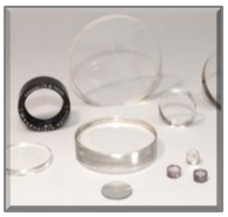
meadowlark optics

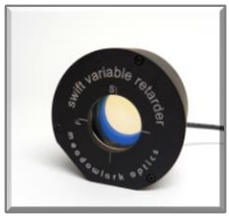
polarization solutions

SPATIAL LIGHT MODULATORS

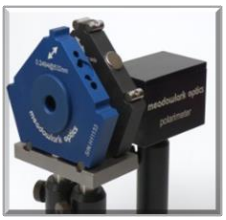


POLARIZERS

WAVEPLATES



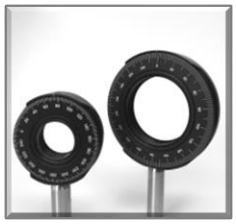
POLARIMETERS



LIQUID CRYSTAL DEVICES

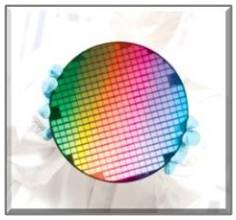
FILTERS

POCKELS CELLS



CONTRACT MANUFACTURING

CUSTOM CAPABILITIES



ENGINEERING SERVICES

We take on what others won't……. Challenge Accepted.

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Polarizers


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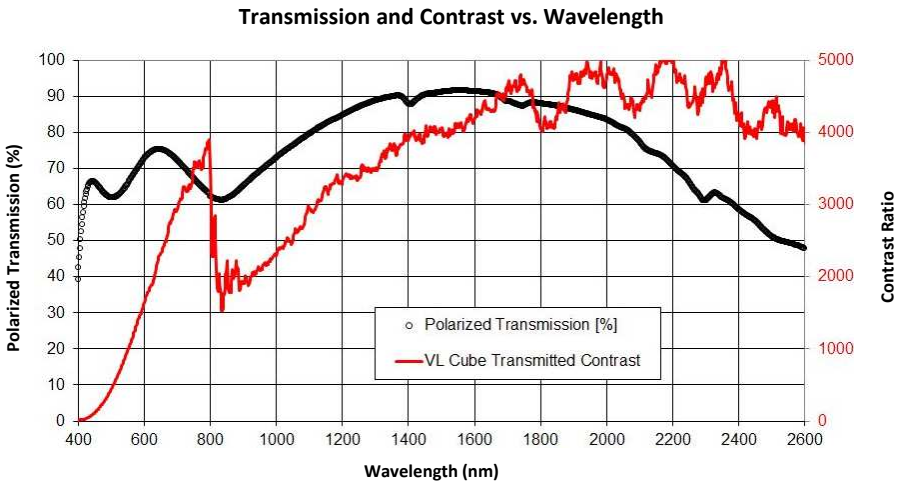
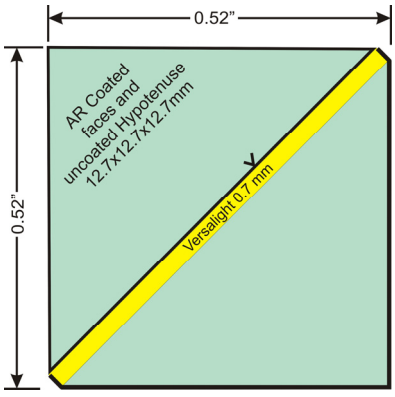
Wire Grid VersaLight™ Polarizing Beam Splitter

Meadowlark Optics presents its Versalight™ wire grid polarizing beam splitters. Manufactured for wavelength ranges between 420 and 2600 nm, this polarizer is ideal for broadband and wide field-of-view applications.

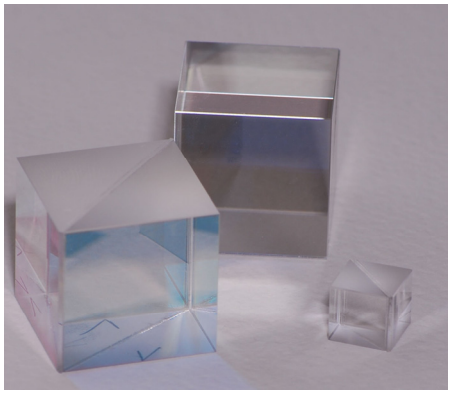
Wire grid polarizing beam splitters are manufactured out of our Versalight wire grid polarizer sandwiched between right angle prisms. No AR coatings are standard for maximum wavelength usage. Broadband AR coatings are available on the faces of the cube covering either visible (450 to 1100 nm) or IR (1000 to 2400 nm.) Please contact your Meadowlark Optics Sales Engineer for assistance with your custom needs.



Typical measured contrast ratio (red) and transmission (blue) over relevant wavelength range.



Mechanical configuration of wire grid polarizer cube. One face of wire grid is index matched to right angle prism to avoid ghost reflections.



Key Features

- 420 to 2600 nm
- Wide acceptance angle
- Excellent transmitted contrast

Polarization Suite

Linear Polarizers

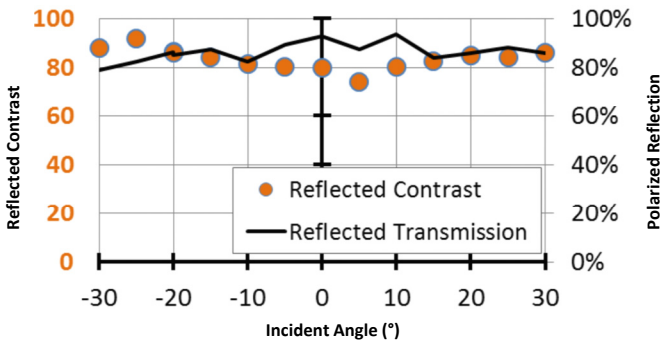
Precision Linear Polarizer
High Contrast Linear Polarizer
Ultra-High Contrast Linear Polarizer
Glan-Thompson Polarizer
Ultra Broadband Polarizer
MWIR Polarizer
Deep Ultraviolet Polarizer

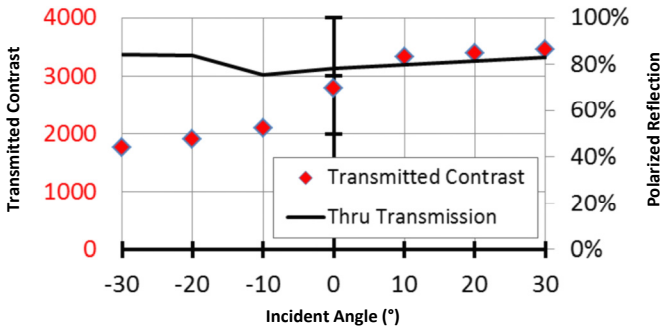
Beamsplitting Polarizers

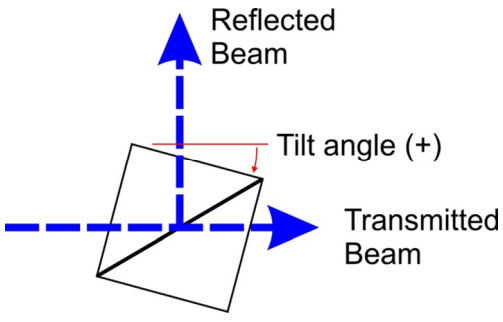
Wire Grid Versalight Polarizer
Wire Grid Versalight Beam Splitter
Laser Line Beamsplitting Polarizer
Broadband Beamsplitting Polarizer
Polarizing Bandpass Filter

Circular Polarizers

Dichroic Circular Polarizer
Beam Separator







SPECIFICATIONS

Substrate Material	N-BK7 (or equivalent)
Average Reflectivity: 450-1100 nm -VIS 1000-2400 nm -IR 420-2600 nm -UNC	< 2.0% < 2.0% ~ 4.25%
Transmitted Wavefront Distortion	≤ λ/2 (P-V @ 633 nm) ≤ λ/8 (RMS @ 633 nm)
Surface Quality	80 – 50 scratch-dig
Beam Deviation (transmittance)	≤ 5 arc min
Dimensional Tolerance	± 0.020 in.
Acceptance Angle	± 40˚
Operating Temperature	-40˚C to + 75˚C

Many options, including custom sizes and shapes are available. Please contact your Meadowlark Optics Sales Engineer for more information.

ORDERING INFORMATION

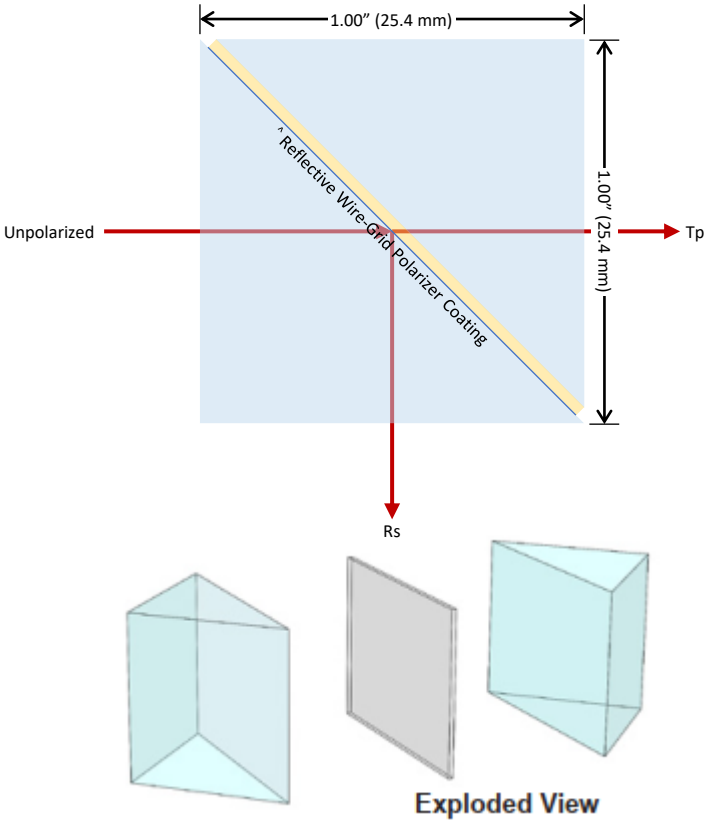
Unmounted

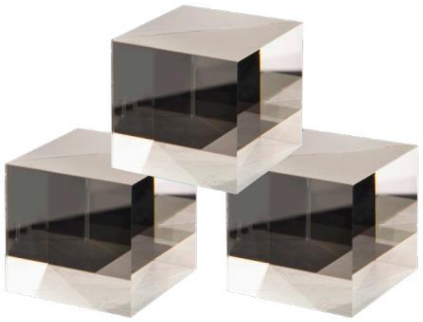
Dimension in. (mm)	***Clear Aperture in. (mm)***	***Part Number***
0.52 x 0.52 x 0.50 (13.2 x 13.2 x 12.7 mm)	0.40 (10.2 mm)	BV – 050 – VIS BV – 050 – IR BV– 050 – UNC
1.02 x 1.02 x 1.00 (25.9 x 25.9 x 25.4 mm)	0.80 (20.3 mm)	BV – 100 – VIS BV – 100 – IR BV – 100 – UNC
2.02 x 2.02 x 2.00 (51.3 x 51.3 x 50.8 mm)	1.60 (40.6 mm)	BV – 200 – VIS BV – 200 – IR BV – 200 – UNC

Wiregrid Polarizing Beam Splitter – ICE Cube

Meadowlark Optics is now the exclusive provider of the ICE Cube™ formerly offered by Moxtek. This polarizing beam splitter (PBS) cube is optimized for use over a wide range of acceptance angles while maintaining color uniformity and image contrast in the visible wavelength ranges. The ICE Cube allows compact optical designs with reduced optical paths. Engineers are now able to design smaller systems while maintaining excellent optical performance. The ICE Cube polarizer performance exceeds that for the commonly used thin film MacNeille cubes in both acceptable wavelength range and angle of incidence range while providing more than twice the contrast ratio in the transmitted beam for most wavelengths.

The ICE Cube is assembled by embedding our polarizing beam splitter plate between two AR coated glass prisms. These cubes are designed with Nanowire® grid structures centered on the hypotenuse of the ICE Cube. The ICE Cube PBS separates natural light into two main orthogonal, linearly polarized components; the p-polarized light which is transmitted while the s-polarized light is reflected at a 90˚ angle. In principle, half of the incident light is reflected, and the other half is transmitted.





Key Features

- Wide angle of incidence range
- Uniformity over wide range of angles
- High contrast and transmission over wide range of angles

Polarization Suite

Linear Polarizers

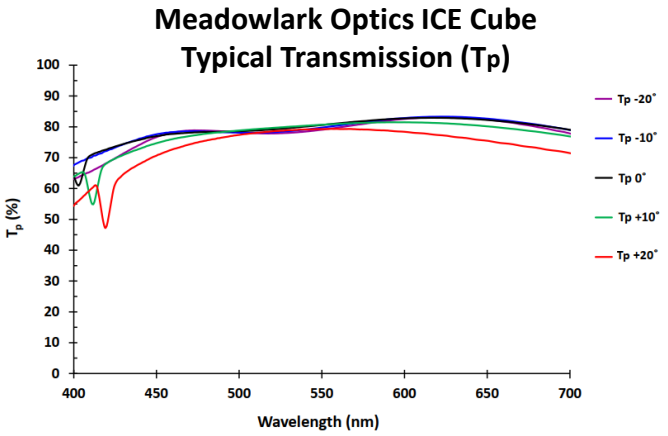
Precision Linear Polarizer
High Contrast Linear Polarizer
Ultra-High Contrast Linear Polarizer
Glan-Thompson Polarizer
Ultra Broadband Polarizer
MWIR Polarizer
Deep Ultraviolet Polarizer

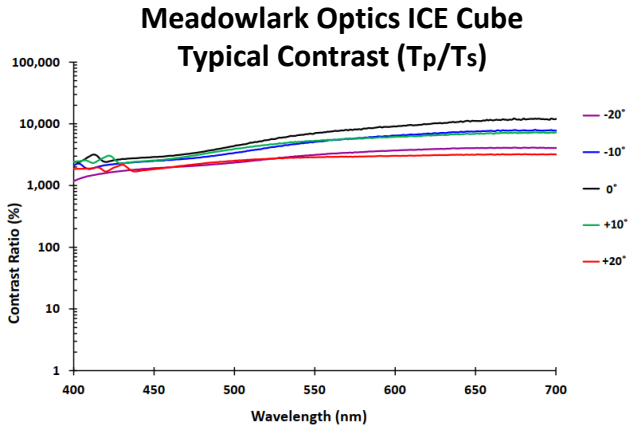
Beamsplitting Polarizers

Wire Grid Versalight Polarizer
Wire Grid Versalight Beam Splitter
Laser Line Beamsplitting Polarizer
Broadband Beamsplitting Polarizer
Polarizing Bandpass Filter

Circular Polarizers

Dichroic Circular Polarizer
Beam Separator





SPECIFICATIONS

Substrate Material	N-BK7
Operating Wavelength:	400-700 nm (typical average for azimuthal)
Average Reflectivity:	<0.5% @ 400-700 nm (4x cube faces)
Transmitted Wavefront Distortion	≤ λ/3 (Typical @ 633 nm)
Surface Quality	40 – 20 scratch-dig
Beam Deviation (transmittance)	≤ 5 arc min
Dimensional Tolerance	+ 0.0 mm/-0.25 mm
Acceptance Angle	Up to ± 25˚
Maximum Temperature	90˚C

Many options, including custom wavelengths and sizes are available. Please contact your Meadowlark Optics Solutions Engineer for more information.

ORDERING INFORMATION

Unmounted		
Dimension in. (mm)	***Clear Aperture in. (mm)***	***Part Number***
1.00 x 1.00 x 1.00 in 25.4 x 25.4 x 25.4 mm	0.90 in 22.9 mm	BV-100-ICE

Typical Angle of Incidence (AOI) Performance

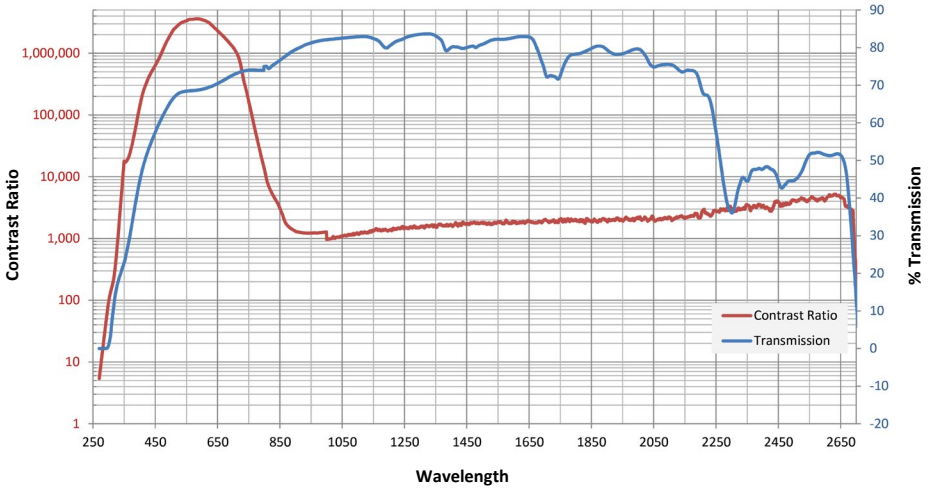
ICE Cube Typical Performance	*Angle of Incidence (AOI) Averaged 400 - 700 nm*					
	0˚	**± 5˚**	**± 10˚**	**± 15˚**	**± 20˚**	**± 25˚**
Tp %	78	78	77	76	75	73
Ts %	0.016	0.015	0.017	0.020	0.020	0.025
Rs %	84	84	84	84	84	84
Rp %	1.7	1.6	2.2	3	4.3	6
Contrast Ratio	7,100	7,100	7,100	6,700	5,600	4,100
Efficiency %	66.3	66.0	65.5	64.7	63.6	62.1

Ultra Broadband Polarizer

Meadowlark Optics now offers an extremely broadband polarizer solution with up to 1,000,000:1 contrast ratio. Our new Ultra Broadband Polarizer performs well over a wavelength range of 300 to 2700 nm, rivaling the span of a Glan-Thompson calcite polarizer in a thin, compact design.

The proprietary composition of the Ultra Broadband Polarizer allows for an unprecedented width of spectral range at a fraction of the cost of other competing polarizers. This cost savings is coupled with a mount thickness of only 0.182" and high contrast over the entire range from UV to MWIR. Its wide acceptance angle, remarkably larger possible clear aperture, and compact, light-weight design allow for versatility in complex or space-limited optical setups. Ask about Meadowlark's wide range of custom options available.

Ultra Broadband Polarizer Contrast and Transmission vs. Wavelength (nm)



Typical transmission (blue) and Contrast (red) vs. Wavelength over the useable wavelength range of an uncoated part.

Key Features

- Extremely broadband
- Wide acceptance angle
- Custom sizes and shapes
- Excellent transmitted contrast
- Thin, compact design

Polarization Suite

Linear Polarizers

Precision Linear Polarizer
High Contrast Linear Polarizer
Ultra-High Contrast Linear Polarizer
Glan-Thompson Polarizer
Ultra Broadband Polarizer
MWIR Polarizer
Deep Ultraviolet Polarizer

Beamsplitting Polarizers

Wire Grid Versalight Polarizer
Wire Grid Versalight Beam Splitter
Laser Line Beamsplitting Polarizer
Broadband Beamsplitting Polarizer
Polarizing Bandpass Filter

Circular Polarizers

Dichroic Circular Polarizer
Beam Separator

SPECIFICATIONS

Stock Version	
Substrate Material	UV Grade Fused Silica
Wavelength Range	300 – 2700 nm (uncoated)
Transmitted Wavefront Distortion *(Custom options available for improvement of TWD)*	≤ 3.5 λ per inch (P-V @ 633 nm) ≤ 1 λ per inch (RMS @ 633 nm)
Acceptance Angle	± 40˚
Surface Quality	80 – 50 scratch-dig
Laser Damage Threshold *(if oriented in preferred direction)*	0.80 J/cm^2 at 355 nm 0.20 J/cm^2 at 532 nm 0.30 J/cm^2 at 1064 nm
Operating Temperature	-50˚C to + 50˚C
Polarizer Thickness	~0.087 in.
Mount Thickness	0.182 in.
Custom Options	
Size	0.5” – 4.0”
Shape	Customer specified

AR Coatings available. Please contact your Meadowlark Optics Sales Engineer for more information.

ORDERING INFORMATION

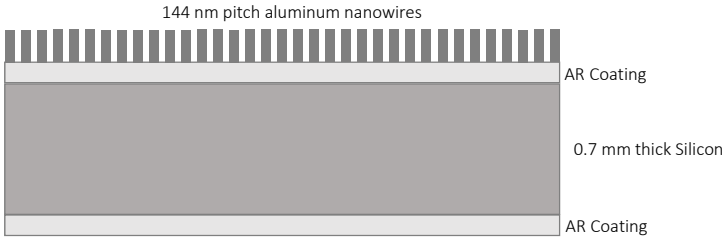
Diameter in. (mm)	***Clear Aperture in. (mm)***	***Part Number***
Ø1.00 (25.4 mm)	Ø0.75 (19.3 mm)	GPM – 100 – UNC
Ø1.50 (38.1 mm)	Ø1.25 (32.0 mm)	GPM – 150 – UNC
Ø2.00 (50.8 mm)	Ø1.75 (44.7 mm)	GPM – 200 – UNC

The standard sizes and specifications listed are only our most typically manufactured with many custom possibilities available.

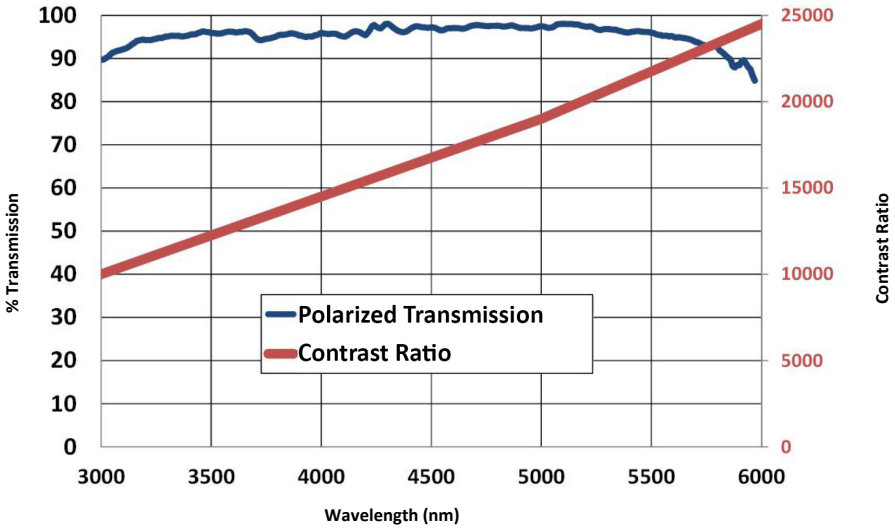
MWIR Polarizer

This polarizer is a wire grid on an antireflection coated silicon substrate optimized for 3 to 6 microns. The ring mounting provides for ease of handling and has the polarization transmission direction marked. The wire grid surface is quite delicate and should only be cleaned non-mechanically. Standard outer diameters are one and two inch but custom sizes, shapes and unmounted polarizers are also available.

Cross section of MWIR Polarizer



Transmission and Contrast vs. Wavelength



Typical measured contrast ratio (red) and transmission (blue) over relevant wavelength range.

Key Features

- Excellent contrast ratio
- Thin profile
- High transmission
- Custom apertures > 2 inches available

Polarization Suite

Linear Polarizers

Precision Linear Polarizer
High Contrast Linear Polarizer
Ultra-High Contrast Linear Polarizer
Glan-Thompson Polarizer
Ultra Broadband Polarizer
MWIR Polarizer
Deep Ultraviolet Polarizer

Beamsplitting Polarizers

Wire Grid Versalight Polarizer
Wire Grid Versalight Beam Splitter
Laser Line Beamsplitting Polarizer
Broadband Beamsplitting Polarizer
Polarizing Bandpass Filter

Circular Polarizers

Dichroic Circular Polarizer
Beam Separator

SPECIFICATIONS	
Substrate Material	Silicon, 0.7 mm thick
Coating	Double side AR
Wavelength Range	3 µm to 6 µm
Contrast Ratio	See graph
Acceptance Angle	≤ 20˚
Transmitted Wavefront Distortion (per inch)	≤ 1.5λ (P-V at 4µm) ≤ λ/3 (RMS at 4µm)
Beam Deviation	≤ 2 arc min
Maximum Aperture	Up to 4 inches circular
Surface Quality	80 – 50 scratch-dig

ORDERING INFORMATION			
Diameter in. (mm)	***Clear Aperture in. (mm)***	***Thickness in. (mm)***	***Mounted Part Number***
Ø1.00 (25.4 mm)	Ø0.76 (19.3 mm)	0.182 (4.62 mm)	MPM – 100
Ø2.00 (50.8 mm)	Ø1.76 (44.7 mm)	0.182 (4.62 mm)	MPM – 200

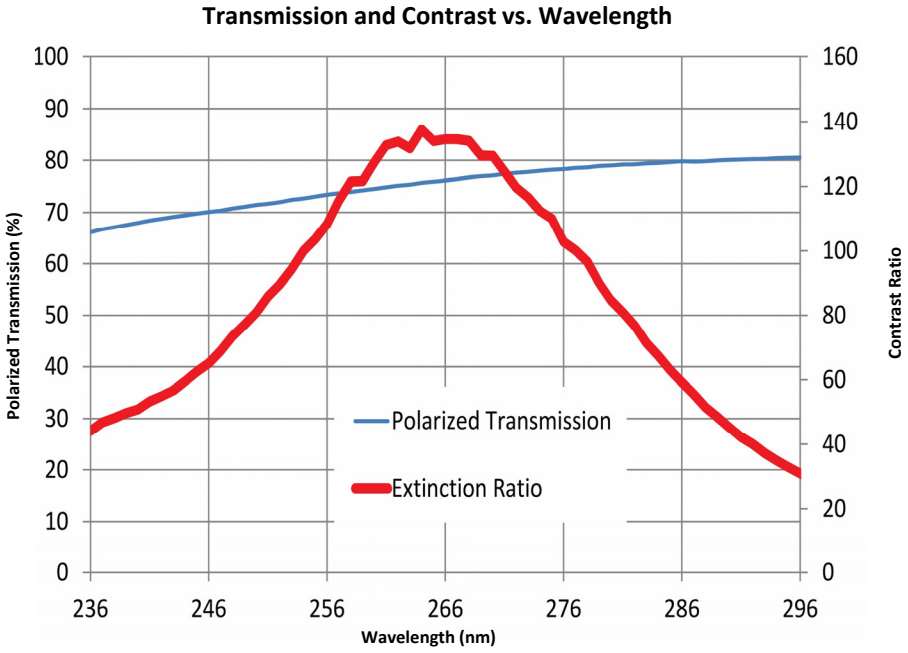
Deep Ultraviolet Polarizer

Meadowlark Optics is pleased to offer several polarizer and retarder options that work in the ultraviolet region of the light spectrum.

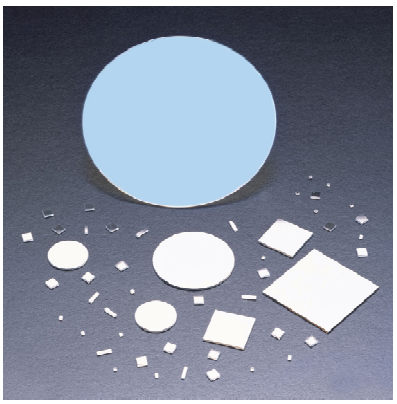
Developed for wavelengths between 245 and 285 nm, the Deep Ultraviolet Polarizer is ideal for applications around 266 nm. Additionally, this polarizer is transparent in the visible range, allowing visible light to easily pass through.

The UV Polarizer has a proprietary structure that allows for a high laser damage threshold. A few of the applications where DUV polarizers are used include: DUV lithography and metrology, UV laser optics, semiconductor wafer processing, surface polarimetry, astronomical polarimetry, and liquid crystal photo alignment.

Custom shapes and sizes are possible due to the large manufactured substrates. Please contact your Meadowlark Optics Sales Engineer for assistance with your custom needs.



Typical measured contrast (red) and transmission (blue) over relevant wavelength range.



Key Features

• • •

245 to 285 nm

Wire grid polarizer

High damage threshold

Transmission of > 60%

Contrast Ratio up to 150:1

Polarization Suite

• • •

Linear Polarizers

Precision Linear Polarizer

High Contrast Linear Polarizer

Ultra-High Contrast Linear Polarizer

Glan-Thompson Polarizer

Ultra Broadband Polarizer

MWIR Polarizer

Deep Ultraviolet Polarizer

Beamsplitting Polarizers

Wire Grid Versalight Polarizer

Wire Grid Versalight Beam Splitter

Laser Line Beamsplitting Polarizer

Broadband Beamsplitting Polarizer

Polarizing Bandpass Filter

Circular Polarizers

Dichroic Circular Polarizer

Beam Separator

SPECIFICATIONS

Substrate Material	Fused Silica, 1.0 mm thick
Wavelength Range	245 – 285 nm
Transmitted Wavefront Distortion	≤ λ/2 (P-V @ 633 nm) ≤ λ/8 (RMS @ 633 nm)
Surface Quality	40 – 20 scratch-dig
Beam Deviation	≤ 5 arc min
Acceptance Angle	0˚ ± 6˚
Operating Temperature	- 40˚C to + 80˚C

Customs sizes and shapes are available.
Please contact your Meadowlark Optics Sales Engineer for more information.

ORDERING INFORMATION

Mounted Square		
Dimensions in. (mm)	***Clear Aperture in. (mm)***	***Square Part Number***
Up to 2.00 (50.8 mm)	Up to 1.20 (30.5 mm)	DUV – 050 – 0266S
Unmounted Square		
0.50 (12.7 mm)	0.40 (20.3 mm)	DUV – 100 – 0266S
1.00 (50.8 mm)	0.80 (20.3 mm)	DUV – 100 – 0266S
2.00 (50.8 mm)	1.60 (40.6 mm)	DUV – 200 – 0266S
Unmounted Round		
2.00 (50.8 mm)	1.60 (40.6 mm)	DUV – 200 – 0266

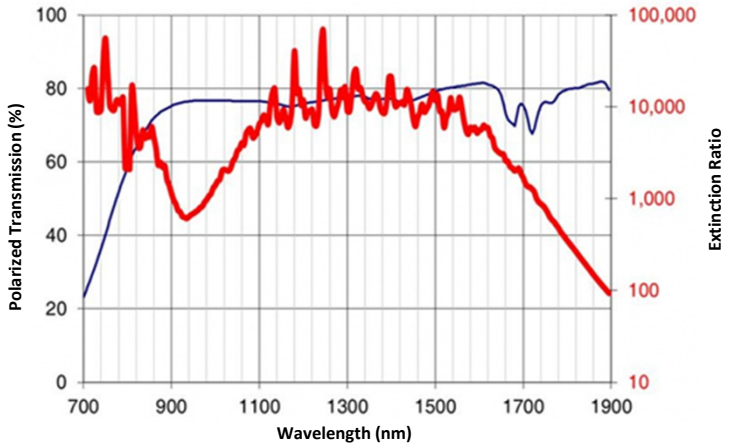
Precision Linear Polarizer

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

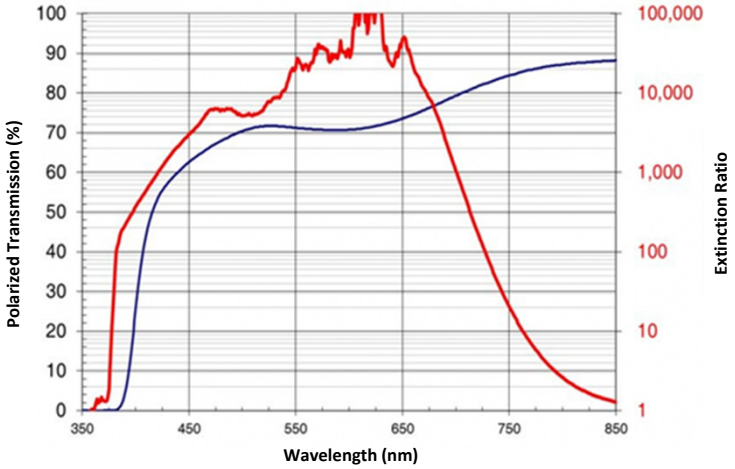
We use various polarizer materials to cover wavelengths between 320 and 2000 nm. Both visible and near infrared polarizers are supplied with a high-efficiency, broadband antireflection (AR) coating; single-layer AR coatings are optional on our ultraviolet polarizers.

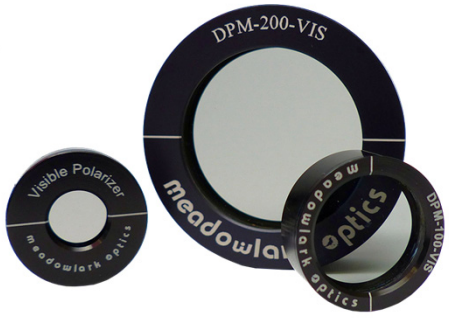
Both mounted and unmounted Precision Linear Polarizers are offered as standard products. Meadowlark Optics Precision Linear Polarizers have their transmission axis clearly marked.

NIR polarizer 2 performance, specify – NIR2



Visible polarizer performance, specify - VIS





Key Features

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

Polarization Suite

Linear Polarizers

Precision Linear Polarizer
High Contrast Linear Polarizer
Ultra-High Contrast Linear Polarizer
Glan-Thompson Polarizer
Ultra Broadband Polarizer
MWIR Polarizer
Deep Ultraviolet Polarizer

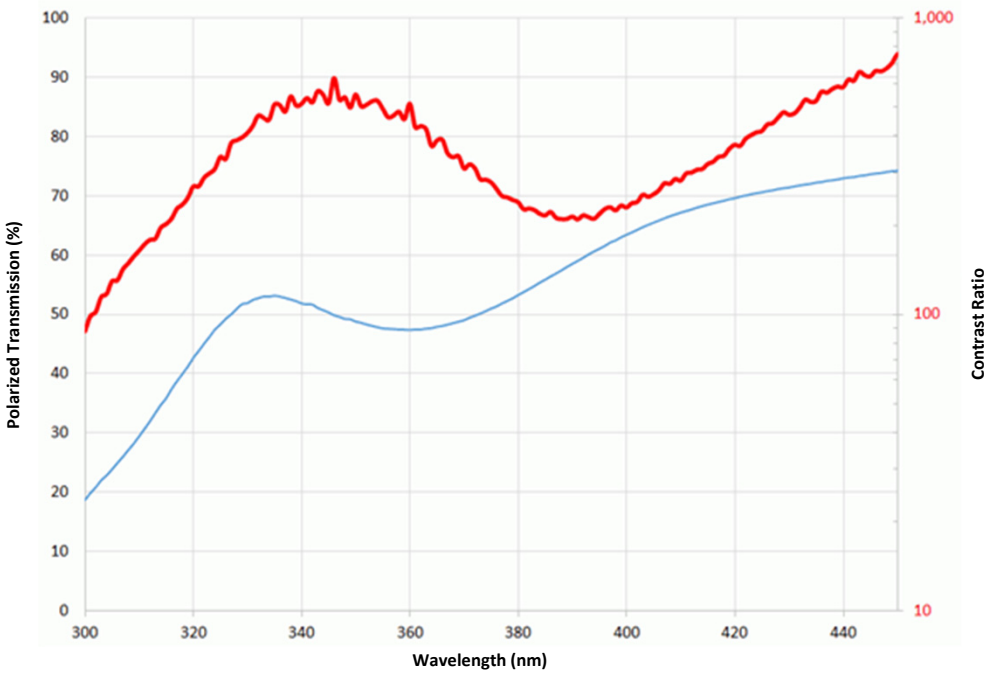
Beamsplitting Polarizers

Versalight Polarizer
Wire Grid Beam Splitter
Laser Line Beamsplitting Polarizer
Broadband Beamsplitting Polarizer
Polarizing Bandpass Filter

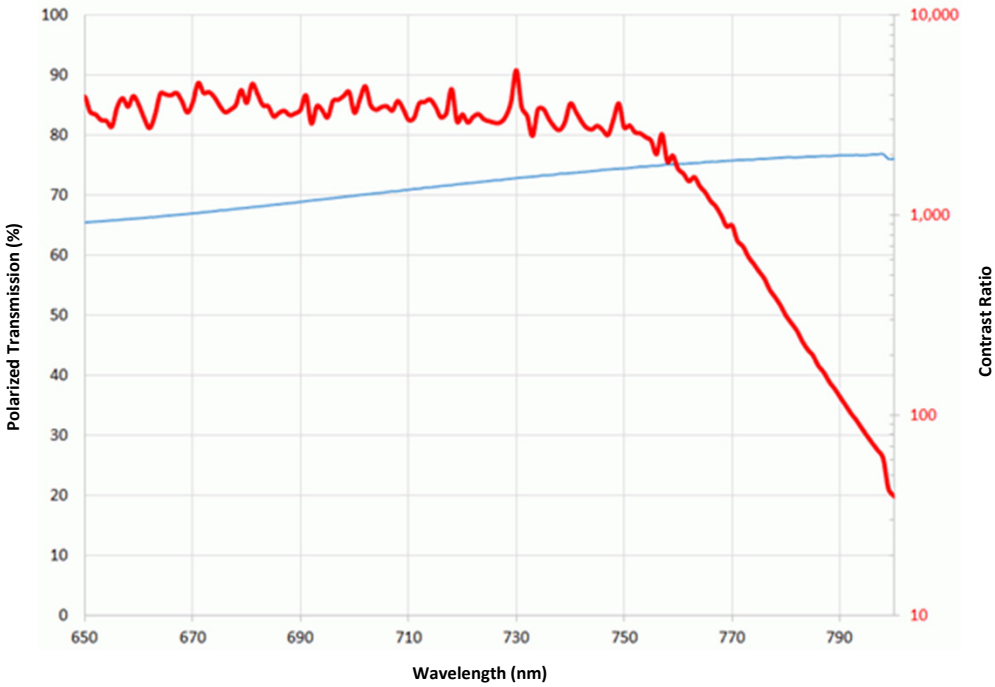
Circular Polarizers

Dichroic Circular Polarizer
Beam Separator

UV polarizer performance, specify – UV1 (uncoated window)



NIR polarizer 1 performance, specify – NIR1



ORDERING INFORMATION

Mounted			
Clear Aperture in. (mm)	***Thickness ± 0.020 in. (±0.51 mm)***	***Diameter ± 0.005 in. (± 0.13 mm)***	***Part Number***
0.40 (10.2 mm)	0.25 (6.35 mm)	Ø1.00 (Ø25.4 mm)	DPM – 050 – UV1
0.40 (10.2 mm)	0.25 (6.35 mm)	Ø1.00 (Ø25.4 mm)	DPM – 050 – VIS
0.40 (10.2 mm)	0.25 (6.35 mm)	Ø1.00 (Ø25.4 mm)	DPM – 050 – NIR1
0.40 (10.2 mm)	0.25 (6.35 mm)	Ø1.00 (Ø25.4 mm)	DPM – 050 – NIR2 – n
0.70 (17.8 mm)	0.35 (8.9 mm)	Ø1.00 (Ø25.4 mm)	DPM – 100 – UV1
0.70 (17.8 mm)	0.35 (8.9 mm)	Ø1.00 (Ø25.4 mm)	DPM – 100 – VIS
0.70 (17.8 mm)	0.35 (8.9 mm)	Ø1.00 (Ø25.4 mm)	DPM – 100 – NIR1
0.70 (17.8 mm)	0.35 (8.9 mm)	Ø1.00 (Ø25.4 mm)	DPM – 100 – NIR2 – n
1.20 (30.5 mm)	0.50 (12.7 mm)	Ø2.00 (Ø50.8 mm)	DPM – 200 – UV1
1.20 (30.5 mm)	0.50 (12.7 mm)	Ø2.00 (Ø50.8 mm)	DPM – 200 – VIS
1.20 (30.5 mm)	0.50 (12.7 mm)	Ø2.00 (Ø50.8 mm)	DPM – 200 – NIR1
1.20 (30.5 mm)	0.50 (12.7 mm)	Ø2.00 (Ø50.8 mm)	DPM – 200 – NIR2 – n
Unmounted			
Clear Aperture in. (mm)	***Thickness ± 0.020 in. (±0.51 mm)***	***Diameter +0/-0.010 in (+0/-0.25mm)***	***Part Number***
0.40 (10.2 mm)	0.13 (3.3 mm)	Ø0.50 (Ø12.7 mm)	DP – 050 – UV1
0.40 (10.2 mm)	0.13 (3.3 mm)	Ø0.50 (Ø12.7 mm)	DP – 050 – VIS
0.40 (10.2 mm)	0.14 (3.6 mm)	Ø0.50 (Ø12.7 mm)	DP – 050 – NIR1
0.40 (10.2 mm)	0.14 (3.6 mm)	Ø0.50 (Ø12.7 mm)	DP – 050 – NIR2 – n
0.80 (20.3 mm)	0.26 (6.6 mm)	Ø1.00 (Ø25.4 mm)	DP – 100 – UV1
0.80 (20.3 mm)	0.26 (6.6 mm)	Ø1.00 (Ø25.4 mm)	DP – 100 – VIS
0.80 (20.3 mm)	0.27 (6.9 mm)	Ø1.00 (Ø25.4 mm)	DP – 100 – NIR1
0.80 (20.3 mm)	0.27 (6.9 mm)	Ø1.00 (Ø25.4 mm)	DP – 100 – NIR2 – n

Custom AR coatings are available on all polarizers.

