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THORLABS

BE02-05-A - September 28, 2022

Item # BE02-05-A was discontinued on September 28, 2022. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

- **Continuously Variable Beam Expansion**
- **2X to 5X Zoom**
- **AR-Coated Optics**

BE02-05-A
400 - 650 nm AR Coating

BE02-05-B
650 - 1050 nm AR Coating

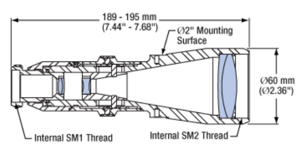
BE02-05-C
1050 - 1620 nm AR Coating

Hide Overview

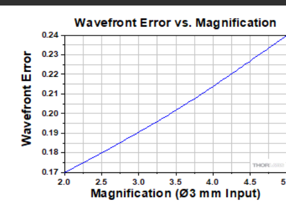
OVERVIEW

Features

- Max Beam Diameter (1/e^2): Ø4.0 mm
- Surface Quality: 20-10 (Scratch-Dig)
- Wavefront Error: <λ/4
- AR Coating: R_{avg} < 0.5% Over Coating Range
- Input Aperture Threading: SM1 (1.035"-40)
- Output Aperture Threading: SM2 (2.035"-40)
- Post-Mountable via 8-32 and M4 Taps
- Housing Length (L):
  - -A and -B: 188 - 195 mm
  - -C: 174 - 181 mm



Click to Enlarge
Diagram of BE02-05 Beam Expanders



Click to Englarge
Nominal Values for Peak-to-Valley Wavefront Error

Thorlabs' Variable Magnification Galilean Beam Expanders have a 2X - 5X continuously variable beam expansion ratio. The expansion ratio can be adjusted from the minimum to the maximum value via one full rotation of the zoom control. Once the desired magnification is obtained, a setscrew can be tightened to lock the magnification. If the beam exiting the expander is collimated and the magnification is changed, the focus should be readjusted to maintain collimation. Please note that the induced wavefront error varies with the magnification ratio. This wavefront error can be seen in the graph to the right.

Our variable beam expanders are offered with a broadband antireflection coating for the 400 - 650 nm (-A), 650 - 1050 nm (-B), or 1050 - 1620 nm (-C) range. These units also feature achromatic operation over the specified AR coating range. The input lens can also be rotated to adjust the distance between the input and output lenses in order to compensate for the divergence or convergence of the output beam. Each beam expander features SM-threaded input and output ports (see the diagram above for details), making them compatible with a number of Thorlabs components such as lens tubes. The housing features both 8-32 and M4 taps for mounting. Additionally, this housing has a Ø2" portion so that it can be mounted in our KS2 Ø2" mirror mount.

Thorlabs offers variable magnification beam expanders that use a sliding lens to achieve expansions from 0.5X to 2X. Other beam expander options available are our UV fused silica, achromatic, and ZnSe fixed beam expanders, UV fused silica and achromatic zoom beam expanders, and reflective beam expanders. For more information on our extensive line of beam expanders, please see the *Beam Expanders* tab.

Hide Specs

SPECS

Item #	Expansion	Input Aperture	Max Input Beam Diameter (1/e^2)	Input Threading	Output Threading	Mounting Holes	AR Coating Range	Lens Substrates
BE02-05-A	2X - 5X	Ø8.0 mm	Ø4.0 mm	SM1 (1.035"-40)	SM2 (2.035"-40)	8-32 (M4)	400 - 650 nm	N-BK7, SF2, N-FK5, SF5
BE02-05-B	2X - 5X	Ø8.0 mm	Ø4.0 mm	SM1 (1.035"-40)	SM2 (2.035"-40)	8-32 (M4)	650 - 1050 nm	BAFN10, SFL6, N-FK5, LAKN22

BE02-05-C	2X - 5X	Ø8.0 mm	Ø4.0 mm	SM1 (1.035"-40)	SM2 (2.035"-40)	8-32 (M4)	1050 - 1620 nm	BAFN10, SFL6, N-FK5, LAKN22

Hide Damage Thresholds

DAMAGE THRESHOLDS

Damage Threshold Data for Thorlabs' Variable Beam Expanders

The specifications to the right are the damage thresholds for Thorlabs' variable beam expanders.

