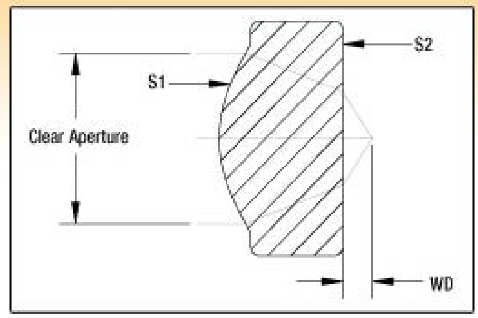
56 Sparta Avenue • Newton, New Jersey 07860
(973) 300-3000 Sales • (973) 300-3600 Fax
www.thorlabs.com

# C021TME-D - September 18, 2015

Item # C021TME-D was discontinued on September 18, 2015. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

## MOLDED IR ASPHERIC LENSES

- High NA (up to 0.85)
- Diffraction-Limited Performance
- Broadband AR-Coated Optics
- Collimate or Focus Light with a Single Element





Hide Overview

## OVERVIEW

### Features

- Focus or Collimate Light without Introducing Spherical Aberration
- Ø4.00 mm, Ø5.00 mm, or Ø7.80 mm Unmounted Clear Aperture
- AR Coated for 1.8 - 3 µm (-D), 3 - 5 µm (-E), or 8 - 12 µm (-F)
- Available Unmounted or Mounted in a Threaded, Engraved Stainless Steel Housing
- Black Diamond Substrate Provides Stable Operation up to 130 °C

| Webpage Features | |
|---|---|
| (info icon) | Click for complete specifications, documents, and drawings. |
| Performance Hyperlink | Click to view item-specific focal length shift data and spot diagrams at various wavelengths. |

| 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. |

| Alternative Aspheric Lenses | |
|---|---|
| Coating Designation | Spectral Range |
| Uncoated | Visible and NIR |
| -A | 350 - 700 nm |
| -B | 650 - 1050 nm |
| -C | 1050 - 1620 nm |
| -D | 1.8 - 3 µm |
| -E | 3 - 5 µm |
| -F | 8 - 12 µm |
| -405 | 405 nm |
| -1064 | 1064 nm |

Spherical aberration often prevents a spherical lens from achieving diffraction-limited performance. The surfaces of an aspheric lens are corrected for spherical aberration, thereby providing a robust single element solution for many applications, such as collimating the output of a fiber or laser diode, coupling light into a fiber, spatial filtering, or imaging light onto a detector. In particular, our IR aspheric lenses are ideal for collimating light from mid-wavelength infrared (MWIR) and long-wavelength infrared (LWIR) sources, including Quantum Cascade Lasers (QCLs).

### Hungry for Your MIR Thoughts

Contact Us

Thorlabs is adding products to its portfolio that are specifically designed for the MIR spectral range. In addition, we have started several new R&D collaborations within the last year. If you have new product ideas, comments on our existing MIR portfolio, see Thorlabs as a potential partner for an MIR project, or just want to provide some feedback,

| Common Specifications | |
|---|---|
| **Substrate** | Black Diamond-2 |
| **Refractive Index** | 2.630 at 2.5 µm[a] |
| **Damage Threshold**[b] | 100 W/cm$^2$ (1064 nm, CW)<br>0.1 J/cm$^2$ (1064 nm, 10 ns) |
| **Surface Quality (Bulk Material)** | 80-50 Scratch-Dig |
| **Coefficient of Thermal Expansion** | 13.5 x 10$^{-6}$ / °C |
| **Thermooptic Coefficient (Δn / ΔT)** | 91 x 10$^{-6}$ / °C |

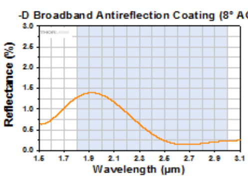
- See the *Refractive Index* tab for the wavelength-dependent refractive index.
- The damage threshold of these lenses is limited by the AR coating.

These molded glass lenses are available we'd welcome the opportunity to hear from you. unmounted or premounted in stainless steel lens housings that are engraved with the part number for easy identification. These housings have a metric external threading that makes them easy to integrate into an optical setup or OEM application. For example, they are readily adapted to our SM1 (1.035"-40) Lens Tubes by using our Aspheric Lens Adapters. Mounted aspheres can also be used as a drop-in replacement for multi-element microscope objectives in conjunction with our RMS-threaded Objective Replacement Adapters.

