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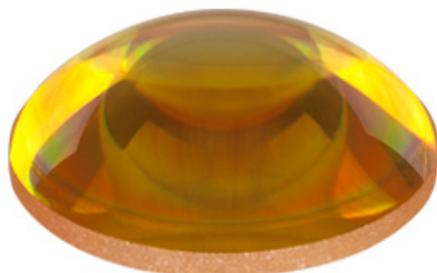


## LE7667-F - August 24, 2022

Item # LE7667-F was discontinued on August 24, 2022. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

### ZINC SELENIDE POSITIVE MENISCUS LENSES, AR COATED: 8 - 12 MM

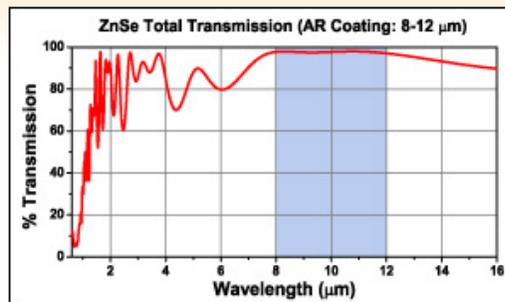
- ▶ AR Coating Optimized for the 8 - 12  $\mu\text{m}$  Range
- ▶ Ideal for CO<sub>2</sub> Laser Applications Due to Low Absorption Coefficient
- ▶ Increases the NA of an Optical System



LE7185-F  
( $\text{\O}1''$ )



LE7246-F  
( $\text{\O}1/2''$ )



#### OVERVIEW

##### Features

- ZnSe Substrate
- Broadband AR Coating for the 8 - 12  $\mu\text{m}$  Range
- Focal Lengths from 15 mm to 1000 mm Available

Thorlabs'  $\text{\O}1/2''$  and  $\text{\O}1''$  Zinc Selenide (ZnSe) positive meniscus lenses are available with a broadband AR coating optimized for the 8  $\mu\text{m}$  to 12  $\mu\text{m}$  spectral range deposited on both surfaces. This coating greatly reduces the high surface reflectivity of the substrate, yielding an average transmission in excess of 97% over the entire AR coating range. See the Graphs tab for detailed information. ZnSe lenses are particularly well suited for use with high-power CO<sub>2</sub> lasers.

When handling optics, one should always wear gloves. This is especially true when working with zinc selenide, as it is a hazardous material. For your safety, please follow all proper precautions, including wearing gloves when handling these lenses and thoroughly washing your hands afterward. Due to the low hardness of ZnSe, additional care should be taken to not damage these lenses. Click [here](#) to download a pdf of the MSDS for ZnSe.

##### Specifications

Specifications	
Substrate Material	Laser-Grade Zinc Selenide <sup>a</sup>
AR Coating Range	8 - 12 $\mu\text{m}$
Reflectance over Coating Range (Avg.)	<1.5%
Damage Threshold <sup>b</sup>	5 J/cm <sup>2</sup> (10.6 $\mu\text{m}$ , 100 ns, 1 Hz, $\text{\O}0.478$ mm)
Diameter Tolerance	+0.00/-0.10
Thickness Tolerance	$\pm 0.2$ mm
Focal Length Tolerance	$\pm 1\%$
Surface Quality	60-40 Scratch-Dig
Spherical Surface Power <sup>c</sup>	3 $\lambda/2$
Spherical Surface Irregularity (Peak to Valley)	$\lambda/2$
Centration	$\leq 3$ arcmin
Clear Aperture	80% of Diameter
Design Wavelength	10.6 $\mu\text{m}$

- Click Link for Detailed Specifications on the Substrate
- Limited by the Antireflection Coating
- Much like surface flatness for flat optics, spherical surface power is a measure of the deviation between the surface of the curved optic and a calibrated reference gauge, typically for a 633 nm source, unless otherwise stated. This specification is also commonly referred to as surface fit.

## Best Form Design

Due to the high refractive index of ZnSe, the spherical best form design for a ZnSe lens is the positive meniscus design. Therefore, these lenses induce small aberrations, spot sizes, and wavefront errors comparable to best form lenses constructed of other materials. See the *graphs* tab for a comparison of the aberrations induced by different lens shapes.

