

Linear Polarizer Principles

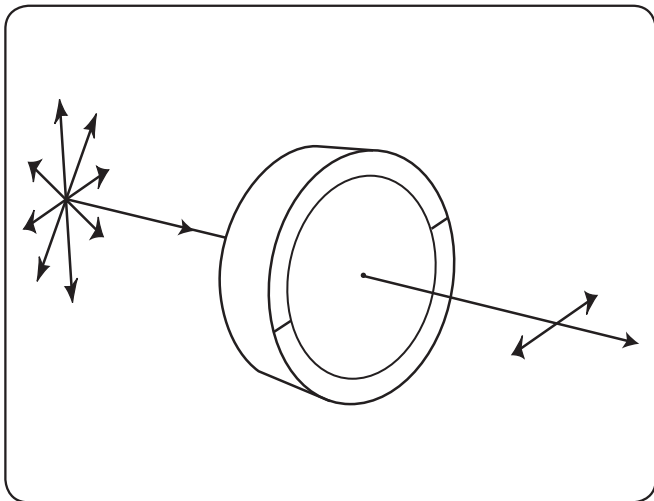


Fig. 1-1 Regardless of input polarization, a linear polarizer transmits only linearly polarized light.

Ideal linear polarizers allow the transmission of only one polarization state with zero leakage of all other polarization states. Rotating the linear polarizer about the optical axis changes the output plane of polarization. Thus, a perfect linear polarizer transmits only 50% of an unpolarized input beam and two perfect polarizers with their transmission axes crossed totally extinguish an incident beam. Imperfections in polarizers such as scattering sites, material defects (such as pinholes in thin films) and field-of-view effects reduce ideal polarizers' contrast.

When choosing a linear polarizer, several key factors must be considered including: cost, wavelength range, aperture size, acceptance angle, damage threshold, transmission efficiency and extinction ratio. Extinction ratio (or contrast ratio) is defined as the ratio of transmitted intensity through parallel polarizers to the transmitted intensity through crossed polarizers. Meadowlark Optics offers polarizers with extinction ratios as high as 10,000,000:1 over the operating wavelength range.

Meadowlark Optics now offers four types of linear polarizers: dichroic (polymer and glass), dielectric beamsplitting, wire grid and calcite crystal.

Dichroic Polarizers – Polymer and Glass

Meadowlark Optics offers an extensive line of dichroic polarizers made from both polymer and treated glass materials. Dichroic refers to the selective polarization absorption of the anisotropic polarizing material (Diatenuation). These polarizers are usually constructed by laminating a thin, stretched and dyed polymer film between two polished and antireflection-coated glass windows. The resulting compact component offers excellent value and is often the best choice for flux densities below 1 watt/cm². Selecting the appropriate dichroic polarizing material enables excellent extinction ratio performance over the wavelength range from 310 to 5000 nm. Due to small variations in the polarization material, extinction ratios degrade over larger apertures for all dichroic polarizers. Meadowlark Optics has improved the transmission of dichroic polarizers with high-efficiency, broadband antireflection coatings on the glass windows used in our product design. Laminated glass construction contributes to a substantial improvement in transmitted wavefront distortion. Our polarizer assembly greatly improves the product durability, allowing for easy and repeated cleaning.

Meadowlark Optics also offers a line of high contrast dichroic glass polarizers for the near and mid infrared regions of the spectrum up to 5000 nm. High throughput and contrast make these polarizers an excellent choice for near infrared requirements. Key advantages of dichroic polarizers include superior angular acceptance and extreme flexibility for custom shapes and sizes. Please call one of our Sales Engineers for assistance.

Beamsplitting Polarizers

Beamsplitting polarizers divide unpolarized incident light into two (usually) orthogonal, linearly polarized beams. Low absorption coatings provide an excellent combination of damage resistance and extinction ratio at a moderate price. Rugged beamsplitter cubes are easily mounted and therefore designed into many instrument applications. Beamsplitting polarizers offer the unique advantage of providing two linearly polarized output beams, one transmitting straight through and the second “splitting” off at precisely 90 degrees. When necessary, the extinction ratio of the reflected beam can be dramatically improved by adding a dichroic polarizer to the output face. Meadowlark Optics offers both Laser Line and Broadband Beamsplitting Polarizers, covering visible to near infrared applications. Laser Line Beamsplitting Polarizers offer the advantage of V-type antireflection coatings, improving efficiency by limiting surface losses. Broadband Beamsplitting Polarizers are more versatile for tunable wavelength or broadband sources.

Note: Polarizers are available from less than 5mm square to 200 mm and greater diameter

Linear Polarizer Principles

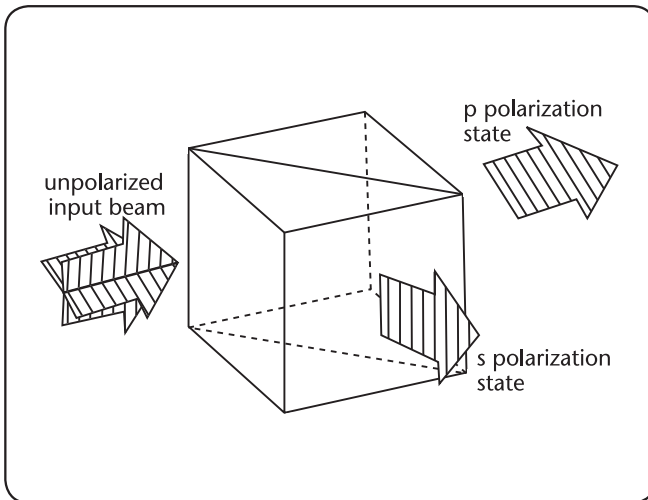


Fig. 1-2 Beamsplitting Polarizers provide two orthogonally polarized beams, conveniently separated by 90°.

Calcite Polarizers

Calcite is a naturally occurring birefringent crystal with excellent polarization properties including very high extinction ratio and transmission efficiency. Aperture sizes are limited, since large optically uniform pieces of this natural crystal are rare. Calcite material exhibits extremely broadband transmission performance, from 320 to 2300 nm. Meadowlark Optics offers Glan-Thompson calcite polarizers. Manufactured from Grade A optical calcite material, the design takes advantage of total internal reflection to separate the two polarization components. Glan-Thompson Polarizers are recommended where a wide acceptance angle is important for overall system performance. However, the version with cemented construction limits both power handling and ultraviolet performance.

Wire Grid Polarizers

VersaLight wire grid polarizers are the modern outgrowth of the 1888 experiments by Heinrich Hertz using fine metallic wires wrapped around a non-conductive frame. Instead of manually arranging an array of fine conductive wires, lithographic techniques are used to place sub 100 nm pitch aluminum conductors on glass substrates. When incident unpolarized radiation interacts with the wire grid, differences in boundary conditions drive different behavior for the two orthogonal polarizations. Electromagnetic radiation incident on the “wires” oscillate free electrons which have a much higher mobility along the wires than in the transverse dimension. Ideally, the wires behave as a perfect reflector for the parallel field and pass 100% of the transverse field. Material defects and Joule heating reduce the contrast of the polarizer, which is also strongly affected by the wavelength of the light passing through it. (Longer wavelengths are closer approximations to the ideal solution as their wavelengths become much greater than the wire grid spacing.)

Versalight polarizers are available in large aperture sizes up to 200mm diameter with high contrast across the visible and near infrared spectrum. They can handle relatively high power and are more durable when coated. Specially selected ultraviolet transmissive material is available on a custom basis. Please contact a Meadowlark Optics Sales Engineer for assistance.

Linear Polarizer Principles

Polarizer and Retarder References:

1. T. Baur and S. McClain, "Polarization Issues in Optical Design" in *Optical System Design*, edited by Robert Fischer, (SPIE press, McGraw-Hill, 2008), Chap 19.
2. J.M. Bennett, "Polarization," in *Handbook of Optics*, edited by M. Bass, (McGraw-Hill, New York, 1995), Vol. I, Chap. 5; J.A. Dobrowolski, "Optical Properties of Films and Coatings," *ibid.*, Vol. I, Chap. 42; J.M. Bennett, "Polarizers," *ibid.*, Vol. II, Chap. 3; S. Wu, "Liquid Crystals," *ibid.*, Vol. II, Chap. 14.
3. D. Clarke and J.F. Grainger, *Polarized Light and Optical Measurement*, (Pergamon Press, New York, 1971).
4. D.S. Kliger, J.W. Lewis and C.E. Randall, *Polarized Light in Optics and Spectroscopy*, (Academic Press, San Diego, Calif., 1990).
5. W.A. Shurcliff, *Polarized Light: Production and Use*, (Harvard University Press, Cambridge, Mass., 1966).
6. D.A. Holmes, "Exact Theory of Retardation Plates," *J. Opt. Soc. Am.* **54**, 1115 (1964).
7. P.D. Hale and G.W. Day, "Stability of Birefringent Linear Retarders (Waveplates)," *Appl. Opt.* **27** (24), 5146 (1988).
8. D. Malacara, *Optical Shop Testing*, (John Wiley and Sons, New York, 1978).
9. G. Love, "Wave-front Correction and Production of Zernike Modes with a Liquid-Crystal Spatial Light Modulator", *Appl. Opt.* **36** (7), 1517 (1997).