For NIR2 polarizers, choose from the following AR coatings:

NIR2 - 1 covers 650 - 950 nm
NIR2 - 2 covers 900 - 1250 nm
NIR2 - 3 covers 1200 - 1700 nm

SPECIFICATIONS

Substrate Material	
Ultraviolet Visible Near Infrared	UV Grade Fused Silica N-BK7 N-BK7
Polarizer Material	Dichroic Polymer
Transmitted Wavefront Distortion (P-V @ 632.8 nm)	
Ultraviolet Visible Near Infrared	≤ λ/2 ≤ λ/5 ≤ λ/2
Surface Quality	40 – 20 scratch-dig
Beam Deviation	
Ultraviolet Visible Near Infrared	≤ 2 arc-min ≤ 1arc-min ≤ 2 arc-min
Reflectance (per surface, at normal incidence)	
Ultraviolet Visible Near Infrared	~4.25% (uncoated) ≤ 0.5% ≤ 0.5%
Storage Temperature	
Ultraviolet Visible Near Infrared	-50˚C to + 50˚C -50˚C to + 50˚C -50˚C to + 50˚C
Operating Temperature	
Ultraviolet Visible Near Infrared	-50˚C to + 50˚C -50˚C to + 50˚C -50˚C to + 50˚C
Laser Damage Threshold	1W/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.

Custom coatings are available. Please contact your Meadowlark Optics sales engineer for a custom quote.

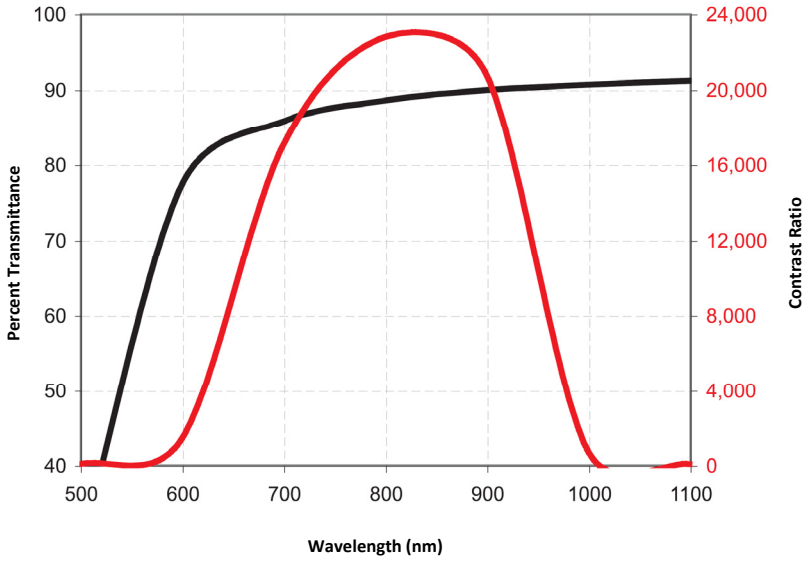
High Contrast Linear Polarizer

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 improved 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.

Typical transmission for a High Contrast Linear Polarizer centered at 800 nm



Extinction ratio is measured with a Glan-Thompson polarizer.

Key Features

- Very high contrast
- High transmission
- Absorptive dichroic glass

Polarization Suite

Linear Polarizers

Precision Linear Polarizer
High Contrast Linear Polarizer
Ultra-High Contrast Linear Polarizer
Glan-Thompson Polarizer
Ultra Broadband Polarizer
MWIR Polarizer
Deep Ultraviolet Polarizer

Beamsplitting Polarizers

Versalight Polarizer
Wire Grid Beam Splitter
Laser Line Beamsplitting Polarizer
Broadband Beamsplitting Polarizer
Polarizing Bandpass Filter

Circular Polarizers

Dichroic Circular Polarizer
Beam Separator

SPECIFICATIONS	
Polarizer Material	Dichroic Glass
Substrate Material	BK 7 Grade A, fine annealed
Transmitt ed Wavefront Distortion (at 632.8 nm)	≤ λ/4
Surface Quality	40 – 20 scratch-dig
Beam Deviation	≤ 3 arc min
Reflectance (per surface)	≤ 0.5% at normal incidence
Temperature Range	-50˚C to +70˚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. (mm)	***Clear Aperture in. (mm)***	***Thickness in. (mm)***	***Wavelength Range***	***Part Number***
1.00 (25.4 mm)	0.40 (10.16 mm)	0.25 (6.35 mm)	Please specify	PPM – 050 – λ
1.00 (25.4 mm)	0.70 (17.78 mm)	0.35 (8.89 mm)	Please specify	PPM – 100 – λ

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

Ultra-High Contrast Linear Polarizer

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		
Substrate Material		
Ultraviolet Visible Infrared SWIR / MWIR		UV Grade Fused Silica N-BK7 N-BK7 Design dependent
Polarizer Material		
Ultraviolet Visible Infrared SWIR / MWIR		Dichroic Glass
Transmitted Wavefront Distortion (P-V @ 632.8 nm)		
Ultraviolet Visible Infrared SWIR / MWIR		≤ 1λ per Ø10 mm ≤ 1λ per Ø10 mm ≤ 1λ per Ø10 mm Design Dependent
Surface Quality		
Ultraviolet Visible Infrared SWIR / MWIR		40 – 20 scratch-dig
Contrast Ratio		
Ultraviolet:	362 – 392 nm 360 – 397 nm 357 – 403 nm	> 100,000:1 > 10,000:1 > 1,000:1
Visible:	600 – 1,200 nm 550 – 1,500 nm	> 100,000:1 > 1,000:1
Infrared:	850 – 1,600 nm 750 – 1,800 nm 650 – 2,000 nm	> 100,000:1 > 10,000:1 > 1,000:1
SWIR / MWIR:	2,000 – 4,500 nm 1,500 – 5,000 nm	>10,000:1 > 1,000:1
Beam Deviation		
Ultraviolet Visible Infrared SWIR / MWIR		≤ 5arc-min ≤ 5arc-min ≤ 5arc-min ≤ 10 arc-min / 12.5 mm ≤ 5 arc-min / 25 mm
Reflectance		
Uncoated Coated (optional)		~4.25% per surface at normal incidence R avg ≤ 0.5%over specified band (refer to available AR coatings)
Operating Temperature		
Ultraviolet Visible Infrared SWIR / MWIR (unlaminated)		-20˚C to +50˚C -20˚C to +50˚C -20˚C to +50˚C -50˚C to +400˚C

Specifications above are for laminated Ultra-high contrast polarizers. For unlaminated parts, please contact your Meadowlark Optics Sales Engineer.

Key Features

• • •

Extremely high contrast, greater than 100,000:1

Unlaminated part usable to 400˚C

Wavelength ranges within 340 to 5000 nm

Absorptive dichroic glass

Optical quality substrates for exceptional wavefront distortion

Polarization Suite

• • •

Linear Polarizers

Precision Linear Polarizer

High Contrast Linear Polarizer

Ultra-High Contrast Linear Polarizer

Glan-Thompson Polarizer

Ultra Broadband Polarizer

MWIR Polarizer

Deep Ultraviolet Polarizer

Beamsplitting Polarizers

Wire Grid Versalight Polarizer

Wire Grid Versalight Beam Splitter

Laser Line Beamsplitting Polarizer

Broadband Beamsplitting Polarizer

Polarizing Bandpass Filter

Circular Polarizers

Dichroic Circular Polarizer

Beam Separator

ORDERING INFORMATION			
Mounted and Laminated			
Clear Aperture in. (mm)	***Thickness in. (mm)***	***Diameter ± 0.005 in. (± 0.13 mm)***	***Part Number***
0.40 (10.2 mm)	0.25 (6.35 mm)	Ø1.00 (Ø25.4 mm)	UPM – 050 – UV
0.40 (10.2 mm)	0.25 (6.35 mm)	Ø1.00 (Ø25.4 mm)	UPM – 050 – VIS
0.40 (10.2 mm)	0.25 (6.35 mm)	Ø1.00 (Ø25.4 mm)	UPM – 050 – IR
0.70 (17.8 mm)	0.35 (8.89 mm)	Ø1.00 (Ø25.4 mm)	UPM – 100 – UV
0.70 (17.8 mm)	0.35 (8.89 mm)	Ø1.00 (Ø25.4 mm)	UPM – 100 – VIS
0.70 (17.8 mm)	0.35 (8.89 mm)	Ø1.00 (Ø25.4 mm)	UPM – 100 – IR
Mounted and Unlaminated			
0.40 (10.2 mm)	0.185 (4.70 mm)	Ø1.00 (Ø25.4 mm)	UPM – 050 – MIR
0.70 (17.8 mm)	0.185 (4.70 mm)	Ø1.00 (Ø25.4 mm)	UPM – 100 – MIR
Unmounted and Laminated			
Clear Aperture in. (mm)	***Thickness in. (mm)***	***Diameter +0/-0.010 in. (+0/-0.25 mm)***	***Part Number***
0.40 (10.2 mm)	0.14 (3.56 mm)	Ø0.50 (Ø12.7 mm)	UHP – 050 – UV
0.40 (10.2 mm)	0.14 (3.56 mm)	Ø0.50 (Ø12.7 mm)	UHP – 050 – VIS
0.40 (10.2 mm)	0.14 (3.56 mm)	Ø0.50 (Ø12.7 mm)	UHP – 050 – IR
0.80 (20.3 mm)	0.26 (6.60 mm)	Ø1.00 (Ø25.4 mm)	UHP – 100 – UV
0.80 (20.3 mm)	0.26 (6.60 mm)	Ø1.00 (Ø25.4 mm)	UHP – 100 – VIS
0.80 (20.3 mm)	0.26 (6.60 mm)	Ø1.00 (Ø25.4 mm)	UHP – 100 – IR
Unmounted and Unlaminated			
0.40 (10.2 mm)	0.008 (0.203 mm)	Ø0.50 (Ø12.7 mm)	UHP – 050 – MIR
0.80 (20.3 mm)	0.008 (0.203 mm)	Ø1.00 (Ø25.4 mm)	UHP – 100 – MIR

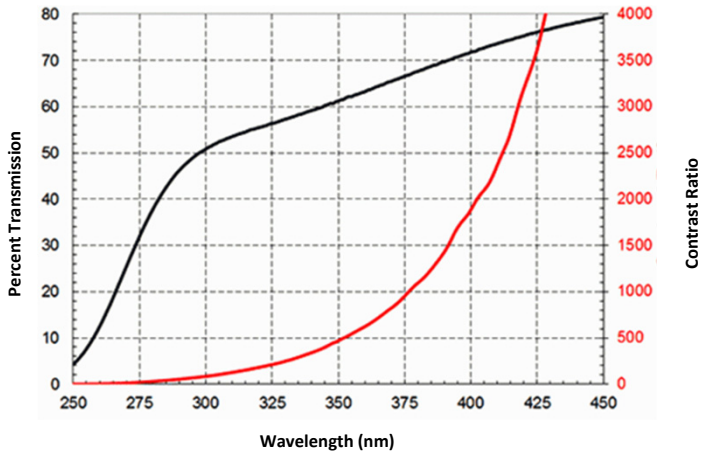
Anti-reflection coating options are available:
AR0 covers 350 - 450 nm with R avg ≤ 0.5%
AR1 covers 400 - 700 nm with R avg ≤ 0.5%
AR2 covers 650 - 950 nm with R avg ≤ 0.5%
AR3 covers 900 - 1250 nm with R avg ≤ 0.5%
AR4 covers 1200 - 1700 nm with R avg ≤ 0.5%

Wire Grid VersaLight™ Polarizer

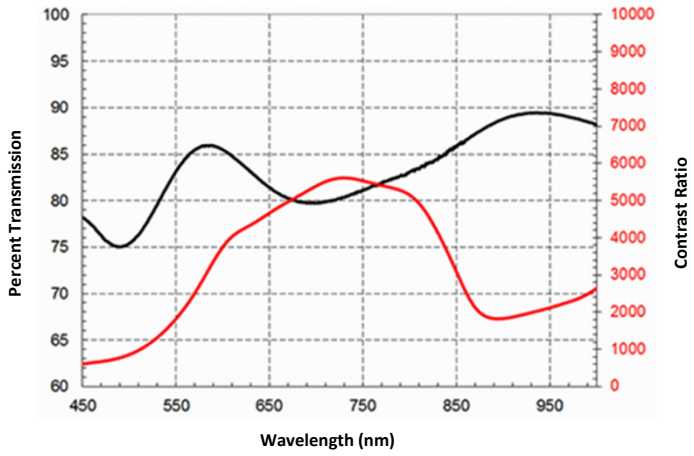
VersaLight™ is constructed of a thin layer of aluminum MicroWires® on a glass substrate and sets a new standard for applications requiring high durability, contrast and a wide field of view for visible through infrared wavelengths. VersaLight offers the performance quality of dichroic sheet polarizers while extending the operating temperature to 200° C.

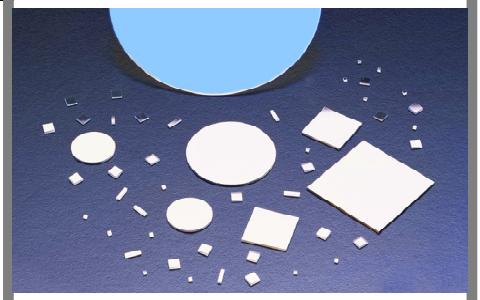
The nature of VersaLight's MicroWire construction allows it to perform as an exceptional polarizing beam splitter. In operation, VersaLight reflects one polarization state and transmits another, both with high contrast. VersaLight offers the broadest band and highest field of view of any polarizer material presently 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 200 mm rounds.

Typical UV VersaLight Polarizer Performance



Typical NIR VersaLight Polarizer Performance





Key Features

- Broadband use
- Reflective polarizer
- Large acceptance angle
- High heat resistance

Polarization Suite

Linear Polarizers

Precision Linear Polarizer
High Contrast Linear Polarizer
Ultra-High Contrast Linear Polarizer
Glan-Thompson Polarizer
Ultra Broadband Polarizer
MWIR Polarizer
Deep Ultraviolet Polarizer

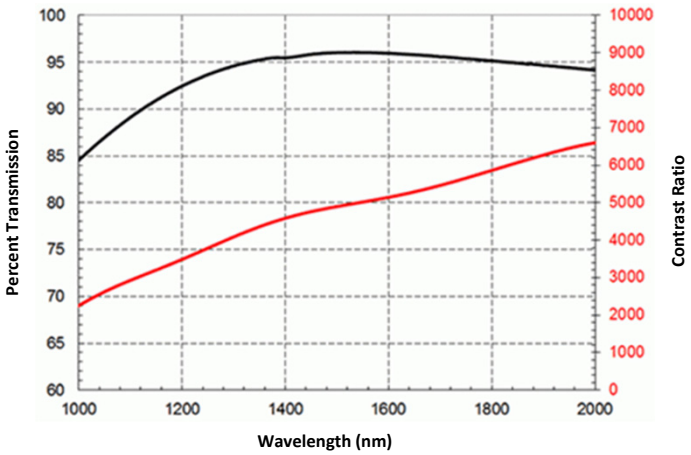
Beamsplitting Polarizers

Wire Grid Versalight Polarizer
Wire Grid Versalight Beam Splitter
Laser Line Beamsplitting Polarizer
Broadband Beamsplitting Polarizer
Polarizing Bandpass Filter

Circular Polarizers

Dichroic Circular Polarizer
Beam Separator

Typical IR VersaLight Performance



SPECIFICATIONS

Wavelength Range	
Ultraviolet	325 nm to 450 nm
Near infrared	450 nm to 1000 nm
Infrared	1000 nm to 2000 nm
Substrate Material	
Ultraviolet	UV Grade Fused Silica
Near Infrared	Eagle XG®
Infrared	Eagle XG®
Transmitted Wavefront Distortion (P-V @ 632.8 nm)	
Ultraviolet	~ λ/4 per in.
Near Infrared	~ 5λ per in.
Infrared	~ 5λ per in.
Surface Quality	80 – 50 scratch-dig
Beam Deviation	≤ 1arc-min
Contrast Ratio (see graph)	Typical Reflection > 80:1 Typical Transmission > 2000:1
Maximum Temperature	200˚C for single layer
Laser Damage Threshold	10 KW/cm^2, CW at 1540 nm

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

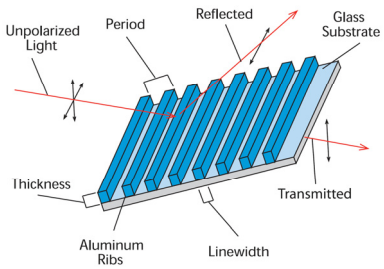
UV VersaLight is optimized for 300-450 nm
NIR VersaLight is optimized for 450-1000 nm
IR VersaLight is optimized for 1000-2000 nm

ORDERING INFORMATION

Thickness ± .002 in. (± 0.05 mm)	*Diameter +0/-0.010 in. (+0/-0.25 mm)*	*Part Number*
Square		
0.039 (1.0 mm)	0.5 × 0.5 (12.7 × 12.7)	VLS – 050 – UV
0.028 (0.7 mm)	0.5 × 0.5 (12.7 × 12.7)	VLS – 050 – NIR
0.028 (0.7 mm)	0.5 × 0.5 (12.7 × 12.7)	VLS – 050 – IR
0.039 (1.0 mm)	1.0 × 1.0 (25.4 × 25.4)	VLS – 100 – UV
0.028 (0.7 mm)	1.0 × 1.0 (25.4 × 25.4)	VLS – 100 – NIR
0.028 (0.7 mm)	1.0 × 1.0 (25.4 × 25.4)	VLS – 100 – IR
0.039 (1.0 mm)	2.0 × 2.0 (50.8 × 50.8)	VLS – 200 – UV
0.028 (0.7 mm)	2.0 × 2.0 (50.8 × 50.8)	VLS – 200 – NIR
0.028 (0.7 mm)	2.0 × 2.0 (50.8 × 50.8)	VLS – 200 – IR
Round		
0.039 (1.0 mm)	Ø0.5 (Ø12.7 mm)	VLR – 050 – UV
0.028 (0.7 mm)	Ø0.5 (Ø12.7 mm)	VLR – 050 – NIR
0.028 (0.7 mm)	Ø0.5 (Ø12.7 mm)	VLR – 050 – IR
0.039 (1.0 mm)	Ø1.0 (Ø25.4 mm)	VLR – 100 – UV
0.028 (0.7 mm)	Ø1.0 (Ø25.4 mm)	VLR – 100 – NIR
0.028 (0.7 mm)	Ø1.0 (Ø25.4 mm)	VLR – 100 – IR
0.039 (1.0 mm)	Ø2.0 (Ø50.8 mm)	VLR – 200 – UV
0.028 (0.7 mm)	Ø2.0 (Ø50.8 mm)	VLR – 200 – NIR
0.028 (0.7 mm)	Ø2.0 (Ø50.8 mm)	VLR – 200 – IR

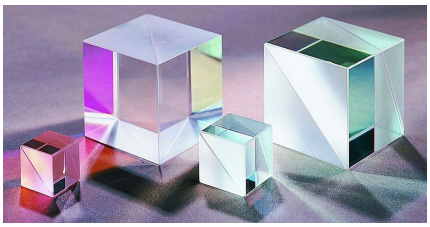
Call for information on even higher contrast, doubled assemblies. Custom sizes are available. Please contact your Meadowlark Optics Sales Engineer for assistance.

Wire Grid VersaLight Polarizer Construction and Use



Laser Line Beamsplitting Polarizer

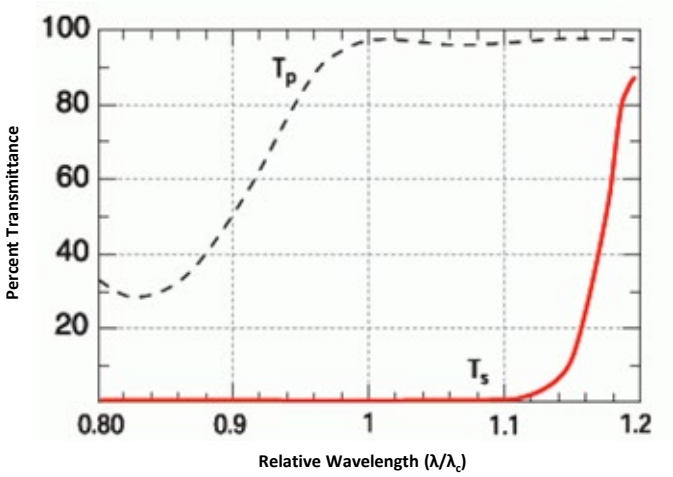
Right-angle prisms are matched in pairs to produce high quality laser line beamsplitting polarizers with superior wavefront quality in both transmission and reflection. The hypotenuse face of one prism is coated with a multilayer dielectric beamsplitting coating optimized for laser performance. Two prisms 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 with approximately 1000:1 contrast. These polarizers perform best with collimated or near-collimated light.

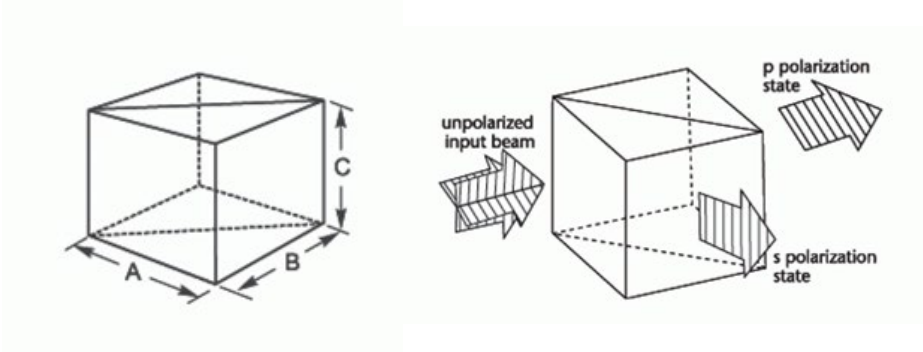


Key Features

- High contrast
- Low reflectance
- Low transmitted wavefront distortion

Typical Performance of a Laser Line Beamsplitting Polarizer





Beamsplitting polarizers provide two orthogonally polarized beams, conveniently separated by 90°

Polarization Suite

Linear Polarizers

Precision Linear Polarizer
High Contrast Linear Polarizer
Ultra-High Contrast Linear Polarizer
Glan-Thompson Polarizer
Ultra Broadband Polarizer
MWIR Polarizer
Deep Ultraviolet Polarizer

Beamsplitting Polarizers

Wire Grid Versalight Polarizer
Wire Grid Versalight Beam Splitter
Laser Line Beamsplitting Polarizer
Broadband Beamsplitting Polarizer
Polarizing Bandpass Filter

Circular Polarizers

Dichroic Circular Polarizer
Beam Separator

SPECIFICATIONS	
Substrate	N-BK7
Surface Flatness (P-V @ 632.8 nm)	≤ λ/4 for p-polarized beam
Surface Quality	40 – 20 scratch-dig
Beam Deviation	
Transmitted	≤ 3 arc-min
Reflectance (per surface)	≤ 0.25%
Contrast Ratio	
Transmitted	≥ 1,000:1
Transmission	
p-polarized light **s-polarized light**	≥ 95% transmitted ≥ 99.8% reflected
Storage Temperature	-50˚C to + 80˚C
Operating Temperature	-50˚C to + 80˚C
Laser Damage Threshold	≥ 0.5 J / cm2, 10 ns

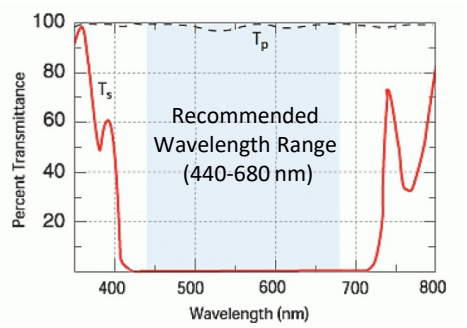
ORDERING INFORMATION	
Dimensions ± 0.020 in. (± 0.51 mm)	***Part Number***
0.50 × 0.50 x 0.50 (12.7 x 12.7 x 12.7 mm)	BP – 050 – λ
1.00 × 1.00 × 1.00 (25.4 × 25.4 × 25.4 mm)	BP – 100 – λ

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, sizes, or shapes.

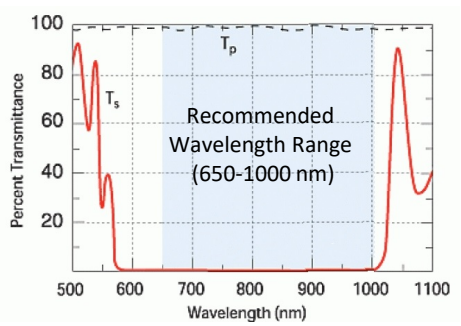
Broadband Beamsplitting Polarizer

For applications involving broadband or tunable wavelength sources, Meadowlark Optics presents a 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. These broadband designs require well-collimated input and accurate angular alignment for optimal performance. All four entrance and exit faces are antireflection coated to minimize losses.

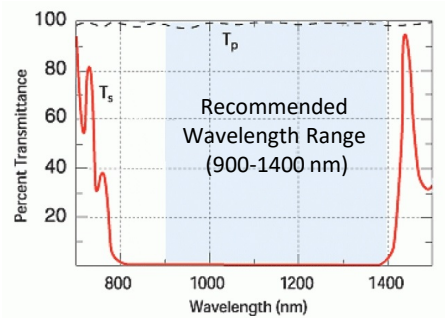
Typical Design Performance of Visible Broadband Beamsplitting Polarizer



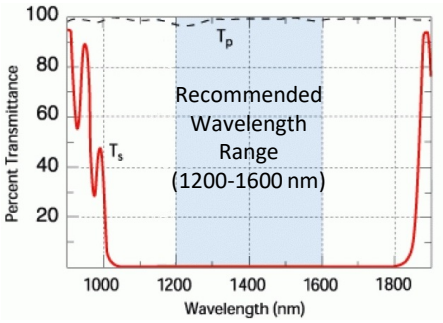
Typical Design Performance of IR1 Broadband Beamsplitting Polarizer

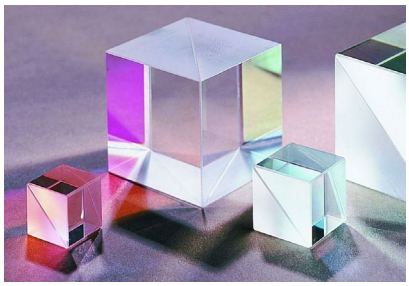


Typical Design Performance of IR2 Broadband Beamsplitting Polarizer



Typical Design Performance of IR3 Broadband Beamsplitting Polarizer





Key Features

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

Polarization Suite

Linear Polarizers

Precision Linear Polarizer
High Contrast Linear Polarizer
Ultra-High Contrast Linear Polarizer
Glan-Thompson Polarizer
Ultra Broadband Polarizer
MWIR Polarizer
Deep Ultraviolet Polarizer

Beamsplitting Polarizers

Wire Grid Versalight Polarizer
Wire Grid Versalight Beam Splitter
Laser Line Beamsplitting Polarizer
Broadband Beamsplitting Polarizer
Polarizing Bandpass Filter

Circular Polarizers

Dichroic Circular Polarizer
Beam Separator

SPECIFICATIONS

Wavelength Range	
Visible **Near IR1** **Near IR2** **Near IR3**	440 – 680 nm 650 – 1000 nm 900 – 1400 nm 1200 – 1600 nm
Substrate Material	SF 2
Surface Quality	40 – 20 scratch - dig
Surface Flatness	≤ λ/8 (@ 633 nm)
Beam Deviation	≤ 3 arc-min
Dimension Tolerance	≤ +0/-0.20 mm
Reflectance (per surface)	≤ 0.5% avg
Contrast Ratio	≥ 500:1 (Average)
Transmission (p-polarized light) **Transmission** (s-polarized light)	≥ 90% avg ≥ 99.8% avg
Clear Aperture	Central 85% diameter
Temperature Range	-50˚C to +80˚C
Laser Damage Threshold	≥ 0.5 J/cm2 (10 ns)

ORDERING INFORMATION

Clear Aperture	***Dimensions*** ***+0.00/ – 0.01 in.*** ***(+0.00/– 0.25 mm)***	***Part Number***
Visible (440 – 680 nm)		
0.425 × 0.425 × 0.425 (10.8 x 10.8 x 10.8 mm)	0.50 × 0.50 × 0.50 (12.7 x 12.7 x 12.7 mm)	BB – 050 – VIS
0.85 × 0.85 × 0.85 (21.6 × 21.6 × 21.6 mm)	1.00 × 1.00 × 1.00 (25.4 × 25.4 × 25.4 mm)	BB – 100 – VIS
Near IR1 (650 – 1000 nm)		
0.425 × 0.425 × 0.425 (10.8 x 10.8 x 10.8 mm)	0.50 × 0.50 × 0.50 (12.7 x 12.7 x 12.7 mm)	BB – 050 – IR1
0.85 × 0.85 × 0.85 (21.6 × 21.6 × 21.6 mm)	1.00 × 1.00 × 1.00 (25.4 × 25.4 × 25.4 mm)	BB – 100 – IR1
Near IR2 (900 – 1400 nm)		
0.425 × 0.425 × 0.425 (10.8 x 10.8 x 10.8 mm)	0.50 × 0.50 × 0.50 (12.7 x 12.7 x 12.7 mm)	BB – 050 – IR2
0.85 × 0.85 × 0.85 (21.6 × 21.6 × 21.6 mm)	1.00 × 1.00 × 1.00 (25.4 × 25.4 × 25.4 mm)	BB – 100 – IR2
Near IR3 (1200 – 1600 nm)		
0.425 × 0.425 × 0.425 (10.8 x 10.8 x 10.8 mm)	0.50 × 0.50 × 0.50 (12.7 x 12.7 x 12.7 mm)	BB – 050 – IR3
0.85 × 0.85 × 0.85 (21.6 × 21.6 × 21.6 mm)	1.00 × 1.00 × 1.00 (25.4 × 25.4 × 25.4 mm)	BB – 100 – IR3

Custom sizes available. Please contact one of our Solutions Engineers for more information.

Glan-Thompson Polarizer

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

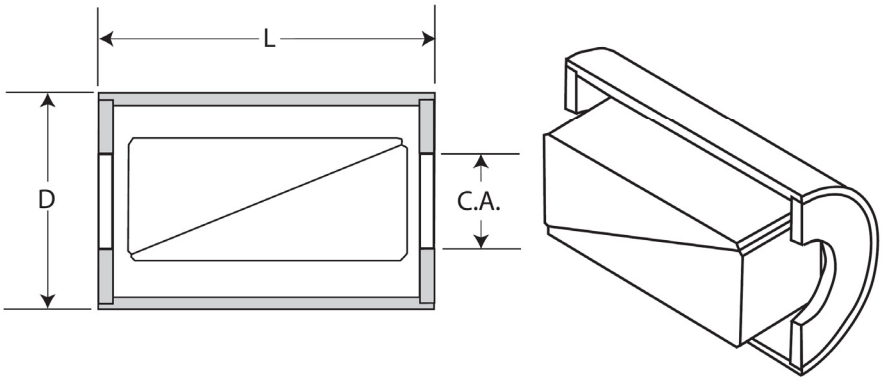
Meadowlark Optics offers Glan-Thompson Polarizers, intended for precision optical instrumentation and low power laser applications. Key advantages of Glan-Thompson Polarizers include excellent extinction ratio performance and a broad spectral range.

Our Glan-Thompson Polarizers are supplied in a black anodized cylindrical housing for easy mounting. The housing is marked to indicate the polarization axis of the transmitted beam. The rejected component of the beam is totally internally reflected and eventually absorbed by the anodized aluminum.

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.

Glan - Thompson Polarizer Construction



Key Features

- Broad spectral range
- Excellent extinction ratio
- Wide field of view
- Low wavefront distortion

Polarization Suite

Linear Polarizers

Precision Linear Polarizer
High Contrast Linear Polarizer
Ultra-High Contrast Linear Polarizer
Glan-Thompson Polarizer
Ultra Broadband Polarizer
MWIR Polarizer
Deep Ultraviolet Polarizer

Beamsplitting Polarizers

Wire Grid Versalight Polarizer
Wire Grid Versalight Beam Splitter
Laser Line Beamsplitting Polarizer
Broadband Beamsplitting Polarizer
Polarizing Bandpass Filter

Circular Polarizers

Dichroic Circular Polarizer
Beam Separator

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 Single layer MgF2	~ 4.5% ~ 1.5%
Beam Deviation	± 3 arc min
Acceptance Angle	± 5˚
Wavelength Range	320 – 2300 nm
Recommended Safe Operating Limit	25-30 W/cm² CW

ORDERING INFORMATION

Clear Aperture (mm)	*Wavelength Range (nm)*	*AR Coating*	*Part Number*
5.0	320 – 2300	None	GTP – M05
5.0	400 – 700	MgF_2	GTP – M05 – 0550
5.0	650 – 1000	MgF_2	GTP – M05 – 0825
5.0	1000 – 1500	MgF_2	GTP – M05 – 1250
8.0	320 – 2300	None	GTP – M08
8.0	400 – 700	MgF_2	GTP – M08 – 0550
8.0	650 – 1000	MgF_2	GTP – M08 – 0825
8.0	1000 – 1500	MgF_2	GTP – M08 – 1250
10.0	320 – 2300	None	GTP – M10
10.0	400 – 700	MgF_2	GTP – M10 – 0550
10.0	650 – 1000	MgF_2	GTP – M10 – 0825
10.0	1000 – 1500	MgF_2	GTP – M10 – 1250

Dichroic Circular Polarizer

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, it's 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 polarizer 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:

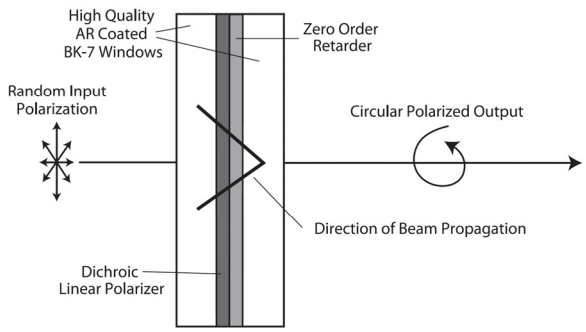
- Dichroic Polarizer / Zero-Order Retarder
- Beamsplitting Polarizer / Zero-Order Retarder

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

True zero-order retarders are used in the assembly of our Dichroic Circular Polarizers and tight retardance tolerances contribute to the final performance. Once aligned, both polarizer and retarder materials are laminated between optically flat substrates, providing a peak-to-valley transmitted wavefront distortion of less than λ/5. Anti-reflection 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. Our standard Dichroic Circular Polarizers are designed for single wavelength applications.

Dichroic Circular Polarizer Construction



Key Features

• • •

High isolation

Large diameters available

Low transmitted wavefront distortion

Polarization Suite

• • •

Linear Polarizers

Precision Linear Polarizer

High Contrast Linear Polarizer

Ultra-High Contrast Linear Polarizer

Glan-Thompson Polarizer

Ultra Broadband Polarizer

MWIR Polarizer

Deep Ultraviolet Polarizer

Beamsplitting Polarizers

Wire Grid Versalight Polarizer

Wire Grid Versalight Beam Splitter

Laser Line Beamsplitting Polarizer

Broadband Beamsplitting Polarizer

Polarizing Bandpass Filter

Circular Polarizers

Dichroic Circular Polarizer

Beam Separator

SPECIFICATIONS

Standard Wavelengths	532, 632.8, 670, 780, 850, 1064, and 1550 nm
Substrate Material	N-BK7
Polarizer Material	Dichroic Polymer
Retarder Material	Birefringent Polymer
Transmitted Wavefront Distortion (P-V @ 632.8 nm)	
Visible **Near Infrared**	≤ λ/5 ≤ λ/2
Beam Deviation	
Visible **Near Infrared**	≤ 1 arc-min ≤ 2 arc-min
Surface Quality	40 – 20 scratch-dig
Reflectance (per surface)	≤ 0.5%
Isolation	> 99.8%
Storage Temperature	-20˚C to +50˚C
Operating Temperature	-20˚C to +50˚C
Laser Damage Threshold	1 W/cm^2, CW

Prolonged exposure to strong ultraviolet radiation may damage these polarizers.

