Polarization can be a complex subject. Listed below are key criteria which should be considered in order to ensure that any polarization effects present produce the desired result.

INITIAL POLARIZATION STATE

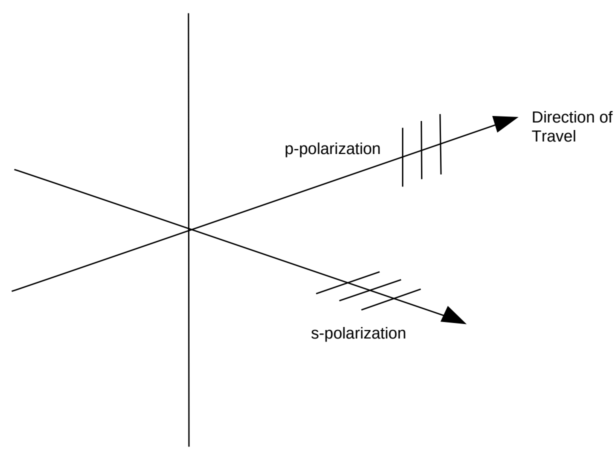
Optical radiation across the spectrum is in the form of transverse electromagnetic waves - that is, the directions of the oscillating electric and magnetic fields of any particular wave are perpendicular to the direction of travel and to each other. Polarization occurs when the electric field components (vectors quantities) for the many waves in a beam assume a preferred direction rather than being randomly distributed. The electric field vector is used to describe the various states of polarization.

Unpolarized radiation

Most incoherent sources emit rays that have electric fields with no preferred orientation and are therefore unpolarized. (Note that some do, in fact, exhibit a small degree of polarization which may need consideration.)

Linear Polarization

A beam is said to be linearly or plane polarized when all the electric field vectors are oriented in the same direction - or plane of polarization. The plane of polarization is perpendicular to the direction of travel.
When the plane of polarization is parallel to the plane of incidence, this is known as p-polarization. If the plane of polarization is perpendicular to the plane of incidence, this is known as s-polarization. The plane of incidence contains the direction of the incident beam and the normal to the surface.



Analysis of other states of polarization other than these two specific cases is generally simplified by using vector analysis where the direction of polarization is resolved into two orthogonal axes. For each axis amplitude and phase can be analyzed before being recombined.

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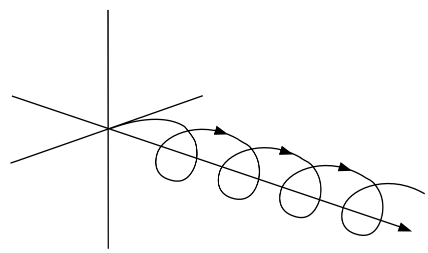
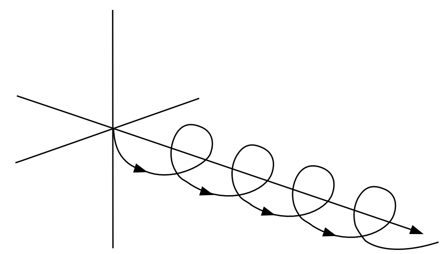
INITIAL POLARIZATION STATE (continued)

Circular Polarization

Circular polarization occurs when the two electric vectors have equal amplitudes but differ in phase by 90° ($\lambda/4$). The combined electric field vector describes a circle about the direction of travel. When viewed towards the source, a vector rotating clockwise is known as right-handed circularly polarized light and, conversely, one rotating anti-clockwise is left-handed circularly polarized light.



Right Handed Circular Polarization



Left Handed Circular Polarization

Elliptical Polarization

Linear and circular polarization are specific cases of elliptical polarization. Elliptical polarization is the more general case when the amplitudes of the two electric vectors are different but the phase difference between them is constant. The combined electric field vector follows a three-dimensional ellipse about the direction of travel.

DESIRED POLARIZATION STATE

Changes from the initial state of polarization can be achieved in one of three ways

a) By converting polarized radiation into unpolarized radiation. Using a depolarizer (Page 304) will generally achieve the desired result.

b) By creating linear, circular or elliptical polarization from an unpolarized beam. Linear polarization can be obtained using Crystal, Plate and Sheet Polarizers (Pages 288-293). Alternatively two orthogonal linearly polarized beams are produced using a Polarizing Beamsplitter Cube (Page 300).

c) By modifying the initial state of polarization to another state which has the same degree of polarization, e.g. linear to circular using a Quarter Waveplate (Page 295) or rotation of the plane of polarization using a Half Waveplate (Page 295) or Optical Rotator (Page 293).

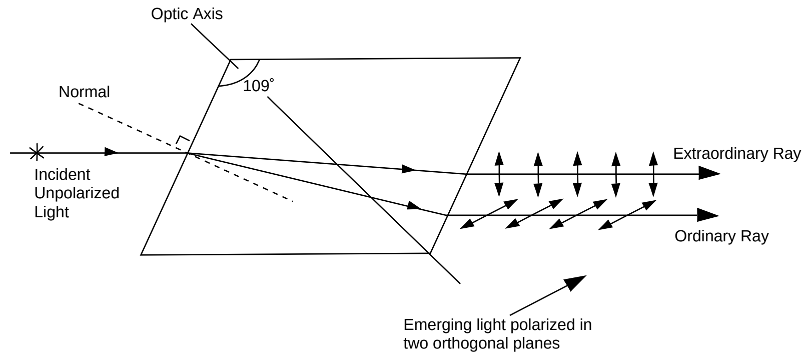
For b) and c) it is necessary to use components which introduce polarization effects.

Polarized radiation can be produced in a number of ways

Birefringence (or double refraction)

Polarized radiation can be produced from unpolarized beams by using a component made from a material which exhibits birefringence. Birefringent materials are anisotropic crystals, i.e. they possess different optical, electric, piezoelectric and elastic properties depending on their orientation. They have more than one refractive index value. Uniaxial crystals, such as calcite and magnesium fluoride, have two refractive indices and one axis of symmetry - the optic axis. Along this axis there is no birefringence. However a ray entering the material along any other direction is split into two separate rays which are polarized perpendicular to each other. They are known as the ordinary ray and the extraordinary ray. The ordinary ray propagates in a plane perpendicular to the optic axis and obeys Snell's laws of refraction and reflection using the ordinary index n_0. The extraordinary ray propagates in a plane containing the optic axis and obeys Snell's laws of refraction and reflection using the refractive index n_E associated with the extraordinary wave normal direction. This index is a complex function of both n_0 and n_E and can be calculated using the index ellipsoid.

DESIRED POLARIZATION STATE (continued)



Birefringence in a Calcite Crystal

Suitably cut and oriented prisms made from birefringent materials are used to manufacture polarizers and retarders. Most are made from calcite since this exhibits a high degree of separation between the ordinary and extraordinary rays, has a wide spectral range, is relatively easy to handle and is available in reasonably-sized pieces.
Some birefringent crystals are biaxial, i.e. they have two optic axes and three different refractive index values. Mica which is used in retarders is a biaxial crystal.
The materials mentioned so far have all exhibited linear birefringence, i.e. there is a unique direction of propagation (optic axis) for which the refractive index values of the ordinary and extraordinary rays coincide.

There is another group of materials, such as crystalline quartz, which exhibits circular birefringence. In this case the refractive indices of the two rays never coincide. There is, however, a direction of travel for which the difference is a minimum and this may be regarded as the optic axis. If a plane polarized beam is incident along the optic axis, it is separated into ordinary and extraordinary beams, which are collinear circularly polarized beams, one being left-handed and the other right-handed. They have different velocities. The resultant effect, known as optical activity, is to produce a progressive rotation of the plane of polarization as the beams pass through the material. This is used in Ealing Optical Rotators (Page 293).

Calcite	n_O = 1.658	n_E = 1.486	
Crystal Quartz	n_O = 1.544	n_E = 1.553	
Mica	n_1 = 1.552	n_2 = 1.582	n_3 = 1.587

Refractive Index Values (at 589nm) for Materials used in Ealing Polarizers

Dichroism

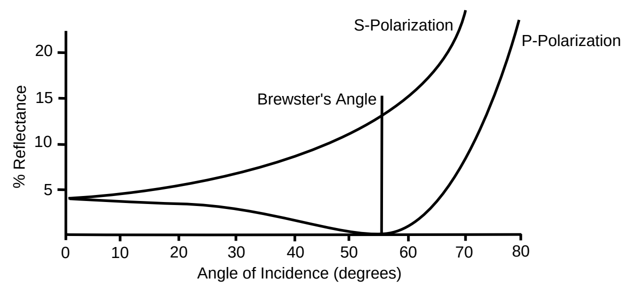
This is the phenomenon exhibited by some materials whereby radiation polarized in one direction is selectively absorbed more than that which is polarized in the orthogonal direction. Dichroic materials are used to transmit almost completely plane polarized light while absorbing everything else. Both Ealing Polarcor™ and Sheet Polarizers are dichroic. Polarcor™ (Page 292) is a special type of glass in which the dichroism is achieved through the alignment of silver particles within the glass. Ealing Sheet Polarizers (Page 291) are made from long chain organic polymers that have been oriented in a preferential direction. Light which oscillates in a plane parallel to the chain is absorbed and that which is perpendicular is transmitted.

SELECTING A POLARIZING COMPONENT - TECHNICAL CONSIDERATIONS

DESIRED POLARIZATION STATE (continued)

Reflection at a surface

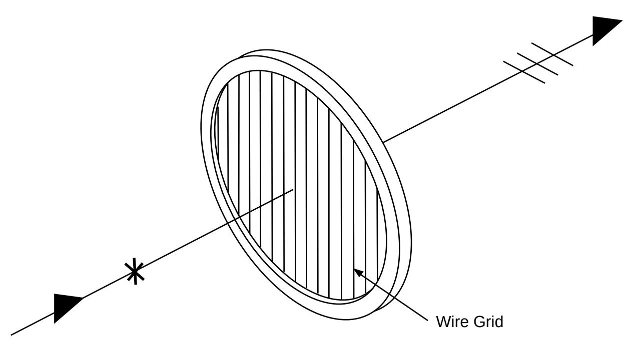
A beam incident on a surface at any angle other than normal is polarized to some extent. The reflectivities for s- and p-polarization for various angles of incidence are shown below. It can be seen that the reflectivity reaches zero for p-polarization at a specific angle of incidence - Brewster's angle. At this angle, 86.5% of s-polarization is transmitted, with the remainder being reflected. This phenomenon is used in Ealing Polarizing Beamsplitting Cubes (Page 300) which have a multilayer dielectric coating diagonally across the cube. This produces an effect which is equivalent to stacking many plates together at Brewster's angle. At each surface, the p-polarized component is fully transmitted with the percentage transmission for the s-polarized components being successively reduced until it becomes insignificant.