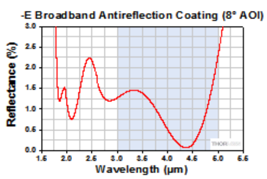
**Black Diamond**

Black Diamond-2 (BD-2), a chalcogenide made of an amorphous mixture of germanium (28%), antimony (12%), and selenium (60%), has several advantages over germanium, which is traditionally used to fabricate IR optics. BD-2's thermally stable refractive index (see the *Refractive Index* tab) and low coefficient of thermal expansion (13.5 x 10$^{-6}$ / °C) result in a smaller change in focal length as a function of temperature than for germanium. Additionally, germanium suffers from transmission loss as temperature increases, while BD-2 aspheric lenses can be used in environments up to 130 °C. This material performs particularly well over the 1.7 - 2.2 µm spectral range, providing >99% transmission and a flat dispersion curve. Click here to download a pdf of the MSDS for BD-2.

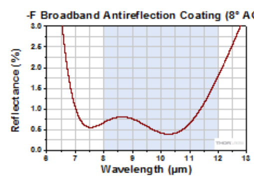
If an unmounted aspheric lens is being used to collimate the light from a point source or laser diode, the side with the greater radius of curvature should face the point source or laser diode. To collimate light using one of our mounted aspheric lenses, orient the housing so that the externally threaded end of the mount faces the source.



Click to Enlarge
Click Here for Raw Data



Click to Enlarge
Click Here for Raw Data

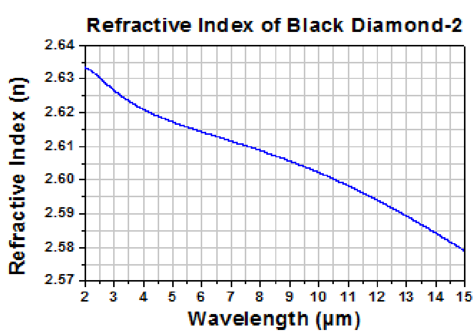


Click to Enlarge
Click Here for Raw Data

The shaded region in each graph indicates the range for which the coating is specified.

Hide Refractive Index

## REFRACTIVE INDEX



Click to Enlarge

| Herzberger Coefficient | Value |
|---|---|
| A | 2.614 |
| B | 1.491 x 10$^{-1}$ |
| C | -2.875 x 10$^{-1}$ |
| D | -9.573 x 10$^{-5}$ |
| E | -5.109 x 10$^{-7}$ |
| F | 9.894 x 10$^{-10}$ |

The refractive index of Black Diamond-2 (BD-2) as a function of wavelength, shown above, was calculated using the Herzberger Equation, an infrared-specific analog of the Sellmeier Equation. The Herzberger coefficients for BD-2 are given to the table to the right.

**Herzberger Equation (for λ in µm)**

$$n = A + BL + CL^2 + D\lambda^2 + E\lambda^4 + F\lambda^6$$

$$L = \frac{1}{\lambda^2 - 0.028}$$

Hide Fiber Coupling

FIBER COUPLING

## Choosing a Lens for Fiber Coupling

Aspheric lenses are commonly used to couple incident light with a spot size of 1 - 5 mm into a single mode fiber. The following simple example illustrates the key specifications to consider when trying to choose the correct lens.

**Example**

- Wavelength: 2 µm
- Fiber: P1-2000-FC-1
- Collimated Beam Diameter Prior to Lens: Ø2 mm

At 2 µm, Thorlabs' P1-2000-FC-1 single mode patch cable is specified with a mode field diameter (MFD) of 13 µm. This specification should be matched to the diffraction-limited spot size given by the following equation:

$$\phi_{spot} = \frac{4\lambda f}{\pi D}$$

Here, *f* is the focal length of the lens, λ is the wavelength of the input light, and *D* is the diameter of collimated beam incident on the lens. Solving for the desired focal length of the collimating lens yields

$$f = \frac{\pi D(MFD)}{4\lambda} = \frac{\pi(0.002\text{ m})(13 \times 10^{-6}\text{ m})}{4(2 \times 10^{-6}\text{ m})} = 10.2\text{ mm}$$

The mounted aspheric lens that is AR coated for our 2 µm wavelength and most closely matches the desired focal length of 10.2 mm is our C021TME-D (*f* = 11.00 mm), shown below. Its clear aperture of 4.00 mm is easily larger than the collimated beam diameter of 2 mm. It therefore meets the requirements of the example setup.

For optimal coupling, the spot size of the focused beam should be smaller than the MFD of the single mode fiber. Therefore, if an aspheric lens is not available that provides an exact match, choose an aspheric lens with a focal length that is shorter than that yielded by the calculation above. Alternatively, assuming the clear aperture of the aspheric lens is sufficiently large, the beam can be expanded before the aspheric lens to allow the focused beam to have a tighter spot.

