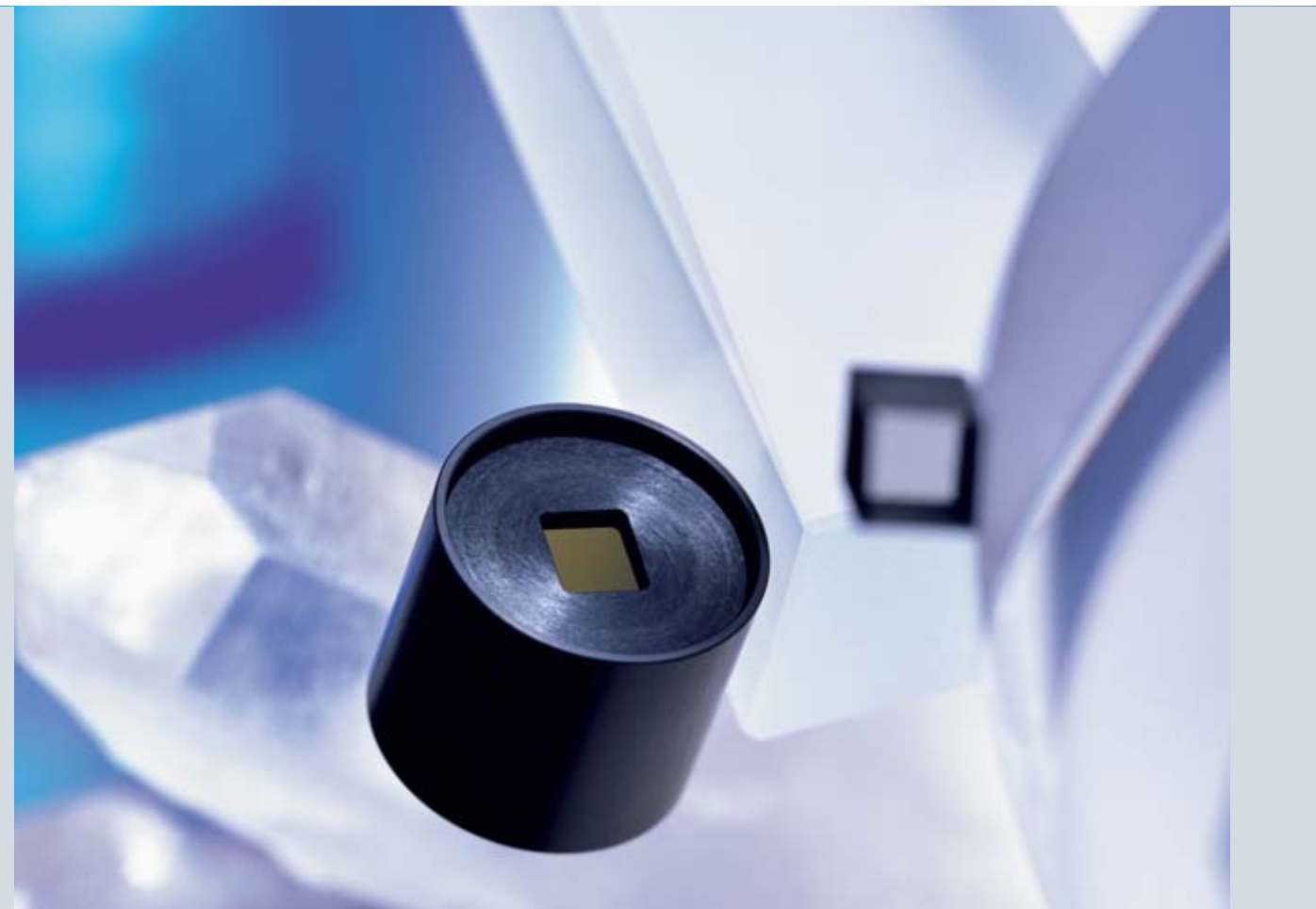# Crystal optics
Product portfolio

JENOPTIK I Optical Systems

Optical Systems Division

JENOPTIK Laser, Optik, Systeme GmbH
Göschwitzer Straße 25
07745 Jena I Germany
Phone +49 364165-3148 I Fax -3677
optics@jenoptik.com
www.jenoptik-los.com

Coastal Optical Systems, Inc.
16490 Innovation Drive
Jupiter I FL 33478 I USA
Tel. +1256859-1886 I Fax -5890
sales@coastalopt.com
www.coastalopt.com

017840-020-99-14-1008 en

Optics

Crystal optics
for a wide range of applications

Crystal optics fulfill a function in optical systems for applications in laser technology, semiconductor industry, metrology and medical technology, as well as applications in security and defense and in aerospace industry.