Positive meniscus (convex-concave) lenses, which are thicker in the middle than at the edges and cause light rays to converge, are designed to minimize third-order spherical aberration. When used to focus a collimated beam, the convex side of the lens should face the source to minimize spherical aberration. They are often used in conjunction with other lenses to decrease the focal length, and therefore increase the numerical aperture (NA), of an optical assembly. Since a positive meniscus lens has a greater radius of curvature on the concave side of the lens than on the convex side, real images can be formed.

Thorlabs will accept all ZnSe lenses back for proper disposal. Please contact Tech Support to make arrangements for this service.



### Zemax Files

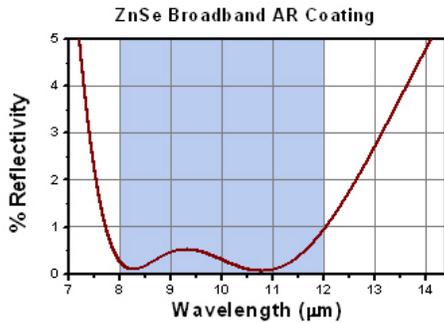
Click on the red Document icon next to the item numbers below to access the Zemax file download. Our entire Zemax Catalog is also available.



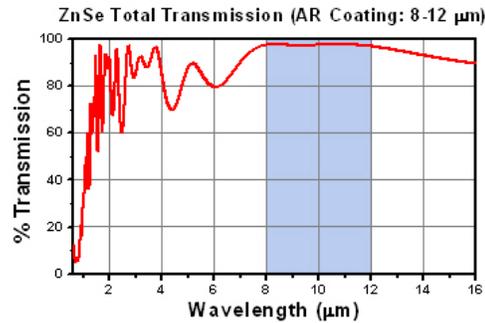
## Selection Guide

Zinc Selenide Lenses		More [+]	Other MIR Lenses		More [+]	Other Spherical Singlets		More [+]
Plano-Convex		<a href="#">E4 Coated (2 - 13 <math>\mu\text{m}</math>)</a>	Calcium Fluoride	Plano-Convex	<a href="#">Uncoated (0.18 - 8.0 <math>\mu\text{m}</math>)</a>	Plano-Convex	<a href="#">Plano-Convex</a>	
		<a href="#">E2 Coated (4.5 - 7.5 <math>\mu\text{m}</math>)</a>			<a href="#">D Coated (1.65 - 3.0 <math>\mu\text{m}</math>)</a>		<a href="#">Bi-Convex</a>	
		<a href="#">E3 Coated (7 - 12 <math>\mu\text{m}</math>)</a>			<a href="#">E Coated (2 - 5 <math>\mu\text{m}</math>)</a>		<a href="#">Best Form</a>	
Bi-Convex		<a href="#">E3 Coated (7 - 12 <math>\mu\text{m}</math>)</a>		Bi-Convex	<a href="#">Uncoated (0.18 - 8.0 <math>\mu\text{m}</math>)</a>		<a href="#">Plano-Concave</a>	
		<a href="#">E4 Coated (2 - 13 <math>\mu\text{m}</math>)</a>			<a href="#">E Coated (2 - 5 <math>\mu\text{m}</math>)</a>		<a href="#">Bi-Concave</a>	
Plano-Concave		<a href="#">E2 Coated (4.5 - 7.5 <math>\mu\text{m}</math>)</a>		Plano-Concave	<a href="#">Uncoated (0.18 - 8.0 <math>\mu\text{m}</math>)</a>		<a href="#">Positive Meniscus</a>	
		<a href="#">E3 Coated (7 - 12 <math>\mu\text{m}</math>)</a>			<a href="#">E Coated (2 - 5 <math>\mu\text{m}</math>)</a>	<a href="#">Negative Meniscus</a>		
Bi-Concave		<a href="#">E3 Coated (7 - 12 <math>\mu\text{m}</math>)</a>		Bi-Concave	<a href="#">Uncoated (0.18 - 8.0 <math>\mu\text{m}</math>)</a>			
Positive Meniscus		F Coated (8 - 12 $\mu\text{m}$ )		Positive Meniscus	<a href="#">E Coated (2 - 5 <math>\mu\text{m}</math>)</a>			
Negative Meniscus		<a href="#">F Coated (8 - 12 <math>\mu\text{m}</math>)</a>			<a href="#">Uncoated (0.18 - 8.0 <math>\mu\text{m}</math>)</a>			
				Negative Meniscus	<a href="#">E Coated (2 - 5 <math>\mu\text{m}</math>)</a>			
				Magnesium Fluoride	Plano-Convex	<a href="#">Uncoated (0.2 - 6 <math>\mu\text{m}</math>)</a>		
			Barium Fluoride	Plano-Convex	<a href="#">E Coated (2 - 5 <math>\mu\text{m}</math>)</a>			
			Silicon	Plano-Convex	<a href="#">E Coated (2 - 5 <math>\mu\text{m}</math>)</a>			
			Germanium	Plano-Convex	<a href="#">E3 Coated (7 - 12 <math>\mu\text{m}</math>)</a>			

