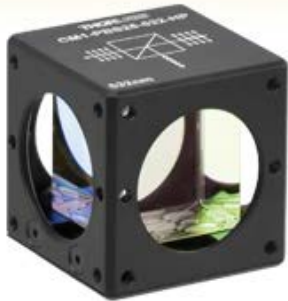


## CM1-PBS25-532-HP - Nov. 18, 2016

Item # CM1-PBS25-532-HP was discontinued on Nov. 18, 2016. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

### HIGH-POWER, LASER LINE, POLARIZING BEAMSPLITTER CUBES, MOUNTED

- ▶ **Damage Threshold:  $>10 \text{ J/cm}^2$**
- ▶ **Available Wavelengths: 405, 532, 633, 780, and 1064 nm**
- ▶ **SM1 and 30 mm Cage System Compatible**



CM1-PBS25-532-HP



CCM1-PBS25-1064-HP



Mounted Beamsplitting  
Cube in 30 mm Cage Setup

[Hide Overview](#)

#### OVERVIEW

##### Features

- High Damage Threshold:  $>10 \text{ J/cm}^2$
- Available for 405 nm, 532 nm, 633 nm, 780 - 808 nm, or 1064 nm Wavelengths
- Optical Contact at Beamsplitter Interface
- 1" (25.4 mm) Cubes in 30 mm Cage System Compatible Mounts
- Four SM1-Threaded (1.035"-40) Ports



Click for Details  
The engraving on the mount indicates the item # and one of the two preferred beam paths.

Thorlabs offers high-power, polarizing, beamsplitter cubes mounted in 30 mm cage system compatible housings, which features four SM1-threaded ports. These cubes separate the S and P polarization components by reflecting the S component at the dielectric beamsplitter coating, while allowing the P component to pass. For the highest polarization extinction ratio, use the transmitted beam, which offers an extinction ratio of  $T_p:T_s > 2000:1$ . These beamsplitter cubes have a dielectric V-coating on four faces that minimizes reflectance over the specified wavelengths. They are designed for use at 405 nm, 633 nm, the 780 - 808 nm range, or with one of two major Nd:YAG harmonics (532 nm or 1064 nm). For detailed specifications, please see the *Specs* tab.

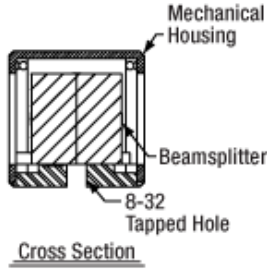
The beamsplitting interface of these cubes has an epoxy-free, optical contact bond, which results in insignificant levels of absorption and scattering loss. By polishing the internal diagonal surfaces of each cube to such a high flatness as to achieve optical contact, Thorlabs has been able to manufacture compact, thermally stable beamsplitter cubes with higher transmission and minimal beam displacement. Since the beamsplitting coating is only applied to one of the two diagonal surfaces prior to the optical contacting, for best results the prism should be oriented to utilize one of the entrance faces as indicated in the diagram to the right. Each part is engraved with the item number and a set of arrows showing one of the two preferred beam paths to ease in using these components.

Each beamsplitter cube is epoxied within the cage cube mount and cannot be removed from the mount. However, empty 30 mm cage cubes are available that are compatible with our line of unmounted polarizing beamsplitter cubes. The cage cube can be mounted on the post via an 8-32, M4, or M6 x 0.5 tapped hole on the bottom; cubes with an M6 x 0.5 tap include two adapters for 8-32 and M4 post mounting. These cage cubes have four SM1-threaded ports. Additional cube-compatible SM1-threaded  $\text{\O}1/2$ " rotation mounts are also offered separately. Other cage cubes can be connected to this housing through the use of cage rods and our ERSCA adapters.

For a complete selection of our cube-mounted optics please see the *Mounted Optics Guide* tab.

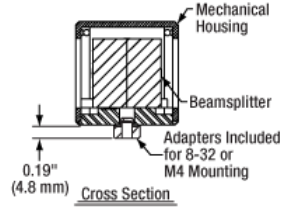
We are in the process of updating our Mounted Beamsplitter Cubes from a housing that requires mounting adapters to housings with dedicated 8-32 or M4 taps. A mixture of imperial, metric, and universal items appear below. Please see these drawings for key differences between these versions.

### Imperial Cage Cube



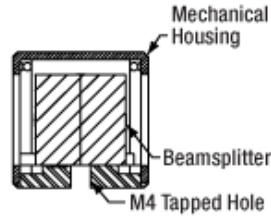
Cross Section  
 Click for Details  
 The imperial cage cube has an 8-32 mounting tap on the bottom.

### Universal Cage Cube



Cross Section  
 Click for Details  
 The universal cage cube has an M6 x 0.5 tap on the bottom. Two adapters are included for 8-32 or M4 post mounting.

### Metric Cage Cube



Cross Section  
 Click for Details  
 The metric cage cube has an M4 x 0.7 mounting tap on the bottom.

