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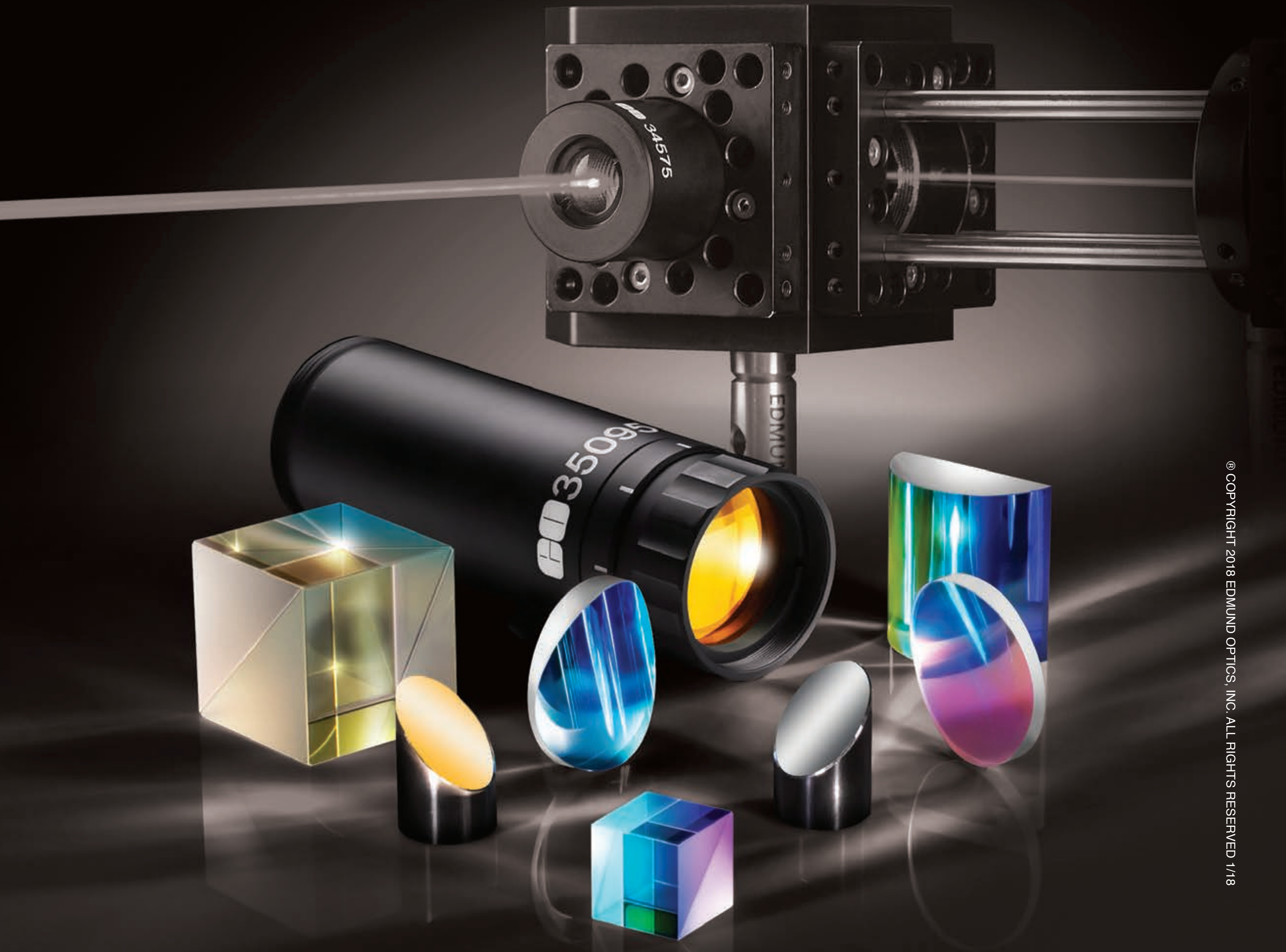
ULTRAVIOLET OPTICS



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Edmund Optics® (EO) is a premier supplier of UV optics including mirrors, lenses, filters, and beam expanders. EO offers free engineering and technical support, along with an extensive technical library of online videos, application notes, and calculators. Additional product documentation including over 37,000 data sheets, Zemax files, 3D models, and filter curves are also available.

Why Edmund Optics®?

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- ISO 9001 Certified and MIL-SPEC quality systems
- Wide range of metrology including interferometers, cavity ring-down (CRD) spectrometers, Shack-Hartmann wavefront sensors, profilometers, and coordinate measurement machines (CMMs)

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- Optics manufacturing in USA, Europe, and Asia
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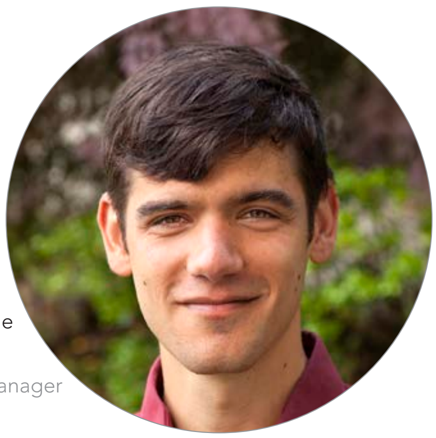
TECHNICAL EXPERTS AT YOUR SERVICE

“The optics EO makes enable the future and I love developing technology and product that inevitably helps customers achieve their goals. By being part of the initial development, EO has its hand in creating laser systems that process materials for tomorrow’s applications and those that advance medical applications that are making way for the next generation of medical care.”



Stefaan Vandendriessche
Laser Optics Product Line Manager

For **MORE INFORMATION**, visit **www.edmundoptics.com/lo**

UV Optics: Tighter Tolerances and Different Materials

The UV Challenge – Tighter Surface Specifications

The main challenge associated with manufacturing ultraviolet (UV) optics is that surface tolerances must be much tighter than those of visible and IR optics. The standard P-V irregularity tolerance for precision lenses is λ/10, therefore the physical accuracy required in manufacturing is dependent on the wavelength at which the optic will used. Because tolerances are quoted at a fixed wavelength of 632.8nm, λ/10 implies 632.8nm regardless of design wavelength. Relative performance will be worse at short UV wavelengths. For instance, a lens used at 308nm will require an irregularity tolerance twice as tight as a lens used at 632.8nm to maintain the same relative level of wavefront distortion. This same principle also applies to optical coatings. The thickness of simple coatings are typically specified to quarter or half wavelengths of light. For UV coatings, the deposition process requires much more accurate monitoring; small fluctuations in production results in much greater errors in the UV than they would in the visible or IR spectra.

Figure 1: Tighter surface specifications are required when manufacturing UV Optics

The short wavelengths of UV light typically absorb and scatter much more than visible or IR light. Surface imperfections such as scratches and pits are amplified under UV light and even the smallest surface flaws can be points of absorption or scatter, reducing system throughput. In order to minimize energy loss, a tight surface quality specification is required. While the standard surface quality for precision lenses used with visible light is 40-20, a surface quality of 10-5 may be required for UV applications. Scattering can lead to energy loss, a reduction in the efficiency of your optical system, and even false signals in applications using imaging sensors or other detectors. UV materials exhibit greater dispersion than visible or IR materials, leading to significant aberration in broadband UV applications. To avoid this, many UV optical systems use reflective optics to avoid dispersion inside the bulk material.

Optical Substrates and Coatings

Absorption and scatter not only lead to a loss in throughput, but can also result in component damage and failure. Too much UV absorption may actually bleach a substrate and alter its chemical properties, leading to component failure. In order to prevent this, UV substrates must fully transmit the entire desired wavelength range and be polished to near perfection. Some of the most common UV-transmitting substrates include UV Fused Silica, Calcium Fluoride (CaF_2), and Sapphire. UV Fused Silica is the most commonly used UV substrate due to its affordability, accessibility, and easy fabrication compared to many other UV-transmitting materials. UV Fused Silica also transmits wavelengths down to 193nm and offers a low coefficient of thermal expansion. CaF_2 has a low refractive index, low axial and radial birefringence, and transmits wavelengths down to 180nm, making it suitable for UV excimer laser applications. Sapphire is ideal for use in harsh environments because of its extreme surface hardness, high thermal conductivity, high dielectric constant, and strong resistance to a variety of chemical acids or alkalis. With extreme resistance to UV darkening, high quality sapphire is often used in high power UV applications and some types of optical Sapphire transmits down to 150nm. Birefringence is one disadvantage of sapphire, but when cut properly along the crystal's C-axis, birefringence is minimized.

UV absorption can also bleach and damage optical coatings, not just the bulk material. Because of this, different coating materials are needed for both transmissive and reflective optics operating within the UV spectrum. Deep-UV (DUV) mirror coatings are also particularly sensitive to small coating thickness errors because material limitations in the UV produce relatively narrowband reflectors.

Multiphoton Absorption

Light only transmits through transmissive optics without being absorbed when it has an energy smaller than the substrate's bandgap energy and cannot excite electrons from the valence band of the material to the conduction band. Multiphoton absorption occurs when two or more photons are spontaneously absorbed to excite an electron into the conduction band, causing light that would normally transmit through the optic to be absorbed. UV light has more energy than visible and IR radiation because the energy of light is inversely proportional to wavelength. Multiphoton absorption can become substantial in the UV and at high optical intensities, increasing absorption and starting a runaway process which will ultimately damage the optic. Single-photon absorption is linearly dependent on the intensity of incident light, but multiphoton absorption is dependent on the square of the light intensity and will dominate over linear absorption at high intensities. Materials with a high refractive index are especially susceptible to multiphoton absorption because they have a small band gap energy.

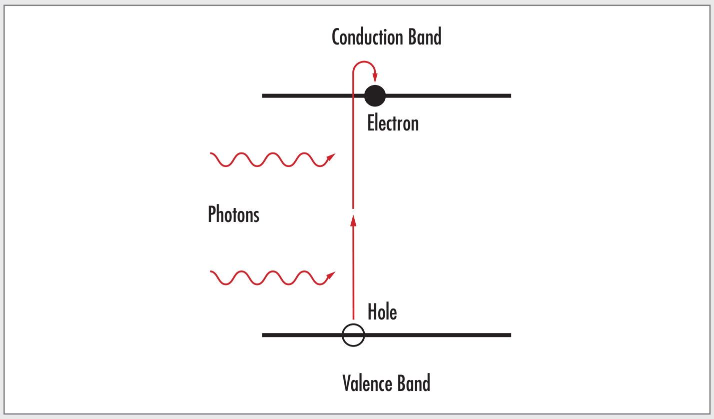


Figure 2: Multiphoton absorption exciting an electron into the conduction band, causing light that would normally be transmitted to be absorbed

Why Laser Damage Testing is Critical for UV Laser Applications

Laser Damage Threshold (LDT), also known as Laser Induced Damage Threshold (LIDT), is one of the most important specifications to consider when integrating an optical component into a laser system. It is defined within the ISO standard as the "highest quantity of laser radiation incident upon the optical component for which the extrapolated probability of damage is zero" (ISO 21254-1:2011).