The comprehensive range of products supplied by Jenoptik includes high-quality optics made of crystalline and other materials. This technological knowledge is rooted in the decades of experience accumulated by two long-established companies, Jenoptik and Steeg & Reuter. Steeg & Reuter is one of the oldest manufacturers of crystal optics in Germany.

In addition to the development and manufacturing of optical solutions, the Optical Systems Division also supplies customized crystal optics from its manufacturing site in Giessen. All crystal optics, from a single component up to assembled optical modules, are manufactured to the highest degree of accuracy and precision.

The basics of polarization optics

Crystals feature optical properties that are responsible for reflection, diffraction and absorption of light, among other things, which makes crystal optics to an important part of the photonics.

Light is electromagnetic radiation consisting of transverse electromagnetic waves. The polarization of transverse waves is described by the electrical field, which oscillates perpendicularly to the propagation direction of the beam. Natural light, the field strength vector of which oscillates statistically in all directions, is therefore unpolarized. When light is manipulated by optical components, usually by total reflection of the beam, it can be made to oscillate in just one direction which is perpendicular to the direction of propagation and is said to be polarized.

Glass is optically isotropic; many crystals, however, exhibit the phenomenon of anisotropy. An important consequence of this is birefringence. These crystals have different refraction indices, which depend on the polarization of light and split it into an ordinary and extraordinary ray depending on the orientation of the optical axis. With waveplates, the splitting brings about a phase difference in the rays that travel at different speeds through the crystal plate. Both rays are then perpendicular to each other and display birefringent dispersion.

Another special property of crystals is their high transmission value, which enables their utilization in a wide range of applications in the ultraviolet and infrared spectral region in laser technology, in the semiconductor industry and metrology.

Optical materials

Naturally grown crystals often occur in the polycrystalline form. In other words, the crystalline solids consist of many tiny crystals, which are separated from each other by grain boundaries. These natural structures exhibit defects in the three-dimensional periodic arrangement of atoms within the lattice structure and therefore represent a special challenge in optics manufacturing.

Working with different materials possess challenges to the manufacturing technologies and demands the most advanced, cutting edge production processes. At Jenoptik, an X-ray goniometer with a double monochromator is deployed to align axes accurately. In this way, crystal optics with length, width and diameter ranging from just a few to 150 millimeters can be created.

The effects of optical polarization, which the interaction of light causes in optical materials, can be calculated with systems of equations (polarization transfer functions: Maxwell, Fresnel and Jones-matrix; the Mueller-matrix) and visualized with Poincare sphere.

The following pages contain an overview of materials and their particular optical properties in order to illustrate the differences between anisotropic crystals and other optical materials.

Quality in the STEEG & REUTER tradition

Overview of materials

We use materials with the optical properties that will provide the optimum results for the applications in question.

In producing high-precision optics we process both natural and synthetic crystals.