[Hide Specs](#)

## S P E C S

Item #	Design Wavelength	Damage Threshold	Mounting Tap
CCM1-PBS25-405-HP	405 nm	70 W/cm (405 nm, CW, Ø30 µm) <sup>a</sup>	8-32
CCM1-PBS25-405-HP/M			M4 x 0.7
CM1-PBS25-532-HP	532 nm	>10 J/cm <sup>2</sup> (532 nm, 10 ns, 10 Hz, Ø0.43 mm)	M6 x 0.5 with 8-32 and M4 Adapters
CCM1-PBS25-633-HP	633 nm	-	8-32
CCM1-PBS25-633-HP/M			M4 x 0.7
CM1-PBS25-780-HP	780 nm	>10 J/cm <sup>2</sup> (810 nm, 10 ns, 10 Hz, Ø0.062 mm)	M6 x 0.5 with 8-32 and M4 Adapters
CCM1-PBS25-1064-HP	1064 nm	>10 J/cm <sup>2</sup> (1064 nm, 10 ns, 10 Hz, Ø1.00 mm)	8-32
CCM1-PBS25-1064-HP/M			M4 x 0.7

- This is a certification measurement. Instead of damaging the optic, the maximum power of the laser was reached with no damage. The power density of your beam should be calculated in terms of W/cm. For an explanation of why linear power density provides the best metric for long pulse and CW sources, please see the *Damage Thresholds* tab.

Common Specifications	
Beamsplitter Cube Size	1" (25.4 mm)
Material	UV Fused Silica
AR Coating Reflection	<0.25% at Design Wavelength
Extinction Ratio <sup>a</sup>	T <sub>p</sub> :T <sub>s</sub> > 2000:1
Transmission Efficiency	T <sub>p</sub> > 95%
Reflection Efficiency	R <sub>s</sub> > 99.5%
Transmitted Beam Deviation	±5 arcmin

Reflected Beam Deviation	90° ± 20 arcmin
Clear Aperture	>Ø20.3 mm
Transmitted Wavefront Error <sup>b</sup>	<λ/4 at 633 nm
Surface Flatness	λ/10 at 633 nm
Surface Quality	20-10 Scratch-Dig

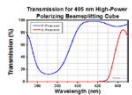
- The extinction ratio (ER) is the ratio of the maximum transmission of a linearly polarized signal when the polarizer's axis is aligned with the signal to the minimum transmission when the polarizer is rotated by 90°.
- Wavefront error is for both the transmitted and reflected beams.

[Hide Graphs](#)

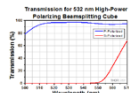
## GRAPHS

### Transmission and Reflection Data

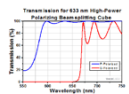
This tab contains plots for the typical transmission of our high-power polarizing beamsplitter cubes and plots of the reflectance for the AR coatings used on the outer surfaces of the cubes.



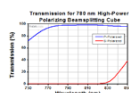
[Click to Enlarge](#)  
[Click Here for Raw Data](#)



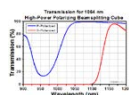
[Click to Enlarge](#)  
[Click Here for Raw Data](#)



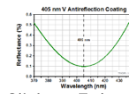
[Click to Enlarge](#)  
[Click Here for Raw Data](#)



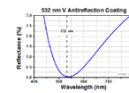
[Click to Enlarge](#)  
[Click Here for Raw Data](#)



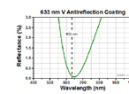
[Click to Enlarge](#)  
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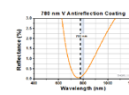
[Click to Enlarge](#)  
[Click Here for Raw Data](#)



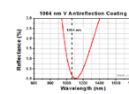
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[Hide Application Idea](#)

## APPLICATION IDEA

### Variable Beamsplitter/Attenuator

Thorlabs offers several variable beamsplitters/attenuators designed for discrete wavelengths that can be used to continuously vary the transmitted intensity of a linearly polarized beam of light. If you are interested in a variable attenuator at another wavelengths or for use with higher powers, it is possible to build your own using one of our mounted high-power beamsplitter cubes, a half-wave plate, and the CRM05 rotation mount.

## Operation

Linearly polarized light enters the beamsplitter/attenuator through the half-wave plate and is rotated by twice the angle between the half-wave plate's fast axis and the polarization of the incoming beam. Next, the light encounters the beamsplitter cube, where it is separated into its P and S polarization states. The P-polarized light passes straight through the cube, while the S-polarized light is reflected at a 90° angle out the side of the cube. The ratio of P:S polarized light entering the beamsplitter cube can be continuously varied by changing the angle of the half-wave plate's fast axis.

The transmitted output of the variable beamsplitter/attenuator will have the same polarization state as the incoming light if the incident beam is P-polarized. For a P-polarized incoming beam, maximum transmission is achieved when the fast axis is aligned to the beam polarization. Minimum transmission occurs when the fast-axis of the wave plate is at a 45° angle to the incoming beam: the light will be rotated to the S-polarization and be reflected out the side of the beamsplitting cube.

