

- High quality optical glass lenses
- Custom designs available
- Numerical aperture up to 0.83
- Diameters from 0.250 mm to 25.0 mm
- Diffraction-limited performance
- Available in standard and custom housings

For today's sophisticated and compact laser systems, aspheres are the most powerful lenses for managing laser light. In these systems, spherical aberration is the most prevalent performance detractor. It arises from the use of spherical surfaces and artificially limits focusing and collimating accuracy.

Although it has been known for centuries that spherical geometry is not optimal for refracting light, the expense of fabricating non-spherical (aspheric) surfaces has inhibited their use. With the breakthrough of LightPath's glass molding technology, this optimal lens geometry has become a reality.

Molded lenses are used in a variety of photonics products: barcode scanners, laser diode to fiber couplings, optical data storage, and medical lasers, to name a few. In many of these applications, the material of choice is optical glass because of its durability and performance stability over a wide environmental range. High power transmittance is also an added advantage.

The benefits of glass molding technology become apparent when traditional methods of grinding and polishing become cost-prohibitive. The direct molding process eliminates the need for any grinding or polishing, offering aspheric lenses at practical prices for system designers. Molding is the most consistent and economical way to produce aspheres in large volumes.

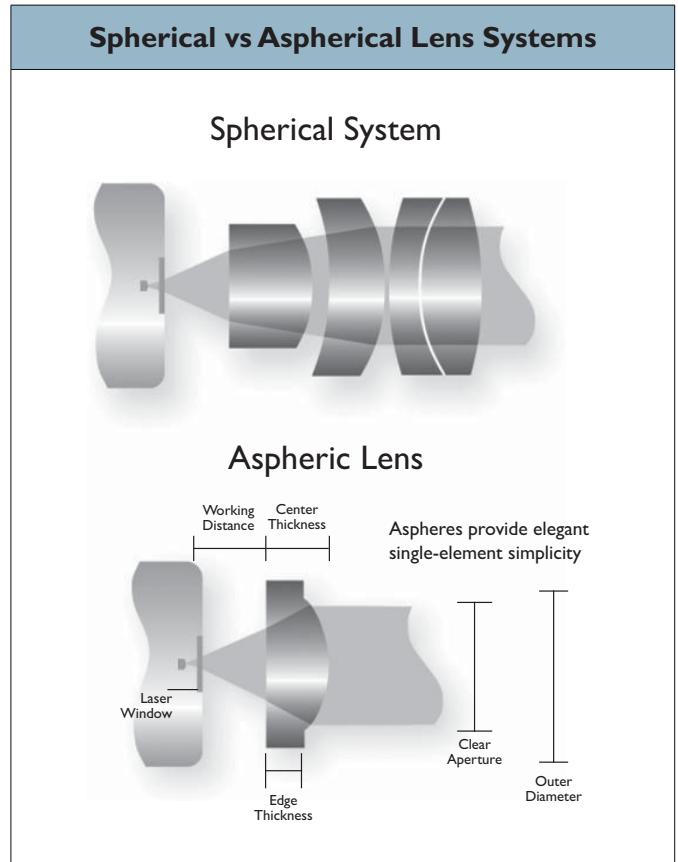
Small and lightweight, our aspheres collimate or focus light as a single element. This means less complex systems, fewer alignment requirements, less re-work and shorter assembly time. Our aspheres are molded; therefore the lenses have excellent piece-to-piece uniformity. They are made of glass, which is the most durable optical material available, capable of withstanding repeated cleaning and performing at specification despite extreme temperature and moisture variations.

## Guaranteed Performance

LightPath's aspheric lenses are inspected and optically tested to ensure complete customer satisfaction. Visual cosmetic inspection is performed on 100% of all lenses per MIL-PRF-13830B with a scratch/dig spec of 40/20. Other inspection criteria including 80/40 and 20/10 can be provided upon request.

Typical Tolerances	
Outer Diameter (OD)	± 0.015 mm
Clear Aperture (CA)	± 0.100 mm
Effective Focal Length (EFL)	± 1%
Working Distance (WD)	± 1% of EFL

Optical performance is guaranteed by test methods utilizing 632.8 mm interferometer measuring transmitted RMS wavefront error listed in the individual lens specification. LightPath can also perform customized optical tests in order to screen for specific application criteria.