GRAPHS



Shown above is a graph of the theoretical percent reflectivity of the AR coating as a function of wavelength. The average reflectivity in the 8 - 12  $\mu\text{m}$  range is <1.5%. The blue shading indicates the region for which the AR coating is optimized.



Shown above is a graph of the theoretical transmission of the AR-coated zinc selenide Bi-Convex lens. The blue shaded region denotes the 8 - 12  $\mu\text{m}$  spectral range where the AR coating is optimized. For this wavelength range, the measured transmission is in excess of 97%.

**Total Transmission of Optic (ZnSe Substrate + AR Coating)**

The table below gives the approximate transmission of these optics for a few select wavelengths in the 0.6 - 16  $\mu\text{m}$  range. To see an excel file that lists all measured transmission values for this wavelength range, please click [here](#). Please note that the transmission values stated for wavelengths outside of the AR coating range are approximate and can vary significantly by coating lot.

Wavelength ( $\mu\text{m}$ )	Total Transmission						
0.6	0.117	4.6	0.740	8.6	0.978	12.6	0.961
1.0	0.312	5.0	0.880	9.0	0.975	13.0	0.953
1.4	0.674	5.4	0.874	9.4	0.975	13.4	0.945
1.8	0.875	5.8	0.810	9.8	0.976	13.8	0.936
2.2	0.810	6.2	0.802	10.2	0.978	14.2	0.928
2.6	0.803	6.6	0.845	10.6	0.979	14.6	0.920
3.0	0.859	7.0	0.904	11.0	0.979	15.0	0.913
3.4	0.880	7.4	0.950	11.4	0.977	15.4	0.906
3.8	0.962	7.8	0.973	11.8	0.973	15.8	0.900
4.2	0.733	8.2	0.979	12.2	0.968		

## Using Positive Meniscus Lenses

- Achieve Tighter Focusing by Combining a Meniscus Lens with Plano-Convex Lenses
- Build Multi-Element Lens Systems to Achieve Higher NA without Significant Increases in Aberrations

Positive meniscus lenses are designed to minimize spherical aberration. They have one convex and one concave surface. When used in combination with another lens, a positive meniscus lens will shorten the focal length and increase the NA of the system. Doing so greatly reduces the transverse and lateral aberrations. In such a configuration, the convex surface of both lenses should be facing away from the image. As an example, Figure 1c shows an N-BK7 meniscus lens being used to shorten the focal length of a 100 mm focal length plano-convex lens at 588 nm. For a ZnSe plano-convex / meniscus pair with  $f = 100$  mm, a  $60 \mu\text{m}$  focused spot is typically achievable.