## Construction

The example shown here uses a CCM1-PBS25-405-HP polarizing beamsplitter cube, a WPMH05M-405 Ø1/2" half-wave plate, and the CRM05 rotation mount. When selecting a beamsplitter cube and wave plate to use, make sure that they are optimized for the same wavelength and that any damage thresholds provided suit your application.

1. Begin by removing the half-wave plate from its mount. The wave plate is held in the mount by an SM05RR retaining ring, which can be loosened using an SPW603 spanner wrench. The edge of the wave plate is polished flat to mark the fast axis.
2. Install the wave plate in the CRM05 using the included SM05RR retaining ring. Make sure to note the engraved angle on the CRM05 that aligns with the fast-axis of the wave plate.
3. Screw the assembly into the input port of the polarizing beamsplitter cube.

The variable beamsplitter/attenuator is now ready for use.



Click to Enlarge  
Components to build a variable beamsplitter/attenuator are shown here.

Component	Quantity
Mounted High-Power Beamsplitter Cube	1
Ø1/2" Half-Wave Plate	1
Continuous Rotation Mount (CRM05)	1
Spanner Wrench for SM05 Retaining Rings (SPW603)	1

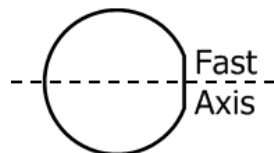
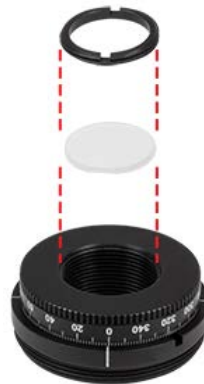


Figure 1. A flat section on the edge of the wave plate marks the fast axis.



Click to Enlarge  
Figure 2. Mount the Ø1/2" wave plate in the CRM05 rotation mount using the included SM05RR retaining ring.



Click to Enlarge  
Figure 3. Screw the rotation mount onto the SM1-threaded input aperture of the mounted beamsplitter cube to complete the variable attenuator.

[Hide Mounted Optics Guide](#)

## MOUNTED OPTICS GUIDE

### 30 mm Cage-Cube-Mounted Optics Selection Guide

The table below provides links to all of our 30 mm Cage-Cube-Mounted optics. For our selection of 16 mm Cage-Cube-Mounted Optics, please see our 16 mm Cage Systems guide.

--	--	--

		
Non-Polarizing Beamsplitter Cube	Polarizing Beamsplitter Cube	High-Power Polarizing Beamsplitter Cube
		
Pellicle Beamsplitters	Laser Line Polarizing Beamsplitter Cube	Circular / Variable Polarizers
		
Penta Prisms	Turning Mirrors	Variable Beamsplitters / Attenuators

### 30 mm Cage Cube Empty Optic Mounts Selection Guide

	
Rectangular Dichroic Mirrors and Filters	Empty Compact 30 mm Cage Cube

[Hide Damage Thresholds](#)

## DAMAGE THRESHOLDS

### Damage Threshold Data for Thorlabs' High-Power, Polarizing, Beamsplitter Cube

The specifications to the right are measured data for Thorlabs' polarizing beamsplitter cubes.

Damage Threshold Specifications	
Design Wavelength	Damage Threshold
405 nm	70 W/cm (405 nm, CW, Ø30 µm) <sup>a,b</sup>
532 nm	>10 J/cm <sup>2</sup> (532 nm, 10 ns, 10 Hz, Ø0.43 mm)
780 - 808 nm	>10 J/cm <sup>2</sup> (810 nm, 10 ns, 10 Hz, Ø0.062 mm)
1064 nm	>10 J/cm <sup>2</sup> (1064 nm, 10 ns, 10 Hz, Ø1.00 mm)

- The stated damage threshold is a certification measurement, as opposed to a true damage threshold (i.e., the optic was able to withstand the maximum output of the laser with no damage).
- The power density of your beam should be calculated in terms of W/cm. For an explanation of why the linear power density provides the best metric for long pulse and CW sources, please see the "Continuous Wave and Long-Pulse Lasers" section below.

### 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  $0.43 \text{ J/cm}^2$  (1064 nm, 10 ns pulse, 10 Hz,  $\text{Ø}1.000 \text{ mm}$ ) before damage.

According to the test, the damage threshold of the mirror was  $2.00 \text{ J/cm}^2$  (532 nm, 10 ns pulse, 10 Hz,  $\text{Ø}0.803 \text{ mm}$ ). 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.

## Continuous Wave and Long-Pulse Lasers

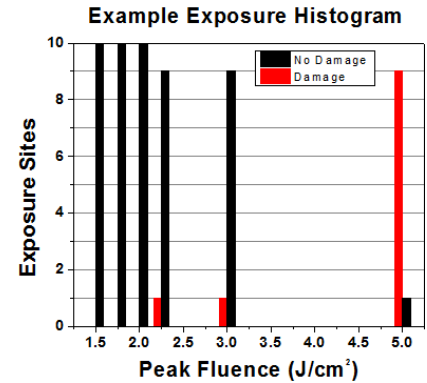
When an optic is damaged by a continuous wave (CW) laser, it is usually due to the melting of the surface as a result of absorbing the laser's energy or damage to the optical coating (antireflection) [1]. Pulsed lasers with pulse lengths longer than  $1 \mu\text{s}$  can be treated as CW lasers for LIDT discussions. Additionally, when pulse lengths are between 1 ns and  $1 \mu\text{s}$ , 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.