Precision Linear Polarizers



Key Benefits

- High extinction ratios
- Excellent surface quality
- Wide angular acceptance
- Low transmitted wavefront distortion
- Ultraviolet, visible, near infrared wavelengths

Extinction ratios in figures are measured against a Glan-Thompson polarizer.

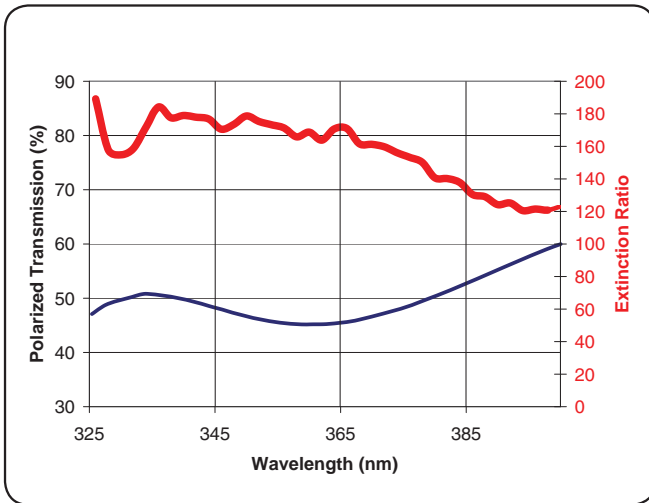


Fig. 1-3 Ultraviolet polarizer performance, specify – UV1

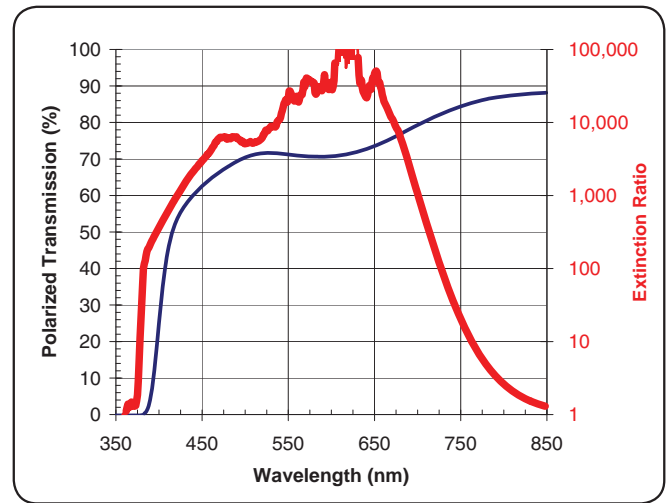


Fig. 1-4 Visible polarizer performance, specify – VIS

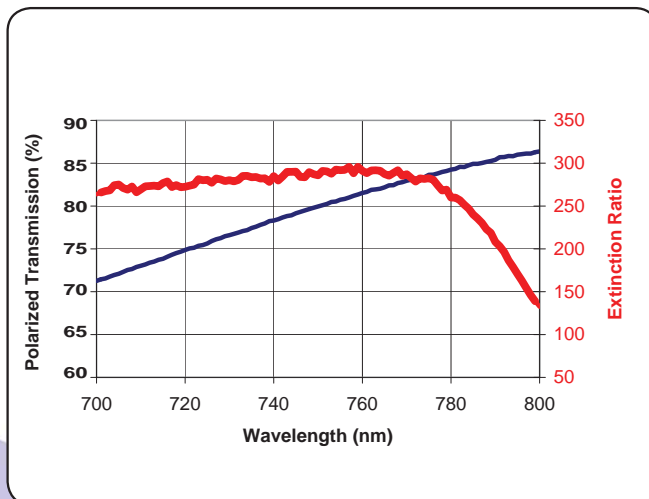


Fig. 1-5 Near infrared polarizer 1 performance, specify – NIR1

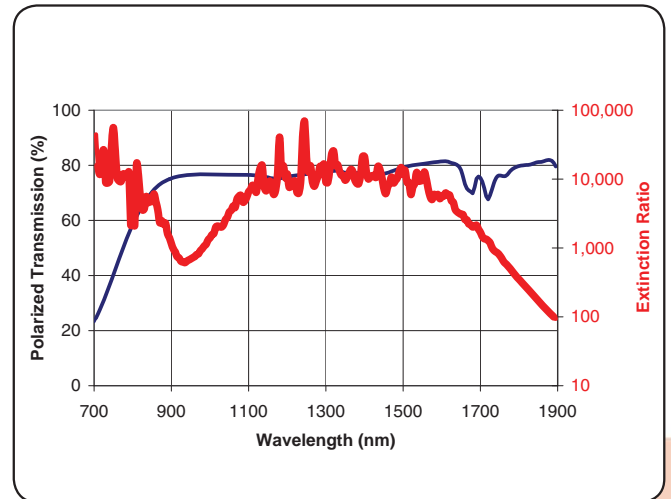


Fig. 1-6 Near infrared polarizer 2 performance, specify – NIR2

Precision Linear Polarizers

Meadowlark Optics manufactures Precision Linear Polarizers using dichroic sheet polarizer material laminated between high quality glass substrates (BK 7 material, $\lambda/10$ flat). For visible wavelength polarizers, this construction produces a total transmitted wavefront distortion of less than $\lambda/5$.

We use various polarizer materials to cover wavelengths between 320 and 2000 nm. Both visible and near infrared polarizers are supplied with a high-efficiency, broadband antireflection (AR) coating; single-layer AR coatings are optional on our ultraviolet polarizers.

Both mounted and unmounted Precision Linear Polarizers are offered as standard products. Meadowlark Optics Precision Linear Polarizers have their transmission axis clearly marked.

SPECIFICATIONS	
Polarizer Material	Dichroic Polymer
Substrate Material	
Ultraviolet	UV Grade Synthetic Fused Silica
Visible	BK 7 Grade A, fine annealed
Near Infrared	BK 7 Grade A, fine annealed
Transmitted Wavefront Distortion (at 632.8 nm)	
Ultraviolet	$\leq \lambda/2$
Visible	$\leq \lambda/5$
Near Infrared	$\leq \lambda/2$
Surface Quality	40-20 scratch and dig
Beam Deviation	
Ultraviolet	≤ 2 arc min
Visible	≤ 1 arc min
Near Infrared	≤ 2 arc min
Reflectance (per surface, at normal incidence)	
Ultraviolet	$\sim 4.25\%$ (uncoated)
Visible	$\leq 0.5\%$
Near Infrared	$\leq 0.5\%$
Diameter Tolerance	
Mounted	± 0.005 in.
Unmounted	$+0/-0.010$ in.
Thickness Tolerance	± 0.020 in.
Storage Temperature Range	
Ultraviolet	-50°C to $+50^\circ\text{C}$
Visible	-50°C to $+50^\circ\text{C}$
Near Infrared	-50°C to $+40^\circ\text{C}$
Recommended Safe Operating Limit	1 W/cm ² , CW 200 mJ/cm ² , 20 ns, visible 2 J/cm ² , 20 ns, 1064 nm
<i>Prolonged exposure to strong ultraviolet radiation may damage these polarizers.</i>	
<i>Custom coatings are available. Please contact your Meadowlark Optics sales engineer for a custom quote.</i>	

ORDERING INFORMATION			
Mounted			
Diameter (in.)	Clear Aperture (in.)	Thickness (in.)	Part Number
1.00	0.40	0.25	DPM-050-UV1
1.00	0.40	0.25	DPM-050-VIS
1.00	0.40	0.25	DPM-050-NIR1
1.00	0.40	0.25	DPM-050-NIR2-n
1.00	0.70	0.35	DPM-100-UV1
1.00	0.70	0.35	DPM-100-VIS
1.00	0.70	0.35	DPM-100-NIR1
1.00	0.70	0.35	DPM-100-NIR2-n
2.00	1.20	0.50	DPM-200-UV1
2.00	1.20	0.50	DPM-200-VIS
2.00	1.20	0.50	DPM-200-NIR1
2.00	1.20	0.50	DPM-200-NIR2-n
Unmounted			
Diameter (in.)	Clear Aperture (in.)	Thickness (in.)	Part Number
0.50	0.40	0.13	DP-050-UV1
0.50	0.40	0.13	DP-050-VIS
0.50	0.40	0.14	DP-050-NIR1
0.50	0.40	0.14	DP-050-NIR2-n
1.00	0.80	0.26	DP-100-UV1
1.00	0.80	0.26	DP-100-VIS
1.00	0.80	0.27	DP-100-NIR1
1.00	0.80	0.27	DP-100-NIR2-n
<i>Custom AR coatings are available on all polarizers.</i>			
<i>For NIR2 polarizers, please choose from the following AR coating options:</i>			
<i>NIR2 – 1 covers 650 – 950 nm</i>			
<i>NIR2 – 2 covers 900 – 1250 nm</i>			
<i>NIR2 – 3 covers 1200 – 1700 nm</i>			

High Contrast Linear Polarizers

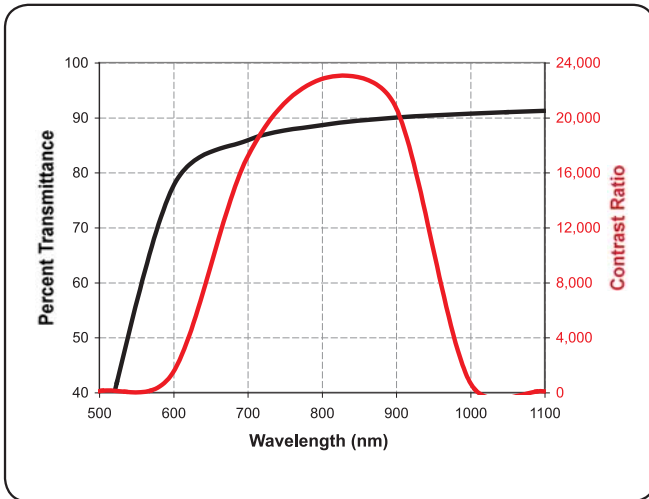


Fig. 1-7 Typical transmission for a High Contrast Linear Polarizer centered at 800 nm. Extinction ratio is measured a Glan-Thompson polarizer

Key Benefits

- High Contrast
- High Transmission
- Absorptive Dichroic Glass

In response to the need for improved contrast in the near infrared region, Meadowlark Optics now offers a line of High Contrast Linear Polarizers. These polarizers are constructed by laminating Polarcor™ dichroic glass polarizers between high quality glass substrates to achieve superior wavefront performance and surface quality.