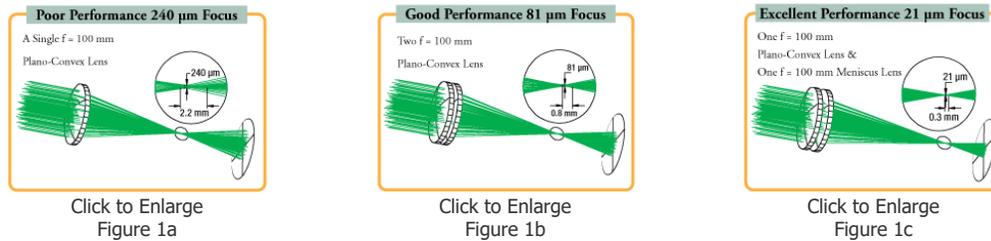


Figure 1. These figures illustrate the performance gains that can be achieved by using multi-element imaging systems. The combination of a N-BK7 meniscus lens and a N-BK7 plano-convex lens yields a  $21 \mu\text{m}$  focused spot versus a  $240 \mu\text{m}$  spot at 588 nm from the single N-BK7 plano-convex lens. For a ZnSe plano-convex / meniscus pair with  $f = 100$  mm, a  $60 \mu\text{m}$  focused spot is typically achievable.

## Damage Threshold Data for Thorlabs' F-Coated ZnSe Lenses

The specifications to the right are measured data for Thorlabs' F-coated, ZnSe lenses. Damage threshold specifications are constant for all F-coated, ZnSe lenses, regardless of the size or focal length of the lens.

Damage Threshold Specifications	
Coating Designation (Item # Suffix)	Damage Threshold
-F	5 J/cm <sup>2</sup> (10.6 μm, 100 ns, 1 Hz, Ø0.478 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

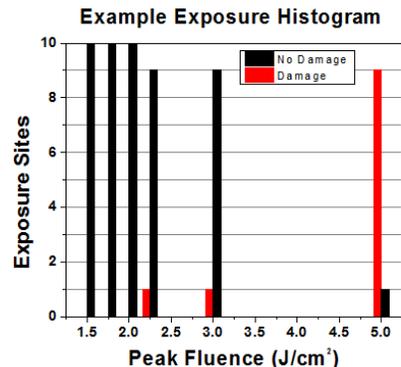
Thorlabs' LIDT testing is done in compliance with ISO/DIS 11254 and ISO 21254 specifications.

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 30 seconds (CW) or for a 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<sup>2</sup> (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<sup>2</sup> (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 Damage
1.50 J/cm <sup>2</sup>	10	0	10
1.75 J/cm <sup>2</sup>	10	0	10
2.00 J/cm <sup>2</sup>	10	0	10
2.25 J/cm <sup>2</sup>	10	1	9
3.00 J/cm <sup>2</sup>	10	1	9
5.00 J/cm <sup>2</sup>	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.

When pulse lengths are between 1 ns and 1 μs, laser-induced damage can occur either because of absorption or a dielectric breakdown (therefore, a user 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 high 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. Beam diameter of your beam (1/e<sup>2</sup>)
3. Approximate intensity profile of your beam (e.g., Gaussian)
4. Linear power density of your beam (total power divided by 1/e<sup>2</sup> beam diameter)

Thorlabs expresses LIDT for CW lasers as a linear power density measured in W/cm. 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 size, as demonstrated by the graph to the right. Average linear power density can be calculated using the equation below.

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

The calculation above 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.

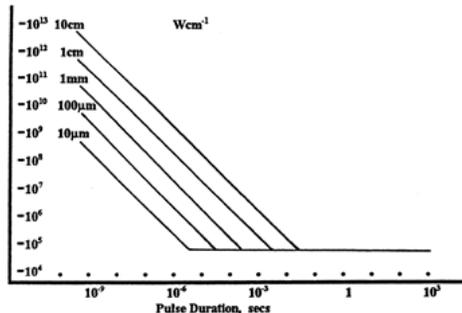
Please note that we have a buffer built in between the specified damage thresholds online and the tests which we have done, which accommodates variation between batches. Upon request, we can provide individual test information and a testing certificate. The damage analysis will be carried out on a similar 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