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.

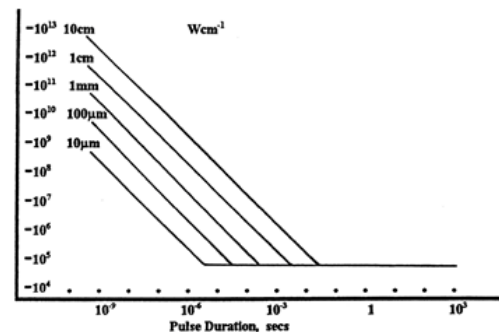
In order to use the specified CW damage threshold of an optic, it is necessary to know the following:

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

The power density of your beam should be calculated in terms of  $\text{W/cm}$ . The graph to the right shows why expressing the LIDT as a linear power density provides the best metric for long pulse and CW sources. In this regime, the LIDT given as a linear power density can be applied to any beam diameter; one does not need to compute an adjusted LIDT to adjust for changes in spot



Example Test Data			
Fluence	# of Tested Locations	Locations with Damage	Locations Without Damage
$1.50 \text{ J/cm}^2$	10	0	10
$1.75 \text{ J/cm}^2$	10	0	10
$2.00 \text{ J/cm}^2$	10	0	10
$2.25 \text{ J/cm}^2$	10	1	9
$3.00 \text{ J/cm}^2$	10	1	9
$5.00 \text{ J/cm}^2$	10	9	1



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].

size. This calculation assumes a uniform beam intensity profile. You must now consider hotspots in the beam or other non-uniform 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):

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

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.

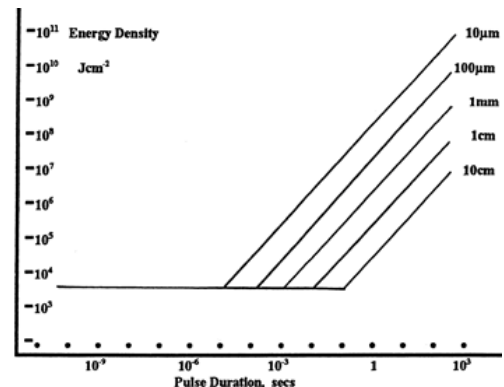
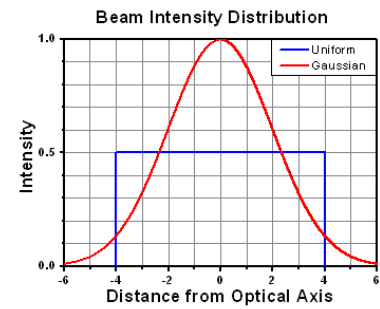
Pulses shorter than  $10^{-9}$  s cannot be compared to our specified LIDT values with much reliability. In this ultra-short-pulse regime various mechanics, such as multiphoton-avalanche ionization, take over as the predominate damage mechanism [2]. In contrast, pulses between  $10^{-7}$  s and  $10^{-4}$  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)

The energy density of your beam should be calculated in terms of  $J/cm^2$ . The graph to the right shows why expressing the LIDT as an energy density provides the best metric for short pulse sources. In this regime, the LIDT given as an energy density can be applied to any beam diameter; 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.



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].

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<sup>2</sup> at 1064 nm scales to 0.7 J/cm<sup>2</sup> at 532 nm):

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

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/cm<sup>2</sup>, 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/cm<sup>2</sup>) 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:

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

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<sup>-9</sup> s and 10<sup>-7</sup> s. For pulses between 10<sup>-7</sup> s and 10<sup>-4</sup> 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).

[Hide LIDT Calculations](#)

## LIDT CALCULATIONS

In order to illustrate the process of determining whether a given laser system will damage an optic, a number of example calculations of laser induced damage threshold are given below. For assistance with performing similar calculations, we provide a spreadsheet calculator that can be downloaded by clicking the button to the right. To use the calculator, enter the specified LIDT value of the optic under consideration and the relevant parameters of your laser system in the green boxes. The spreadsheet will then calculate a linear power density for CW and pulsed systems, as well as an energy density value for pulsed systems. These values are used to calculate adjusted, scaled LIDT values for the optics based on accepted scaling laws. This calculator assumes a Gaussian beam profile, so a correction factor must be introduced for other beam shapes (uniform, etc.). The LIDT scaling laws are determined from empirical relationships; their accuracy is not guaranteed. Remember that absorption by optics or coatings can significantly reduce LIDT in some spectral regions. These LIDT values are not valid for ultrashort pulses less than one nanosecond in duration.