Hide Lens Equation

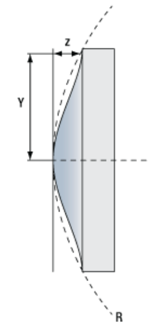
LENS EQUATION

## Aspheric Lens Design Formula

- Positive Radius Indicates that the Center of Curvature is to the Right of the Lens
- Negative Radius Indicates that the Center of Curvature is to the Left of the Lens

| Definitions of Variables | |
|---|---|
| z | Sag (Surface Profile) |
| Y | Radial Distance from Optical Axis |
| R | Radius of Curvature |
| k | Conic Constant |
| $A_4$ | 4th Order Aspheric Coefficient |
| $A_6$ | 6th Order Aspheric Coefficient |
| $A_n$ | *n*th Order Aspheric Coefficient |

The target values of these constants are available by clicking on the Info Icons below or by viewing the .pdf and .dxf files available for each lens. Links to the files can be found under the Drawings and Documents tab or by clicking on the part number in the price tables below.




Click to Enlarge Reference Drawing

$$z = \frac{Y^2}{R\left(1+\sqrt{1-(1+k)\frac{Y^2}{R^2}}\right)} + A_4Y^4 + A_6Y^6 + \cdots + A_nY^n$$

**Aspheric Lens Equation**

Hide Damage Thresholds

DAMAGE THRESHOLDS

## Damage Threshold Data for Thorlabs' Molded IR Aspheric Lenses

The specifications to the right are measured data for Thorlabs' molded IR aspheric lenses. Damage threshold specifications are constant for all black diamond IR aspheric lenses, regardless of the focal point of the lens.

| Damage Threshold Specifications | |
|---|---|
| **Damage Specification Type** | **Damage Threshold** |
| **Pulse** | 0.1 J/cm$^2$ (1064 nm, 10 ns) |
| **CW** | 100 W/cm$^2$ (1064 nm) |

## Laser Induced Damage Threshold Tutorial

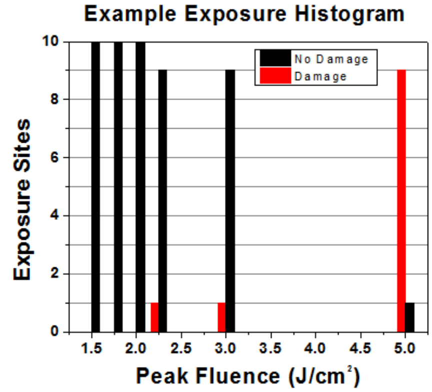
The following is a general overview of how laser induced damage thresholds are measured and how the values may be utilized in determining the appropriateness of an optic for a given application. When choosing optics, it is important to understand the Laser Induced Damage Threshold (LIDT) of the optics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

## Testing Method

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

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

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



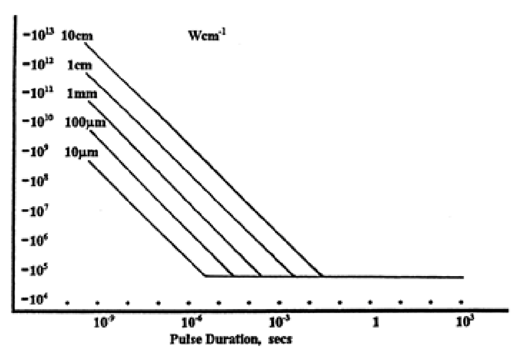

| Example Test Data | | | |
|---|---|---|---|
| Fluence | # of Tested Locations | Locations with Damage | Locations Without Damage |
| 1.50 J/cm$^2$ | 10 | 0 | 10 |
| 1.75 J/cm$^2$ | 10 | 0 | 10 |
| 2.00 J/cm$^2$ | 10 | 0 | 10 |
| 2.25 J/cm$^2$ | 10 | 1 | 9 |
| 3.00 J/cm$^2$ | 10 | 1 | 9 |
| 5.00 J/cm$^2$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

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

## 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.

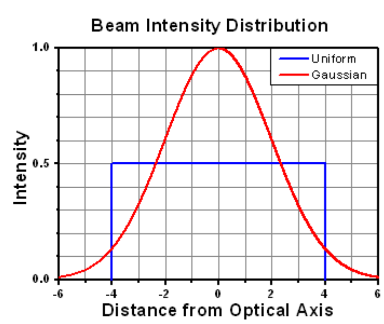



LIDT in linear power density vs. pulse length and spot size. For long pulses to CW, linear power density becomes a constant with spot size. This graph was obtained from [1].