Reflectivities of p- and s-polarization at Varying Angles of Incidence

Reflection by wire grids

A beam incident on a grid of regular finely spaced reflective parallel wires is split such that the component parallel to the grid is reflected leaving a transmitted beam which is largely linearly polarized. For this to work efficiently, the spacing between the wires in the grid must be very small - ideally less than $\lambda/2$, where λ is the shortest wavelength of interest. This type of polarizer is therefore more easily constructed for the infrared. Ealing Infrared Wire Grid Polarizers (Page 293) are manufactured at a dedicated facility using a holographic type of grid construction. In this way, uniform narrow grid spacing is achieved repeatably to produce high efficiency polarizers.



Scattering

Light which is scattered at 90° is s-polarized. Polarizing components are not generally configured using scattering effects. However, for certain beamsplitting radiometric applications the nature of the polarization at any point should be clearly understood and care should be taken in designing any such systems.

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SELECTING A POLARIZING COMPONENT - TECHNICAL CONSIDERATIONS

WAVELENGTH RANGE

It is important to consider which specific wavelength or wavelength range is required. Some polarizing components are designed/coated for operation at one specific wavelength, others have very good broadband performance. Detailed spectral transmission figures are given for each product and are also summarized in the table on Pages 286 and 287.

Note that components that are wavelength specific have a suffix according to the table below.

Wavelength (nm)	Catalog Number Suffix	Wavelength (nm)	Catalog Number Suffix
248	/50	694	/62
266	/51	750	/63
308	/52	780	/64
355	/53	800	/65
488	/54	820	/66
500	/55	830	/67
514	/56	850	/68
532	/57	900	/69
589	/58	905	/70
633	/59	1064	/71
650	/60	1300	/72
670	/61	1550	/73

APERTURE AND ACCEPTANCE ANGLE

Care must be taken to ensure that the properties of the incident beam are compatible with the polarizing component. Crystal components generally have fairly small apertures. In addition many have very small acceptance (field) angles due to the design and functioning of the component. (See individual component specifications.)
Plate and Sheet Polarizers provide significantly higher clear apertures and acceptance angles and are ideal for medium and low power applications.

EXTINCTION RATIO

The extinction ratio of a polarizer provides a measure of polarization purity, i.e. how effectively it is separating the s- and p-polarized components of incident light. It is given by the ratio of the transmissions of p-polarized light to that of s-polarized light in the predominantly p-polarized beam emerging from the polarizer.
Polarizing components based on birefringence offer the highest extinction ratios - Ealing crystal polarizers offer extinction ratios of 10^5. Extinction ratios for dichroic components are substantially lower at about 10^3.

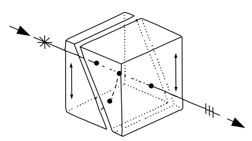
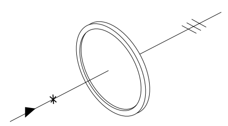
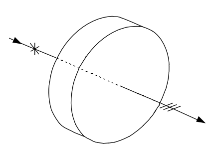
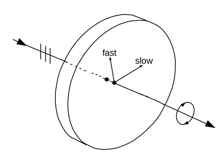
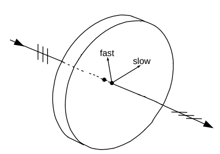
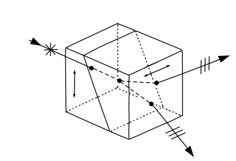
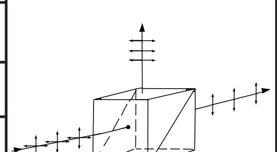
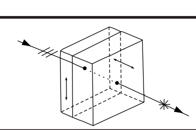
DAMAGE THRESHOLD

Damage threshold figures are given for individual Ealing polarizing components and are summarized in the table on Pages 286 and 287. It should be noted that these figures are for guidance only and have often been known to have been exceeded. Exact damage thresholds depend on each individual configuration.
Birefringent materials, such as calcite, have high damage threshold values. However, it should be noted that these values are substantially reduced if the component is cemented or coated. Air-spaced components should be chosen for high power applications. Plate polarizers offer good damage threshold performance, while Sheet Retarders and Mica Waveplates are suitable for low power applications only.

QUALITY

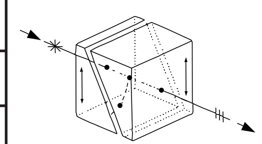
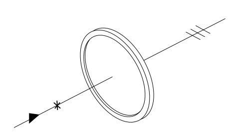
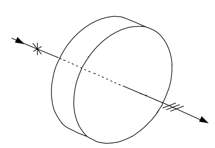
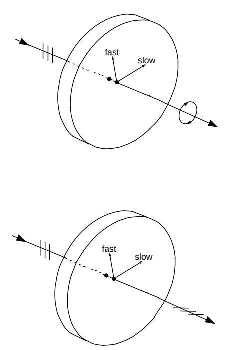
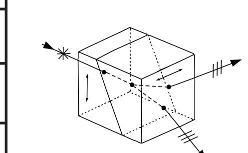
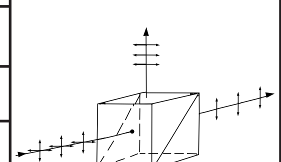
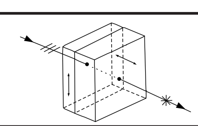
For high power applications it is particularly important to manufacture the crystal component from very high quality material and then to ensure a high standard of flatness and scratch/dig. Ealing Crystal Polarizers are all fabricated from specially selected calcite material and to exacting standards (see individual components for details).

SELECTING A POLARIZING COMPONENT - OVERVIEW OF THE EALING RANGE

PRODUCT RANGE			POLARIZATION CHARACTERISTICS OF OUTPUT	WAVELENGTH RANGE (nm)	MAXIMUM APERTURE (mm)
CRYSTAL POLARIZERS	GLAN LASER		Linear p-polarized	220-2800	20
	HIGH TRANSMISSION GLAN LASER				15
	GLAN TAYLOR				20
	GLAN THOMPSON			350-2500	
	MINIATURE GLAN THOMPSON				5
SHEET POLARIZERS	VISIBLE POLYMER FILM		Linear	350-750	101.6
	UV-VISIBLE POLYMER FILM			200-800	
	INFRARED POLYMER FILM			800-2200	
	POLARIZER/ANALYZER UNITS		Variable	350-750	
PLATE POLARIZERS	POLARCOR™		Linear	740-1580	25
	INFRARED WIRE GRID POLARIZERS			1000-35000	
	OPTICAL ROTATORS		Rotation of plane of polarization	220-2800	20
RETARDERS	MULTIPLE ORDER WAVEPLATES		Quarterwave retarders–circular polarization Half wave retarders–linear polarization with 90° rotation	248-1550	15
	ZERO ORDER WAVEPLATES				
	MICA WAVEPLATES				
	ACHROMATIC WAVEPLATES			400-1100	9
	ACHROMATIC FRESNEL RHOMBS			400-700	10
	OPTICAL ISOLATOR ASSEMBLIES		Isolation of reflected beams	532-1064	12.7
	SOLEIL BABINET COMPENSATOR		Variable retardation	200-2700	10
POLARIZING BEAMSPLITTING PRISMS	WOLLASTON PRISMS		p- and s-polarized beams transmitted with 10-25° separation	350-2500	20
	ROCHON PRISMS				
	HIGH POWER POLARIZING BEAMSPLITTING CUBES		Transmitted– p polarized Reflected– s polarized	308-1064	21.5
	NARROW BAND POLARIZING BEAMSPLITTING CUBES			488-1550	
	BROAD BAND POLARIZING BEAMSPLITTING CUBES			450-1550	
	GLAN THOMPSON BEAMSPLITTING PRISMS		p- and s-polarized beams transmitted with 44° separation	350-2500	12
	BEAM DISPLACEMENT PRISMS		2 parallel transmitted beams	220-2800	
	POLARIZING WEDGES		p- and s-polarized beams transmitted with 3.5° separation		
	VARIABLE BEAMSPLITTERS		p- and s-polarized beams of varying intensity	266-1064	12.7
DEPOLARIZERS	WEDGE		Unpolarized 'scrambled' radiation	High power 220-2600 Low power 350-2600	25
	LYOT				

SELECTING A POLARIZING COMPONENT - OVERVIEW OF THE EALING RANGE

FIELD ANGLE (DEGREES)	DAMAGE THRESHOLD	EXTINCTION RATIO/ POLARIZATION PURITY	APPLICATIONS	PAGE NUMBER
8	CW 100W/cm² pulse(1ns) 300MW/cm²	10^5	High power laser work Intra-cavity gain switching Beam combination Pulse extraction Feedback elimination	288
	CW 10W/cm² pulse(1ns) 20MW/cm²		Low and medium power work	289
15, 26	CW 1W/cm²		With monochromators, low power lasers, light sources, precision instruments	
15, 26, 41			Fiber optics	
90	CW 3W/cm²	>10^4	Production and analysis of polarized beams when used in pairs Elimination of unwanted beams	291
				290
>45	pulse(13ns) 6 J/cm²	10^4	Laser diode windows, Instrument filters, Optical heads, Optical isolators, Analysers	292
40	CW 10W/cm²	10^2	IR analysers, coupling devices, attenuators, spectrophotometer accessories, beamsplitters	293
	CW 100W/cm² pulse(1ns) 300MW/cm²		Rotation of plane of polarization in laser systems	
	pulse(1ns) 500MW/cm²		Quarter Waveplates: Production of Circular Polarization. Suppressing of reflections. Half Waveplates: Rotating Plane of Polarization, Modulators, Variable Beamsplitters	295
	very low power only		Low power production of circular polarization (λ/4) or rotation (λ/2), stress analysis	296
	CW 100W/cm² pulse(1ns) 300MW/cm²		Broadband applications	
	CW 2W/cm² pulse(1ns) 20MW/cm²			297
		10^5	Isolation of back reflections in laser systems	
			Analysis and selection of any state of polarization	298
20	CW 1W/cm²	10^5	Polarization analysis, Beam separation	299
	CW 1KW/cm² pulse(1ns) 500mJ/cm²	>200	High power laser polarizers, combiners and attenuators	300
	CW 100W/cm²	>10^3	CW laser attenuation, Beam combination and attenuators Clean up	
	pulse(1ns) 100mJ/cm²	>200	With broadband and tunable sources	301
	CW 1W/cm²	10^5	Applications requiring high extinction ratio, high beam separation and wavelength independence	
	CW 130W/cm² pulse(1ns) 300MW/cm²		Laser beam separation, fiber optic work	302
	CW 20W/cm² pulse(1ns) 200MW/cm²		Lower cost means of producing small beam separation of high power beams	
	High power models pulse(1ns) >500MW/cm²		Continuously variable output of p and s polarized beams	303
730	High power CW 20W/cm² pulse(1ns) 200MW/cm²		Depolarization of any beam	304
	Low power CW 2W/cm² pulse(1ns) 20MW/cm²		Depolarization of multi-wavelength beams	