Using a laser in an application offers a variety of benefits to a standard light source, including monochromaticity, directionality, and coherence. Laser beams often contain high energies and are capable of damaging sensitive optical components. When integrating a laser and optical components into a system, understanding the effects of laser beams on optical surfaces and how laser damage threshold is quantified for optical components is essential.

The type of damage induced to an optical component by a laser beam is dependent on multiple factors including wavelength, pulse length, polarization, repetition rate, spatial characteristics, and more. During exposure to a continuous wave (CW) laser, failure can occur due to laser energy absorption and thermal damage or melting of the substrate material or the optical coating. The damage caused by a short nanosecond laser pulses is typically due to dielectric breakdown of the material that results from exposure to the high electric fields in the laser beam. For pulse widths in between these two regimes or for high rep rate laser systems, laser induced damage may result from a combination of thermally induced damage and breakdown. For ultrashort pulses, about 10ps or less, nonlinear mechanisms such as multiphoton absorption and multiphoton ionization become important.

Because of the statistical nature of laser induced damage and the assumptions behind the extrapolation, LIDT unfortunately cannot be considered the value below which no damage will ever occur. An incorrect understanding of LIDT can lead to significantly higher costs than necessary, or worse, to coating failures in the field. When dealing with high power lasers, LIDT is an important specification for all types of laser optics, including reflective, transmissive, and beam shaping components.

Laser induced damage in optical coatings causes degradation in performance and can even result in catastrophic failure. Different root causes of damage create different morphologies of laser induced damage. Understanding these morphologies is important for coating and process development. Figure 1 shows a visual example of Laser Induced Damage where an optic has been damaged by a UV laser.

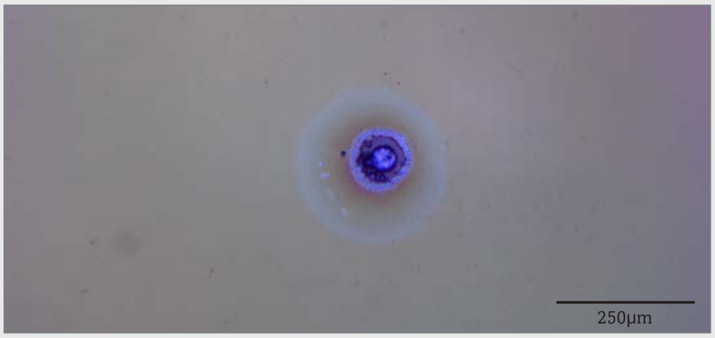


Figure 1: Coating failure caused by a UV laser

UV Lasers

There are numerous advantages to using UV lasers as opposed to longer wavelengths such as infrared or visible light. In materials processing, infrared or visible lasers melt or vaporize material, which can hinder the creation of small, precise features and damage the structural integrity of the substrate. On the other hand, UV lasers process materials by directly breaking the atomic bonds in the substrate, which means that no peripheral heating is created around the beam spot. This reduces damage to material, allowing UV lasers to process thin and delicate materials much more effectively than visible and infrared lasers. The lack of peripheral heating also facilitates the creation of very precise cuts, holes, and other fine features. Additionally, laser spot size is directly proportional to wavelength. Thus, UV lasers have a higher spatial resolution than visible or infrared lasers and lead to even more precise processing of materials.

However, the short wavelengths of UV lasers impact the LIDT of optics used with them. UV light is scattered more than visible or infrared light and also contains more energy, causing it to be absorbed and even bleach component substrates. Similarly to how UV lasers cut materials by breaking atomic bonds, unwanted absorption of UV lasers can break the bonds in an optical component or coating, leading to failure. This reduces the component's LIDT and an optic will usually have a lower LIDT at UV wavelengths than at visible or infrared wavelengths. When dealing with LIDT, it is important to remember that LIDT is directly related to wavelength.

UV Optics

UV optics must be carefully designed and manufactured to withstand the effects of UV damage. UV optics must contain a lower than usual amount of bubbles within them, have a homogeneous refractive index across the optic, and a limited birefringence, a specification which correlates the polarization of light with an optic's refractive index. Additionally, in cases involving the use of UV lasers, UV optics should take into account prolonged periods of exposure. An example of a material used in UV applications would be Calcium Fluoride (CaF_2), which has all of the aforementioned attributes required to withstand the effects of UV damage. However, in certain applications even CaF_2 optics can be damaged. For instance, if you use CaF_2 optics in high-humidity environments they will perform poorly because they are highly hygroscopic, absorbing moisture easily.

Therefore, when using a UV laser it is crucial to consider the Laser Damage Threshold. If an optic is selected that is not made for UV wavelengths, then the specification for LIDT may be misleading. For standard laser optic components, LIDT will rarely be given for wavelengths in the UV part of the spectrum. Rather, LIDT will be given for higher wavelengths. UV optics provide an LIDT that is tested specifically using UV wavelengths, ensuring more accurate LIDT specifications.

References

- ISO 21254-1:2011 – Lasers and laser-related equipment

The Importance of Beam Diameter for Laser Damage Threshold

Laser-Induced Damage Threshold (LIDT) values specify whether an optical component can be safely used with a laser of a given power. But, laser optics sometimes fail when illuminated by lasers with powers below the specified LIDT because the laser beam used for LIDT testing had too small of a beam diameter relative to defect density.

Modeling Laser Damage Threshold with Probability

Laser damage under nanosecond pulse lasers is generally caused by defects on the optic surface. The probability of finding any particular number of defects (n) within any given area of the sample surface is a function of the defect density (D) and follows the Poisson distribution:

$$P = \frac{e^{D}D^{n}}{n}$$

The defect density is unit less because it is the product of beam area (A) and the number density of defects per unit surface area (δ) on the optic. The probability (P) of finding a region free of defects can be determined by solving for n = 0. The maximum fraction of undamaged test sites (assuming a flat-top beam and uniform fluence) is equal to the probability of that region on the surface being free of defects. The damage probability is its compliment.

$$P = 1 - e^{-D}$$

Increasing defect density should increase the damage probability, but increasing the beam area has the identical effect. This allows the damage probability to be normalized by the beam radius.

$$P = 1 - [1 - P_0]^{(\frac{\omega}{\omega_0})^2}$$

P_0 is the damage probability using the tested beam diameter (ω_0) and P is the expected damage probability given the true application beam size (ω). Normally, the LIDT test is conducted using a relatively small diameter beam (200µm minimum according to ISO-21254).

In the case of a Gaussian beam, fluence is not uniform and varies as a function of distance from the beam center. For a Gaussian beam and a defect population following a normal distribution, the damage probability is approximated using a Burr distribution - a continuous probability distribution for a random variable that is non-negative. The cumulative distribution function (CDF) can be graphed using the following equation where F is fluence, µ is the mean and σ is the standard deviation of the defect distribution:

$$P = 1 - [1 + (F/\mu)^{\sigma-1}]^{-\sigma D}$$

Scaling of LIDT Value with Beam Diameter

Laser beam diameter directly impacts the probability of damage during testing. When beam size is significantly larger than defect areal density ($w^2 \gg \delta$), unlikely events are detectable. When the beam size is too small, low defect densities are not always detectable and parts may appear better than they actually are. The scaling of laser damage with beam diameter is demonstrated in Figure 2. In this scenario a large number of defects have a threshold fluence of 10J, and a small number (1%) have a threshold fluence of 1J. Scaling the beam diameter from 0.2 to 20mm will drastically change the damage probability function and therefore change the LIDT value that would be produced from this test. With the 0.2mm beam, the chance that one of the 1J threshold defects will be detected is small. For this reason, the damage probability will remain very low until after a fluence of 10J, the fluence equaling that of the most common defect. Increasing the beam size from 0.2 to 2mm makes it much more likely that the 1J threshold defects will be detected, causing a sharp increase in damage probability at a fluence of 1J. By scaling the beam diameter to 20mm, the damage probability at 1J increases to almost certain probability of damage.

This illustrates the importance of using a laser beam with a large enough diameter to adequately sample the surface of the optic being tested. Using too small of a beam in testing LIDT will result in an inaccurate LIDT specification and possible failure during real-world applications. Published LIDT values can be misleading if the beam diameter used for testing is not reported. Talk to your optics manufacturer about testing protocols and their statistical implications for your laser application.

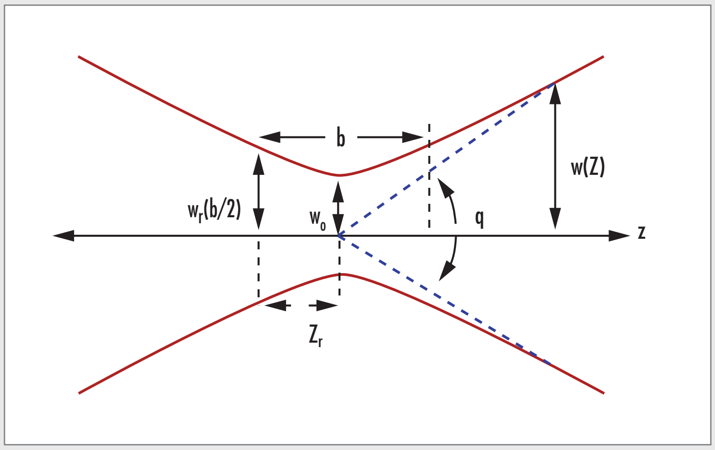


Figure 1: Profile of a Gaussian beam

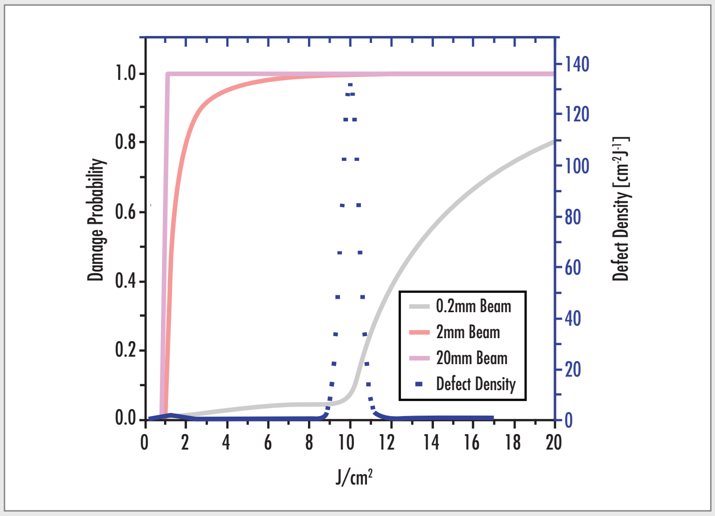


Figure 2: Scaling of laser damage probability with beam size

References

- ISO 21254-1:2011 – Lasers and laser-related equipment

Superior Process Control for Consistent Quality

The recent surge in UV optics applications has led to a corresponding increase in UV optics manufacturers. The challenge for those seeking UV optics is no longer finding a supplier, but ensuring they receive optics with the proper specifications for their given application. Given the expense of the metrology required for precision UV testing, it is often difficult for customers to verify that their optics are meeting advertised specifications. Edmund Optics® (EO) tested 41 off-the-shelf samples of 355nm laser line mirrors from 4 competitors against our TECHSPEC® 355nm laser line mirrors for Laser Induced Damage Threshold (LIDT), reflectivity, surface accuracy, and parallelism. The testing was a double-blind study, reducing bias by ensuring that the experimenters did not know whose mirror they were testing. The following plots show whether the mirrors passed or failed their advertised specifications.

