



Best Form Lenses

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Best Form Laser Lens Theory

What are Bestforms:

Simple focusing and collimating of laser light can often be accomplished by using a single lens element. However, the focused spot size, energy intensity and image quality are all dependent on, not only the focal length, but also the laser beam diameter, the lens radii and the center thickness of the element. Since there are many different lens radii combinations that could be used to achieve a particular focal length, the task becomes one of finding the best combination to minimize or eliminate lens aberrations. A Best Form lens is a singlet lens which has been optimized to have diffraction limited ($< 1/4$ wave) wavefront distortion.

A Best Form Laser Lens will focus a laser beam of a given diameter to the smallest spot size possible. As will be discussed, the spot size is proportional to the input beam diameter and the focal length of the lens.

Definitions

Throughout the following overview of diffraction limited lenses the following definitions will be used:

- D = Lens Aperture (mm)
- f = Focal Length (mm)
- λ = Wavelength (microns)
- 2a = $(1/e)^2$ Laser Beam Diameter
- W_0 = $(1/e)^2$ Diameter at the Beam Waist
- θ = Full Angle Beam Divergence (mrad)

What is Diffraction Limited?

During the course of a lens design, the goal is always to minimize third order aberrations such as spherical aberration, coma, astigmatism and distortion. For focusing systems these aberrations manifest as changes in the focused spot energy distribution. Most often the aberrated wavefronts are discussed in terms of wavefront distortion or Optical Path Difference (OPD). If the aberrations can be corrected to the extent of reducing the OPD to less than one quarter of the wavelength of the incident light, then the system is considered diffraction limited. In such cases, the focused spot intensity distribution is essentially unchanged.

Uniform Intensity Distribution

When a diffraction limited lens system is irradiated at its aperture with a uniform intensity distribution (top hat beam profile), a diffraction pattern is formed at the focus. The pattern consists of a bright central spot surrounded by rings of rapidly diminishing intensity.

The diameter of the central spot, known as the Airy disc, is approximated by the following equation:

$$S = 2.44 \lambda(f/D)$$

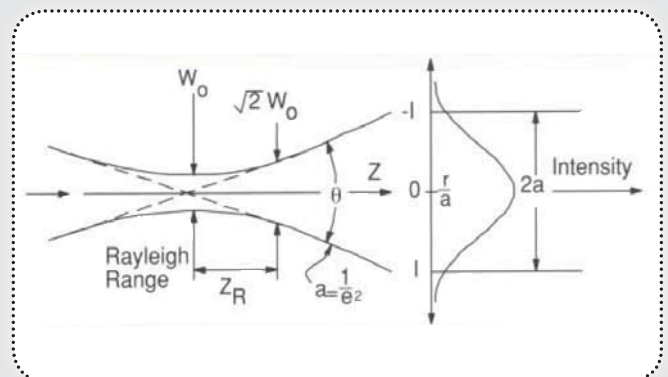
In the absence of any lens imperfection, 84% of the total energy is contained within the central spot diameter. For an optical path difference of $1/4$ wave (diffraction limited) the central spot remains unchanged in size, however the energy contained within it is reduced to 64%.

Gaussian Intensity Distribution

In general, the more common energy distribution for a laser beam is Gaussian i.e. TEM_{00} . If a lens system is irradiated by such a distribution, the focused intensity distribution will be as follows:

$$I(r) = I_0 \exp\{-2r^2/a^2\} = (2P_0/\pi a^2) \exp\{-2r^2/a^2\}$$

where P_0 is the total output power, and $I(r)$ is the intensity at the distance r from the beam center.



Bestform Laser Lens Theory

Focusing Gaussian Laser Beams

In the case where the lens is illuminated with a Gaussian beam, the ratio of the beam diameter to the lens diameter ($2a/D$) becomes an important factor. As the ratio approaches 1, truncation from the lens boundary produces diffraction effects at the focal point. The energy distribution at this point most closely resembles the Airy pattern. If the ratio is 1/2.8 or less the spot size can then be approximated by:

$$S_e = 1.27 \lambda f / (2a)$$

where S_e represents the $1/e^2$ beam diameter. At this ratio 86.5% of the laser energy is contained within this diameter. Note that this equation is theoretical and applies if the laser beam is essentially an ideal, distortion-free Gaussian beam.