ORDERING INFORMATION

Mounted			
Clear Aperture in. (mm)	***Thickness in. (mm)***	***Diameter ± 0.005 in. (± 0.13 mm)***	***Part Number***
0.40 (10.2 mm)	0.25 (6.35 mm)	Ø1.00 (Ø25.4 mm)	CPM – 050 – λ
0.70 (17.8 mm)	0.35 (8.9 mm)	Ø1.00 (Ø25.4 mm)	CPM – 100 – λ
1.20 (30.5 mm)	0.50 (12.7 mm)	Ø2.00 (Ø50.8 mm)	CPM – 200 – λ
Unmounted			
Clear Aperture in. (mm)	***Thickness in. (mm)***	***Diameter +0/-0.010 in. (+0/-0.25 mm)***	***Part Number***
0.40 (10.2 mm)	0.13 (3.3 mm)	Ø0.50 (Ø12.7 mm)	CP – 050 – λ
0.80 (20.3 mm)	0.26 (6.6 mm)	Ø1.00 (Ø25.4 mm)	CP – 100 – λ

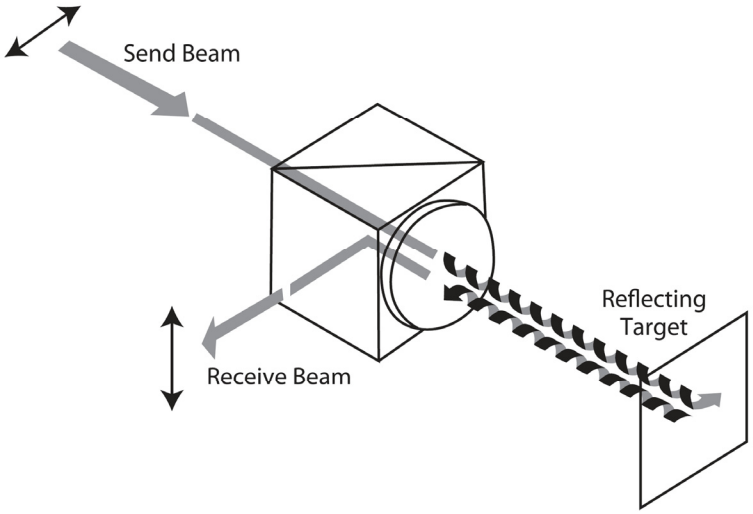
Meadowlark Optics standard Dichroic Circular Polarizers provide left-hand circular output.
Please call to request a quote for right-hand output.
Append a "-RH" to your part number for right hand circular output.

Beam Separator

Meadowlark Optics' Beam Separators are designed for laser line applications and consist of a true zero-order quarter-wave retarder aligned with its fast axis at 45° to the transmission axis of a Laser Line Beamsplitting Polarizer.

The transmitted beam is circularly polarized, regardless of the input beam polarization state. Our true zero-order Precision Retarders are quarter-wave within ± λ/350 and aligning the fast axis to within 1° ensures greater than 99.8% source isolation from specular back reflections.

Beam Separator function



Key Features

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

Polarization Suite

Linear Polarizers

Precision Linear Polarizer
High Contrast Linear Polarizer
Ultra-High Contrast Linear Polarizer
Glan-Thompson Polarizer
Ultra Broadband Polarizer
MWIR Polarizer
Deep Ultraviolet Polarizer

Beamsplitting Polarizers

Wire Grid Versalight Polarizer
Wire Grid Versalight Beam Splitter
Laser Line Beamsplitting Polarizer
Broadband Beamsplitting Polarizer
Polarizing Bandpass Filter

Circular Polarizers

Dichroic Circular Polarizer
Beam Separator

SPECIFICATIONS	
Material	BK 7 Grade A, fine annealed
Transmitted Wavefront Distortion (at 632.8 nm)	≤ λ/5
Clear Aperture	Central 80% diameter
Reflectance (per surface)	≤ 0.5% at normal incidence
Surface Quality	40 – 20 scratch-dig
Beam Deviation	≤ 3 arc min
Acceptance Angle	± 2˚
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. (mm)	*Clear Aperture in. (mm)*	*Part Number*
0.50 (12.7 mm)	0.40 (10.16 mm)	BS – 050 – λ
1.00 (25.4 mm)	0.80 (20.32 mm)	BS – 100 – λ

Please substitute your wavelength in nanometers for λ.

Custom sizes and wavelengths over 400-1600 nm are available. Please contact your Meadowlark Optics Sales Engineer for more information.

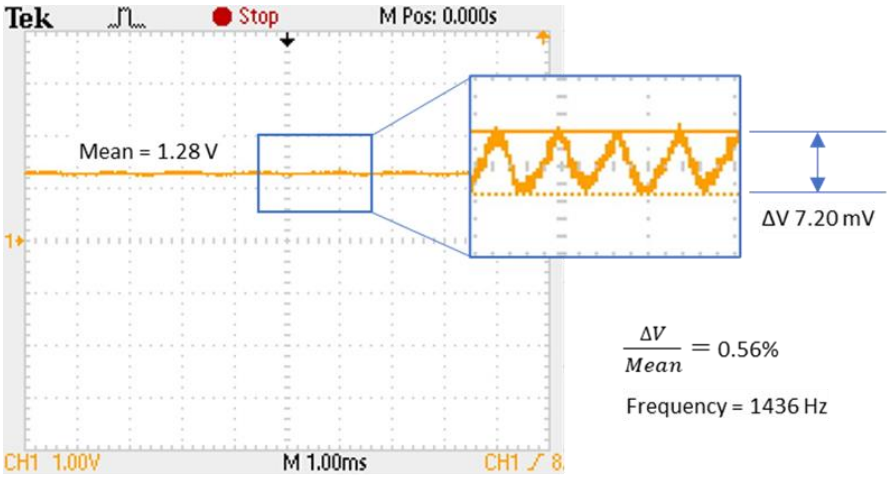
Spatial Light Modulators

Spatial Light Modulator – 1024 x 1024

High Speed Analog, Phase Only – up to 2 kHz

Meadowlark Optics' Liquid Crystal on Silicon (LCoS) Spatial Light Modulators (SLMs) are uniquely designed for pure phase applications and incorporate analog data addressing with high refresh rates (1400 Hz). This combination provides users with the fastest response times with high phase stability. The 1024 x 1024 SLM is good for applications requiring high speed, high diffraction efficiency, low phase ripple and high-power lasers.

High Phase Stability – Making an LCOS SLM faster usually means the phase stability is worse. However, we've combined our traditional analog drive scheme with new proprietary technologies to suppress phase instabilities to 0.05% to 2.0% without compromising speed. Phase ripple is quantified by measuring the variation in intensity of the 1st order diffracted spot as compared to the mean intensity while writing a blazed phase grating to the SLM. Since phase stability varies as a function of pixel voltage, this measurement approach is an average and does not represent all scenarios. If your application requires extremely low phase ripple, please contact a Meadowlark Solutions Engineer for more information on the 19x12 SLM



Typical data showing phase stability of the HSP1K-488-800 at 532 nm

SLM Features

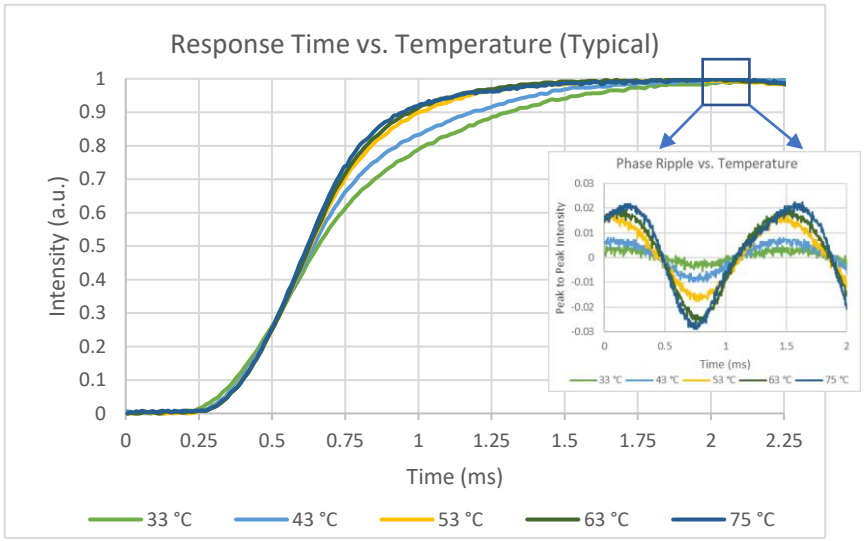
- High resolution
- High speed
- High Phase Stability
- Pure analog phase control
- High first order efficiency
- High reflectivity
- High power handling
- On-board Memory
- Wavelengths from 488-1650 nm

Software Features

- Input and Output Triggers
- Image Generation
- Automated Sequencing
- Wavefront Calibration
- Global and Regional Look Up Tables
- Temperature Monitoring
- Look-up-table Calibration Kit

High Speed with High Phase Stability - Great care was taken in the design of the 1024 x 1024 silicon backplane to enable high speed operation while simultaneously maximizing phase stability. The 1024 x 1024 SLM is incredibly fast with liquid crystal response times ranging from 0.6 to 8 ms (wavelength dependent) for a full wave of modulation. In our ultra-high speed model customers can control the temperature set point to find the perfect balance between switching speed and phase stability.

Tunable temperature control to balance speed and stability

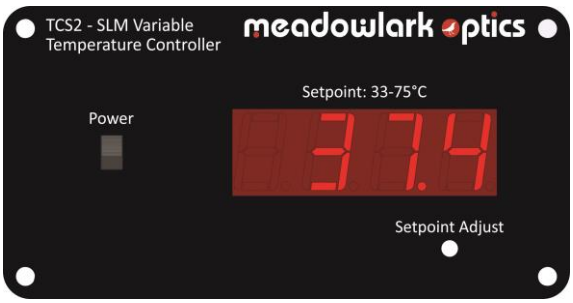


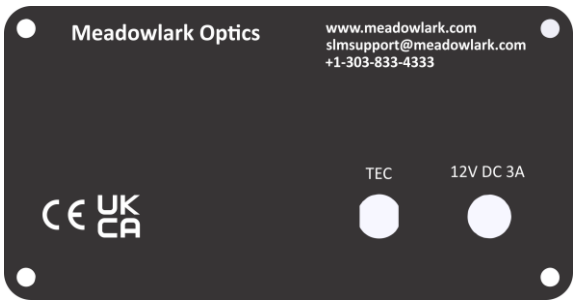
Sub-millisecond liquid crystal response times are measured in the far field. Images applied to the SLM are toggled between an 8-pixel, 2π phase grating and a solid image. Data captured while operating from 33°C to 75°C, using 10 to 90% reference levels. Results show typical switching speeds and phase stability at 532 nm.

TEC Heater

Part Number TCS2

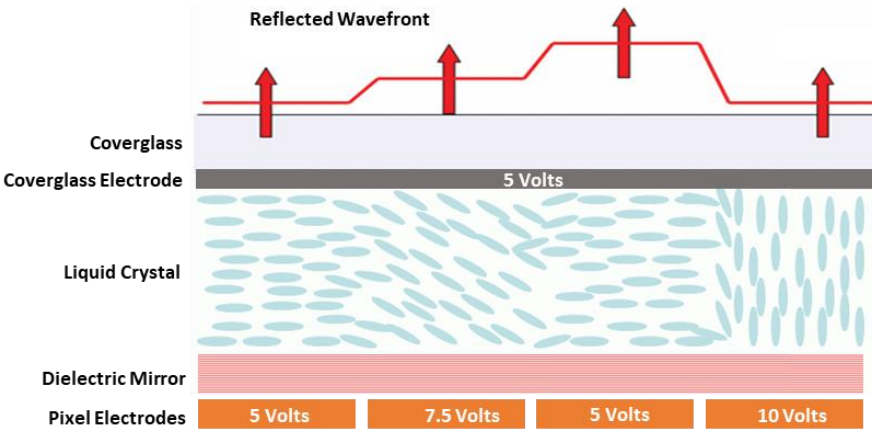
Thermoelectric Cooler (TEC) gives the user control over the temperature in which to operate the SLM. Heating the liquid crystals increase the switching speed, and cooling the liquid crystals improves phase stability.

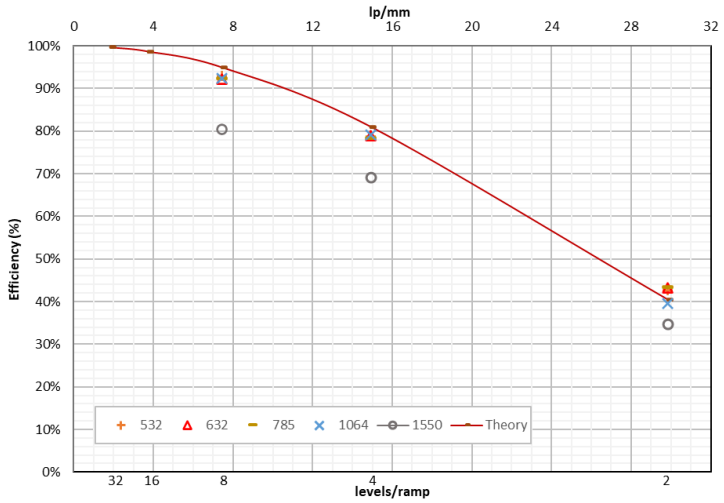




Diffraction Efficiency (0th-order) – This is the amount of light retained in the 0th-order (dc) when writing solid grayscale images to the SLM as compared to the amount of light in the 0th order when the SLM is replaced with a reference mirror. This measurement quantifies losses in the coverglass coatings, losses due to wavelength dependent reflectivity of the pixel pads, as well as losses to diffraction from reflecting off the pixilated structure of the backplane. In the case of a dielectric mirror coated model, the measurement accounts for losses due to imperfect reflectivity of this dielectric mirror coating. The 0th order diffraction efficiency will vary as a function of wavelength due to differences in coating materials and designs. It will also vary with pixel value due to the inherent change in the index of refraction of the liquid crystal that results in a change in the Fresnel reflections inside the liquid crystal cell. Most standard SLMs will range from 70 – 90%, while the dielectric mirror coated models will range from 92 – 98%.

High Efficiency Dielectric Mirror Coating – Optically, the backplane is converted into a flat dielectric mirror by depositing dielectric layers to eliminate the amplitude and optical path variations associated with the underlying aluminum pixel structure. The dielectric stack is kept thin to minimize any drop in electric field across the LC layer as shown in the figure below.

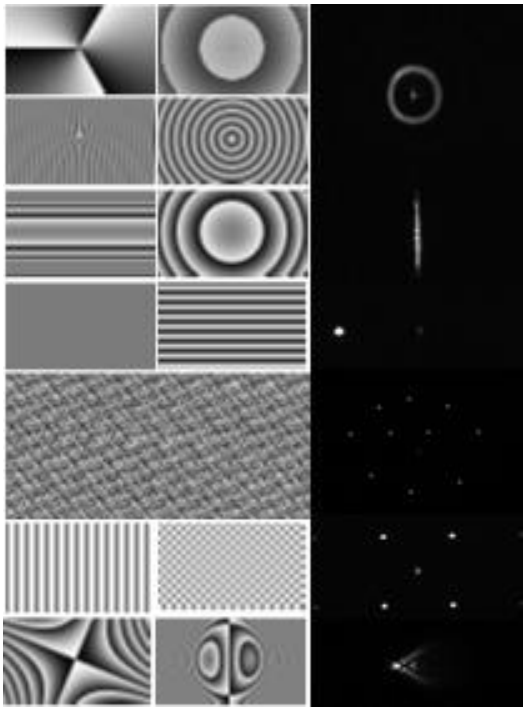




Typical Measured 1st Order Diffraction Efficiency

Diffraction Efficiency (1st-order) – This is the percentage of light measured in the 1st-order when writing a linear repeating phase ramp to the SLM as compared to the light in the 0th order when no pattern is written to the SLM. 1st-order diffraction efficiency varies as a function of the number of phase levels, or pixels, in the phase ramp. Example measurement data taken at various wavelengths is shown below for phase ramps with 2 to 8 phase levels between 0 and 2π.

Software - Meadowlark Optics' SLMs are supplied with a graphical user interface and software development kits that support LabVIEW, Matlab, Python, and C++. The software allows the user to generate images, to correct aberrations, to calibrate the global and/or regional optical response over 'n' waves of modulation, to sequence at a user defined frame rate, and to monitor the SLM temperature.



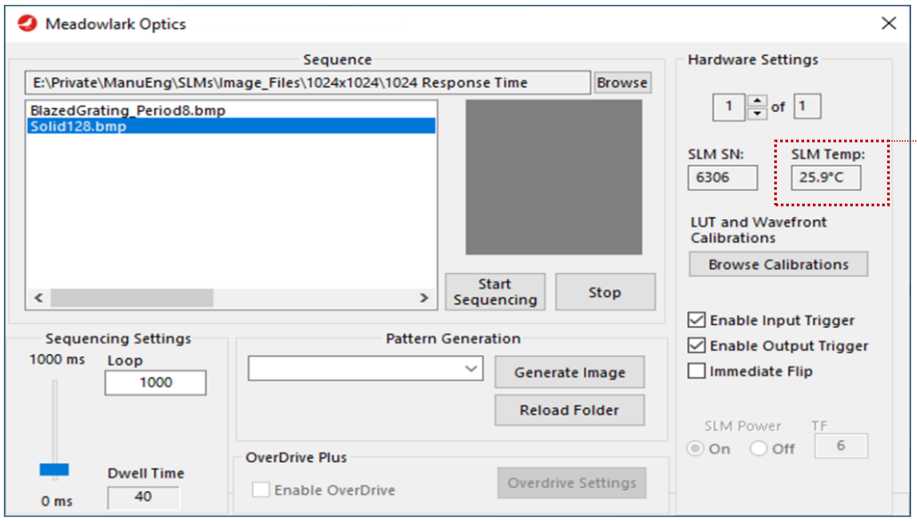
Global or Regional Calibrations - Regional calibrations provide the highest spatial phase fidelity commercially available by regionally characterizing the phase response to voltage and calibrating on a pixel-by-pixel basis.

Image Generation Capabilities

Bessel Beams: Spiral Phase, Fork, Concentric Rings, Axicons
Lens Functions: Cylindrical, Spherical
Gratings: Blazed, Sinusoid
Diffraction Patterns: Stripes, Checkerboard, Solid, Random Phase Holograms, Zernike Polynomials, Superimpose Images

Optional Look-Up-Table Calibration Kit (Part Number LUT1)

Meadowlark includes a calibrated LUT at one of our standard test sources (405, 532, 635, 785, 1064, or 1550 nm). If the user wants to work at a different wavelength, we recommend purchasing our Look-Up-Table Calibration Kit. It provides the tools needed to create a custom LUT based on the user's wavelength and operating temperature for optimal performance. The kit is shipped with software and a National Instruments NI-6000 data acquisition card. The user only needs to provide a photodetector at their desired wavelength.

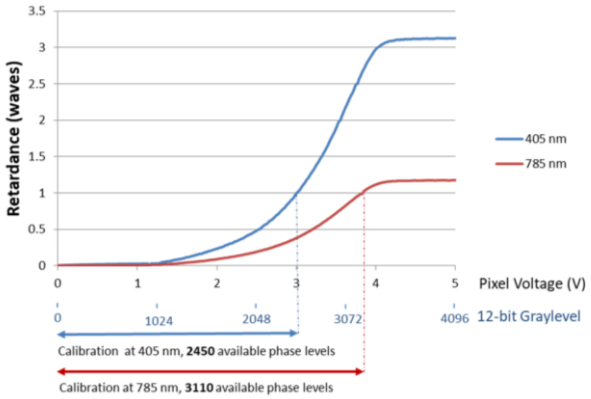


On chip temperature sensors allow the user to monitor the SLM temperature either through the example program or the software developer kits.

Hardware Interface - The 1024 x 1024 SLM system includes a Gen3 x8 PCIe controller with input and output triggers and low latency image transfers. Triggering can be performed on SLM chip refresh period boundaries of 696 µs, or even in the middle of refresh periods for applications requiring the SLM be tightly synchronized to external hardware. The controller also includes 752 frames of internal memory that can be loaded in advance, then sequenced at full speed in order to minimize traffic on the PCIe bus during operation. Using the 8-bit input/12-bit out design enables the SLM to support a broad wavelength range without sacrificing linear phase levels

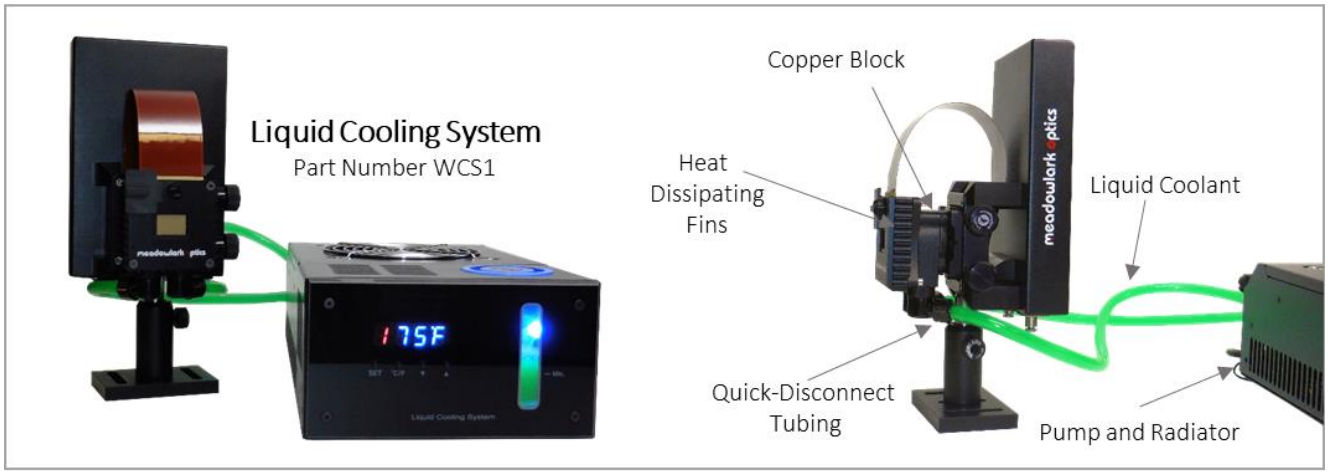
ONE SLM supports a broad wavelength range without losing linear phase levels

PCIe Controller supports high frame rates (up to 1436.1 Hz)



High Power Capability - Meadowlark SLMs are designed for compatibility with high power lasers through use of low absorption materials, large pixel pads, dielectric mirror options, and liquid cooling. If you are using a high power laser please contact Meadowlark with more information about your average power, pulse width, repetition rate, and beam diameter incident on the SLM. We will compare your laser specifications to our catalog of collected measurements and make a recommendation for the power handling limit of your optical system.

Liquid Cooling System - A copper block is attached to the back of the optical head to draw heat out of the SLM chip. The copper block is coupled via 2 meters of quick-disconnect tubing to cooling unit containing an external pump, radiator, and fan to cool the liquid down to ambient temperature. Includes one bottle of liquid coolant. The liquid cooling system not only pulls heat away from the SLM, it also keeps the SLM at a consistent temperature to ensure no change in modulation occurs as temperature varies.



1024 x 1024 Analog Spatial Light Modulator Specifications

Resolution: 1024 x 1024
Fill Factor: 97.2%

Array Size: 17.40 x 17.40 mm
Pixel Pitch: 17 x 17 µm

Zero-Order Diffraction Efficiency: 75 - 87%
With Dielectric Mirror Coating: 92 – 98%

HIGH SPEED

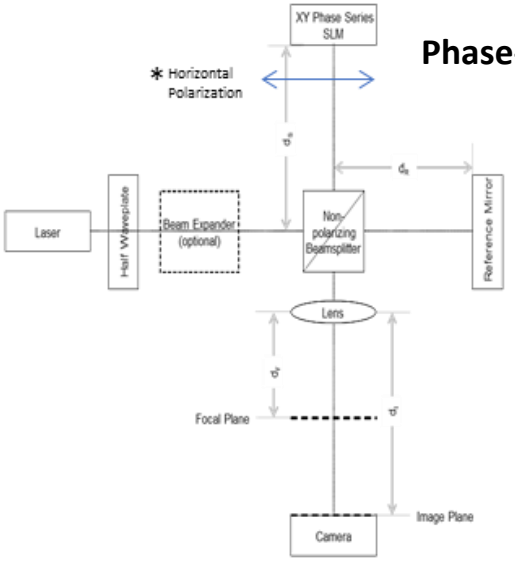
Standard Calibration Wavelengths	HIGH SPEED Liquid Crystal Response Time			Calibrated Wavefront Distortion
	AR Coating Range 488 – 850 nm	AR Coating Range 500 – 1200 nm	AR Coating Range 850 – 1650 nm	
532 nm	≤ 1.0 ms	≤ 1.4 ms	–	λ/5
635 nm	≤ 1.3 ms	≤ 1.8 ms	–	λ/6
785 nm	≤ 1.8 ms	≤ 2.4 ms	–	λ/7
1064 nm	–	≤ 3.4 ms	≤ 5.5 ms	λ/10
1550 nm	–	–	≤ 8.0 ms	λ/12

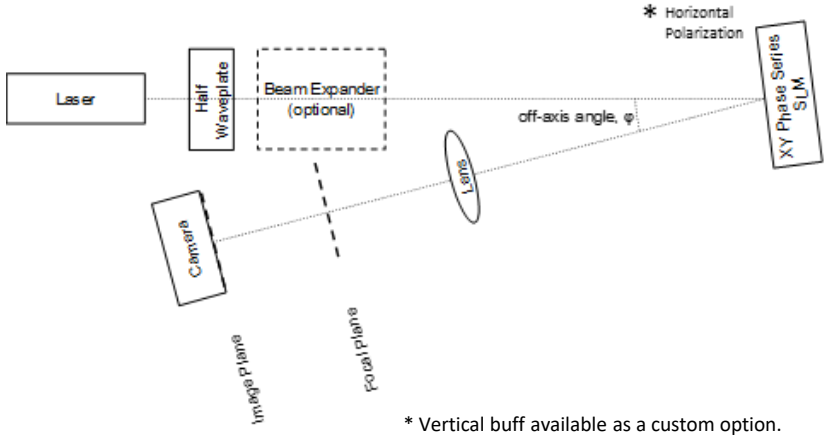
ULTRA HIGH SPEED

Standard Calibration Wavelengths	ULTRA HIGH SPEED Liquid Crystal Response Time			Calibrated Wavefront Distortion
	AR Coating Range 488 – 850 nm	AR Coating Range 500 – 1200 nm	AR Coating Range 850 – 1650 nm	
532 nm	≤ 0.6 ms	≤ 0.7 ms	–	λ/5
635 nm	≤ 0.7 ms	≤ 0.9 ms	–	λ/6
785 nm	≤ 0.9 ms	≤ 1.2 ms	–	λ/7
1064 nm	–	≤ 1.7 ms	≤ 2.0 ms	λ/10
1550 nm	–	–	≤ 3.9 ms	λ/12

Model Number Guide:

Phase-only Optical Test Setups

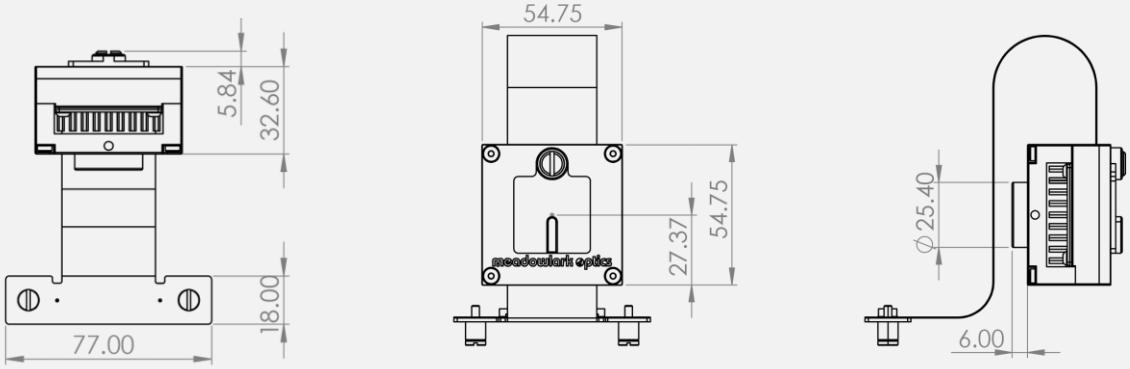




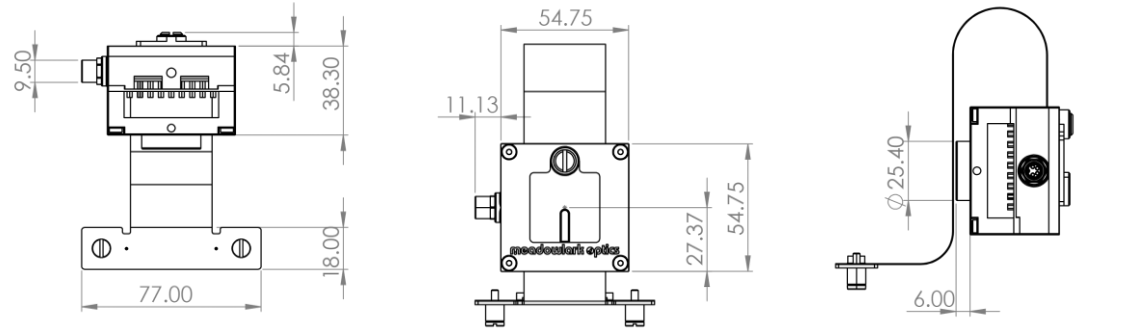
* Vertical buff available as a custom option.

1024 x 1024 Spatial Light Modulator Component Dimensions

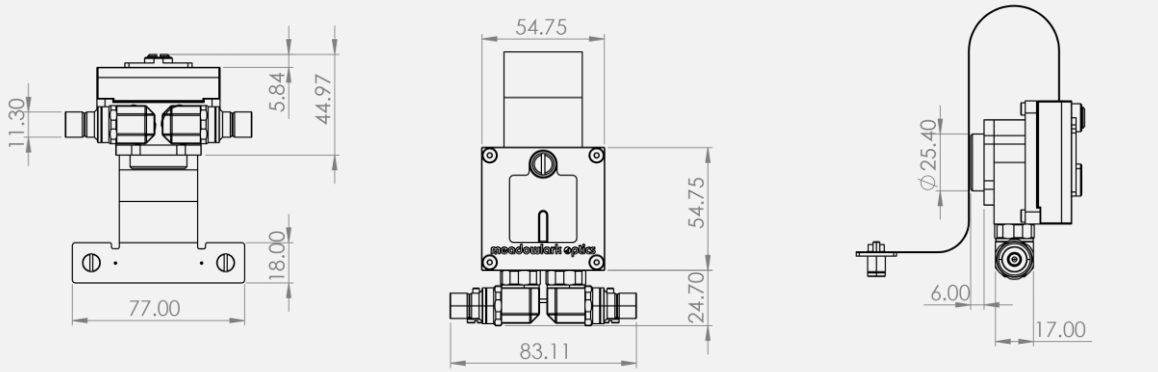
HSP1K Optical Head



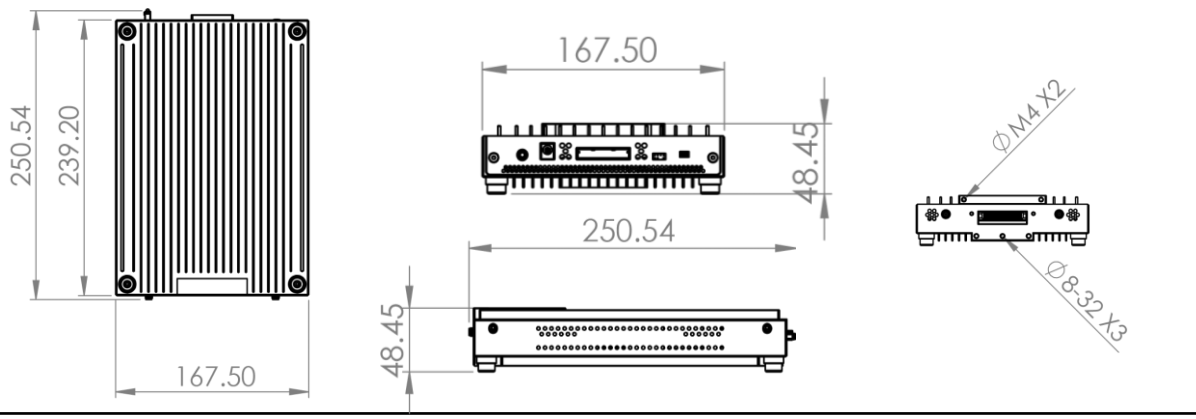
UHSP1K Optical Head



Liquid Cooled Optical Head

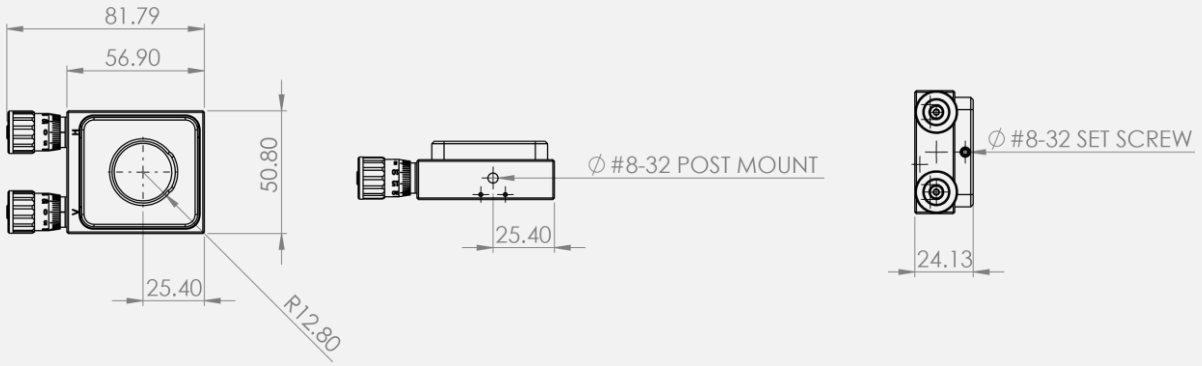


PCIe Controller

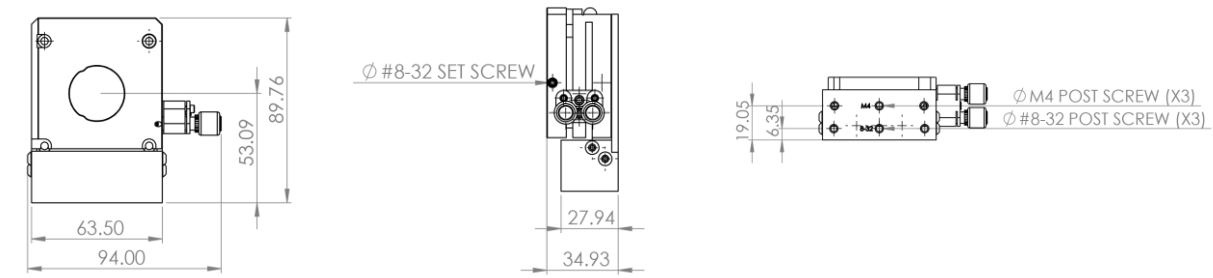


Tip/Tilt Stage Dimensions

VM1 Tip/Tilt Stage



Siskiyou Tip/Tilt Stage

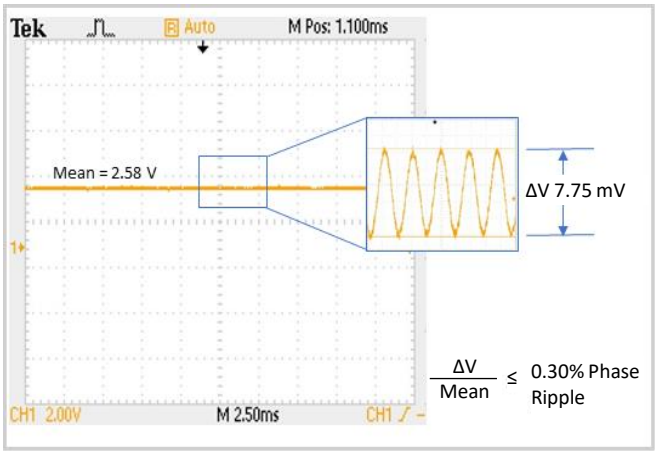


Spatial Light Modulator – 1920 x 1200

E-Series: Educational, Economical & Entry-level

Meadowlark Optics is pleased to introduce our latest E-Series Spatial Light Modulator (SLM). Don't let the name fool you; with improved specifications over our previous model, it is anything but entry-level. It is, however, economical and ideally suited for educational labs with a limited budget. Liquid Crystal on Silicon (LCoS) Spatial Light Modulators (SLMs) are uniquely designed for pure phase applications and incorporate analog data addressing with high refresh rates. This combination provides users with the fastest response times and highest phase stabilities commercially available. Meadowlark offers both transmissive and reflective SLMs in either one- or two-dimensions. Phase-only SLMs can also be used for amplitude-only or a combination of both.

High Phase Stability - Meadowlark Optics is known for having the fastest SLMs with the least amount of phase ripple on the market. Our backplanes are custom designed with high refresh rates and direct analog drive schemes, resulting in phase ripple for most configurations between 0.10 – 0.30%, with some configurations around 1 – 2%. For customers who require even better performance, customization is possible with phase ripple as low as 0.025% (0.0008 π radians). Phase ripple is quantified by measuring the variation in intensity of the 1st order diffracted spot as compared to the mean intensity while writing a blazed phase grating to the SLM.



1st order Intensity when writing a phase ramp to the SLM

Hardware Interface Options -

The 1920 x 1200 SLM is offered with a 60 Hz HDMI Controller enabling customers to take advantage of our fast liquid crystal response times. Standard hardware includes output trigger for synchronization.