Meadowlark Optics High Contrast Linear Polarizers offer the performance of calcite polarizers in large apertures. Contrast ratios are available as high as 10,000:1. Custom wavelength ranges from 630 to 1580 nm with 60 to 80 nm bandpasses and sizes from 10 to 25 mm are available. Please contact a Meadowlark Optics Sales Engineer to discuss your specific application.

SPECIFICATIONS

Polarizer Material	Dichroic Glass
Substrate Material	BK 7 Grade A, fine annealed
Transmitted Wavefront Distortion (at 632.8 nm)	$\leq \lambda/4$
Surface Quality	40-20 scratch and dig
Beam Deviation	≤ 3 arc min
Reflectance (per surface)	$\leq 0.5\%$ at normal incidence
Temperature Range	-50°C to $+70^{\circ}\text{C}$
Recommended Safe Operating Limit	1 W/cm ² , CW 200 mJ/cm ² , 20 ns, visible 2 J/cm ² , 20 ns, 1064 nm

Prolonged exposure to strong ultraviolet radiation may damage these polarizers.

ORDERING INFORMATION

Diameter (in.)	Clear Aperture (in.)	Thickness (in.)	Wavelength Range	Part Number
1.00	0.40	0.25	specify	PPM - 050 - λ
1.00	0.70	0.35	specify	PPM - 100 - λ

Custom sizes are available. Please contact your Meadowlark Optics sales engineer for assistance.

Ultra-High Contrast Linear Polarizers



Key Benefits

- Extremely high contrast greater than 10,000,000:1
- Unlaminated part usable to 400° C
- Wavelength ranges 340 to 5000 nm
- Absorptive Dichroic Glass

If you need extremely high contrast polarizers, then Meadowlark Optics now has the solution for you. Our UHP-UV series polarizers offer high contrast in the UV from 360 to 400 nm and our UHP-LNIR series polarizers offer high contrast over the exceptionally broad range from 650 to 5000 nm.

SPECIFICATIONS	
Polarizer Material	Dichroic Glass
Substrate Material	
Ultraviolet	Borofloat glass
Visible	D263T display float glass
Infrared	D263T display float glass
Long near-infrared	Design dependent
Transmitted Wavefront Distortion (at 632.8nm)	≤ 1λ per 10mm diameter
Surface Quality	40-20 scratch and dig
Beam Deviation	≤ 5 arc min
Reflectance (per surface)	~ 4.25% at normal incidence
Diameter Tolerance	
Mounted	±0.005 in.
Unmounted	+0/-0.010 in.
Temperature Range *	
Laminated	-20° C to +50° C
<i>Specifications above are for laminated Ultra-high contrast polarizers. For unlaminated parts, please contact your Meadowlark Optics Sales Engineer.</i>	
<i>* unlaminated parts can survive -50° C to +400° C</i>	

ORDERING INFORMATION			
Mounted			
Diameter (in.)	Clear Aperture (in.)	Thickness (in.)	Part Number
1.00	0.40	0.25	UPM - 050 - UV
1.00	0.40	0.25	UPM - 050 - VIS
1.00	0.40	0.25	UPM - 050 - IR
1.00	0.40	0.25	UPM - 050 - LNIR
1.00	0.70	0.35	UPM - 100 - UV
1.00	0.70	0.35	UPM - 100 - VIS
1.00	0.70	0.35	UPM - 100 - IR
1.00	0.70	0.35	UPM - 100 - LNIR
Unmounted			
Diameter (in.)	Clear Aperture (in.)	Thickness (in.)	Part Number
0.50	0.40	0.07	UHP - 050 - UV
0.50	0.40	0.07	UHP - 050 - VIS
0.50	0.40	0.07	UHP - 050 - IR
0.50	0.40	0.07	UHP - 050 - LNIR
1.00	0.80	0.07	UHP - 100 - UV
1.00	0.80	0.07	UHP - 100 - VIS
1.00	0.80	0.07	UHP - 100 - IR
1.00	0.80	0.07	UHP - 100 - LNIR
<i>Custom anti-reflection coating options are available. Please call your Meadowlark Optics Sales Engineer for assistance.</i>			
<i>For example:</i>			
<i>UV covers 340-410nm with R ≤ 1.0%</i>			
<i>IR-AR1 covers 450-750 nm with R ≤ 0.5%</i>			
<i>IR-AR2 covers 550-850 nm with R ≤ 0.5%</i>			
<i>IR-AR3 covers 600-1200 nm with R ≤ 0.5%</i>			
<i>IR-AR4 covers 1200-1750 nm with R ≤ 0.5%</i>			