Damage Threshold Specifications		
Item # Suffix	**Laser Type**	**Damage Threshold**
-A	Pulsed	0.5 J/cm² (532 nm, 10 ns Pulse, 10 Hz, Ø0.566 mm)
	CW[a]	600 W/cm (532 nm, Ø0.020 mm)
-B	Pulsed	5.0 J/cm² (810 nm, 10 ns Pulse, 10 Hz, Ø0.155 mm)
	CW[a]	9,000 W/cm (1064 nm, Ø0.025 mm)
-C	Pulsed	5.0 J/cm² (1542 nm, 10 ns Pulse, 10 Hz, Ø0.181 mm)
	CW[a]	350 W/cm (1550 nm, Ø0.194 mm)

- a. The power density of your beam should be calculated in terms of W/cm. For an explanation of why the linear power density provides the best metric for long pulse and CW sources, please see the "Continuous Wave and Long-Pulse Lasers" section below.

Laser Induced Damage Threshold Tutorial

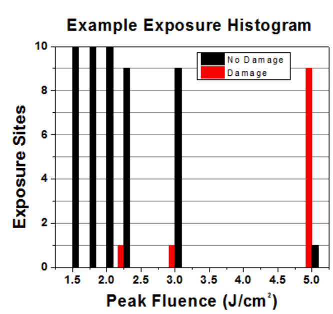
The following is a general overview of how laser induced damage thresholds are measured and how the values may be utilized in determining the appropriateness of an optic for a given application. When choosing optics, it is important to understand the Laser Induced Damage Threshold (LIDT) of the optics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

Testing Method

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

First, a low-power/energy beam is directed to the optic under test. The optic is exposed in 10 locations to this laser beam for 30 seconds (CW) or for a number of pulses (pulse repetition frequency specified). After exposure, the optic is examined by a microscope (~100X magnification) for any visible damage. The number of locations that are damaged at a particular power/energy level is recorded. Next, the power/energy is either increased or decreased and the optic is exposed at 10 new locations. This process is repeated until damage is observed. The damage threshold is then assigned to be the highest power/energy that the optic can withstand without causing damage. A histogram such as that below represents the testing of one BB1-E02 mirror.

The photograph above is a protected aluminum-coated mirror after LIDT testing. In this particular test, it handled 0.43 J/cm^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.

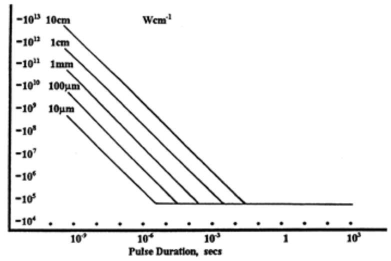
Continuous Wave and Long-Pulse Lasers

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.

When pulse lengths are between 1 ns and 1 µs, laser-induced damage can occur either because of absorption or a dielectric breakdown (therefore, a user must check both CW and pulsed LIDT). Absorption is either due to an intrinsic property of the optic or due to surface irregularities; thus LIDT values are only valid for optics meeting or exceeding the surface quality specifications given by a manufacturer. While many optics can handle high power CW lasers, cemented (e.g., achromatic doublets) or highly absorptive (e.g., ND filters) optics tend to have lower CW damage thresholds. These lower thresholds are due to absorption or scattering in the cement or metal coating.

Pulsed lasers with high pulse repetition frequencies (PRF) may behave similarly to

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



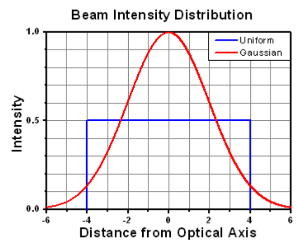
LIDT in linear power density vs. pulse length and spot size. For long pulses to CW, linear power density becomes a constant with spot size. This graph was obtained from [1].

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

Thorlabs expresses LIDT for CW lasers as a linear power density measured in W/cm. In this regime, the LIDT given as a linear power density can be applied to any beam diameter; one does not need to compute an adjusted LIDT to adjust for changes in spot size, as demonstrated by the graph to the right. Average linear power density can be calculated using the equation below.

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



The calculation above assumes a uniform beam intensity profile. You must now consider hotspots in the beam or other non-uniform intensity profiles and roughly calculate a maximum power density. For reference, a Gaussian beam typically has a maximum power density that is twice that of the uniform beam (see lower right).

