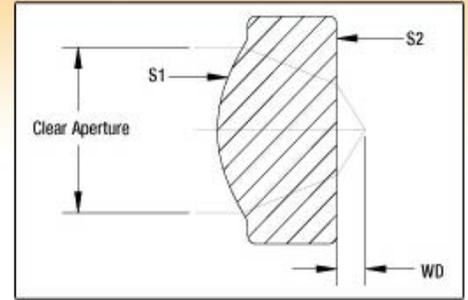


390021-E - July 16, 2015

Item # 390021-E was discontinued on July 16, 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



390021-D



390028-F



C028TME-E



390036-E



C036TME-D



C028TME-F

[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

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).

Webpage Features	
	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

Common Specifications	
Substrate	Black Diamond-2
Refractive Index	2.630 at 2.5 µm ^a

Our molded glass aspheres are available 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

Hungry for Your MIR Thoughts

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, we'd welcome the opportunity to hear from you.



[Contact Us](#)

Damage Threshold^b	100 W/cm ² (1064 nm, CW) 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
Theroptic Coefficient (Δn / ΔT)	91 x 10 ⁻⁶ / °C

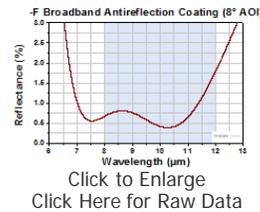
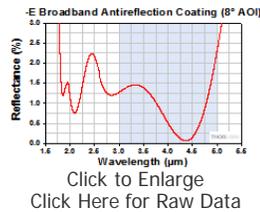
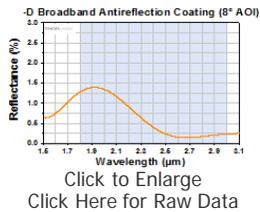
- See the *Refractive Index* tab for the wavelength-dependent refractive index.
- The damage threshold of these lenses is limited by the AR coating.

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.

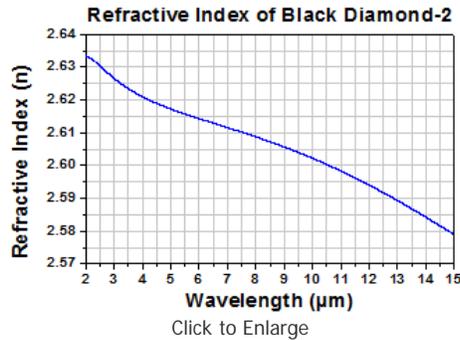
If an unmounted aspheric lens is being used to collimate the light from a point source or laser diode, the side with the greater radius of curvature should face the point source or laser diode. To collimate light using one of our mounted aspheric lenses, orient the housing so that the externally threaded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



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

[Hide Refractive Index](#)

REFRACTIVE INDEX



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)

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

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

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

[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: $\varnothing 2$ 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

Lens Design Formula

- Positive Radius Indicates that the Vertex is Located Left of the Center
- Negative Radius Indicates that the Vertex is Located Right of the Center

$$z = \frac{Y^2}{R(1 + \sqrt{1 - (1 + k)Y^2/R^2})} + A_4 Y^4 + A_6 Y^6 + A_8 Y^8 + A_{10} Y^{10} + A_{12} Y^{12}$$

Variable Definitions	
z	SAG as a Function of Y
R	Radius of Curvature
k	Conic Constant
A ₄	4 th Order Aspheric Coefficient
A ₆	6 th Order Aspheric Coefficient
A ₈	8 th Order Aspheric Coefficient
A ₁₀	10 th Order Aspheric Coefficient
A ₁₂	12 th Order Aspheric Coefficient

Aspheric Lens Coefficients

The aspheric lens coefficients are listed on the product page that is loaded by clicking on the part number in the price table below and in the .pdf and .dxf files available for each lens. Links to the files can be found under the *Documents & Drawings* tab or by clicking on the part number in the price table below.

COLLIMATION TUTORIAL

Choosing a Collimation Lens for Your Laser Diode

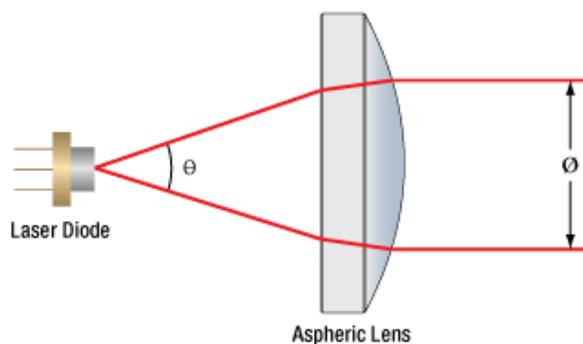
Since the output of a laser diode is highly divergent, collimating optics are necessary. Since aspheric lenses do not introduce spherical aberration, they are commonly chosen when the collimated laser beam is to be between one and five millimeters. A simple example will illustrate the key specifications to consider when choosing the correct lens for a given application.

Example:

Laser Diode to be Used: L780P010

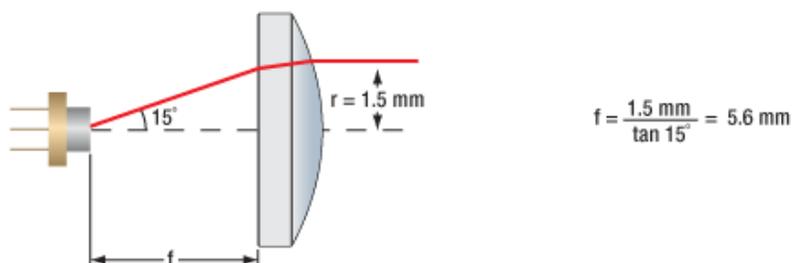
Desired Collimated Beam Diameter: $\varnothing 3$ mm (Major Axis)

The specifications for the L780P010 laser diode indicate that the typical parallel and perpendicular FWHM beam divergences are 10° and 30° , respectively. Therefore, as the light diverges, an elliptical beam will result. To collect as much light as possible during the collimation process, consider the larger of these two divergence angles in any calculations (i.e., in this case use 30°). If you wish to convert your elliptical beam into a round one, we suggest using an Anamorphic Prism Pair, which magnifies one axis of your beam.



