56 Sparta Avenue • Newton, New Jersey 07860
(973) 300-3000 Sales • (973) 300-3600 Fax
www.thorlabs.com

THORLABS

ELU-25-20X-248 - March 13, 2015

Item # ELU-25-20X-248 was discontinued on March 13, 2015. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

UV OPTICAL BEAM EXPANDERS, SLIDING LENS DESIGN

- ► **2.5X, 5X, 10X, or 20X Beam Expansion**
- ► **Narrowband AR Coating at 248 nm or 351 nm**
- ► **Diffraction-Limited Performance**

OVERVIEW

Features

- 2.5X, 5X, 10X, or 20X Beam Expansion
- Produce Diverging, Collimated, or Focusing Beams
- Sliding Lens Adjustment that Minimizes Walk-Off
- Best Form Narrowband UV AR-Coated Lenses
- High Damage Threshold of 500 MW/cm²
- Removable Endcaps Protect Optics

Mechanical Housing Update
Please note that Thorlabs is in the process of updating the mechanical housings of these beam expanders. For more details, see the Mechanical Housing Update section below.

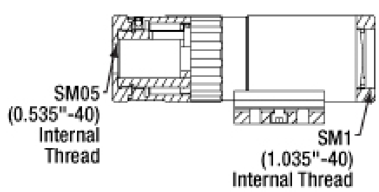
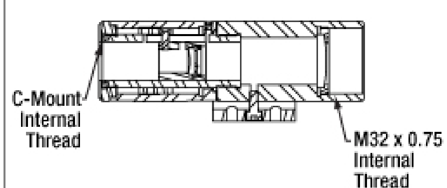
The ELU series of Galilean Beam Expanders are designed to expand or reduce the diameter of an input beam while introducing a wavefront error of less than λ/4, (i.e. diffraction-limited performance). An expanded beam can be focused to a narrower diffraction-limited waist; such a reduced beam is sometimes necessary for use with optics or instruments that have narrow input apertures such as the SA200 family of scanning Fabry-Perot interferometers.

The housing contains two best form lenses that are designed to minimize aberrations in the recollimated beam. Both optics have narrowband AR coatings to minimize surface reflections. The input lens is mounted in a precision-milled tube that can slide in and out of the tube containing the output lens. The sliding design allows for the adjustment of the collimating lens and minimizes the beam walk-off effect that is inherent to lens adjustments. The beam expander can be mounted via either the 1/4"-20 or the M6-threaded hole in the base. In addition, the groove milled into the base can be used to clamp the beam expander to an optical table using CL6 mounting cleats (not included). The beam expanders have threaded input and output apertures, which allow additional lenses and filters to be installed easily along the optical axis of the beam expander.

Thorlabs also offers many other types of beam expanders, including variable and fixed beam expanders whose expansion ratio is achieved via rotation as well as beam expanders with a non-rotating adjustment mechanism that have a narrowband AR coating for 1064 nm or a broadband AR coating for the 400 - 650 nm, 650 - 1050 nm, or 1050 - 1620 nm range. For more information on our extensive line of beam expanders, please click on the *Selection Guide* tab.

Mechanical Housing Update
These beam expanders originally featured an internal C-Mount threading on the input side and an internal M32 x 0.75 threading on the output side. In order to improve mechanical compatibility with Thorlabs' SM05- (0.535"-40) and SM1-threaded (1.035"-40) optomechanics, Thorlabs is in the process of converting the housing design so that it has internal SM05 threading on the input side and internal SM1 threading on the output side. Please refer to the table below to determine whether a given beam expander is currently being shipped with the new housing.

Thorlabs offers an extensive line of thread adapters for converting from one threading to another. Should you have any concerns, please contact Technical Support.