Ultra-High Contrast Linear Polarizers

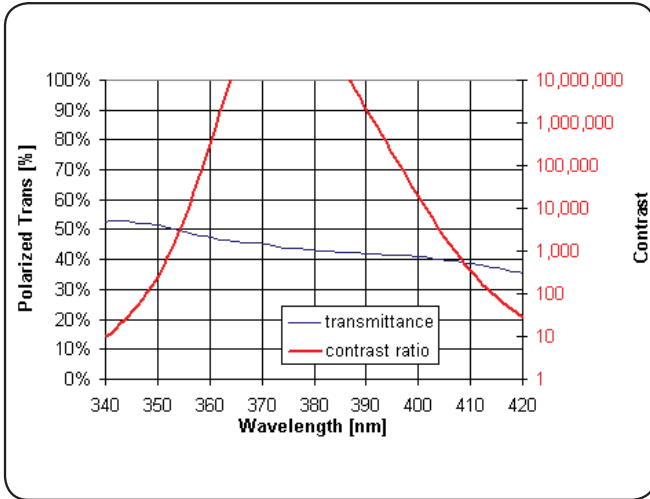


Fig. 1-8 Ultra-High Contrast UV Polarizer

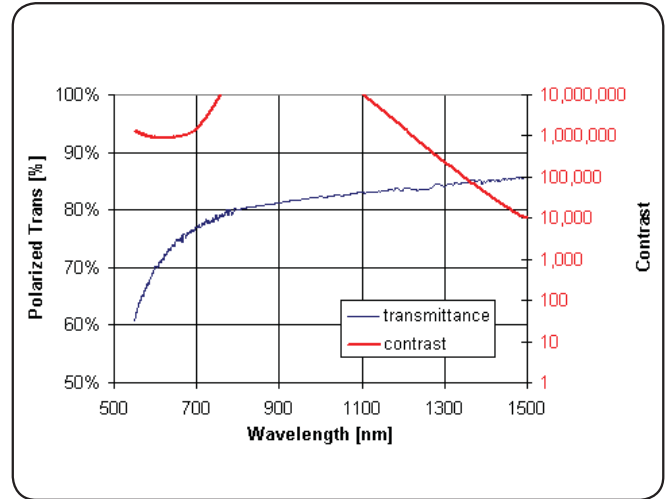


Fig. 1-9 Ultra-High Contrast VIS Polarizer

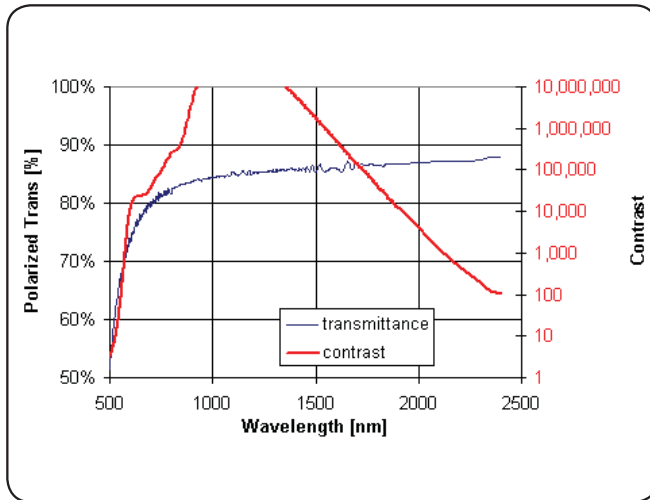


Fig. 1-10 Ultra-High Contrast IR Polarizer

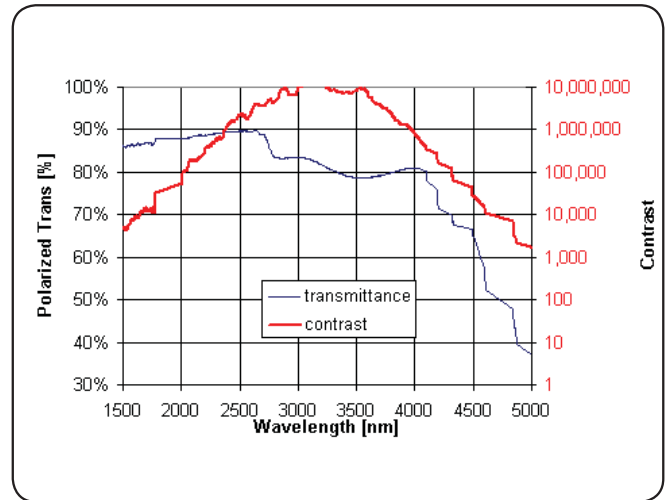
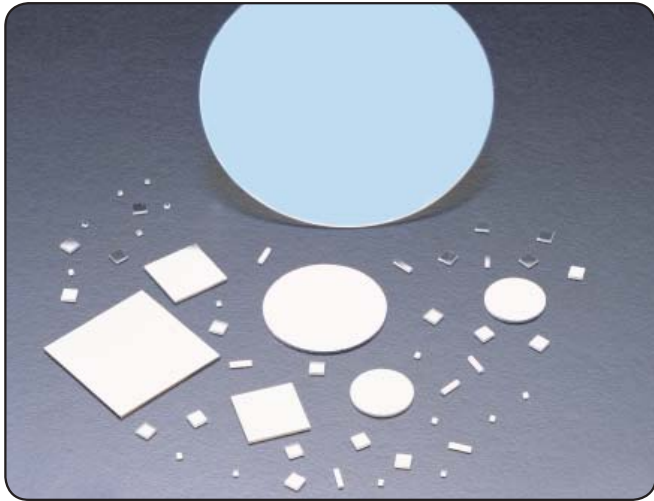


Fig. 1-11 Ultra-High Contrast LNIR Polarizer

VersaLight™ Polarizers



Key Benefits

- Broadband use
- Reflective polarizer
- Large acceptance angle

VersaLight™ is constructed of a thin layer of aluminum MicroWires® on a glass substrate and sets a new standard for applications requiring high durability, contrast and a wide field of view from the visible through infrared wavelengths, including the telecom region.

VersaLight offers the performance quality of dichroic sheet polarizers while extending the operating temperature to 200° C.

The nature of VersaLight's MicroWire construction allows it to perform as an exceptional polarizing beam splitter. In operation, VersaLight reflects one polarization state and transmits another, both with high contrast. VersaLight offers the broadest band and highest field of view of any material currently available.

VersaLight can be shaped as needed and stacked to achieve very high contrast ratios. Large aperture VersaLight Polarizers are available on a custom basis, up to 8" rounds.

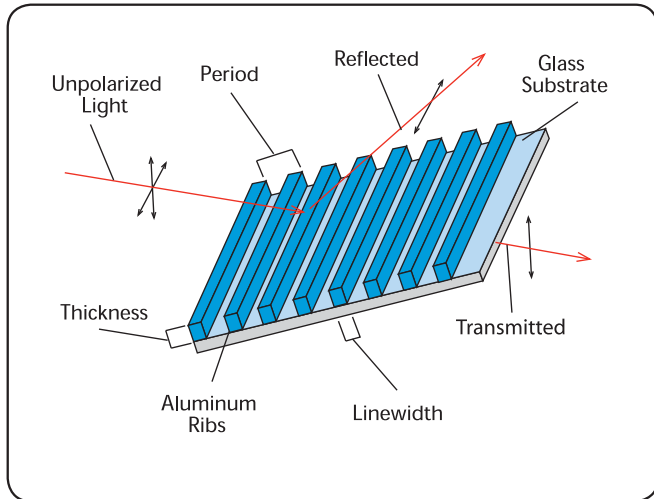


Fig. 1-12 VersaLight Polarizer construction and use

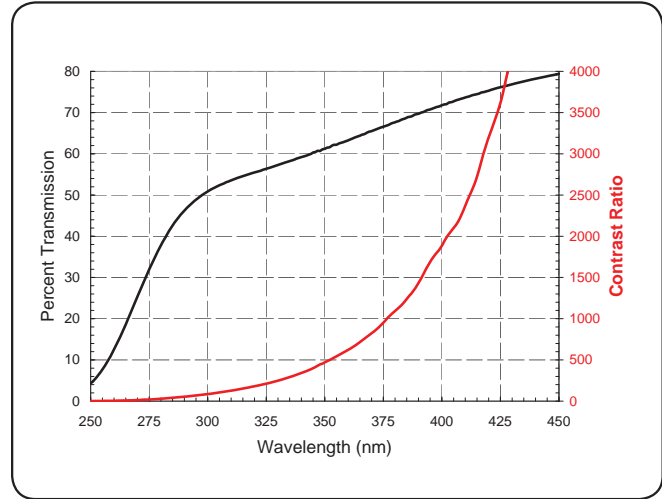


Fig. 1-13 Typical UV VersaLight Polarizer performance

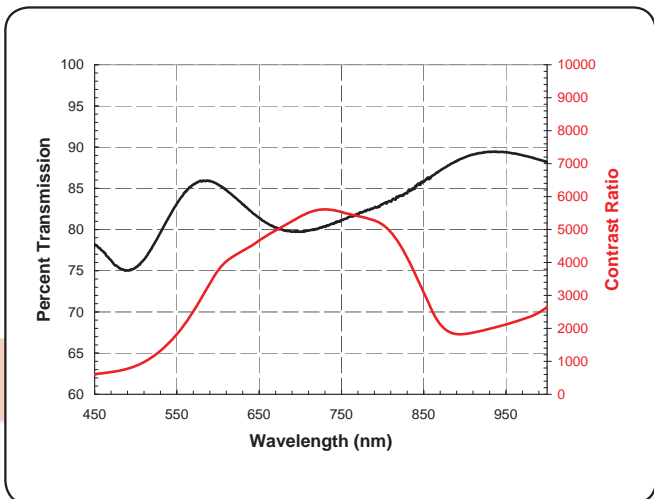


Fig. 1-14 Typical NIR VersaLight Polarizer performance

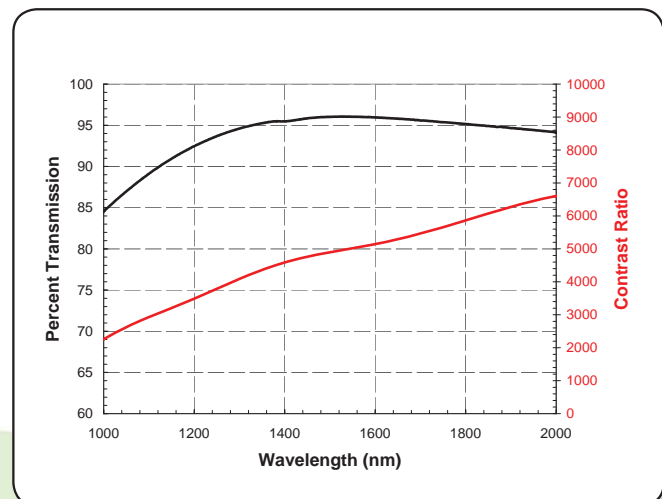


Fig. 1-15 Typical IR VersaLight Polarizer performance

VersaLight™ Polarizers

SPECIFICATIONS

Substrate Material

Ultraviolet	UV grade fused silica
Near Infrared	Precision float glass
Infrared	Precision float glass

Typical contrast in reflection > 30:1

Thickness

Ultraviolet	1.1 mm
Near Infrared	0.7 mm
Infrared	0.7 mm

Transmitted Wavefront Distortion (at 632.8 nm)

Ultraviolet	~ $\lambda/4$ per inch
Near Infrared	~ 5 λ per inch
Infrared	~ 5 λ per inch

Surface Quality 80-50 scratch and dig

Beam Deviation ≤ 1 arc min

Wavelength Range 400 nm to > 2000 nm

Maximum Temperature 200° C for single layer

Laser Damage Threshold 50 KW/cm², CW, 1540 nm

Outside Dimensions

Round	1 to 200 mm
Square	1 to 140 mm

On ultraviolet VersaLight, the wire grid surface will be unprotected, fragile and cannot be touched.