## Optical Performance

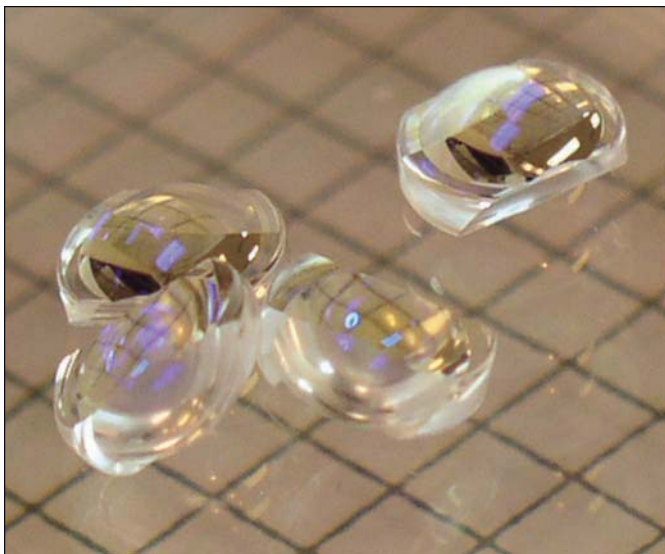
The primary optical specification is the root-mean-squared transmitted wavefront error (RMS WFE). It is measured on a phase shift interferometer at the wavelength of 632.8 nm. Most of our lenses are guaranteed to be diffraction limited, which means the RMS WFE  $< 0.070 \lambda$  at the design wavelength.

## Numerical Aperture

Our molded aspheric lenses are available with numerical apertures ranging from 0.15 up to 0.83. Lower NAs are best when a large depth of focus is important or when you need nearly circular beams. Examples of applications that would use a low numerical aperture are bar code scanners, surveying instruments, and small weapons sights. High numerical aperture lenses are important when you need to focus light down to a small spot size or when you need the maximum light capture from a diode laser. High numerical aperture applications include data storage and industrial printing.

## Shapes and Sizes

LightPath aspheric lenses are typically plano-convex or bi-convex, with diameters as large as 25 mm or as small as 0.250 mm. LightPath has the capability to dice the lenses to specified shapes for easier mounting.

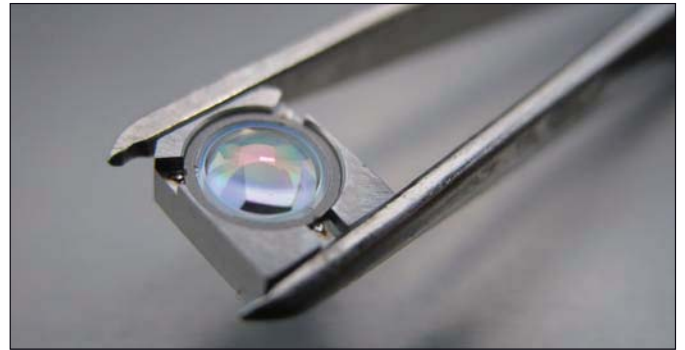


## Diffraction Hybrid Lenses

By combining a refractive aspheric lens with a diffractive feature on one surface, you can do sophisticated beam shaping on your laser light. You can also use diffractive hybrid lenses to make your system achromatic over a range of wavelengths. LightPath hybrid lenses are custom designed to each particular application. See page 34.

## Lens Holders

Several of our catalog lenses are available pre-mounted in metal holders. Using our unique Mold-In-Place (MIP) technology, we can actually mold the lens directly inside of a steel holder, eliminating the need for adhesives in your package. We can epoxy our lenses into Stainless Steel or Kovar mounts so you can weld them directly into your system.



## Custom Aspheres

Our catalog details 53 standard types of available aspheric lenses. If you do not see a lens that fits your particular application, **we would be happy to design one for you**. Our sales and engineering teams work closely together to assist you in design, prototyping, and production of custom glass aspheric lenses. LightPath offers custom lens solutions for high volume manufacturing at prices equal to those of standard off-the-shelf lenses. We pride ourselves on being the fastest custom lens designers in the industry.

When determining specifications for custom aspheric lenses, the following parameters are typically used to specify lens performance. A LightPath product expert would be happy to discuss the following list of parameters with you to determine the appropriate lens for your application.