The results of the study showed that EO TECHSPEC® 355nm laser line mirrors were the only mirrors that met every advertised specification. Competitor 1 met every advertised specification except for reflectivity, Competitor 2 failed every advertised specification except for parallelism, Competitor 3 failed every advertised specification except for surface accuracy, and Competitor 4 failed every advertised specification except for reflectivity.

Consistently meeting Laser Induced Damage Threshold (LIDT), reflectivity, surface accuracy, and parallelism on laser mirrors is vital for reliable performance, and is a primary focus for our manufacturing facilities for both prototype and volume production.

Both in-process and final metrology is essential for ensuring that final parts meet their advertised specifications. EO employs a wide variety of metrology equipment including interferometers, profilometers, cavity ring-down (CRD) spectrophotometers, Shack-Hartmann wavefront sensors, and coordinate measuring machines (CMMs) to ensure the quality of optical components and assemblies manufactured in our 5 global manufacturing facilities. Product testing and certification reports are also available upon request.

The durability and lifetime of UV optics play an important role in emerging UV Optics applications, reinforcing the necessity for UV Optics suppliers to produce products that meet their published specifications. By manufacturing products whose performance matches that of the published specifications, customers will avoid overspecifying their optics and have a better opportunity to meet their application timelines and budgets.

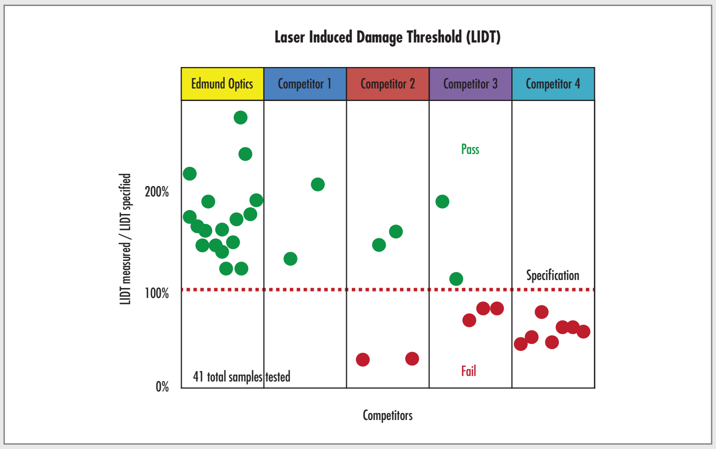


Figure 1: Only the mirrors from EO and Competitor 1 met their advertised LIDT specification

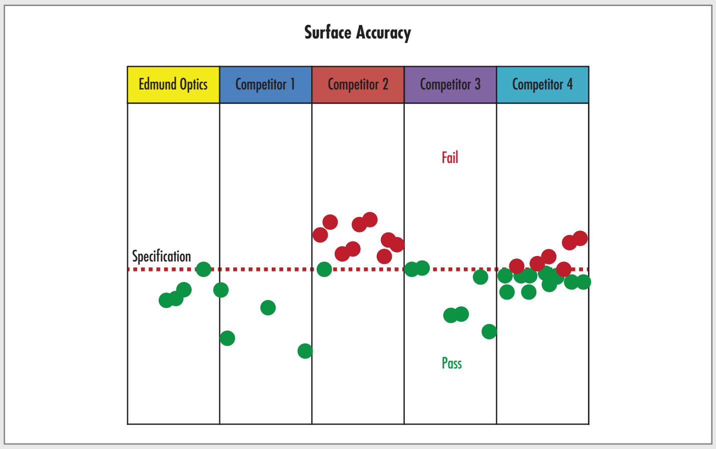


Figure 2: The mirrors from EO, Competitor 1, and Competitor 3 met their advertised surface accuracy specification

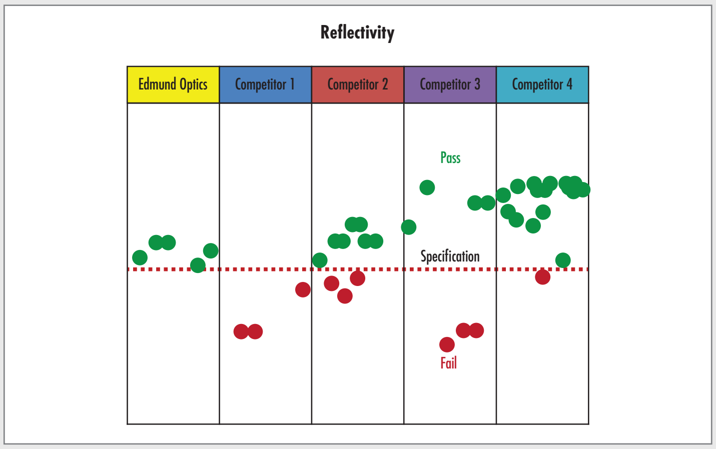


Figure 3: Only the mirrors from EO and Competitor 4 met their advertised reflectivity specification

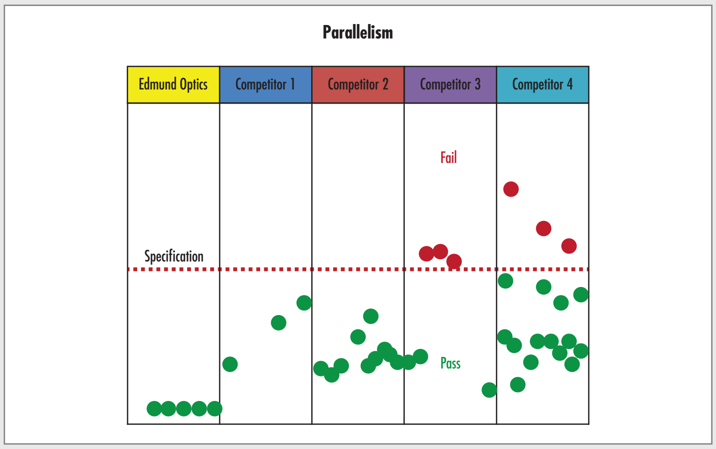


Figure 4: The mirrors from EO, Competitor 1, and Competitor 2 met their advertised parallelism specification

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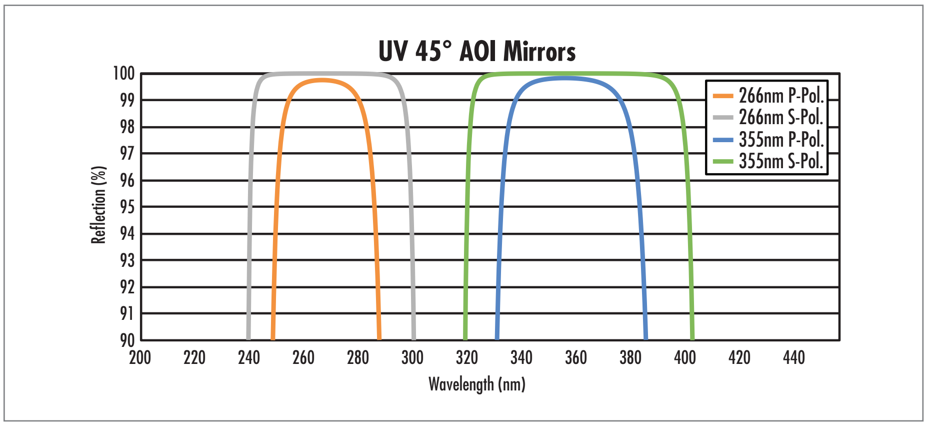
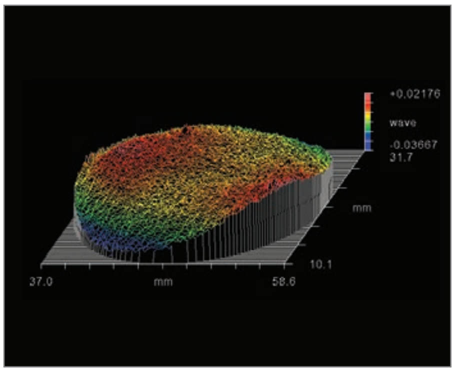
TECHSPEC® Nd:YAG LASER LINE MIRRORS

- **High Damage Thresholds up to 6 J/cm² @ 355nm**
- **>99% Absolute Reflectivity at Design Wavelength**
- **Available at 266nm and 355nm**

TECHSPEC® Nd:YAG Laser Line Mirrors offer the high reflectance and superior surface quality and accuracy needed for demanding laser applications with Nd:YAG and Nd:YLF lasers. Featuring a high damage threshold, these high power laser line mirrors are ideal for beam steering. These mirrors are available in 0˚ and 45˚ AOI options with third harmonic 355nm and fourth harmonic 266nm designs.

Substrate:	Fused Silica	**Diameter Tolerance:**	+0.0/-0.2mm
Surface Quality:	10-5	**Thickness:**	
Surface Flatness:	λ/10 @ 632.8nm	**12.5mm & 25mm Dia.:**	6.0 ±0.2mm
Parallelism:	<3 arcmin	**50mm Dia.:**	10.0 ±0.2mm
Clear Aperture:	>90% of Diameter	**Back Surface:**	Ground





Surface flatness is measured interferometrically. A typical test for #34-820 shows significantly better surface figure after coating than the λ/10 specification.