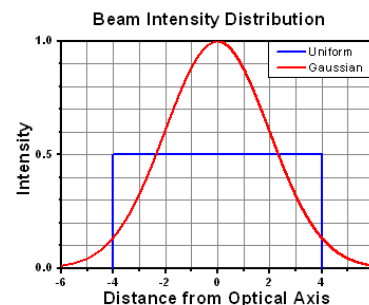
[LIDT Calculator](#)

### CW Laser Example

Suppose that a CW laser system at 1319 nm produces a 0.5 W Gaussian beam that has a 1/e<sup>2</sup> diameter of 10 mm. A naive calculation of the average linear power density of this beam would yield a value of 0.5 W/cm, given by the total power divided by the beam diameter:

$$\text{Linear Power Density} = \frac{\text{Power}}{\text{Beam Diameter}}$$

However, the maximum power density of a Gaussian beam is about twice the maximum power density of a uniform beam, as shown in the graph to the right. Therefore, a more accurate



A Gaussian beam profile has about twice the maximum



determination of the maximum linear power density of the system is 1 W/cm.

intensity of a uniform beam profile.

An AC127-030-C achromatic doublet lens has a specified CW LIDT of 350 W/cm, as tested at 1550 nm. CW damage threshold values typically scale directly with the wavelength of the laser source, so this yields an adjusted LIDT value:

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

The adjusted LIDT value of 350 W/cm x (1319 nm / 1550 nm) = 298 W/cm is significantly higher than the calculated maximum linear power density of the laser system, so it would be safe to use this doublet lens for this application.

#### **Pulsed Nanosecond Laser Example: Scaling for Different Pulse Durations**

Suppose that a pulsed Nd:YAG laser system is frequency tripled to produce a 10 Hz output, consisting of 2 ns output pulses at 355 nm, each with 1 J of energy, in a Gaussian beam with a 1.9 cm beam diameter ( $1/e^2$ ). The average energy density of each pulse is found by dividing the pulse energy by the beam area:

$$\text{Energy Density} = \frac{\text{Pulse Energy}}{\text{Beam Area}}$$

As described above, the maximum energy density of a Gaussian beam is about twice the average energy density. So, the maximum energy density of this beam is ~0.7 J/cm<sup>2</sup>.

The energy density of the beam can be compared to the LIDT values of 1 J/cm<sup>2</sup> and 3.5 J/cm<sup>2</sup> for a BB1-E01 broadband dielectric mirror and an NB1-K08 Nd:YAG laser line mirror, respectively. Both of these LIDT values, while measured at 355 nm, were determined with a 10 ns pulsed laser at 10 Hz. Therefore, an adjustment must be applied for the shorter pulse duration of the system under consideration. As described on the previous tab, LIDT values in the nanosecond pulse regime scale with the square root of the laser pulse duration:

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

This adjustment factor results in LIDT values of 0.45 J/cm<sup>2</sup> for the BB1-E01 broadband mirror and 1.6 J/cm<sup>2</sup> for the Nd:YAG laser line mirror, which are to be compared with the 0.7 J/cm<sup>2</sup> maximum energy density of the beam. While the broadband mirror would likely be damaged by the laser, the more specialized laser line mirror is appropriate for use with this system.

#### **Pulsed Nanosecond Laser Example: Scaling for Different Wavelengths**

Suppose that a pulsed laser system emits 10 ns pulses at 2.5 Hz, each with 100 mJ of energy at 1064 nm in a 16 mm diameter beam ( $1/e^2$ ) that must be attenuated with a neutral density filter. For a Gaussian output, these specifications result in a maximum energy density of 0.1 J/cm<sup>2</sup>. The damage threshold of an NDUV10A Ø25 mm, OD 1.0, reflective neutral density filter is 0.05 J/cm<sup>2</sup> for 10 ns pulses at 355 nm, while the damage threshold of the similar NE10A absorptive filter is 10 J/cm<sup>2</sup> for 10 ns pulses at 532 nm. As described on the previous tab, the LIDT value of an optic scales with the square root of the wavelength in the nanosecond pulse regime:

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

This scaling gives adjusted LIDT values of 0.08 J/cm<sup>2</sup> for the reflective filter and 14 J/cm<sup>2</sup> for the absorptive filter. In this case, the absorptive filter is the best choice in order to avoid optical damage.

#### **Pulsed Microsecond Laser Example**

Consider a laser system that produces 1 μs pulses, each containing 150 μJ of energy at a repetition rate of 50 kHz, resulting in a relatively high duty cycle of 5%. This system falls somewhere between the regimes of CW and pulsed laser induced damage, and could potentially damage an optic by mechanisms associated with either regime. As a result, both CW and pulsed LIDT values must be compared to the properties of the laser system to ensure safe operation.











