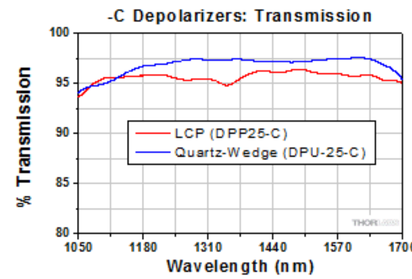
The DPP25-B is an LCP depolarizer and the DPU-25-B is one of Thorlabs' quartz-wedge depolarizers.



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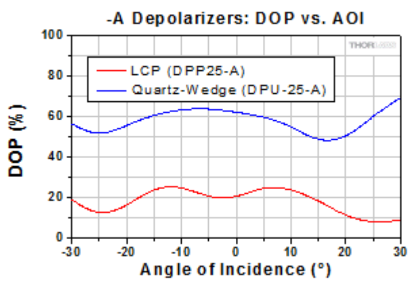
The DPP25-C is an LCP depolarizer and the DPU-25-C is one of Thorlabs' quartz-wedge depolarizers.

Degree of Polarization vs. Angle of Incidence



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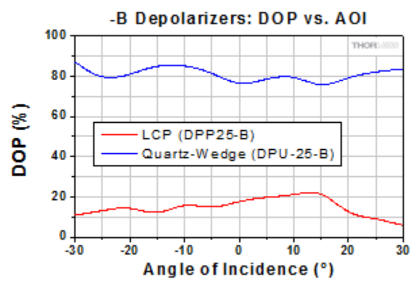
The DPP25-A is an LCP depolarizer and the DPU-25-A is one of Thorlabs' quartz-wedge depolarizers. This test was performed using a 532 nm CPS532 laser diode module (1 nm FWHM bandwidth) with a beam size of Ø1 mm.



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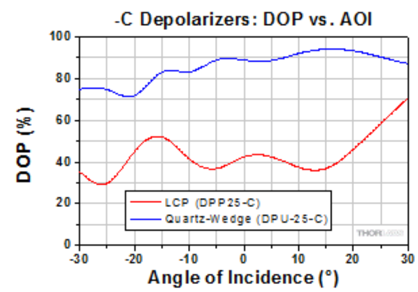
The DPP25-B is an LCP depolarizer and the DPU-25-B is one of Thorlabs' quartz-wedge depolarizers. This test was performed using a 780 nm laser diode module (CPS192, 1 nm FWHM bandwidth) with a beam size of Ø1 mm.



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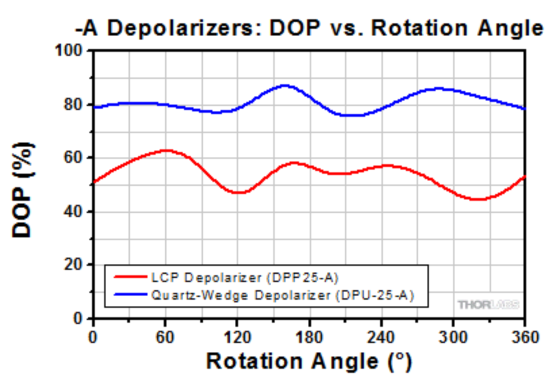
The DPP25-C is an LCP depolarizer and the DPU-25-C is one of Thorlabs' quartz-wedge depolarizers. This test was performed using a 1310 nm MCLS1-1310 laser diode module (1 nm FWHM bandwidth) with a beam size of Ø1 mm.

Degree of Polarization vs. Rotation Angle

The plot below is provided as an example of the variation in Degree of Polarization as the depolarizer is rotated. Actual performance will vary from depolarizer to depolarizer, depending on the alignment of the LCP pattern and the section of the depolarizer illuminated by the incident beam. Rotating a depolarizer around an axis perpendicular to its surface does cause some variation in performance, but overall, the LCP depolarizer still provides a lower degree of polarization for a Ø0.5 mm beam than the quartz-wedge design. Similar results can be expected from the -B and -C depolarizers.