TECHSPEC® Nd:YAG LASER LINE MIRRORS

DWL (nm)	AOI (°)	Reflectivity @ DWL (%)	Diameter (mm)	Thickness (mm)	Damage Threshold	Stock No	Price		
							1-5	6-25	26+
266	0	>99	25.4	9.5	2.5 J/cm² @ 10ns, 20 Hz, 266nm (typical)	#36-323	$195.00	$185.00	Call For OEM Quantity Pricing
266	45	>99.5	12.5	6.0	2 J/cm² @ 10ns	#47-980	$129.00	$107.00	
266	45	>99.5	25.0	6.0	2 J/cm² @ 10ns	#47-981	$164.00	$131.00	
266	45	>99	25.4	6.4	2.5 J/cm² @ 20ns, 20 Hz, 266nm	#34-815	$163.00	$150.00	
266	45	>99	25.4	9.5	2.0 J/cm² @ 10ns, 20 Hz, 266nm	#36-324	$195.00	$185.00	
266	45	>99.5	50.0	10.0	2 J/cm² @ 10ns	#63-116	$233.00	$199.00	
266	0 - 45	>99.9	12.5	6.0	2 J/cm² @ 10ns @ 10 Hz	#88-523	$149.00	$117.00	
266	0 - 45	>99.9	25.0	6.0	2 J/cm² @ 10ns @ 10 Hz	#88-524	$179.00	$141.00	
266	0 - 45	>99.9	50.0	10.0	2 J/cm² @ 10ns @ 10 Hz	#88-525	$269.00	$211.00	
355	0	>99.5	25.4	9.5	6 J/cm² @ 10ns, 20 Hz, 355nm	#36-325	$205.00	$195.00	Call For OEM Quantity Pricing
355	45	>99.8	12.5	6.0	5 J/cm² @ 10ns	#47-323	$124.00	$99.00	
355	45	>99.8	25.0	6.0	5 J/cm² @ 10ns	#47-324	$125.00	$99.00	
355	45	>99.9	25.4	5.0	12 J/cm² @ 1064nm, 10ns	#89-450	$199.00	$189.00	
355	45	>99.5	25.4	6.4	5 J/cm² @ 355nm, 20ns, 10Hz	#34-820	$153.00	$140.00	
355	45	>99.5	25.4	9.5	6 J/cm² @ 10ns, 20 Hz, 355nm	#36-326	$205.00	$195.00	
355	45	>99.8	50.0	10.0	5 J/cm² @ 10ns	#63-117	$214.00	$189.00	
355	45	>99.5	50.8	9.5	6 J/cm² @ 10ns, 20 Hz, 355nm	#36-388	$275.00	$249.00	
355	0 - 45	>99.9	12.5	6.0	5 J/cm² @ 10ns @ 10 Hz	#88-526	$139.00	$109.00	
355	0 - 45	>99.9	25.0	6.0	5 J/cm² @ 10ns @ 10 Hz	#88-527	$169.00	$133.00	
355	0 - 45	>99.9	50.0	10.0	5 J/cm² @ 10ns @ 10 Hz	#88-528	$259.00	$209.00	

TECHSPEC® EXCIMER LASER MIRRORS

- **High Damage Threshold of up to 1.5 J/cm²**
- **Low Loss Dielectric Coatings**
- **Designed for use with Common Excimer Wavelengths**

Ideal for the most demanding UV applications, TECHSPEC® Excimer Laser Mirrors have been optimized for use with high power excimer lasers. A precision UV grade fused silica substrate provides excellent thermal stability and low wavefront distortion. All mirrors are designed for a 45˚ angle of incidence and feature very low polarization dependence. Contact us for 0˚ angle of incidence versions.

Substrate:	Fused Silica
Surface Quality:	10-5
Surface Flatness:	λ/10 @ 632.8nm
Parallelism:	<3 arcmin
Clear Aperture:	90% of Diameter
Angle of Incidence:	45°
Diameter Tolerance:	+0.0/-0.2mm
Thickness:	6.0 ±0.2mm (12.5 and 25mm) 10.0±0.2mm (50mm)
Back Surface:	Ground
Damage Threshold:	1.5 J/cm² (10ns pulse)

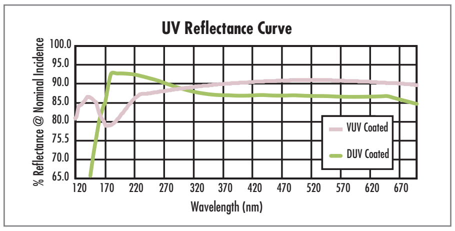
TECHSPEC® EXCIMER LASER MIRRORS

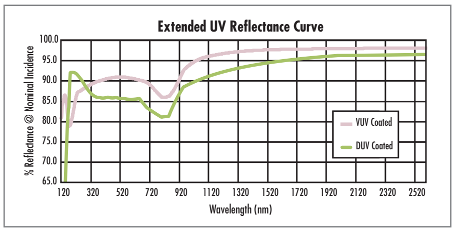
Wavelength (nm)	R_{abs} @DWL (%)	Price – 12.5mm Diameter				Price – 25.0mm Diameter				Price – 50.0mm Diameter			
		Stock No.	1-5	6-25	26+	Stock No.	1-5	6-25	26+	Stock No.	1-5	6-25	26+
193	>97	#47-982	$209.00	$179.00	Call	#47-983	$249.00	$219.00	Call	#48-931	$299.00	$249.00	Call
248	>99	#47-984	$159.00	$128.00	Call	#47-985	$189.00	$152.00	Call	#63-120	$275.00	$220.00	Call

TECHSPEC® PRECISION ULTRAVIOLET MIRRORS

- **Deep UV Enhanced and Vacuum UV Enhanced Versions**
- **Reflection Down to 120nm**
- **>78% Reflectance at Specified Design Wavelength**

TECHSPEC® Precision Ultraviolet Mirrors are ideal for most commercially available light sources and are offered in both Deep UV (DUV) and Vacuum UV Enhanced (VUV) coating options. The DUV coating offers excellent reflection from 190nm to the long-wave infrared (LWIR), while the VUV coating has optimized reflection from 120nm to the LWIR. These TECHSPEC® Precision Ultraviolet Mirrors are designed for 0° angle of incidence and feature an aluminum-based coating for low polarization sensitivity. Note: The soft coating can be easily damaged by fingerprints and aerosols.





Substrate:	Fused Silica	**Reflectivity:**	
Surface Quality:	10-5	**VUV Coated:**	R_{avg} >78% @ 120 - 125nm
Surface Flatness:	λ/10 @ 632.8nm		R_{avg} >85% @ 120 - 600nm
Parallelism:	<3 arcmin	**DUV Coated:**	R_{avg} >88% @ 190 - 195nm
Clear Aperture:	>90%		R_{avg} >85% @ 200 - 600nm
Diameter Tolerance:	+0.0/-0.2mm	**Back Surface:**	Ground
Thickness Tolerance:	±0.2mm		

TECHSPEC® PRECISION ULTRAVIOLET MIRRORS

Diameter (mm)	Thickness (mm)	Design Wavelength (nm)	Price – VUV Coated				Design Wavelength (nm)	Price – DUV Coated			
			Stock No.	1-5	6-25	26+		Stock No.	1-5	6-25	26+
12.5	6.0	120	#33-912	$209.00	$179.00	Call	190	#48-567	$189.00	$129.00	Call
25.0	6.0	120	#33-913	$229.00	$199.00	Call	190	#48-568	$209.00	$149.00	Call
50.0	10.0	120	#33-914	$299.00	$269.00	Call	190	#48-569	$259.00	$189.00	Call

TECHNICAL NOTE

ENHANCED ALUMINUM

The Enhanced Aluminum coating on our Precision Ultraviolet Mirrors consists of a layer of MgF_2 on top of aluminum. This is used to increase the reflectance in the visible or ultraviolet regions. The VUV and DUV Enhanced Aluminum coatings yield increased reflectance from 120 - 600nm. Unlike Enhanced Aluminum coatings made from a multi-layer film of dielectrics on top of aluminum, the MgF_2 coating on the Precision Ultraviolet Mirrors does not improve the handling characteristics of the aluminum coating. Extra care should still be taken to not scratch the mirrors during handling or cleaning.

For information on Metallic Mirror Coatings, **www.edmundoptics.com/metallic-mirror-coatings**

TECHSPEC® PRECISION UV FUSED SILICA ASPHERIC LENSES

- **Low f/#s for Optimum Light Gathering**
- **Low Coefficient of Thermal Expansion**
- **Prescription Information Available**

TECHSPEC® Precision UV Fused Silica Aspheric Lenses offer the benefits of an aspheric element combined with the manufacturing precision of state-of-the-art grinding and polishing equipment. With the available prescription data, these fused silica optics can be easily designed and integrated into complex optical systems. Featuring low f/#'s for optimum light gathering and focusing performance, these fused silica lenses are computer optimized to eliminate spherical and minimize higher order aberrations. UV fused silica optics substrate offers a low coefficient of thermal expansion.

Design Wavelength:	587.6nm	**Surface Accuracy:**	0.75μm RMS
Clear Aperture:	90%	**Surface Quality:**	60-40
10mm Dia.:	80%	**Centering:**	3 - 5 arcmin
12.5mm Dia.:	88%	**Prescription Data:**	See our website
Diameter Tolerance:	+0.0/-0.1mm	**Coating: UV:**	R_{avg} <1.5% @ 250 - 450nm
Center Thickness Tolerance:	±0.1mm	**UV-VIS:**	R_{avg} <2.5% @ 250 - 700nm