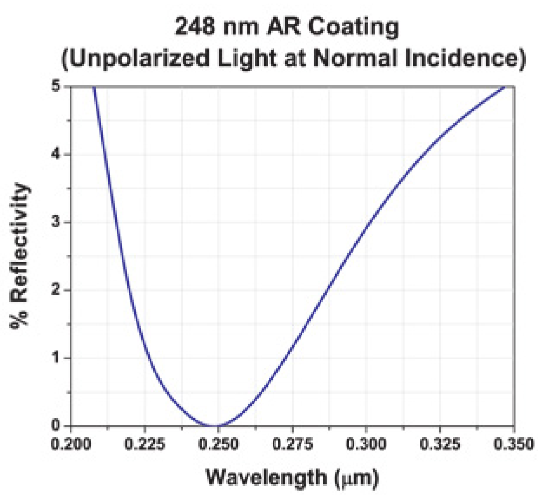
Info	New	Old
Mechanical Drawing (Click for Details)		
Input Threading	SM05 (0.535"-40)	C-Mount
Output Threading	SM1 (1.035"-40)	M32 x 0.75
ELU-25-2.5X-248		X
ELU-25-2.5X-351	X	
ELU-25-5X-248	X	
ELU-25-5X-351	X	
ELU-25-10X-248		X
ELU-25-10X-351	X	
ELU-25-20X-248		X
ELU-25-20X-351	X	

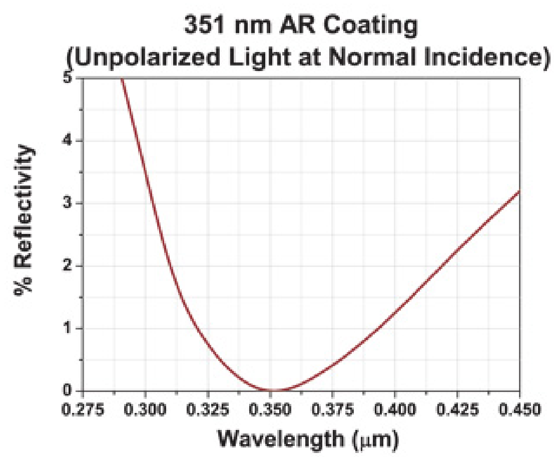
SPECS

Item #	Ravg[a]	T[b]	Damage Threshold[c]	Mag.	Max Input Beam Diameter[d] ($1/e^2$)	Input Aperture	Narrowband AR Coating	Scratch-Dig	Housing Dimensions
ELU-25-2.5X-248	<0.2%	>96%	500 MW/cm²	2.5X	4.4 mm	Ø9 mm	248 nm	10-5	Ø38 x 126 mm
ELU-25-2.5X-351	<0.2%	>96%	500 MW/cm²	2.5X	4.4 mm	Ø9 mm	351 nm	10-5	Ø37.9 x 115.0 mm
ELU-25-5X-248	<0.2%	>96%	500 MW/cm²	5X	2.2 mm	Ø10.9 mm	248 nm	10-5	Ø37.9 x 135.0 mm
ELU-25-5X-351	<0.2%	>96%	500 MW/cm²	5X	2.2 mm	Ø10.9 mm	351 nm	10-5	
ELU-25-10X-248	<0.2%	>96%	500 MW/cm²	10X	1.1 mm	Ø9 mm	248 nm	10-5	Ø38 x 203 mm
ELU-25-10X-351	<0.2%	>96%	500 MW/cm²	10X	1.1 mm	Ø10.9 mm	351 nm	10-5	Ø38.0 x 202.1 mm
ELU-25-20X-248	<0.2%	>96%	500 MW/cm²	20X	0.6 mm	Ø3.5 mm	248 nm	10-5	Ø38 x 278 mm
ELU-25-20X-351	<0.2%	>96%	500 MW/cm²	20X	0.6 mm	Ø3.8 mm	351 nm	10-5	Ø37.9 x 262.1 mm

- Average Reflectance
- Transmittance
- 20 ns Pulses, 20 Hz
- For Diffraction-Limited Performance

COATING CURVES





SELECTION GUIDE

Thorlabs offers several different families of beam expanders to meet various experimental needs. The table below provides a direct comparison of the options we offer. Please contact Tech Support if you would like help choosing the best beam expander for your specific application.