Custom Asphere Specifications		
Wavelength Used	<input type="text"/>	microns
Numerical Aperture (NA)	<input type="text"/>	
Effective Focal Length (EFL)	<input type="text"/>	mm
Minimum Clear Aperture	<input type="text"/>	mm
Minimum Back Focal Length	<input type="text"/>	mm
Mechanical Space Constraints	<input type="text"/>	

Application notes for choosing the right aspheric lens are also available online. Please see [www.lightpath.com/literature/technicalPapers.php](http://www.lightpath.com/literature/technicalPapers.php) for more details.

## Standard Glasses

LightPath Technologies manufactures aspheric lenses using several different types of glass. These glasses have been fully qualified, along with the corresponding AR coating. Transmittance of all five glasses is very good over a large wavelength spectrum.

Lens Code	Glass Type	Refractive Index	Abbe Number	CTE	dn/dT	Equivalent Glasses	RoHS Compliance
350xxx	C-0550	1.605	$v_d = 50.42$	$15 \times 10^{-6} / ^\circ\text{C}$	$-11 \times 10^{-6} / ^\circ\text{C}$	Corning BCD-C2060 & Schott SKI6	✗
352xxx	ECO-550	1.606	$v_d = 50.27$	$11.62 \times 10^{-6} / ^\circ\text{C}$	$2.39 \times 10^{-6} / ^\circ\text{C}$	N/A	✓
354xxx	D-ZK3	1.586	$v_d = 60.71$	$7.6 \times 10^{-6} / ^\circ\text{C}$	$3.2 \times 10^{-6} / ^\circ\text{C}$	Hoya M-BACD5N & Ohara L-BAL35	✓
355xxx	D-ZLaF52LA	1.806	$v_d = 40.79$	$6.9 \times 10^{-6} / ^\circ\text{C}$	$6.5 \times 10^{-6} / ^\circ\text{C}$	Ohara L-LAH53, Hoya M-NBFD130, Sumita K-VC89	✓
370xxx	PBH71	1.922	$v_d = 21.29$	$8.9 \times 10^{-6} / ^\circ\text{C}$	$13.1 \times 10^{-6} / ^\circ\text{C}$	Schott SF66, Hoya FDSI, Sumita PSFN5	✗

### D-ZLAF52LA → 355xxx Series of Lenses

This glass has a higher index of refraction than ECO-550 and is best suited for those applications that require a higher index and need to maintain RoHS compliance.

### D-ZK3 → 354xxx Series of Lenses

This glass is best suited for those applications that require a low cost glass for higher volume manufacturing.

### ECO-550 → 352xxx Series of Lenses

New European (RoHS) and Japanese environmental regulations have restricted the use of lead and other hazardous substances in optical components. ECO-550 is an environmentally friendly alternative to conventional moldable glasses. It has similar optical properties to C-0550, but does not contain hazardous materials.

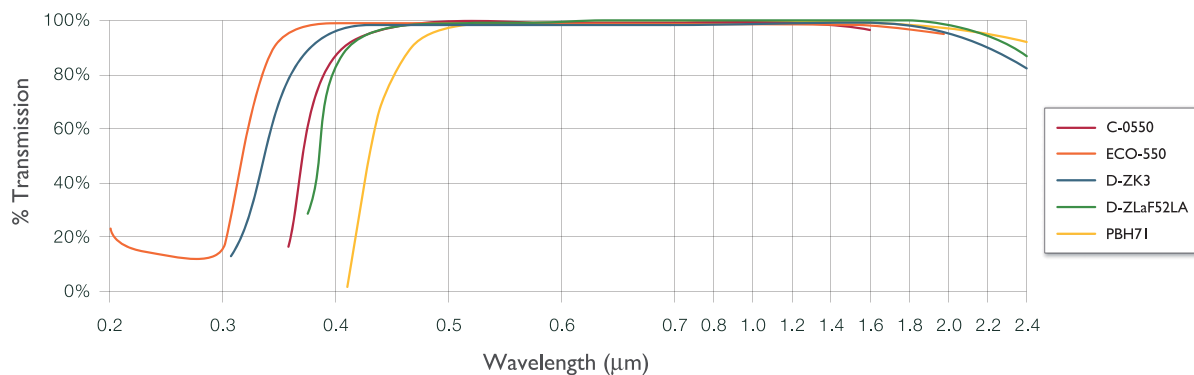
### C-0550 → 350xxx Series of Lenses

Corning® developed a special glass to allow production of highly sophisticated aspheric lenses that are cost effective. The code for this glass is C-0550, and its low dispersion ( $v_d = 50.40$ ) is key for many applications. In durability, it is equivalent to Corning® BCD C2060 or Schott® SKI6. Due to limited availability, this glass should only be used for special projects that require its unique properties.