Now compare the maximum power density to that which is specified as the LIDT for the optic. If the optic was tested at a wavelength other than your operating wavelength, the damage threshold must be scaled appropriately. A good rule of thumb is that the damage threshold has a linear relationship with wavelength such that as you move to shorter wavelengths, the damage threshold decreases (i.e., a LIDT of 10 W/cm at 1310 nm scales to 5 W/cm at 655 nm):

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

While this rule of thumb provides a general trend, it is not a quantitative analysis of LIDT vs wavelength. In CW applications, for instance, damage scales more strongly with absorption in the coating and substrate, which does not necessarily scale well with wavelength. While the above procedure provides a good rule of thumb for LIDT values, please contact Tech Support if your wavelength is different from the specified LIDT wavelength. If your power density is less than the adjusted LIDT of the optic, then the optic should work for your application.

Please note that we have a buffer built in between the specified damage thresholds online and the tests which we have done, which accommodates variation between batches. Upon request, we can provide individual test information and a testing certificate. The damage analysis will be carried out on a similar optic (customer's optic will not be damaged). Testing may result in additional costs or lead times. Contact Tech Support for more information.

Pulsed Lasers

As previously stated, pulsed lasers typically induce a different type of damage to the optic than CW lasers. Pulsed lasers often do not heat the optic enough to damage it; instead, pulsed lasers produce strong electric fields capable of inducing dielectric breakdown in the material. Unfortunately, it can be very difficult to compare the LIDT specification of an optic to your laser. There are multiple regimes in which a pulsed laser can damage an optic and this is based on the laser's pulse length. The highlighted columns in the table below outline the relevant pulse lengths for our specified LIDT values.

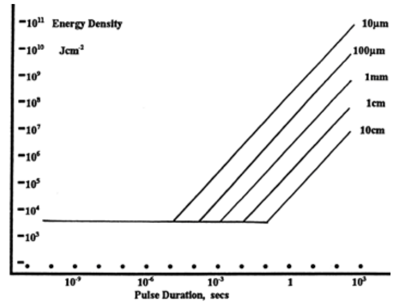
Pulses shorter than 10^{-9} s cannot be compared to our specified LIDT values with much reliability. In this ultra-short-pulse regime various mechanics, such as multiphoton-avalanche ionization, take over as the predominate damage mechanism [2]. In contrast, pulses between 10^{-7} s and 10^{-4} s may 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	No Comparison (See Above)	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/cm^2. The graph to the right shows why expressing the LIDT as an energy density provides the best metric for short pulse sources. In this regime, the LIDT given as an energy density can be applied to any beam diameter; one does not need to compute an adjusted LIDT to adjust for changes in spot size. This calculation assumes a uniform beam intensity profile. You must now adjust this energy density to account for hotspots or



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].

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):

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

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.

[1] R. M. Wood, Optics and Laser Tech. **29**, 517 (1998).
[2] Roger M. Wood, *Laser-Induced Damage of Optical Materials* (Institute of Physics Publishing, Philadelphia, PA, 2003).
[3] C. W. Carr *et al*., Phys. Rev. Lett. **91**, 127402 (2003).
[4] N. Bloembergen, Appl. Opt. **12**, 661 (1973).

Hide Beam Expanders

BEAM EXPANDERS

Thorlabs offers fixed and variable magnification beam expanders, as well as zoom beam expanders that do not need to be refocused when the magnification is adjusted since the collimation remains constant. The table below provides a direct comparison of the options we offer. Please contact Tech Support if you would like help choosing the best beam expander for your specific application.

Beam Expander Description	Fixed Magnification Laser Line, Sliding Lens	Fixed Magnification Achromatic, Sliding Lens	Fixed Magnification Mid-Infrared, Sliding Lens	Zoom, Sliding Lens	Zoom Achromatic, Sliding Lens
Expansions Available	2X, 3X, 5X, 10X, 20X[a]	2X, 3X, 5X, 10X, 15X, 20X	2X, 5X, 10X	0.5X - 2.5X, 1X - 4X	0.5X - 2.5X, 1X - 4X, 2X - 8X, 4X - 16X
AR Coating Range(s) (Item # Suffix)	240 - 360 nm (-UVB) 248 - 287 nm (-266) 325 - 380 nm (-355) 488 - 580 nm (-532) 960 - 1064 nm (-1064)	400 - 650 nm (-A) 650 - 1050 nm (-B) 1050 - 1650 nm (-C)	7 - 12 µm (-E3)	240 - 360 nm (UVB) 330 - 370 nm (3) 495 - 570 nm (2) 980 - 1130 nm (1)	400 - 650 nm (A) 650 - 1050 nm (B) 1050 - 1650 nm (C)
Mirror Coating (Range)	N/A				
Reflectance (per Surface)	R_{avg} < 0.2% (R_{Max} < 1.5% for -UVB)	R_{Max} < 0.5%	R_{avg} < 1.0%	R_{avg} < 0.2% (R_{Max} < 1.5% for UVB)	R_{Max} < 0.5%
	2X: 8.5 mm	2X: 8.5 mm 3X: 9.0 mm			0.5X - 2.5X: 10.9 to 8.0