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The plot above shows the performance of the depolarizer as it is rotated. The test was performed using a 532 nm CPS532 laser diode module (1 nm FWHM bandwidth) with a beam size of Ø0.5 mm. For the quartz-wedge depolarizer, 0° corresponds to the cut edge marking the fast axis of the thick wedge. For the LCP depolarizer, 0° corresponds to the line of parallel fast-axes orientations (see the *Overview* tab for a plot of the fast-axis orientations).

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			DPU-25-B	Quartz-Wedge Achromatic Depolarizer, Ø25.4 mm, AR Coating: 650 - 1050 nm	$650.25	√	Today
			DPU-25-C	Quartz-Wedge Achromatic Depolarizer, Ø25.4 mm, AR Coating: 1050 - 1700 nm	$650.25	√	Today

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DPU-25 **DPU-25-A** **DPU-25-B** **DPU-25-C**

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Spatial Periodicity in the Polarization of the Output Beam

The spatial periodicity in the polarization of the output beam of the polarizer is easily observed when a linearly polarized monochromatic light source is used. The linearly polarized monochromatic beam must have a beam waist larger than 6 mm to generate this spatial periodicity. To observe this effect, place the quartz-wedge depolarizer in the beam so that propagation direction of the beam is normal to and incident upon the thicker wedge of the depolarizer.

To detect the beam's spatial periodicity, place a linear polarizer (analyzer) after the beam exits the quartz-wedge depolarizer. The intensity variation will be banded as shown in the false-color plots shown below. The banding occurs because the degree to which the state of polarization is rotated is identical along any line perpendicular to the thick wedge incline. Several examples of different incident and depolarizer angles are discussed below.

Example 1:

In the first example, a 635 nm, linearly polarized source with a 20 mm beam waist is used. The source light is incident on and propogating normal to the thick wedge of the depolarizer. The light is polarized in the same direction as the optic (fast) axis of the thick wedge. The optic axis of the thin wedge is at a 45^{o} angle with respect to both the incident light polarization and the optic axis of the thick wedge. In this orientation, the wedge incline is also oriented parallel to the incident light polarization.

The orientation of the input polarization and optic axis of the thick and thin wedges is shown in Figure 1. The input polarization is shown in red, the thick wedge optic axis in blue, and the thin wedge optic axis in green. The flat on the top of the depolarizer drawing (solid blue line) is cut perpendicular to the thick wedge optic axis. The flat on the side of the drawing (dashed blue line) is cut perpendicular to the thin wedge optic axis.

A theoretical plot showing the spatially-dependent polarization angle is shown in Figure 2. This false-color plot shows the polarization angle of the output beam from the quartz-wedge depolarizer based on the input beam characteristics described above.

The bands in the false-color plot represent different regions of identical polarization with polarizations varying from being completely along the horizontal axis (perpendicular to the input polarization) to completely along the vertical axis (parallel to the input beam polarization). The separation between the two polarizations in this case is approximately 2 mm. The orientation of the bands are always perpendicular with the thick wedge optic axis, and in this case, are also perpendicular to the input polarization.

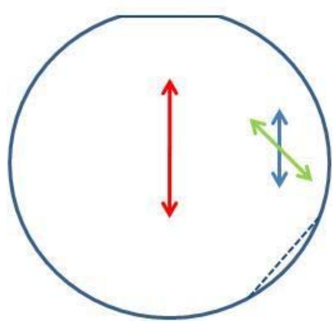

Figure 1. Input polarization in a parallel arrangement with the optic axis of the thick wedge.