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):

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

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

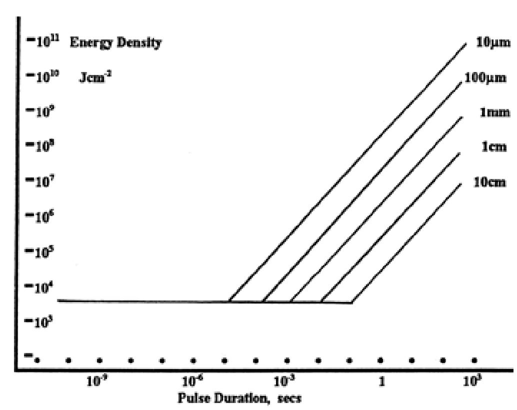
As previously stated, pulsed lasers typically induce a different type of damage to the optic than CW lasers. Pulsed lasers often do not heat the optic enough to damage it; instead, pulsed lasers produce strong electric fields capable of inducing dielectric breakdown in the material. Unfortunately, it 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)




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

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

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

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

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

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

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

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

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

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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).

## Molded IR Aspheric Lenses, AR Coated: 1.8 - 3 µm (-D)

| Item # (Unmounted/ Mounted) | Info | EFL[a] | NA | OD | CA | WD[b] | DW | AR Range | M | Glass | Performance | Thread | Suggested Spanner Wrench |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 390037-D | | 1.873 mm | 0.85 | 5.50 mm | 4.00 mm | 0.723 mm | 9.5 µm | 1.8 - 3 µm | ∞ | BD-2 | 37_Asph.pdf | - | - |
| C037TME-D | | | | 9.24 mm | | 0.34 mm | | | | | | M9 x 0.5 | SPW301 |
| 390036-D | | 4.00 mm | 0.56 | 6.50 mm | 5.00 mm | 3.05 mm | 2.5 µm | 1.8 - 3 µm | ∞ | BD-2 | 36_Asph.pdf | - | - |
| C036TME-D | | | | 9.24 mm | | 2.67 mm | | | | | | M9 x 0.5 | SPW301 |
| 390028-D | | 5.95 mm | 0.56 | 8.0 mm | 7.60 mm | 5.0 mm | 4.1 µm | 1.8 - 3 µm | ∞ | BD-2 | 23046-S01.pdf | - | - |
| C028TME-D | | | | 10.3 mm | | 4.0 mm | | | | | | M10 x 0.5 | SPW801 |
| 390021-D | | 11.00 mm | 0.18 | 5.1 mm | 4.00 mm | 9.8 mm | 3.5 µm | 1.8 - 3 µm | ∞ | BD-2 | 23094-S01.pdf | - | - |
| C021TME-D | | | | 8.2 mm | | 9.2 mm | | | | | | M8 x 0.5 | SPW308 |

- EFL is specified at the design wavelength.
- WD is specified at the design wavelength.

EFL = Effective Focal Length
NA = Numerical Aperture
CA = Clear Aperture

WD = Working Distance
DW = Design Wavelength

OD = Outer Diameter
M = Magnification

| Part Number | Description | Price | Availability |
|---|---|---|---|
| **390037-D** | **f = 1.873 mm, NA = 0.85, Unmounted Geltech Aspheric Lens, AR: 1.8 - 3 µm** | **$294.00** | **Today** |
| **C037TME-D** | **f = 1.873 mm, NA = 0.85, Mounted Geltech Aspheric Lens, AR: 1.8 - 3 µm** | **$319.00** | **Today** |
| **390036-D** | **f = 4.0 mm, NA = 0.56, Unmounted Geltech Aspheric Lens, AR: 1.8 - 3 µm** | **$294.00** | **Today** |
| **C036TME-D** | **f = 4.0 mm, NA = 0.56, Mounted Geltech Aspheric Lens, AR: 1.8 - 3 µm** | **$319.00** | **Today** |
| **390028-D** | **f = 5.95 mm, NA = 0.56 Unmounted Geltech Aspheric Lens, AR: 1.8 - 3 µm** | **$294.00** | **Today** |
| **C028TME-D** | **f = 5.95 mm, NA = 0.56 Mounted Geltech Aspheric Lens, AR: 1.8 - 3 µm** | **$319.00** | **Today** |
| **390021-D** | **f = 11.0 mm, NA = 0.18, Unmounted Geltech Aspheric Lens, AR: 1.8 - 3 µm** | **$285.00** | **Lead Time** |
| **C021TME-D** | **f = 11.0 mm, NA = 0.18, Mounted Geltech Aspheric Lens, AR: 1.8 - 3 µm** | **$285.00** | **Lead Time** |