SLM Features

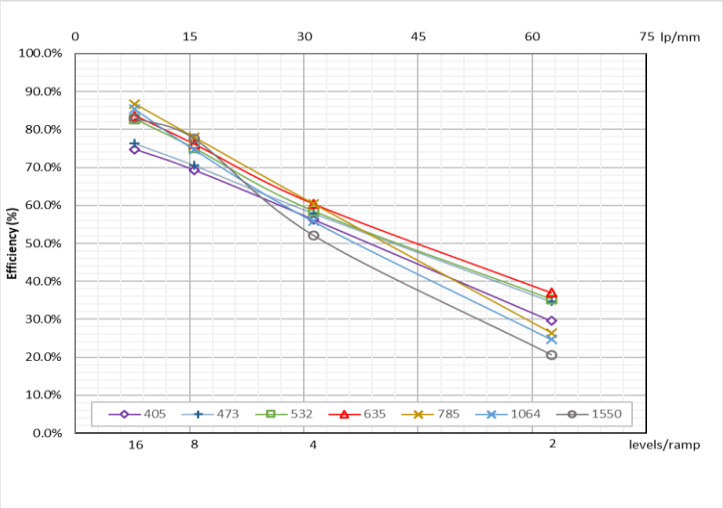
- High resolution
- High Phase Stability
- Pure analog phase control
- High first order efficiency
- High reflectivity
- High power handling
- Compact design
- Wavelengths from 400-1650 nm

Software Features

- Output Trigger
- Image Generation
- Automated Sequencing
- Wavefront Calibration
- Global and Regional Look Up Tables

Diffraction Efficiency (1st-order) -

This is the percentage of light measured in the 1st-order when writing a linear repeating phase ramp to the SLM as compared to the light in the 0th order when no pattern is written to the SLM. Diffraction efficiency varies as a function of the number of phase levels in the phase ramp. The plot to the right shows sample 1st order diffraction efficiency measurements, as a function of the phase ramp period, taken at various wavelengths.

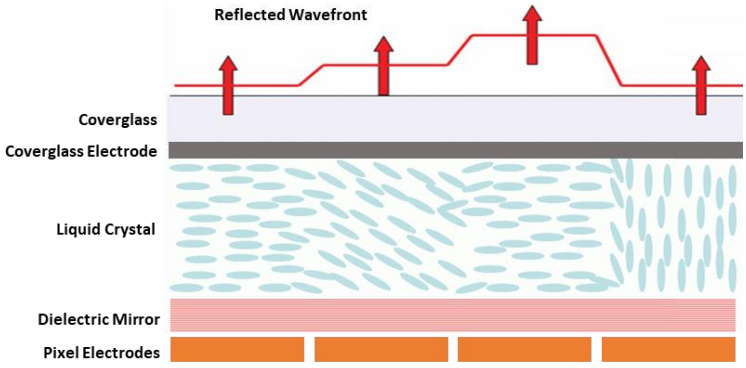


Diffraction Efficiency (0th-order)

This is the amount of light measured in the 0th-order (dc) when the SLM is written with various solid gray levels as a percentage of the amount of light measured when the SLM is replaced with a reference mirror. Therefore, it takes into account losses in transmission through the coatings on the SLM cover window, as well as diffraction losses due to the pixel pads being less than 100% fill-factor. In addition to these losses, this measurement also accounts for losses due to imperfect reflectivity of the aluminum pixel mirrors, or in the case of a dielectric mirror coated model the measurement accounts for losses due to imperfect reflectivity of this dielectric mirror coating. The 0th-order diffraction efficiency will vary as a function of wavelength due to differences in coating materials and designs. It will also vary with pixel value due to the inherent change in the index of refraction of the liquid crystal that results in a change in the Fresnel reflections inside the liquid crystal cell. Most standard SLMs will range from 70 – 90%, while the dielectric mirror coated models will range from 92 – 98%.

High Efficiency Dielectric Mirror Coating

All the light reflecting off the SLM is modulated – including the light between the aluminum pixel electrodes. The reflective pixel structure associated with a LCoS SLM backplane acts as an amplitude grating diffracts some light into higher orders. Optically, the active area of the backplane is converted into a flat dielectric mirror by depositing dielectric layers to eliminate the amplitude and optical path variations associated with the underlying aluminum pixel structure. The dielectric stack is kept thin to minimize any drop in electric field across the LC layer as shown in the figure below. In other words, there are no abrupt changes in phase modulation (such as dead zones) between pixels due to the smoothing which results from separating the LC modulator from the driving electrodes.



1920 x 1200 Analog Spatial Light Modulator

Resolution: 1920 x 1200
Array Size: 15.36 x 9.60 mm
Pixel Pitch: 8.0 x 8.0 µm
Backplane Refresh: 1.35 kHz

Fill Factor: 95.6%
0th Order Diffraction Efficiency: 76 - 91%
0th Order Diffraction Efficiency: 92 – 98% (dielectric mirror)
Controller: HDMI

Standard Calibration Wavelengths	STANDARD SPEED Liquid Crystal Response Time			Calibrated Wavefront Distortion
	AR Coating Range 350 – 850 nm	AR Coating Range 500 – 1200 nm	AR Coating Range 850 – 1650 nm	
405 nm	≤ 13.4 ms			λ/5
532 nm	≤ 14.0 ms	≤ 17.0 ms	–	λ/7
635 nm	≤ 14.5 ms	≤ 17.5 ms	–	λ/8
785 nm	≤ 20.5 ms	≤ 22.5 ms	–	λ/10
1064 nm	–	≤ 25.0 ms	≤ 27.5 ms	λ/10
1550 nm	–	≤ 43.0 ms	≤ 45.0 ms	λ/12

Model Number Guide:

EDM-19x12-488-850-HDM8-WCS1

- EDM: Economical
- HDM8: Dielectric Mirror (optional)
- 19x12: Resolution
- 488-850: Wavelength Range
- WCS1: Controller Type
- Temperature Control (optional)

Software - Meadowlark Optics' SLMs are supplied with a Graphical User Interface and software development kits that support LabVIEW, Matlab, Python and C++. The software allows the user to generate images, to correct aberrations, to calibrate the global and/or regional optical response over 'n' waves of modulation, to sequence at a user defined frame rate, and to monitor the SLM temperature.

Global or Regional Calibrations - Regional calibrations provide the highest spatial phase fidelity commercially available by regionally characterizing the phase response to voltage and calibrating on a pixel-by-pixel basis.

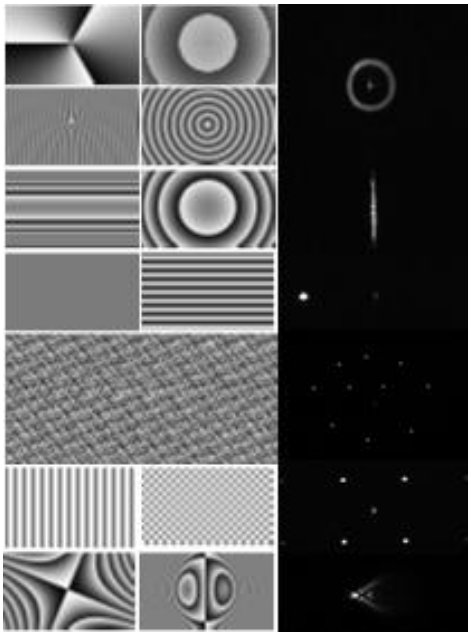
Image Generation Capabilities

Bessel Beams: Spiral Phase, Fork, Concentric Rings, Axicons

Lens Functions: Cylindrical, Spherical

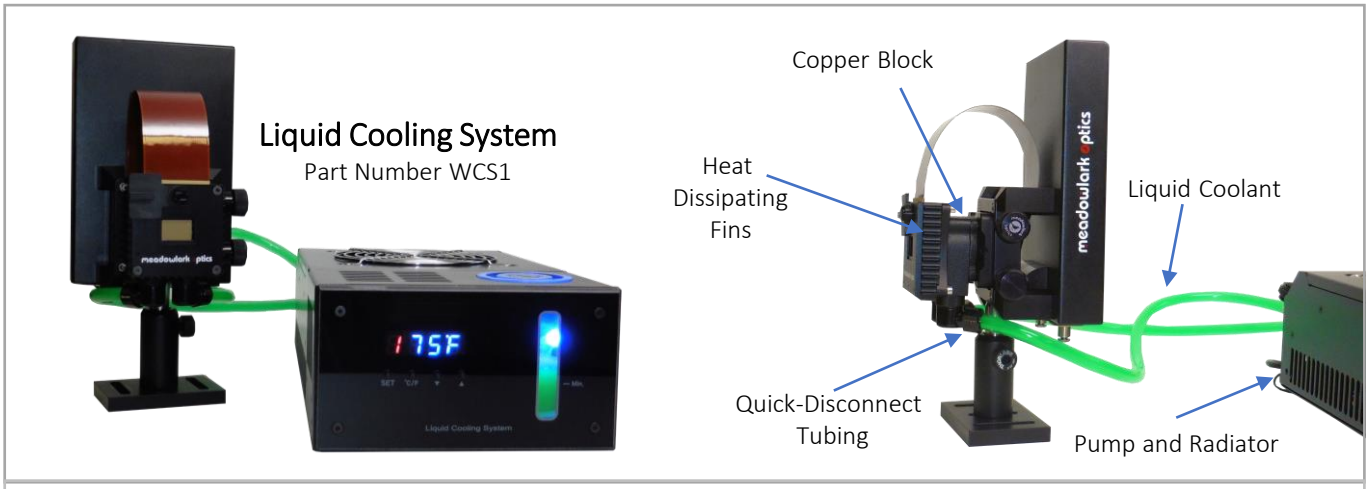
Gratings: Blazed, Sinusoid

Diffraction Patterns: Stripes, Checkerboard, Solid, Random Phase, Holograms, Zernike Polynomials, Superimpose Images

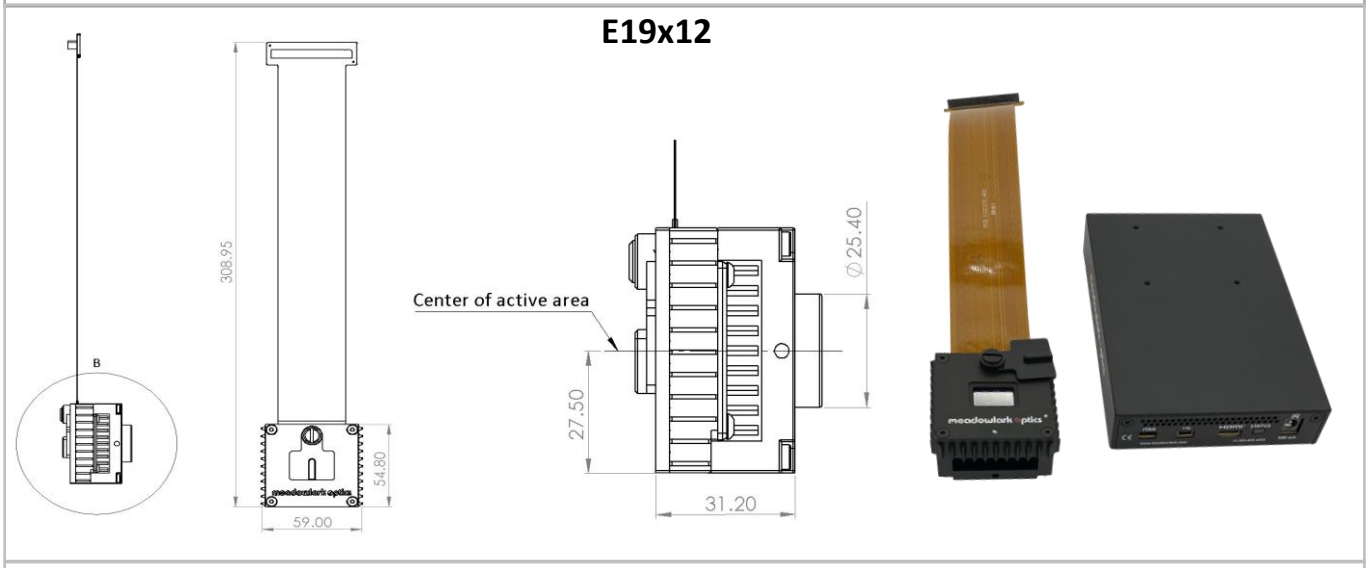


Spatial Light Modulator System Add-ons -

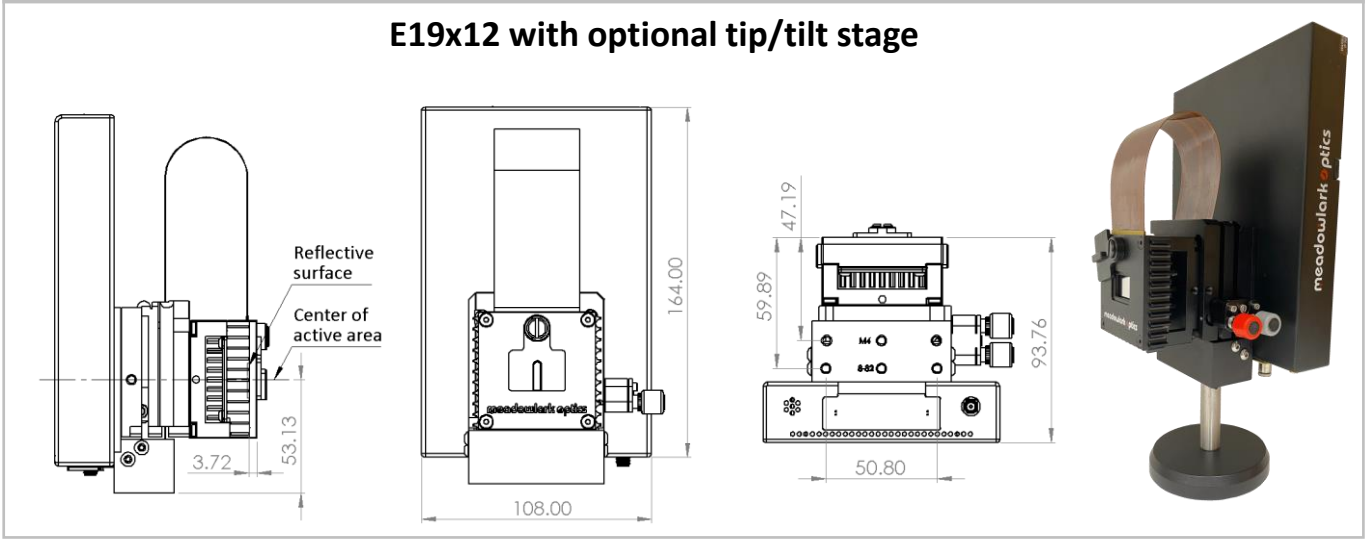
Liquid Cooling System - A copper block is attached to the back of the optical head to draw heat out of the SLM chip. The copper block is coupled via 2 meters of quick-disconnect tubing to cooling unit containing an external pump, radiator, and fan to cool the liquid down to ambient temperature. Includes one bottle of liquid coolant.



E19x12



E19x12 with optional tip/tilt stage

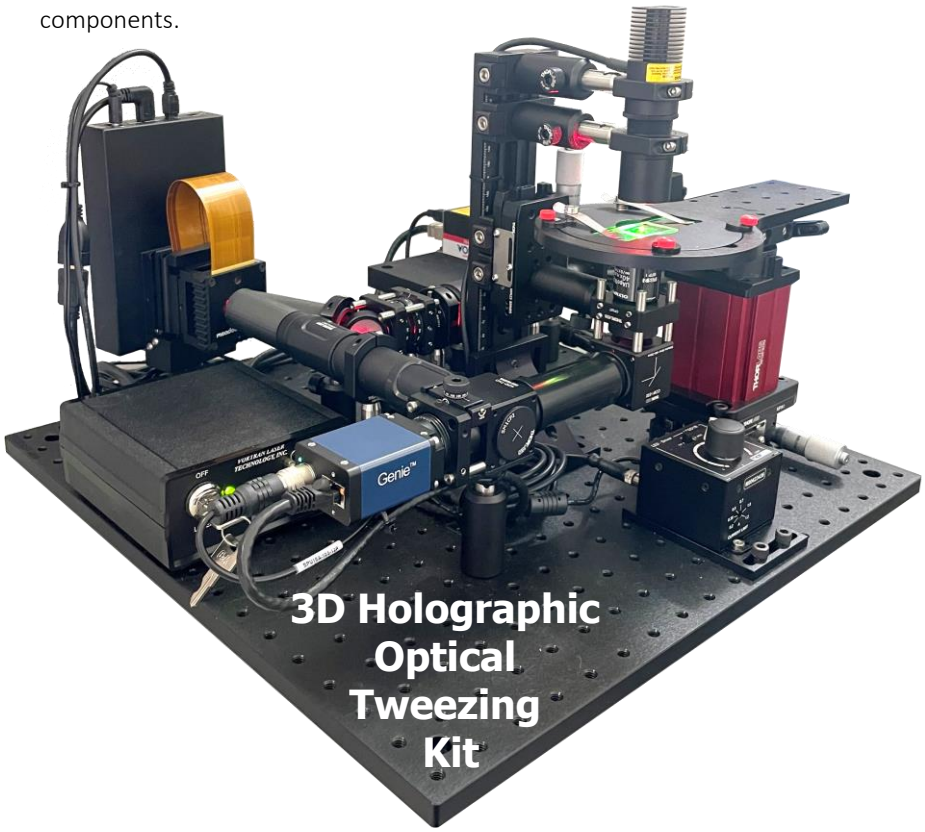


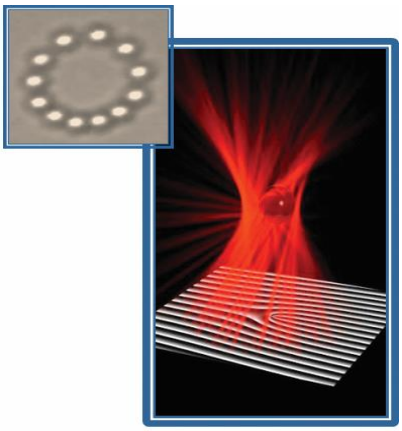
Spatial Light Modulator
3D Holographic Optical Tweezing Kit

Introduction

Optical tweezing can be used to manipulate objects ranging in size from 10's of nanometers to 10's of microns and objects with a variety of material characteristics. Trapping examples include cellular organisms, dielectric spheres, metallic spheres, metallic nanoshells, carbon nanotubes, air bubbles, and even water droplets in air.

The Meadowlark Optics' Optical Tweezing Kit provides researchers with a portable, stand-alone, optical tweezing platform as well as a simple to use graphical user interface (GUI) and software development kit to enable customization, calibration, and computations without requiring in-depth knowledge of tweezing theory. Thus, the default configuration allows a user to quickly and easily manipulate microscopic objects in three dimensions (3D) using the provided GUI and pre-built optical system. The accessible design allows for hassle-free customization allowing users to easily add or remove components.





Key Features

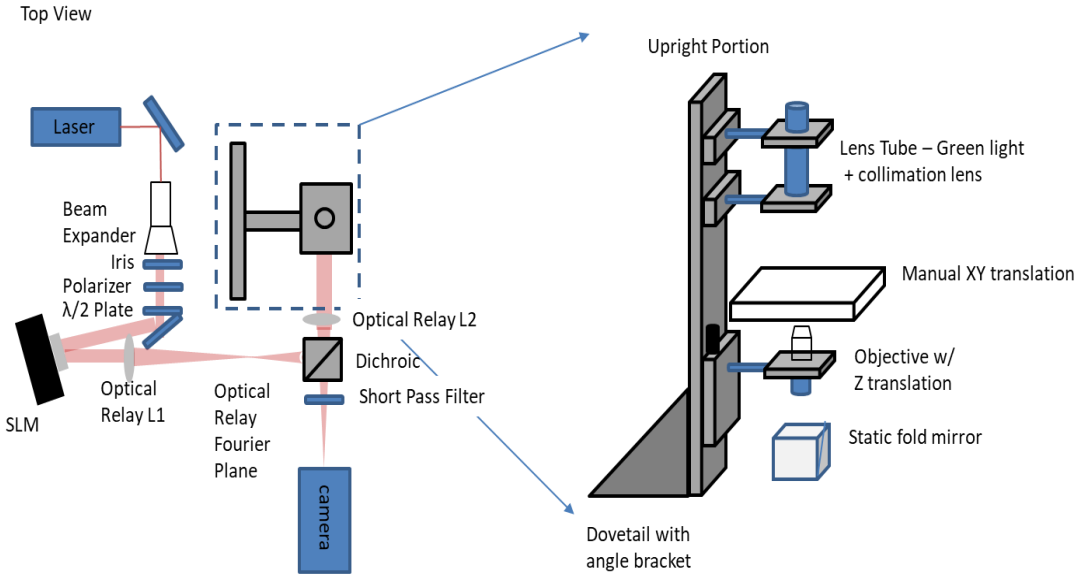
- Complete Optical Tweezing Kit using high resolution 1920 x 1200 SLM
- Custom software to create Holographic Optical Traps
- 3D Particle Manipulation using Holographic Beam Control
- High Temporal Trap Stability
- Spatially Uniform Trapping across 312 x 312-micron field of view

Optical Components

- 1920 x 1200 Spatial Light Modulator
- Camera
- Laser
- Translation Stage
- Oil immersion objective
- Breadboard
- Lenses
- Mirrors
- Polarizers
- All mounting hardware

KEY TRAPPING FEATURES

- Traps can be moved interactively and independently in 3 dimensions
- High-speed Spatial Light Modulator operation increases closed-loop trapping and tracking stability.
- Clearly defined optical design, and accessible implementation make the system ideal for customization.
- Enclosed lens tubes with side ports allow a user to check how light is propagating through the optical system, while simultaneously keeping optics dust-free and the system eye-safe.

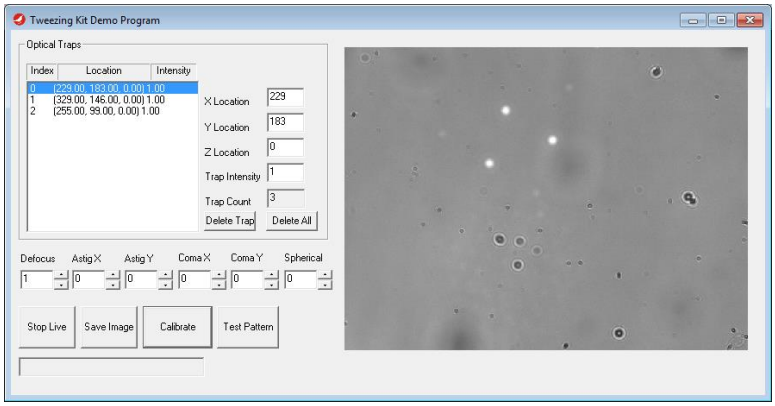


IMAGING

- Bright-field imaging over a large field of view (FOV) of 120 x 90 µm, effective pixel size of 200 nm (depends on microscope objective/camera).
- Magnification and image size optimized to camera chip size with interchangeable relay optics.
- 640 x 480 camera images at 300 frames per second (fps) full-field, up to 3000 fps for one or two beads.

TWEEZING SOFTWARE FEATURES

- GUI with dynamic control of trap number, size, position
- Aberration correction included
- Included SDK functions enable custom software development by computing holograms, as well as computing and applying Affine transformations to co-align camera and tweezing coordinates. SDK functions are compatible with C++, LabVIEW, Matlab, and Python



OPTICAL DESIGN

- 1920 x 1200 Spatial Light Modulator
- Laser, 160 mW at 639 nm
- High NA (1.35) 40x oil immersion microscope objective
- Dichroic beamsplitter directs >90% of 400-870 nm light to camera port
- Minimal moving parts to maximize stability (no floating table required)

PORTABILITY

- Fully enclosed laser beam path allows its use outside of laser labs
- All alignment controls are accessible with laser shielding in place
- Optics come mounted on an 18 x 18-inch breadboard

1920 x 1200 SLM SYSTEM

We recognize researchers may want to use the SLM in multiple experiments. The 3D Holographic Optical Tweezing platform was designed with this in mind. Users can simply remove the SLM from it's post and add it to any other optical setup.

1920 x 1200 SLM System for Optical Tweezing Kit

1920 x 1200 Analog Spatial Light Modulator Specifications

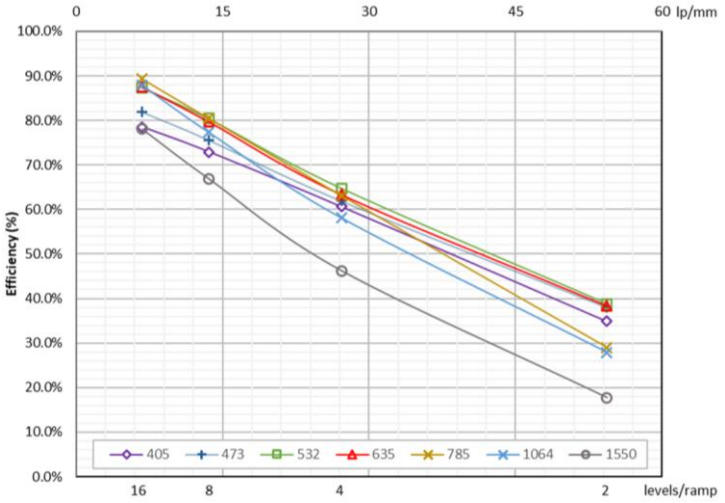
Resolution: 1920 x 1200 **Array Size:** 15.36 x 9.60 mm **Phase Ripple:** 0.10 – 0.30% (custom as low as 0.025%)

Fill Factor: 95.6% **Pixel Pitch**: 8.0 x 8.0 µm **Controller:** HDMI 8-bit

Standard Speed System - Standard Liquid Crystal with HDMI Controller

Specify Calibration Wavelength	Wavefront Distortion	LC Response Time / System Frame Rate	AR Coatings (Ravg <1%)	0th-order Diffraction Efficiency (varies with pixel value)	Reference this Model Number when Ordering
405 nm	λ/3	13.4 ms / 60 Hz	400 – 850 nm	83 – 90%	
473 nm	λ/4	13.7 ms / 60 Hz	400 – 850 nm	84 – 90%	
532 nm	λ/5	14.0 ms / 60 Hz	400 – 850 nm	80 – 88%	**Model E19x12-400-700-HDMI**
635 nm	λ/6	14.5 ms / 60 Hz	400 – 850 nm or 500 – 1200 nm	84 – 89%	
785 nm	λ/7	20.5 ms / 30 Hz	500 – 1200 nm	76 – 79%	**Model E19x12-500-1200-HDMI**
1064 nm	λ/10	25 ms / 30 Hz	500 – 1200 nm or 850 – 1650 nm	85 – 88%	
1550 nm	λ/12	45 ms / 15 Hz	850 – 1650 nm	85 – 91%	**Model E19x12-850-1650-HDMI**

Diffraction Efficiency (1st-order) - This is the percentage of light measured in the 1st-order when writing a linear repeating phase ramp to the SLM as compared to the light in the 0th order when no pattern is written to the SLM. Diffraction efficiency varies as a function of the number of phase levels in the phase ramp. The plot to the right shows sample 1st order diffraction efficiency measurements, as a function of the phase ramp period, taken at various wavelengths.



Software - Meadowlark Optics' SLMs are supplied with a Graphical User Interface and software development kits that support LabVIEW, Matlab, Python and C++. The software allows the user to generate images, to correct aberrations, to calibrate the global and/or regional optical response over 'n' waves of modulation, to sequence at a user defined frame rate, and to monitor the SLM temperature.

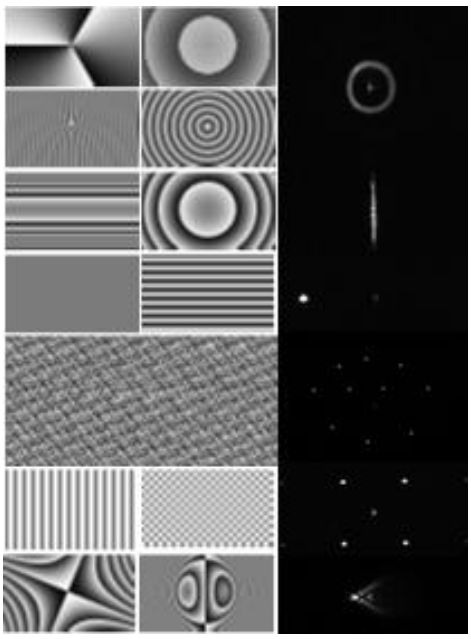


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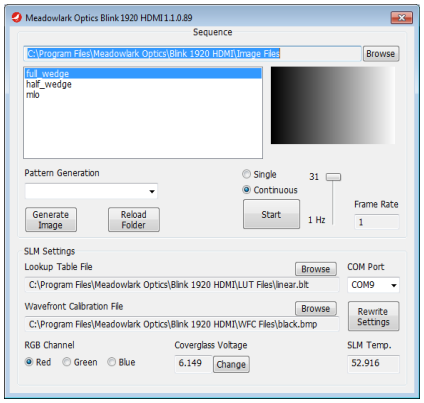
Image Generation Capabilities

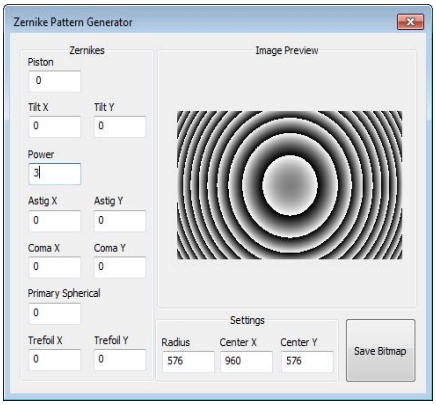
Bessel Beams: Spiral Phase, Fork, Concentric Rings, Axicons

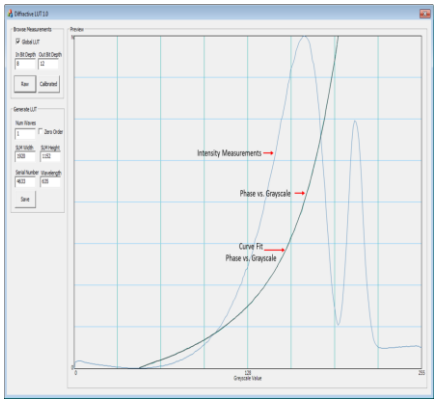
Lens Functions: Cylindrical, Spherical

Gratings: Blazed, Sinusoid

Diffraction Patterns: Stripes, Checkerboard, Solid, Random Phase, Holograms, Zernike Polynomials, Superimpose Images







Waveplates

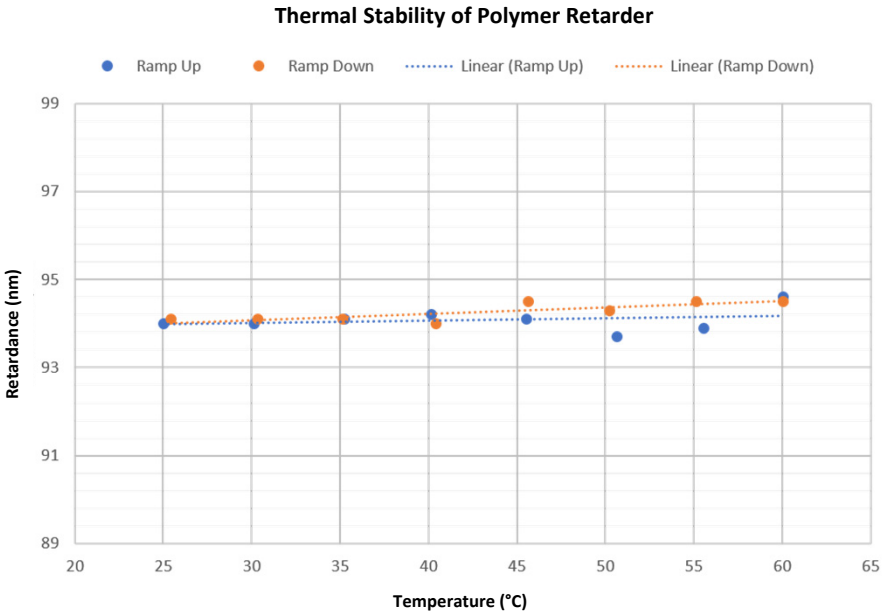
Polymer Film Retarders

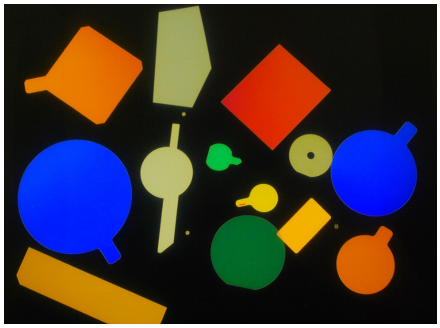
Meadowlark Optics is pleased to present our Bare Polymer Film Retarder. Our proprietary polymer film provides high retardance accuracy in a cost effective product which can be provided in almost any configuration and quantity. The temperature dependence of the nominal retardance is approximately 0.01%/°C, which provides a very stable and versatile polarization solution.

Manufactured in-house for wavelengths between 400 and 1800 nm, this retarder is ideal for applications requiring a high precision, thin and cost effective solution. We are also able to tune the retardance to your Angle of Incidence to optimize performance. AR coatings are available on a special order basis.

Standard shapes and retardance values are available when quick turn-around is needed. We can also accommodate requests for custom shapes sizes (up to 4 inches) and retardance values.

Please contact a Meadowlark Optics Sales Engineer for assistance with your custom requirements.





Key Features

- Very thin profile
- Thermally stable
- High volume scalable
- AR coatings available
- Custom retardance available

Waveplate Suite

- Precision Retarder
- Precision Achromatic Retarder
- Precision Superachromatic Retarder
- Dual-Wavelength Retarder
- Wide Field Retarder
- Liquid Crystal Variable Retarder
- Polymer Film Retarder
- Raptor Applied Polymer Retarder
- Large Aperture Retarder
- Bi-Crystalline Achromatic Retarder

SPECIFICATIONS	
Substrate Material	Polymer Film
Thickness	0.005 inch (127 mm), nominal
Wavelength Range	400 – 1800 nm
Retardance Ranges **Single Layer** **Double Layer**	20 – 1600 nm 1600 – 3000 nm
Reflectance	~4% per surface
Retardance Variation	≤ 2%/inch
Retardance Accuracy	± λ/300
Acceptance Angle	± 6˚
Transmitted Wavefront Distortion **(per inch)**	≤ 2λ (P-V @ 633) ≤ λ/2 (RMS @ 633)
Surface Quality	80 – 50 scratch-dig
Beam Deviation	≤ 30 arc sec
Operating Temperature	-40˚C to +60˚C

ORDERING INFORMATION

Round		
Dimensions in. (mm)	***Clear Aperture in. (mm)***	***Part Number***
Ø0.50 (12.7 mm)	0.45 (11.43 mm)	λ/4 Wave: BQ – 050 – λ λ/2 Wave: BH – 050 – λ
Ø1.00 (25.4 mm)	0.90 (22.86 mm)	λ/4 Wave: BQ – 100 – λ λ/2 Wave: BH – 100 – λ
Ø1.50 (38.1 mm)	1.35 (34.29 mm)	λ/4 Wave: BQ – 150 – λ λ/2 Wave: BH – 150 – λ
Ø2.00 (50.8 mm)	1.80 (45.72 mm)	λ/4 Wave: BQ – 200 – λ λ/2 Wave: BH – 200 – λ
Square		
Dimensions in. (mm)	***Clear Aperture in. (mm)***	***Part Number***
0.50 x 0.50 (12.7 x 12.7)	0.50 x 0.50 (12.7 x 12.7)	λ/4 Wave: BQ – 050x050 – λ λ/2 Wave: BH – 050x050 – λ
1.00 x 1.00 (25.4 x 25.4)	0.90 x 0.90 (22.86 x 22.86)	λ/4 Wave: BQ – 100x100 – λ λ/2 Wave: BH – 100x100 – λ
1.50 x 1.50 (38.1 x 38.1)	1.35 x 1.35 (34.29 x 34.29)	λ/4 Wave: BQ – 150x150 – λ λ/2 Wave: BH – 150x150 – λ
2.00 x 2.00 (50.8 x 50.8)	1.80 x 1.80 (45.72 x 45.72)	λ/4 Wave: BQ – 200x200 – λ λ/2 Wave: BH – 200x200 – λ

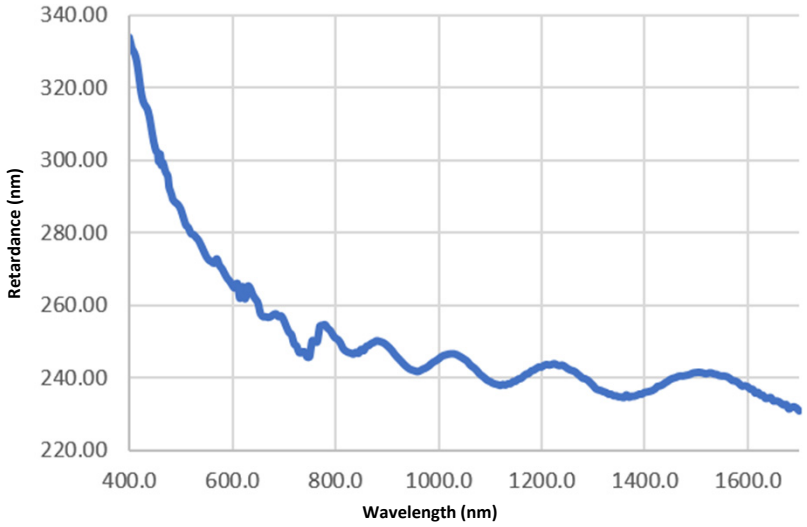
Note: Dimensions are ±0.02

RAPtor Applied Polymer Retarders

Retarder-Applied-Polymer parts are manufactured using a proprietary high birefringent polymer and are true zero order retarders with a typical film thickness less than 10 microns. These parts can be added to customer provided windows and other plano or slightly curved substrates to produce truly custom solutions.

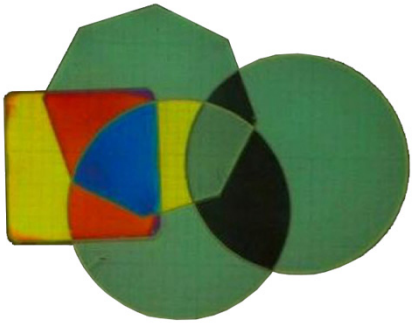
These retarders were originally designed for use in astronomy but have applications wherever a true zero order waveplate would be used. Meadowlark Optics can apply these retarders to substrates from 10 mm to 100 mm diameter (and even larger on a custom basis.)

Actual Retardance Data for a Sample RAPtor Applied Polymer Retarder



Transmission vs. Wavelength

Raptor Retarder films can be applied to your substrates and surfaces. They can be tuned to custom retardance values and are transmissive over a large wavelength range.