	PRODUCT RANGE		POLARIZATION CHARACTERISTICS OF OUTPUT	WAVELENGTH RANGE (nm)	MAXIMUM APERTURE (mm)
CRYSTAL POLARIZERS	GLAN LASER		Linear p-polarized	220-2800	20
	HIGH TRANSMISSION GLAN LASER				15
	GLAN TAYLOR				20
	GLAN THOMPSON			350-2500	
	MINIATURE GLAN THOMPSON				5
SHEET POLARIZERS	VISIBLE POLYMER FILM		Linear	350-750	101.6
	UV-VISIBLE POLYMER FILM			200-800	
	INFRARED POLYMER FILM			800-2200	
	POLARIZER/ANALYZER UNITS		Variable	350-750	
PLATE POLARIZERS	POLARCOR™		Linear	740-1580	25
	INFRARED WIRE GRID POLARIZERS			1000-35000	
	OPTICAL ROTATORS		Rotation of plane of polarization	220-2800	20
RETARDERS	MULTIPLE ORDER WAVEPLATES		Quarterwave retarders– circular polarization Half wave retarders– linear polarization with 90° rotation	248-1550	15
	ZERO ORDER WAVEPLATES				
	MICA WAVEPLATES				
	ACHROMATIC WAVEPLATES			400-1100	9
	ACHROMATIC FRESNEL RHOMBS			400-700	10
	OPTICAL ISOLATOR ASSEMBLIES		Isolation of reflected beams	532-1064	12.7
	SOLEIL BABINET COMPENSATOR		Variable retardation	200-2700	10
POLARIZING BEAMSPLITTING PRISMS	WOLLASTON PRISMS		p- and s-polarized beams transmitted with 10-25° separation	350-2500	20
	ROCHON PRISMS				
	HIGH POWER POLARIZING BEAMSPLITTING CUBES		Transmitted– p polarized Reflected– s polarized	308-1064	21.5
	NARROW BAND POLARIZING BEAMSPLITTING CUBES			488-1550	
	BROAD BAND POLARIZING BEAMSPLITTING CUBES			450-1550	
	GLAN THOMPSON BEAMSPLITTING PRISMS		p- and s-polarized beams transmitted with 44° separation	350-2500	12
	BEAM DISPLACEMENT PRISMS		2 parallel transmitted beams	220-2800	
	POLARIZING WEDGES		p- and s-polarized beams transmitted with 3.5° separation		
	VARIABLE BEAMSPLITTERS		p- and s-polarized beams of varying intensity	266-1064	12.7
DEPOLARIZERS	WEDGE		Unpolarized 'scrambled' radiation	High power 220-2600 Low power 350-2600	25
	LYOT				

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	CW $10W/cm^2$ pulse(1ns) $20MW/cm^2$		Low and medium power work	289
15, 26	CW $1W/cm^2$		With monochromators, low power lasers, light sources, precision instruments	
15, 26, 41			Fiber optics	
90	CW $3W/cm^2$	$>10^4$	Production and analysis of polarized beams when used in pairs Elimination of unwanted beams	291
				290
>45	pulse(13ns) 6 J/cm^2	10^4	Laser diode windows, Instrument filters, Optical heads, Optical isolators, Analysers	292
40	CW $10W/cm^2$	10^2	IR analysers, coupling devices, attenuators, spectrophotometer accessories, beamsplitters	293
	CW $100W/cm^2$ pulse(1ns) $300MW/cm^2$		Rotation of plane of polarization in laser systems	
	pulse(1ns) $500MW/cm^2$		Quarter Waveplates: Production of Circular Polarization. Suppressing of reflections. Half Waveplates: Rotating Plane of Polarization, Modulators, Variable Beamsplitters	295
	very low power only		Low power production of circular polarization (λ/4) or rotation (λ/2), stress analysis	296
	CW $100W/cm^2$ pulse(1ns) $300MW/cm^2$		Broadband applications	
	CW $2W/cm^2$ pulse(1ns) $20MW/cm^2$			297
		10^5	Isolation of back reflections in laser systems	
			Analysis and selection of any state of polarization	298
20	CW $1W/cm^2$	10^5	Polarization analysis, Beam separation	299
	CW $1KW/cm^2$ pulse(1ns) $500mJ/cm^2$	>200	High power laser polarizers, combiners and attenuators	300
	CW $100W/cm^2$ pulse(1ns) $100mJ/cm^2$	$>10^3$	CW laser attenuation, Beam combination and attenuators Clean up	
		>200	With broadband and tunable sources	301
	CW $1W/cm^2$	10^5	Applications requiring high extinction ratio, high beam separation and wavelength independence	
	CW $130W/cm^2$ pulse(1ns) $300MW/cm^2$		Laser beam separation, fiber optic work	302
	CW $20W/cm^2$ pulse(1ns) $200MW/cm^2$		Lower cost means of producing small beam separation of high power beams	
	High power models pulse(1ns) $>500MW/cm^2$		Continuously variable output of p and s polarized beams	303
730	High power CW $20W/cm^2$ pulse(1ns) $200MW/cm^2$ Low power CW $2W/cm^2$ pulse(1ns) $20MW/cm^2$		Depolarization of any beam Depolarization of multi-wavelength beams	304

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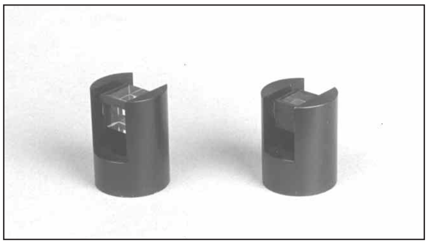
Ealing Catalog

GLAN CRYSTAL POLARIZERS



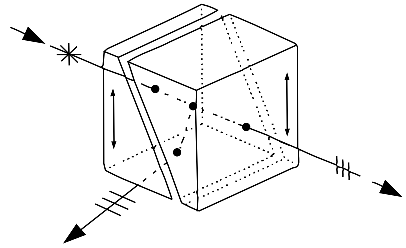
Glan Laser Polarizer (left) and Glan Taylor Polarizer

Crystal Polarizers are used to produce a highly linearly polarized output. Ealing Crystal Polarizers are made from calcite crystals which have been carefully selected by laser inspection. They are manufactured using a number of proprietary processes for cutting, grinding and polishing precision optical surfaces on calcite. Calcite is used because of its very high birefringence, wide spectral transmission and availability in reasonably-sized rhombs. (See Pages 282-283 for more detailed technical information.)

Ealing Crystal Polarizers are based on two forms of polarizers - the Glan Taylor and the Glan Thompson. Glan Taylor Polarizers are air-spaced. The optic axis of the calcite crystal lies in the plane of the entrance and exit faces and normal to the mechanical axis. The internal calcite-air-calcite interface is cut close to Brewster's angle. The extraordinary ray is transmitted straight through, with the ordinary ray being reflected. Glan Taylor Polarizers should be chosen for high power work, high transmission and UV applications.

Glan Thompson Polarizers are constructed from two calcite prisms cemented together. Like Glan Taylor Polarizers, the extraordinary beam is transmitted straight through with the ordinary beam being reflected. Although Glan Thompson Polarizers do not have the power handling or UV transmission capabilities of Glan Taylor Polarizers, they do have much wider acceptance angles. They should therefore be chosen for diverging and converging beams and applications where a large field of view is essential.

Glan Laser Polarizers

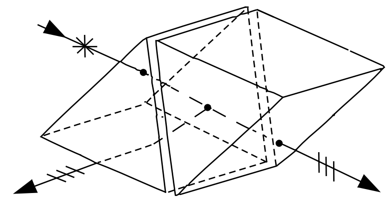


Glan Laser Polarizers are a form of Glan Taylor Polarizer which has been specifically designed for use with high power beams. Their many applications include intra-cavity gain switching, beam combination, pulse extraction and feedback elimination. Ealing Glan Laser Polarizers have two polished surfaces to enable rejected beams to escape, thus avoiding damage due to excess heating. (Note that care must be taken to terminate the rejected beam.) These Polarizers have an air gap. The spectral transmission and damage threshold is therefore limited solely by the specially-selected calcite crystal. Glan Laser Polarizers are supplied in a slotted black anodized aluminum cylinder which gives open access to all four surfaces. Unmounted prisms can be supplied on request.

SPECIFICATIONS

Material:	Schlieren-free calcite	
Wavelength range:	220-2800nm	
Peak transmission:	88%	
Extinction ratio:	10^5	
Beam deviation:	<3 mins	
Flatness at 589nm:	$\lambda/8$	
Surface quality:	20/10	
Field angle:	8°	
Mount dimensions	Dia.(mm)	Length(mm)
7mm aperture:	25.4	29
10mm aperture:	25.4	32
12mm aperture:	25.4	34
15mm aperture:	31.8	38
20mm aperture:	38.1	44
Tolerances:	±0.1mm	
Power handling -		
CW:	100W/cm²	
pulse (1ns):	300MW/cm²	

High Transmission Glan Laser Polarizers



These Glan Laser-type Polarizers are designed so that all four calcite-air interfaces for the transmitted extraordinary ray are at Brewster's angle. This results in a transmission of p-polarized input beams as high as 98%.

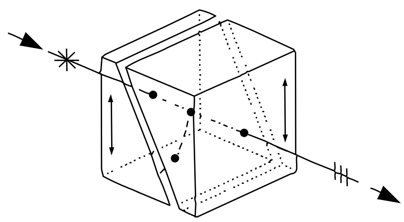
It should be noted that this design of polarizer introduces a lateral displacement to the emerging beam.

In common with all Glan Laser Polarizers, these High Transmission components have two escape windows and are supplied in a black anodized aluminum cylinder with open access to all four faces.