If this relatively long-pulse laser emits a Gaussian 12.7 mm diameter beam ( $1/e^2$ ) at 980 nm, then the resulting output has a linear power density of 5.9 W/cm and an energy density of  $1.2 \times 10^{-4}$  J/cm<sup>2</sup> per pulse. This can be compared to the LIDT values for a WPQ10E-980 polymer zero-order quarter-wave plate, which are 5 W/cm for CW radiation at 810 nm and 5 J/cm<sup>2</sup> for a 10 ns pulse at 810 nm. As before, the CW LIDT of the optic scales linearly with the laser wavelength, resulting in an adjusted CW value of 6 W/cm at 980 nm. On the other hand, the pulsed LIDT scales with the square root of the laser wavelength

and the square root of the pulse duration, resulting in an adjusted value of  $55 \text{ J/cm}^2$  for a  $1 \mu\text{s}$  pulse at  $980 \text{ nm}$ . The pulsed LIDT of the optic is significantly greater than the energy density of the laser pulse, so individual pulses will not damage the wave plate. However, the large average linear power density of the laser system may cause thermal damage to the optic, much like a high-power CW beam.

[Hide Nd:YAG Optics](#)

## ND:YAG OPTICS

Thorlabs offers a wide selection of optics optimized for use with Nd:YAG lasers. Please see below for more information.

Nd:YAG Optics Selection				
Dielectric Mirrors			Beamsplitters	
				
Laser Line Mirrors, 1064 nm, 532 nm, 355 nm, 266 nm	Right-Angle Prism Mirrors, 1064 nm, 532 nm	Cage Cube-Mounted Prism Mirrors, 1064 nm, 532 nm	Harmonic Beamsplitters, 1064 nm, 532 nm, 355 nm, 266 nm	High-Power Polarizing Beamsplitter Cubes, 1064 nm, 532 nm: Unmounted or Mounted
Lenses		Objectives	Filters	
				
UVFS Plano-Convex Lenses, 1064 nm, 532 nm: Unmounted or Mounted	Air-Spaced Doublets, 1064 nm, 532 nm	High Power Focusing Objectives, 1064 nm, 532 nm	Laser Line Filters, 1064 nm: Standard or Premium	Laser Line Filters, 532 nm: Standard or Premium

[Hide BS Selection Guide](#)

## BS SELECTION GUIDE

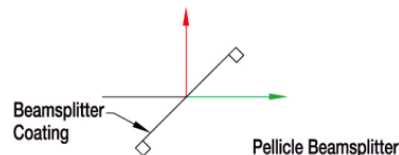
### Beamsplitter Selection Guide

Thorlabs offers five main types of beamsplitters: Pellicle, Cube, Plate, Economy, and Polka Dot. Each type has distinct advantages and disadvantages.

### Legend for Beam Diagrams

Reflected Beam:  Transmitted Beam: 

**Pellicle Beamsplitters** - Pellicle beamsplitters are the best choice when dispersion must be kept to a minimum. They virtually eliminate multiple reflections commonly associated with thicker glass beamsplitters, thus preventing ghosting. In addition, unlike plate beamsplitters, there is a negligible effect on the propagation axis of the transmitted beam with respect to the incident beam.



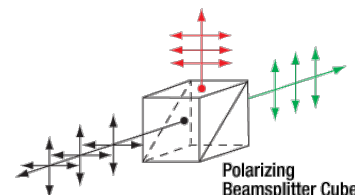
Pellicle beamsplitters have two disadvantages: They exhibit sinusoidal oscillations in the splitting

ratio as a function of wavelength, due to thin film interference effects. [Click Here](#) for more details. They are also extremely delicate. Since they are fabricated by stretching a nitrocellulose membrane over a flat metal frame, the beamsplitter cannot be touched without destroying the optic. Thorlabs offers pellicle beamsplitters mounted in metal rings for use in kinematic mounts as well as 30 mm cage cube-mounted pellicles.

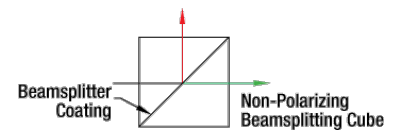
### Beamsplitting Cubes

Thorlabs' beamsplitter cubes are composed of two right-angled prisms. A dielectric coating, which is capable of reflecting and transmitting a portion of the incident beam, is applied to the hypotenuse surface. Since there is only one reflecting surface, this design inherently avoids ghost images, which sometimes occur with plate-type beamsplitters. Antireflection coatings are available on the entrance and exit faces of certain models to minimize back reflections. As well as providing a cost-effective solution, another advantage of the beamsplitting cube is the minimal shift it causes to the path of the transmitted beam.

Thorlabs offers both polarizing and nonpolarizing beamsplitting cubes, in mounted and unmounted



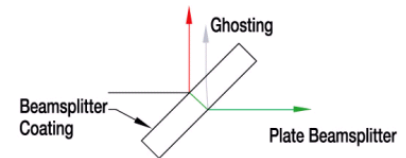
configurations. Mounted beamsplitters are available that are compatible with our 16 mm cage systems as well as our 30 mm cage systems.