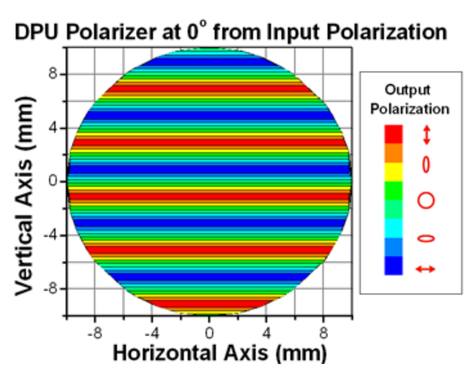

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Figure 2. False-color plot of a calculation showing a linearly polarized input beam parallel to the optic axis of the thick wedge after passing through the depolarizer.

Example 2:

In this example, the same linearly polarized source is used, except the polariation is oriented parallel to the optic axis of the thin wedge and at a 45 degree angle from the optic axis of the thick wedge. The orientation of the input polarization and optic axes of the thick and thin wedges are shown in Figure 3. The input polarization is shown in red, the thick wedge optic axis in blue, and the thin wedge optic axis in green. The flat on the top of the depolarizer drawing (solid blue line) is cut perpendicular to the thick wedge optic axis. The flat on the side of the drawing (dashed blue line) is cut perpendicular to the thin wedge optic axis.

The calculated result for the source and orientation passing through the quartz-wedge depolarizer is shown in Figure 4. As described in Figure 2, the bands in the false-color plot represent the the spatially-dependent regions of identical polarization. Note the orientation of the banding is perpendicular to the optic axis of the thick wedge (and wedge incline as well). The orientation of the input beam has no effect on the orientation of the banding.

Rotating the input polarization only affects the specific polarization of the band. This is easily observed by comparing the bands at 0 mm on the vertical axis in Figs. 2 and 4. In Figure 2, the band at 0 mm has a 45º orientation while in Figure 4, the band at 0 mm has a 90º orientation.

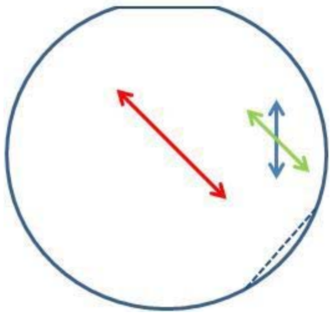

Figure 3. Input polarization in a parallel arrangement with the optic axis of the thin wedge.

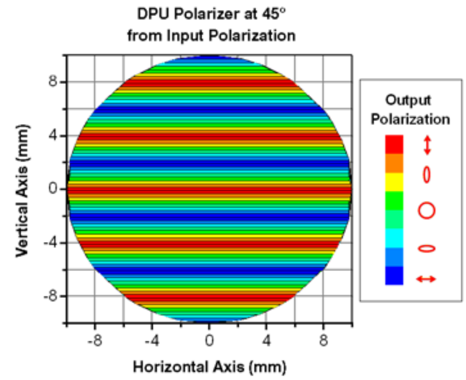

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Figure 4. False-color plot of a calculation showing a linearly polarized input beam parallel to the optical axis of the thin wedge after passing through the depolarizer.

Example 3:

In this last example, the input beam has the same characteristics as in Example 1. However, the quartz-wedge depolarizer is rotated 45º so the input polarization is parallel to the optic axis of the thin wedge. This arrangement is shown in Fig. 5. The input polarization (red arrow) is still incident on the thick wedge; however, it is now perpendicular to the thin wedge flat.

The false-color plot in Fig. 6 shows the calculation result of the input beam described above passing through the quartz-wedge depolarizer. The orientation of the banding is clearly different from the banding in Figs. 2 and 4. The 45º tilt in the pattern is because the banding occurs perpendicular to both the optic axis of the thick wedge and wedge incline.

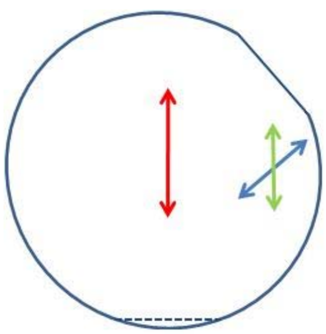

Figure 5. Input polarization in a parallel arrangement with the optic axis of the thin wedge and 45º to the wedge plane.