SPECIFICATIONS

Material:	Schlieren-free calcite	
Wavelength range:	220-2800nm	
P-polarized transmission:	98%	
Extinction ratio:	10^5	
Flatness at 589nm:	$\lambda/8$	
Surface quality:	20/10	
Field angle:	8°	
Beam displacement -		
10mm aperture:	5mm	
12mm aperture:	6mm	
15mm aperture:	7.5mm	
Mount dimensions	Dia.(mm)	Length(mm)
10mm aperture:	25.4	32
12mm aperture:	25.4	34
15mm aperture:	31.8	38
Tolerances:	±0.1mm	
Power handling -		
CW:	100W/cm²	
pulse (1ns):	300MW/cm²	

Glan Taylor Polarizers



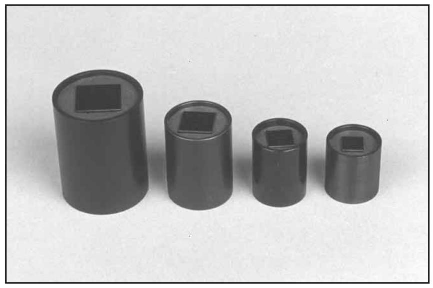
These Glan Taylor Polarizers are ideal for low and medium power applications and where the rejected beam is not required. They do not have any escape windows and are assembled with fine ground black glass cemented to the calcite prisms for efficient absorption of the rejected beam.

Glan Taylor Polarizers are supplied in a slotted black anodized aluminum cylinder. They can be supplied unmounted on request.

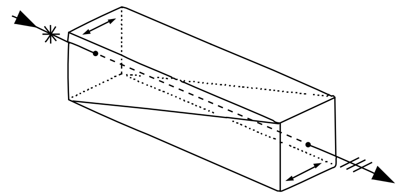
SPECIFICATIONS

Material:	Calcite	
Wavelength range:	220-2800nm	
Peak transmission:	88%	
Extinction ratio:	10^5	
Beam deviation:	<3 mins	
Flatness at 589nm:	λ/8	
Surface quality:	20/10	
Field angle:	8°	
Mount dimensions	Dia.(mm)	Length(mm)
7mm aperture:	25.4	29
10mm aperture:	25.4	32
12mm aperture:	25.4	34
15mm aperture:	31.8	38
20mm aperture:	38.1	44
Tolerances:	±0.1mm	
Power handling - CW:	$10W/cm^2$	
pulse (1ns):	$20MW/cm^2$	

Glan Thompson Polarizers



Glan Thompson Polarizers



Glan Thompson Polarizers provide wide acceptance angles and high extinction ratios. They can be used with monochromators, low power lasers, conventional light sources and for precision instrument applications. Ealing Glan Thompson Polarizers are available with length/aperture ratios of 2.5:1, which provides a field angle of >15° at 589nm and 3:1, which provides a field angle of >26°. The two calcite prisms are cemented together with index matching cement. The unpolished side faces are covered with a black paint which absorbs the reflected component. Glan Thompson Polarizers are supplied in black anodized mounts allowing free access of the entrance and exit beams.

SPECIFICATIONS

Material:	Calcite	
Wavelength range:	350-2500nm	
Peak transmission:	90%	
Extinction ratio:	10^5	
Beam deviation:	<3 mins	
Flatness at 589nm:	λ/8	
Surface quality:	20/10	
Mount dimensions	Dia.(mm)	Length(mm)
43-6865	25.4	19.5
43-6873	25.4	23
43-6881	25.4	27
43-6899	25.4	32
43-6907	31.8	32
43-6915	31.8	38
43-6923	31.8	40
43-6931	31.8	52
43-6949	38.1	52
Tolerances:	±0.1mm	
Max CW Power:	$1W/cm^2$	

Miniature Glan Thompson Polarizers

Miniature Glan Thompson Polarizers have been developed specially for fiber optic applications, where extremely compact polarizing and polarization analysis components are required. They are supplied unmounted.

SPECIFICATIONS

Material:	Calcite
Wavelength range:	350-2500nm
Peak transmission:	90%
Extinction ratio:	10^5
Beam deviation:	<3 mins
Flatness at 589nm:	λ/8
Surface quality:	20/10
Max CW Power:	$1W/cm^2$

POLARIZER / ANALYZER UNITS

SHEET POLARIZERS

For low power applications, Sheet Polarizers can often provide a low cost alternative to Crystal Polarizers.

They are fabricated from a polymer film material which is dichroic (see Page 283 for more details). In the manufacturing process, the material is stretched so that all the molecules are aligned in one direction, and then stained with iodine to assist electron mobility. It is then cemented with index matching cement between two glass or quartz plates.

Unpolarized light passing through a Sheet Polarizer emerges as linearly polarized light. Sheet Polarizers are often used in pairs. When the two polarizers have their axes aligned transmission is at a maximum I_{max}. When the axes are orthogonal to each other transmission is zero, so there is extinction. For intermediate positions the transmission is given by

$$I = I_{max} \cos^2\theta$$

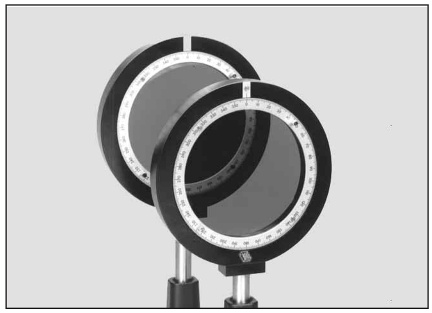
where θ = angle between the axes of the polarizers.

Ealing offers Sheet Polarizer Material for the Visible, UV and Infrared (see opposite Page). Also available are two Polarizer/Analyzer assemblies which are pin mounted for ease of handling.

Sheet Polarizers are not suitable for high power use. Their main applications are for production and analysis of polarized radiation, and the elimination of unwanted beams.

The degree of polarization is virtually independent of the incident angle. They may be used, therefore, in highly convergent or divergent beams and still produce uniform polarization.

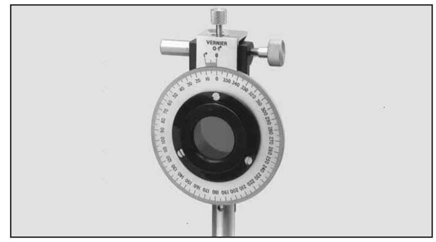
Polarizer/Analyzer Pair



22-9047 Polarizer/Analyzer Pair

Polarizer/Analyzer Pairs are two identical units, each consisting of a Visible Linear Polarizer (shown opposite) mounted in a Rotatable Mount (shown on Page 89). They provide a convenient method of continuously varying the throughput from extinction through to full transmission. They are pin mounted devices.

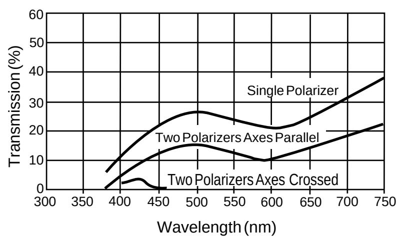
Precision Polarizer/Analyzer Unit



22-9161 Precision Polarizer/Analyzer Pair

The Precision Polarizer/Analyzer Unit is a high quality visible sheet polarizer mounted in a precision 90mm diameter divided circle mount. The assembly is engraved through 360 degrees every one degree, with every ten degree mark extended and numbered. A thumbscrew locks the assembly in approximate position and engages a tangential screw which provides fine adjustment and vernier scale reading to 0.1 degrees.
The unit is pin mounted, with an optical center height of 51mm and a pin length of 93mm.
These are single sheet neutral-colored

Visible Linear Polarizers

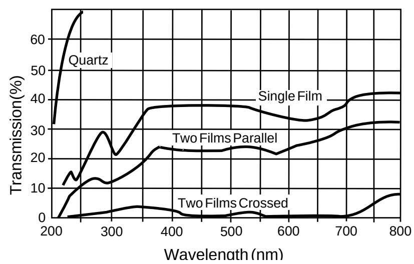


Linear Polarizers with high efficiency from 350nm to 750nm. Total luminous transmittance is 22% for white light; total integrated transmission for two crossed polarizers is 0.05%. The unit is mounted in a sandwich of optically ground and polished glass.

Polarization and transmission characteristics are stable with time and prolonged visible irradiation. High intensity ultraviolet or infrared irradiation will degrade both the polarizing properties and total transmission of the unit. Recommended temperature extremes are -60°C and +80°C. Maximum survival temperature is 90°C. High relative humidity will tend to cause a separation of the glass sandwich and should be avoided.

Thickness is nominally 3.2mm.

UV-Visible Linear Polarizers

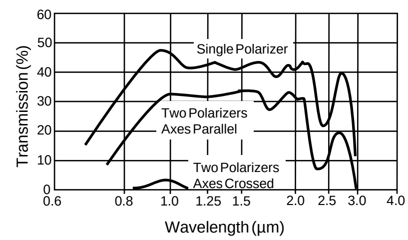


Providing excellent linear polarization from 200nm to 800nm in a single special coating, these polarizers consist of Polacoat formula 105UV mounted on ultraviolet quality, pitch-polished quartz. The top surface is protected with a special mar resistant finish which will withstand normal handling and may be cleaned with a dry lens tissue. The coating is neutral green in color.

Maximum survival temperature is 95°C. Polarization and transmission characteristics do not deteriorate with time or long exposure to UV, visible, or IR irradiation.

Thickness is nominally 1.6mm.

Infrared Linear Polarizer



This Linear Polarizer is effective from 800nm to 2.2µm. Average transmittance is about 35% over the spectral range.

These large diameter units are laminated in an infrared transmitting plastic. Extended ultraviolet irradiation will cause degradation of polarization efficiency. The maximum recommended temperature extremes are -60°C to +80°C. High relative humidity will cause separation of the plastic sandwich.

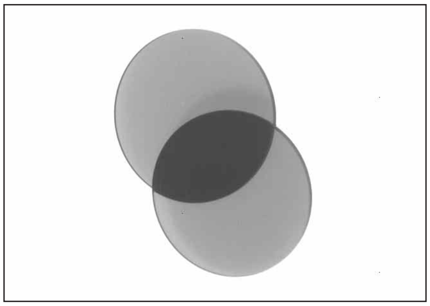
Thickness is nominally 0.75mm.

Suitable Rotatable Mounts for use with all these polarizers are described on Page 89.

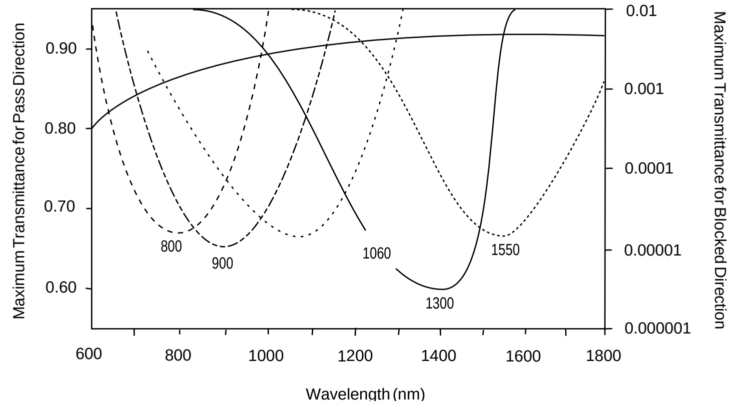
Polarizing Components - plate polarizers

POLARCOR™ POLARIZERS

Polarcor™



Polarcor™ Polarizers



Transmittance of Polarcor™ Polarizers

This polarizing glass provides a highly efficient, durable and compact means of producing linear polarization from an unpolarized beam for near infrared wavelengths.