Often the laser source is not perfectly Gaussian or without divergence. For example, when multimode lasers or TEM₀₀ lasers with divergences over 0.2 mrad are focused with diffraction limited optics, a more reasonable approximation is:

$$S_e = \theta \times f$$

where θ is the full angle beam divergence.

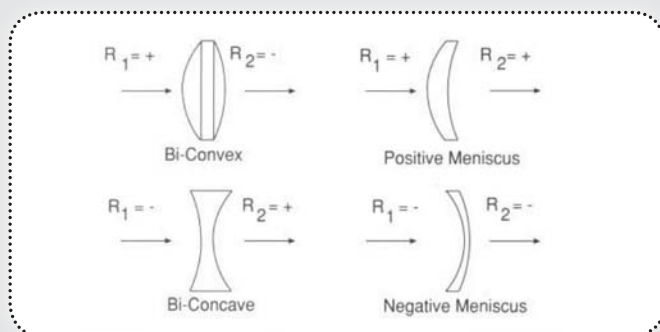
Other Useful Optical Equations

Snell's Law: $n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$

Critical Angle: $\theta_c = \sin^{-1}(n_1/n_2)$

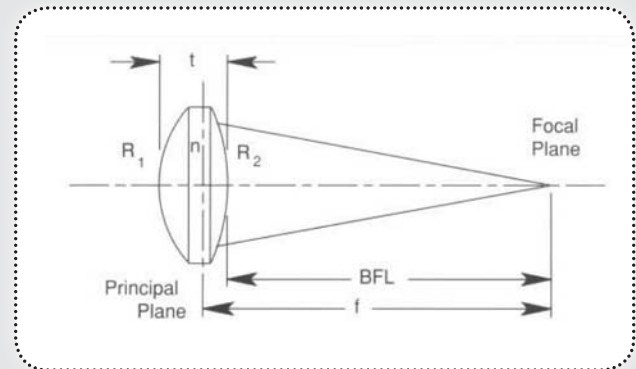
Numerical Aperture: $NA = 1/(2F/\#) = d/(2f)$
where d is the beam diameter and f is the focal length.

Radius Convention



Lensmakers Formula

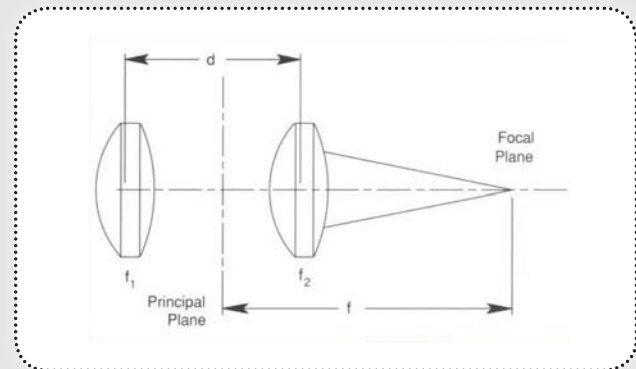
$$1/f = (n-1) \{1/R_1 - 1/R_2 + t(n-1) / (R_1 R_2 n)\}$$



Double Lens Formulas

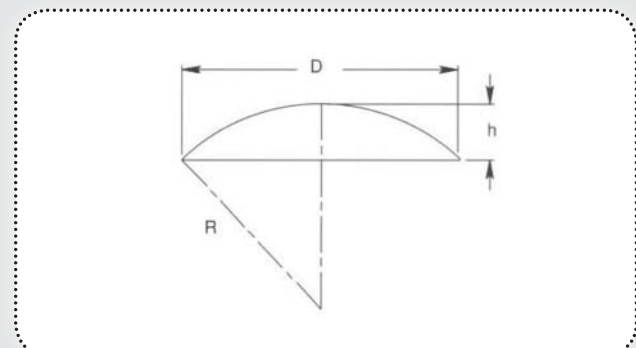
$$1/f = 1/f_1 + 1/f_2 - d/(f_1 f_2)$$

d = distance between principal planes of lenses.