UV VersaLight is optimized for 300-450nm

NIR VersaLight is optimized for 450-1000nm

IR VersaLight is optimized for 1000-2000nm

ORDERING INFORMATION

Standard VersaLight

Dimension	AR Coating	Part Number
<i>Square</i>		
0.5 x 0.5 in.	UV	VLS-050-UV
	NIR	VLS-050-NIR
	IR	VLS-050-IR
1.0 x 1.0 in.	UV	VLS-100-UV
	NIR	VLS-100-NIR
	IR	VLS-100-IR
2.0 x 2.0 in.	UV	VLS-200-UV
	NIR	VLS-200-NIR
	IR	VLS-200-IR
<i>Round</i>		
0.5 in. diameter	UV	VLR-050-UV
	NIR	VLR-050-NIR
	IR	VLR-050-IR
1.0 in. diameter	UV	VLR-100-UV
	NIR	VLR-100-NIR
	IR	VLR-100-IR
2.0 in. diameter	UV	VLR-200-UV
	NIR	VLR-200-NIR
	IR	VLR-200-IR

Call for information on even higher contrast, doubled assemblies.

Custom sizes are available. Please contact your Meadowlark Optics sales engineer for assistance.

Laser Line Beamsplitting Polarizers



Key Benefits

- High Contrast
- Low reflectance
- High damage threshold
- Low transmitted wavefront distortion

Meadowlark Optics right angle prisms are matched in pairs to produce high quality laser line beamsplitting polarizers with superior wavefront quality in both transmission and reflection.

The hypotenuse face of one prism is coated with a multilayer dielectric beamsplitting coating optimized for laser performance. Two prisms are cemented together, protecting the critical coating from performance-degrading environmental factors.

Each cube separates an unpolarized incident beam into two orthogonal, linearly polarized components with negligible absorption. Following the principle of pile-of-plates polarizers, *p* polarized light is transmitted while *s* polarization is reflected.

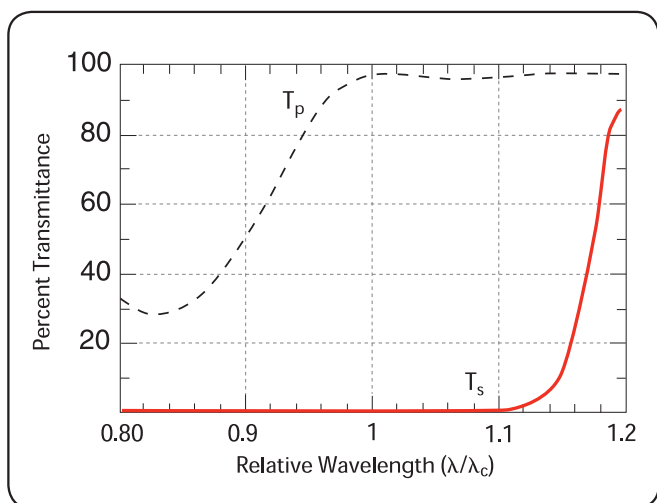


Fig. 1-16 Typical performance of a Laser Line Beamsplitting Polarizer

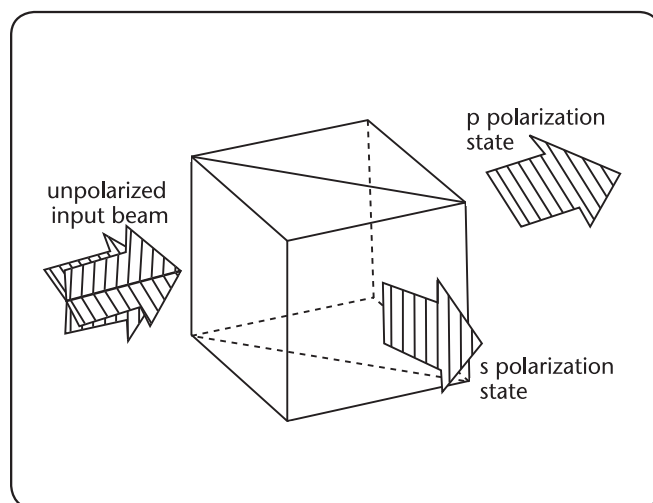


Fig. 1-17 Beamsplitting polarizers provide two orthogonally polarized beams, conveniently separated by 90°

Laser Line Beamsplitting Polarizers

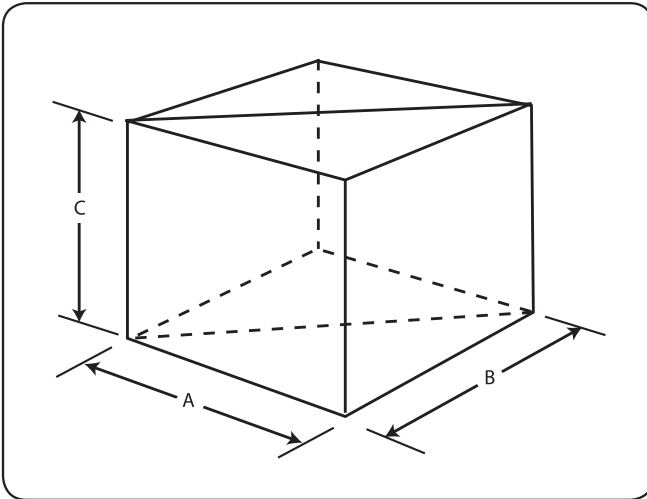


Fig. 1-18 Beamsplitting polarizers provide two orthogonally polarized beams, conveniently separated by 90°

PROBLEM

"How can I find precisely the polarization axis of a polarizer?"

SOLUTION

The polarization direction is marked on all mounted and unmounted polarizers we sell. For a more precise determination, use a laser line beamsplitting polarizer. The transmitted linear polarization direction lies precisely in the plane defined by the incident and reflected laser beams.

SPECIFICATIONS	
Material	BK 7 Grade A, fine annealed
Transmitted Wavefront Distortion (at 632.8 nm)	$\leq \lambda/5$ for p-polarized beam
Contrast Ratio	
Transmitted	$\geq 500:1$
Reflected	$\geq 20:1$
Efficiency	
p-polarized light	$\geq 95\%$ transmitted
s-polarized light	$\geq 99\%$ reflected
Clear Aperture	Central 80% diameter
Reflectance (per surface)	$\leq 0.25\%$ at normal incidence
Surface Quality	40-20 scratch and dig
Beam Deviation	
Transmitted	≤ 3 arc min
Reflected	≤ 6 arc min
Acceptance Angle	$\pm 2^\circ$
Standard Wavelengths:	532, 632.8, 670, 780, 850, 1064 and 1550 nm
Dimensional Tolerance	± 0.020 in.
Temperature Range	-40° C to $+100^\circ$ C
Recommended Safe Operating Limit	500 W/cm ² , CW 300 mJ/cm ² , 10 ns, visible 200 mJ/cm ² , 10 ns, 1064 nm

ORDERING INFORMATION

Dimensions $A = B = C$ (in.)	Part Number
0.50	BP - 050 - λ
1.00	BP - 100 - λ

Please substitute your wavelength in nanometers for λ .

Custom sizes and wavelengths, over 400-1600 nm are available. Call us for pricing on nonstandard wavelengths or sizes.

Broadband Beamsplitting Polarizers



Key Benefits

- High contrast
- Low reflectance
- Broad spectral range
- High damage threshold

For applications involving broadband or tunable wavelength sources, Meadowlark Optics presents a full line of Broadband Beamsplitting Polarizers covering the visible to near infrared region. These cubes offer increased utility for a range of polarization needs.

As with the Laser Line Beamsplitting Polarizers, two usable polarization forms result, conveniently separated by 90°. For unpolarized input, incident light will be equally split, 50% transmitted and reflected. Varying the input polarization axis will change the split ratio.