Hide Molded IR Aspheric Lenses, AR Coated: 3 - 5 µm (-E)

## Molded IR Aspheric Lenses, AR Coated: 3 - 5 µm (-E)

| Item # (Unmounted/ Mounted) | Info | EFL[a] | NA | OD | CA | WD[b] | DW | AR Range | M | Glass | Performance | Thread | Suggested Spanner Wrench |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 390037-E | | 1.873 mm | 0.85 | 5.50 mm | 4.00 mm | 0.723 mm | 9.5 µm | 3 - 5 µm | ∞ | BD-2 | 37_Asph.pdf | - | - |
| C037TME-E | | | | 9.24 mm | | 0.34 mm | | | | | | M9 x 0.5 | SPW301 |
| 390036-E | | 4.00 mm | 0.56 | 6.50 mm | 5.00 mm | 3.05 mm | 2.5 µm | 3 - 5 µm | ∞ | BD-2 | 36_Asph.pdf | - | - |
| C036TME-E | | | | 9.24 mm | | 2.67 mm | | | | | | M9 x 0.5 | SPW301 |
| 390028-E | | 5.95 mm | 0.56 | 8.0 mm | 7.80 mm | 5.0 mm | 4.1 µm | 3 - 5 µm | ∞ | BD-2 | 23046-S01.pdf | - | - |
| C028TME-E | | | | 10.3 mm | | 4.00 mm | | | | | | M10 x 0.5 | SPW801 |

- EFL is specified at the design wavelength.
- WD is specified at the design wavelength.

EFL = Effective Focal Length
NA = Numerical Aperture
CA = Clear Aperture

WD = Working Distance
DW = Design Wavelength

OD = Outer Diameter
M = Magnification

| Part Number | Description | Price | Availability |
|---|---|---|---|
| **390037-E** | **f = 1.873 mm, NA = 0.85, Unmounted Geltech Aspheric Lens, AR: 3 - 5 µm** | **$294.00** | **Today** |
| **C037TME-E** | **f = 1.873 mm, NA = 0.85, Mounted Geltech Aspheric Lens, AR: 3 - 5 µm** | **$319.00** | **3-5 Days** |
| **390036-E** | **f = 4.0 mm, NA = 0.56, Unmounted Geltech Aspheric Lens, AR: 3 - 5 µm** | **$294.00** | **Today** |
| **C036TME-E** | **f = 4.0 mm, NA = 0.56, Mounted Geltech Aspheric Lens, AR: 3 - 5 µm** | **$319.00** | **Today** |
| **390028-E** | **f = 5.95 mm, NA = 0.56, Unmounted Geltech Aspheric Lens, AR: 3 - 5 µm** | **$294.00** | **Today** |
| **C028TME-E** | **f = 5.95 mm, NA = 0.56, Mounted Geltech Aspheric Lens, AR: 3 - 5 µm** | **$319.00** | **Today** |

Hide Molded IR Aspheric Lenses, AR Coated: 8 - 12 µm (-F)

## Molded IR Aspheric Lenses, AR Coated: 8 - 12 µm (-F)

| Item # (Unmounted/ Mounted) | Info | EFL[a] | NA | OD | CA | WD[b] | DW | AR Range | M | Glass | Performance | Thread | Suggested Spanner Wrench |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 390037-F | | 1.873 mm | 0.85 | 5.50 mm | 4.00 mm | 0.723 mm | 9.5 µm | 8 - 12 µm | ∞ | BD-2 | 37_Asph.pdf | - | - |
| C037TME-F | | | | 9.24 mm | | 0.34 mm | | | | | | M9 x 0.5 | SPW301 |
| 390036-F | | 4.00 mm | 0.56 | 6.50 mm | 5.00 mm | 3.05 mm | 2.5 µm | 8 - 12 µm | ∞ | BD-2 | 36_Asph.pdf | - | - |
| C036TME-F | | | | 9.24 mm | | 2.67 mm | | | | | | M9 x 0.5 | SPW301 |
| 390028-F | | 5.95 mm | 0.56 | 8.0 mm | 7.80 mm | 5.0 mm | 4.1 µm | 8 - 12 µm | ∞ | BD-2 | 23046-S01.pdf | - | - |
| C028TME-F | | | | 10.3 mm | | 4.00 mm | | | | | | M10 x 0.5 | SPW801 |
| 390021-F | | 11.00 mm | 0.18 | 5.1 mm | 4.00 mm | 9.8 mm | 3.5 µm | 8 - 12 µm | ∞ | BD-2 | 23094-S01.pdf | - | - |

- EFL is specified at the design wavelength.
- WD is specified at the design wavelength.