Key Features

- Extremely thin and large diameter
- Curved surfaces
- High temperature resistance
- Custom sizes, shapes, wavelengths and retardances available

Waveplate Suite

- Precision Retarder
- Precision Achromatic Retarder
- Precision Superachromatic Retarder
- Dual-Wavelength Retarder
- Wide Field Retarder
- Liquid Crystal Variable Retarder
- Polymer Film Retarder
- Raptor Applied Polymer Retarder
- Large Aperture Retarder
- Bi-Crystalline Achromatic Retarder

SPECIFICATIONS	
Retarder Material	High Birefringence Polymer
Retarder Thickness	< 10 µm**
Substrate Thickness	1.1 mm fused silica
Wavelength Range and Retardance	400 – 1064 nm (λ/2) 400 – 1550 nm (λ/4)
Retardance Accuracy	< ± λ/100
Retardance Uniformity	< λ/100 [<5 nm]
Clear Aperture	80%
Reflectivity (back surface)	≤ 0.5%
Transmitted Wavefront Distortion	≤ λ/2 (P-V @ 633 nm) ≤ λ/8 (RMS @ 633 nm)
Beam Deviation	≤ 5 arc sec
Surface Quality	80-50 scratch-dig
Operating Temperature	-20 °C to 80 °C
Storage Temperature	-40 °C to 80 °C

***exact thickness design dependent*

STOCK ORDERING INFORMATION
(Quarter-Wave and Half-Wave parts)

Diameter in. (mm)	*Clear Aperture in. (mm)*	*Part Number*
Ø1.00 in. (25.4 mm)	Ø0.9 in. (22.9 mm)	PQ – 100 – λ PH – 100 – λ
Ø2.00 in. (50.8 mm)	Ø1.8 in. (45.7 mm)	-200 – λ PH – 200 – λ

CUSTOM DESIGN

Wavelength Range	350 – 3300 nm
Retardance Accuracy	< ± λ/200
Dimensions	Up to 150 mm diameter
Fast Axis Datum / Orientation	Customer specified
Substrate material/geometry/thickness	Customer specified

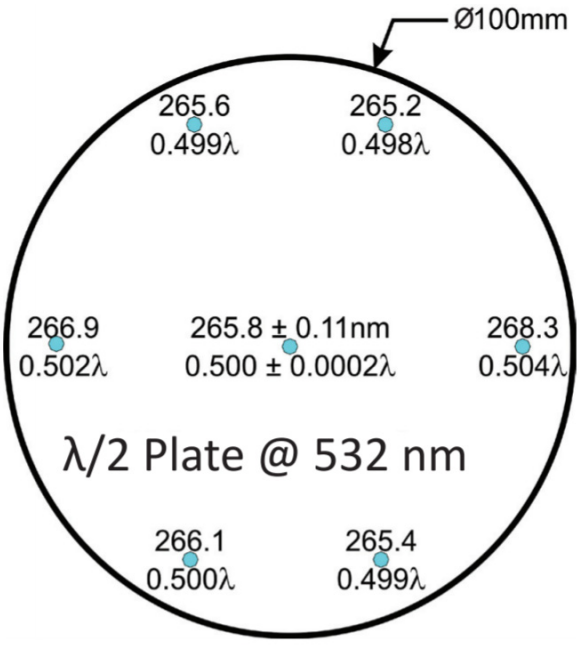
Large Aperture Retarder

For many astronomical, aerospace, and defense projects, large aperture retarders are required. Meadowlark Optics has over thirty-five years of retarder manufacturing expertise and is able to manufacture from a wide variety of materials to facilitate high or low power applications.

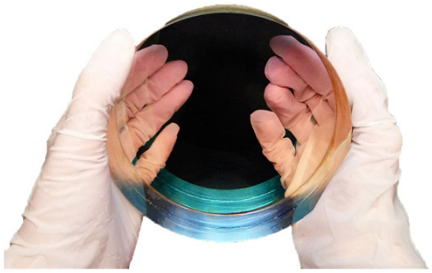
Waveplates up to 150 mm diameter are available. Some materials allow retarders to be used over different wavelengths from the ultraviolet, through the visible and into the near infrared.

Meadowlark Optics uses proprietary methods to ensure the best spatial uniformity of its polymer and crystalline retarders. These retarders have a spatial uniformity of better than two percent across the clear aperture and with the correct substrates, can have a wavefront distortion that is on par with Meadowlark Optics' Precision Retarders.

Meadowlark Optic's liquid crystal variable retarders can also be built with large clear apertures. Please contact your Meadowlark Optics Sales Engineer for assistance and a custom quote.



Actual spatial retardance data from a 100mm Large Aperture Retarder



Key Features

- Outer diameter up to 6 inches
- Clear aperture > 90%
- Custom size retardance and wavelength range available
- Spatial uniformity less than 2% across clear aperture
- Various materials available: (polymer, quartz, sapphire, magnesium fluoride, liquid crystal)
- Less than 15mm Thickness
- True Zero-Order
- Broad Wavelength ranges

Waveplate Suite

- Precision Retarder
- Precision Achromatic Retarder
- Precision Superachromatic Retarder
- Dual-Wavelength Retarder
- Wide Field Retarder
- Liquid Crystal Variable Retarder
- Polymer Film Retarder
- Raptor Applied Polymer Retarder
- Large Aperture Retarder
- Bi-Crystalline Achromatic Retarder

SPECIFICATIONS	
Retarder (Birefringent) Material Options	Polymer Crystalline Quartz Magnesium Fluoride Sapphire Liquid Crystal†
Wavelength	300-2500 nm (please specify)
Retardances	0 to 100s of λ
Retardance Accuracy	
Center **Spatial Uniformity**	≤ λ/100 to ≤ λ/350 ≤ λ/10 to ≤ λ/100
Transmitted Wavefront Distortion	≤ λ to ≤ λ/5 (P-V @ 633) λ/4 to λ/20 (RMS @ 633)]
Surface Quality	40 – 20 scratch-dig to 80 – 50 scratch-dig
Outside Dimensions	Up to 150 mm

Large Aperture retarders are available in a variety of different sizes and shapes with custom retardances at specific wavelengths. Combinations of different materials allow custom achromatic, athermal or wide angle designs. Please contact your Meadowlark Optics Sales Engineer for a custom quote.

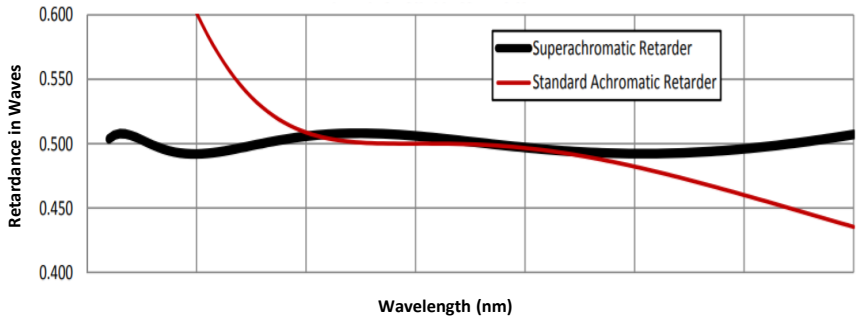
Precision Superachromatic Retarder

Meadowlark Optics is proud to offer our Precision Superachromatic Retarder—with the broadest wavelength coverage of our entire retarder product line. These are available standard for two wavelength ranges; 420 to 1100 nm, and 800 to 1700 nm. Both quarter and half wave retardances available as standard options. Custom devices are available for other wavelength ranges and retardances. Stock items are not anti-reflection coated due to the broad wavelength coverage but custom coatings can be provided.

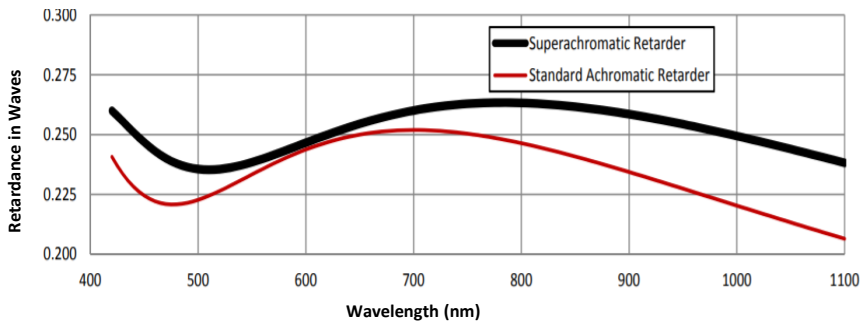
The Superachromatic Retarders contain carefully aligned birefringent polymer sheets laminated between precision polished optically flat N-BK7 windows. While assembly is quite similar to that of our Precision Retarders, optical transmission is slightly reduced because there are more polymer layers and there is no anti-reflection coating.

These retarders are accurate to ±λ/50 over the entire wavelength range; we ship retardance measurements at more than 25 wavelengths accurate to ±0.001 waves with every Precision Superachromatic Retarder.

Half Wave Retardance – VIS to NIR



Quarter Wave Retardance – VIS to NIR

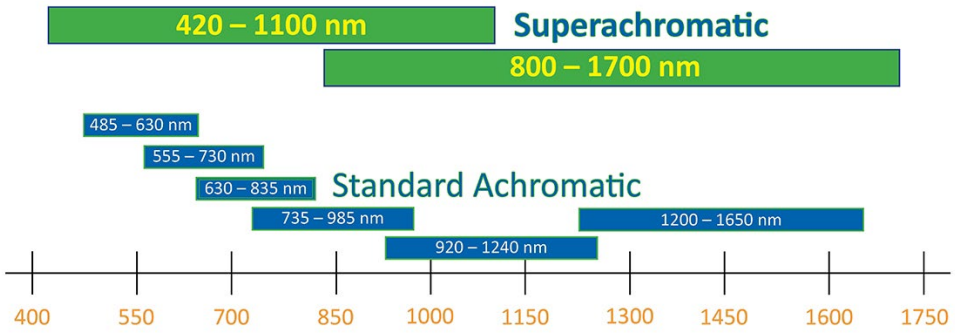


Key Features

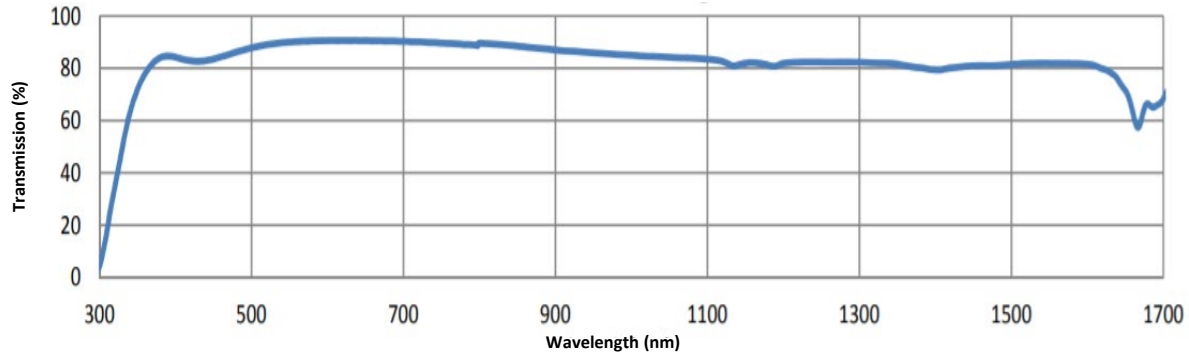
- Ultra-broadband wavelength range
- 420 to 1100 nm and 800 to 1700 nm
- Custom wavelength ranges available
- Custom retardances available
- Superior field of view

Waveplate Suite

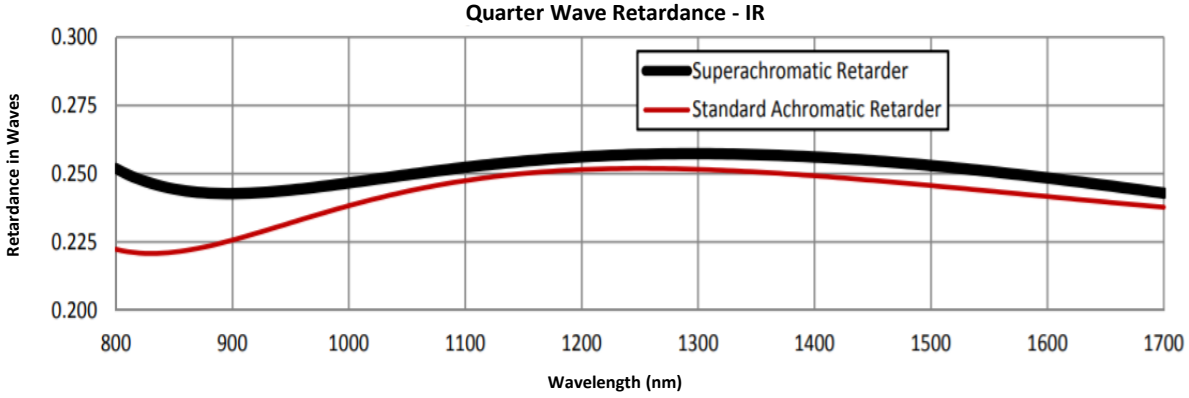
- Precision Retarder
- Precision Achromatic Retarder
- Precision Superachromatic Retarder
- Dual-Wavelength Retarder
- Wide Field Retarder
- Liquid Crystal Variable Retarder
- Polymer Film Retarder
- Raptor Applied Polymer Retarder
- Large Aperture Retarder
- Bi-Crystalline Achromatic Retarder



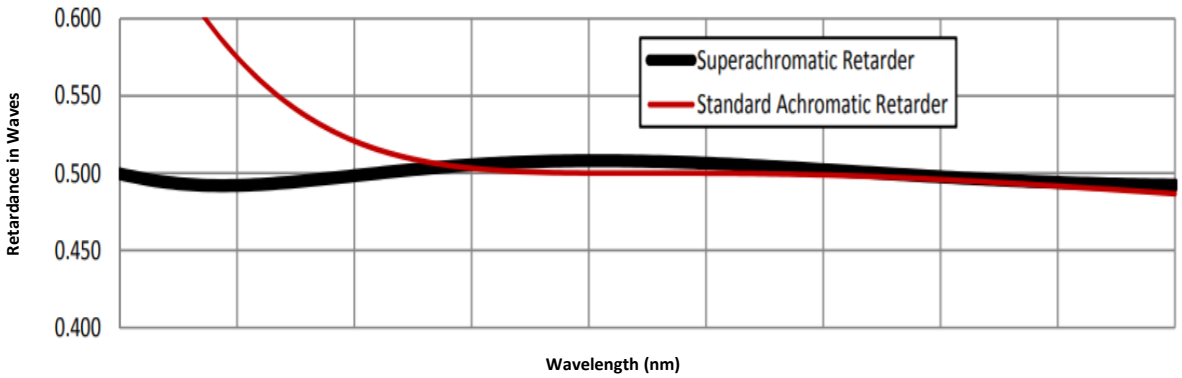
Superachromatic Retarder Transmission



Quarter Wave Retardance - IR



Half Wave Retardance - IR



ORDERING INFORMATION

Mounted					
Diameter ±0.005 in. (±0.13 mm)	***Clear Aperture in. (mm)***	***Thickness ±0.020 in. (±0.51 mm)***	***Wavelength Range (nm)***	***λ/4 Part #***	***λ/2 Part #***
1.00 (25.40)	0.70 (17.80)	0.36 (9.10)	420 – 1100 nm	AQM – 100S	AHM – 100S
1.00 (25.40)	0.70 (17.80)	0.36 (9.10)	800 – 1700 nm	AQM – 100L	AHM – 100L
2.00 (50.80)	1.20 (30.50)	0.50 (12.70)	420 – 1100 nm	AQM – 200S	AHM – 200S
2.00 (50.80)	1.20 (30.50)	0.50 (12.70)	800 – 1700 nm	AQM – 200L	AHM – 200L
Unmounted					
Diameter ±0.010 in. (±0.25 mm)	***Clear Aperture in. (mm)***	***Thickness ±0.020 in. (±0.51 mm)***	***Wavelength Range (nm)***	***λ/4 Part #***	***λ/2 Part #***
1.00 (25.40)	0.80 (20.30)	0.27 (6.90)	420 – 1100 nm	AQ – 100S	AH – 100S
1.00 (25.40)	0.80 (20.30)	0.27 (6.90)	800 – 1700 nm	AQ – 100L	AH – 100L
2.00 (50.80)	1.60 (40.60)	0.51 (13.00)	420 – 1100 nm	AQ – 200S	AH – 200S
2.00 (50.80)	1.60 (40.60)	0.51 (13.00)	800 – 1700 nm	AQ – 200L	AH – 200L

Custom sizes and retardances are available. Please contact your sales engineer for assistance.

SPECIFICATIONS

Retarder Material	Birefringent Polymer
Substrate Material	N-BK7
Wavelength Ranges	420 – 1100 nm 800 – 1700 nm
TWD (1.00 in.)	λ/2 (P-V@633 nm)
Retardance Accuracy	≤λ/50
Acceptance Angle	±10˚
Surface Quality	40 – 20 scratch-dig
Beam Deviation	≤ 2 arc-min
Temperature Range	-20˚C to +50˚C (Operating)
Laser Damage Threshold	500 W/cm^2, CW 300 mJ/cm^2, 10 ns, visible 500 mJ/cm^2, 10 ns, 1064 nm

Precision Retarder

Meadowlark Optics specializes in precision polymer retarders for the visible to near infrared region. Our Precision Retarders have the highest optical quality and tightest retardance tolerance of all polymer retarders. These true zero-order Precision Retarders consist of a birefringent polymer cemented between two precision polished, optically flat BK 7 windows. The retarder fast axis is conveniently marked for quick and easy reference.

Precision Retarders are supplied with a broadband antireflection coating. Optical transmittance of a Precision Retarder is typically greater than 97%. The retardance δ at a wavelength λ that is different from the center wavelength λc is given by:

$$\delta \approx \delta c(\lambda c / \lambda)$$

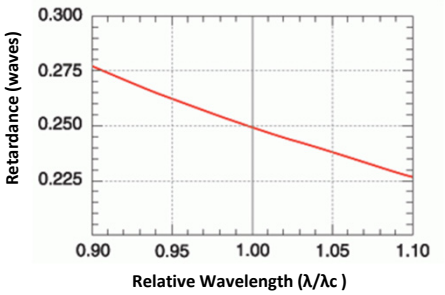
where δc is the retardance at λc.

This relationship is very important when using sources which vary in wavelength from their nominal value. The 2 graphs show the retardance behavior as a function of relative wavelength for a quarter- and half-wave retarder, respectively. The Mueller calculus can be used to calculate the transmitted polarization state based upon the retardance differences from the ideal case.

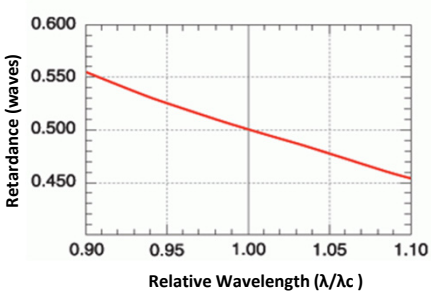
Since polymer retarders are true zero-order devices, they offer the significant advantage of improved angular performance. You can expect less than 1% retardance change over ±10° incidence angle.

Meadowlark Optics has developed precision ellipsometric techniques that can measure retardance to λ/1000.Our metrology for these measurements is the best in the industry. You can have absolute confidence that the calibration measurements supplied with your retarder are of the highest accuracy obtainable.

Quarter-Wave Precision Retarder Performance



Half-Wave Precision Retarder Performance



Key Features

- True zero-order retarders
- Excellent off-axis performance
- Unequaled measured accuracy
- Less temperature dependence than quartz waveplates
- Lower cost than compound zero-order waveplates
- Better angular acceptance than compound zero-order quartz waveplates

Waveplate Suite

- Precision Retarder
- Precision Achromatic Retarder
- Precision Superachromatic Retarder
- Dual-Wavelength Retarder
- Wide Field Retarder
- Liquid Crystal Variable Retarder
- Polymer Film Retarder
- Raptor Applied Polymer Retarder
- Large Aperture Retarder
- Bi-Crystalline Achromatic Retarder

SPECIFICATIONS

Retarder Material	Birefringent Polymer
Substrate Material	N-BK7
Stardard Wavelengths	532, 632.8, 670, 780, 850, 1064, and 1550 nm
Custom Wavelengths	400 – 1800 nm (please specify)
Standard Retardances	λ/2 and λ/4
Retardance Accuracy	≤ λ/350
Retardance Change (at 30˚tilt)	≤ λ/32 (Half-Wave) and ≤ λ/59 (Quarter-Wave)
Transmitted Wavefront Distortion	≤ λ/5
Surface Quality (scratch-dig)	40 – 20
Beam Deviation	≤ 1 arc-min
Reflectance (per surface)	≤ 0.5% at normal incidence
Threshold	500 W/cm^2, CW 600 mJ/cm^2, 20 ns, visible 4 J/cm^2, 20 ns, 1064 nm
Operating Temperature Range	20˚C to 50˚C

Custom retardance values and sizes are available.
Please call for a quote.

ORDERING INFORMATION

Mounted			
Clear Aperture in. (mm)	***Dimensions ± 0.005 in. (± 0.13 mm)***	***Thickness ± 0.020 in. (±0.51 mm)***	***Part Number***
Half-Wave			
0.40 (10.2)	Ø1.00 (Ø25.4)	0.25 (6.35)	NHM – 050 – λ
0.70 (17.8)	Ø1.00 (Ø25.4)	0.35 (8.9)	NHM – 100 – λ
1.20 (30.5)	Ø2.00 (Ø50.8)	0.50 (12.7)	NHM – 200 – λ
Quarter-Wave			
0.40 (10.2)	Ø1.00 (Ø25.4)	0.25 (6.35)	NQM – 050 – λ
0.70 (17.8)	Ø1.00 (Ø25.4)	0.35 (8.9)	NQM – 100 – λ
1.20 (30.5)	Ø2.00 (Ø50.8)	0.50 (12.7)	NQM – 200 – λ
Unmounted			
Clear Aperture in. (mm)	***Dimensions +0/-0.010 in. (+0/-0.25 mm)***	***Thickness ± 0.020 in. (± 0.51 mm)***	***Part Number***
Half-Wave			
0.40 (10.2)	Ø0.50 (Ø12.70)	0.13 (3.3)	NH – 050 – λ
0.80 (20.3)	Ø1.00 (Ø25.4)	0.26 (6.3)	NH – 100 – λ
1.60 (40.6)	Ø2.00 (Ø50.8)	0.51 (13.0)	NH – 200 – λ
Quarter-Wave			
0.40 (10.2)	Ø0.50 (Ø12.70)	0.13 (3.3)	NQ – 050 – λ
0.80 (20.3)	Ø1.00 (Ø25.4)	0.26 (6.3)	NQ – 100 – λ
1.60 (40.6)	Ø2.00 (Ø50.8)	0.51 (13.0)	NQ – 200 – λ

Please specify your center wavelength λ in nanometers when ordering. Custom sizes and shapes with improved transmitted wavefront distortion and/or beam deviation are available. Please call for a quote.

Wide Field Retarder

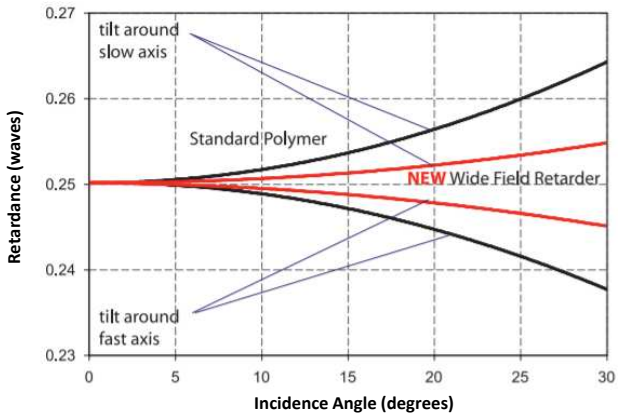
Meadowlark Optics now offers Wide Field Retarders, the latest innovation in near zero-order polymer retarder technology. At their design wavelength, Wide Field Retarders provide a consistent retardance value over a wide acceptance angle, out to 30° or more.

Standard quarter- and half-wave designs are available for common wavelengths in the visible to near infrared region. The graphs show the Wide Field Retarder performance as a function of incidence angle for the both half-wave and quarter-wave designs.

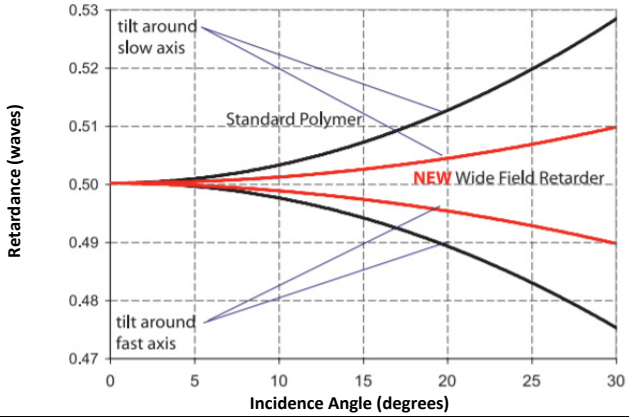
Multilayer broadband antireflection (BBAR) coatings are included as standard. Note that BBAR coating performance varies with incidence angle; these coatings perform best at (or near) normal incidence.

As with all Meadowlark Optics retarders, the fast axis is conveniently marked. Custom retardance values are available for wavelengths from 400-1800 nm. Please call for application assistance or to request a custom quotation.

Quarter-Wave Wide Field Retarder Performance vs. Incidence Angle



Half-Wave Wide Field Retarder Performance vs. Incidence Angle



Key Features

- Unmatched off-axis performance
- Standard and custom wavelength retarders
- Mounted and unmounted versions available
- Off-axis performance ideal for uncollimated light applications

Waveplate Suite

- Precision Retarder
- Precision Achromatic Retarder
- Precision Superachromatic Retarder
- Dual-Wavelength Retarder
- Wide Field Retarder
- Liquid Crystal Variable Retarder
- Polymer Film Retarder
- Raptor Applied Polymer Retarder
- Large Aperture Retarder
- Bi-Crystalline Achromatic Retarder

SPECIFICATIONS

Retarder Material	Birefringent Polymer
Substrate Material	N-BK7
Standard Wavelengths	532, 632.8, 670, 780, 850, 1064, and 1550 nm
Custom Wavelengths	400 – 1800nm (please specify)
Retardance	λ/2 and λ/4
Retardance Accuracy	≤ λ/250 at normal incidence at the center of the part
Retardance Change (at 30˚tilt)	
Half-wave Quarter-wave	≤ λ/100 ≤ λ/200
Transmitted Wavefront Distortion	≤ λ/2
Surface Quality	60 – 40 scratch-dig
Beam Deviation	≤ 1 arc-min
Reflectance (per surface)	
At normal incidence At 30˚ incidence	≤ 0.5% ≤ 1.0%
Operating Temperature	0˚C to 40˚C

ORDERING INFORMATION

Mounted			
Clear Aperture> in. (mm)	***Dimensions ± 0.005 in. (± 0.13 mm)***	***Thickness in. (mm)***	***Part Number***
Quarter Wave			
0.40 (10.2 mm)	Ø1.00 (Ø25.4 mm)	0.25 (6.35 mm)	WQM – 050 – λ
0.70 (17.8 mm)	Ø1.00 (Ø25.4 mm)	0.35 (8.9 mm)	WQM – 100 – λ
Half Wave			
0.40 (10.2 mm)	Ø1.00 (Ø25.4 mm)	0.25 (6.35 mm)	WHM – 050 – λ
0.70 (17.8 mm)	Ø1.00 (Ø25.4 mm)	0.35 (8.9 mm)	WHM – 100 – λ
Unmounted			
Clear Aperture in. (mm)	***Dimensions + 0/-0.010 (+0/-0.25mm)***	***Thickness in. (mm)***	***Part Number***
Quarter Wave			
0.40 (10.2 mm)	Ø0.50 (Ø12.7 mm)	0.14 (3.6 mm)	WFQ – 050 – λ
0.80 (20.3 mm)	Ø1.00 (Ø25.4 mm)	0.28 (7.1 mm)	WFQ – 100 – λ
Half Wave			
0.40 (10.2 mm)	Ø0.50 (Ø12.7 mm)	0.14 (3.6 mm)	WFH – 050 – λ
0.80 (20.3 mm)	Ø1.00 (Ø25.4 mm)	0.28 (7.1 mm)	WFH – 100 – λ

Custom sizes and retardance values are available.
Please contact your Meadowlark Optics sales engineer for a custom quote.

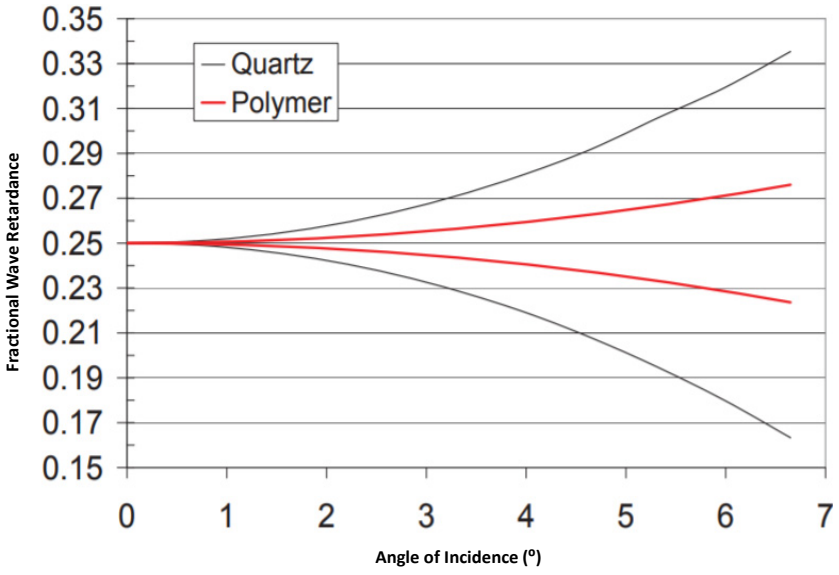
Dual-Wavelength Retarder

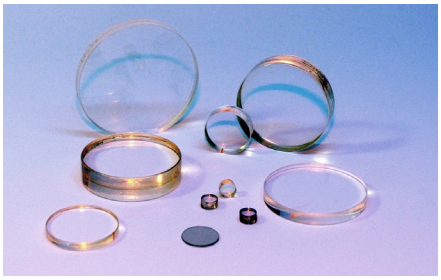
Dual wavelength retarders can provide the same retardance at two wavelengths that are separated in wavelength by more than the span covered by an achromatic retarder. They can also provide different specified retardances at two different wavelengths.

Traditionally these retarders have been made using crystal quartz and are multiorder retarders at both wavelengths. Our dual wavelength retarders use polymers instead. They are usually much lower order and consequently have a slower change in retardance with angle of incidence as shown in the graph. On average the order is about 20% of that for a comparable quartz dual wavelength retarder.

Call for a quote on a custom coating on these normally uncoated retarders. The retardance tolerance is ±0.01waves at both wavelengths. Many custom combinations not listed in the catalog are available. Please call for a quote on your custom requirement. Standard unmounted sizes are 0.50 inches and 1.00 inches.

Dual Wavelength Field of View





Key Features

- Low order
- Wide angular field
- Broad wavelength coverage
- Coated or Uncoated Available
- Mounted or Unmounted Available

Waveplate Suite

- Precision Retarder
- Precision Achromatic Retarder
- Precision Superachromatic Retarder
- Dual-Wavelength Retarder
- Wide Field Retarder
- Liquid Crystal Variable Retarder
- Polymer Film Retarder
- Raptor Applied Polymer Retarder
- Large Aperture Retarder
- Bi-Crystalline Achromatic Retarder

SPECIFICATIONS	
Retarder Material	Birefringent Polymer
Substrate Material	N-BK7
Retardance Accuracy	≤ λ/100 at both wavelengths
Transmitted Wavefront Distortion	≤ λ/4
Beam Deviation	≤ 1 arc-min
Reflectance (per surface)	~ 4% at normal incidence
Storage Temperature	design dependent
Operating Temperature	design dependent

Custom anti-reflection coatings to provide less than 0.5% reflection at both wavelengths are available. Please call your Meadowlark Optics sales engineer for a quote.

ORDERING INFORMATION

Thickness in. (mm)	*Dimensions in. (mm)*	*Part Number*
0.14 (3.6 mm) 0.27 (6.9 mm)	0.50 (Ø12.7 mm) 1.00 (Ø25.4 mm)	D R1 R2 – d – λ1/λ2 D R1 R2 – d – λ1/λ2

R1,R2 = Q for quarter wave, H for half wave
d = Diameter (e.g. -100 is 1" OD)
λ1,λ2 = Design wavelengths. (e.g. -0488 is 488 nm)
DQH-200-λ1,λ2 => 2" Quarter Waveplate @ λ1, Half @ λ2.

Precision Achromatic Retarder

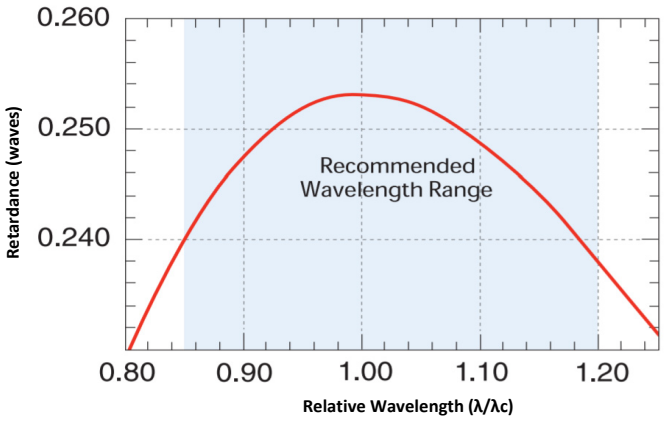
Meadowlark Optics Precision Achromatic Retarders are designed to provide a nearly constant retardance over a broad wavelength region. Standard quarter- and half-wave devices are available for common wavelength regions in the visible and near infrared.

Our Precision Achromatic Retarders consist of carefully aligned birefringent polymer sheets laminated between precision polished, optically flat BK 7 windows. Assembly is quite similar to the assembly of our Precision Retarders.

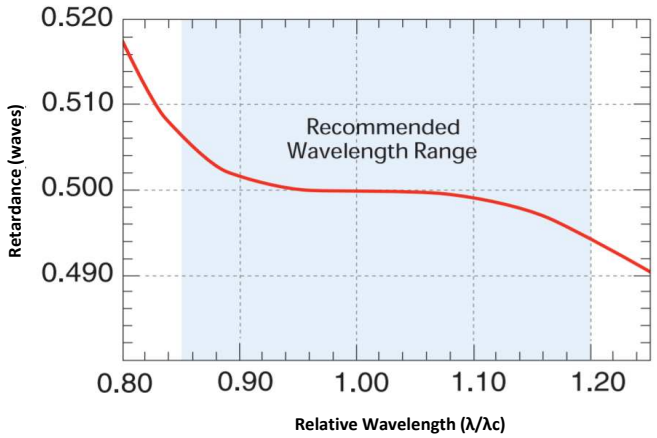
Optical transmittance varies slightly from the Precision Retarder because several polymer layers are used in each Achromatic Retarder.

We provide retardance accurate to λ/100 for all wavelengths in the operating range. Achromatic retarders are an excellent choice for applications requiring broad wavelength use.

Quarter-Wave Achromatic Retarder Performance



Half-wave Achromatic Retarder Performance



Key Features

- Broad spectral range
- Superior field of view
- Thermally Stable
- Custom Wavelengths Available

Waveplate Suite

- Precision Retarder
- Precision Achromatic Retarder
- Precision Superachromatic Retarder
- Dual-Wavelength Retarder
- Wide Field Retarder
- Liquid Crystal Variable Retarder
- Polymer Film Retarder
- Raptor Applied Polymer Retarder
- Large Aperture Retarder
- Bi-Crystalline Achromatic Retarder

SPECIFICATIONS

Retarder Material	Birefringent Polymer
Substrate Material	N-BK7
Standard Wavelengths	
545	(485 – 630 operating range)
630	(555 – 730 operating range)
720	(630 – 835 operating range)
840	(735 – 985 operating range)
1060	(920 – 1240 operating range)
1400	(1200 – 1650 operating range)
Custom Wavelengths	400 – 1800 nm (please specify)
Retardance	λ/4 and λ/2
Retardance Accuracy	≤ λ/100
Transmitted Wavefront Distortion	≤ λ/4
Surface Quality (scratch-dig)	40-20
Beam Deviation	≤ 1 arc – min
Reflectance (per surface)	≤ 0.5% at normal incidence
Threshold	500 W/cm^2, CW 600 mJ/cm^2, 20 ns, visible 4 J/cm^2, 20 ns, 1064 nm
Operating Temperature	-20˚C to +50˚C

ORDERING INFORMATION

Clear Aperture in. (mm)	***Dimensions ± 0.005 in. (± 0.13 mm)***	***Thickness ± 0.020 in. (±0.51 mm)***	***Part Number***
Mounted			
Quarter Wave			
0.40 (10.2)	Ø1.00 (Ø25.4)	0.25 (6.35)	AQM – 050 – λ
0.70 (17.8)	Ø1.00 (Ø25.4)	0.35 (8.9)	AQM – 100 – λ
1.20 (30.5)	Ø2.00 (Ø50.8)	0.50 (12.7)	AQM – 200 – λ
Half Wave			
0.40 (10.2)	Ø1.00 (Ø25.4)	0.25 (6.4)	AHM – 050 – λ
0.70 (17.8)	Ø1.00 (Ø25.4)	0.35 (8.9)	AHM – 100 – λ
1.20 (30.5)	Ø2.00 (Ø50.8)	0.50 (12.7)	AHM – 200 – λ
Unmounted			
Clear Aperture in. (mm)	***Dimensions + 0/-0.010 (+0/-0.25mm)***	***Thickness ± 0.020 in. (±0.51 mm)***	***Part Number***
Quarter Wave			
0.40 (10.2)	Ø0.50 (Ø12.7)	0.14 (3.6)	AQ – 050 – λ
0.80 (20.3)	Ø1.00 (Ø25.4)	0.28 (7.1)	AQ – 100 – λ
1.60 (40.6)	Ø2.00 (Ø50.5)	0.50 (12.7)	AQ – 200 – λ
Half Wave			
0.40 (10.2)	Ø0.50 (Ø12.7)	0.14 (3.6)	AH – 050 – λ
0.80 (20.3)	Ø1.00 (Ø25.4)	0.28 (7.1)	AH – 100 – λ
1.60 (40.6)	Ø2.00 (Ø50.5)	0.50 (12.7)	AH – 200 – λ

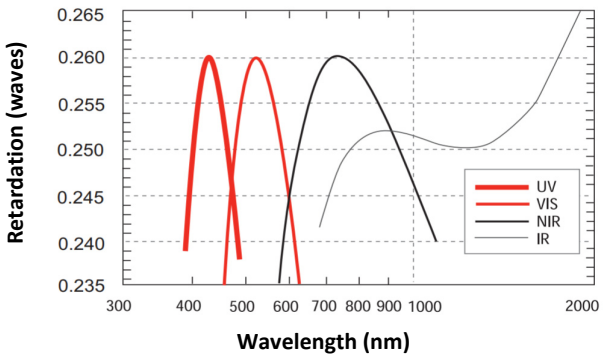
Custom size retarders with improved transmitted wavefront distortion and/or beam deviation are available. Meadowlark Optics one and two-inch diameter retarders conveniently fit our Rotary Mounts.