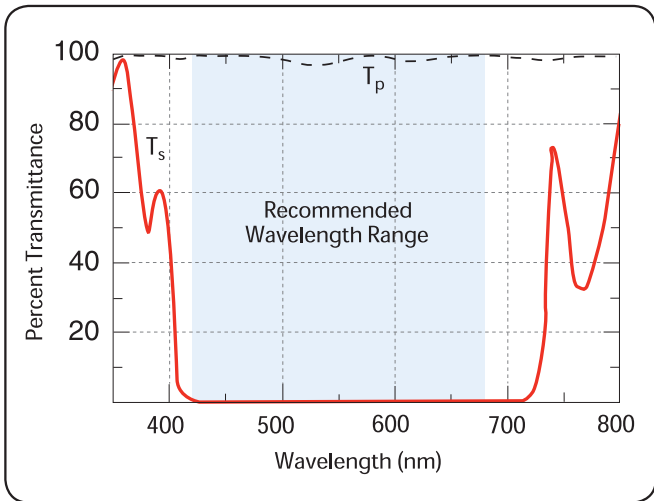


Fig. 1-19 Design Performance of Visible Broadband Beamsplitting Polarizer

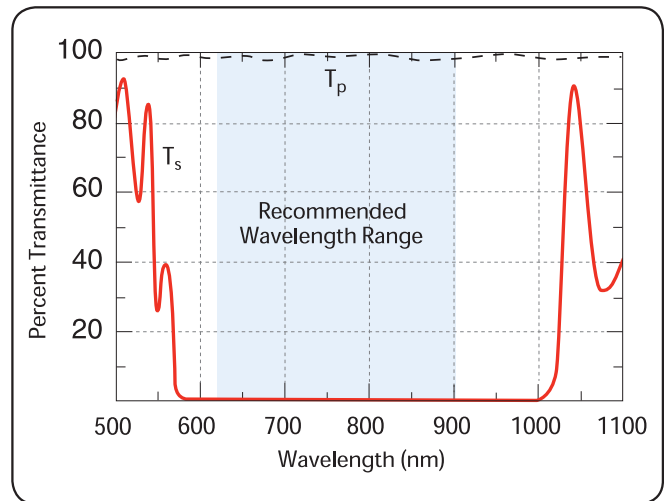


Fig. 1-20 Design Performance of IR1 Broadband Beamsplitting Polarizer

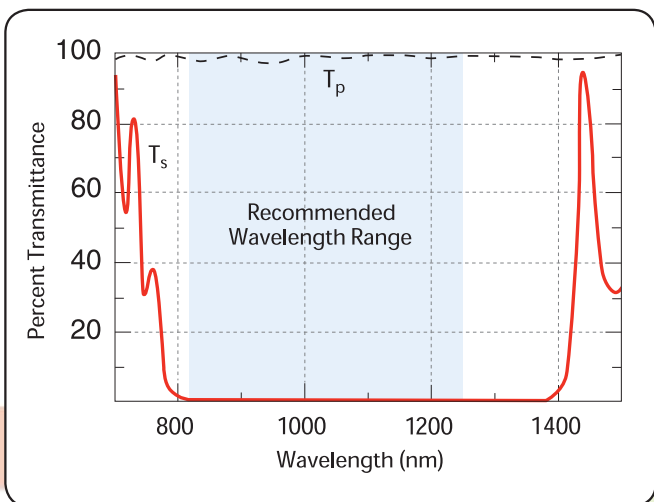


Fig. 1-21 Design Performance of IR1 Broadband Beamsplitting Polarizer

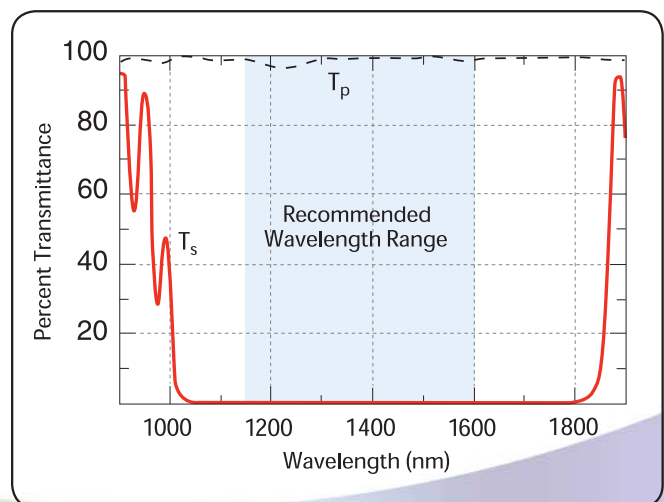


Fig. 1-22 Design Performance of IR3 Broadband Beamsplitting Polarizer

Broadband Beamsplitting Polarizers

The basic construction of this polarizer line is similar to the Laser Line Beamsplitting Polarizers previously described. Our choice of high-index glass for these polarizers aids in providing such broad usable wavelength ranges. However, these broadband designs require well-collimated input and accurate angular alignment for optimum performance.

All four entrance and exit faces are antireflection coated to minimize losses.

SPECIFICATIONS	
Material	SF 2
Transmitted Wavefront Distortion (at 632.8 nm)	$\leq \lambda/5$ for p-polarized beam
Contrast Ratio	
Transmitted	$\geq 500:1$
Reflected	$\geq 20:1$
Efficiency (average over wavelength range)	
p-polarized light	$\geq 95\%$ transmitted
s-polarized light	$\geq 98\%$ reflected
Clear Aperture	Central 80% diameter
Reflectance (per surface)	$\leq 0.5\%$ average at normal incidence
Surface Quality	40-20 scratch and dig
Beam Deviation	
Transmitted	≤ 3 arc min
Reflected	≤ 6 arc min
Acceptance Angle	$\pm 2^\circ$
Wavelength Ranges	
Visible	440-680 nm
Near IR1	620-900 nm
Near IR2	820-1250 nm
Near IR3	1150-1600 nm
Dimensional Tolerance	± 0.020 in.
Temperature Range	-40°C to $+100^\circ\text{C}$
Recommended Safe Operating Limit	500 W/cm ² , CW 300 mJ/cm ² , 10 ns, visible 200 mJ/cm ² , 10 ns, 1064 nm

ORDERING INFORMATION	
<i>Dimensions</i> <i>A = B = C (in.)</i>	<i>Part</i> <i>Number</i>
Visible (440-680 nm)	
0.50	BB - 050 - VIS
1.00	BB - 100 - VIS
Near IR1 (620-900 nm)	
0.50	BB - 050 - IR1
1.00	BB - 100 - IR1
Near IR2 (820-1250 nm)	
0.50	BB - 050 - IR2
1.00	BB - 100 - IR2
Near IR3 (1150-1600 nm)	
0.50	BB - 050 - IR3
1.00	BB - 100 - IR3
<i>Custom sizes are available. Please contact our Sales Department.</i>	

UV Optics

Key Benefits

- Wide range of UV Polarizers/Retarders
- Meadowlark quality
- Standard and Custom Options Available

Meadowlark Optics is pleased to offer several polarizer and retarder options that work in the ultraviolet region of the light spectrum. Collected on this page are some of our offerings, both standard and custom. If you require any ultraviolet polarization optics, please contact your Meadowlark Optics sales engineer for assistance

Polarizers

Currently, Meadowlark Optics has several standard and custom polarizers that work in the ultraviolet region. Our **Precision Linear Polarizer** (see page 6) is our most economical offering and works well for low power applications with wavelengths between 325 - 400 nm. Our **Ultra High Contrast Polarizer** (see page 9) allows the user to obtain contrast ratios in excess of 10,000,000:1 and is optimized for wavelengths between 350 - 410 nm. A custom option with higher transmission and slightly lower contrast ratio is also available. Ultraviolet **VersaLight** (see page 11) works below 300 nm, and can be used as both a reflective and transmissive polarizer. It has a wide acceptance angle and comes in a wide range of shapes and sizes. While it comes standard with no coatings, Meadowlark Optics can apply either broadband antireflection coating opposite the wire grid, over the Ultraviolet region or a V-coat for a specific wavelength. Uncoated **Glan - Thompson Polarizers** (see page 18) also work down to 320 nm and give excellent contrast ratios over a broad wavelength range. By using ultraviolet transmitting optical cement, Meadowlark Optics can go deeper into the ultraviolet region. Meadowlark Optics can manufacture all type of calcite polarizers to work in the ultraviolet region. Also, Meadowlark Optics can produce custom **Laser Line Beamsplitting Polarizers**. Manufactured out of UV Grade Fused Silica, these polarizers are made for common wavelengths in the ultraviolet region. Finally, **Alpha - Barium Borate** is another ultraviolet polarizer option that Meadowlark Optics is currently pursuing. Please contact your Meadowlark Optics sales engineer for assistance.

Retarders

Meadowlark Optics recently added **Compound Zero Order Quartz Retarders** to our standard product offering (see page 29). These are made out of two multiple order quartz retarders with their optic axis directions being perpendicular to each other. Specific ultraviolet wavelengths are available. Quartz retarders are excellent for applications that require consistent performance over thermal variations. We also manufacture **Multiple Order Quartz Retarders** for various wavelengths in the ultraviolet region. By using precision polishing techniques, we can provide excellent transmission, surface and transmitted wavefront quality.

For your achromatic retarder requirements, we recommend the **Bi-Crystalline Achromatic Retarder** (see page 38). These are manufactured out of crystalline quartz and magnesium fluoride. The standard ultraviolet version works to around 400 nm. Custom designs that work deeper into the ultraviolet region are available. We also manufacture **Fresnel Rhombs** that work over broad wavelength ranges, down to 250 nm. Based upon the principles of Total Internal Reflection, each reflection adds one eighth wave of retardance. Fresnel Rhombs come in quarter and half wave versions. Please contact your Meadowlark Optics sales engineer for assistance or a custom quote.

Finally, in response to you, the customer, we are investigating the manufacturing of **Liquid Crystal Devices** for use in the ultraviolet region. Please visit our website, www.meadowlark.com or contact your Meadowlark Optics sales engineer for the latest information and assistance on this or any polarization requirements you may have in the ultraviolet region.