EFL = Effective Focal Length
NA = Numerical Aperture
CA = Clear Aperture

WD = Working Distance
DW = Design Wavelength

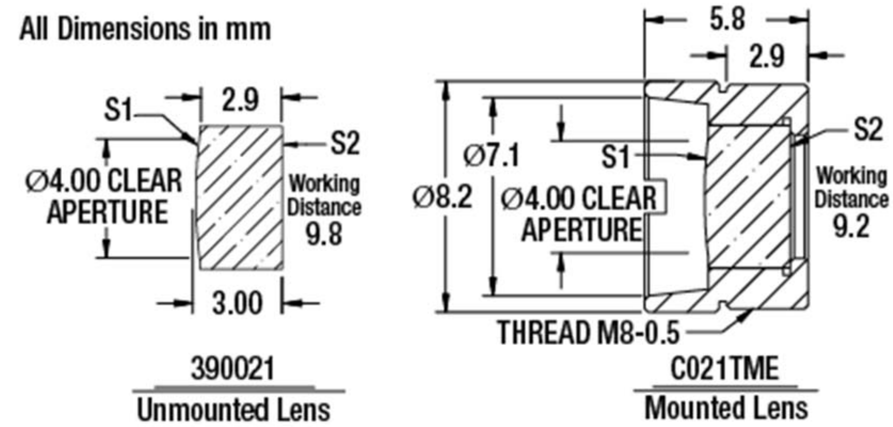
OD = Outer Diameter
M = Magnification

| Part Number | Description | Price | Availability |
|---|---|---|---|
| **390037-F** | **f = 1.873 mm, NA = 0.85, Unmounted Geltech Aspheric Lens, AR: 8 - 12 µm** | **$294.00** | **Today** |
| **C037TME-F** | **f = 1.873 mm, NA = 0.85, Mounted Geltech Aspheric Lens, AR: 8 - 12 µm** | **$319.00** | **Today** |
| **390036-F** | **f = 4.0 mm, NA = 0.56, Unmounted Geltech Aspheric Lens, AR: 4 - 12 µm** | **$294.00** | **Today** |
| **C036TME-F** | **f = 4.0 mm, NA = 0.56, Mounted Geltech Aspheric Lens, AR: 8 - 12 µm** | **$319.00** | **Today** |
| **390028-F** | **f = 5.95 mm, NA = 0.56, Unmounted Geltech Aspheric Lens, AR: 8 - 12 µm** | **$361.00** | **Today** |
| **C028TME-F** | **f = 5.95 mm, NA = 0.56, Mounted Geltech Aspheric Lens, AR: 8 - 12 µm** | **$391.00** | **Today** |
| **390021-F** | **f = 11.0 mm, NA = 0.18, Unmounted Geltech Aspheric Lens, AR: 8 - 12 µm** | **$285.00** | **Today** |

Visit the *Molded IR Aspheric Lenses* page for pricing and availability information:
http://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=4791

## 390021-D and C021TME-D

Specifications | Glass | Aspheric Coefficients




### Lens Specifications

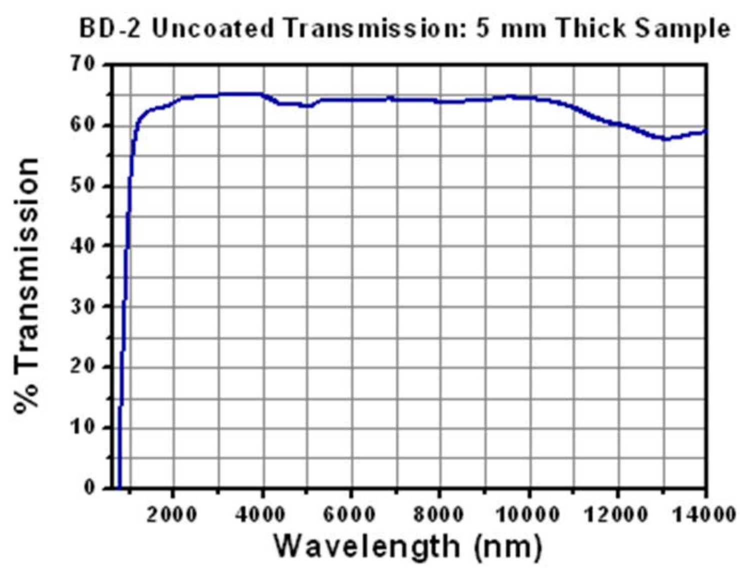
| | | | |
|---|---|---|---|
| **Design Wavelength** | 3500 nm | **Magnification** | Infinite |
| **Numerical Aperture** | 0.18 | **Window Thickness** | |
| **Clear Aperture** | 4.00 mm | **Laser Window Material / Index** | N/A |
| **Effective Focal Length** | 11.0 mm | **Glass** | BD-2 |
| **Working Distance** | 9.80 mm | **Surface Quality** | 80-50 Scratch-Dig(Entire Bulk Material) |