Sagittal Height of a Spherical Surface

$$h = R - (R^2 - (D/2)^2)^{1/2}$$



VIS Best Form Lenses

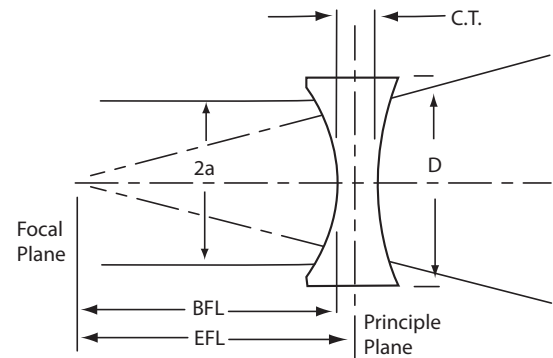
Special Optics Best Form lenses are designed from fused silica to have the best (or least) aspherical aberration. This is achieved by polishing both sides to different radii optimized for an infinite conjugate source. The lenses are optimized for minimum spot size and can theoretically reach diffraction limited performance for small input beam diameters. Our negative focal length lenses are asymmetric biconcave.

Specifications

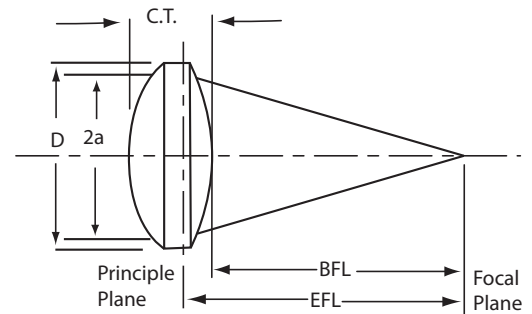
Material Fused Silica
 Surface Irregularity..... < ¼ Wave
 Centration < 2 Arc Minutes
 Surface Quality..... 10-5
 AR Coatings..... < 0.5% R @ 400-700,
 600-900 or 1064 nm

Features

- Corrected for Minimal Spherical Aberration
- Diffraction Limited Design
- High Damage Threshold Coating
- In Stock for Immediate Delivery
- Highest Grade Raw Materials Used



Negative VIS Best Form Lens



Positive VIS Best Form Lens

Negative VIS Best Form Lenses

Model Number ¹	D	EFL ²	BFL ²	CT	ET	d ²	Working F# ²	F#	Spot Size
5-2406-12N-λ	6.35	-12.2	-12.7	2	2.99	2.6	-4.7	-1.9	4.9
5-2406-13N-λ	6.35	-13.4	-14.1	2	2.89	2.8	-4.8	-2.1	5.4
5-2406-18N-λ	6.35	-17.5	-18.4	2	2.65	3.5	-5.0	-2.8	7.0
5-2413-21N-λ	12.7	-21.4	-22.6	3	5.17	4.2	-5.1	-1.7	8.6
5-2413-25N-λ	12.7	-24.5	-24.7	2	3.97	4.5	-5.4	-1.9	9.8
5-2413-30N-λ	12.7	-30.0	-30.4	3	4.50	5.4	-5.6	-2.4	12.1
5-2419-38N-λ	19.05	-38.0	-38.5	4	6.71	6.4	-5.9	-2.0	15.3
5-2419-53N-λ	19.05	-52.5	-53.7	4	5.93	8.2	-6.4	-2.8	21.1
5-2419-61N-λ	19.05	-60.9	-63.2	4	5.66	9	-6.8	-3.2	24.5
5-2425-75N-λ	25.4	-75.0	-76.5	5	7.39	10.4	-7.2	-3.0	30.1
5-2425-80N-λ	25.4	-80.4	-81.8	3	5.22	11.4	-7.1	-3.2	32.3
5-2425-93N-λ	25.4	-92.8	-95.0	5	6.94	12.2	-7.6	-3.7	37.3
5-2425-100N-λ	25.4	-100.4	-92.8	5	6.77	13.4	-7.5	-4.0	40.3
5-2425-107N-λ	25.4	-106.6	-107.2	3	4.68	13.4	-8.0	-4.2	42.8

1. Please replace λ with working distance wavelength when ordering.
 2. Calculations based on wavelength = 633 nm.
 All measurements are in mm.