### PBH71 → 370xxx Series of Lenses

For aspheric lenses that require a glass with a higher index of refraction, LightPath also offers lenses made from Ohara® PBH71 glass. Its high index ( $n_d = 1.92286$ ) allows designers to minimize aberrations in lenses with high numerical apertures. It has the added benefit of a lower coefficient of thermal expansion.

Standard Glass Internal Transmission Curves (5 mm thickness)



LightPath's capabilities include most high volume moldable glasses from Corning®, Schott®, Sumita®, and CDGM®.

## Standard Anti-Reflective Coatings

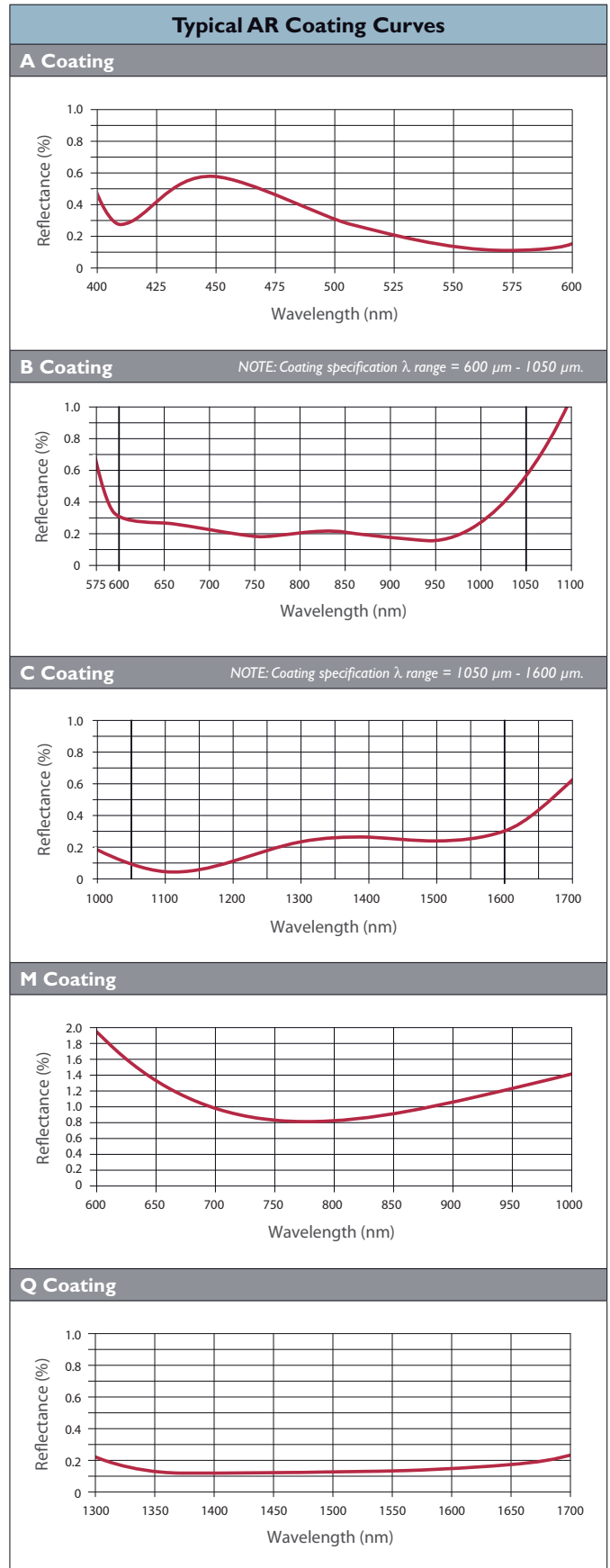
LightPath offers a variety of multilayer broadband coatings to reduce the back reflection from a nominal 6% for uncoated lenses. The choice of which AR coating is appropriate depends on the type of glass the lens is made from and the wavelength at which the lens will be used.