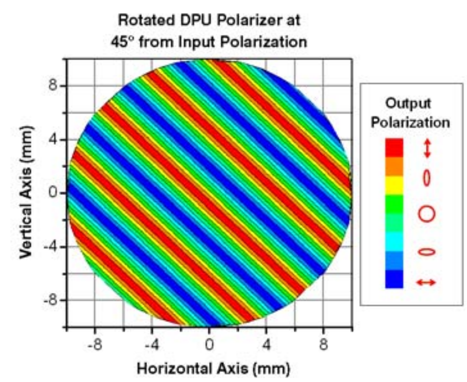

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Figure 6. False-color plot of a calculation showing a linearly polarized input beam parallel to the optic axis of the thin wedge after passing through the depolarizer at a 45º angle to the wedge plane.

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Damage Threshold Data for Thorlabs' Achromatic Depolarizers

The specifications to the right are measured data for Thorlabs' achromatic depolarizers.

Damage Threshold Specifications	
Item # Suffix	Damage Threshold
-A	7.5 J/cm² at 532 nm, 10 ns, 10 Hz, Ø0.504 mm
-B	7.5 J/cm² at 810 nm, 10 ns, 10 Hz, Ø0.144 mm
-C	7.5 J/cm² at 1542 nm, 10 ns, 10 Hz, Ø0.123 mm

Laser Induced Damage Threshold Tutorial

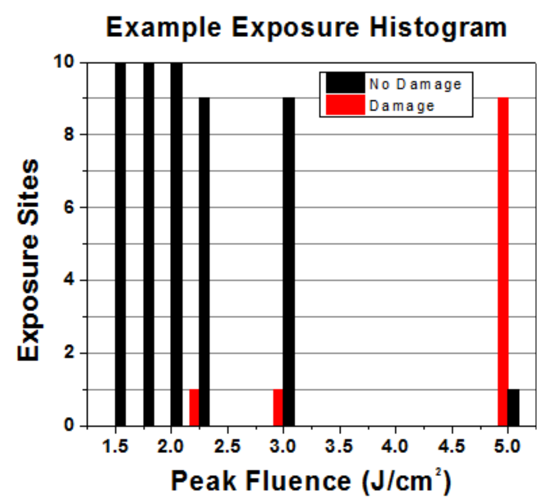
The following is a general overview of how laser induced damage thresholds are measured and how the values may be utilized in determining the appropriateness of an optic for a given application. When choosing optics, it is important to understand the Laser Induced Damage Threshold (LIDT) of the optics being used. The LIDT for an optic greatly depends on the type of laser you are using. Continuous wave (CW) lasers typically cause damage from thermal effects (absorption either in the coating or in the substrate). Pulsed lasers, on the other hand, often strip electrons from the lattice structure of an optic before causing thermal damage. Note that the guideline presented here assumes room temperature operation and optics in new condition (i.e., within scratch-dig spec, surface free of contamination, etc.). Because dust or other particles on the surface of an optic can cause damage at lower thresholds, we recommend keeping surfaces clean and free of debris. For more information on cleaning optics, please see our *Optics Cleaning* tutorial.

Testing Method

Thorlabs' LIDT testing is done in compliance with ISO/DIS11254 specifications. A standard 1-on-1 testing regime is performed to test the damage threshold.

First, a low-power/energy beam is directed to the optic under test. The optic is exposed in 10 locations to this laser beam for a set duration of time (CW) or number of pulses (pulse repetition frequency specified). After exposure, the optic is examined by a microscope (~100X magnification) for any visible damage. The number of locations that are damaged at a particular power/energy level is recorded. Next, the power/energy is either increased or decreased and the optic is exposed at 10 new locations. This process is repeated until damage is observed. The damage threshold is then assigned to be the highest power/energy that the optic can withstand without causing damage. A histogram such as that below represents the testing of one BB1-E02 mirror.