TECHSPEC® PRECISION UV FUSED SILICA ASPHERIC LENSES

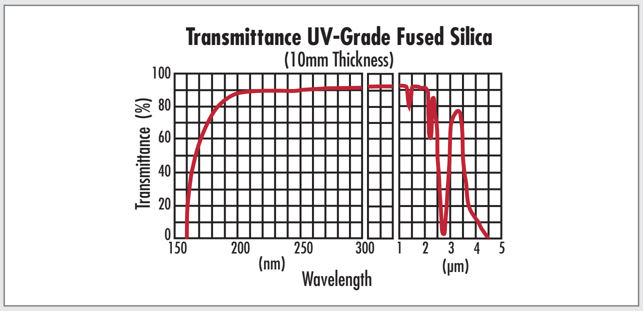
*DCX Lens Shape

Dia. (mm)	EFL (mm)	Numerical Aperture	BFL (mm)	CT (mm)	ET (mm)	Stock No. Uncoated	Price – Uncoated 1-5	Price – Uncoated 6-25	Price – Uncoated 26+	Stock No. UV Coated	Stock No. UV-VIS Coated	Price – Coated 1-5	Price – Coated 6-25	Price – Coated 26+
10.0	8.0	0.63	2.52	8.00	3.05	#87-973	$305.00	$244.00	Call For OEM Quantity Pricing	#87-977	#87-981	$325.00	$260.00	Call For OEM Quantity Pricing
10.0	10.0	0.50	5.89	6.00	2.77	#87-974	$295.00	$236.00		#87-978	#87-982	$315.00	$252.00	
12.5	10.0	0.63	4.52	8.00	2.03	#87-975	$335.00	$268.00		#87-979	#87-983	$355.00	$284.00	
12.5	12.5	0.50	8.39	6.00	1.98	#87-976	$325.00	$260.00		#87-980	#87-984	$345.00	$276.00	
15.0	10.0	0.75	2.69*	11.40	3.70	#33-947	$425.00	$340.00		#33-951	#33-955	$445.00	$356.00	
15.0	12.5	0.60	6.33	9.00	2.47	#67-264	$415.00	$332.00		#67-269	#84-334	$435.00	$348.00	
15.0	15.0	0.50	10.03	7.25	2.43	#48-534	$415.00	$332.00		#49-693	#84-335	$435.00	$348.00	
15.0	20.0	0.38	15.89	6.00	2.68	#48-535	$415.00	$332.00		#49-694	#84-336	$435.00	$348.00	
15.0	25.0	0.30	22.01	4.36	1.79	#33-948	$415.00	$332.00		#33-952	#33-956	$435.00	$348.00	
25.0	17.5	0.69	8.37*	14.80	2.85	#33-949	$495.00	$396.00	Call For OEM Quantity Pricing	#33-953	#33-957	$515.00	$412.00	Call For OEM Quantity Pricing
25.0	20.0	0.63	10.40	14.00	2.27	#67-265	$475.00	$380.00		#67-270	#84-337	$495.00	$396.00	
25.0	25.0	0.50	18.32	9.75	1.75	#48-536	$465.00	$372.00		#49-695	#84-338	$485.00	$388.00	
25.0	30.0	0.42	24.17	8.50	2.21	#48-537	$465.00	$372.00		#49-696	#84-339	$485.00	$388.00	
25.0	50.0	0.25	46.50	5.13	1.61	#33-950	$465.00	$372.00		#33-954	#33-958	$485.00	$388.00	
50.0	40.0	0.63	21.15	27.50	4.07	#67-266	$715.00	$572.00		#67-271	#84-340	$755.00	$604.00	
50.0	50.0	0.50	36.63	19.50	3.49	#67-267	$695.00	$556.00		#67-272	#84-341	$735.00	$588.00	
50.0	60.0	0.42	48.34	17.00	4.42	#67-268	$695.00	$556.00		#67-273	#84-342	$735.00	$588.00	

TECHNICAL NOTE

PROPERTIES OF FUSED SILICA

Fused Silica is a material used in a wide variety of Ultraviolet, Visible, and Near Infrared application spaces in the 0.18 to 3μm spectral region. Its low index of refraction, low coefficient of thermal expansion, and high hardness make it an ideal material for a variety of rugged applications. Below is a table of the Optical, Thermal, and Mechanical properties of Fused Silica substrate optics.



OPTICAL PROPERTIES	
Bulk Absorption Coefficient @ 1μm	≤ 0.00001/cm
Temperature Change of Refractive Index @ 0.5μm (dn/dT)	9.25 x 10^{-6}/°C
Transmission Range	0.18 to 3μm
Refractive Index	1.4570 @ 632.8nm
THERMAL PROPERTIES	
Thermal Conductivity @ 20°C	1.3 W/m K
Specific Heat Capacity	703 J/Kg °K
Linear Expansion Coefficient	0.55 x 10^{-6}/°C
Softening Point	1585 °C
MECHANICAL PROPERTIES	
Young's Modulus	72.7 GPa
Shear Modulus	31.4 GPa
Bulk Modulus	35.4 GPa
Rupture Modulus	52.4 MPa
Knoop Hardness	522 kg/mm²
Density	2.201 g/cm³
Poisson's Ratio	0.16

TECHSPEC® PLANO-CONVEX (PCX) UV FUSED SILICA LENSES

- **UV-Grade Fused Silica**
- **Wavelength Range of 200nm to 2.2µm**
- **Variety of Coating Options Available**

TECHSPEC® Plano-Convex (PCX) UV Fused Silica Lenses feature precision specifications and a variety of coating options on a broadband substrate. Fused Silica is commonly used in applications from the Ultraviolet (UV) through the Near-Infrared (NIR) and its low index of refraction, low coefficient of thermal expansion, and low inclusion content make it ideal for laser applications and harsh environmental conditions. TECHSPEC® Plano-Convex (PCX) UV Fused Silica Lenses feature industry leading diameter and centration specifications, making them ideal for integration into demanding imaging and targeting applications.

Substrate:	UV Grade Fused Silica	**Edge Thickness Tolerance:**	Reference Value		
Diameter Tolerance:	+0.000/-0.025mm	**Power (P-V):**	1.5λ	**Clear Aperture:**	Diameter - 1.0mm
Center Thickness Tolerance:		**Irregularity (P-V):**	λ/4	**Centration:**	≤1 arcmin
12.0mm Diameter:	±0.05mm	**Surface Quality:**	40-20	**Edges:**	Fine Ground, Protective Bevel as Needed
25mm Diameter:	±0.10mm	**Focal Length Tolerance:**	±1%		

TECHSPEC® PLANO-CONVEX (PCX) UV FUSED SILICA LENSES

Diameter (mm)	Effective FL (mm)	Back FL (mm)	Center Thicknes (mm)	Edge Thickness (mm)	Radius R_1 (mm)	Stock No.	Price - Uncoated 1-5	Price - Uncoated 6-25	Price - Uncoated 26+	UV-AR Coated Stock No.	UV-VIS Coated Stock No.	Price 1-5	Price 6-25	Price 26+
12.0	18.0	15.26	4.00	1.41	8.25	#48-668	$95.00	$76.00	Call For OEM Quantity Pricing	#48-675	#48-814	$110.00	$88.00	Call For OEM Quantity Pricing
12.0	25.0	22.31	3.92	2.22	11.46	#48-024	$95.00	$76.00		#48-029	#48-815	$110.00	$88.00	
12.0	30.0	27.56	3.55	2.17	13.75	#48-025	$90.00	$72.00		#48-030	#48-816	$105.00	$84.00	
12.0	40.0	37.85	3.13	2.12	18.34	#48-026	$90.00	$72.00		#48-031	#48-818	$105.00	$84.00	
12.0	50.0	48.01	2.90	2.10	22.92	#48-027	$85.00	$68.00		#48-032	#48-819	$100.00	$80.00	
12.0	72.0	70.29	2.50	1.95	33.01	#36-684	$85.00	$68.00		#36-696	#36-708	$100.00	$80.00	
12.0	100.0	98.33	2.44	2.05	45.85	#48-028	$85.00	$68.00		#48-033	#48-820	$100.00	$80.00	
25.0	35.0	29.17	8.50	2.51	16.05	#36-689	$110.00	$88.00		#36-701	#36-713	$125.00	$100.00	
25.0	50.0	46.00	5.84	2.13	22.92	#48-274	$110.00	$88.00		#48-284	#48-822	$125.00	$100.00	
25.0	75.0	71.96	4.43	2.08	34.39	#48-275	$105.00	$84.00		#48-285	#48-824	$120.00	$96.00	
25.0	100.0	97.40	3.79	2.05	45.85	#48-276	$105.00	$84.00		#48-286	#48-825	$120.00	$96.00	
25.0	125.0	122.65	3.42	2.04	57.30	#48-277	$99.00	$79.20		#48-287	#48-826	$114.00	$91.20	
25.0	150.0	147.82	3.18	2.04	68.79	#48-278	$99.00	$79.20		#48-288	#48-827	$114.00	$91.20	
25.0	175.0	172.94	3.01	2.03	80.23	#48-279	$99.00	$79.20		#48-289	#48-828	$114.00	$91.20	
25.0	200.0	198.02	2.88	2.02	91.69	#48-280	$99.00	$79.20		#48-290	#48-829	$114.00	$91.20	
25.0	250.0	248.14	2.71	2.03	114.61	#48-281	$99.00	$79.20		#48-291	#48-830	$114.00	$91.20	

TECHSPEC® LASER GRADE PLANO CONVEX (PCX) LENSES

- **High Damage Threshold**
- **Fused Silica Substrate**

Our TECHSPEC® Laser Grade PCX Lenses are ideal for high energy laser applications. Featuring precision fused silica substrates, these lenses offer improved surface quality and irregularity vs. our TECHSPEC® Precision PCX UV Fused Silica lenses. Custom laser line coatings between 193 and 2200nm are available – contact our sales department for more information.

Substrate:	UV Grade Fused Silica
Damage Threshold: 266nm:	2 J/cm², 10ns pulse
355nm:	4 J/cm², 10ns pulse
Diameter Tolerance:	
6mm:	+0.0/-0.05mm
12mm:	+0.0/-0.1mm
Thickness Tolerance:	
≤6mm:	±0.05
≥12mm:	±0.1
Focal Length Tolerance:	±1%
Surface Quality:	20-10
Surface Accuracy (P-V):	λ/10
Clear Aperture:	85%
Coating (as noted):	R_{abs}<0.25% @ DWL
Centering Tolerance:	<1 arcmin

TECHSPEC® LASER GRADE PLANO CONVEX (PCX) LENSES

Diameter (mm)	Effective FL (mm)	Back FL (mm)	Center Thickness (mm)	Edge Thickness (mm)	Stock No. Uncoated	Price – Uncoated 1-5	Price – Uncoated 6-25	Price – Uncoated 26+	266nm Stock No.	355nm Stock No.	Price – Coated 1-5	Price – Coated 6-25	Price – Coated 26+
6.0	12.0	10.63	2.00	1.11	#87-924	$120.00	$96.00	Call For OEM Quantity Pricing	#87-928	#87-932	$140.00	$112.00	Call For OEM Quantity Pricing
6.0	18.0	16.62	2.00	1.44	#87-925	$120.00	$96.00		#87-929	#87-933	$140.00	$112.00	
6.0	24.0	22.63	2.00	1.58	#87-926	$120.00	$96.00		#87-930	#87-934	$140.00	$112.00	
12.0	18.0	15.26	4.00	1.41	#67-090	$130.00	$104.00		#67-939	#67-949	$150.00	$120.00	
12.0	25.0	22.31	3.92	2.22	#67-091	$130.00	$104.00		#67-940	#67-950	$150.00	$120.00	
12.0	36.0	34.29	2.50	1.37	#67-092	$130.00	$104.00		#67-941	#67-951	$150.00	$120.00	
12.0	50.0	48.01	2.90	2.10	#67-093	$130.00	$104.00		#67-942	#67-952	$150.00	$120.00	
25.0	38.0	33.03	7.25	1.96	#67-094	$150.00	$120.00		#67-943	#67-953	$175.00	$140.00	
25.0	50.0	46.00	5.84	2.13	#67-095	$150.00	$120.00		#67-944	#67-954	$175.00	$140.00	
25.0	75.0	71.96	4.43	2.08	#67-096	$150.00	$120.00		#67-945	#67-955	$175.00	$140.00	
25.0	100.0	97.40	3.79	2.05	#67-097	$150.00	$120.00		#67-946	#67-956	$175.00	$140.00	
25.0	150.0	147.82	3.18	2.04	#67-098	$150.00	$120.00		#67-947	#67-957	$175.00	$140.00	
25.0	250.0	248.14	2.71	2.03	#67-099	$150.00	$120.00		#67-948	#67-958	$175.00	$140.00	

TECHSPEC® UV FUSED SILICA PCX CYLINDER LENSES

- Excellent UV Transmission
- Low Coefficient of Thermal Expansion
- Precision Design

Our TECHSPEC® Fused Silica PCX Cylinder Lenses are ideal for UV applications operating in harsh or rugged environments. Focusing light in only one dimension, cylinder lenses are commonly used with linear sensor arrays, or to create a line from a laser source. For custom coating requirements, please contact our sales department.