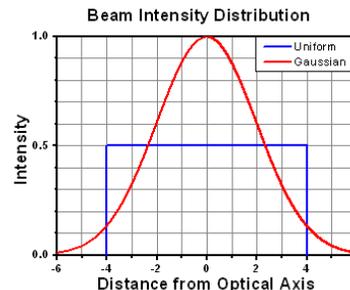
As previously stated, pulsed lasers typically induce a different type of damage to the optic than CW lasers. Pulsed lasers often do not heat the optic enough to damage it; instead, pulsed lasers produce strong electric fields capable of inducing dielectric breakdown in the material. Unfortunately, it 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<sup>-9</sup> 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<sup>-7</sup> s and 10<sup>-4</sup> 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 <sup>-9</sup> s	10 <sup>-9</sup> < t < 10 <sup>-7</sup> s	10 <sup>-7</sup> < t < 10 <sup>-4</sup> s	t > 10 <sup>-4</sup> s
Damage Mechanism	Avalanche Ionization	Dielectric Breakdown	Dielectric Breakdown or Thermal	Thermal
Relevant Damage Specification	No Comparison (See Above)	Pulsed	Pulsed and CW	CW



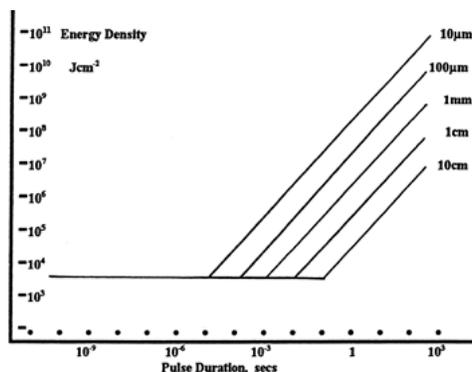
LIDT in linear power density vs. pulse length and spot size. For long pulses to CW, linear power density becomes a constant with spot size. This graph was obtained from [1].



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  $1 J/cm^2$  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.

[1] R. M. Wood, Optics and Laser Tech. **29**, 517 (1998).

[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).

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.

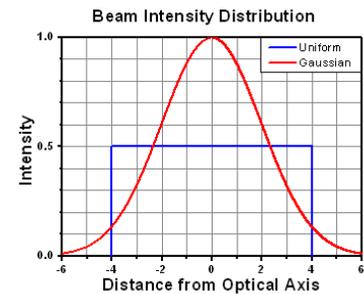
**LIDT Calculator**

#### CW Laser Example

Suppose that a CW laser system at 1319 nm produces a 0.5 W Gaussian beam that has a  $1/e^2$  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 determination of the maximum linear power density of the system is 1 W/cm.



A Gaussian beam profile has about twice the maximum 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  $\times$  (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  $\sim 0.7 \text{ J/cm}^2$ .

The energy density of the beam can be compared to the LIDT values of  $1 \text{ J/cm}^2$  and  $3.5 \text{ J/cm}^2$  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  $0.45 \text{ J/cm}^2$  for the BB1-E01 broadband mirror and  $1.6 \text{ J/cm}^2$  for the Nd:YAG laser line mirror, which are to be compared with the  $0.7 \text{ J/cm}^2$  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  $0.1 \text{ J/cm}^2$ . The damage threshold of an NDUV10A  $\text{\O}25 \text{ mm}$ , OD 1.0, reflective neutral density filter is  $0.05 \text{ J/cm}^2$  for 10 ns pulses at 355 nm, while the damage threshold of the similar NE10A absorptive filter is  $10 \text{ J/cm}^2$  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  $0.08 \text{ J/cm}^2$  for the reflective filter and  $14 \text{ J/cm}^2$  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  $1 \mu\text{s}$  pulses, each containing  $150 \mu\text{J}$  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  $12.7 \text{ mm}$  diameter beam ( $1/e^2$ ) at 980 nm, then the resulting output has a linear power density of  $5.9 \text{ W/cm}$  and an energy density of  $1.2 \times 10^{-4} \text{ J/cm}^2$  per pulse. This can be compared to the LIDT values for a WPQ10E-980 polymer zero-order quarter-wave plate, which are  $5 \text{ W/cm}$  for CW radiation at 810 nm and  $5 \text{ J/cm}^2$  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  $6 \text{ W/cm}$  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 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.