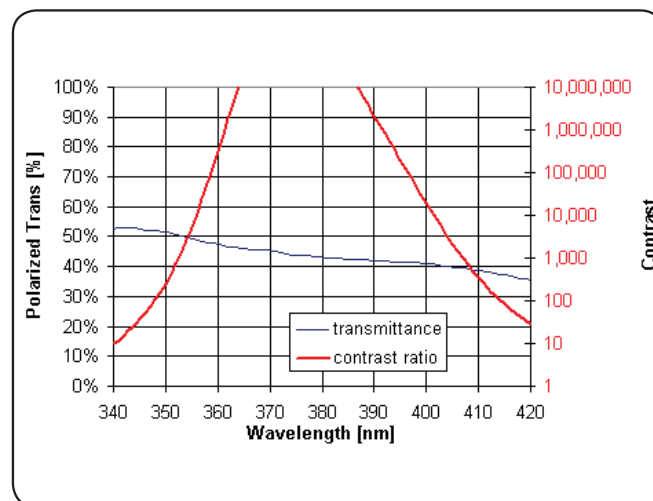


Fig. 1-23 Ultra-High Contrast UV Polarizer has excellent contrast over 350 to 410 nm

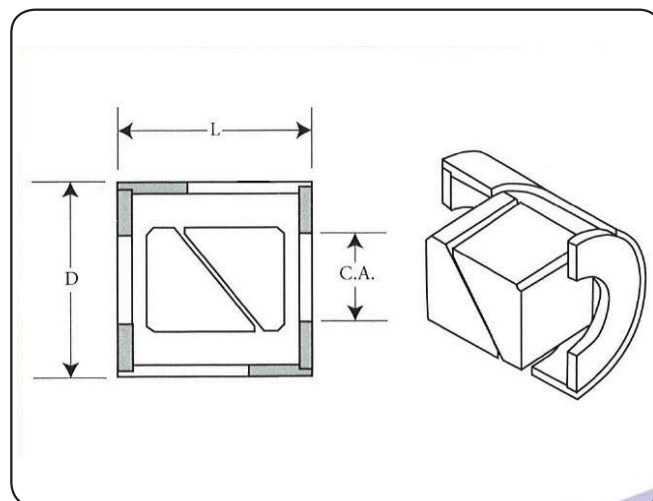


Fig. 1-24 Uncoated, air-spaced Glan-Laser Calcite Polarizers can be used from 250 to 2300 nm

Glan-Thompson Polarizers

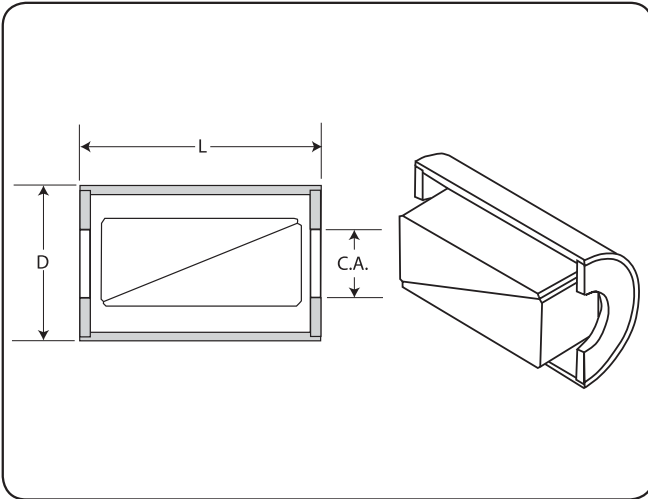
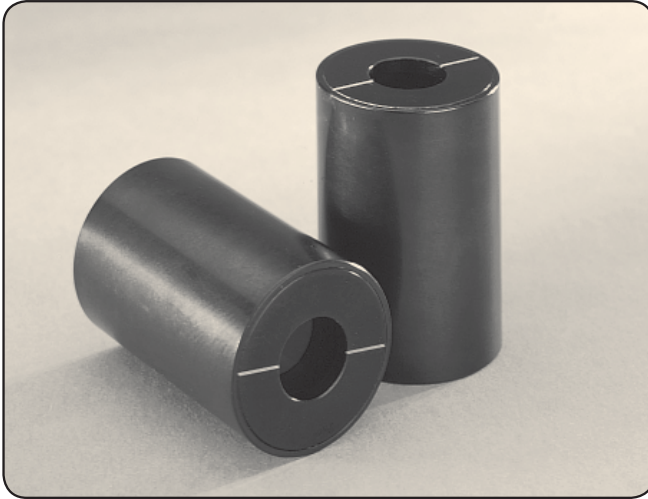


Fig. 1-24 Glan-Thompson Polarizer construction

ORDERING INFORMATION			
Clear Aperture (mm)	Wavelength Range (nm)	AR Coating	Part Number
5	320 – 2300	None	GTP – M05
5	400 – 700	MgF ₂	GTP – M05 – 0550
5	650 – 1000	MgF ₂	GTP – M05 – 0825
5	1000 – 1500	MgF ₂	GTP – M05 – 1250
8	320 – 2300	None	GTP – M08
8	400 – 700	MgF ₂	GTP – M08 – 0550
8	650 – 1000	MgF ₂	GTP – M08 – 0825
8	1000 – 1500	MgF ₂	GTP – M08 – 1250
10	320 – 2300	None	GTP – M10
10	400 – 700	MgF ₂	GTP – M10 – 0550
10	650 – 1000	MgF ₂	GTP – M10 – 0825
10	1000 – 1500	MgF ₂	GTP – M10 – 1250

Key Benefits

- Broad spectral range
- Excellent extinction ratio

Calcite is a naturally occurring birefringent crystal. By precisely controlling internal prism angles in our calcite polarizers, a very efficient linear polarizer is produced.

Meadowlark Optics offers Glan-Thompson Polarizers, intended for precision optical instrumentation and low power laser applications. Key advantages of Glan-Thompson Polarizers include excellent extinction ratio performance and a broad spectral range.

Our Glan-Thompson Polarizers are supplied in a black anodized cylindrical housing for easy mounting. Although raw calcite material transmits down to 215 nm, the cement interface limits ultraviolet transmission. For this reason, we recommend Glan-Thompson Polarizers for use over 320-2300 nm.

Three antireflection coating options cover the visible to near infrared range. Uncoated Glan-Thompson Polarizers are also available.

SPECIFICATIONS	
Material	Grade A Optical Calcite
Extinction Ratio	10,000:1 over central 2/3 of clear aperture
Reflectance (per surface, at normal incidence)	
Uncoated	~ 4.5%
Single layer MgF ₂	~ 1.5%
Beam Deviation	± 3 arc min
Acceptance Angle	± 5°
Wavelength Range	320-2300 nm
Recommended Safe Operating Limit	25-30 W/cm ² CW

Optical Isolation with Circular Polarizers



Key Benefits

- Reduce back reflection
- Beam separation
- Combines polarizer and retarder in one component

Circular Polarizers transmit either left-circular polarized light or right-circular polarized light for an input beam of any polarization state.

When circularly polarized light is reflected, its propagation direction reverses, changing left-circular polarization to right-circular polarization and vice-versa. Therefore the same polarizer that produces circular polarization of the incident beam will block the return beam.

Achievement of optical isolation using the circular polarizers described in this catalog requires that the reflection be specular and that no significant depolarization or polarization modification occur in any intervening medium between the reflector and optical isolator.

We offer circular polarizers in two basic designs, each for use in air:

- Dichroic Polarizer/Zero-Order Retarder
- Beamsplitting Polarizer/Zero-Order Retarder

Both designs take advantage of the handedness change of a circularly polarized beam upon reflection. Again, by changing the handedness of the circularly polarized beam, back reflections are blocked by the polarizer.

The degree of this blocking is commonly used to evaluate circular polarizer performance. Termed “isolation”, it can be considered similar to the extinction ratio specification of a linear polarizer.

Isolation represents the percentage of an incident beam which is blocked on its second pass through the circular polarizer. High isolation implies less light will be returned to the source.

A more detailed description of the characteristics of circularly polarized light is provided in *Polarized Light in Optics and Spectroscopy*, page 5.

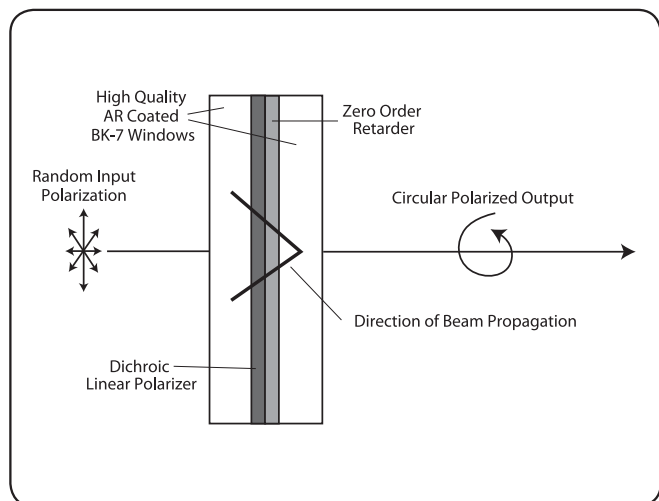


Fig. 1-25 Dichroic Circular Polarizer construction

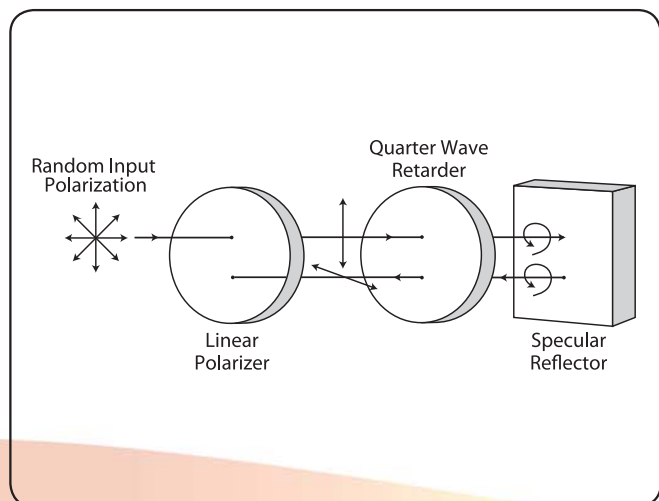


Fig. 1-26 Optical isolation using a circular polarizer

Custom sizes are available. Please contact our Sales Department.