TECHSPEC® UV FUSED SILICA PCX CYLINDER LENSES

Dia. (mm)	EFL (mm)	BFL (mm)	CT (mm)	ET (mm)	Radius (mm)	Uncoated Stock No.	Price – Uncoated 1-5	Price – Uncoated 6-25	Price – Uncoated 26+	UV-AR Stock No.	UV-VIS Stock No.	Price – Coated 1-5	Price – Coated 6-25	Price – Coated 26+
12.5	25.0	22.94	3.0	1.15	11.46	#68-168	$149.00	$119.20	Call For OEM Qty. Pricing	#68-176	#86-042	$169.00	$135.20	Call For OEM Qty. Pricing
12.5	50.0	48.63	2.0	1.13	22.93	#68-169	$149.00	$119.20		#68-177	#86-043	$169.00	$135.20	
12.5	75.0	73.63	2.0	1.43	34.39	#68-170	$149.00	$119.20		#68-178	#86-044	$169.00	$135.20	
12.5	100.0	98.63	2.0	1.57	45.85	#68-171	$149.00	$119.20		#68-179	#86-045	$169.00	$135.20	
25.0	50.0	46.58	5.0	1.29	22.93	#68-172	$199.00	$159.20		#68-180	#86-046	$219.00	$175.20	
25.0	75.0	72.60	3.5	1.15	34.39	#68-173	$199.00	$159.20		#68-181	#86-047	$219.00	$175.20	
25.0	100.0	97.94	3.0	1.26	45.85	#68-174	$199.00	$159.20		#68-182	#86-048	$219.00	$175.20	
25.0	150.0	147.94	3.0	1.85	68.77	#68-175	$199.00	$159.20		#68-183	#86-049	$219.00	$175.20	

Substrate:	UV Grade Fused Silica
Diameter Tolerance:	+0.0/-0.2mm
Center Thickness Tolerance:	±0.1mm
Surface Quality:	40-20
EFL Tolerance:	±3%
Wedge Tolerance:	15 arcmin

TECHSPEC® BEAM SHAPING FUSED SILICA CYLINDER LENSES

- Offers Superior Performance from UV to IR
- Fused Silica Substrate
- Laser Optic Surface Quality

TECHSPEC® Beam Shaping Fused Silica Cylinder Lenses feature precision specifications for the most demanding applications. These lenses are constructed of premium grade fused silica optical glass and are tailored for laser applications with a surface quality of 20-10. Our TECHSPEC® Beam Shaping Fused Silica Cylinder Lenses feature tight wedge tolerances, typically less than 3 arcmin in all dimensions. Integration of these lenses is facilitated by square form factors allowing convenient mounting options.

TECHSPEC® BEAM SHAPING FUSED SILICA CYLINDER LENSES

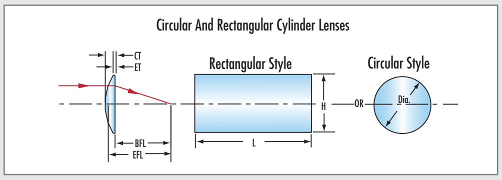
Size(mm) (H x L)	EFL (mm)	BFL (mm)	CT (mm)	ET (mm)	Radius (mm)	Uncoated Stock No.	Uncoated Price	UV-VIS Coated	Price
12.7 x 12.7	50.0	47.95	3.00	2.10	22.925	#36-089	$195.00	#36-107	$210.00
25.4 x 25.4	50.0	46.58	5.00	1.16	22.925	#36-090	$275.00	#36-108	$295.00
25.4 x 25.4	75.0	72.26	4.00	1.57	34.385	#36-091	$275.00	#36-109	$295.00
25.4 x 25.4	100.0	97.39	3.80	2.01	45.845	#36-092	$275.00	#36-110	$295.00
12.7 x 12.7	-50.0	-52.06	3.00	3.81	22.925	#36-094	$195.00	#36-112	$210.00
25.4 x 25.4	-50.0	-52.06	3.00	6.64	22.925	#36-095	$275.00	#36-113	$295.00
25.4 x 25.4	-75.0	-77.06	3.00	5.31	34.385	#36-096	$275.00	#36-114	$295.00

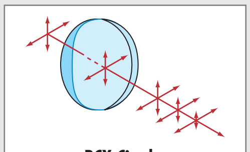
Substrate:	Fused Silica
Dimensional Tolerance:	+0.0/-0.025mm
Center Thickness Tolerance:	±0.1mm
Power (P-V) @ 632.8nm:	1.5λ
Irregularity (P-V) @ 632.8nm:	λ/4
Surface Quality:	20-10
Plano Axis Wedge:	<3 arcmin
Power Axis Wedge:	<4.5 arcmin
Axial Twist:	<3 arcmin

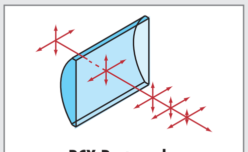
TECHNICAL NOTE

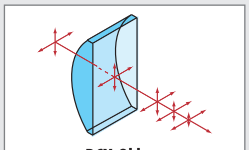
WHAT ARE CYLINDER LENSES?

Cylinder Lenses are a type of lens that have differing radii in the X and Y axes, causing the lens to have a cylindrical or semi-cylindrical shape, and image magnification in only a single axis. Cylinder lenses are commonly used as laser line generators, or to adjust image height size or correct for astigmatism in imaging systems.




PCX Circular


PCX Rectangular


PCX Oblong

Visit our website to learn more at **www.edmundoptics.com/what-are-cylinder-lenses**

TECHSPEC® HIGH PERFORMANCE OD 4 LONGPASS FILTERS

- **Cut-On Slope <1%**
- **Rejection OD ≥4.0**
- **≥91% Transmission in Pass Band**

Our High Performance Longpass filters feature high transmission in the pass band combined with superior blocking in the rejection band. With a rejection band optical density of 4.0 combined with ≥91% transmission in the pass band these filters are ideal for a wide variety of applications. Create custom bandpass filters by combining with our TECHSPEC® High Performance Shortpass Filters.

Substrate:	UV Grade Fused Silica
Diameter Tolerance:	+0.0/-0.2mm
Thickness: 12.5mm Dia.:	2.0 ±0.1mm
25mm Dia.:	3.0 ±0.1mm
50mm Dia.:	5.0 ±0.1mm
Clear Aperture:	>80%
Surface Quality:	40-20
Wavefront Distortion:	≤λ/4 RMS @ 633nm
Slope Factor:	<1%
Pass Band Transmission:	≥91% average
Rejection Band Blocking:	OD ≥4.0
Cut-On Tolerance:	±1%
Angle of Incidence:	0°
Coating Type:	Hard dielectric sputtered coating
Durability:	MIL-C-48497A, Section 3.4.1

TECHSPEC® HIGH PERFORMANCE OD 4 LONGPASS FILTERS

Cut-On Wavelength (nm)	Rejection Band (nm)	Transmission Band (nm)	12.5mm Diameter Stock No.	1-5	6-25	25mm Diameter Stock No.	1-5	6-25	50mm Diameter Stock No.	1-5	6-25
325	200 - 320	333 - 1650	#34-295	$175.00	$135.00	#34-296	$220.00	$190.00	#34-297	$450.00	$360.00
350	200 - 345	358 - 1650	#34-298	$175.00	$135.00	#34-299	$220.00	$190.00	#34-300	$450.00	$360.00
375	200 - 370	383 - 1650	#34-301	$175.00	$135.00	#34-302	$220.00	$190.00	#34-303	$450.00	$360.00

TECHSPEC® HARD COATED OD 4 10nm BANDPASS FILTERS

- **Ideal for Life Sciences or Chemical Analysis**
- **Available in UV, VIS, and IR Center Wavelengths**
- **Feature High Performance Hard Coatings**

TECHSPEC® Hard Coated OD 4 10nm Bandpass Filters are narrowband filters used extensively in applications including flame photometry, elemental or laser line separation, fluorescence, laser diode cleanup, or chemical detection or analysis. TECHSPEC® Hard Coated OD 4 10nm Bandpass Filters feature durable hard coatings to minimize filter degradation while increasing transmission. These optical filters offer steep slopes with deep blocking to achieve high performance in demanding applications.

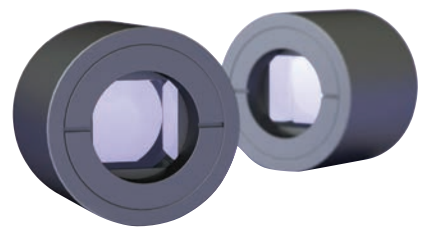
Diameter Tolerance:	+0.0/-0.1mm
Mount Thickness:	5mm
Surface Quality:	80-50
Blocking:	OD >4.0
CWL Tolerance:	±2nm
FWHM Tolerance:	±2nm