Standard Coatings			
Lens Series	Coating	$\lambda$ Range ( $\mu\text{m}$ )	$R_{\text{MAX}}$
352xxx, 354xxx, 355xxx	MLBB-A	400 - 600	< 1.0%
352xxx, 354xxx, 355xxx	MLBB-B	600 - 1050	< 1.0%
352xxx, 354xxx, 355xxx	MLBB-C	1050 - 1600	< 1.0%
352xxx, 354xxx, 355xxx	MLBB-M	700 - 900	< 2.0%
370xxx	MLBB-Q	1300 - 1700	< 0.25%

Available Coatings			
Lens Series	Coating	$\lambda$ Range ( $\mu\text{m}$ )	$R_{\text{MAX}}$
352xxx	MLBB-D	1300 - 1700	< 0.25%
352xxx	MLBB-E	1800 - 2400	< 0.50%
370xxx	MLBB-O	600 - 1050	< 1.0%
370xxx	MLBB-P	1050 - 1600	< 1.0%

LightPath's rigorous qualification process ensures that all of the standard coatings will pass the abrasion and adhesion resistance requirements of ISO+9211-4-1996.

**LightPath is happy to provide any AR coatings based on specific requirements.**



## For Diode Collimation

One of the most common uses for aspheric lenses is in the collimation of edge emitting diode lasers. With over 35 standard lenses in LightPath's catalog to choose from, however, this can sometimes be a confusing task. The guide below will clear up some of the questions about choosing the best lens to use with a specific laser for a particular application.

Due to the way that the laser cavity is constructed in edge emitting diode lasers, light is emitted in a diverging, elliptical geometry - so the divergence is typically specified in both the x and y axes separately. The axis with the larger divergence is called the "fast axis" and the axis with the smaller divergence is called the "slow axis".

When selecting a lens to collimate the laser, first consider the Numerical Aperture of the lens. If the application requires a high amount of the laser light to be coupled through the system, a lens with a high enough NA must be chosen. The NA of a lens is a measure of the maximum amount of divergence that the lens can capture from the laser. Ideally, a lens should be used that has an NA higher than the NA of the laser's fast axis. If not, the laser will "clip" the lens causing some of the light to be wasted. To convert the laser NA to the divergence angle (and vice-versa), use this formula:

$$NA = n \cdot \sin(\phi)$$

In most cases,  $n = 1$  since the NA of the laser is defined in air. Therefore, solving for the equation is simplified to:

$$\phi = \sin^{-1}(NA)$$

It is important to note that  $\phi$  is the **half** angle of the divergence cone and is given at the **marginal ray** (not  $1/e^2$  or half angle half max).

After the minimum NA necessary for the lens is determined, next consider what beam diameter is preferred. Although ray-tracing is necessary to precisely determine the beam diameter for a given NA source with a particular lens, it can be approximated with the following formula:

$$Beam\ Diameter \cong 2 \cdot EFL \cdot NA$$

where EFL is the effective focal length of the lens and NA is the numerical aperture of the source (not the NA of the lens).

### Important Note:

Some laser manufacturers give the NA of the source in different terms, such as half max (50% point) or  $1/e^2$  (87% point). Whatever type of number is entered into the formula for the NA of the source will be the same type of number given for the beam diameter.

For example, if the half max NA for a laser is used with the above formula, you will get the half max beam diameter. There is no simple way to convert from a half max number or a  $1/e^2$  beam diameter to a full beam diameter for a specific source because it depends on the intensity profile of the source itself. A reasonable approximation, though, for most edge emitting diode lasers is to assume a Gaussian beam profile. Using this beam profile, you can convert the beam diameters as follows:

1. To convert a half max beam diameter to a full beam diameter, multiply the diameter by 2.576.
2. To convert a  $1/e^2$  beam diameter to a full beam diameter, multiply the diameter by 1.517.

Remember that most edge emitting diodes are elliptical, so the beam diameter will be different in the x-axis versus the y-axis. Use the formula above to calculate the beam diameter in both axes to determine the shape of the collimated, elliptical beam.

## For Fiber Coupling

Another common use for aspheric lenses is to couple laser light into optical fibers. Choosing the right lens or lenses to do the coupling is important to maintain high efficiency in the optical system. The guide below is intended to show how best to do this while using off-the-shelf components. This guide assumes that the input laser light has already been collimated (not diverging).

When selecting a lens to focus light into a fiber, first consider what focal length lens is needed. Let's revisit the formula given previously:

$$Beam\ Diameter \cong 2 \cdot EFL \cdot NA$$

Solving for EFL it becomes:

$$EFL \cong \frac{Beam\ Diameter}{2 \cdot NA}$$

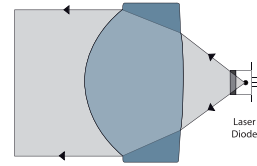
where NA is the numerical aperture of the fiber that is used for the coupling.