Max Input Beam Diameter	3X: 9.0 mm 5X: 4.3 mm 10X: 2.8 mm 20X: 2.0 mm	5X: 5.0 mm 10X: 3.0 mm 15X: 2.5 mm 20X: 2.0 mm	2X: 9.5 mm 5X: 6.7 mm 10X: 3.5 mm	0.5X - 2.5X: 10.9 to 8.0 mm 1X - 4X: 10.9 to 8.8 mm	mm 1X - 4X: 10.9 to 8.8 mm 2X - 8X: 6.0 to 4.4 mm 4X - 16X: 6.0 to 2.7 mm
Wavefront Error	<λ/4 (Peak to Valley)				
Surface Quality	10-5 Scratch-Dig	20-10 Scratch-Dig	80-50 Scratch-Dig	10-5 Scratch-Dig	20-10 Scratch-Dig

- a. These 20X beam expanders are only available with V coatings for 355 nm, 532 nm, or 1064 nm.

Beam Expander Description	Variable Magnification, Rotating Lens	Variable Magnification, Sliding Lens	Reflective Beam Expander Fixed Magnification
Expansions Available	2X - 5X	0.5X - 2X	2X, 4X, 6X
AR Coating Range(s) (Item # Suffix)	400 - 650 nm (-A) 650 - 1050 nm (-B) 1050 - 1620 nm (-C)	400 - 650 nm (-A) 650 - 1050 nm (-B)	N/A
Mirror Coating (Range)	N/A		Protected Silver (450 nm - 20 µm)
Reflectance (per Surface)	R_{avg} < 0.5%	R_{avg} < 0.5%	R_{avg} > 96%
Max Input Beam Diameter	2X - 5X: 4.0 mm	0.5X - 2X: 6.0 mm to 3.0 mm	3 mm
Wavefront Error	<λ/4		<λ/10[a] (RMS)
Surface Quality	20-10 Scratch-Dig		40-20 Scratch-Dig

- a. For a Ø1.5 mm Input Beam at 2X magnification, Ø1.0 mm Input Beam at 4X magnification, or Ø0.5 mm Input Beam at 6X magnification.

Hide 2X - 5X Variable Zoom Galilean Beam Expanders

2X - 5X Variable Zoom Galilean Beam Expanders

Part Number	Description	Price	Availability
BE02-05-A	**Optical Beam Expander, 2X - 5X Zoom, AR Coated: 400 - 650 nm**	**$1,341.88**	**Lead Time**
BE02-05-B	**Optical Beam Expander, 2X - 5X Zoom, AR Coated: 650 - 1050 nm**	**$1,341.88**	**Lead Time**
BE02-05-C	**Optical Beam Expander, 2X - 5X Zoom, AR Coated: 1050 - 1620 nm**	**$1,533.90**	**7-10 Days**