\varnothing = Beam Diameter Θ = Divergence Angle

From the information above, the focal length of the lens can be determined, using the thin lens approximation:



With this information known, it is now time to choose the appropriate collimating lens. Thorlabs offers a large selection of aspheric lenses to choose from. For this application the ideal lens is a -B AR-coated molded glass aspheric lens with focal length near 5.6 mm. The C171TMD-B (mounted) or 354171-B (unmounted) aspheric lenses have a focal length of 6.20 mm, which will result in a collimated beam diameter (major axis) of 3.3 mm. Next, check to see if the numerical aperture (NA) of the diode is smaller than the NA of the lens:

$$0.30 = NA_{\text{Lens}} > NA_{\text{Diode}} \approx \sin(15^\circ) = 0.26$$

Up to this point, we have been using the FWHM beam diameter to characterize the beam. However, a better practice is to use the $1/e^2$ beam diameter. For a Gaussian beam profile, the $1/e^2$ diameter is almost equal to 1.7X the FWHM diameter. The $1/e^2$ beam diameter therefore captures more of the laser diode's output light (for greater power delivery) and minimizes far-field diffraction (by clipping less of the incident light).

A good rule of thumb is to pick a lens with an NA twice of the NA of the laser diode. For example, either the A390-B or the A390TM-B could be used as these lenses each have an NA of 0.53, which is more than twice the approximate NA of our laser diode (0.26). Note that these lenses each have a focal length of 4.6 mm, resulting in an approximate major beam diameter of 2.5 mm.

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/cm² (1064 nm, 10 ns pulse, 10 Hz, Ø1.000 mm) before damage.

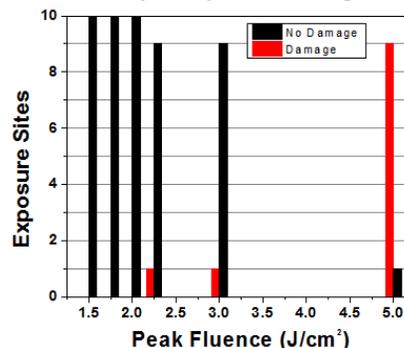
According to the test, the damage threshold of the mirror was 2.00 J/cm² (532 nm, 10 ns pulse, 10 Hz, Ø0.803 mm). Please keep in mind that it is only representative of one coating run and that Thorlabs' specified damage thresholds account for coating variances.

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

Example Exposure Histogram



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

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

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

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

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 relevant pulse lengths for our specified LIDT values.

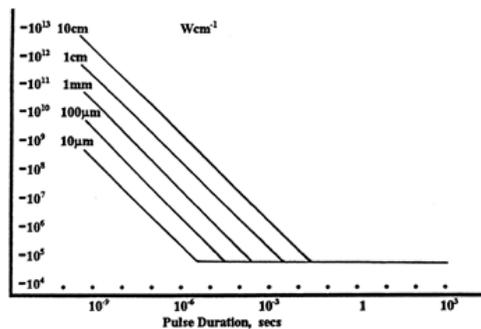
Pulses shorter than 10^{-9} s cannot be compared to our specified LIDT values with much reliability. In this ultra-short-pulse regime various mechanics, such as multiphoton-avalanche ionization, take over as the predominate damage mechanism [2]. In contrast, pulses between 10^{-7} s and 10^{-4} s may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

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

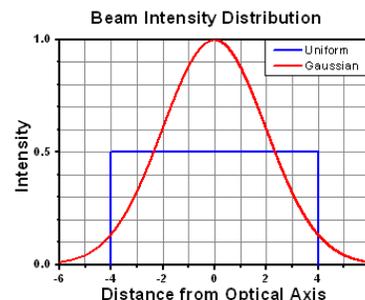
When comparing an LIDT specified for a pulsed laser to your laser, it is essential to know the following:

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

The energy density of your beam should be calculated in terms of J/cm². The graph



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].



Item # (Unmounted/ Mounted)	Info	EFL ^a	NA	CA	WD ^b	DW	OD	M	Performance	Thread	Suggested Spanner Wrench
390037-F		1.873 mm	0.85	4.00 mm	0.723 mm	9.5 μm	5.50 mm	∞	37_Asph.pdf	-	-
C037TME-F					0.34 mm		9.24 mm			M9 x 0.5	SPW301
390036-F		4.00 mm	0.56	5.00 mm	3.05 mm	2.5 μm	6.50 mm	∞	36_Asph.pdf	-	-
C036TME-F					2.67 mm		9.24 mm			M9 x 0.5	SPW301
390028-F		5.95 mm	0.56	7.80 mm	5.0 mm	4.1 μm	8.0 mm	∞	23046-S01.pdf	-	-
C028TME-F					4.00 mm		10.3 mm			M10 x 0.5	SPW801
390021-F		11.00 mm	0.18	4.00 mm	9.8 mm	3.5 μm	5.1 mm	∞	23094-S01.pdf	-	-
C021TME-F					9.2 mm		8.2 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-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
C021TME-F	f = 11.0 mm, NA = 0.18, Mounted Geltech Aspheric Lens, AR: 8 - 12 μm	\$310.00	Today