VIS Best Form Lenses

Positive VIS Best Form Lenses

Model Number ¹	D	EFL ²	BFL ²	CT	ET	d ²	Working F# ²	F#	Spot Size
5-2425-40-λ	25.4	39.9	31.8	8	3.09	5.9	6.8	1.6	16.0
5-2425-51-λ	25.4	50.8	45.7	6	2.30	7.0	7.3	2.0	20.4
5-2425-54-λ	25.4	53.9	50.5	6	2.58	7.3	7.4	2.1	21.7
5-2425-60-λ	25.4	59.0	53.9	6	2.87	9.0	6.6	2.3	23.7
5-2425-71-λ	25.4	71.4	66.0	6	3.45	9.0	7.9	2.8	28.7
5-2425-75-λ	25.4	75.1	70.6	6	3.58	9.5	7.9	3.0	30.2
5-2425-101-λ	25.4	101.5	96.7	6	4.23	11.8	8.6	4.0	40.8
5-2425-108-λ	25.4	107.6	104.5	5	3.34	12.4	8.7	4.2	43.2
5-2425-122-λ	25.4	121.8	117.8	6	4.53	13.5	9.0	4.8	48.9
5-2425-150-λ	25.4	149.9	145.7	6	4.81	15.9	9.4	5.9	60.2
5-2425-160-λ	25.4	160.1	156.9	5	3.89	16.7	9.6	6.3	64.3
5-2425-175-λ	25.4	175.4	171.3	6	4.99	17.8	9.9	6.9	70.5
5-2425-210-λ	25.4	209.9	206.5	5	4.16	20.4	10.3	8.3	84.3
5-2425-246-λ	25.4	246.3	243.0	5	4.28	25.4	9.7	9.7	99.0
5-2425-252-λ	25.4	252.4	249.7	4	3.30	23.4	10.8	9.9	101.4
5-2425-270-λ	25.4	269.6	266.3	5	4.34	24.6	11.0	10.6	108.3
5-2425-300-λ	25.4	298.1	294.9	5	4.41	25.4	11.7	11.7	19.8
5-2425-325-λ	25.4	325.6	321.8	5	4.46	25.4	12.8	12.8	130.8
5-2425-500-λ	25.4	500.1	496.5	5	4.65	25.4	19.7	19.7	201.0
5-2425-534-λ	25.4	534.0	530.3	5	4.67	25.4	21.0	21	214.6
5-2425-750-λ	25.4	754.7	751.1	5	4.77	25.4	29.7	29.7	303.3
5-2425-790-λ	25.4	790.4	786.8	5	4.78	25.4	31.1	31.1	317.6
5-2425-1000-λ	25.4	1014	1010	5	4.83	25.4	39.9	39.9	407.3
5-2425-1500-λ	25.4	1513	1510	5	4.88	25.4	59.6	59.6	608.0
5-2425-2000-λ	25.4	2010	2006	5	4.91	25.4	79.1	79.1	807.7
5-2425-2950-λ	25.4	2953	2949	5	4.94	25.4	116.3	116.3	1186.6
5-2451-102-λ	50.8	101.7	95.3	9	1.65	11.9	8.5	2.0	40.9
5-2451-108-λ	50.8	107.9	102.4	9	2.12	12.4	8.7	2.1	43.4
5-2451-122-λ	50.8	121.9	115.6	9	2.97	13.6	9.0	2.4	49.0
5-2451-150-λ	50.8	150.3	144.3	9	4.18	15.9	9.5	3.0	60.4
5-2451-159-λ	50.8	159.0	152.0	10.8	6.25	16.6	9.6	3.1	63.9
5-2451-212-λ	50.8	210.4	204.4	10	6.62	20.5	10.3	4.1	84.5
5-2451-239-λ	50.8	239.1	233.4	9	6.01	22.5	10.6	4.7	96.1
5-2451-270-λ	50.8	269.8	265.4	7	5.68	24.6	11.0	5.3	108.4
5-2451-282-λ	50.8	282.4	275.5	9	6.48	25.4	11.1	5.6	113.5
5-2451-500-λ	50.8	502.4	496.0	9	7.59	25.4	19.8	9.9	201.9
5-2451-535-λ	50.8	534.7	529.5	7	5.68	39.7	13.5	10.5	214.9

1. Please replace λ with working distance wavelength when ordering.
 2. Calculations based on wavelength = 633 nm.
 All measurements are in mm.