Beam Expander Description	**UV Sliding Lens**	**Visible-IR Sliding Lens**	**1064 nm Sliding Lens**	**Visible-IR Rotating Lens**	**Visible-IR Variable Ratio Rotating Lens**	**Visible-IR Sliding Lens**	**Broadband Fixed Ratio**
Expansions Available	2.5X, 5X, 10X, 20X	2.5X, 3X, 5X, 10X, 20X	2.5X, 5X, 10X, 20X	2X, 3X, 5X, 10X, 15X, 20X	2 - 5X 5 - 10X	0.5 - 2X	2X, 4X, 6X
AR Coating Range(s) Available	248 nm 351 nm	400 - 650 nm 650 - 1050 nm 3000 - 5000 nm	1064 ± 40 nm	400 - 650 nm 650 - 1050 nm 1050 - 1620 nm		400 - 650 nm 650 - 1050 nm	N/A
Mirror Coating (Range)	N/A						Protected Silver (450 nm - 20 µm)
Average Reflectance (per Surface)	<0.2%	<0.5% (<2% for -E Coating)	<0.2%	<0.5%		<0.5%	>96%
Max Input Beam Diameter ($1/e^2$)[a]	2.5X: Ø4.4 mm 5X: Ø2.2 mm 10X: Ø1.1 mm 20X: Ø0.6 mm	2.5X: Ø4.4 mm 3X: Ø4.0 mm 5X: Ø2.2 mm 10X: Ø1.1 mm 20X: Ø0.6 mm	2.5X: Ø4.4 mm 5X: Ø2.2 mm 10X: Ø1.1 mm 20X: Ø0.6 mm	2X, 3X: Ø4.0 mm 5X, 10X, 15X, 20X: Ø2.25 mm	Ø3.0 mm	0.5X: Ø6.0 mm to 2X: Ø3.0 mm	Ø3 mm
Input Aperture	2.5X: Ø9 mm 5X: Ø10.9 mm 10X: Ø9 or Ø10.9 mm 20X: Ø3.5 or Ø3.8 mm	2.5X: Ø9 or Ø11.0 mm 3X: Ø11.0 mm 5X: Ø10.9 mm 10X: Ø9 or Ø10.9 mm 20X: Ø3.5 or Ø3.8 mm	2.5X: Ø11 mm 5X, 10X: Ø10.9 mm 20X: Ø3.5 mm	2X, 3X: Ø8 mm 5X, 10X, 15X, 20X: Ø4.5 mm	Ø8.0 mm	Ø10.0 mm	Ø6 mm
Wavefront Error	<λ/4						<λ/10[b]
Surface Quality	10-5 Scratch-Dig (20-10 Scratch-Dig for -E Coating)			20-10 Scratch-Dig			40-20 Scratch-Dig
Optics	Two Best-Form or Spherical Lenses			One Plano-Concave Singlet, One Doublet	Spherical Singlets and Doublets		Two Spherical Mirrors

- For Diffraction-Limited Performance
- Ø1.5 mm Input Beam for 2X, Ø1.0 mm Input Beam for 4X, Ø0.5 mm Input Beam for 6X

DAMAGE THRESHOLDS

Damage Threshold Data for Thorlabs' Sliding UV Beam Expanders

The specifications to the right are measured data for Thorlabs' sliding UV beam expanders. Damage threshold specifications are constant for all sliding UV beam expanders, regardless of the center wavelength or magnification of the beam expander.

Damage Threshold Specifications	
Item # prefix	**Damage Threshold**
ELU-	500 MW/cm^2 (20 ns Pulses, 20 Hz)

Laser Induced Damage Threshold Tutorial

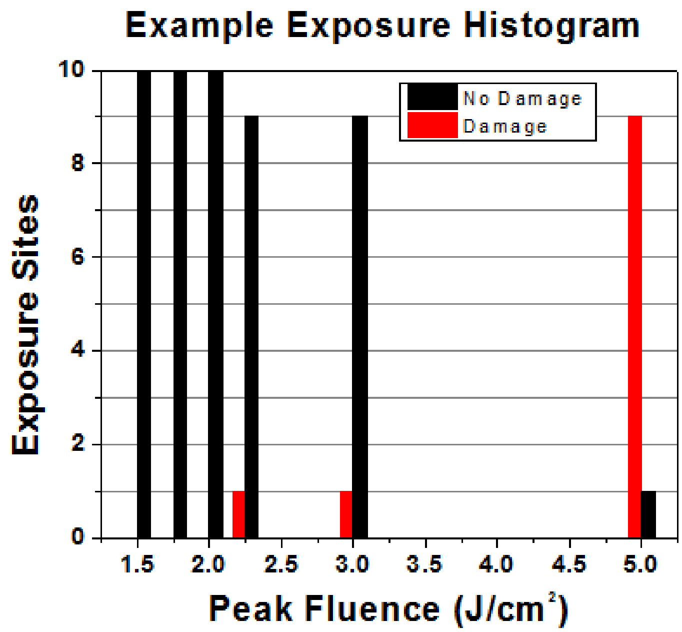
This following is a general overview of how laser induced damage thresholds are measured and how the values may be utilized in determining the appropriateness of an optic for a given application. When choosing optics, it is important to understand the Laser Induced Damage Threshold (LIDT) of the optics 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 (prf 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.