Polarcor™ is a mixed alkali boro-silicate glass containing elongated, submicroscopic silver particles aligned along a common axis. These particles preferentially absorb the polarization component of the beam which is aligned with their long axis. The mechanism, resonant absorption by the silver conduction electrons, allows high transmission from beams that are polarized perpendicular to the particles and almost complete absorption for those polarized parallel to the particles. The length of the particles is optimized to absorb at different wavelengths in the near infrared.

Five different nominal wavelengths are available, which can be used to cover all major laser lines in the near infrared. They are supplied in four different diameters, all 1mm thick and are available unmounted or in a ring for easy handling. The 43-7335 Adapter Plate allows the mounted polarizers to be fitted in the 23-2355 Rotatable Mount (Page 89).

These Polarizers have a very high contrast ratio of 10,000:1, (contrast ratio is defined as the ratio of the transmittance of a linearly polarized beam aligned for maximum transmission to that aligned for maximum extinction). Typical transmission and extinction figures are shown on the graph.

In addition, these polarizers offer wide acceptance angles and extreme compactness. They also have high temperature resistance and excellent durability.
Typical applications include polarizing windows for Laser Diodes, Instrument Filters, Analyzers, Optical Heads and Optical Isolators.

SPECIFICATIONS

Material:	Polarcor™
Refractive Index:	1.523
Usable Wavelength Range -	
800nm:	740-860nm
900nm:	840-960nm
1060nm:	960-1160nm
1300nm:	1270-1340nm
1550nm:	1500-1580nm
Contrast Ratio:	10,000:1
Thickness:	1mm
Ring Mounted:	

polarizer dia (mm)	outer dia (mm)	clear aperture(mm)
6	10	4
10	15	8
15	20	12
25	30	21

Acceptance Angle:	>45°
Max. Temperature:	400°C.(1hr)
Damage Threshold Pulse (13ns) -	
transmission:	6 J/cm²
blocked:	0.1 J/cm²

Polarcor™ is a registered trademark of Corning Inc.

Infrared Wire Grid Polarizers


Infrared Wire Grid Polarizer

These polarizers use a regular narrowly-spaced reflective grid to provide a highly efficient and compact linear polarizer in the infrared. Incident radiation is split such that the reflected component is polarized parallel to the grid with the transmitted component being polarized in the orthogonal direction.

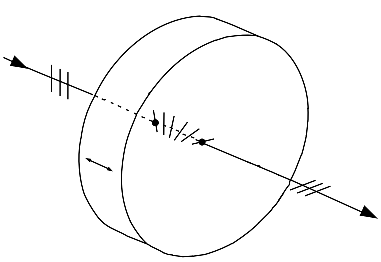
The main applications for these polarizers are as low power laser polarizers, attenuators and coupling devices, infrared analyzers, spectrophotometer accessories for crystals and plastics, polarization interferometer beamsplitters and analyzers and in plasma diagnostics.

Ealing Infrared Wire Grid Polarizers are constructed using a special holographic technique which provides the repeatable sub-micron grid spacing required for efficient operation as a polarizer. A photoresist coating on a suitable infrared-transmitting substrate is exposed to an interference fringe pattern interferometrically generated from monochromatic light. The developed resist has a regular sinusoidal profile which is subsequently vacuum aluminized at an oblique angle to create the array of parallel conductors.
Several different infrared substrates are available providing a variety of spectral range options. They all have exceptionally high transmission efficiencies and low absorption making them suitable for use with lasers (10W/cm² maximum). There is no lateral displacement at normal incidence and it is also possible to use these polarizers in converging and diverging beams.
All Infrared Wire Grid Polarizers have a 25mm aperture and are supplied in a ring mount for ease of handling.
The mount diameter is 41mm and the thickness is 6.5mm. The 43-8846 Adapter Plate allows these polarizers to be mounted in the 23-2355 Rotatable Mount shown on page 89.

SPECIFICATIONS

	Catalog Number				
	43-8796	43-8804	43-8812	43-8820	43-8838
Substrate material	KRS-5	AR/AR Ge	CaF_2	BaF_2	ZnSe
Spectral range	2-35µm	8-14µm	1-9µm	1-12µm	1-14µm
Working aperture	25mm	25mm	25mm	25mm	25mm
Mount diameter	41mm	41mm	41mm	41mm	41mm
Grid period	0.25µm	0.4µm	0.25µm	0.25µm	0.25µm
Transmission	74% @ 10µm 70% @ 3µm	90% @ 10.6µm	85% (average)	85% (average)	70% (average)
Transmission of unwanted radiation	0.25% @ 10µm 1.5% @ 3µm	0.25% @ 10µm	1% @ 3µm 3% @ 1.5µm	1% @ 3µm 3% @ 1.5µm	2.8% @ 2.5µm 1% @ 10µm
Degree of polarization	99% @ 10µm 95% @ 3µm	99% @ 10.6µm 93% @ 1.5µm	98% @ 3-9µm 93% @ 1.5µm	98% @ 3-11µm 97% @ 10µm	93% @ 2.5µm
Extinction ratio	148:1 @ 10µm 23:1 @ 3µm	180:1 @ 10.6µm 30:1 @ 2.5µm	170:1 @ 7µm 42:1 @ 3µm	200:1 @ 10µm 17:1 @ 2.5µm	140:1 @ 10µm
Field angle	40°	40°	40°	40°	40°
Power handling	10W/cm²	10W/cm²	10W/cm²	10W/cm²	10W/cm²

Optical Rotators



Ealing Optical Rotators use the optical activity characteristic, demonstrated by crystalline quartz (see Page 283) to rotate the plane of polarization of a linearly polarized beam.
The thickness provides standard rotations of either 45° or 90°. Other angles are available on request. All Rotators are supplied in mounts.

SPECIFICATIONS

Material:	Schlieren-free calcite
Wavelength range:	220-2800nm
Peak transmission:	92%
Beam parallelism:	<3 mins
Flatness at 589nm:	λ/8
Surface quality:	20/10
Mount dimensions - diameter-	
12mm aperture:	25.4mm
20mm aperture:	31.8mm
length:	10mm
Tolerances:	±0.1mm
Power handling -	
CW:	100W/cm²
pulse:(1ns):	300MW/cm²

Polarizing Components - retarders

RETARDERS

RETARDATION PLATES

Retardation Plates

A Retardation Plate, or Waveplate, resolves a beam of polarized light into two orthogonal components, retards the phase of one component relative to the other and then recombines the components into a single beam with new polarization characteristics.

Waveplates are made from materials which exhibit birefringence (see Pages 282-283). The velocities of the extraordinary and ordinary rays through the birefringent material vary inversely with their refractive indices. For the case of crystal quartz (used in Ealing Multiple and Zero Order Waveplates) the extraordinary beam has a higher refractive index and therefore a slower velocity. For this reason its direction is known as the 'slow' axis with the direction of the ordinary beam known as the 'fast' axis.
The difference in velocities gives rise to a phase difference when the two beams recombine. In the case of an incident linearly polarized beam this is given by

$$\theta = \frac{\pm 2\pi d\,(n_e - n_o)}{\lambda}$$

where:
θ = phase difference
d = thickness of waveplate in mm
n_e, n_o = refractive indices of extra-ordinary and ordinary rays respectively
λ = wavelength in nm

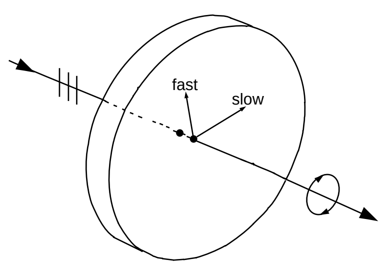
At any specific wavelength the phase difference is governed by the thickness of the retarder. Quarter and Half Waveplates are two specific cases of this.
For Retarders that will operate at more than one wavelength see Pages 296-298.

QUARTER WAVEPLATES

The construction of a Quarter Waveplate is such that the fast axis lies in the surface at 45° to the input polarization. The input beam is therefore resolved into two components of equal amplitude but varying velocities.

A Quarter Waveplate is used to convert linearly polarized beams into circularly polarized beams (and vice versa). This occurs when the thickness of the Quarter Waveplate is such that the phase difference is $\pi/2$ (zero order) or $3\pi/2$, $5\pi/2$, $7\pi/2$, etc (multiple orders). In practice the thickness required to produce a phase difference of $\pi/2$ is only approx 17µm, which is too thin to manufacture. For this reason, Multiple Order Waveplates often provide a convenient means of producing the required retardation - Ealing Multiple Order Waveplates typically have thicknesses corresponding to $11\pi/2$ or $13\pi/2$.

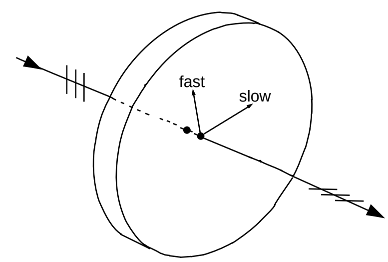
For some applications a zero order retardation is necessary. In this case, Zero Order Waveplates are constructed using two plate halves.(See opposite Page.)



There are many applications for Quarter Waveplates. These include creating circular polarization from linear or linear polarization from circular, ellipsometry, optical pumping, suppressing unwanted reflections (when used in conjunction with a polarizer) and optical isolation (when used with a Polarizing Beamsplitting Cube.) Complete isolator assemblies are shown on Page 297.

HALF WAVEPLATES

The thickness of a Half Waveplate is such that the phase difference is π (zero order) or 3π, 5π, 7π, etc (multiple orders). A linearly polarized beam incident on a Half Waveplate emerges as a linearly polarized beam but rotated such that its angle to the optic axis is twice that of the incident beam. It is usual to have the fast axis lying in the surface of the retarder at 45° to the input polarization. The Half Waveplate therefore introduces a 90° rotation of the plane of polarization. Like Quarter Waveplates, Half



Waveplates are available as Multiple Order or Zero Order for a variety of wavelengths. (See details on the opposite Page.)

Applications for Half Waveplates include rotating the plane of polarization (e.g. in a laser), electro-optic modulation and as a variable ratio beamsplitter (when used in conjunction with a polarizing cube - see Page 303 for a complete assembly).

Multiple Order Waveplates

MULTIPLE OR ZERO ORDER WAVEPLATES - TECHNICAL CONSIDERATIONS

A Multiple Order Waveplate is simpler in construction and hence lower in cost. However, there are a number of parameters which can seriously affect the retardation value if they are not controlled very tightly.