UV Best Form Lenses

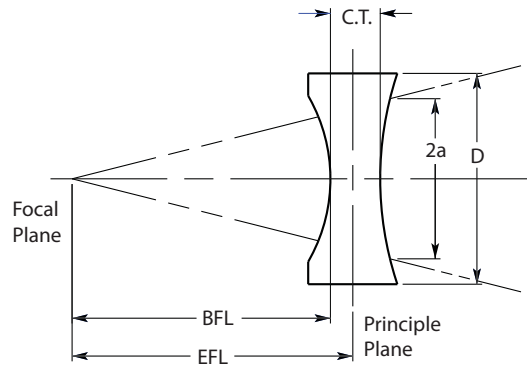
Special Optics UV Best Form lenses are designed from UV grade fused silica to have the best (or least) aspherical aberration. This is achieved by polishing both sides to different radii optimized for an infinite conjugate source. The lenses are optimized for minimum spot size and can theoretically reach diffraction limited performance for small input beam diameters. Our negative focal length Best Form lenses are asymmetric biconcave.

Specifications

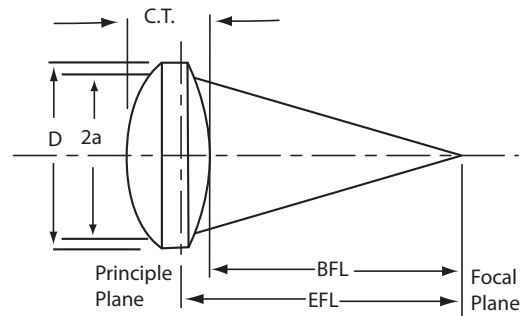
Material UV Grade Fused Silica
 Surface Irregularity 1/4 Wave
 Centration < 2 Arc Minutes
 Surface Quality 10-5
 AR Coatings < 0.50% R @ 248 - 400 nm.
 193 nm AR Coating available for an additional charge.

Features

- Fabricated From UV Grade Materials
- High Damage Threshold Coatings
- Designed For Excimer Lasers
- In Stock for Immediate Delivery



Negative UV Best Form Lens



Positive UV Best Form Lens

Negative UV Best Form Lenses

Model Number ¹	D	EFL ²	BFL ²	CT	ET	d ²	Working F# ²
5-2306-11N-λ	6.35	-11.0	-11.5	2	2.94	2.0	-5.5
5-2306-12N-λ	6.35	-12.0	-12.6	2	2.89	2.2	-5.5
5-2306-16N-λ	6.35	-15.5	-16.0	2	2.64	2.6	-6.0
5-2313-19N-λ	12.70	-19.2	-20.5	3	5.17	3.1	-6.2
5-2313-22N-λ	12.70	-22.0	-21.8	2	3.97	3.5	-6.3
5-2313-26N-λ	12.70	-26.4	-28.3	3	4.50	4.0	-6.6
5-2319-34N-λ	19.05	-33.7	-35.1	3	5.71	4.8	-7.0
5-2319-47N-λ	19.05	-47.2	-47.9	4	5.93	6.2	-7.6
5-2319-49N-λ	19.05	-48.5	-49.8	3	4.87	6.4	-7.6
5-2319-55N-λ	19.05	-54.7	-56.8	4	5.66	6.9	-7.9
5-2325-67N-λ	25.40	-67.4	-68.4	5	7.39	8.2	-8.2
5-2325-72N-λ	25.40	-72.2	-73.6	3	5.22	8.6	-8.4
5-2325-83N-λ	25.40	-83.4	-85.2	5	6.94	9.5	-8.8
5-2325-90N-λ	25.40	-90.2	-92.7	5	6.77	10.2	-8.8
5-2325-96N-λ	25.40	-95.8	-101.2	3	4.68	10.2	-9.4

1. Please replace λ with working distance wavelength when ordering.
 2. Calculations based on wavelength = 248 nm.
 All measurements are in mm.