Dichroic Circular Polarizers



SPECIFICATIONS	
Polarizer Material	Dichroic Polymer
Retarder Material	Birefringent Polymer
Substrate Material	BK 7 Grade A, fine annealed
Standard Wavelengths	532, 632.8, 670, 780, 850, 1064 and 1550 nm
Isolation	>99.8%
Transmitted Wavefront Distortion (at 632.8 nm)	
Visible	$\leq \lambda/5$
Near Infrared	$\leq \lambda/2$
Surface Quality	40-20 scratch and dig
Beam Deviation	
Visible	≤ 1 arc min
Near Infrared	≤ 2 arc min
Reflectance (per surface)	$\leq 0.5\%$ at normal incidence
Diameter Tolerance	
Mounted	± 0.005 in.
Unmounted	$+0/-0.010$ in.
Temperature Range	-20° C to $+50^{\circ}$ C
Recommended Safe Operating Limit	1 W/cm ² , CW
<i>Prolonged exposure to strong ultraviolet radiation may damage these polarizers.</i>	

Key Benefits

- High isolation
- Large diameters available
- Low transmitted wavefront distortion

Meadowlark Optics Dichroic Circular Polarizers consist of a dichroic linear polarizer and true zero-order quarter-wave retarder. Accurately aligning the retarder fast axis at 45° to the linear polarization direction ensures optimum performance.

True zero-order retarders (page 30-31) are used in the assembly of our Dichroic Circular Polarizers. Tight retardance tolerances also contribute to the final performance.

Once aligned, both polarizer and retarder materials are laminated between high quality optical flats, providing less than $\lambda/5$ transmitted wavefront distortion. Antireflection coated windows ensure surface reflection losses are minimized.

Achievement of the desired polarization effect requires proper orientation of your Dichroic Circular Polarizer. Be sure to position the indicator marking in the direction of beam propagation. For maximum transmission, rotate the circular polarizer to align a linearly polarized input beam polarization direction parallel to the marks on the housing.

Our standard Dichroic Circular Polarizers are designed for single wavelength applications. Achromatic versions are also available on a custom basis. Please call for application assistance.

ORDERING INFORMATION			
Mounted			
Diameter (in.)	Clear Aperture (in.)	Thickness (in.)	Part Number
1.00	0.40	0.25	CPM - 050 - λ
1.00	0.70	0.35	CPM - 100 - λ
2.00	1.20	0.50	CPM - 200 - λ
Unmounted			
Diameter (in.)	Clear Aperture (in.)	Thickness (in.)	Part Number
0.50	0.40	0.13	CP - 050 - λ
1.00	0.80	0.26	CP - 100 - λ

Meadowlark Optics standard Dichroic Circular Polarizers provide left-hand circular output. Please call to request a quote for right-hand circular output. Append a "-RH" to your part number for right-hand circular output.

Beam Separators

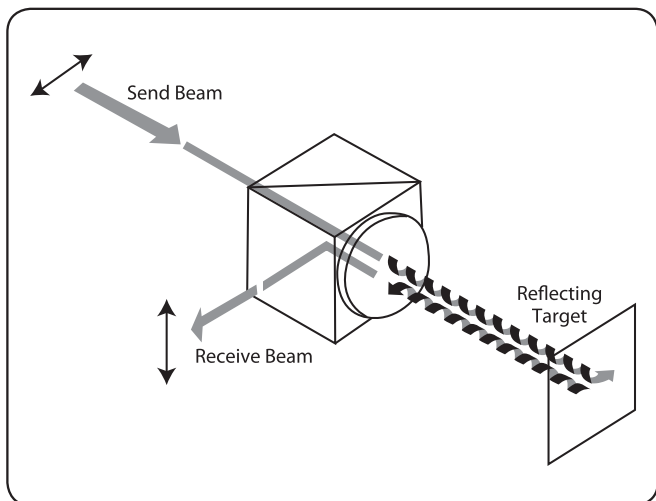


Fig. 1-27 Beam Separator function

Key Benefits

- High isolation
- Large diameters available
- Low transmitted wavefront distortion

Meadowlark Optics Beam Separators are specially designed for laser line applications. Assembly consists of a true zero-order quarter-wave retarder (page 30-31) oriented with its fast axis at 45° to the transmission axis of a Laser Line Beamsplitting Polarizer (page 13-14). The transmitted beam is circularly polarized, regardless of the input beam polarization state.

Our true zero-order Precision Retarders are one quarter-wave within $\pm \lambda/350$ waves. Aligning the fast axis to within 1° ensures greater than 99.8% source isolation from specular back reflections.

SPECIFICATIONS	
Material	BK 7 Grade A, fine annealed
Transmitted Wavefront Distortion (at 632.8 nm)	$\leq \lambda/5$
Clear Aperture	Central 80% diameter
Reflectance (per surface)	$\leq 0.5\%$ at normal incidence
Surface Quality	40-20 scratch and dig
Beam Deviation	≤ 3 arc min
Acceptance Angle	$\pm 2^\circ$
Standard Wavelengths	532, 632.8, 670, 780, 850, 1064 and 1550 nm
Dimensional Tolerance	± 0.020 in.
Temperature Range	-20° C to +50° C
Recommended Safe Operating Limit	500 W/cm ² , CW 300 mJ/cm ² , 10 ns, visible 200 mJ/cm ² , 10 ns, 1064 nm

ORDERING INFORMATION		
Cube Dimensions (in.)	Clear Aperture (in.)	Part Number
0.50	0.40	BS - 050 - λ
1.00	0.80	BS - 100 - λ

Please substitute your wavelength in nanometers for λ .

Custom sizes are available. Custom wavelengths over 400-1600 nm are available. Please contact our Sales Department to obtain a custom quote.

Polarizer Selection Chart

Linear						
Polarizer Type	Page	Product Features	Wavelength Range			
			500	1000	1500	2000
Precision Dichroic	6	<ul style="list-style-type: none"> • custom shapes and large apertures available • ultraviolet, visible, near infrared versions • most economical linear polarizer choice • limited power handling capability 				
High Contrast	8	<ul style="list-style-type: none"> • high contrast • high transmission • wavelength-specific design 				
Ultra-High Contrast	9	<ul style="list-style-type: none"> • broad spectral performance • high temperature resistance • highest available contrast ratio • excellent ultraviolet product option 				
Glan-Thompson	18	<ul style="list-style-type: none"> • excellent extinction ratio • broad spectral performance • multilayer BBAR coatings also available 				
Beamsplitting						
VersaLight	11	<ul style="list-style-type: none"> • broad spectral performance • specularly reflective operation • high power handling capability • visible and near infrared versions • up to 170 mm apertures available 				
Laser Line	13	<ul style="list-style-type: none"> • high contrast • low reflectance • high damage threshold 				
Broadband	15	<ul style="list-style-type: none"> • high contrast • high damage threshold • broad spectral performance 				
Circular						
Dichroic Circular	20	<ul style="list-style-type: none"> • high isolation • large diameters available • achromatic versions for broadband performance 				
Beam Separator	21	<ul style="list-style-type: none"> • high isolation • excellent wavefront quality • robust opto-mechanical design 				

standard products custom options

Polarizer Selection Chart

Linear				
Reflectance (maximum per surface)	Beam Deviation (maximum)	Transmitted Wavefront Distortion (maximum at 632.8 nm)	Acceptance Angle	Clear Aperture (diameter)
UV: ~4.25% VIS: 0.50% NIR: 0.50%	UV: 2 arc min VIS: 1 arc min NIR: 2 arc min	UV: $\lambda/2$ VIS: $\lambda/5$ NIR: $\lambda/2$	$\pm 10^\circ$	0.40, 0.70, 0.80, 1.20 in.
0.50%	3 arc min	$\lambda/4$	$\pm 5^\circ$	0.40, 0.70 in.
~4% (uncoated)	5 arc min	1λ per 10mm diameter	$\pm 5^\circ$	0.40, 0.70, 0.80 in.
~1.50% (coated) ~4.50% (uncoated)	3 arc min	λ	$\pm 5^\circ$	5, 8, 10 mm
Beamsplitting				
1.50%	1 arc min	UV: $\lambda/4$ per inch NIR: 5 λ per inch IR: 5 λ per inch	$\pm 45^\circ$	0.40, 0.80 in.
0.25%	Trans: 3 arc min Ref: 6 arc min	$\lambda/5$	$\pm 2^\circ$	0.40, 0.80 in.
0.50%	Trans: 3 arc min Ref: 6 arc min	$\lambda/5$	$\pm 2^\circ$	0.40, 0.80 in.
Circular				
0.50%	VIS: 1 arc min NIR: 2 arc min	VIS: $\lambda/5$ NIR: $\lambda/2$	$\pm 2^\circ$	0.40, 0.70, 0.80, 1.20 in.
0.50%	3 arc min	$\lambda/5$	$\pm 2^\circ$	0.40, 0.80 in.

Polarizer and Retarder sets available, see page 42.