Material	Transmission between T = 50 % spots in µm	Maximal trans-mission	Reflexion loss on 2 optical surfaces	Thermal expansion dl/dT	Water solubility by 300 K in g/100g water	Melting point in °C	Hard-ness	Density in g/cm³	200 nm ordinary beam	200 nm extra-ordinary beam	500 nm ordinary beam	500 nm extra-ordinary beam	1 µm ordinary beam	1 µm extra-ordinary beam	3 µm ordinary beam	3 µm extra-ordinary beam	5 µm	10 µm	30 µm	50 µm
Cristalline quartz (SiO_2)	0.15 … 4	90	8.2 % at 2 µm	7.3×10^{-6}	1×10^{-3}	1700	740 K	2.648	1.6508	1.66394	1.54822	1.55746	1.53514	1.54392	1.49953		1.417	no T.	no T.	no T.
Mica	0.28 … 8	90	8 %	$3.24\ 10^{-4}$	insoluble		2 – 3 M	2.76					1.602	1.606						
Calcite ($Ca[CO_3]$)	0.22 … 3	90	11.9 %	2.5×10^{-5}	1.4×10^{-3}	1339	155 K	2.17	1.90284	1.57649	1.665	1.4895	1.643	1.48		1.474	no T.	no T.	no T.	no T.
Magnesium fluoride (MgF_2)	0.12 … 8	95	4.9 % at 500 nm	1.5×10^{-5}	7.6×10^{-3}	1300	102 K	3.18			1.38		1.38		1.36		1.34	no T.	no T.	no T.
Calzium fluoride (CaF_2)	0.13 … 11	90	5.6 % at 6 µm	1.8×10^{-5}	1.7×10^{-3}	1423	158 K	3.18	1.49608		1.43704		1.4288		1.41793		1.39901	1.316	no T.	no T.
Sapphire (Al_2O_3)	0.17 … 5.5	90	6 %	5.08×10^{-5}	insoluble	2040	1370 K	3.98	no T.		1.77		1.76		1.71		1.63	no T.	no T.	no T.
Germanium (Ge)	1.8 … 23	45	52 % at 10.6 µm	6×10^{-6}	insoluble	937	692 K	5.33	no T.		no T.		no T.		4.0452		4.017	4.0026	4	4
Silicon (Si)	1.2 … 15	50	46 % at 10.6 µm	4.1×10^{-6}	5×10^{-3}	1420	1150 K	2.33	no T.		no T.		no T.		3.432		3.4223	3.4179	3.41	3.41
Lithium fluoride (LiF)	0.105 … 8	90	4.4 % at 4 µm	1.6×10^{-5}	0.27	870	110 K	2.639	1.4413		1.3943		1.38711		1.3666		1.32661	no T.	no T.	no T.
Zinc selenide (ZnSe)	0.5 … 20	70	30 % at 10.6 µm	7.6×10^{-6}	1×10^{-3}	1526	110 K	5.27	no T.		2.66		2.48		2.43		2.43	2.41	no T.	no T.
Zinc sulfide (ZnS)	0.4 … 14	70	25 % at 10.6 µm	6.8×10^{-6}	6.9×10^{-4}	1830	150 K	4.08	no T.		2.435	2.421	2.303	2.301	2.29		2.25	2.2	no T.	no T.
KDP	0.18 … 1.4	90	8 % at 800 nm	3.4×10^{-5}	33	253		2.332	1.6		1.5		1.49		no T.		no T.	no T.	no T.	no T.
Amorphous quartz glass	0.2 … 4.5	90	6.3 % at 2 µm	0.5×10^{-6}	insoluble	1700	461 K	2.202	1.551		1.462		1.45		1.41		no T.	no T.	no T.	no T.

Quality in the STEEG & REUTER tradition

Retardation plates

Rotardation plates are elements used in polarization optics and are used to change the polarization of light in a controlled method. Their physical fundamentals are based on the principle of birefringence. Light waves hit an anisotropic crystal, which splits the beam into two rays, the ordinary ray and the extraordinary ray. If the ray passes through a birefringent crystal, the different refractive indices of the material causes a phase difference in its orthogonal components.

Depending on the value of the phase difference, a retardation plate can be for example a $\lambda/4$ or a $\lambda/2$ plate. With adjustment to the relative axis alignment, the created retardation causes lineary polarized light to either rotate ($\lambda/2$ plate), or circularly polarized light to be created from lineary polarized light ($\lambda/4$ plate).

The different types allow a wide range of applications. In the area of metrology, this includes the measurement of surfaces, or in microscopy, in order to increase color diffe- rences in an object observed between crossed polarizers at right angles to each other.