390021-D

C021TME-D

## 390021-D and C021TME-D

Specifications | Glass | Aspheric Coefficients




| | |
|---|---|
| $V_d$ number | - |
| CTE ($10^{-6}$ / °C) | 13.5 |
| Thermo optic coefficient ($10^{-6}$ / °C) ($\Delta n/\Delta T$) | 91 |

## 390021-D and C021TME-D

Specifications | Glass | **Aspheric Coefficients**

| Surface | Side 1 | Side 2 |
|---|---|---|
| **R(mm)** | 17.858297 | - |
| **k** | -2.168822 | - |
| $A_2$ | 0 | - |
| $A_4$ | 0 | - |
| $A_6$ | 0 | - |
| $A_8$ | 0 | - |
| $A_{10}$ | 0 | - |
| $A_{12}$ | 0 | - |

Side 1 and Side 2 are labeled as ASP1 and ASP2, respectively, on the drawings shown on the Specifications tab.

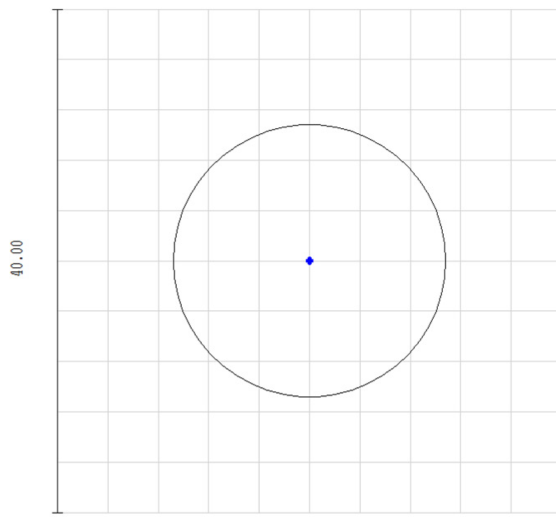
| | | | |
|---|---|---|---|
| z | SAG as a Function of Y | $A_4$ | $4^{th}$ Order Aspheric Coefficient |
| R | Radius of Curvature | $A_6$ | $6^{th}$ Order Aspheric Coefficient |
| k | Conic Constant | $A_8$ | $8^{th}$ Order Aspheric Coefficient |
| $A_2$ | $2^{nd}$ Order Aspheric Coefficient | $A_n$ | $n^{th}$ Order Aspheric Coefficient |

$$z = \frac{Y^2}{R\left(1+\sqrt{1-(1+k)Y^2/R^2}\right)} + A_2Y^2 + A_4Y^4 + A_6Y^6 + A_8Y^8 + A_{10}Y^{10} + A_{12}Y^{12} + A_{14}Y^{14} + A_{16}Y^{16}$$