The photograph above is a protected aluminum-coated mirror after LIDT testing. In this particular test, it handled 0.43 J/cm^2 (1064 nm, 10 ns pulse, 10 Hz, Ø1.000 mm) before damage.



According to the test, the damage threshold of the mirror was 2.00 J/cm^2 (532 nm, 10 ns pulse, 10 Hz, Ø0.803 mm). Please keep in mind that these tests are performed on clean optics, as dirt and contamination can significantly lower the damage threshold of a component. While the test results are only representative of one coating run, Thorlabs specifies damage threshold values that account for coating variances.

Example Test Data			
Fluence	# of Tested Locations	Locations with Damage	Locations Without

Continuous Wave and Long-Pulse Lasers

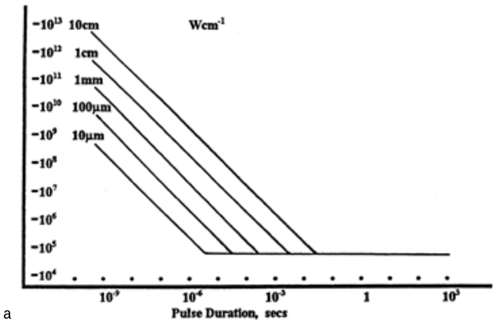
When an optic is damaged by a continuous wave (CW) laser, it is usually due to the melting of the surface as a result of absorbing the laser's energy or damage to the optical coating (antireflection) [1]. Pulsed lasers with pulse lengths longer than 1 µs can be treated as CW lasers for LIDT discussions. Additionally, when pulse lengths are between 1 ns and 1 µs, LIDT can occur either because of absorption or a dielectric breakdown (must check both CW and pulsed LIDT). Absorption is either due to an intrinsic property of the optic or due to surface irregularities; thus LIDT values are only valid for optics meeting or exceeding the surface quality specifications given by a manufacturer. While many optics can handle high power CW lasers, cemented (e.g., achromatic doublets) or highly absorptive (e.g., ND filters) optics tend to have lower CW damage thresholds. These lower thresholds are due to absorption or scattering in the cement or metal coating.

			Damage
1.50 J/cm^2	10	0	10
1.75 J/cm^2	10	0	10
2.00 J/cm^2	10	0	10
2.25 J/cm^2	10	1	9
3.00 J/cm^2	10	1	9
5.00 J/cm^2	10	9	1

Pulsed lasers with high pulse repetition frequencies (PRF) may behave similarly to CW beams. Unfortunately, this is highly dependent on factors such as absorption and thermal diffusivity, so there is no reliable method for determining when a high PRF laser will damage an optic due to thermal effects. For beams with a large PRF both the average and peak powers must be compared to the equivalent CW power. Additionally, for highly transparent materials, there is little to no drop in the LIDT with increasing PRF.

In order to use the specified CW damage threshold of an optic, it is necessary to know the following:

1. Wavelength of your laser
2. Linear power density of your beam (total power divided by 1/e^2 spot size)
3. Beam diameter of your beam (1/e^2)
4. Approximate intensity profile of your beam (e.g., Gaussian)

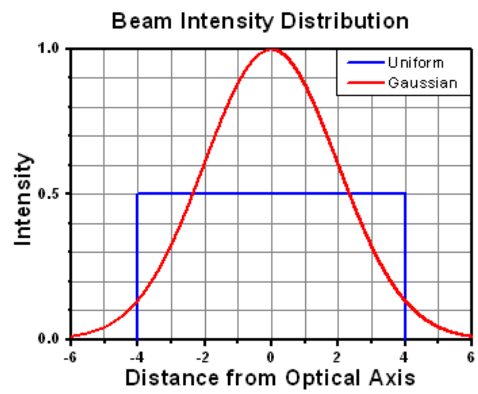


LIDT in linear power density vs. pulse length and spot size. For long pulses to CW, linear power density becomes a constant with spot size. This graph was obtained from [1].