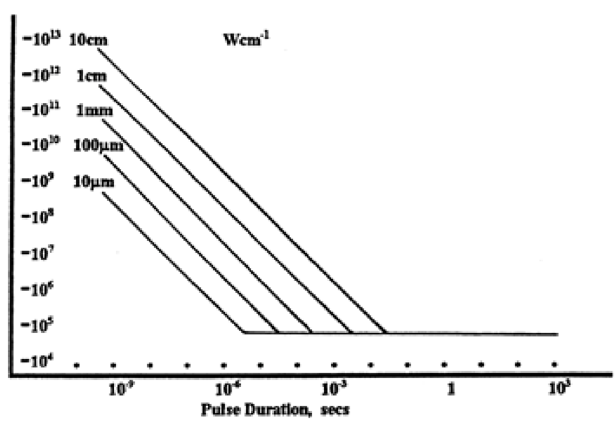
According to the test, the damage threshold of the mirror was 2.00 J/cm^2 (532 nm, 10 ns pulse, 10 Hz, Ø0.803 mm). Please keep in mind that it is only representative of one coating run and that Thorlabs' specified damage thresholds account for coating variances.

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

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.

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.

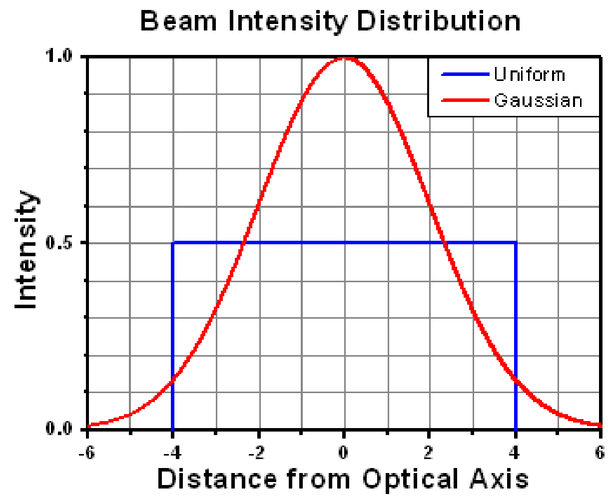


LIDT in linear power density vs. pulse length and spot size. For long pulses to CW, linear power density becomes a constant with spot size. This graph was obtained from [1].

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)

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). 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

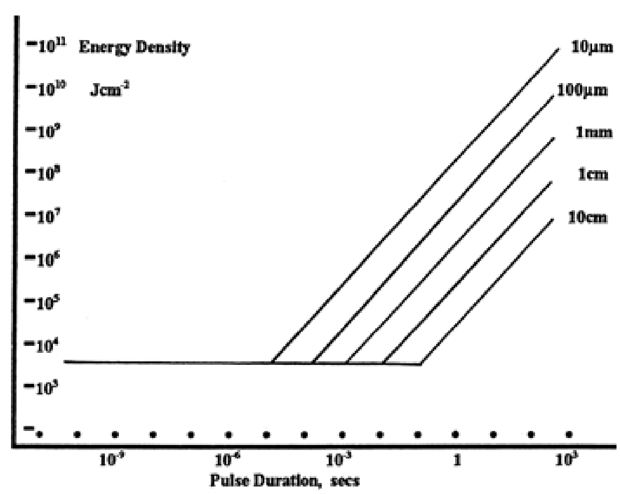
As previously stated, pulsed lasers typically induce a different type of damage to the optic than CW lasers. Pulsed lasers often do not heat the optic enough to damage it; instead, pulsed lasers produce strong electric fields capable of inducing dielectric breakdown in the material. Unfortunately, it 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 pulse lengths that our specified LIDT values are relevant for.

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 power 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):

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

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^2, 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^2) 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^{-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.

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[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).

Visit the *UV Optical Beam Expanders, Sliding Lens Design* page for pricing and availability information:
http://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=2973