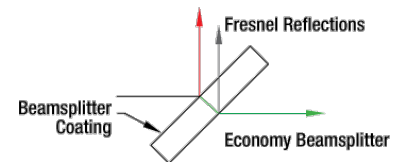
**Polarizing Beamsplitters** - Thorlabs' polarizing plate and cube beamsplitters split randomly polarized beams into two orthogonal, linearly polarized components (S and P), as shown in the diagram to the right. S-polarized light is reflected at a 90° angle with respect to the incident beam while p-polarized light is transmitted. Polarizing beamsplitters are useful in applications where the two polarization components are to be analyzed or used simultaneously. Thorlabs offers broadband 16 mm cage cube-mounted, broadband 30 mm cage cube-mounted, and broadband unmounted polarizing beamsplitter cubes, as well as laser line 30 mm cage cube-mounted and laser line unmounted cubes. Additionally, Thorlabs offers wire grid polarizing beamsplitters which have a larger Angle of Incidence and work with uncollimated light. For applications requiring higher power, we also offer high-power polarizing beamsplitting cubes.

**Non-Polarizing Beamsplitting Cubes** - These cubes provide a 50:50 splitting ratio that is nearly independent of the polarization of the incident light. The low polarization dependence of the metallic-dielectric coating allows the transmission and reflection for s- and p-polarization states to be within 10% or 15% of each other. These beamsplitters are particularly useful with randomly polarized lasers and are specifically designed for applications in which polarization effects must be minimized. Thorlabs offers 16 mm cage cube-mounted, 30 mm cage cube-mounted, and unmounted beamsplitter cubes.

**Plate Beamsplitters** - Thorlabs' plate beamsplitters are optimized for an incidence angle of 45° and feature a dielectric coating on the front surface for long-term stability. To help reduce unwanted interference effects (e.g., ghost images) caused by the interaction of light reflected from the front and back surfaces of the optic, a wedge has been added to the round versions of these beamsplitters. Dispersion, ghosting, and shifting of the beam may all be potential problems, however. These are the best choice for a general-purpose beamsplitter. Thorlabs offers both polarizing and nonpolarizing plate beamsplitters.

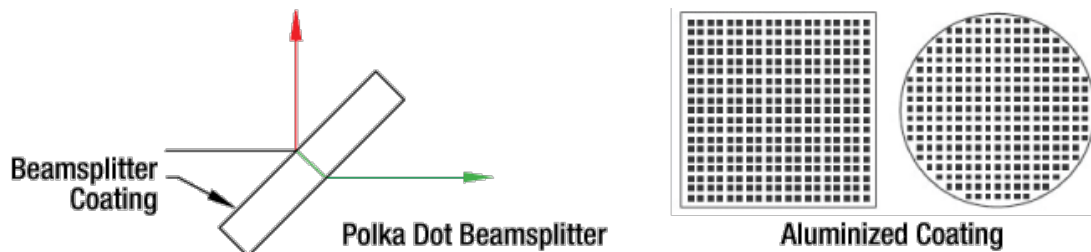


**Economy Beamsplitters** - These are the most cost effective of all the beamsplitter types. Thorlabs' economy beamsplitters, which have an exposed oxide coating on one side and are uncoated on the other side, are designed to have either a 50:50 or 30:70 splitting ratio throughout the visible spectrum (450 - 650 nm) when used with unpolarized light incident at 45°.



Please note that the Fresnel reflections off of the uncoated back surface of these economy beamsplitters can lead to interference effects in the reflected beam. For applications sensitive to these effects, consider using a beamsplitting cube or a pellicle beamsplitter.

**Polka Dot Beamsplitters** - This type of beamsplitter consists of a glass substrate with a vacuum-deposited reflective coating that is applied over an array of apertures, giving the beamsplitter a "polka dot" appearance. Half of the incident beam is reflected from the coating, and half of the beam is transmitted through the uncoated portion of the substrate.



Polka dot beamsplitters are useful over a wide wavelength range and are negligibly angle sensitive, which makes them ideal for splitting the energy emitted from a radiant source. These are not recommended for imaging applications, such as interferometry, as the polka dot pattern will affect the image.

[Hide Polarizer Guide](#)

polarizers offers coverage from the visible range to the beginning of the Far-IR range. Our nanoparticle linear film polarizers provide extinction ratios as high as 100 000:1. Alternatively, our other film polarizers offer an affordable solution for polarizing light from the visible to the Near-IR. Next, our beamsplitting polarizers allow for use of the reflected beam, as well as the more completely polarized transmitted beam. Finally, our alpha-BBO (UV), calcite (visible to Near-IR), rutile (Near-IR to Mid-IR), and yttrium orthovanadate (YVO<sub>4</sub>) (Near-IR to Mid-IR) polarizers each offer an exceptional extinction ratio of 100 000:1 within their respective wavelength ranges.

To explore the available types, wavelength ranges, extinction ratios, transmission, and available sizes for each polarizer category, click *More [+]* in the appropriate row below.