The temperature dependence of waveplates is directly proportional to the retardation value and hence the thickness. Typical temperature sensitivities are 1 degree change in retardance per °C for the Multiple Order and 0.1 degree for the Zero Order. For situations where temperature stability cannot be guaranteed, a Zero Order Waveplate should therefore be chosen.

Wavelength

For a Multiple Order Waveplate, the design wavelength must be specified very accurately - even a 0.2nm change in wavelength will produce a 10% change in retardation. A Zero Order Waveplate offers much more tolerance in wavelength variations. (A change of approx. 15nm in wavelength results in a 1% retardation change.)

Angle of Incidence and Degree of Collimation

For any beam which does not pass through the waveplate at normal incidence, there will be an increase in path length, increasing as the waveplate becomes thicker. This produces greater changes in retardation. It is particularly important to have a collimated input beam when using a Multiple Order Waveplate. If this cannot be ensured, a Zero Order Waveplate should be considered.

Zero Order Waveplates

Ealing Multiple Order Waveplates are available for a stock range of wavelengths. Mounted in a 25.4mm diameter mount, these crystal quartz waveplates are manufactured to exacting standards. They are suitable for a wide variety of applications. However, the retardation value of a Multiple Order Waveplate is strongly dependent on temperature, wavelength, angle of incidence and degree of collimation. Where these are important, a Zero Order Waveplate will usually solve the problem. Non-standard wavelengths available on request.

Temperature

SPECIFICATIONS

Material:	Crystalline quartz
Retardation tolerance:	±0.005λ
Wavefront distortion:	λ/8
AR coating:	<0.25%R per surface
Diameter:	25.4mm
Aperture:	15mm
Thickness:	8mm
Damage threshold - pulse:	500MW/cm²

Ealing Zero Order Waveplates have been designed for those applications where a thickness is required which corresponds to a zero order phase difference. This is achieved by constructing the waveplate from two halves with their fast axes crossed. The thicknesses of these two halves are chosen so that the difference in retardation between them is equivalent to the zero order required. Any variation in temperature, wavelength, angle of incidence and collimation, affects both plates similarly and hence these effects are largely cancelled out. Non-standard wavelengths available on request.

Achromatic Waveplates

SPECIFICATIONS

Material:	Crystalline quartz
Retardation tolerance:	±0.005λ
Wavefront distortion:	λ/8
AR coating:	<0.25%R per surface
Diameter:	25.4mm
Aperture:	15mm
Thickness:	8mm
Damage threshold - pulse:	500MW/cm²

MICA / ACHROMATIC WAVEPLATES

Mica Waveplates

can be used to provide low cost general purpose Quarter and Half Waveplates. Mica does, however, have a relatively strong absorption and low resistance to damage and its use should therefore be limited to low power applications. Typical applications include spectroscopy, stress analysis and low power optical systems. Ealing Mica Waveplates are made by cementing the thin, specially selected mica layer between two polished crown glass plates with index matching cement. Mica Waveplates are available either for specific wavelengths or for broad-band use. The Broadband Retarder is constructed from three Mica Waveplates which are then cemented between cover plates. All are supplied in a 25.4mm diameter mount. Specific wavelengths may be requested at no extra charge. AR Coatings and other sizes can be supplied on request.
A Soleil-Babinet Compensator

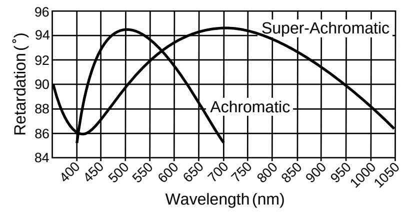
SPECIFICATIONS

Material:	Specially selected mica sandwiched between crown glass cover plates
Retardation Tolerance:	± 2%
Diameter:	25mm ± 0.2mm
Thickness:	3mm ± 0.2mm

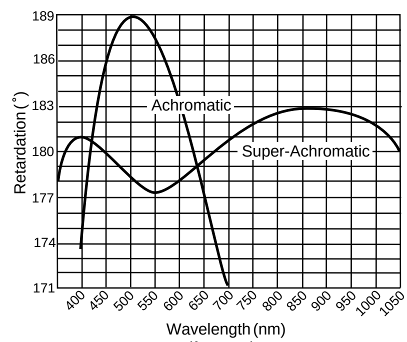
The wavelength dependence of birefringence dictates that the spectral range of standard Multiple and Zero Order Waveplates is very limited (approx. 10nm for Zero Order). To accommodate tunable sources and broadband applications Ealing offers two Achromatic Waveplates and also a Super Achromatic Waveplate for very broadband use.

All are supplied in a 25.4mm diameter mount and have a clear aperture of 9mm.

Achromatic Waveplates are zero order waveplates made from a matched pair of magnesium fluoride and crystalline quartz plates. Their thicknesses are selected such that the resulting retardation is nearly constant over the spectral range (see graphs). They are air-spaced and can therefore be used for high power applications (300MW/cm^2 pulse, 100W/cm^2 CW).
The Super Achromatic Waveplate consists of three pairs of matched magnesium fluoride and crystalline quartz plates. They are cemented together to eliminate Fresnel reflection losses and are therefore only suitable for low power work. They provide a uniform retardation from 350-1100nm.
Fresnel Rhombs are extremely useful



Quarter Waveplates



Half Waveplates

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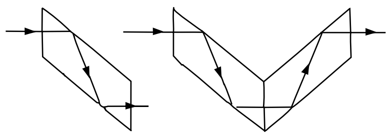
Achromatic Fresnel Rhombs

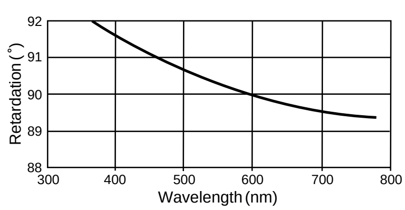


Achromatic Quarter Wave Retarder — Achromatic Half Wave Retarder

Achromatic Retarders. They are constructed from BK7 glass and utilize the different phase changes on reflection for the p and s components of an incident linearly polarized beam. The Rhomb angles are chosen to be 54°42' so that the phase change on reflection is 45°. Two reflections within a single Rhomb produce a quarter waveplate and four reflections within a pair of Rhombs produce a half waveplate.

The retardation varies with wavelength as shown on the graph below.

SPECIFICATIONS

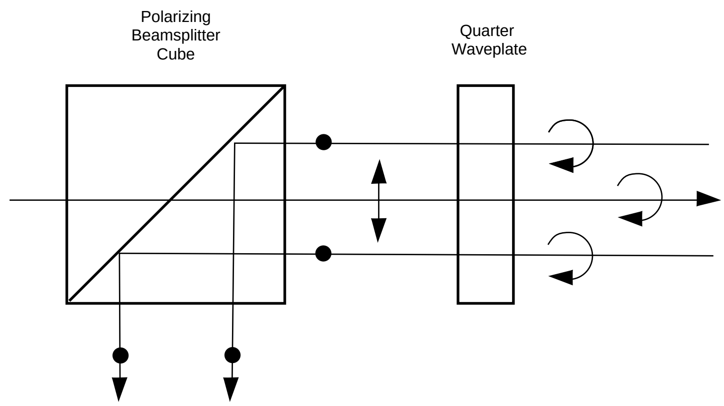


Material:	BK7
Wavelength range:	400-700nm
Peak transmission:	90%
Surface quality:	20/10
Mount diameter:	25.4mm
Mount tolerances:	±0.1mm
Clear aperture:	10mm
Power handling -	
CW:	2W/cm²
pulse (1ns):	20MW/cm²

The birefringent properties of mica

Optical Isolator Assemblies

Optical Isolator Assembly



These Optical Isolator Assemblies consist of a Polarizing Beamsplitting Cube and a Quarter Waveplate which together provide a convenient-to-use package. They are used primarily to ensure that back reflections within laser systems can be eliminated efficiently when required.

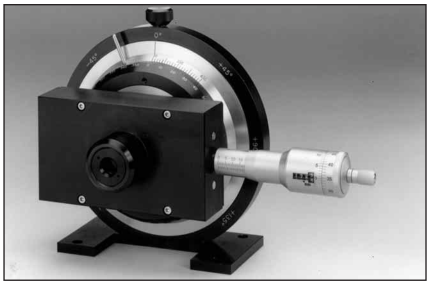
The input beam passes through the Polarizing Beamsplitting Prism, which transmits only the p-polarization component (see Page 300). This then passes through the Quarter Waveplate, emerging circularly polarized. When it has undergone retroreflections (from windows, mirrors, backscatter etc.) it returns circularly polarized in the opposite direction. On passing back through the Quarter Waveplate, it emerges s-polarized and is reflected off at 90° by the Polarizing Beamsplitting Cube.

SPECIFICATIONS

Material:	
Prism:	BK7
Waveplate:	Crystal Quartz
Transmitted Wavefront:	λ/4
Extinction Ratio:	10^5
Housing	Black Anodized Aluminum

SOLEIL-BABINET COMPENSATORS

Soleil-Babinet Compensator/ Adjustable Retarder



Soleil-Babinet Compensator

functions as an adjustable zero order retarder over the wavelength range 200-2700nm. It allows complete analysis and selection of the state of polarization of a beam and can be used for inspection and comparative work.

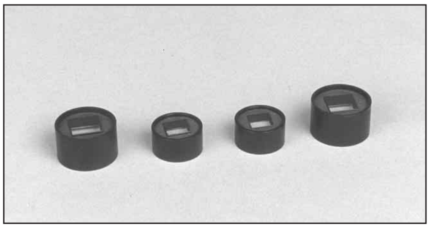
Ealing's Soleil-Babinet Compensator consists of two crystalline quartz wedges with their optic axes parallel and at 45° to the polarization direction of the input beam. One wedge is fixed and the other, which is attached to a crystalline quartz compensating block with its axis at 90° to the wedge, is adjustable by a micrometer screw. This adjustment changes the path difference through the instrument and hence the retardation.
It can be used to select a uniform phase difference between the extraordinary and ordinary rays of 0 to 2π. As a result, incident elliptically or circularly polarized light can be converted into linearly polarized light by introducing the appropriate compensation. Conversely, any desired polarization form can be obtained by pre-setting the appropriate values.

The Soleil-Babinet Compensator is mounted conveniently on a precision ballbearing indexing head which has a fixed outer circumference graduated 0°, 180°, +45°, +90°, +135°, -45°, -90° and -135°. The inner circumference is rotatable through 360° and has indicator marks at one degree increments with each 10° being labelled. The outer circumference has a knurled locking screw for absolute fixing. A 1/4-20 tapped hole is located at the 180° mark for pin mounting. The micrometer adjustment screw has a four-place digital readout. The fifth place can be interpolated from alignment marks on the micrometer barrel. All Compensators are supplied in wooden instrument cases with instruction manual and calibration data.