Recommended Mounting Options for Thorlabs Lenses		
Item #		Mounts for $\varnothing 2$ mm to $\varnothing 10$ mm Optics
Imperial	Metric	
(Various)		Fixed Lens Mounts and Mini-Series Fixed Lens Mounts for Small Optics, $\varnothing 5$ mm to $\varnothing 10$ mm
(Various)		Small Optic Adapters for Use with Standard Fixed Lens Mounts, $\varnothing 2$ mm to $\varnothing 10$ mm
Item #		Mounts for $\varnothing 1/2$ " ( $\varnothing 12.7$ mm) Optics
Imperial	Metric	
LMR05	LMR05/M	Fixed Lens Mount for $\varnothing 1/2$ " Optics
MLH05	MLH05/M	Mini-Series Fixed Lens Mount for $\varnothing 1/2$ " Optics
LM05XY	LM05XY/M	Translating Lens Mount for $\varnothing 1/2$ " Optics
SCP05		16 mm Cage System, XY Translation Mount for $\varnothing 1/2$ " Optics
(Various)		$\varnothing 1/2$ " Lens Tubes, Optional SM05RRC Retaining Ring for High-Curvature Lenses (See Below)
Item #		Mounts for $\varnothing 1$ " ( $\varnothing 25.4$ mm) Optics
Imperial	Metric	
LMR1	LMR1/M	Fixed Lens Mount for $\varnothing 1$ " Optics
LM1XY	LM1XY/M	Translating Lens Mount for $\varnothing 1$ " Optics
ST1XY-S	ST1XY-S/M	Translating Lens Mount with Micrometer Drives (Other Drives Available)
CXY1		30 mm Cage System, XY Translation Mount for $\varnothing 1$ " Optics
(Various)		$\varnothing 1$ " Lens Tubes, Optional SM1RRC Retaining Ring for High-Curvature Lenses (See Below)
Item #		Mount for $\varnothing 1.5$ " Optics
Imperial	Metric	
LMR1.5	LMR1.5/M	Fixed Lens Mount for $\varnothing 1.5$ " Optics
(Various)		$\varnothing 1.5$ " Lens Tubes, Optional SM1.5RR Retaining Ring for $\varnothing 1.5$ " Lens Tubes and Mounts
Item #		Mounts for $\varnothing 2$ " ( $\varnothing 50.8$ mm) Optics
Imperial	Metric	



Click to Enlarge  
LMR1 Fixed Mount with  
 $\varnothing 1$ " Lens



Click to Enlarge  
LM2XY Translating Mount  
with  $\varnothing 2$ " Lens



Click to Enlarge  
CXY1 Translation Mount  
and  
SM1 Lens Tube Mounted  
in a  
30 mm Cage System



Click to Enlarge  
 $\varnothing 1$ " Optic Mounted in a  
ST1XY-S XY Translator

Recommended Mounting Options for Thorlabs Lenses		
LMR2	LMR2/M	Fixed Lens Mount for $\varnothing 2''$ Optics
LM2XY	LM2XY/M	Translating Lens Mount for $\varnothing 2''$ Optics
CXY2		60 mm Cage System, XY Translation Mount for $\varnothing 2''$ Optics
(Various)		$\varnothing 2''$ Lens Tubes, Optional SM2RRC Retaining Ring for High-Curvature Lenses (See Below)
Item #		Adjustable Optic Mounts
Imperial	Metric	
LH1	LH1/M	Adjustable Mount for $\varnothing 0.28''$ ( $\varnothing 7.1$ mm) to $\varnothing 1.80''$ ( $\varnothing 45.7$ mm) Optics
LH2	LH2/M	Adjustable Mount for $\varnothing 0.77''$ ( $\varnothing 19.6$ mm) to $\varnothing 2.28''$ ( $\varnothing 57.9$ mm) Optics
VG100	VG100/M	Adjustable Clamp for $\varnothing 0.5''$ ( $\varnothing 13$ mm) to $\varnothing 3.5''$ ( $\varnothing 89$ mm) Optics
SCL03	SCL03/M	Self-Centering Mount for $\varnothing 0.15''$ ( $\varnothing 3.8$ mm) to $\varnothing 1.77''$ ( $\varnothing 45.0$ mm) Optics
SCL04	SCL04/M	Self-Centering Mount for $\varnothing 0.15''$ ( $\varnothing 3.8$ mm) to $\varnothing 3.00''$ ( $\varnothing 76.2$ mm) Optics
LH160C	LH160C/M	Adjustable Mount for 60 mm Cage Systems, $\varnothing 0.50''$ ( $\varnothing 13$ mm) to $\varnothing 2.00''$ ( $\varnothing 50.8$ mm) Optics
SCL60C	SCL60C/M	Self-Centering Mount for 60 mm Cage Systems, $\varnothing 0.15''$ ( $\varnothing 3.8$ mm) to $\varnothing 1.77''$ ( $\varnothing 45.0$ mm) Optics