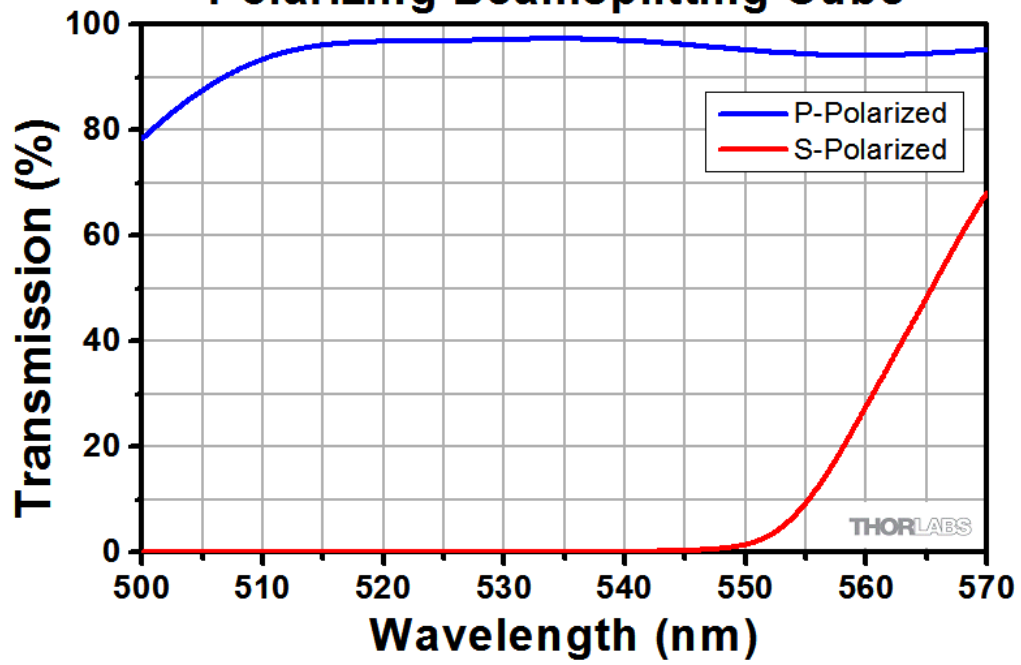
<b>Wire Grid Polarizers</b>
<b>Film Polarizers</b>
<b>Beamsplitting Polarizers</b>
<b>alpha-BBO Polarizers</b>
<b>Calcite Polarizers</b>
<b>Quartz Polarizers</b>
<b>Magnesium Fluoride Polarizers</b>
<b>Yttrium Orthovanadate (YVO<sub>4</sub>) Polarizers</b>
<b>Rutile Polarizers</b>

- Click on the graph icons in this column to view a transmission curve for the corresponding polarizer. Each curve represents one substrate sample or coating run and is not guaranteed.
- Mounted in a protective box, unthreaded ring, or cylinder that indicates the polarization axis.
- Available unmounted or in an SM05-threaded (0.535"-40) mount that indicates the polarization axis.
- Available unmounted or in an SM1-threaded (1.035"-40) mount that indicates the polarization axis.
- Available in an SM1-threaded (1.035"-40) mount that indicates the polarization axis.
- Available unmounted or mounted in cubes for cage system compatibility.
- Calcite's transmittance of light near 350 nm is typically around 75% (see *Transmission* column).
- Available unmounted or in an unthreaded Ø1/2" housing.
- The transmission curves for calcite are valid for linearly polarized light with a polarization axis aligned with the mark on the polarizer's housing.
- The 1064 nm V coating corresponds to a -C26 suffix in the item number.
- Available unmounted or mounted in a protective box or unthreaded cylinder that indicates the polarization axis.

[Hide](#)

Part Number	Description	Price	Availability
CCM1-PBS25-405-HP/M	NEW! Customer Inspired!30 mm Cage-Cube-Mounted, High-Power Polarizing Beamsplitter Cube, 405 nm, M4 Tap	\$590.00	Today
CCM1-PBS25-633-HP/M	NEW! Customer Inspired!30 mm Cage-Cube-Mounted, High-Power, Polarizing Beamsplitter Cube, 633 nm, M4 Tap	\$590.00	Today
CCM1-PBS25-1064-HP/M	NEW! Customer Inspired!30 mm Cage-Cube-Mounted, High-Power Polarizing Beamsplitter Cube, 1064 nm, M4 Tap	\$590.00	Today
CM1-PBS25-532-HP	30 mm Cage-Cube-Mounted, High-Power Polarizing Beamsplitter Cube, 532 nm, 8-32 and M4 Adapters	\$590.00	3-5 Days
CM1-PBS25-780-HP	30 mm Cage-Cube-Mounted, High-Power Polarizing Beamsplitter Cube, 780 - 808 nm, 8-32 and M4 Adapters	\$590.00	3-5 Days
CCM1-PBS25-405-HP	NEW! Customer Inspired!30 mm Cage-Cube-Mounted, High-Power, Polarizing Beamsplitter Cube, 405 nm, 8-32 Tap	\$590.00	Today
CCM1-PBS25-633-HP	NEW! Customer Inspired!30 mm Cage-Cube-Mounted, High-Power, Polarizing Beamsplitter Cube, 633 nm, 8-32 Tap	\$590.00	Today
CCM1-PBS25-1064-HP	NEW! Customer Inspired!30 mm Cage-Cube-Mounted, High-Power Polarizing Beamsplitter Cube, 1064 nm, 8-32 Tap	\$590.00	Today

## Transmission for 532 nm High-Power Polarizing Beamsplitting Cube



## 532 nm V Antireflection Coating