TECHSPEC® HARD COATED OD 4 10nm BANDPASS FILTERS

CWL (nm)	FWHM (nm)	Trans. Color	Minimum Trans. (%)	Blocking Range (nm)	12.5mm Diameter Stock No.	1-5	6-25	26+	25mm Diameter Stock No.	1-5	6-25	26+	50mm Diameter Stock No.	1-5	6-25	26+	Typical Applications
250	10	●	>50	200 - 650	#35-871	$150.00	$135.00	Call	#35-878	$235.00	$195.00	Call	#35-885	$530.00	$490.00	Call	KrF Laser Line / Argon SHG
260	10	●	>50	200 - 650	#35-872	$150.00	$135.00		#35-879	$235.00	$195.00		#35-886	$530.00	$490.00		Nucleic Acid Quantitation
270	10	●	>60	200 - 650	#35-873	$150.00	$135.00		#35-880	$235.00	$195.00		#35-887	$530.00	$490.00		Nucleic Acid Quantitation
280	10	●	>60	200 - 650	#35-874	$150.00	$135.00		#35-881	$235.00	$195.00		#35-888	$530.00	$490.00		Protein Absorption - Tyr & Trp
285	10	●	>65	200 - 650	#35-875	$150.00	$135.00		#35-882	$235.00	$195.00		#35-889	$530.00	$490.00		SO_2 Absorption Band
290	10	●	>70	200 - 700	#35-876	$150.00	$135.00		#35-883	$235.00	$195.00		#35-890	$530.00	$490.00		Ethanal Peak
300	10	●	>75	200 - 700	#35-877	$150.00	$135.00	Call For OEM Quantity Pricing	#35-884	$235.00	$195.00	Call For OEM Quantity Pricing	#35-891	$530.00	$490.00	Call For OEM Quantity Pricing	Protein Absorption - Tyr & Trp
310	10	●	>70	200 - 1200	#34-972	$125.00	$99.00		#34-976	$199.00	$159.00		#34-980	$475.00	$365.00		XeCl Excimer Laser (UV-B)
313	10	●	>75	200 - 1200	#34-973	$125.00	$99.00		#34-977	$199.00	$159.00		#34-981	$475.00	$365.00		Mercury Emission Line
320	10	●	>75	200 - 1200	#34-974	$125.00	$99.00		#34-978	$199.00	$159.00		#34-982	$475.00	$365.00		Brilliant Ultraviolet (BUV) Excitation
330	10	●	>75	200 - 1200	#34-975	$125.00	$99.00		#34-979	$199.00	$159.00		#34-983	$475.00	$365.00		FluoroGold Excitation
337	10	●	≥85	200 - 1200	#65-067	$125.00	$99.00		#65-128	$199.00	$159.00		#65-189	$475.00	$375.00		N Laser Line
340	10	●	≥85	200 - 1200	#65-068	$125.00	$99.00		#65-129	$199.00	$159.00		#65-190	$475.00	$375.00		FURA Excitation
355	10	●	≥85	200 - 1200	#34-490	$125.00	$99.00		#34-491	$199.00	$159.00		#34-492	$475.00	$365.00		355nm Coherent® OBIS™ Line
365	10	●	≥85	200 - 1200	#65-069	$125.00	$99.00		#65-130	$199.00	$159.00		#65-191	$475.00	$375.00		Hg Emission / Ar Laser Line
375	10	●	≥85	200 - 1200	#86-732	$125.00	$99.00		#86-736	$199.00	$159.00		#86-740	$475.00	$375.00		OPSL Laser Line
394	10	●	≥85	200 - 1200	#65-070	$125.00	$99.00		#65-131	$199.00	$159.00		#65-192	$475.00	$375.00		S Emission Line

GLAN-TYPE POLARIZERS

- **Broadband Performance from 220 - 2200nm**
- **High Extinction Ratios**
- **High Laser Damage Thresholds**



Glan-Type Polarizers are mounted, polarizing prisms used in applications that require broad spectral ranges, high extinction ratios, or high polarization purities. Glan-Taylor Polarizers are medium-power, air-spaced UV to NIR polarizers that transmit the extraordinary beam. The ordinary beam is then reflected and absorbed by black glass plates that have been cemented to the prism. Glan-Laser Polarizers are similar to Glan-Taylor, but are designed for higher power applications. Glan-Laser Polarizers utilize an advanced polishing technique for minimizing surface scatter and feature two escape windows for passing the high power rejected light. Glan-Thompson Polarizers are low power polarizers that are ideal for UV, visible, or NIR applications, feature a cemented design, and transmit the extraordinary beam while absorbing the reflected ordinary beam.

Diameter:	25.4mm
Extinction Ratio:	$<5 \times 10^{-6}$
Surface Quality:	20-10
Beam Deviation:	<3 arcmin
Wavefront Distortion:	$\lambda/4$ @ 632.8nm
Coating:	Single layer MgF_2
Damage Threshold:	
Glan-Laser:	>500 MW/cm²
Glan-Taylor:	>200 MW/cm²
Glan-Thompson:	>100 MW/cm²

GLAN-TAYLOR AND GLAN-LASER POLARIZERS

Polarizer Type	Wavelength (nm)	Substrate	8mm Clear Aperture					12.7mm Clear Aperture				
			Length (mm)	Stock No.	1-5	6-25	26+	Length (mm)	Stock No.	1-5	6-25	26+
Glan-Taylor	220 - 350	α-BBO	17.0	#89-549	$895.00	$815.00	Call	21.0	#89-550	$1,195.00	$1,095.00	Call
Glan-Taylor	350 - 2200	Calcite	17.0	#89-547	$695.00	$635.00		21.0	#89-548	$895.00	$815.00	
Glan-Laser	220 - 350	α-BBO	30.4	#89-553	$995.00	$905.00		31.5	#89-554	$1,295.00	$1,165.00	
Glan-Laser	350 - 2200	Calcite	24.5	#89-551	$795.00	$725.00		27.5	#89-552	$995.00	$905.00	

GLAN-THOMPSON POLARIZERS

Polarizer Type	Wavelength (nm)	Substrate	8mm Clear Aperture					10mm Clear Aperture					12.7mm Clear Aperture				
			Length (mm)	Stock No.	1-5	6-25	26+	Length (mm)	Stock No.	1-5	6-25	26+	Length (mm)	Stock No.	1-5	6-25	26+
Glan-Thompson	350 - 2200	Calcite	28	#89-544	$595.00	$545.00	Call	33	#89-545	$695.00	$635.00	Call	40	#89-546	$795.00	$725.00	Call

QUARTZ WAVEPLATES (RETARDERS)

- **Zero Order and Multiple Order Waveplates**
- **$\lambda/4$ and $\lambda/2$ Retardance**
- **Mounted in Black Anodized Aluminum Frame**

Available in multiple order and zero order, Quartz Waveplates (Retarders) are ideal for a range of applications. Multiple order waveplates are ideal for applications where the wavelength deviates less than ±1% from the design wavelength of the waveplate. For applications with a greater than ±1% deviation, zero order waveplates are recommended due to their increased bandwidth and lower sensitivity to temperature change. To ease system integration, the fast axis is marked on the edge of the mount.

Substrate:	Quartz Single-Crystal
Surface Quality:	10-5
Retardation Tolerance:	$\pm\lambda/200$
Wavefront Distortion:	$\lambda/10$
Parallelism:	0.5 arcsec
AR Coating:	<0.25% per surface
Recommended Energy Limits:	1kW/cm² (CW) 3.5J/cm², 10ns pulse
Temperature Coefficient:	
Zero Order:	$0.0001\lambda/°C$ (Design temp. 20°C)
Multiple Order:	$0.0015\lambda/°C$ (Design temp. 20°C)

MULTIPLE ORDER WAVEPLATES

	Diameter: 12.7mm Clear Aperture: 8.0mm Thickness: 6.4mm			Diameter: 25.4mm Clear Aperture: 15.0mm Thickness: 7.8mm			Diameter: 30.0mm Clear Aperture: 23.0mm Thickness: 6.0mm		
Design Wavelength	**$\lambda/4$ Stock No.**	**$\lambda/2$ Stock No.**	**Price**	**$\lambda/4$ Stock No.**	**$\lambda/2$ Stock No.**	**Price**	**$\lambda/4$ Stock No.**	**$\lambda/2$ Stock No.**	**Price**
266nm	#85-068	#85-079	$225.00	#48-471	#48-472	$280.00	#65-913	#65-914	$350.00
355nm	#85-072	#85-080	$225.00	#48-473	#48-474	$280.00	#65-915	#65-916	$350.00
405nm	#85-073	#85-081	$225.00	#83-923	#83-924	$280.00	#83-925	#83-926	$350.00
488nm	#85-074	#85-082	$225.00	#48-475	#48-476	$280.00	#65-917	#65-918	$350.00
514.5nm	#85-075	#85-083	$225.00	#43-690	#43-691	$280.00	#48-477	#48-478	$350.00
532nm	#85-076	#85-084	$225.00	#43-694	#43-695	$280.00	#48-479	#48-480	$350.00
632.8nm	#85-077	#85-085	$225.00	#43-698	#43-699	$280.00	#48-481	#48-482	$350.00
1064nm	#85-078	#85-086	$225.00	#43-702	#43-703	$280.00	#48-483	#48-484	$350.00

ZERO ORDER WAVEPLATES

	Diameter: 12.7mm Clear Aperture: 8.0mm Thickness: 6.4mm			Diameter: 25.4mm Clear Aperture: 15.0mm Thickness: 7.8mm			Diameter: 30.0mm Clear Aperture: 23.0mm Thickness: 6.0mm			Diameter: 50.8mm Clear Aperture: 34.0mm Thickness: 9.0mm			Diameter: 76.2mm Clear Aperture: 46.0mm Thickness: 9.0mm		
Design Wavelength	**$\lambda/4$ Stock No.**	**$\lambda/2$ Stock No.**	**Price**	**$\lambda/4$ Stock No.**	**$\lambda/2$ Stock No.**	**Price**	**$\lambda/4$ Stock No.**	**$\lambda/2$ Stock No.**	**Price**	**$\lambda/4$ Stock No.**	**$\lambda/2$ Stock No.**	**Price**	**$\lambda/4$ Stock No.**	**$\lambda/2$ Stock No.**	**Price**
266nm	#85-017	#85-031	$375.00	#48-485	#48-486	$430.00	#65-897	#65-898	$570.00	N/A	N/A	–	N/A	N/A	–
355nm	#85-018	#85-032	$375.00	#46-548	#46-549	$430.00	#65-899	#65-900	$570.00	#85-047	#85-052	$1,495.00	#85-058	#85-063	$2,195.00
405nm	#85-019	#85-033	$375.00	#83-927	#83-928	$430.00	#83-929	#83-930	$570.00	N/A	N/A	–	N/A	N/A	–

TECHSPEC® DA FIXED YAG BEAM EXPANDERS

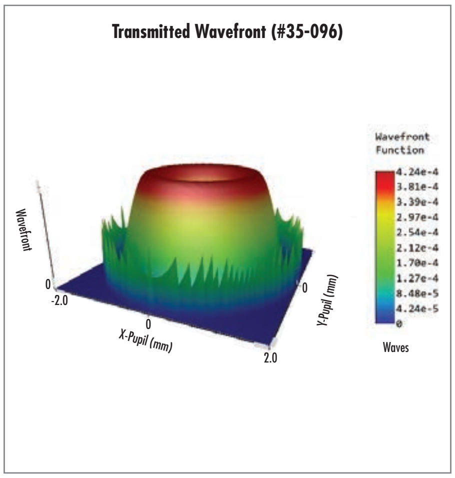
- **λ/10 Transmitted Wavefront Error**
- **Divergence Adjustment**
- **Designed for Nd:YAG Wavelengths: 266nm and 355nm**

TECHSPEC® DA (Divergence Adjustable) Fixed YAG Beam Expanders are designed for demanding laser applications including laser materials processing, medical, and research. These compact beam expanders are optimized at Nd:YAG wavelengths for high performance transmitted wavefront, with designs achieving λ/10 transmitted wavefront error. TECHSPEC DA Fixed YAG Beam Expanders easily mount with M30 x 1 threading and provide excellent value both for single unit purchases as well as volume integration.