### Mounting High-Curvature Optics

Thorlabs' retaining rings are used to secure unmounted optics within lens tubes or optic mounts. These rings are secured in position using a compatible spanner wrench. For flat or low-curvature optics, standard retaining rings manufactured from anodized aluminum are available from  $\varnothing 5$  mm to  $\varnothing 4''$ . For high-curvature optics, extra-thick retaining rings are available in  $\varnothing 1/2''$ ,  $\varnothing 1''$ , and  $\varnothing 2''$  sizes.

Extra-thick retaining rings offer several features that aid in mounting high-curvature optics such as aspheric lenses, short-focal-length plano-convex lenses, and condenser lenses. As shown in the animation to the right, the guide flange of the spanner wrench will collide with the surface of high-curvature lenses when using a standard retaining ring, potentially scratching the optic. This contact also creates a gap between the spanner wrench and retaining ring, preventing the ring from tightening correctly. Extra-thick retaining rings provide the necessary clearance for the spanner wrench to secure the lens without coming into contact with the optic surface.

### $\varnothing 1/2''$ ZnSe Positive Meniscus Lenses

Item #	Diameter	Focal Length	Diopter <sup>a</sup>	Radius of Curvature 1	Radius of Curvature 2	Center Thickness	Edge Thickness <sup>b</sup>	Back Focal Length <sup>c</sup>	Reference Drawing
LE7246-F	1/2"	15.0 mm	+66.6	7.5 mm	9.0 mm	2.9 mm	2.0 mm	11.6 mm	
LE7276-F	1/2"	20.0 mm	+50.0	7.5 mm	7.8 mm	3.0 mm	2.7 mm	15.3 mm	
LE7963-F	1/2"	40.0 mm	+25.0	10.9 mm	11.3 mm	3.0 mm	2.9 mm	33.6 mm	

Suggested Fixed Lens Mount: LMR05(M)

- Reciprocal of the Focal Length in Meters
- Edge Thickness Given Before 0.2 mm at  $45^\circ$  Typical
- Chamfer Measured at the Design Wavelength, 10.6  $\mu\text{m}$

Part Number	Description	Price	Availability
LE7246-F	$\varnothing 1/2''$ ZnSe Positive Meniscus Lens, f = 15.0 mm, ARC: 8-12 $\mu\text{m}$	\$395.97	Today
LE7276-F	$\varnothing 1/2''$ ZnSe Positive Meniscus Lens, f = 20.0 mm, ARC: 8-12 $\mu\text{m}$	\$395.97	Today
LE7963-F	$\varnothing 1/2''$ ZnSe Positive Meniscus Lens, f = 40.0 mm, ARC: 8-12 $\mu\text{m}$	\$395.97	Today