Bi-Crystalline Achromatic Retarder

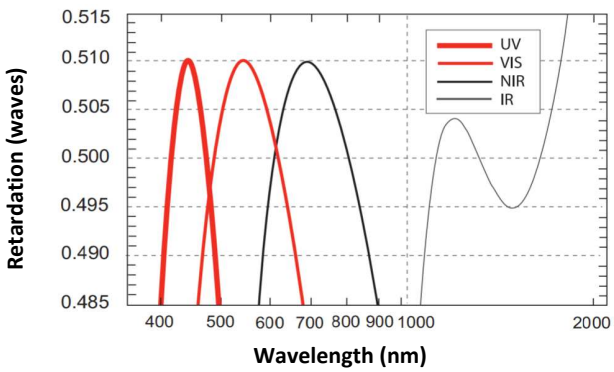
Meadowlark Optics is pleased to offer a selection of quarter and half-wave achromatic retarders that span the UV, visible, near IR and IR portions of the spectrum. Two multi-order crystalline retarders, one made of crystalline quartz and the other magnesium fluoride, are combined in a subtractive mode to give an effective zero-order waveplate. By a careful choice of waveplate thicknesses, retardance dispersion is balanced to give a nearly constant retardance (in waves) over a broad range of wavelengths. The useable wavelength range is defined to give a retardance value within λ/100 of the nominal value. Custom designs with larger achromatic ranges or deeper UV wavelengths are available on request.

Bi-Crystalline Achromats are similar in achromatic performance to our polymer achromats in the visible, but they excel in the IR. They have higher power handling capability than our polymer achromats and can with stand higher storage temperatures. Their field of view is narrow compared to polymer achromats. Typically, they cannot be expected to meet their retardance accuracy for rays whose incidence angles exceed 1.5°. If you must have the performance of a Bi-Crystalline Achromat and a large field of view, call us. We have a proprietary design that can be your polarization solution.

Quarter-Wave Bi-Crystalline Achromatic Retarder Performance



Half-Wave Bi-Crystalline Achromatic Retarder Performance



Key Features

- High Damage Threshold
- Volume Pricing
- Superior IR performance
- Broad Spectral Performance
- UV Models Available

Waveplate Suite

- Precision Retarder
- Precision Achromatic Retarder
- Precision Superachromatic Retarder
- Dual-Wavelength Retarder
- Wide Field Retarder
- Liquid Crystal Variable Retarder
- Polymer Film Retarder
- Raptor Applied Polymer Retarder
- Large Aperture Retarder
- Bi-Crystalline Achromatic Retarder

SPECIFICATIONS

Retarder Material	Quartz & Magnesium Fluoride
Retardance Accuracy	λ/4 or λ/2
Temp. Coefficient of Retardance	λ/500 per ˚C
Standard Wavelengths - Quarter Wave	
Ultraviolet **Visible** **Near Infrared** **Infrared**	395 – 465 nm 475 – 590 nm 600 – 900 nm 690 – 2050 nm
Standard Wavelengths - Half Wave	
Ultraviolet **Visible** **Near Infrared** **Infrared**	412 – 475 nm 500 – 650 nm 600 – 840 nm 1190 – 1660 nm
Transmitted Wavefront Distortion	≤ λ/4
Surface Quality (scratch-dig)	40 – 20
Beam Deviation	≤ 1 arc-min
Reflectance (per surface)	≤ 0.5% at normal incidence
Storage Temperature	-40˚C to + 75˚C
Threshold	2 J/cm2, 10 ns, 1064 nm

ORDERING INFORMATION

Mounted		
Clear Aperture in. (mm)	***Diameter in. (mm)***	***Part Number***
Half Wave		
0.40 (10.2 mm)	Ø1.00 (Ø25.4 mm)	CHM – 050
Quarter Wave		
0.40 (10.2 mm)	Ø1.00 (Ø25.4 mm)	CQM – 050
Unmounted		
Clear Aperture in. [mm)	***Diameter in. (mm)***	***Part Number***
Half Wave		
0.40 (10.2 mm)	Ø0.50 (Ø12.7 mm)	CH – 050
Quarter Wave		
0.40 (10.2 mm)	Ø0.50 (Ø12.7 mm)	CQ – 050

We offer standard Bi-Crystalline Achromatic Retarders to cover 4 regions of the spectrum: UV, VIS, NIR, IR Please specify wavelength region when placing order.

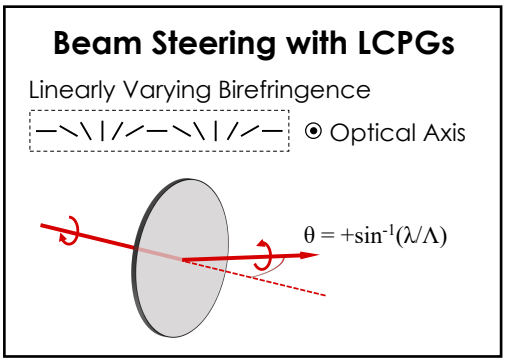
Liquid Crystal Devices

Liquid Crystal Polarization Grating Technology

Meadowlark Optics' Liquid Crystal Polarization Gratings utilize spatially varying birefringence to create highly efficient polarization-sensitive gratings. Circularly polarized light can be directed into either the +1 or -1 order depending on the handedness of the incident light. By using a stack of N LCPGs and half-waveplate switches, it is possible to steer to 2^N discrete angles in 1-D or 2-D arrays.

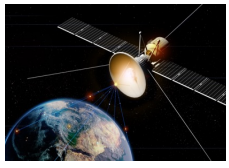
Liquid crystal polarization gratings are also known as geometric phase gratings, Pancharatnam-Berry phase gratings, and diffractive waveplates. These transmissive gratings efficiently (> 99.5%) diffract circularly polarized light to either the first positive or negative order, based on the handedness of the incident light. By incorporating fast electro-optic half-wave polarization retarders to control the handedness of polarization, Meadowlark can develop custom LCPG devices and systems with a range of leading capabilities:

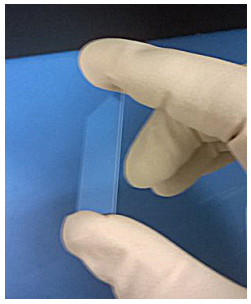
- Wide-angle beam steering > 100°
- Large apertures > 20 cm
- Sub-millisecond switching times
- Dramatically reduced size, weight, and power (SWaP) requirements
- Random-access and inertia-less beam steering
- Dynamic focusing also available



Applications of LCPG Beam Steering

Wind Sensing, Laser Communications, Autonomous Driving, Active Imaging



Benefits of LCPG Beam Steering

- Low size, weight, and power
- Random-access scanning
- Robust non-mechanical operation
- Large apertures possible (>15cm)
- Diffraction-limited wavefront quality
- High diffraction efficiency (>99%)
- Up to 80°×80° steering demonstrated
- Demonstrated in VIS to MWIR

Liquid Crystal Suite

Variable Retarders
Liquid Crystal Variable Retarder
UV Variable Retarder
MWIR Variable Retarder
OEM LCVR

Rotators
Achromatic High-Speed Rotator
Binary Rotator
Polarization Rotator

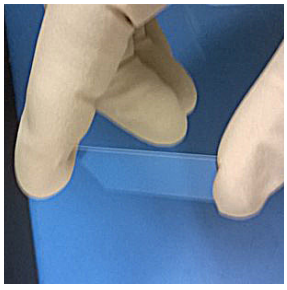
Shutters / Attenuators
Achromatic High-Speed Shutter
High Contrast Shutter
Variable Attenuator

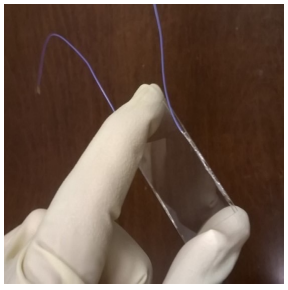
Controllers
Analog Controller
FLC Controller
LC Digital Interface Controller
Temperature Controller
Two Channel High Voltage Controller

ORDERING INFORMATION

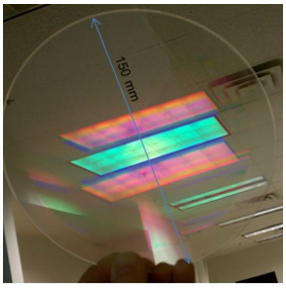
Meadowlark can provide custom systems to meet your needs using the patented liquid crystal polarization grating (LCPG) beam steering technology. When contacting us for a quote, please provide:

- Clear Aperture (mm)
- Operating Wavelength (nm)
- 1D or 2D Steering
- Number of Angles
- Maximum Steering Angle (°)
- Response Time/Switching Speed (ms)
- Housing/Mechanical Interface Requirements
- Description of Application & Additional Details





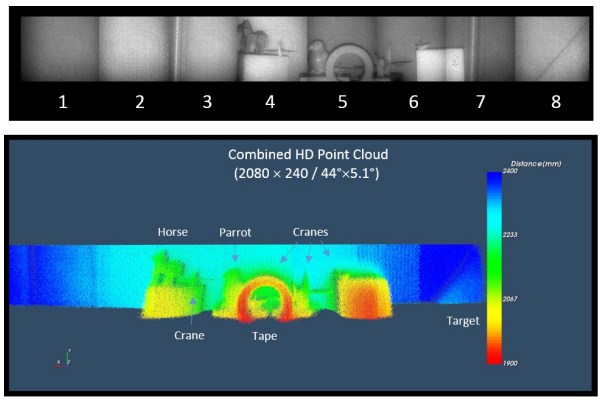
LCPG (left) and LC halfwave switch (right) on 200 µm glass.



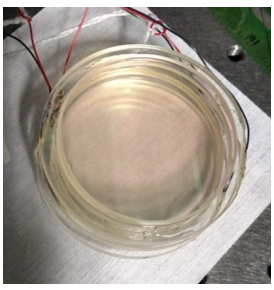
A 2-mm LCPG-based variable optical attenuator (left) and a 15-cm diameter LCPG (right).

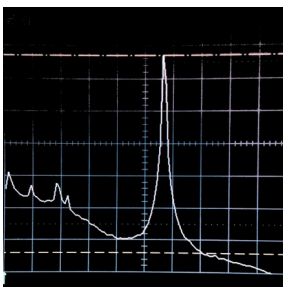
Non-Mechanical Steering for a Range of Aperture Sizes

BNS has built LCPGs and LC switches using thin 200 µm glass and with apertures ranging from 2 mm to 200 mm. Thin glass enables discrete steering to >1,000 revolvable angles with transmissive assemblies < 1 cm thick. Meanwhile the ability to steer large beams over large angles makes this approach unique among non-mechanical steering technologies for replacing large gimbals or steering large collection apertures in optical receiver paths.



LCPG steering used to stitch 8 fields of view in flash lidar.





A 5 cm aperture LCPG steering system (left) used to steer coherent Doppler lidar. System had 1 dB insertion loss, 29 dB CNR on target (right) and no measurable contribution from side-lobes or leakage.

LCPG Steering for Lidar

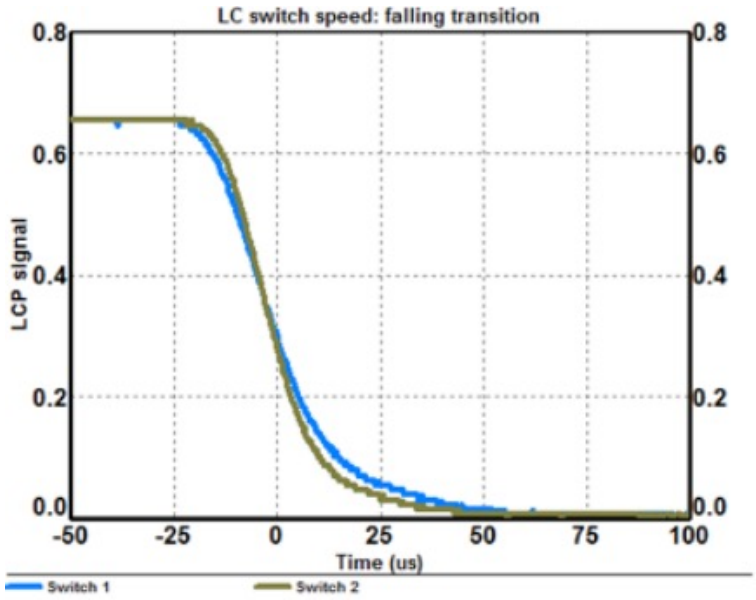
LCPG technology excels at non-mechanical beam steering for many narrowband sensors including lidar. To date, BNS has demonstrated LCPG beam steering for both coherent and direct detection lidars and both monostatic and bistatic architectures. Due to the ability to steer light in discrete steps over large angles, LCPG beam steering is particularly well suited to steering flash lidar systems and coherent doppler lidar wind sensing systems.

Liquid Crystal Polarization Grating Lenses

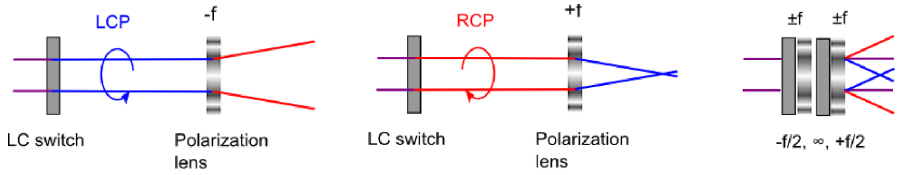
Fast • Non-mechanical • Remote Focusing

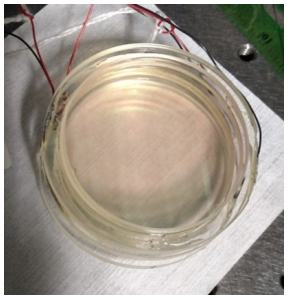
Liquid Crystal Polarization Gratings utilize spatially varying birefringence to create highly efficient polarization-sensitive gratings. Circularly polarized light will see a positive or negative lens depending on the handedness of the incident light. By using an alternating stack of LCPGs and half-waveplate switches, we can produce large discrete focus changes in <40 µs.

Fast, Discrete Refocusing (>500 µm in < 40 µs)

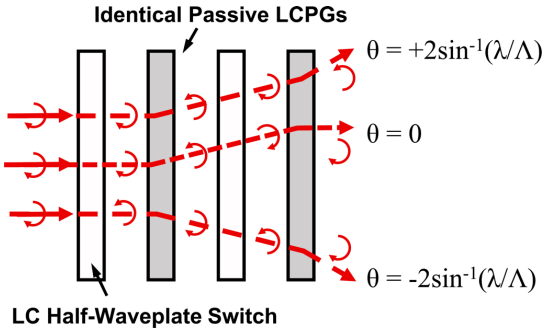


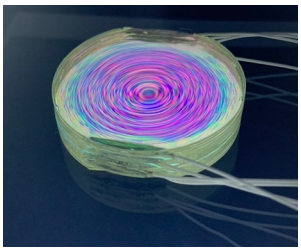
Stackable for access to many focal planes





LCPG Lens Stack Schematic





Benefits of LCPG Lens Remote Focusing

• • •

Low size, weight, and power

- <40 µs fast direction
- <3 ms slow direction
- Robust non-mechanical operation
- Large apertures possible (>5 cm)
- High diffraction efficiency (>99%)
- Simple microscope integration
- Demonstrated in VIS to MWIR
- Broadband systems possible

Liquid Crystal Suite

• • •

Variable Retarders
Liquid Crystal Variable Retarder
UV Variable Retarder
MWIR Variable Retarder
OEM LCVR

Rotators
Achromatic High-Speed Rotator
Binary Rotator
Polarization Rotator

Shutters / Attenuators
Achromatic High-Speed Shutter
High Contrast Shutter
Variable Attenuator

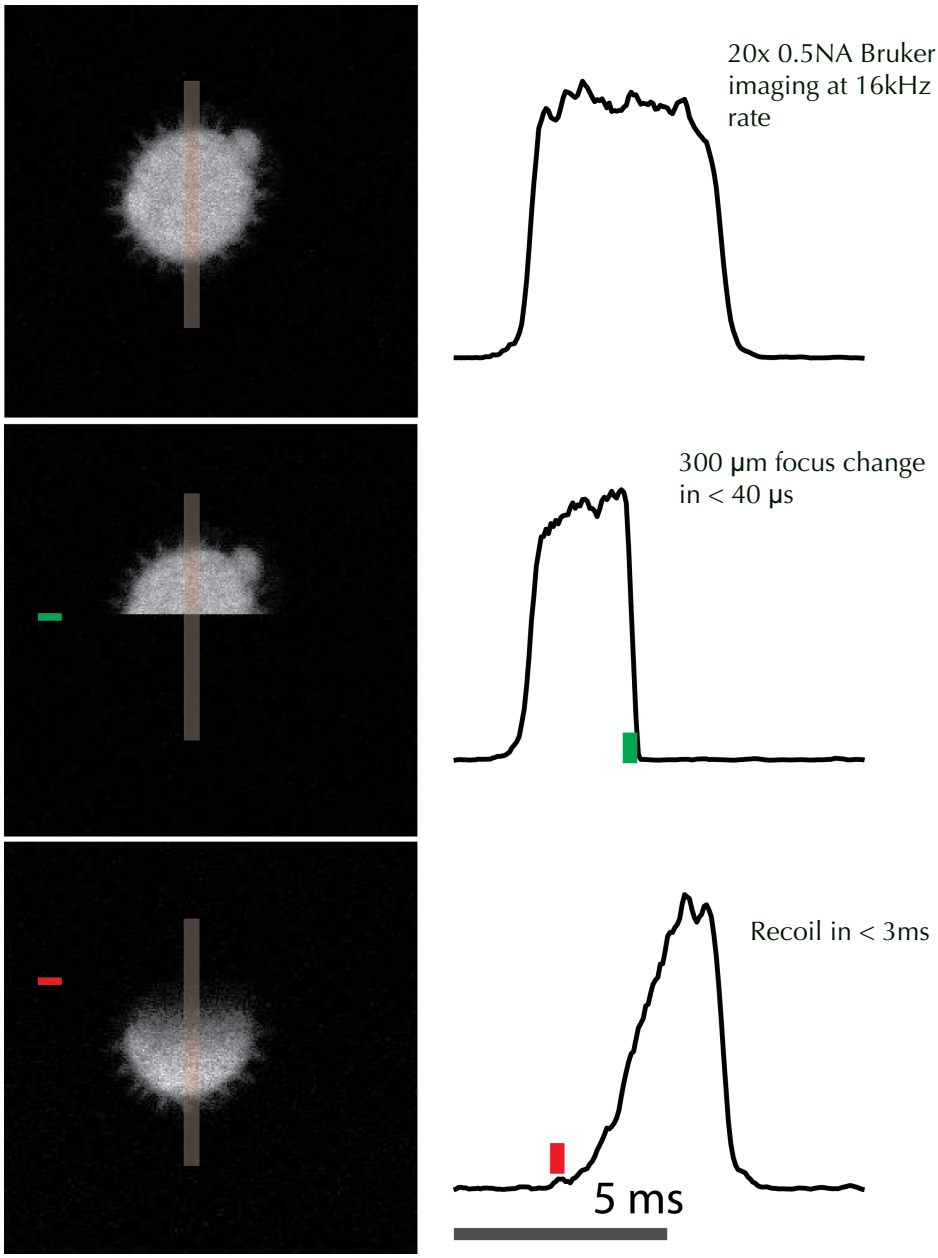
Controllers
Analog Controller
FLC Controller
LC Digital Interface Controller
Temperature Controller
Two Channel High Voltage Controller

ORDERING INFORMATION

Meadowlark can provide custom systems to meet your needs using the patented liquid crystal polarization grating (LCPG) beam steering technology. When contacting us for a quote, please provide:

- Nominal Focal Lengths and/or Focal Plane Shifts (mm)
- Tolerance Requirements
- Response Time (ms)
- Wavelength (nm)
- Diameter (mm)
- Description of Application & Additional Details

Remote focusing in a two-photon microscope

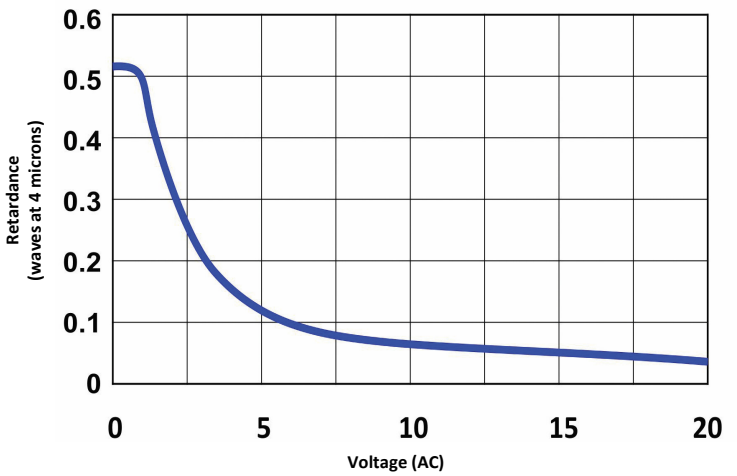


2P microscope images courtesy of Darcy Peterka, Columbia University

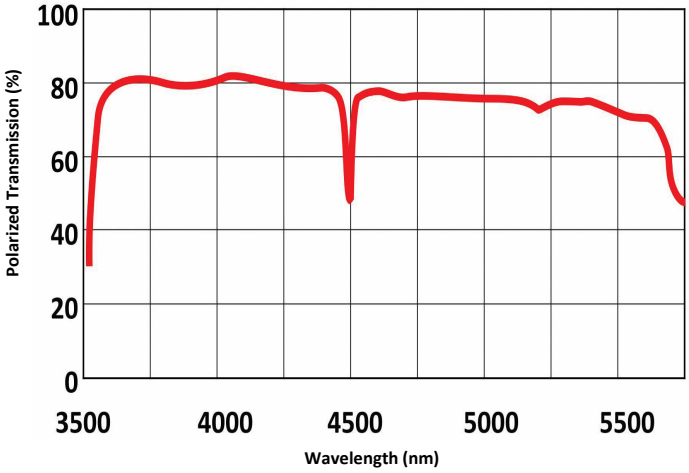
MWIR Variable Retarder/Waveplate

Liquid crystal technology for polarization control now extends into the mid infrared. A Liquid Crystal Variable Retarder (*LCVR*, also called a phase retarder or rotator) is a liquid crystal filled waveplate device placed in the light path of an optical system to allow its electronic modulation, by phase retardation or rotation of the plane of polarization. LCVRs are filled with a solution of nematic liquid crystal (LC) molecules which rotate the plane of polarization of transmitted light. Two transparent conductive films allow an AC voltage to be applied across the optics cell. As the voltage is increased, the default orientation of the LC molecules is disrupted, changing the degree of rotation or optical phase retardation of transmitted polarized light.

Retardance vs. Voltage



Transmission vs. Wavelength



Key Features

• • •

3600 to 5500 nm transmission

Non-mechanical polarization control

Computer controllable

Useful for variable attenuation

Liquid Crystal Suite

• • •

Variable Retarders

Liquid Crystal Variable Retarder

UV Variable Retarder

MWIR Variable Retarder

OEM LCVR

Rotators

Achromatic High Speed Rotator

Binary Rotator

Polarization Rotator

Shutters / Attenuators

Achromatic High Speed Shutter

High Contrast Shutter

Variable Attenuator

Controllers

Analog Controller

FLC Controller

LC Digital Interface Controller

Temperature Controller

Two Channel High Voltage Controller

SPECIFICATIONS	
Retarder Material	Nematic liquid crystal
Substrate Material	Anti-reflection coated germanium
Wavelength Range	3.6 µm to 5.7 µm
Maximum Retardance	½ λ at 4 µm
Minimum Retardance	0.06 λ at 4 µm at 10 V
Reflectance	≤ 5% per external surface
Operating Temperature Range	0˚C to + 50˚C
Response Times	< 100 ms

Custom configurations available.

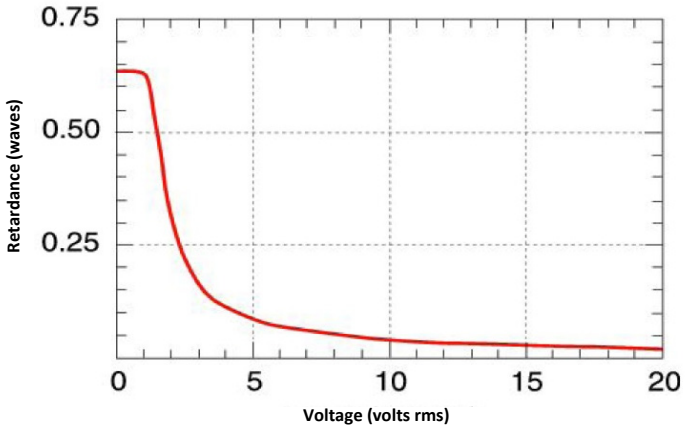
ORDERING INFORMATION			
Diameter in. (mm)	***Clear Aperture in. (mm)***	***Thickness in. (mm)***	***Part Number***
2.00 in. (50.8 mm)	0.70 in. (17.8 mm)	0.75 in. (19.05 mm)	LVR – 200 – MIR

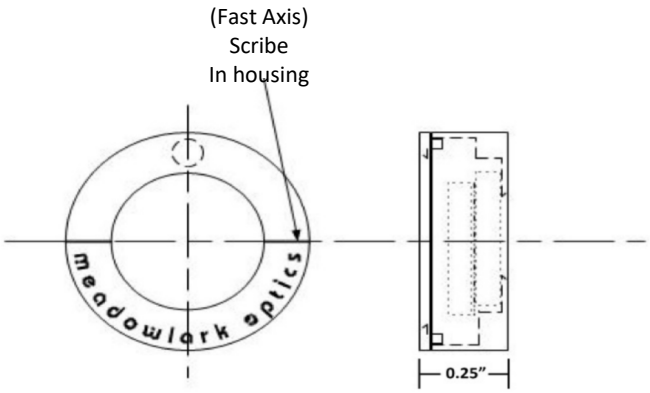
OEM Liquid Crystal Variable Retarder

Meadowlark Optics is pleased to announce a small, mounted liquid crystal family of products intended for space constrained or OEM applications. By removing the temperature control circuitry, the overall dimensions of the housing can be significantly reduced. For even tighter mechanical constraints, un-mounted cells are also available with flying leads or custom connectors.

A Liquid Crystal Variable Retarder (*LCVR*, also called a phase retarder or rotator) is a liquid crystal filled waveplate device placed in the light path of an optical system to allow its electronic modulation, by phase retardation or rotation of the plane of polarization. LCVRs are filled with a solution of nematic liquid crystal (LC) molecules which rotate the plane of polarization of transmitted light. Two transparent conductive films allow an AC voltage to be applied across the optics cell. As the voltage is increased, the default orientation of the LC molecules is disrupted, changing the degree of rotation or optical phase retardation of transmitted polarized light.

Retardance vs. Voltage





Key Features

- Precision control at lower cost
- Scalable quantities
- Thin housing
- Large clear aperture
- Usable from 450 to 1800 nm

Liquid Crystal Suite

Variable Retarders
Liquid Crystal Variable Retarder
UV Variable Retarder
MWIR Variable Retarder
OEM LCVR

Rotators
Achromatic High Speed Rotator
Binary Rotator
Polarization Rotator

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Achromatic High Speed Shutter
High Contrast Shutter
Variable Attenuator

Controllers
Analog Controller
FLC Controller
LC Digital Interface Controller
Temperature Controller
Two Channel High Voltage Controller

SPECIFICATIONS	
Retarder Material	Nematic liquid crystal
Substrate Material	Optical quality synthetic fused silica
Wavelength Range	450 – 1800 nm (please specify)
Retardance Range	~30 nm to λ/2 custom ranges are available
Transmitted Wavefront Distortion	λ/2 (P-V @ 633) λ/8 (RMS @ 633)
Surface Quality	80 – 50 scratch-dig
Beam Deviation	3 arc min
Reflectance (per surface)	0.5% at normal incidence
Diameter Tolerance	± 0.005 in.
Temperature Range	0˚C to 50˚C
Laser Damage Threshold	500 W/cm^2, CW 300 mJ/cm^2, 10 ns, visible

ORDERING INFORMATION

Diameter in. (mm)	*Clear Aperture in. (mm)*	*Thickness in. (mm)*	*Part Number*
1.00 (25.4 mm)	0.49 (12.5 mm)	0.25 (6.35 mm)	LVT – 100

We offer standard liquid crystal variable retarders to cover four spectral regions:

VIS: 450 – 700 nm
IR 1: 650 – 950 nm
IR 2: 900 – 1250 nm
IR 3: 1200 – 1700 nm

Please specify a spectral region when placing your order.

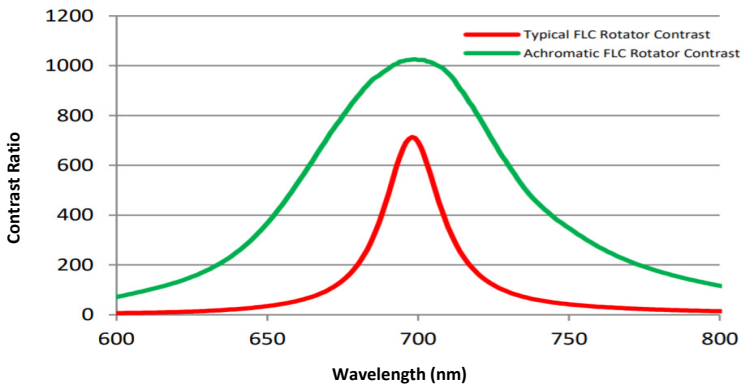
Achromatic High Speed Polarization Rotators & Shutters

Meadowlark Optics' Achromatic Ferroelectric Polarization Rotator features high speed and exceptional polarization purity over broad wavelength ranges. FLC devices offer a significant performance advantage in optical shutter and rotator applications demanding the fastest optical response times available.

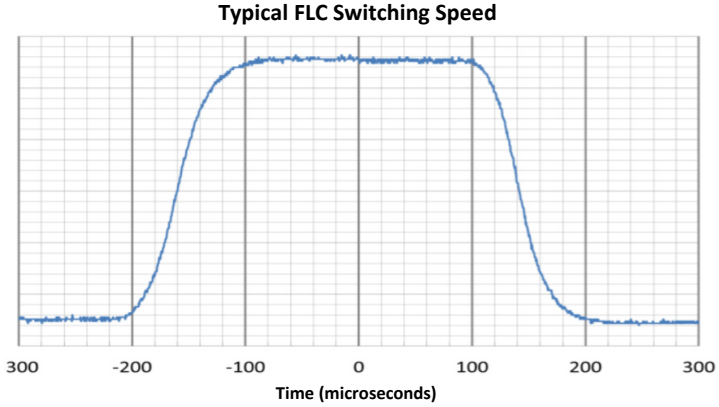
Since these devices are solid state – undesirable mechanical motion, associated noise, and vibration problems are eliminated. Key features of our FLC devices include 100 microsecond switching speed, high contrast linearly polarized output, and operation over the widest wavelength range available.

Typical applications of the FLC Achromatic Rotator include single camera 3D video capture, broadband phase modulators, beam steering, and polarimetry. Achromatic rotators are not limited to visible spectrum; we can design and build them in the near infrared as well.

High Polarization Purity over a Broad Wavelength Range



Typical FLC Switching Speed



Key Features

- Broadband performance
- Extremely fast switching speeds
- Silent, vibration-free
- Low-voltage operation
- OEM sizes and shapes
- No mechanical motion

Liquid Crystal Suite

Variable Retarders
Liquid Crystal Variable Retarder
UV Variable Retarder
MWIR Variable Retarder
OEM LCVR

Rotators
Achromatic High Speed Rotator
Binary Rotator
Polarization Rotator

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Achromatic High Speed Shutter
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Variable Attenuator

Controllers
Analog Controller
FLC Controller
LC Digital Interface Controller
Temperature Controller
Two Channel High Voltage Controller

ROTATOR SPECIFICATIONS

Retarder Material	Ferroelectric liquid crystal
Substrate Material	Fused silica
Wavelength Range	405 – 850 nm *custom ranges up to 2 microns*
Transmitted Wavefront Distortion	λ/2 (P-V @ 633) λ/8 (RMS @ 633)
Surface Quality	60 – 40 scratch-dig
Beam Deviation	≤ 5 arc min
Outside Diameter (mounted)	2.00 ± 0.005 in. *please inquire about custom sizes*
Clear Aperture	0.70 in. (17.8 mm)
Response Time (10-90% & 90-10%)	≤ 100 µs at room temp *wavelength dependent*
Operating Temperature	20˚C to 30˚C
Storage Temperature	0˚C to 60˚C
Driver Requirements	± 5 to 30 Volts, 50% duty cycle

SHUTTER SPECIFICATIONS

(rotator with polarizers – includes specifications from above table)

Polarizer Material	Dichroic Polymer
Transmission *please inquire about higher transmission options*	≥ 30% (typical - unpolarized light) ≥ 65% (typical - polarized light)
Wavelength Range	450-720 nm *custom ranges up to 2 microns*
Transmitted Wavefront Distortion	λ/2 (P-V @ 633) λ/8 (RMS @ 633)
Contrast Ratio	≥ 200:1

CONTROLLER SPECIFICATIONS

Dimensions	5.3 in. W x 5.3 in. L x 2.0 in. H 13.5 cm W x 13.5 cm L x 5.1 cm H
Number of LC Channels	Two, running identical programs 180 degrees out of phase
Output Waveform	Bipolar ± 15V peak voltage, ± 10V holding voltage
Amplitude Resolution	16-bit; 1 mV voltage resolution
Internal Drive	1 to 10,000 Hz, 50% duty cycle, frequency controlled by front-panel 10-turn knob

ORDERING INFORMATION

Product Description	*Diameter in. (mm)*	*Clear Aperture in. (mm)*	*Thickness in. (mm)*	*Part Number*
Rotator	2.00 (50.8 mm)	0.70 (17.78 mm)	1.38 (19.05 mm)	FPA – 200 – λ
Shutter	1.00 (25.4 mm)	0.37 (9.4 mm)	1.42 (36.07 mm)	FCS – 100 – λ
	2.00 (50.8 mm)	0.70 (17.78 mm)	1.13 (28.7 mm)	FCS – 200 – λ
Controller	N/A	N/A	N/A	FC – 010

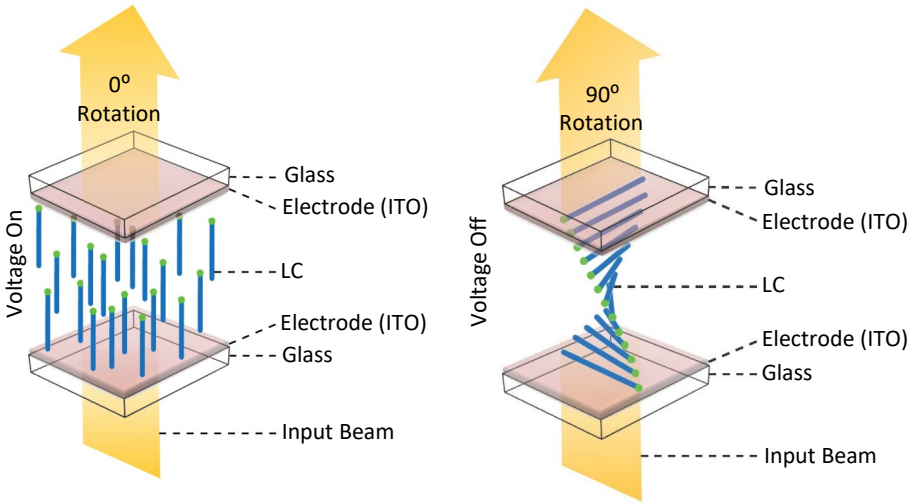
Please specify a wavelength when placing your order.

Binary Liquid Crystal Rotator

An Optical Rotator is a two-state device used to rapidly switch between two orthogonal sites of linear polarization. One state has output linear polarization parallel to an input linear polarization state. This occurs when voltage is applied to the rotator. The other state has output polarization orthogonal to the input polarization and occurs when no voltage is applied.

Meadowlark Optics manufactures and sells liquid crystal (LC) based Optical Rotators for applications requiring active timing control of beam transmittance by using them in combination with high quality polarizers. Key features of our Optical Rotators include high-speed binary operation, high purity linear polarized output, and maximum extinction ratio performance. Since these devices are solid state – undesirable mechanical motion, associated noise, and vibration problems are eliminated.

Binary LC Rotators deliver optimum extinction ratio performance, often greater than 10,000:1 across the visible wavelength range, when used with high quality polarizers. Even higher extinction performance is achieved over narrower bandwidths or for single laser line applications. Up to 100% duty cycle operation is standard. This Rotator has a broad operating temperature range, designed to meet applications requiring low cost components with negligible impact on performance.