It is important to note that the EFL value that is calculated above is the **minimum** EFL needed to couple the light completely into the fiber. Longer EFL lenses can be used, but the spot size on the fiber tip will become larger. Therefore, it is best practice to use the shortest EFL lens possible that is larger than the minimum value specified above.

# Geltech Aspheric Lenses

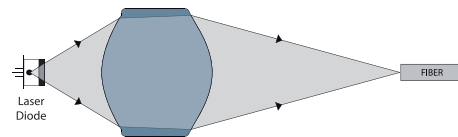
Standard Lenses				
Lens Code	NA	EFL (mm)	CA (mm)	OD (mm)
352022	0.47	4.47	4.20	5.42
352080	0.55	3.89	4.29	6.33
352105	0.54	5.50	6.00	7.20
352110	0.40	6.24	5.00	7.20
352115	0.52	6.75	7.00	9.20
352125	0.50	10.00	10.00	11.00
352140	0.55	1.45	1.60	2.40
352150	0.50	2.00	2.00	3.00
352170	0.30	6.16	3.70	4.70
352220	0.25	11.00	5.50	7.22
352230	0.55	4.51	4.95	6.33
352240	0.50	8.00	8.00	9.94
352260	0.16	15.29	5.00	6.50
352280	0.15	18.40	5.50	6.50
352330	0.68	3.10	5.00	6.33
352340	0.62	4.03	5.00	6.33
352350	0.42	4.50	3.70	4.70
352440	0.53 / 0.27	2.95	4.00 / 4.20	4.70
352450	0.30 / 0.30	1.16	1.15 / 1.15	1.80
352610	0.60	4.00	4.80	6.325
352671	0.60	4.02	4.80	6.33
352673	0.60	4.02	4.80	6.33
352710	0.50	1.49	1.50	2.65
352-A375	0.30	7.50	4.50	6.51
352-A390	0.53	4.60	4.89	6.00
352-A397	0.30	11.00	6.59	7.20
354057	0.20	13.00	5.20	6.33
354058	0.22	12.00	5.20	6.33
354059	0.19	14.00	5.20	6.33
354060	0.30	9.60	5.20	6.33
354061	0.24	11.00	5.20	6.33
354062	0.24	11.00	5.20	6.00
354120	0.15	15.04	4.50	5.00
354130	0.21	6.00	2.50	3.00
354171	0.30	6.20	3.70	4.70
354430	0.15	5.00	1.60	2.00
354550	0.18	6.10	2.20	2.79
354560	0.18	13.86	5.10	6.33
354850	0.13	22.00	5.50	6.33
354996	0.24	11.00	5.50	6.33
355160	0.55	2.73	3.00	4.00
355200	0.43 / 0.12	1.14	1.13 / 1.3	2.40
355390	0.55	2.75	3.60	4.50
355660	0.60	2.97	3.60	4.00
370060	0.600	0.682	0.840	2.500
370631	0.55 / 0.13	0.382	0.40 / 0.53	0.550
370840	0.800	0.750	1.200	3.000
370880	0.600	0.700	0.840	2.500
370890	0.300	1.800	1.080	3.000
370920	0.800	0.750	1.200	1.670
370930	0.600	0.700	0.840	1.765
370940	0.170	4.000	1.370	3.000
370945	0.100	2.510	0.510	2.250

## Laser Diode Collimating Lenses



Lens Code	NA	EFL (mm)	CA (mm)	OD (mm)	Window Thickness (mm)
352022	0.47	4.47	4.20	5.42	1.20
352105	0.54	5.50	6.00	7.20	0.25
352110	0.40	6.24	5.00	7.20	0.275
352115	0.52	6.75	7.00	9.20	0.25
352125	0.50	10.00	10.00	11.00	0.25
352140	0.55	1.45	1.60	2.40	none
352150	0.50	2.00	2.00	3.00	0.25
352170	0.30	6.16	3.70	4.70	0.275
352220	0.25	11.00	5.50	7.20	0.25
352230	0.55	4.51	4.95	6.325	0.25
352240	0.50	8.00	8.00	9.94	0.25
352330	0.68	3.10	5.00	6.325	none
352350	0.42	4.50	3.70	4.70	none
352673	0.60	4.02	4.80	6.325	0.25
352710	0.50	1.49	1.50	2.65	0.25
352-A375	0.30	7.50	4.50	6.51	0.275
352-A390	0.53	4.60	4.89	6.00	0.275
352-A397	0.30	11.00	6.68	6.15	0.275
355390	0.68	2.75	3.60	4.00	none
355660	0.60	2.97	3.60	4.00	none
370060	0.60	0.682	0.84	2.50	none
370840	0.80	0.75	1.20	3.00	none
370880	0.60	0.70	0.84	2.50	none
370890	0.30	1.80	1.08	3.00	none
370920	0.80	0.75	1.20	3.60	none
370930	0.60	0.70	0.84	1.77	none