**Ø1" ZnSe Positive Meniscus Lenses**

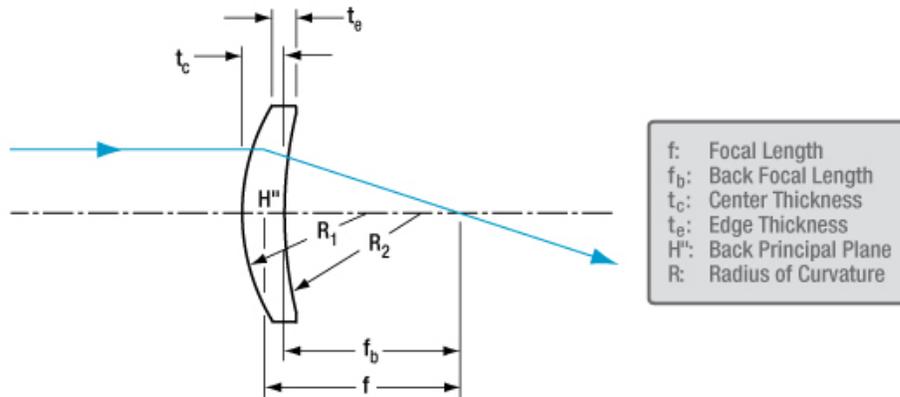
Item #	Diameter	Focal Length	Diopter <sup>a</sup>	Radius of Curvature 1	Radius of Curvature 2	Center Thickness	Edge Thickness <sup>b</sup>	Back Focal Length <sup>c</sup>	Reference Drawing
LE7185-F	1"	25.4 mm	+39.4	15.5 mm	22.6 mm	4.7 mm	2.0 mm	20.9 mm	
LE7981-F	1"	50.0 mm	+20.0	15.5 mm	16.9 mm	4.0 mm	3.1 mm	42.5 mm	
LE7996-F	1"	75.0 mm	+13.3	21.0 mm	23.3 mm	4.0 mm	3.5 mm	66.6 mm	
LE7031-F	1"	100.0 mm	+10.0	28.4 mm	32.6 mm	4.0 mm	3.6 mm	91.8 mm	
LE7667-F	1"	150.0 mm	+6.7	42.7 mm	50.7 mm	4.0 mm	3.7 mm	141.8 mm	
LE7898-F	1"	200.0 mm	+5.0	57.7 mm	69.7 mm	4.0 mm	3.8 mm	191.9 mm	
LE7495-F	1"	500.0 mm	+2.0	146.1 mm	181.6 mm	4.0 mm	3.9 mm	492.0 mm	
LE7117-F	1"	750.0 mm	+1.3	219.6 mm	274.5 mm	4.0 mm	3.9 mm	742.0 mm	
LE7199-F	1"	1000.0 mm	+1.0	293.0 mm	367.5 mm	4.0 mm	3.9 mm	992.0 mm	

Suggested Fixed Lens Mount: LMR1(M)

- a. Reciprocal of the Focal Length in Meters
- b. Edge Thickness Given Before 0.2 mm at 45° Typical
- c. Chamfer Measured at the Design Wavelength, 10.6  $\mu\text{m}$

Part Number	Description	Price	Availability
LE7185-F	Ø1" ZnSe Positive Meniscus Lens, f = 25.4 mm, ARC: 8-12 $\mu\text{m}$	\$572.33	Today
LE7981-F	Ø1" ZnSe Positive Meniscus Lens, f = 50.0 mm, ARC: 8-12 $\mu\text{m}$	\$572.33	Lead Time
LE7996-F	Ø1" ZnSe Positive Meniscus Lens, f = 75.0 mm, ARC: 8-12 $\mu\text{m}$	\$572.33	Today
LE7031-F	Ø1" ZnSe Positive Meniscus Lens, f = 100.0 mm, ARC: 8-12 $\mu\text{m}$	\$572.33	Today
LE7667-F	Ø1" ZnSe Positive Meniscus Lens, f = 150.0 mm, ARC: 8-12 $\mu\text{m}$	\$572.33	Today
LE7898-F	Ø1" ZnSe Positive Meniscus Lens, f = 200.0 mm, ARC: 8-12 $\mu\text{m}$	\$572.33	Today
LE7495-F	Ø1" ZnSe Positive Meniscus Lens, f = 500.0 mm, ARC: 8-12 $\mu\text{m}$	\$572.33	Today
LE7117-F	Ø1" ZnSe Positive Meniscus Lens, f = 750.0 mm, ARC: 8-12 $\mu\text{m}$	\$572.33	Today
LE7199-F	Ø1" ZnSe Positive Meniscus Lens, f = 1000.0 mm, ARC: 8-12 $\mu\text{m}$	\$572.33	Today

Info Icon :



Please note the focal length is determined from the back principal plane, which does not necessarily line up with the edge thickness.