Key Features

- High polarization purity
- Silent, vibration-free
- Low-voltage operation
- Broad thermal range
- Faster switching speeds than LCVRs

Liquid Crystal Suite

Variable Retarders
Liquid Crystal Variable Retarder
UV Variable Retarder
MWIR Variable Retarder
OEM LCVR

Rotators
Achromatic High Speed Rotator
Binary Rotator
Polarization Rotator

Shutters / Attenuators
Achromatic High Speed Shutter
High Contrast Shutter
Variable Attenuator

Controllers
Analog Controller
FLC Controller
LC Digital Interface Controller
Temperature Controller
Two Channel High Voltage Controller

SPECIFICATIONS	
Retarder Material	Twisted Nematic liquid crystal
Substrate Material	Optical quality synthetic fused silica
Wavelength Range	400 – 1800 nm (please specify)
Transmitted Wavefront Distortion	λ/4 (P-V @ 633) λ/16 (RMS @ 633)
Response Time (VIS)	≤ 5 ms
Surface Quality	40 – 20 scratch-dig
Beam Deviation	2 arc min
Reflectance (per surface)	0.5% at normal incidence
Diameter Tolerance	± 0.10 in.
Temperature Range	10˚C to 60˚C (Operating) -40˚C to 90˚C (Storage)
Laser Damage Threshold	500 W/cm^2, CW 300 mJ/cm^2, 10 ns, visible

ORDERING INFORMATION			
Diameter in. (mm)	***Clear Aperture in. (mm)***	***Thickness in. (mm)***	***Part Number***
1.00 (25.4 mm)	0.37 (9.4 mm)	1.23 (31.24 mm)	LTN – 100 – λ
2.00 (50.8 mm)	0.70 (17.8 mm)	0.75 (19.05 mm)	LTN – 200 – λ

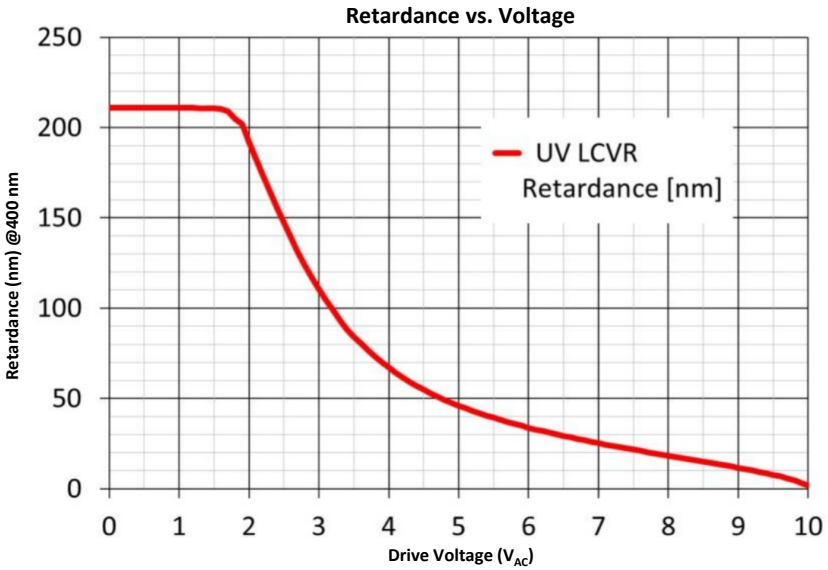
Please specify one of the following spectral regions when placing your order:

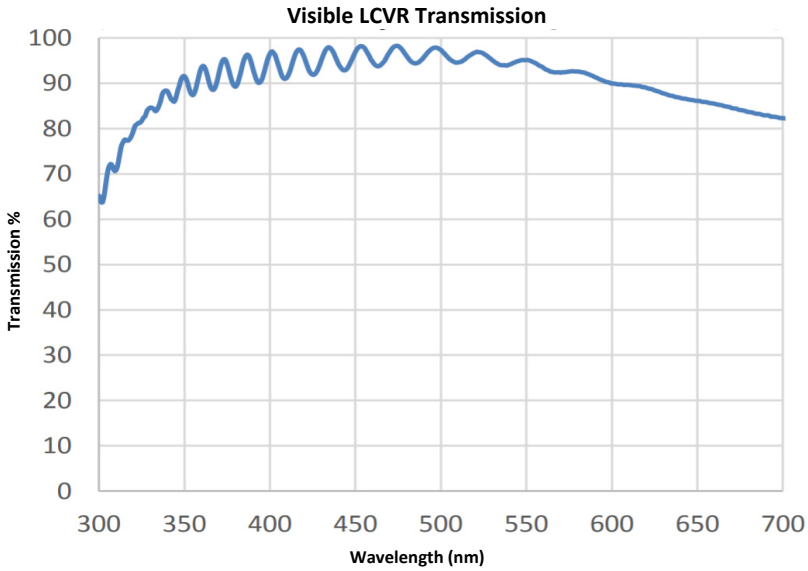
VIS: 450 – 700 nm *IR 1: 650 – 950 nm*

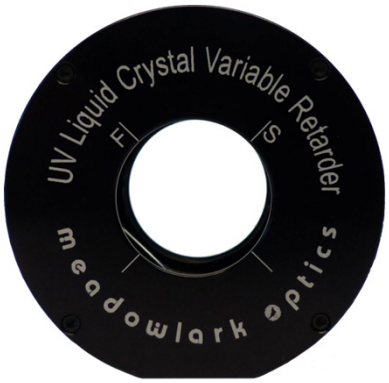
IR 2: 900 – 1250 nm *IR 3: 1200 – 1700 nm*

UV Liquid Crystal Variable Retarder

Liquid crystal technology for polarization control now extends into the ultraviolet. While standard LC materials are susceptible to UV light damage below 450 nm, Meadowlark has designed a new UV resistant LCVR material capable of operating at lower wavelengths (as low as 350 nm). These parts can be custom configured for use as variable attenuators or polarization rotators and are compatible with our standard line of liquid crystal controllers.







Key Features

- Phase or Amplitude modulation of UV spectrum
- Analog modulation
- Non-mechanical polarization control
- Low absorption
- High UV tolerance LC

Liquid Crystal Suite

Variable Retarders

Liquid Crystal Variable Retarder
UV Variable Retarder
MWIR Variable Retarder
OEM LCVR

Rotators

Achromatic High Speed Rotator
Binary Rotator
Polarization Rotator

Shutters / Attenuators

Achromatic High Speed Shutter
High Contrast Shutter
Variable Attenuator

Controllers

Analog Controller
FLC Controller
LC Digital Interface Controller
Temperature Controller
Two Channel High Voltage Controller

SPECIFICATIONS	
Retarder Material	Nematic liquid crystal
Substrate Material	UV grade fused silica
Wavelength Range	350 – 450 nm (please specify)
Maximum Retardance	1/2 λ at 400 nm
Minimum Retardance	0.06 λ at 400 nm (at 10 V)
Transmitted Wavefront Distortion	λ/4 (P-V @ 633) λ/16 (RMS @ 633)
Surface Quality	40 – 20 scratch-dig
Beam Deviation	2 arc min
Reflectance*	AR Coatings are available
Diameter Tolerance	± 0.010 in.
Temperature Range	0˚C to + 50˚C (Operating)

Custom configurations available.

ORDERING INFORMATION			
Diameter in. (mm)	***Clear Aperture in. (mm)***	***Thickness in. (mm)***	***Part Number***
1.00 (25.4 mm)	0.37 (9.4 mm)	1.23 (31.24 mm)	LVR – 100 – UV
2.00 (50.8 mm)	0.70 (17.8 mm)	0.75 (19.05 mm)	LVR – 200 – UV

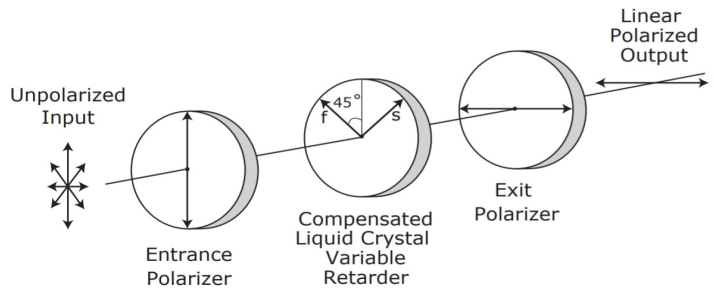
Liquid Crystal Variable Attenuator

Meadowlark Optics' Liquid Crystal Variable Attenuator (LCVA) offers real-time, continuous control of light intensity. Our attenuator consists of an LC Variable Retarder (with attached compensator) operating between crossed linear polarizers. With crossed polarizers, light transmission is maximized by applying the correct voltage to achieve half-wave retardance from the LC cell. Half-wave operation rotates the incoming polarization direction by 90°, so that light is passed by the second polarizer. Minimum transmission is obtained with the retarder operating at zero (or a whole number of) waves.

Transmission decreases as the applied AC voltage amplitude increases (half- to zero-waves retardance). The relationship between transmittance T and retardance (in degrees) for crossed polarizer configuration is given by: $T(\Theta) = 1/2\ [1 - \cos(\Theta)]$ Tmax where Tmax is the maximum transmittance when retardance is exactly one-half wave (or 180°).

Maximum transmission is dependent upon properties of the LC Variable Retarder as well as the polarizers used in your system.

Extinction ratio is defined as the maximum transmission (LC cell at half-wave) divided by the minimum transmission (LC cell at zero waves). Values exceeding 1000:1 can be obtained for a single wavelength by optimizing the applied voltage levels for minimum and maximum transmission. We guarantee a minimum extinction ratio of 500:1 at your specified wavelength.



Standard Liquid Crystal Variable Attenuator design uses crossed linear polarizers

Key Features

- High contrast ratio
- Computer control capabilities
- Continuous control of light intensity

Liquid Crystal Suite

Variable Retarders
Liquid Crystal Variable Retarder
UV Variable Retarder
MWIR Variable Retarder
OEM LCVR

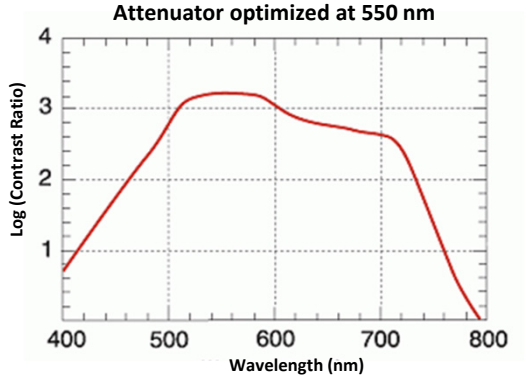
Rotators
Achromatic High Speed Rotator
Binary Rotator
Polarization Rotator

Shutters / Attenuators
Achromatic High Speed Shutter
High Contrast Shutter
Variable Attenuator

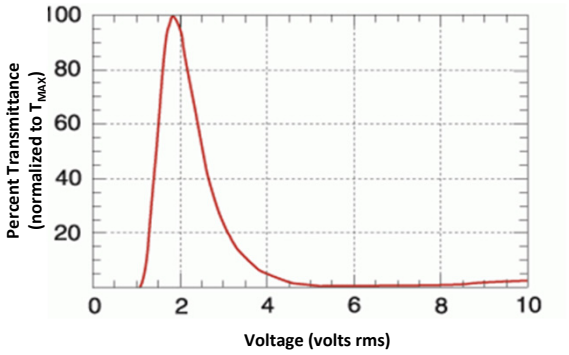
Controllers
Analog Controller
FLC Controller
LC Digital Interface Controller
Temperature Controller
Two Channel High Voltage Controller

A Liquid Crystal Variable Attenuator can be configured with high efficiency calcite or beamsplitting polarizers to maximize light transmittance and increase damage threshold. With a linearly polarized input beam and a calcite polarizer, transmittance values exceed 90% at most wavelengths. Very high extinction ratios, in excess of 5000:1, can be achieved with custom double attenuators. In this design, two Liquid Crystal Variable Retarders are combined with three polarizers.

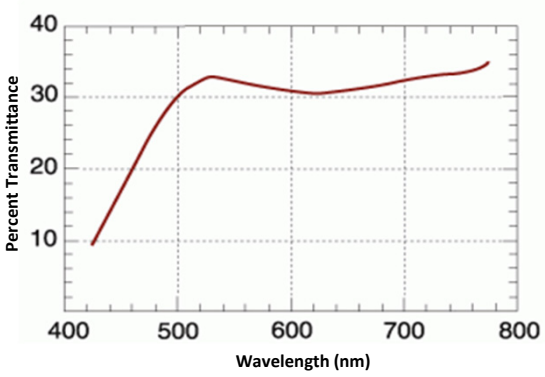
Typical Contrast Ratio of a Liquid Crystal Variable Attenuator optimized at 550 nm



Normalized transmittance of Liquid Crystal Variable Attenuator with crossed linear polarizers at a single wavelength



Unpolarized Transmittance as a function of wavelength for LC Variable Attenuator, optimized for 550 nm, with polarizers and unpolarized input



SPECIFICATIONS

Retarder Material	Nematic liquid crystal with Birefringent polymer
Polarizer Material	Dichroic polymer
Substrate Material	Optical quality synthetic fused silica
We offer standard liquid crystal variable attenuators to cover four spectral regions: VIS: 450 – 700 nm IR 1: 650 – 950 nm IR 2: 900 – 1250 nm IR 3: 1200 – 1700 nm	
Contrast Ratio	500:1 at single wavelength
Transmitted Wavefront Distortion (at 632.8 nm)	≤ λ/4 (each component)
Surface Quality	40 – 20 scratch-dig
Beam Deviation	≤ 2 arc min
Reflectance (per surface)	≤ 0.5% at normal incidence
Diameter Tolerance	±0.005 in.
Temperature Range	0˚C to + 50˚C
Recommended Safe Operating Limit	1 W/cm^2, CW (with dichroic polarizers)

ORDERING INFORMATION

Diameter in. (mm)	*Clear Aperture in. (mm)*	*Thickness in. (mm)*	*Part Number*
1.00 (25.4 mm)	0.37 (9.4 mm)	1.23 (31.24 mm)	LVA – 100 – λ
2.00 (50.8 mm)	0.70 (17.8 mm)	0.75 (19.05 mm)	LVA – 200 – λ
3.00 (76.2 mm)	1.60 (40.64 mm)	1.00 (25.4 mm)	LVA – 300 – λ

Please specify operating wavelength λ in nanometers when placing your order
Custom sizes are available.

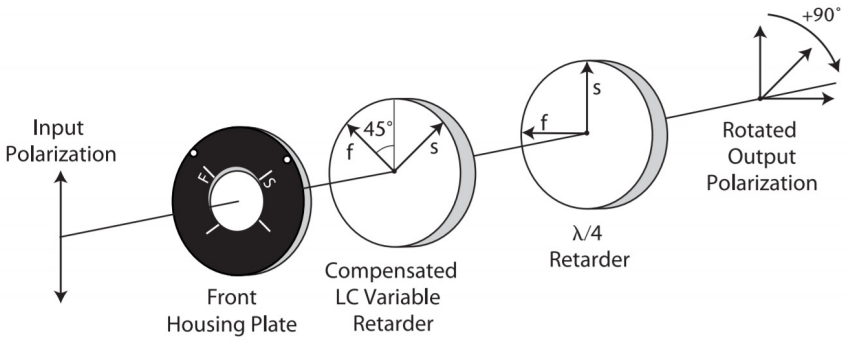
Liquid Crystal Polarization Rotators

Our Liquid Crystal Polarization Rotator (LPR) continuously rotates the polarization orientation of a monochromatic, linearly polarized input beam. Our LPR consists of a compensated Liquid Crystal Variable Retarder combined with a zero-order polymer quarter-wave retarder. The fast axis of the liquid crystal variable retarder is oriented at 45° to the slow axis of the quarter-wave retarder and the linearly polarized input must be parallel to the quarter-wave retarder slow axis. Polarization rotation is achieved by electrically controlling the retardance of the Liquid Crystal Variable Retarder, eliminating any mechanical motion.

A quarter-wave retarder converts elliptical polarization formed by the Liquid Crystal Variable Retarder to linear polarization. The rotation angle is equal to one-half the retardance change from the Liquid Crystal Variable Retarder. Response time of the LPR depends upon the desired amount of rotation. Small rotations have a longer response time because of a smaller change in the electric field strength.

Polarization purity is defined as the ratio of the rotated linear component to the orthogonal component and, on average, polarization purity (or extinction ratio) is better than 150:1. We provide test data including the required voltages corresponding to polarization orientations, in 10° increments, from approximately -40° to approximately 140° rotation. These measurements are taken at ambient temperature for your specified wavelength.

Standard Liquid Crystal Polarization Rotators are supplied without an input polarizer. Input polarization direction must be precisely aligned for optimum performance.



Operation of a Liquid Crystal Polarization Rotator showing complete rotation of a linearly polarized input beam

Key Features

- High power capability
- High polarization purity
- Computer control capability
- 180 degree polarization rotation
- Continuous rotation of linearly polarized light

Liquid Crystal Suite

Variable Retarders
Liquid Crystal Variable Retarder
UV Variable Retarder
MWIR Variable Retarder
OEM LCVR

Rotators
Achromatic High Speed Rotator
Binary Rotator
Polarization Rotator

Shutters / Attenuators
Achromatic High Speed Shutter
High Contrast Shutter
Variable Attenuator

Controllers
Analog Controller
FLC Controller
LC Digital Interface Controller
Temperature Controller
Two Channel High Voltage Controller

SPECIFICATIONS	
Retarder Material	Nematic liquid crystal with Birefringent polymer
Substrate Material	Optical quality synthetic fused silica
Wavelength	450 – 1800 nm (please specify)
Polarization Rotation	180˚ or more
Polarization Purity	150:1 average
Transmittance	> 92% with polarized input
Transmitted Wavefront Distortion (at 632.8 nm)	≤ λ/4
Surface Quality	40 – 20 scratch-dig
Beam Deviation	≤ 2 arc min
Reflectance (per surface)	≤ 0.5% at normal incidence
Diameter Tolerance	±0.005 in.
Temperature Range	0˚C to 50˚C
Recommended Safe Operating Limit	t 500 W/cm2 , CW 300 mJ/cm2 , 10 ns, visible

ORDERING INFORMATION

Diameter in. (mm)	*Clear Aperture in. (mm)*	*Thickness In. (mm)*	*Part Number*
1.00 (25.4 mm)	0.37 (9.4 mm)	1.23 (31.25 mm)	LPR – 100 – λ
2.00 (50.8 mm)	0.70 (17.8 mm)	0.75 (19.05 mm)	LPR – 200 – λ
3.00 (76.2 mm)	1.60 (40.64 mm)	1.00 (25.4 mm)	LPR – 300 – λ

Please specify operating wavelength λ in nanometers when placing your order.
Custom sizes are available. Please contact our Sales Department for a custom quote.

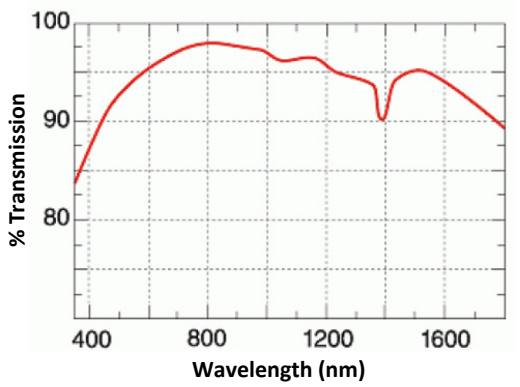
Liquid Crystal Variable Retarders

These products all use nematic liquid crystal materials to electrically control polarization. Meadowlark Optics standard liquid crystal products provide tunable retardation by changing the effective birefringence of the material with applied voltage, thus altering the input polarized light to any chosen elliptical, linear or circular polarization.

Our precision Liquid Crystal Variable Retarders require unique fabrication and assembly steps. We construct these retarders using optically flat fused silica windows coated with our transparent conductive Indium Tin Oxide (ITO). Our ITO coating is specially designed for maximum transmission from 450 – 1800 nm

A thin dielectric layer is applied over the ITO and gently rubbed, to provide for liquid crystal molecular alignment. Two windows are then carefully aligned and spaced a few microns apart. The cavity is filled with birefringent nematic liquid crystal material. Electrical contacts are attached and the device is environmentally sealed. We carefully place the Liquid Crystal Variable Retarder in an anodized aluminum housing such that the fast and slow axes are both at 45° relative to a convenient mounting hole.

Typical Transmission Through an Uncoated Liquid Crystal Device



Anisotropic nematic liquid crystal molecules from uniaxial birefringent layers in the liquid crystal cell. An essential feature of nematic material is that, on average, molecules are aligned with their long axes parallel, but with their centers randomly distributed. With no voltage applied, the liquid crystal molecules lie parallel to the glass substrates and maximum retardation is achieved.

Key Features

- Computer control capability
- Temperature control options
- Usable from 450 to 1800 nm
- Precision non-mechanical retardation control

Liquid Crystal Suite

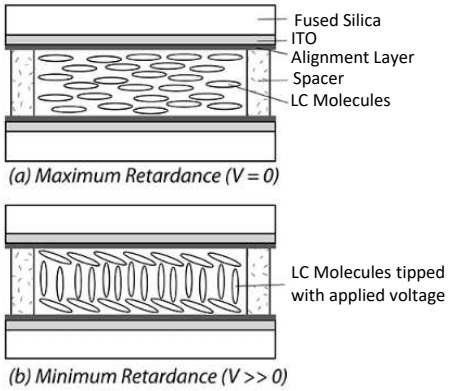
Variable Retarders
Liquid Crystal Variable Retarder
UV Variable Retarder
MWIR Variable Retarder
OEM LCVR

Rotators
Achromatic High Speed Rotator
Binary Rotator
Polarization Rotator

Shutters / Attenuators
Achromatic High Speed Shutter
High Contrast Shutter
Variable Attenuator

Controllers
Analog Controller
FLC Controller
LC Digital Interface Controller
Temperature Controller
Two Channel High Voltage Controller

When voltage is applied, liquid crystal molecules begin to tip perpendicular to the fused silica windows. As voltage increases, molecules tip further causing a reduction in the effective birefringence and hence, retardance. Molecules at the surface, however, are unable to rotate freely because they are pinned at the alignment layer. This surface pinning causes a residual retardance of ~30 nm even at high voltage (20 volts).



Liquid Crystal Variable Retarder construction showing molecular alignment (a) without and (b) with applied voltage

We achieve zero (or any custom) retardance with a subtractive fixed polymer retarder, called a compensator, attached to the liquid crystal cell. Negative retardance values are sometimes preferred, for example, when converting between right- and left-circularly polarized states. Placing a compensated Liquid Crystal Variable Retarder between two high extinction polarizers creates an excellent optical attenuator, with convenient electronic control.

As with any anisotropic material, retardance is dependent upon thickness and birefringence. Liquid crystal material birefringence depends on operating wavelength, drive voltage and temperature. The overall retardance of a liquid crystal cell decreases with increasing temperature (approximately -0.4% per °C).

Response Time

Liquid Crystal Variable Retarder response time depends on several parameters, including layer thickness, viscosity, temperature, variations in drive voltage and surface treatment. Liquid crystal response time is proportional to the square of the layer thickness and therefore, the square of the total retardance.

Response time also depends upon direction of the retardance change. If the retardance increases, response time is determined solely by mechanical relaxation of the molecules. If retardance decreases in value, response time is much faster due to the increased electric field across the liquid crystal layer. It takes about 5 ms to switch from one-half to zero waves (low to high voltage) and about 20 ms to switch from zero to one-half wave (high to low voltage).

Response time improves by using custom materials with high birefringence and a thinner liquid crystal layer. At higher temperature, material viscosity decreases, also contributing to a faster response.

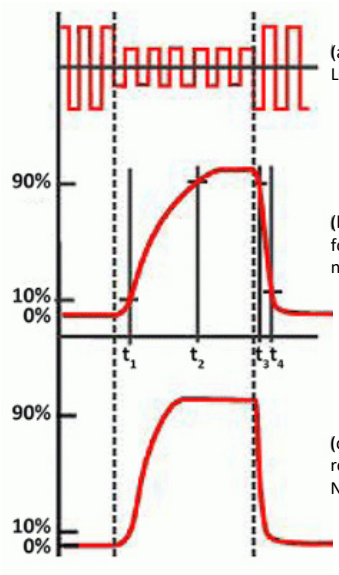
Another technique involves the Transient Nematic Effect (TNE) to improve response times. With this drive method, a high voltage spike is applied to accelerate the molecular alignment parallel to the applied field. Voltage is then reduced to achieve the desired retardance.

When switching from low to high retardance all voltage is momentarily removed to allow the liquid crystal molecules to undergo natural relaxation. Out Four Channel Digital Interface conveniently provides the necessary TNE voltage profiles.

Our standard Liquid Crystal Variable Retarders provide a minimum retardance range of ~30 nm to at least half-wave at the specified wavelength. With an attached compensator, retardance is guaranteed to range from zero to at least half-wave at the specified wavelength. Custom retardance ranges (up to a few waves) and custom compensators are available. Contact our sales department to discuss your requirements.

Each Liquid Crystal Variable Retarder is supplied with retardance versus voltage performance data for your specified wavelength. A coaxial cable with mating connector is provided for easy attachment to one of our electronic controllers.

Temporal response of LC Variable Retarder with an applied voltage at 2 kHz square wave. Excessive DC voltage will damage the liquid crystal

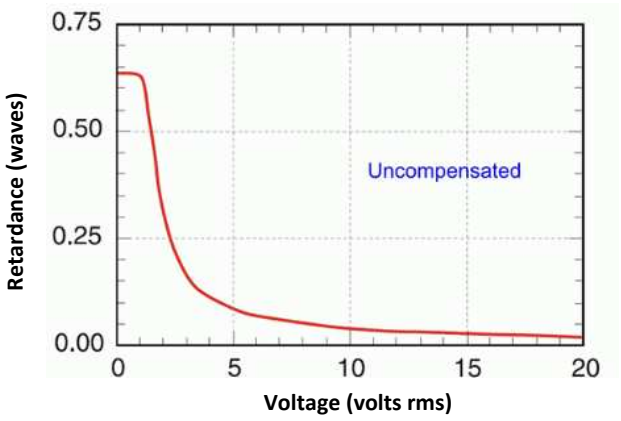


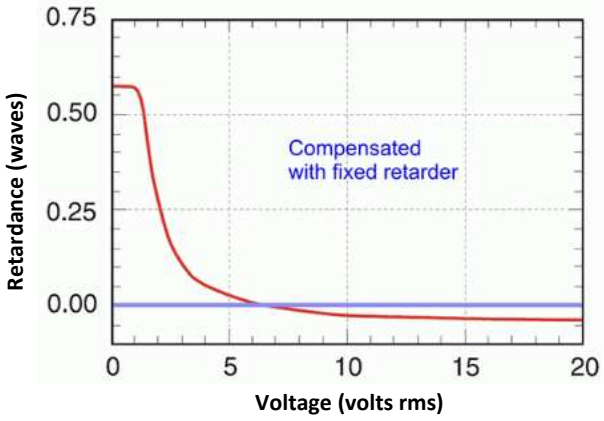
(a) Applied voltage to LC variable Retarder

(b) Typical temporal response for half-wave operation at 632.8 nm (21°C)

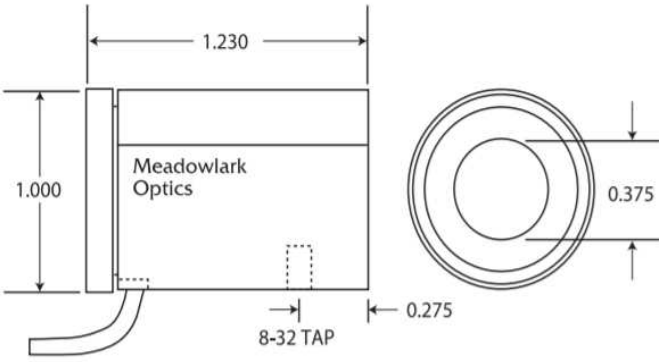
(c) Improved temporal response using Transient Nematic Effect

Liquid Crystal Variable Retarder performance versus applied voltage at 632.8 nm, 210 C.

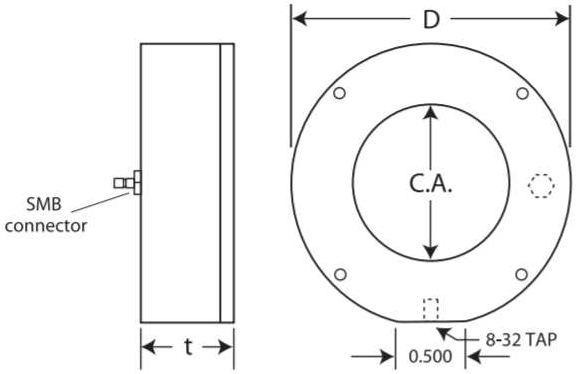




Liquid crystal devices should be electrically driven with an AC waveform with no DC component to prevent ionic buildup which can damage the liquid crystal layer. We require a 2 kHz square wave of adjustable amplitude for controlling our Liquid Crystal Variable Retarders (LCVR). Our Basic Controller and Four Channel Interface ensure these drive requirements are met. A temperature sensing and control option can be added to our LCVRs for accurate controlling of the operating temperature. The sensor is attached directly to the LCVR substrate, outside its clear aperture. Without this option, retardance decreases by approximately 0.2% to 0.3% per °C increase in temperature.



Model LVR-100 Dimensions



Model LVR-200 and LVR-300 Dimensions

SPECIFICATIONS

Retarder Material	Nematic liquid crystal
Substrate Material	Optical quality synthetic fused silica
Wavelength Range	450 – 1800 nm (specify)
Retardance Range	
Without Compensator With Compensator	~30 nm to λ/2 0 to λ/2 (Custom ranges are available)
Transmitted Wavefront Distortion (at 632.8 nm)	≤ λ/4
Surface Quality	40 – 20 scratch-dig
Beam Deviation	≤ 2 arc min
Reflectance (per surface)	≤ 0.5% at normal incidence
Diameter Tolerance	± 0.005 in.
Temperature Range	0°C to 50°C
Recommended Safe Operating Limit	500 W/cm^2, CW 300 mJ/cm^2, 10 ns, visible

ORDERING INFORMATION

Diameter, D (in.)	*Clear Aperture, CA (in.)*	*Thickness, t (in.)*	*Part Number*
Without Attached Compensator (30 nm to λ/2)			
1.00	0.37	1.23	LVR – 100
2.00	0.70	0.75	LVR – 200
3.00	1.60	1.00	LVR – 300
With Attached Compensator (0 nm to λ/2)			
1.00	0.37	1.23	LRC – 100
2.00	0.70	0.75	LRC – 200
3.00	1.60	1.00	LRC – 300

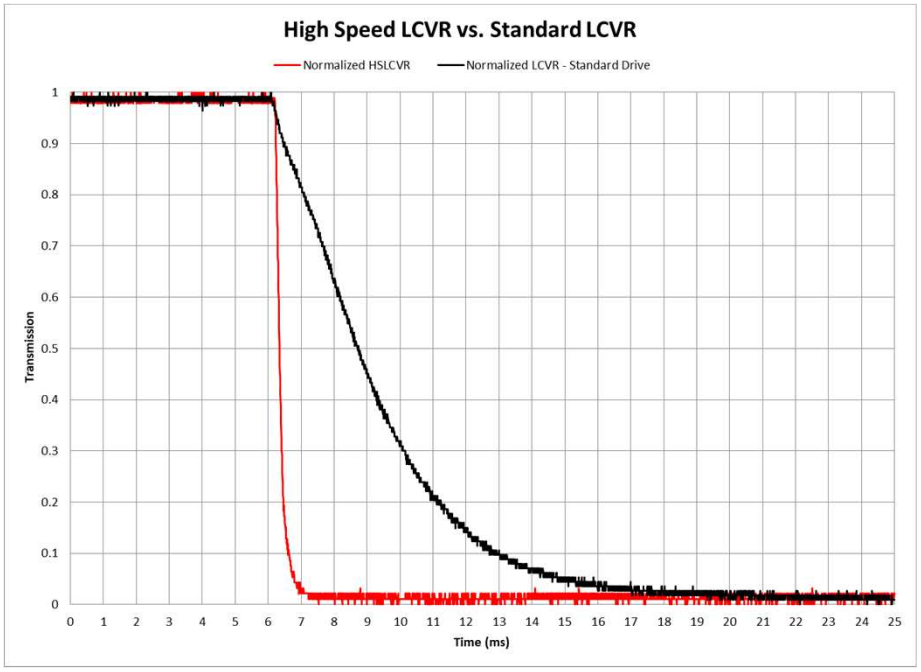
High Speed Liquid Crystal Variable Retarder System

Meadowlark's newest liquid crystal (LC) product, the high speed LC variable retarder (HS LCVR) has a 10X speed improvement over our award winning standard LCVR. The sub-millisecond speeds are achieved without the 50/50 duty cycle drive scheme required by our ferroelectric liquid crystal components, but are nearly as fast. The new HS LCVR uses nematic liquid crystal materials to electrically control polarization and provide tunable retardation by changing the effective birefringence of the material with applied voltage, thus altering the input polarized light to any chosen elliptical, linear or circular polarization.

Our precision HS LCVR requires unique fabrication and assembly steps. We construct these retarders using optically flat fused silica windows coated with our transparent conductive Indium Tin Oxide (ITO). Our ITO coating is specially designed for maximum transmission over the operating wavelength.

Response Time

Meadowlark's HS LCVR utilizes unique surface alignment procedures coupled with precise temperature control and a new drive scheme to achieve the fastest possible switching times. The HS LCVR reaches switching speeds of ~50 microseconds to switch from one-half to zero waves (low to high voltage) and ~500 microseconds to switch from zero to one-half wave (high to low voltage) at 532nm.



Key Features

- Sub-millisecond speeds
- Standard LC Drive Schemes
- Includes heated housing
- Precision non-mechanical retardation control

Liquid Crystal Suite

Variable Retarders

Liquid Crystal Variable Retarder
UV Variable Retarder
MWIR Variable Retarder
OEM LCVR

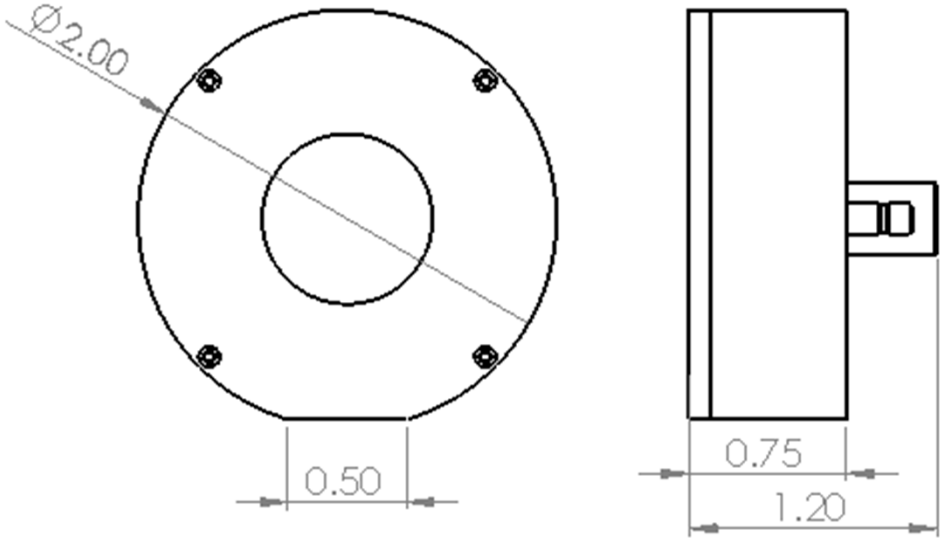
Rotators

Achromatic High Speed Rotator
Binary Rotator
Polarization Rotator

Shutters / Attenuators

Achromatic High Speed Shutter
High Contrast Shutter
Variable Attenuator

Meadowlark Optic's HS LCVR must be paired with a HSD5020 digital interface. The HSD5020 will keep the HS LCVR at optimum temperature and voltage ranges for best performance. The driver features 4 separate drive schemes and has the ability to drive two HS LCVR cells at the same time.



SPECIFICATIONS

Retarder Material	Nematic liquid crystal
Substrate Material	Optical quality synthetic fused silica
Wavelength Range	450 - 700 nm
Typical LC Rise Time (10 – 90%) **Typical LC Fall Time (90 – 10%)**	50 µs @ 532 nm 500 µs @ 532 nm
Retardance	0 to λ/2
Transmitted Wavefront Distortion (at 632.8 nm)	≤ λ/4
Surface Quality	40 – 20 scratch-dig
Beam Deviation	≤ 2 arc min
Reflectance (per surface)	≤ 0.5% at normal incidence
Temperature Range	50°C
Recommended Safe Operating Limit	500 W/cm^2, CW 300 mJ/cm^2, 10 ns, visible

ORDERING INFORMATION

Diameter, D (in.)	*Clear Aperture, CA (in.)*	*Thickness, t (in.)*	*Part Number*
2.00	0.70	0.75	HSLRC – 200

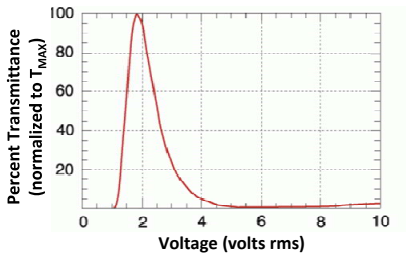
Driver Specifications

Fundamental Drive Waveform	10 KHz AC square wave
Modulation Amplitude	0-10 V rms
DC Offset	<5 mV
Communication Interface	USB
Output Channels	2 Cells
Modulation Waveforms	Chop, Gate, Steady State, Idle
CE Compliance	Compliant

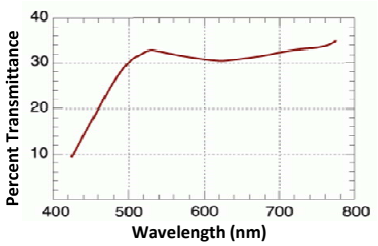
High Contrast Optical Shutter

This liquid crystal shutter is a vibration-free alternative to mechanical shutter that is especially convenient for use in polarized light beams. The liquid crystal switches between a state that rotates the input polarization by 90° with no voltage applied and a state that makes no change in the input polarization with 8 to 10 volts applied. The applied voltage is 2kHz AC as supplied by our D5020 or B1010 liquid crystal drivers. The liquid crystal configuration is twisted nematic. The shutter is supplied with integral dichroic visible polarizers that function over the wavelength range of 450 nm to 700 nm to provide an average contrast ratio of better than 1,000:1 over this wavelength range. Shutters with larger aperture sizes and with wavelength coverage to 2.1 microns are available on a custom basis. Please call with your special requirements.

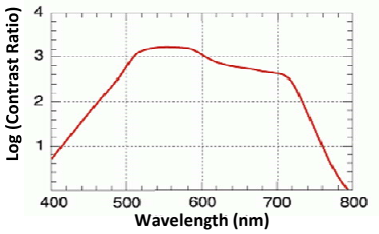
Normalized transmittance of Liquid Crystal Variable Attenuator with crossed linear polarizers at a single wavelength



Unpolarized Transmittance as a function of wavelength for LC Variable Attenuator, optimized for 550 nm, with polarizers and unpolarized input



Typical Contrast Ratio of a Liquid Crystal Variable Attenuator optimized at 550 nm



Key Features

- High contrast ratio
- Computer control capabilities
- No mechanical motion
- No vibration

Liquid Crystal Suite

Variable Retarders

Liquid Crystal Variable Retarder
UV Variable Retarder
MWIR Variable Retarder
OEM LCVR

Rotators

Achromatic High Speed Rotator
Binary Rotator
Polarization Rotator

Shutters / Attenuators

Achromatic High Speed Shutter
High Contrast Shutter
Variable Attenuator

Controllers

Analog Controller
FLC Controller
LC Digital Interface Controller
Temperature Controller
Two Channel High Voltage Controller

SPECIFICATIONS

Liquid Crystal Configuration	Twisted nematic
Substrate Material	Optical quality synthetic fused silica
Polarizer Material	Dichroic polymer
Wavelength Range	450 – 700 nm
Contrast Ratio (average)	1,000:1
Angular Field of View	25˚ incidence angle with some reduction above 10˚
Switching Time (10% to 90%) at room temperature	
Closed to Open: Open to Closed:	5 milliseconds 0.4 milliseconds
Transmitted Wavefront Distortion (at 632.8 nm)	≤ λ/2
Surface Quality	60 – 40 scratch-dig
Reflectance (per surface)	≤ 0.5% at normal incidence
Beam Deviation	≤ 5 arc min
Recommended Safe Operating Limit	1 W/cm^2, CW
Glass Thickness	0.48 – 0.52 in.
Polarization Direction	Vertical on input face, horizontal on output face
Storage Temperature	-20˚C to + 80˚C
Operating Temperature	0˚C to + 50˚C

ORDERING INFORMATION

Diameter in. (mm)	*Clear Aperture in. (mm)*	*Thickness in. (mm)*	*Part Number*
1.00 (25.4 mm)	0.37 (9.4 mm)	1.23 (31.24 mm)	LCS – 100 – λ
2.00 (50.8 mm)	0.70 (17.8 mm)	0.75 (19.05 mm)	LCS – 200 – λ
3.00 (76.2 mm)	1.60 (40.64 mm)	1.00 (25.4 mm)	LCS – 300 – λ

Please specify operating wavelength λ in nanometers when placing your order.