Transmitted Wavefront, P-V:	λ/10 nominal @ DWL
Coating Specification:	R_{abs} ≤0.25% @ DWL
Maximum Entrance Aperture:	10mm
10X:	7.5mm
Maximum Exit Aperture:	23mm
10X (355nm):	26mm
10X (266nm):	32mm
Substrate:	Fused Silica
Mounting Threads:	M30 x 1

TECHSPEC® DA FIXED YAG BEAM EXPANDERS

Expansion Power	Desig Wavelength DWL (nm)	Input Beam for <λ/10 Nominal Performance (mm)	Housing Diameter (mm)	Length (mm)	Damage Threshold, Pulsed	Stock No.	Price 1-9	Price 10-24	Price 25+
2X	266	<4	29.95	71.9	1.5 J/cm² @ 10ns, 20Hz, 266nm	#35-092	$249.00	$229.00	Call For OEM Quantity Pricing
3X	266	<4	29.95	73.4		#35-096	$249.00	$229.00	
5X	266	<2.7	40.0	86.0		#35-100	$349.00	$329.00	
7X	266	<2.4	40.0	87.0		#35-108	$349.00	$329.00	
10X	266	<1.9	48.0	91.9		#35-114	$349.00	$329.00	
2X	355	<4	29.95	79.1	2.5 J/cm² @ 10ns, 20Hz, 355nm	#35-093	$249.00	$229.00	
3X	355	<4	29.95	77.1		#35-097	$249.00	$229.00	
5X	355	<3	40.0	89.0		#35-101	$349.00	$329.00	
7X	355	<2.6	40.0	90.0		#35-109	$349.00	$329.00	
10X	355	<2.3	39.95	82.6		#35-115	$349.00	$329.00	



The design wavefront for the 3X 266nm beam expander (#35-096) displayed allows for a λ/10 specification for transmitted wavefront.

DIMENSIONS

Expansion Power	Design Wavelength (nm)	Housing Diameter (mm)	Length with Thread (mm)	Length without Thread (mm)
2X	266	29.95	77.9	71.9
3X	266	29.95	79.7	73.7
5X	266	40.0	86.0	80.0
7X	266	40.0	87.0	81.3
10X	266	48.0	91.9	98.4
2X	355	29.95	85.1	79.1
3X	355	29.95	82.8	76.8
5X	355	40.0	89.0	83.5
7X	355	40.0	90.0	84.4
10X	355	39.95	89.1	82.6
10X	1064	39.95	89.5	83

ACCESSORIES

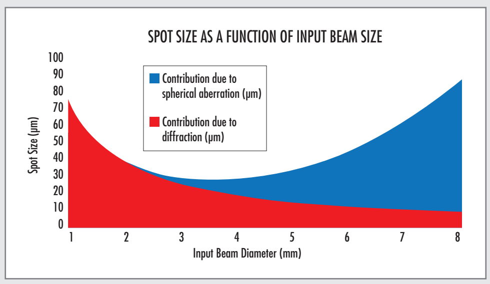
Description	Stock No.	Price
Female M30 x 1.0 to Male 1" x 32 TPI (C-Mount) Adapter	#35-474	$29.00
Female M30 x 1.0 to Male M24 x 0.5 Adapter	#35-475	$29.00
Female M30 x 1.0 to Male M22 x 0.75 Adapter	#35-476	$29.00
Female M30 x 1.0 to Male M16 x 0.75 Adapter	#35-477	$29.00
Female M30 x 1.0 to Male 1.035" x 40 TPI Adapter	#35-478	$29.00

TECHNICAL NOTE

SPOT SIZE VS INPUT BEAM SIZE

Focused laser spot size is fundamentally determined by the combination of diffraction (blue) and aberrations (red). In this example we can assume that spherical aberration is the dominant aberration, and consider it the only type of aberration. By using a beam expander within a laser system, the input beam diameter is increased by a factor m, reducing the divergence by a factor m. When the beam is finally focused down to a small spot, this spot is a factor of m smaller than for the unexpanded beam for an ideal, diffraction limited spot.

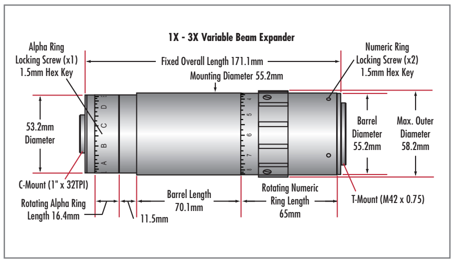
There is however a tradeoff with spherical aberration, which increases as the spot size increases. At small input beam diameters, the spot size is diffraction limited. As the input beam diameter increases, spherical aberration starts to dominate the spot size.

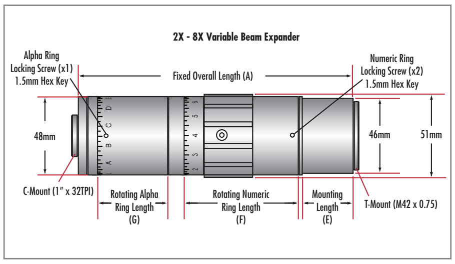


TECHSPEC® RESEARCH-GRADE VARIABLE BEAM EXPANDERS

- **1X - 3X and 2X - 8X Continuous Magnification**
- **Non-Rotating Lenses Minimize Beam Wander**
- **λ/4 Transmitted Wavefront**

TECHSPEC® Research-Grade Variable Beam Expanders (RVBX) are ideal for high power laser applications where magnification changes may be required, such as prototyping or R&D. Additionally, these beam expanders use internal translation and focusing mechanisms to continuously adjust magnification and laser divergence without affecting overall housing length. This compact Galilean design removes the need to make system accommodations for changes in length and eases system integration.





SPECIFICATIONS

Expansion Power	Max Input Aperture (mm)	Max Output Aperture (mm)	Max Input Beam Tilt (mrad)
1X - 3X	10	30	1
2X - 8X	15	30	1

TECHSPEC® RESEARCH-GRADE VARIABLE BEAM EXPANDERS

Magnification	Design Wavelength (nm)	Coating	Transmitted Wavefront	Stock No.	Price 1-5	Price 6-10	Price 11+
1X - 3X	266	266nm V-Coat, R_{abs} <0.25%	<λ/4 for Input Beam ≤5mm	#87-559	$1,095.00	$879.00	Call For OEM Quantity Pricing
1X - 3X	355	355nm V-Coat, R_{abs} <0.25%	<λ/4 for Input Beam ≤5mm	#87-560	$999.00	$849.00	Call For OEM Quantity Pricing
2.5X - 8X	266	266nm V-Coat, R_{abs} <0.25%	<¾λ for Input Beam ≤4mm (2.5X - 4X) <λ/2 for Input Beam ≤2mm (>4X)	#87-565	$1,290.00	$1,039.00	Call For OEM Quantity Pricing
2X - 8X	355	355nm V-Coat, R_{abs} <0.25%	<λ/4 for Input Beam ≤4mm (2X - 6X) <λ/4 for Input Beam ≤2mm (>6X)	#87-566	$1,290.00	$1,039.00	Call For OEM Quantity Pricing

TECHSPEC® ULTRA DIVERGENCE ADJUSTABLE BEAM EXPANDERS

- **λ/10 Transmitted Wavefront**
- **Collimation Adjustment Using Non-Rotating Optics**
- **Compact Galilean Designs that Minimize Beam Wander**

TECHSPEC® UDA Fixed Power Laser Beam Expanders offer diffraction-limited performance over the large input beam diameters, eliminating the need for critical alignment. Focus adjustment is provided that can also be used for divergence correction or collimation. C and T input/output mounting threads are compatible with Edmund Optics' line of threaded mounting components, or mounting can be achieved using an optional mounting clamp.

Lens Element Material: Fused Silica, Corning 7980
Transmitted Wavefront: λ/10 @ 1mm Input Beam Diameter; λ/4 @ Input Beam Diameter: 4mm (3X), 3mm (5X & 10X)
Focus Range: 1.5m - ∞
Focus Travel: ±7.5mm

Mount: **Input:** Male C-Thread (1" x 32 TPI); **Output:** Male T2-Thread (M42 x 0.75)
Coating: UV Broadband
Coating Specification: R_{avg} <0.5% @ 260-365nm; R_{avg} <0.25% @ 266nm & 355nm

ACCESSORIES

Description	Stock No.	Price
M43 x 0.5 (male) Output Adapter	#59-137	$39.00
M30 x 1.0 (male) Input Adapter	#59-138	$39.00
Mounting Clamp, English	#59-475	$99.00
Mounting Clamp, Metric	#59-476	$99.00

TECHSPEC® ULTRA DIVERGENCE ADJUSTABLE BEAM EXPANDERS

Expansion Power	Entrance Aperture (mm)	Exit Aperture (mm)	Housing Max Length* (mm)	Housing Max. Diameter (mm)	Stock No.	Price 1-5	Price 6-10	Price 11+
3X	11	33	92	46	#68-270	$679.00	$548.00	Call
5X	10	33	89	46	#68-271	$709.00	$572.00	Call
10X	8	33	102	46	#68-272	$729.00	$588.00	Call

*Includes Threads

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Danfoss IXA and Edmund Optics are Creating a Cleaner Environment Using UV Spectroscopy

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DANFOSS IXA

The future depends on monitoring and regulating air pollution, which is an essential step towards creating a cleaner environment

Monitoring and regulating air pollution is an essential step towards creating a cleaner environment. Danfoss IXA, a high-tech company based in Denmark, is developing a device called MES 1001, a marine emission sensor based on ultraviolet absorption spectroscopy which monitors the NO, NO_2, SO_2 and NH_3 emissions produced by cargo ships to ensure that they are complying with all environmental regulations. The optical sensor is placed inside the exhaust system of ships, so the involved optics will be exposed to extreme conditions and must be able to withstand temperatures up to 500°C and very high pressures simultaneously. ■

THE SOLUTION

EO investigated many different materials and mounting options to prevent cracking optics and outgassing adhesives at the extremely high temperatures and pressures the sensor would be exposed to. By iterating the design process multiple times and researching in different materials these issues were solved and Edmund Optics delivered an optical assembly that could survive the harsh environment inside a ship's exhaust system. Edmund Optics is proud to be a part of this product which will positively impact the environment and support a global effort to reduce harmful emissions. ■

During that time Danfoss IXA

"found the support from [EO's] project managers extremely fruitful and very efficient in bringing the development process to success."

- Finn Haugaard, Danfoss IXA

VIEW THE FULL CASE STUDY AT www.edmundoptics.com/danfoss

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