The power density of your beam should be calculated in terms of W/cm. The graph to the right shows why the linear power density provides the best metric for long pulse and CW sources. Under these conditions, linear power density scales independently of spot size; one does not need to compute an adjusted LIDT to adjust for changes in spot size. This calculation assumes a uniform beam intensity profile. You must now consider hotspots in the beam or other nonuniform intensity profiles and roughly calculate a maximum power density. For reference, a Gaussian beam typically has a maximum power density that is twice that of the uniform beam (see lower right).

Now compare the maximum power density to that which is specified as the LIDT for the optic. If the optic was tested at a wavelength other than your operating wavelength, the damage threshold must be scaled appropriately. A good rule of thumb is that the damage threshold has a linear relationship with wavelength such that as you move to shorter wavelengths, the damage threshold decreases (i.e., a LIDT of 10 W/cm at 1310 nm scales to 5 W/cm at 655 nm):

$$Adjusted\ LIDT = LIDT\ Power \left(\frac{Your\ Wavelength}{LIDT\ Wavelength}\right)$$



While this rule of thumb provides a general trend, it is not a quantitative analysis of LIDT vs wavelength. In CW applications, for instance, damage scales more strongly with absorption in the coating and substrate, which does not necessarily scale well with wavelength. While the above procedure provides a good rule of thumb for LIDT values, please contact Tech Support if your wavelength is different from the specified LIDT wavelength. If your power density is less than the adjusted LIDT of the optic, then the optic should work for your application.

Please note that we have a buffer built in between the specified damage thresholds online and the tests which we have done, which accommodates variation between batches. Upon request, we can provide individual test information and a testing certificate. The damage analysis will be carried out on a similar optic (customer's optic will not be damaged). Testing may result in additional costs or lead times. Contact Tech Support for more information.

Pulsed Lasers

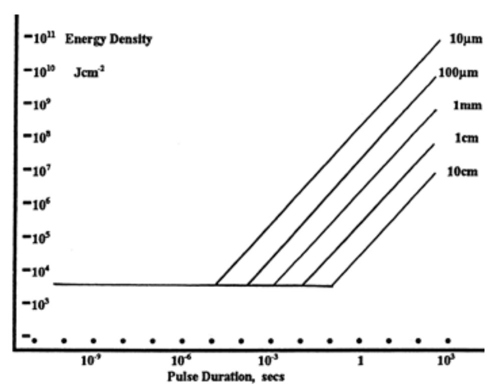
As previously stated, pulsed lasers typically induce a different type of damage to the optic than CW lasers. Pulsed lasers often do not heat the optic enough to damage it; instead, pulsed lasers produce strong electric fields capable of inducing dielectric breakdown in the material. Unfortunately, it can be very difficult to compare the LIDT specification of an optic to your laser. There are multiple regimes in which a pulsed laser can damage an optic and this is based on the laser's pulse length. The highlighted columns in the table below outline the relevant pulse lengths for our specified LIDT values.

Pulses shorter than 10^{-9} s cannot be compared to our specified LIDT values with much reliability. In this ultra-short-pulse regime various mechanics, such as multiphoton-avalanche ionization, take over as the predominate damage mechanism [2]. In contrast, pulses between 10^{-7} s and 10^{-4} s may cause damage to an optic either because of dielectric breakdown or thermal effects. This means that both CW and pulsed damage thresholds must be compared to the laser beam to determine whether the optic is suitable for your application.