Analog Liquid Crystal Controller

Meadowlark Optics is excited to announce the release of the Model B1010, our new Analog Liquid Crystal Controller. This liquid crystal (LC) driver is designed to integrate with any single (standard) Meadowlark Optics LC device currently offered as well as any nematic Liquid Crystal device compatible with the specifications listed. Independent voltage settings allow easy and repeatable selection of two retardance values. Often, it is desirable to modulate between the two states. For example, switching between quarter-wave and three quarter-wave retardance changes linearly polarized light between left and right circular. A manual toggle allows easy switching between two states. Banana jacks between the knobs allow for continuous voltage monitoring without interfering with LC device connections. Each Meadowlark Optics Liquid Crystal Variable Retarder is supplied with a plot of its actual retardance versus voltage. Using your Model B1010 Controller and this retardance plot ensures accurate retardance to voltage correlation.

SPECIFICATIONS	
Output Voltage	0 to 20 V_{AC}, RMS, maximum
Fundamental Drive Waveform	2 kHz AC square wave
External Modulation (input)	None
Output Bias	± 10 mV $_{DC}$
Power Requirements	12 V_{DC} 200 mA or 9V battery External power supply included 100-240 V_{AC} 50-60 Hz, 0.3 A International Plugs
Battery Life	1 hour (intended for convenience, not as a primary power source)
External Dimensions (W x D x H)	3.3 x 6.0 x 2.2 in.
Weight	< 1 lb.
CE Compliance	Compliant

ORDERING INFORMATION	
Item	***Part Number***
Analog Liquid Crystal Controller	B1010

Key Features

Convenient, stand-alone bench-top operation

Versatile – compatible with all standard Meadowlark Optics liquid crystal devices

Out-of-the-box functionality
Sets up in minutes

Optional battery supply

Banana jacks allow for easy multimeter attachment

Liquid Crystal Suite

Variable Retarders
Liquid Crystal Variable Retarder
UV Variable Retarder
MWIR Variable Retarder
OEM LCVR

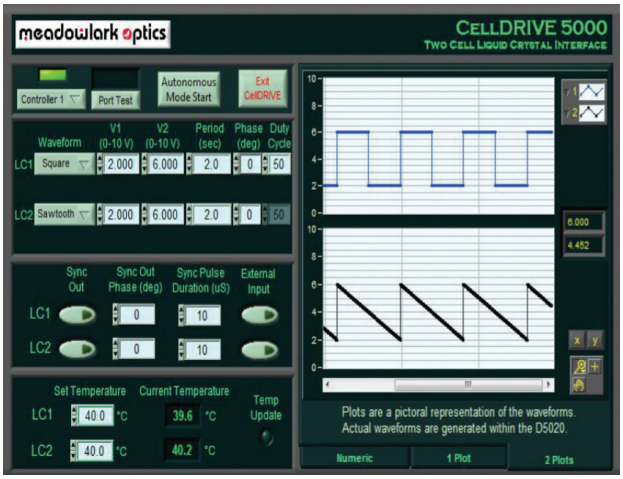
Rotators
Achromatic High Speed Rotator
Binary Rotator
Polarization Rotator

Shutters / Attenuators
Achromatic High Speed Shutter
High Contrast Shutter
Variable Attenuator

Controllers
Analog Controller
FLC Controller
LC Digital Interface Controller
Temperature Controller
Two Channel High Voltage Controller

Liquid Crystal Digital Interface – D5020

The D5020 Liquid Crystal Digital Interface is the next generation in the evolution of Meadowlark Optics Liquid Crystal Controllers. The Digital Controller is designed for user functionality and productivity. The D5020 provides a “set and go” function that allows the controller to run autonomously without a computer.



CellDRIVE 5000 User Interface

Controlling multiple Liquid Crystal cells has never been easier. CellDRIVE 5000 software provides a separate sync output for each channel as well as temperature sensing and control on both channels. The 2 kHz square wave output can be amplitude modulated with sinusoidal, square, triangle, sawtooth and transient nematic effect waveforms.

D5020 Package:

- D5020 Controller Unit
- Front Panel SMB I/O Connectors
- User Manual
- USB Cable
- Power Supply and Power Cable
- Temperature Sensing and Control capability
- CellDRIVE 5000 Software
- National Instruments LabVIEW™ virtual Instrument Drivers

Key Features

- Two channels of voltage and temperature sensing & control (TSC)
- USB powered (unless using TSC)
- Waveforms generated internally
- Independent SMB I/O Connectors for each channel
- Multiple external control options
- Includes USB and LabVIEW™ code example

Liquid Crystal Suite

Variable Retarders

Liquid Crystal Variable Retarder
UV Variable Retarder
MWIR Variable Retarder
OEM LCVR

Rotators

Achromatic High Speed Rotator
Binary Rotator
Polarization Rotator

Shutters / Attenuators

Achromatic High Speed Shutter
High Contrast Shutter
Variable Attenuator

Controllers

Analog Controller
FLC Controller
LC Digital Interface Controller
Temperature Controller
Two Channel High Voltage Controller

SPECIFICATIONS	
Fundamental Drive Waveform	2 kHz AC square wave
Modulation Amplitude	0 – 10 Vrms (20 Vrms option available)
Modulation Resolution	1 mV (0.155 mV using LabVIEW™ subroutines)
DC Offset	< 5 mV
Communications Interface	USB
LC Cell to Controller Connections	SMA – SMB, 2 m cable length
CE Compliant	
Dimensions (L x W x H)	5.50 x 5.25 x 1.63 in.
Weight	1.8 lbs. (with cables)
Modulation Waveforms	External modulation Input (0 - 5 V) Sinusoidal Triangle Square Sawtooth Transient nematic effect
Temperature Control (2 Channels)	Active heating/passive cooling within ± 1˚C of nominal set point
Sync Output	TTL, user specified timing and phase
System Requirements: Windows™ Vista, 7 or 8 Requires LabVIEW™ version 2010 or higher for use with LabVIEW™ instrument Library	

ORDERING INFORMATION

Item	*Part Number*
LC Digital Interface	D5020
LC Digital Interface (20V rms)	D5020-20V
SMA to SMB Cables	SMA-SMB
Sync Cables (SMB to BNC)	SMB-BNC

Please contact a sales engineer for more information.

Two Channel High Voltage Interface

Our two Channel High Voltage Digital Interface is designed for independent high precision computer control of up to two Meadowlark Optics Swift LC liquid crystal devices at one time.

The D3060HV Package includes all the functionality of the D3050 plus the high voltage circuitry necessary for Swift LC devices. Also included is capability for temperature monitoring and control on one channel. The Advanced Package allows the amplitude of the 13 kHz square wave output to be driven either by an external signal supplied to a front panel connector or specific CellDRIVE generated waveforms including sinusoidal, square, triangle, sawtooth and transient nematic effect waveforms. Additional functions include the capability to output a sync pulse on a front panel connector at desired points in the CellDRIVE generated waveforms and the ability to save/restore all CellDRIVE settings to/from a file.

Package Includes:

- D3060HV Controller Unit with external input and sync output front panel connectors
- User Manual
- USB and RS232 cables
- Temperature control cable
- LC – Controller interface cable
- Power supply and power cable
- Temperature monitoring and control
- CellDRIVE 3100 HV Software
- National Instruments LabVIEW™ virtual instruments driver

Key Features

USB or RS232 interface

C++ code examples

Compact and simple to use

Microsoft® HyperTerminal configuration file included

Independent control of voltage levels on two channels to 10 mV resolution

Includes National Instruments LabVIEW™ Virtual Instrument drivers to interface with custom software

Liquid Crystal Suite

Variable Retarders

Liquid Crystal Variable Retarder
UV Variable Retarder
MWIR Variable Retarder
OEM LCVR

Rotators

Achromatic High Speed Rotator
Binary Rotator
Polarization Rotator

Shutters / Attenuators

Achromatic High Speed Shutter
High Contrast Shutter
Variable Attenuator

Controllers

Analog Controller
FLC Controller
LC Digital Interface Controller
Temperature Controller
Two Channel High Voltage Controller

SPECIFICATIONS	
Fundamental Drive Waveform	13 kHz ac square wave
Modulation Amplitude	0 – 100 V rms
Modulation Resolution	10 mV (1.55 mV using LabVIEW™ subroutines)
DC Offset	< 50 mV
Communications Interface	USB or RS232
LC Cell to Controller Connections	LEMO™ RF cable, 2 m length
Power Requirements	100-240 V ac 47 – 63 Hz 2.5 A
Safety Feature	Keyed Interlock Switch
Modulation Waveforms	External modulation input (0-5 V) Sinusoidal Triangle Square Sawtooth Transient nematic effect
Temperature Control	Active heating/passive cooling to within ± 1˚C of nominal set point
Sync Output	TTL, 1 µs pulse, user specified phase

ORDERING INFORMATION	
Item	***Part Number***
High Voltage Controller	D3060HV

Temperature Controller – TC3051

The Meadowlark Optics TC3051 is a single channel, microprocessor based temperature controller specifically designed to work with Meadowlark Optics' liquid crystal devices equipped with the Temperature Sensing and Control (TSC) option.

The TC3051 requires minimal setup:

1. Connect the included power supply.
2. Connect the temperature control cable to both the TC3051 and the liquid crystal device.
3. Turn the power on.

SPECIFICATIONS	
Requirements	100 – 240V ac, 47 – 63 Hz, 500 mA
Fuse	Internal (not user serviceable)
Environment	0˚C to + 50˚C (Operating) -55˚C to + 100˚C (Storage)
External Dimensions (W x D x H)	5.08 x 5.25 x 1.50 in. (12.90 x 13.33 x 3.81 cm)
Weight	lb. (0.45 kg)
Temperature Readout Resolution	1˚C
Temperature Readout Range	0˚C to 99˚C
Setpoint Resolution	1˚C
Setpoint Range	20˚C to 60˚C

ORDERING INFORMATION	
Temperature Controller	TC3051

Key Features

• • •

Stand Alone

LED Display

1 Channel Temperature Control

Liquid Crystal Suite

• • •

Variable Retarders

Liquid Crystal Variable Retarder

UV Variable Retarder

MWIR Variable Retarder

OEM LCVR

Rotators

Achromatic High Speed Rotator

Binary Rotator

Polarization Rotator

Shutters / Attenuators

Achromatic High Speed Shutter

High Contrast Shutter

Variable Attenuator

Controllers

Analog Controller

FLC Controller

LC Digital Interface Controller

Temperature Controller

Two Channel High Voltage Controller

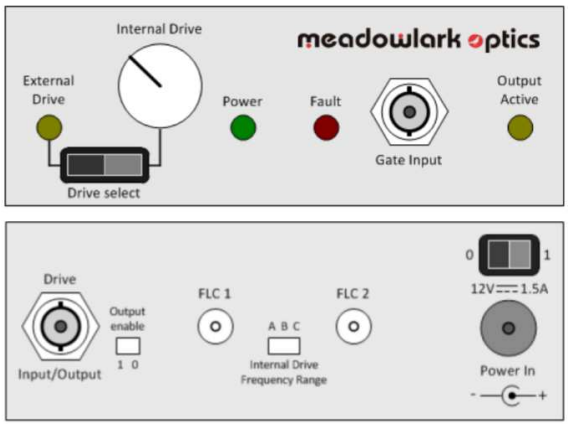
Ferroelectric Liquid Crystal Controller

The FCS010 is a two-channel liquid crystal controller specifically designed to drive our ferroelectric liquid crystal shutters and rotators. It has two short-circuit protected output channels driven 180 degrees out of phase.

The pre-configured controller waveforms are optimized for FLC devices. We can tailor the waveform to your specific needs based on application and purchased FLC device. The drive waveform is output through SMA connectors. This controller is 100% RoHS compliant and is powered by a separate 12V international power supply.

SPECIFICATIONS	
Dimensions	5.3 in. W x 5.3 in. L x 2.0 in. H 13.5 cm W x 13.5 cm L x 5.1 cm H
Number of LC Channels	Two, running identical programs 180˚ out of phase
Output Waveform	Bipolar ± 15V peak voltage, ± 10V holding voltage
Amplitude Resolution	16-bit; 1 mV voltage resolution
Internal Drive	1 to 10,000 Hz, 50% duty cycle, frequency controlled by front-panel 10-turn knob

ORDERING INFORMATION	
Ferroelectric Liquid Crystal Controller	FCS010



Compact, rugged, light weight – 5.3 x 5.3 x 2 in. form factor

Key Features

• • •

Automatically DC balances

External modulation

10V output

Gate input

Drive I/O

Frequency range 1 Hz – 10 kHz

Liquid Crystal Suite

• • •

Variable Retarders

Liquid Crystal Variable Retarder

UV Variable Retarder

MWIR Variable Retarder

OEM LCVR

Rotators

Achromatic High Speed Rotator

Binary Rotator

Polarization Rotator

Shutters / Attenuators

Achromatic High Speed Shutter

High Contrast Shutter

Variable Attenuator

Controllers

Analog Controller

FLC Controller

LC Digital Interface Controller

Temperature Controller

Two Channel High Voltage Controller

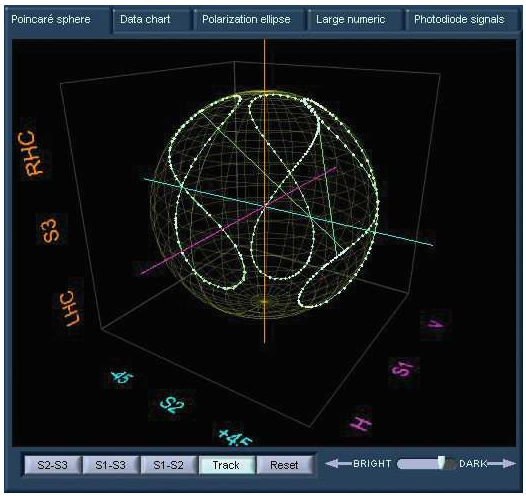
Other Capabilities

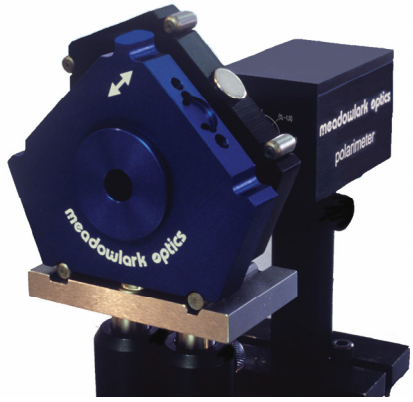
Polarimeter

Our user-friendly Polarimeters provide high accuracy and reliability in an easy to use instrument, suitable for manufacturing and laboratory applications.

Our Polarimeter is a compact system with convenient computer control that accurately measures Stokes Parameters 10 times per second. It quantifies the State of Polarization (SOP) and graphically displays the Poincaré Sphere, Polarization Ellipse, or running chart.

The Meadowlark Optics system contains no spinning waveplates, motors, or other moving parts to wear or cause vibrations. Patented algorithms provide high accuracy and calibration versatility.





Key Features

- Compact
- No moving parts
- Broad wavelength range
- Fiber and free space versions
- Visible and near infrared versions

SPECIFICATIONS	
Absolute Degree of Polarization Accuracy	≤ 1%
Measurement Frequency	10 Hz
Resolution	0.001 of a Stokes Parameter
Maximum Operating Temperature	40˚C
Optical Head Dimensions	2.83 x 1.75 x 1.75 in.
Minimum Optical Power to maintain accuracy*	10 µW
Input Aperture	2 mm

These specifications describe performance at 23 ± 3 °C ambient temperature.
*sensitivity can be increased to 1 mW by special request

System Requirements:
• Windows™
• USB Port
• Use of LabView™ Instrument Library requires LabView™ version 6.1 or newer full development system.

ORDERING INFORMATION		
Wavelength Range	***Version***	***Part Number***
450 – 1100 (nm)	Visible	PMI – VIS
900 – 1700 (nm)	Near Infrared	PMI – NIR

Optional Accessories:
Eigenstate Generator Set*
Fiber optic cable adapter
- Visible
- Infrared
Angle-polished fiber collimator adapter
Calibration at additional wavelengths
*The Eigenstate Generator Set enables precise Polarimeter recalibration

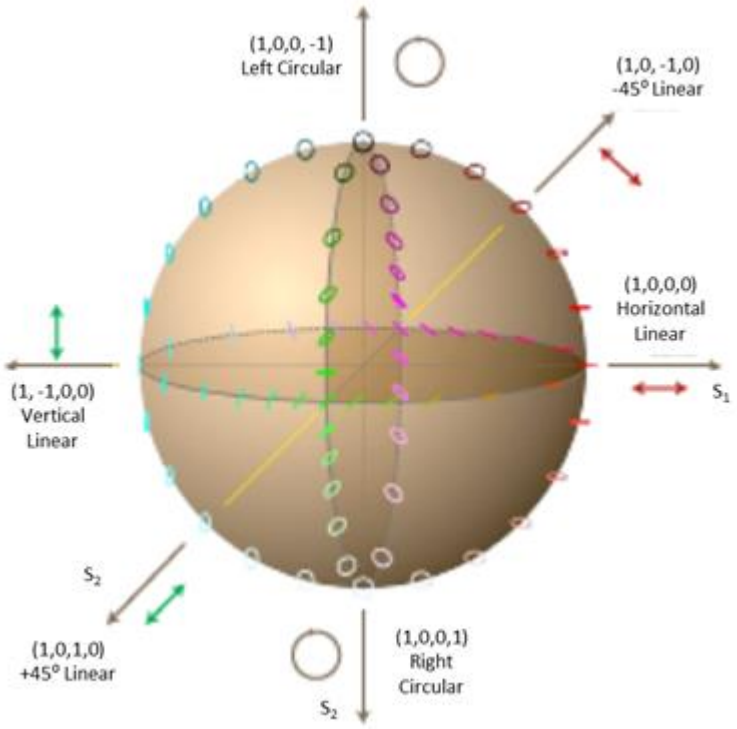
Eigenstate Calibration Set

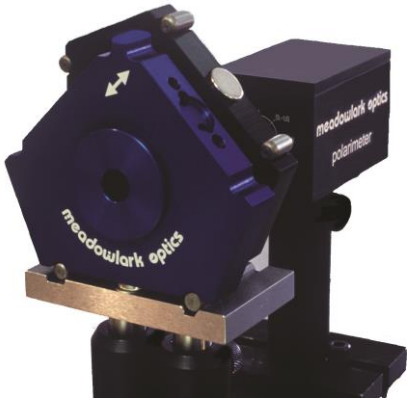
Meadowlark Optics' Eigenstate Calibration Sets are tools which produces six polarization eigenstates: linear polarized light at angles of 0, 90, +45, -45 degrees as well as circular right-handed and circular left-handed polarized light.

These states are created by using a precision dichroic linear polarizer in a black housing and a precision quarter waveplate in a blue housing. The housings are CNC machined so that the accuracy of the angles is better than 1 arc minute. Pins on the housings mate to a v-groove and a flat groove in a quasi-kinematic fashion, while magnets provide holding force. This scheme facilitates precise, simple and fast indexing of the polarization eigenstates. Large arrows on the housing indicate the transmission axis of the polarizer and the fast axis of the waveplates for ease of use. Available for wavelength ranges from 450-1700 nm.

Eigenstate Retarders are additional retarders that can be purchased at the same time as your Eigenstate Calibration Set and Polarimeter. Wavelengths available from 450-1700 nm, with broadband options also available.

Poincaré Sphere showing six polarization eigenstates





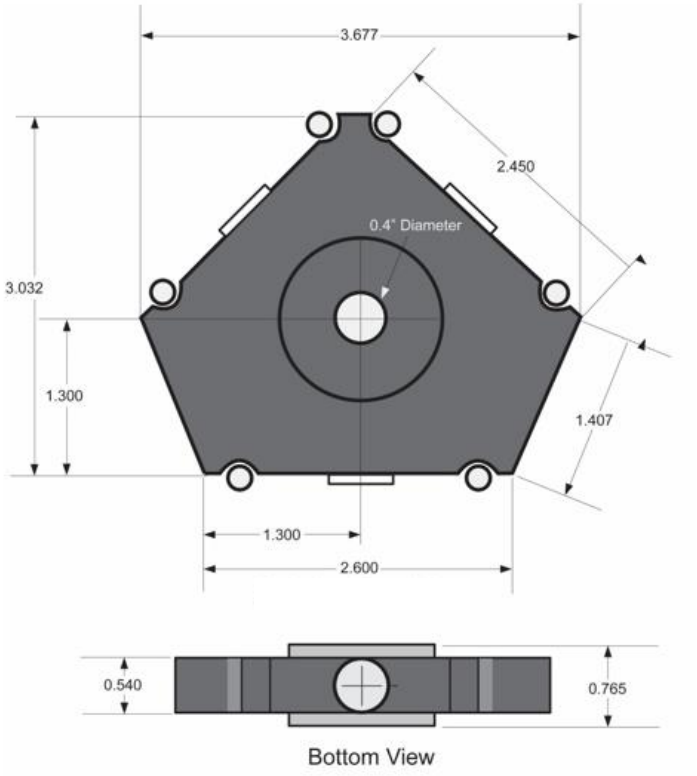
Key Features

- Ellipsometry
- Polarization control
- Polarization analysis
- Calibration accessory for PMI Series polarimeters

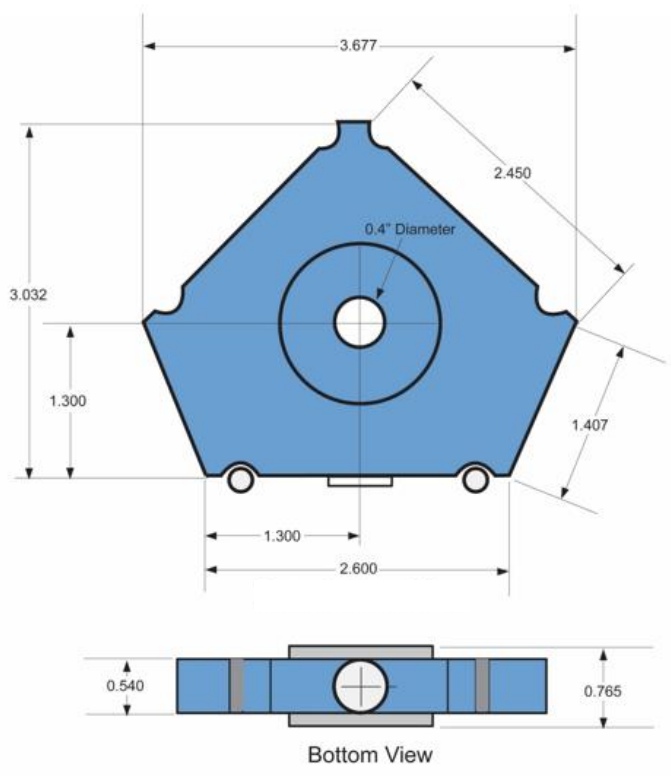
Other Systems

- Spatial Light Modulators
- Tunable Optical Filters
- Pockels Cell Modulators
- Photomultiplier Systems
- Tri-Color Filter

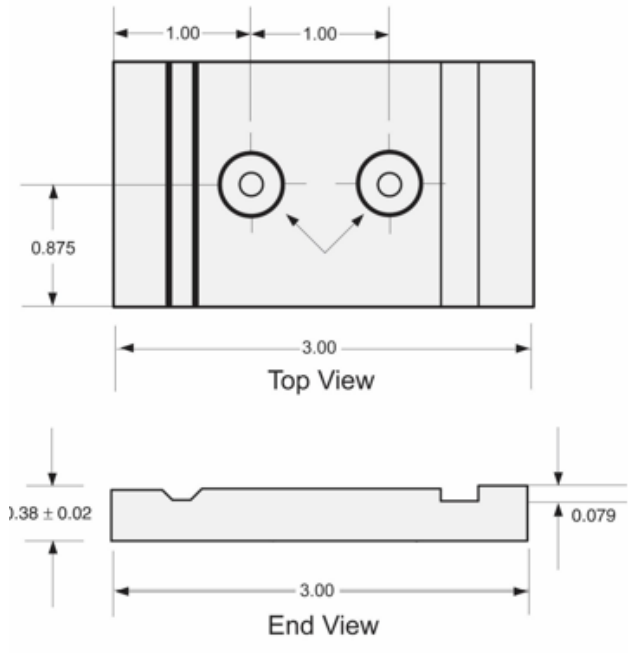
Polarizer Front View



Retarder Front View



Eigenstate Baseplate



Calibration Sequence	Stokes Vector	SOP Description	Polarizer Orientation	Waveplate Orientation
Step 1	(1,1,0,0)	Horizontal	↔	Removed
Step 2	(1,-1,0,0)	Vertical	↕	Removed
Step 3	(1,0,1,0)	+45°	⤢	Removed
Step 4	(1,0,-1,0)	-45°	⤡	Removed
Step 5	(1,0,0,1)	Right Circular	↔ ↕	⤢ ⤡
Step 6	(1,0,0,-1)	Left Circular	↕	⤢ ⤡

Polarimeter calibration is greatly simplified by the Eigenstate Calibrator sequence outlined above

SPECIFICATIONS FOR MONOCHROMATIC EIGENSTATE CALIBRATION SET	
Retardance Accuracy	λ/350
Thickness	0.79 ± 0.015 in (20.06 ± 0.38 mm)
Clear Aperture	0.32 in (8.13 mm)

SPECIFICATIONS FOR BROADBAND EIGENSTATE CALIBRATION SET	
Wavelength Range – VIS	450 – 800 nm
Wavelength Range – NIR	690 – 1200 nm
Wavelength Range – IR	1100 – 1700 nm
Retardance Accuracy	λ/50
Thickness	1.10 ± 0.02 in (27.94 ± 0.51 mm)
Clear Aperture	0.197 in (5.0 mm)

ORDERING INFORMATION FOR CALIBRATION SETS (POLARIZER AND RETARDER)	
Item	***Part Number***
Single Wavelength Eigenstate Calibration Set	ECS – λ *(Please specify your operating wavelength λ in nm when ordering)*
Broadband Eigenstate Calibration Set – VIS	ECS – VIS
Broadband Eigenstate Calibration Set – NIR	ECS – NIR
Broadband Eigenstate Calibration Set – IR	ECS – IR

ORDERING INFORMATION FOR CALIBRATION RETARDERS OR POLARIZERS (INDIVIDUAL COMPONENTS)	
Single Wavelength Eigenstate Retarder	EGR – λ *(Please specify your operating wavelength λ in nm when ordering)*
Broadband Eigenstate Polarizer (450 – 1700 nm)	EGP – GTP
Achromatic Eigenstate Retarder – VIS (450 – 800 nm)	EGR – VIS
Achromatic Eigenstate Retarder – NIR (690 – 1200 nm)	EGR – NIR
Achromatic Eigenstate Retarder – IR (1100 –1700 nm)	EGR – IR

Customs options available. Please contact one of our Solutions Engineers for more information.

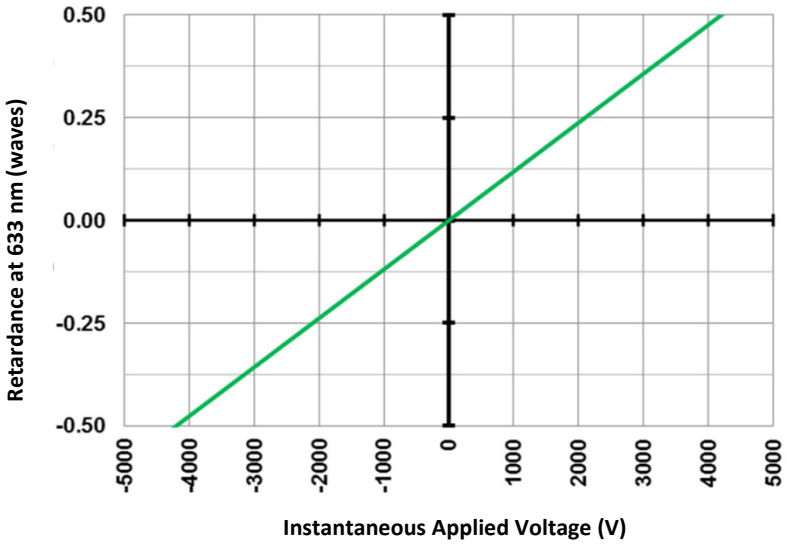
Pockels Cell Modulators

Our longitudinal Pockels Cells are often used in polarimetry on imaging light beams and in the chopping of polarized beams. They consist of Z-cut KD*P crystals between protective windows that have transparent indium-tin oxide electrodes applied to their interior faces. The electrodes produce a uniform electric field normal to the optical faces and permit use of a thin (approximately 3 mm) KD*P crystal.

As shown on the response graph, the electric field creates a positive or negative retardance value depending on the instantaneous field direction.

The thin crystal additionally makes these cells suitable for use in non-collimated imaging light beams slower than f/20. Meadowlark specializes in clear apertures up to 40 mm. These devices are useful as variable retarders in applications requiring very fast switching.

Due to the wide variation in customer applications, Meadowlark is unable to provide a turn-key high voltage driver, but is pleased to help identify the critical voltage/current requirements.



Key Features

- Large clear apertures (40 mm)
- Suitable for imaging applications
- Symmetric nanosecond switching times

SPECIFICATIONS at 633 NM, 20 0C	
Transmission	>90% @ 633 nm
Quarter Wave Voltage	<2200 V (linear w/wavelength)
Maximum Voltage	±4500 V
AC Voltage Modulation Range	10 Hz to 10 kHz (must be AC with no DC bias)
Nominal Capacitance	~120 pF (25 mm) ~200 pF (40 mm)
Contrast Ratio	>1000:1 (Collimated Light)
Cell Dimensions	Ø2.25" x 1.01" (25 mm CA) Ø2.95" x 1.18" (40 mm CA)
Operating Temperature	5 0C to 35 0C

ORDERING INFORMATION	
Part Number	Pockels Cell - 25 nm - λ Pockels Cell - 40 nm - λ

Please note that power supply, cables and software are not included.

Retardance Measurement Station

Meadowlark Optics' Retardance Measurement Station, Model TB1000, is the first commercial product for high precision measurements of waveplates. Customer demand triggered the development of the TB1000. This turnkey, fully-enclosed system measures the retardance of multi-order waveplates and same-material compound zero-order waveplates (Sapphire, Magnesium Fluoride, and Quartz). The TB1000 is versatile and portable and can be easily moved from the R&D lab to the production floor, bringing the precision of Meadowlark Optics Metrology Services from our lab to yours.

Retardance measurements are obtained in under 2 seconds with the user-friendly software in just one click. A reference retarder is included with each shipment to ensure the system is meeting the calibration as measured at the factory prior to shipping.

Optional items can be added to the TB1000. The standard system has alignment marks to assist in placement of the waveplate on the measurement bay. This area can be customized per the user's crystal dimensions with our drop-in alignment guide, which ensures that measurements are spatially accurate each and every time.

Quartz Reference Retarder Included
with retardance data over a 7.6 mm area.

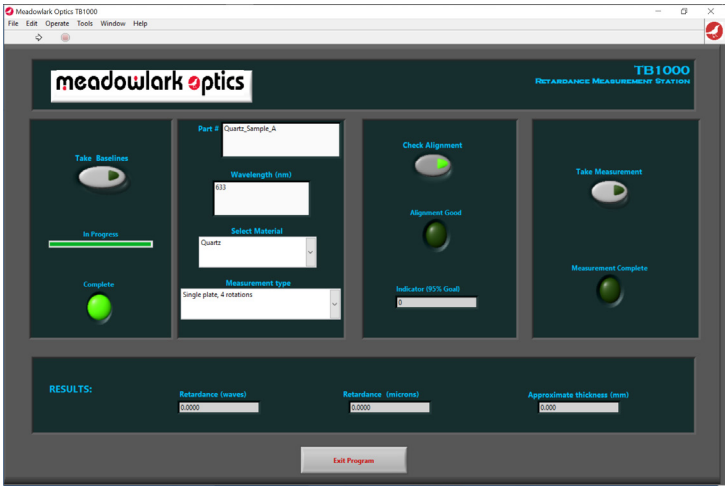
Optional custom drop-in alignment guides →

Key Features

- Retardance measurements in under 2 seconds with one-click
- Highly Repeatable
- Fast Axis Alignment Check
- Automatic Dark and Bright Reference
- User-friendly Software Interface
- Reference Retarder Included

The TB1000 software is fully automated and provides user's retardance measurements with a simple click. It only takes <2 seconds to obtain accurate, repeatable results.

Due to variation in crystal structure, calculating the retardance based on the thickness of the material using only a listed birefringence can lead to errors. The TB1000 allows an end user to accurately measure the real retardance of each waveplate.



TB1000 Software Interface

Retardance in crystals will change with temperature variation. As a rule of thumb, the retardance (in waves) for a 1 mm thick quartz retarder varies by about -0.5% per °C. For this reason, we encourage regular monitoring of air temperature around the equipment if small retardance changes are concerning. Alternatively, you can use the reference retarder included with the TB1000 to confirm accurate readings.

Sample Measurements using TB1000

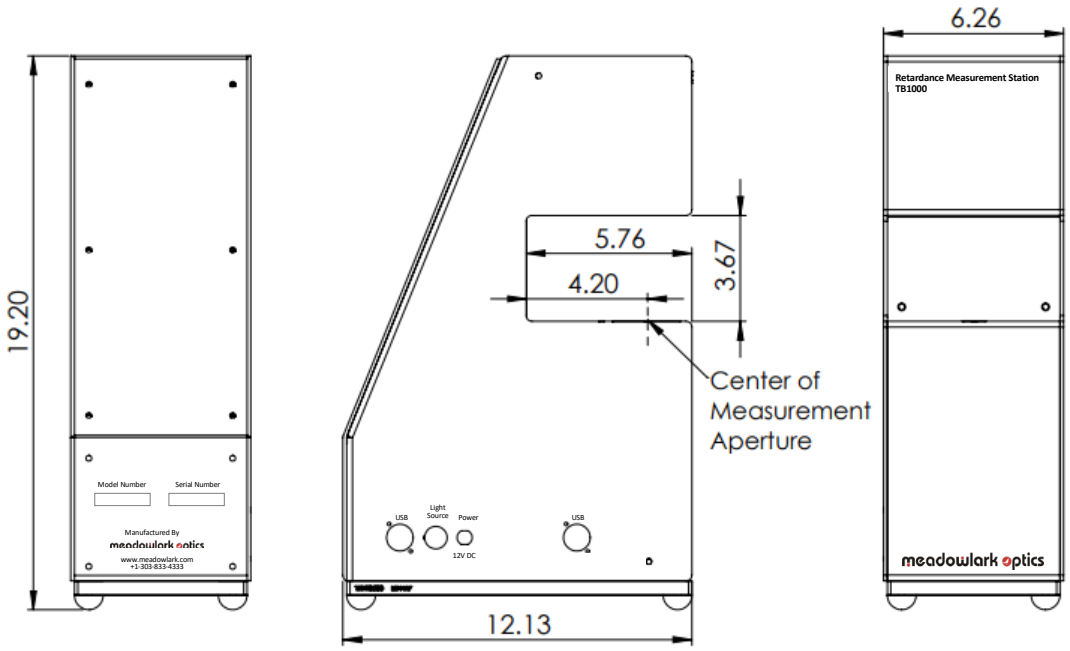
Material	[1]Measured Thickness in mm	[2]Calculated Retardance in nm (waves)	[3]Measured Retardance in nm (waves)
Quartz A	3.068	27,770 (43.870)	27,705 (43.768)
Quartz B	1.623	14,691 (23.208)	14,648 (23.142)
Quartz C	0.198	1,792 (2.830)	1,753 (2.771)
Sapphire A	1.733	13,976 (22.079)	13,958 (22.052)
Sapphire B	3.475	28,018 (44.262)	27,984 (44.210)
MgF2 A	2.320	27,300 (43.127)	27,184 (42.945)
MgF2 B	0.483	5,789 (9.145)	5,667 (8.953)

1. Measured on Heidenhain length gauge.
2. Retardance calculated using $\delta = \beta t/\lambda$, using Measured Thickness
3. Measured at 633nm on TB1000.

Retardance Measuring Station

SPECIFICATIONS	
Retardation Range	0.1 – 45 waves at 630 nm (default)
Wavelength measurement range capabilities	380 nm to 4.5 µm
Maximum optic size (to center)	8.2" (208 mm)
Retardance Accuracy[1]	0.005 waves at 630 nm
Measurement Rate[2]	<2 seconds
Measurement Spot Diameter	3.8 mm
Measurement Units	nm, λ (for retardance) or mm (for thickness)
Crystal Types	Quartz Sapphire Magnesium fluoride
Interfaces	USB 2.0

[1] Highest retardance accuracy obtained with four measurements.
[2] Minimum speed retardance is obtained.



ORDERING INFORMATION	
Item	***Part Number***
Retardance Measuring Station	TB1000
Optional Sample Holder Kit	TB1000-SHK

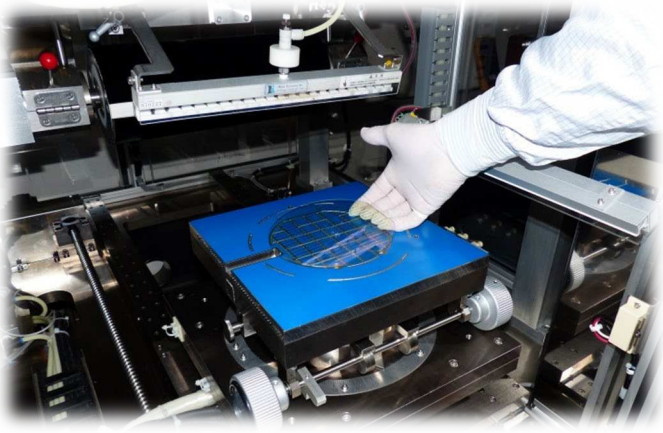
CUSTOM CAPABILITIES

- Liquid crystal based on specific application
- UV to MWIR
- Sizes from 3 mm to 200 mm
- Custom shapes
- Any quantity
- Spatially patterned waveplates

ENGINEERING SERVICES

- In-house modeling software
- Thin film design
- Pancharatnam retarder design
- Tunable filter design
- Fabry-Perot design
- Engineering consulting

CONTRACT MANUFACTURING



- Metrology
- Micro-dicing
- Shaping
- Polishing
- Water jetting
- Laser marking
- Rapid prototyping
- OEM capability

meadowlark optics

Contact a sales engineer at:

www.meadowlark.com - sales@meadowlark.com

303-833-4333

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