SPECIFICATIONS

Materials -	
optics:	Laser quality crystalline quartz
housing:	Non-magnetic metal
Diameter:	152.4mm
Clear aperture:	10mm
Thickness:	105.3mm (compensator and mount)
Dimensional tolerance:	±0.25mm
Optical center:	75.2mm (bottom to optical center line)
Maximum height:	243.5mm (micrometer fully extended)
Wavefront distortion:	<λ/4 at 633nm
Wavelength range:	200nm-2700nm
Retardation range:	320nm = 0 to 2λ
633nm = 0 to 1λ	
1230nm = 0 to λ/2	
2500nm = 0 to λ/4	
Readout:	4 place digital; fifth place interpolated
Resolution:	0.001λ (0 to 25,000 on digital readout)
Temperature range:	0°C to 70°C

WOLLASTON AND ROCHON PRISMS



Wollaston and Rochon Prisms

tolerances: ±0.1mm
Max. CW power: 1W/cm^2

Wollaston and Rochon Prisms use the properties of birefringence (see Page 282) to split an input beam and separate it into extraordinary and ordinary beams. They both consist of two prisms cemented together. The optic axes of these two prisms are at right angles to each other (in contrast to the prism polarizers on Pages 288-289, where the axes are parallel).

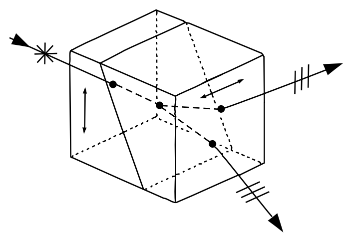
Wollaston Prisms provide a greater deviation than Rochon Prisms.

In a Wollaston Prism both beams are deviated as they pass through, whereas in a Rochon Prism only the extraordinary ray is deviated, with the ordinary ray passing straight through.

Both Wollaston and Rochon Prisms are available in calcite as standard, but can be supplied in quartz and magnesium fluoride for UV applications on request. Deviation may also be varied to customer requirements by changing the prism cut angle.

Note that deviation varies with wavelength - for Wollaston Prisms the angular separation varies from 24° at 350nm to 18° at 2.5µ. The field angle varies between 22° and 17° over the same wavelength range. There is a similar wavelength dependence for Rochon Prisms, the values being half those for Wollastons.

Wollaston Prisms



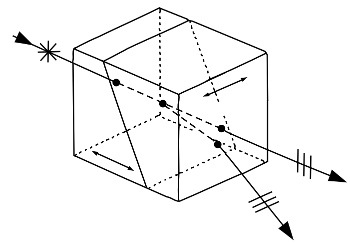
Wollaston Prisms are commonly used as polarization analyzers, providing a polarization beamsplitter with an angular deviation of 20°. They consist of two prisms cemented together. Both the ordinary and extraordinary beams travel collinearly at first, but with different refractive indices. At the interface the beams are interchanged, so that the ordinary beam enters a medium of lower refractive index and is refracted away from the normal. The extraordinary beam enters a medium of higher refractive index and is refracted towards the normal. Thus a divergence is created between the two beams, which is further increased at the exit surface. The deviations of the ordinary and extraordinary beams are nearly symmetrical about the input beam axis.

Ealing Wollaston Prisms are supplied complete in a mount.

SPECIFICATIONS

Material:	Calcite
Wavelength range:	350-2500nm
Deviation (at 600nm):	20°
Field angle (at 600nm):	20°
Peak transmission:	90%
Extinction ratio:	10^5
Surface quality:	20/10
Flatness at 589nm:	λ/8
Mount dimensional tolerances:	±0.1mm

Rochon Prisms



tolerances: ±0.1mm
Max. CW power: 1W/cm^2

Rochon Prisms consist of two cemented prisms. Both ordinary and extraordinary beams propagate collinearly down the optic axis in the first prism. Upon entering the second prism the ordinary beam experiences the same refractive index and continues undeviated. However, the optic axis of the second prism results in the extraordinary beam having a lower refractive index and it is therefore refracted. The angle of refraction is further increased at the exit surface.

Ealing Rochon Prisms are supplied complete in a mount.

SPECIFICATIONS

Material:	Calcite
Wavelength range:	350-2500nm
Deviation (at 600nm):	10°
Field angle (at 600nm):	20°
Peak transmission:	90%
Extinction ratio:	10^5
Surface quality:	20/10
Flatness at 589nm:	λ/8
Mount dimensional tolerances:	±0.1mm

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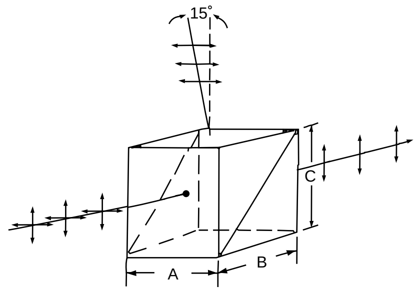
POLARIZING BEAMSPLITTING CUBES

POLARIZING BEAMSPLITTING CUBES

Polarizing Beamsplitting Cubes split randomly-polarized beams into two beams - one is transmitted straight through and the other is reflected internally and emerges from another face of the cube. Both beams are very highly polarized, the transmitted beam being p-polarized and the reflected beam s-polarized.

They are constructed from two right angle prisms made from glass or fused silica. The hypotenuse face of one of the prisms is coated with a multilayer dielectric coating which is optimized for a particular wavelength. This coating is such that the reflection from each layer is partially polarized (see Page 284) and the cumulative effect of the multilayer coating produces a transmitted and reflected beam both of which are highly polarized. The two prisms are bonded together with index-matching cement. The entrance and exit faces are antireflection coated. The main applications for Polarizing Beamplitting Cubes are as polarizers, beam combiners and in conjunction with retarders as variable attenuators and isolators.
These Polarizing Beamsplitting Cubes

High Power Polarizing Beamsplitting Cubes



have been specially constructed for use in high power applications. They consist of two right angle prisms which are air-spaced and then edge sealed for environmental stability. Ealing High Power Laser Beam-splitting Cubes are supplied in BK7 for all wavelengths except 308nm which is fused silica. They are available for commonly-used high power laser wavelengths.
The angle between transmitted and reflected beams is 105°.

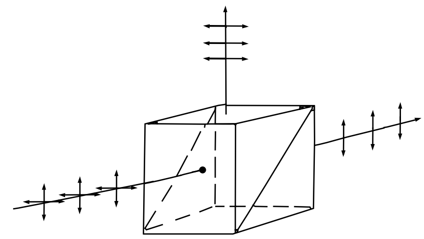
SPECIFICATIONS

Transmission (p-polarized)	90% (70% for 308nm)
Reflection (s-polarized):	99.5% (99.2% for 308nm)
AR coating:	≤0.25% per surface
Typical polarizing bandwidth:	20nm at 1064nm
Transmitted wavefront:	λ/4 at 633nm
Surface quality:	20/10
Extinction ratio:	>200:1
Dimensions (mm) -	A B C
308nm:	20.3 28 25.4
35.6	40.6 40.6
other wavelengths:	12.7 12.7 15.2
25.4	25.4 30.5
Dimensional tolerance:	±0.5mm
Power handling -	
CW:	1kW/cm²
pulse (1ns)	500mJ/cm²

Narrow Band Polarizing

Beamsplitting Cubes

Narrow Band Polarizing Beamsplitting



Cubes are cemented components that are optimized for specific wavelengths. They are the best choice for use with single line CW lasers, attenuators, beam combining and clean-up. The angle between the transmitted and reflected beam is 90°.

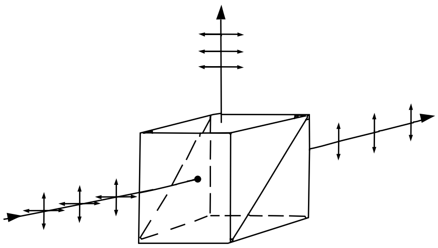
SPECIFICATIONS

Material:	BK7
Transmission (p-polarized):	>95%
Reflection (s-polarized):	>99.9%
AR coating:	≤0.25% per surface
Typical polarizing bandwidth:	10nm at 515nm
Transmitted wavefront:	λ/4 at 633nm
Surface quality:	20/10
Extinction ratio:	>1000:1
Dimensional tolerance:	±0.5mm
Clear aperture:	85% of cube dimension
Power handling -	
CW:	100W/cm²
pulse (1ns)	100mJ/cm²

These cemented Polarizing

POLARIZING BEAMSPLITTING CUBES / GLAN THOMPSON BEAMSPLITTING PRISMS

Broad Band Polarizing Beamsplitting Cubes



Beamsplitting Cubes are coated to enable operation over a wide range of wavelengths.

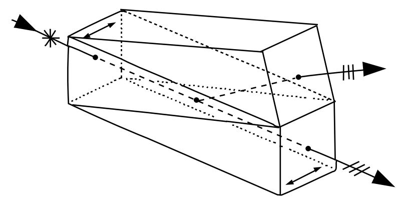
The polarization separation is excellent with the transmitted and reflected beams at 90° to each other irrespective of wavelength.

SPECIFICATIONS

Material:	SF2 glass
Transmission (p-polarized):	>90% average
Reflection (s-polarized):	>99.5% average
AR coating:	Broad band on all entrance and exit faces
Transmitted wavefront:	$\lambda/4$ at 633nm
Surface quality:	40/20
Extinction ratio:	>200:1 average
Dimensional tolerance:	±0.5mm
Clear aperture:	85% of cube dimension
Power handling -	
CW:	100W/cm^2
pulse (1ns)	100mJ/cm^2

Polarizing Beamsplitting Cubes may

Glan Thompson Beamsplitting Prisms



pulse (1ns): 300MW/cm^2

Unlike standard Glan Thompson Polarizers (Page 289), where the s-polarized ordinary ray is reflected and absorbed, these Beamsplitting Prisms have an additional escape window to allow transmission of the ordinary ray. The escape window is designed such that the beam emerges normal to it, ensuring that there is no chromatic dispersion. The p-polarized extraordinary ray is transmitted undeviated in the usual way. Ealing Glan Thompson Beamsplitting Prisms have an angular deviation between the two beams of 44° and this is not wavelength dependent. Other deviations are available on request.

The main applications for these prisms are where there is a need for either a high extinction ratio, a high beam separation or wavelength independence. They are also useful where it is essential that the extraordinary ray is transmitted undeviated. These prisms, being cemented, are not suitable for high power applications. They are supplied mounted.