Pulse Duration	$t < 10^{-9}$ s	$10^{-9} < t < 10^{-7}$ s	$10^{-7} < t < 10^{-4}$ s	$t > 10^{-4}$ s
Damage Mechanism	Avalanche Ionization	Dielectric Breakdown	Dielectric Breakdown or Thermal	Thermal
Relevant Damage Specification	N/A	Pulsed	Pulsed and CW	CW

When comparing an LIDT specified for a pulsed laser to your laser, it is essential to know the following:

1. Wavelength of your laser
2. Energy density of your beam (total energy divided by 1/e^2 area)
3. Pulse length of your laser
4. Pulse repetition frequency (prf) of your laser
5. Beam diameter of your laser (1/e^2)
6. Approximate intensity profile of your beam (e.g., Gaussian)



LIDT in energy density vs. pulse length and spot size. For short pulses, energy density becomes a constant with spot size. This graph was obtained from [1].

The energy density of your beam should be calculated in terms of J/cm^2. The graph to the right shows why the energy density provides the best metric for short pulse sources. Under these conditions, energy density scales independently of spot size, one does not need to compute an adjusted LIDT to adjust for changes in spot size. This calculation assumes a uniform beam intensity profile. You must now adjust this energy density to account for hotspots or other nonuniform intensity profiles and roughly calculate a maximum energy density. For reference a Gaussian beam typically has a maximum energy density that is twice that of the 1/e^2 beam.

Now compare the maximum energy density to that which is specified as the LIDT for the optic. If the optic was tested at a wavelength other than your operating wavelength, the damage threshold must be scaled appropriately [3]. A good rule of thumb is that the damage threshold has an inverse square root relationship with wavelength such that as you move to shorter wavelengths, the damage threshold decreases (i.e., a LIDT of 1 J/cm^2 at 1064 nm scales to 0.7 J/cm^2 at 532 nm):

$$Adjusted\ LIDT = LIDT\ Energy \sqrt{\frac{Your\ Wavelength}{LIDT\ Wavelength}}$$

You now have a wavelength-adjusted energy density, which you will use in the following step.

Beam diameter is also important to know when comparing damage thresholds. While the LIDT, when expressed in units of J/cm2, scales independently of spot size; large beam sizes are more likely to illuminate a larger number of defects which can lead to greater variances in the LIDT [4]. For data presented here, a <1 mm beam size was used to measure the LIDT. For beams sizes greater than 5 mm, the LIDT (J/cm2) will not scale independently of beam diameter due to the larger size beam exposing more defects.

The pulse length must now be compensated for. The longer the pulse duration, the more energy the optic can handle. For pulse widths between 1 - 100 ns, an approximation is as follows:

$$Adjusted\ LIDT = LIDT\ Energy \sqrt{\frac{Your\ Pulse\ Length}{LIDT\ Pulse\ Length}}$$

Use this formula to calculate the Adjusted LIDT for an optic based on your pulse length. If your maximum energy density is less than this adjusted LIDT maximum energy density, then the optic should be suitable for your application. Keep in mind that this calculation is only used for pulses between 10^{-9} s and 10^{-7} s. For pulses between 10^{-7} s and 10^{-4} s, the CW LIDT must also be checked before deeming the optic appropriate for your application.

Please note that we have a buffer built in between the specified damage thresholds online and the tests which we have done, which accommodates variation between batches. Upon request, we can provide individual test information and a testing certificate. Contact Tech Support for more information.

[1] R. M. Wood, Optics and Laser Tech. **29**, 517 (1997).
[2] Roger M. Wood, *Laser-Induced Damage of Optical Materials* (Institute of Physics Publishing, Philadelphia, PA, 2003).
[3] C. W. Carr *et al.*, Phys. Rev. Lett. **91**, 127402 (2003).
[4] N. Bloembergen, Appl. Opt. **12**, 661 (1973).

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MIR Wire Grid Polarizers on Silicon Substrates	Glan-Taylor Polarizers	Yttrium Orthovanadate Beam Displacers	Quartz-Wedge Depolarizers
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