# Spot Diagrams and Focal Length Shift for Molded Glass IR Aspheric Lenses 390021 and C021TME

### At Design Wavelength 3.5 µm

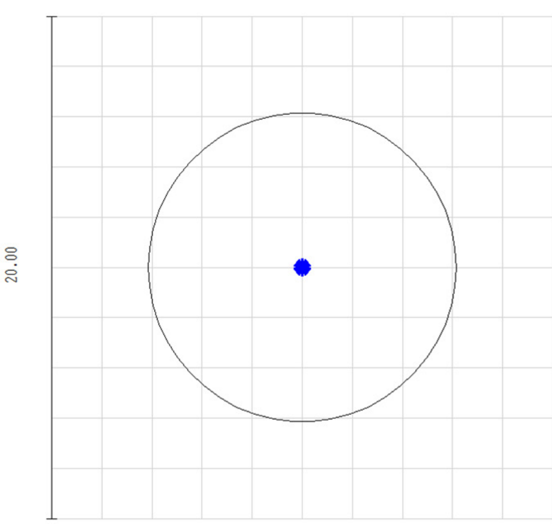
RMS Radius = 0.061 µm




## *Spot Diagrams for D-Coated Lens (390021-D)*

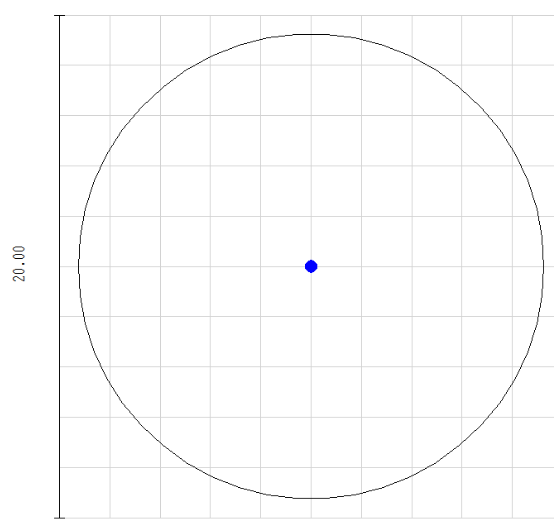
### 2.0 µm

RMS Radius = 0.154 µm




### 3.0 µm

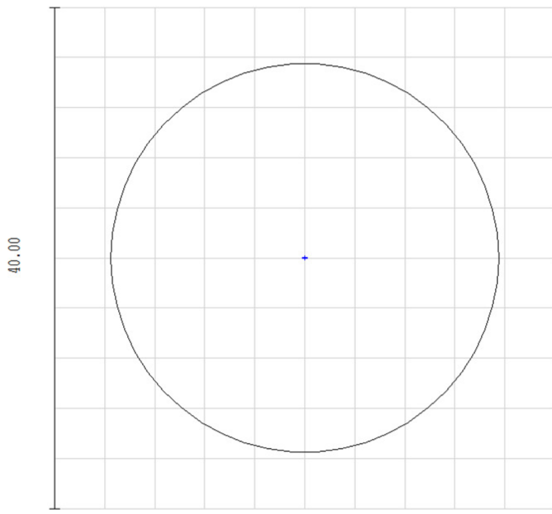
RMS Radius = 0.090 µm



## *Spot Diagram for E-Coated Lens (390021-E)*

**5.0 µm**

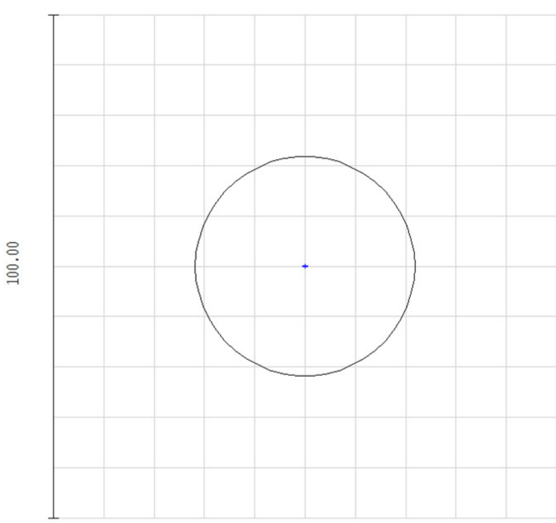
**RMS Radius = 0.016 µm**




## *Spot Diagrams for F-Coated Lens (390021-F)*

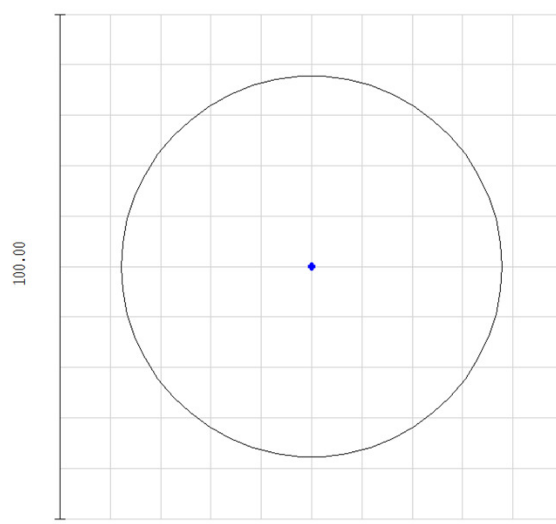
**7.0 µm**

**RMS Radius = 0.055**




**12.0 µm**

**RMS Radius = 0.215**



## *Chromatic Focal Shift*

**Maximum Focal Shift Range: 316.820 µm**
**Diffraction Limited Range: 89.873 µm**