SPECIFICATIONS

Material:	Calcite
Wavelength range:	350-2500nm
Peak transmission:	90%
Extinction ratio:	10^5
Surface quality:	20/10
Beam deviation:	<3 mins
Mount dimensions -	
diameter -	
7, 10mm aperture:	25.4mm
12mm aperture:	31.8mm
length-	
7mm aperture:	36mm
10mm aperture:	44mm
12mm aperture:	49mm

Dimensional

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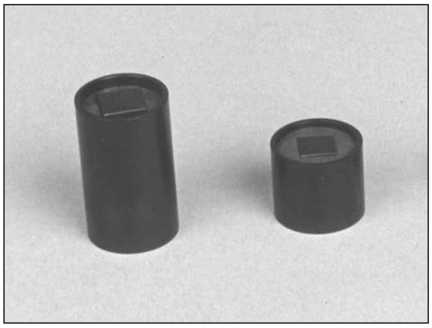
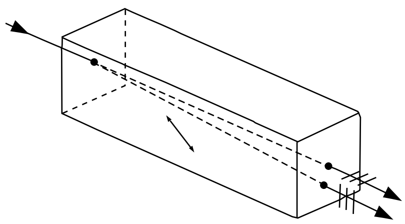
Polarizing Components - beamsplitting prisms

POLARIZING BEAM DISPLACEMENT / WEDGE PRISMS

Beam Displacement Prisms



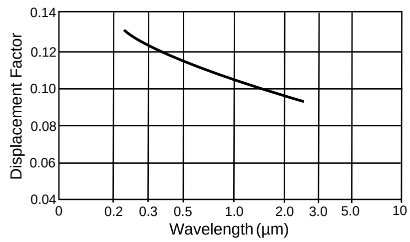
Beam Displacement Prisms



These calcite Beam Displacement Prisms provide two parallel beams (the ordinary and extraordinary rays) with a constant lateral displacement between them. The main applications for these prisms are for dividing a laser beam into two components and for fiber optic work.

Beam Displacement Prisms are oriented such that their entrance and exit faces are parallel. They are inclined at 42° to the optic axis to maximize the displacement.

Note that the displacement varies with wavelength. The displacement factor that relates the lateral offset to thickness ratio varies from 0.13 to 0.09 over the wavelength range 220–2600nm (see graph).

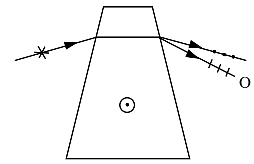


Other sizes are available on request.

SPECIFICATIONS

Material:	Schlieren-free calcite
Wavelength range:	220-2800nm
Peak transmission:	92%
Extinction ratio:	10^5
Beam parallelism:	<3 mins
Flatness at 589nm:	λ/8
Surface quality:	20/10
Mount dimensions -	
diameter:	25.4mm
length - 2mm displacement:	22mm
length - 4mm displacement:	42mm
length - 6mm displacement:	62mm
Dimensional tolerances:	±0.1mm
Power handling - CW:	130W/cm²

Polarizing Wedges



These single calcite Polarizing Wedges provide a simple and inexpensive means of separating the polarization components of an input beam. They are able to accept high power levels and are available for a range of different wavelengths.

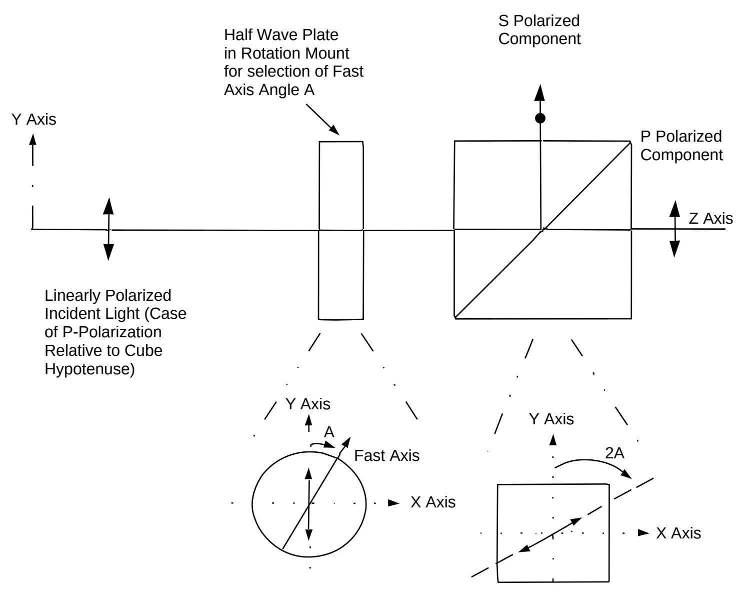
The angular separation between the ordinary and extraordinary rays is determined by the wedge angle and the wavelength. Ealing Polarizing Wedges have a standard separation of 3.5°. Other angular separations are available on request. Note that the output beams are not collinear with the input beam.

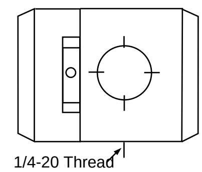
Ealing Polarizing Wedges are supplied complete in a mount and have a 12mm clear aperture. Other sizes can be provided - please contact Ealing for further details.

SPECIFICATIONS

Material:	Calcite
Wavelength range:	220-2800nm
Peak transmission:	92%
Angular separation:	3.5°
Polarization purity:	10^5
Flatness at 589nm:	λ/8
Surface quality:	20/10
Mount dimensions -	
Diameter:	25.4mm
Length:	34mm
Power handling -	
CW	20W/cm²
Pulse (1ns):	200MW/cm²

High Power and Standard Variable Polarizing Beamsplitters / Attenuators





be used in conjunction with Half Waveplates (Page 295) to produce a continuously Variable Beamsplitter. Ealing offers Variable Beamsplitter combinations already assembled for ease of use. The incident light must be linearly polarized for the assembly to work properly, but the plane of polarization can have any orientation. The Half Waveplate is in a mount that can be rotated manually about the optical axis of the assembly. For a given incident angle A, the light emerges from the Half Waveplate still linearly polarized, but with its polarization plane at an angle 2A. This is then incident on the Polarizing Beamsplitting Cube and is separated in p- and s-polarized components, which vary according to the angle A. The assembly therefore serves as a Variable Beamsplitter by dividing the incident light intensity among s- and p-polarization components in a continuously variable way according to the setting of the angle A.
Ealing offers two assemblies - one for general use and the other specifically for high power applications.

The p-polarized light transmitted by the assembly is simply an attenuated version of the incident light with variable attenuation according to the angle A and the assembly can thus be thought of as a Variable Attenuator. Ealing Polarizing Variable Beamsplitter Assemblies are available in two different sizes for a wide variety of wavelengths. The materials used are crystal quartz, fused silica or BK7 depending on wavelength.

SPECIFICATIONS

Transmission range:	1%- 95%
Transmitted wavefront:	$\lambda/4$ at 633nm
AR coating:	$\leq$0.25% on all entrance and exit faces
Housing:	Black anodized aluminum
Housing dimensions -	
6.4mm aperture -	
Diameter:	25.4mm
Length:	33mm
12.7mm aperture -	
Diameter:	50.8mm
Length:	48.3mm
Power handling -	
high power models:	>500MW/cm^2 at 1064nm (1ns pulse)

Polarizing Components - depolarizers

DEPOLARIZERS

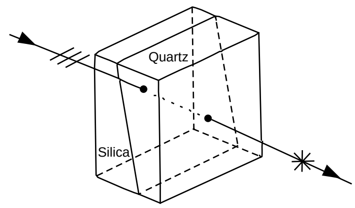
DEPOLARIZERS

There are some circumstances where a linearly polarized beam is undesirable, e.g. with a polarization-sensitive instrument such as a reflecting spectrometer and in situations where polarized beams are produced from mirrors, gratings and prisms.
A true Depolarizer does not exist. However, Ealing offers two types of component which will change the beam into a pseudo-depolarized beam by scrambling up the polarization.
Wedge Depolarizers can be used for any input beams. Lyot Depolarizers, however, rely for their operation on having many different wavelengths present. For monochromatic radiation a Wedge Depolarizer should be chosen.

Note that it is also possible to use an integrating sphere for depolarization (see Section 3). While very effective, they do however result in substantial losses in power.

In some cases it is sufficient to convert linearly polarized beams into circularly polarized beams. Quarter waveplates (Pages 294-296) can then be used.

Wedge Depolarizers



Ealing Wedge Depolarizers consist of a crystalline quartz wedge and a compensating fused silica wedge (for correction of angular deviation). The optic axis of the crystalline quartz wedge lies in the plane of the wedge and at 45° to the input polarization. This has the effect of acting like a retardation plate which has a variable retardation across the aperture. The overall result is to produce depolarization for any input wavelength.

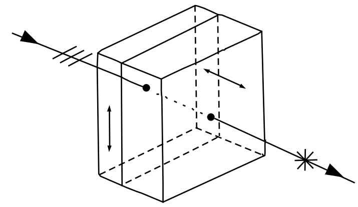
Wedge Depolarizers are supplied as cemented components for low power applications, and as optically contacted components where power handling is important.

Wedge Depolarizers are supplied unmounted.

SPECIFICATIONS

Wavelength range -	
low power:	350-2600nm
high power:	220-2600nm
Peak transmission:	92%
Beam deviation:	<3 mins
Flatness at 589nm:	λ/8
Surface quality:	20/10
Field angle:	>30°
Thickness:	nominal 6mm
Power handling -	
low power CW:	2W/cm^2
pulse (1ns):	20MW/cm^2
high power CW:	20W/cm^2
pulse (1ns):	200MW/cm^2

Lyot Depolarizers



Ealing Lyot Depolarizers are useful components for beams containing many different wavelengths - unlike Wedge Depolarizers they cannot be used for monochromatic beams.

Lyot Depolarizers consist of two crystalline quartz plates assembled with their optic axes lying in the plane of the plates, aligned at 45°. One plate is exactly twice the thickness of the other. Depolarization occurs due to the production of varying amounts of circularly and elliptically polarized radiation of different wavelengths.

Ealing Lyot Depolarizers are supplied as cemented components for low power applications and as optically contacted components for high power applications.

Lyot Depolarizers are supplied unmounted.

SPECIFICATIONS

Wavelength range -	
low power:	350-2600nm
high power:	220-2600nm
Peak transmission:	92%
Beam deviation:	<3 mins
Flatness at 589nm:	λ/8
Surface quality:	20/10
Field angle:	>30°
Thickness:	nominal 6mm
Power handling -	
low power CW:	2W/cm^2
pulse (1ns):	20MW/cm^2
high power CW:	20W/cm^2
pulse (1ns):	200MW/cm^2