UV Best Form Lenses

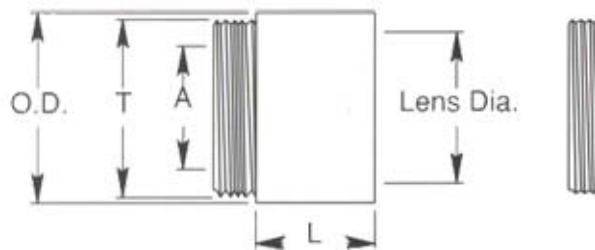
Positive UV Best Form Lenses

Model Number ¹	D	EFL ²	BFL ²	CT	ET	d ²	Working F# ²
5-2325-36-λ	25.4	35.9	28.1	8	3.09	4.5	8.0
5-2325-46-λ	25.4	45.7	40.8	6	2.30	5.4	8.5
5-2325-49-λ	25.4	48.5	45.2	6	2.575	5.5	8.8
5-2325-53-λ	25.4	53.0	47.6	6	2.87	6.9	7.7
5-2325-64-λ	25.4	64.2	59.0	6	3.45	6.9	9.3
5-2325-67-λ	25.4	67.4	64.4	5	2.58	7.2	9.4
5-2325-91-λ	25.4	91.2	86.7	6	4.23	9.0	10.1
5-2325-97-λ	25.4	96.7	93.7	5	3.34	9.4	10.3
5-2325-110-λ	25.4	109.5	105.6	6	4.53	10.3	10.6
5-2325-135-λ	25.4	134.8	130.7	6	4.81	12	11.2
5-2325-144-λ	25.4	143.9	140.8	5	3.99	12.6	11.4
5-2325-158-λ	25.4	157.6	153.9	6	4.99	13.5	11.7
5-2325-190-λ	25.4	190.0	187.0	5	4.16	15.5	12.3
5-2325-221-λ	25.4	221.4	218.2	5	4.28	17.4	12.7
5-2325-227-λ	25.4	226.9	224.2	4	3.30	17.7	12.8
5-2325-242-λ	25.4	242.3	239.1	5	4.34	18.7	13.0
5-2325-268-λ	25.4	268.0	264.8	5	4.41	20.1	13.3
5-2325-293-λ	25.4	292.6	288.9	5	4.46	21.1	13.9
5-2325-450-λ	25.4	449.5	445.9	5	4.65	25.4	17.7
5-2325-480-λ	25.4	480.0	476.3	5	4.67	25.4	18.9
5-2325-678-λ	25.4	678.2	674.7	5	4.77	25.4	26.7
5-2325-710-λ	25.4	710.3	706.8	5	4.78	25.4	28.0
5-2325-911-λ	25.4	911.0	907.6	5	4.83	25.4	35.9
5-2325-1360-λ	25.4	1360	1357	5	4.88	25.4	53.5
5-2325-1800-λ	25.4	1806	1803	5	4.91	25.4	71.1
5-2325-2650-λ	25.4	2653	2650	5	4.94	25.4	104.5
5-2351-92-λ	50.8	91.5	85.3	9	1.65	9.1	10.1
5-2351-97-λ	50.8	97.1	91.7	9	2.12	9.4	10.3
5-2351-110-λ	50.8	109.6	103.6	9	2.97	10.3	10.6
5-2351-135-λ	50.8	135.1	129.3	9	4.18	12.1	11.2
5-2351-144-λ	50.8	144.1	140.1	7	2.50	12.6	11.4
5-2351-190-λ	50.8	190.2	186.0	7	3.62	15.5	12.3
5-2351-215-λ	50.8	214.9	209.4	9	6.01	17.1	12.6
5-2351-242-λ	50.8	242.5	238.2	7	5.68	18.7	13.0
5-2351-254-λ	50.8	253.8	247.2	9	6.48	19.3	13.2
5-2351-452-λ	50.8	451.5	445.4	9	7.59	29.8	15.2
5-2351-481-λ	50.8	480.6	475.5	7	5.68	30.6	15.7

1. Please replace λ with working distance wavelength when ordering.
 2. Calculations based on wavelength = 248 nm.
 All measurements are in mm.

Lens Mounts

Single Element Lens Mounts



Single Element Lens Mounts

Model	Lens Dia. (mm)	A (mm)	O.D. (mm)	L (mm)	T Thread (inches)
60-15-19	19	16	25.4	12.7	0.875-32
60-15-25	25	22	31.8	12.7	1.125-32
60-15-38	38	34	44.5	15.9	1.625-32
60-15-51	51	47	57.2	15.9	2.125-32
60-15-76	76	71	82.6	22.2	3.125-32