LOCK
M4
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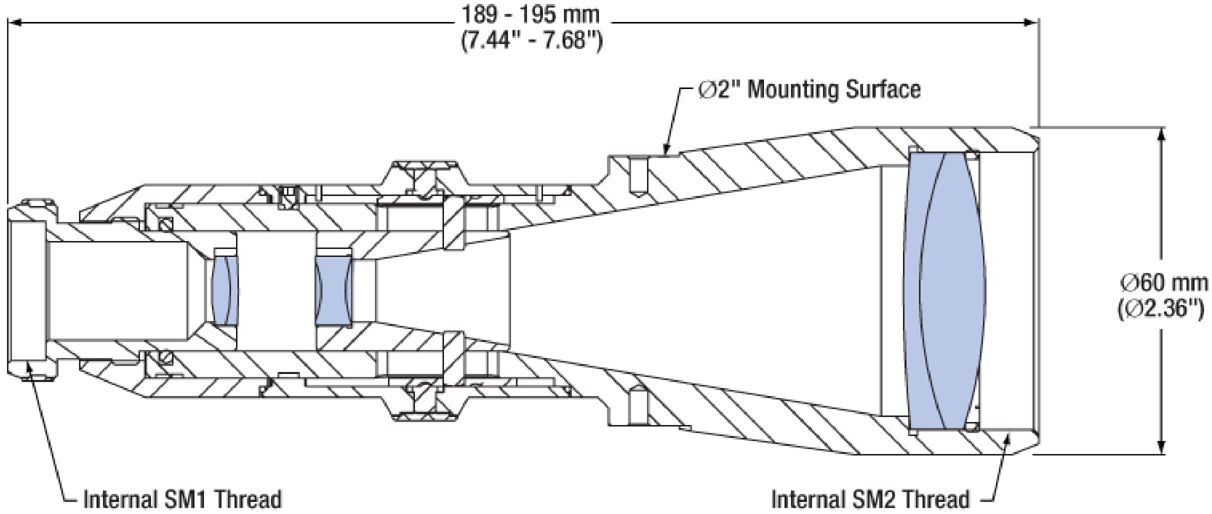
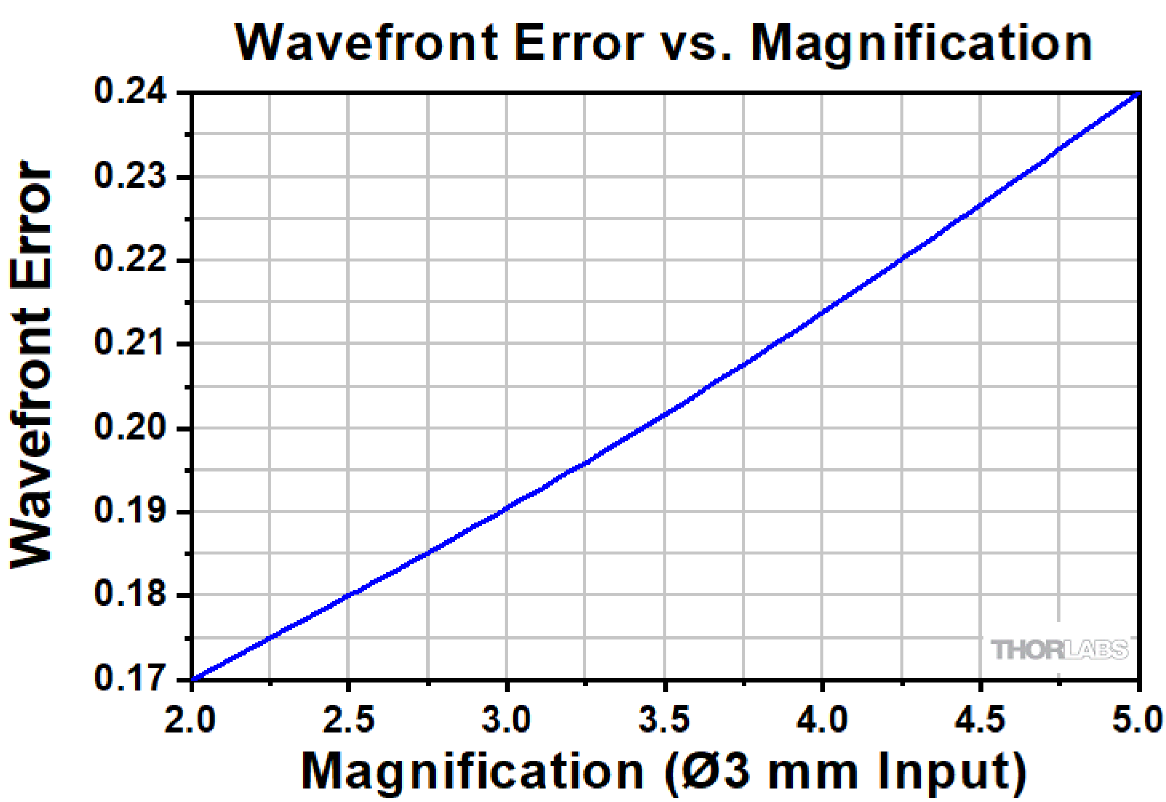
BE02-05-A


189 - 195 mm
(7.44" - 7.68")
Ø2" Mounting Surface
Ø60 mm
(Ø2.36")
Internal SM1 Thread
Internal SM2 Thread


Wavefront Error vs. Magnification
Wavefront Error
0.24
0.23
0.22
0.21
0.20
0.19
0.18
0.17
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Magnification (Ø3 mm Input)
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