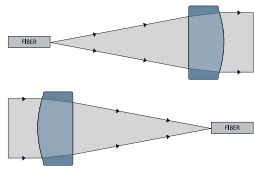
## Laser to Fiber Coupling Lens



Lens Code	NA (object)	NA (image)	MAG	EFL (mm)	OD (mm)
352440	0.53	0.27	2.00	2.95	4.70
355200	0.43	0.12	3.64	1.14	2.40
370631	0.55	0.13	4.02	0.382	1.20

# Geltech Aspheric Lenses

## Fiber Collimating/Coupling Lenses

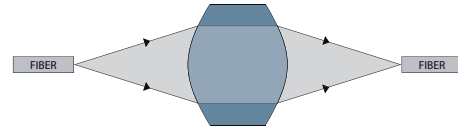


Fiber Collimating

Fiber Coupling

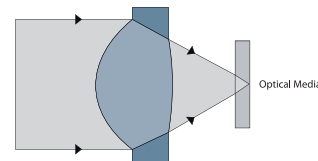
Lens Code	NA	EFL (mm)	CA (mm)	OD (mm)
352170	0.30	6.16	3.70	4.70
352220	0.25	11.00	5.50	7.20
352260	0.16	15.29	5.00	6.50
352280	0.15	18.40	5.50	6.50
354057	0.20	13.00	5.20	6.33
354058	0.22	12.00	5.20	6.33
354059	0.19	14.00	5.20	6.33
354060	0.30	9.60	5.20	6.33
354061	0.24	11.00	5.20	6.33
354062	0.24	11.00	5.20	6.00
354120	0.15	15.04	4.50	5.00
354130	0.21	6.00	2.50	3.00
354171	0.30	6.20	3.70	4.70
354430	0.15	5.00	1.50	2.00
354550	0.18	6.10	2.20	2.80
354560	0.18	13.86	5.10	6.325
354850	0.13	22.00	5.50	6.33
354996	0.24	11.00	5.50	6.33
370890	0.30	1.80	1.08	3.00
370940	0.17	4.00	1.37	3.00
370945	0.10	2.51	0.51	2.25

## Fiber to Fiber Coupling Lens



Lens Code	NA (object)	NA (image)	MAG	EFL (mm)	OD (mm)
352450	0.30	0.30	1.00	1.16	1.80

## Data Storage Objective Lenses



Lens Code	NA	EFL (mm)	CA (mm)	OD (mm)	Media Thickness (mm)
352022	0.47	4.47	4.20	5.42	1.20
352080	0.55	3.89	4.29	6.325	1.20
352340	0.62	4.03	5.00	6.325	1.20
352610	0.60	4.00	4.80	6.325	1.20
352671	0.60	4.02	4.80	6.33	0.250
352673	0.60	4.02	4.80	6.33	0.250
355160	0.55	2.73	3.00	4.00	1.20

## Geltech Aspheric Lens Selection Guide

		Focal Length (mm)				
		0 - 1.9	2 - 3.9	4 - 5.9	6 - 9.9	10 - 22
Numerical Aperture (NA)	0.10 - 0.19		370945	370940 354430	354550	354560 354059 354120 352260 352280 354850
	0.20 - 0.29				354130	354061 354062 354996 352220 354058 354057
	0.30 - 0.39	352450 370890			352170 354171 354060 352-A375	352-A397
	0.40 - 0.49	355200		352022 352350	352110	
	0.50 - 0.59	370631 352140 352710	352150 355390 352440 352080	352230 352-A390 352105	352115 352240	352125
	0.60 - 0.69	370060 370880 370930	355660 352330	352671 352673 352340		
	0.70 - 0.89	370840 370920				