Typically, retardation plates are made from optically aniso- tropic materials with a suitable thickness and alignment, whereby birefringent crystals such as quartz, mica or magnesium fluoride are principally used. High-precision quartz plates are made from natural or synthetic quartz and have retardation tolerances of a few nanometers. The effective spectral range depends on the used material and its optical properties. For quartz, for example, this is in a range from 180 nm to 2.8 µm.

Quartz retardation plates
Retardation plates made of quartz are the most frequently represented. With their high levels of accuracy, they are found in a wide range of technologies. In many appli- cations, the value necessitates a constant temperature in the working wavelength range. However, as the materials expand or contract with thermal fluctuation, the refractive indices of the ordinary and extraordinary rays change. In this way, it is possible to produce different types of retar- dation plates with different designs and to optimize their cost-performance ratio depending on the specification and application.

Multiple-order plates (Type S)
The multiple-order plate is the most typical representative of plates with a good cost-performance ratio, but with relatively high temperature dependence. These plates are designed specifically for a defined retardation and allow higher order retardation with a preset wavelength and temperature.

Zero-order plates (Type D)
Zero-order plates are designed for applications with a specific wavelength and consist of two combined quartz plates that are either optically contacted or mounted with an air gap. These plates are extensively temperature- independent, as expansion effects are almost completely eliminated. Retardation plates with an air gap are usually mounted according to customer's requirements.

Low-order plates (Type SF)
Low-order plates are an alternative option. Due to their low absolute mechanical thickness (till 0.08 mm), they operate relatively independently of thermal fluctuations and consist of a single quartz plate designed for the use with a specific wavelength and are made in the right thickness for the required retardation. The industrial manufacturing of such extremely thin plates embodies a very high level of technological sophistication, as high standards of accuracy and cleanness are demanded.

Mica retardation plates
Mica retardation plates represent a low-cost and readily available alternative to the high-precision quartz retardat- ion plates and achromatic plates. They are usually cemen- ted between covering glass pieces due to interference. Their laser resistance is then approximately 1 W/cm^2, or they are refined with customized antireflection coatings. Depending on the working wavelength, extra coating raises the destruction threshold considerably.

Mica retardation plates are made by splitting the natural material to create plates in diameters of up to 150 mm. After splitting, optically clean sections without inclusions or streaks and without divergent crystal zones are separated from damaged areas to be used in a wide range of different applications.

Only selected mica of the best optical purity and with a high transmission value is used. The following standard types are differentiated:

Type A:
Zero-order plate for 550 nm ±10%. Mica plates are cemented between two glass covers. Used in the visible spectral range from 400 nm to 700 nm.

Type B:
Zero-order plate. Mica plates are cemented between two glass covers. Used in the spectral range from 400 nm to 2,5 µm. The wavelength must be specified exactly.

Type C:
Zero-order plate without glass covers. Used in the spectral range from 350 nm to 3.5 µm. The wavelength must be specified exactly.

Retardation plates

Achromatic retardation plates

Achromatic retardation plates for standard products are made out of quartz and magnesium fluoride. The plates are cut parallel to the optical axis and cover a specific wavelength range. The accuracy of the retardation is typically ± 10 %.

The combination of several retardation plates allows a retardation that is as independent as possible from the wavelength, so achromatic retardation plates can be used over a wavelength range. They are either made of several plates of the same material and different axis positions or different thicknesses, consisting of different birefringent materials, cemented and mounted together to form a retardation.

The simplest option for an achromatic waveplate is a combination of quartz and calcite.

Jenoptik has all the essential technologies for the manufacturing and mounting of achromatic retardation plates.

On customers' request, we manufacture specific and standardized crystal optics as prototypes and transfer them into series production. This also applies to Fresnel parallelepipeds and rhombs.

Technical specifications

	Quartz-retardation plates	Mica retardation plates	Achromatic retardation plates
Material:	Quartz (synthetic or natural)	Mica (glass insert: BK7)	Quartz, MgF_2
Spectral range:	180 nm up to 2.8 µm	700 nm up to 2.5 µm	180 nm up to 2.8 µm
Wavefront deformation:	$\lambda/10$ at 633 nm	$\lambda/10 \dots 1\lambda$ at 633 nm	$\lambda/10$ at 633 nm
Surface quality:	5/3 x 0.063	5/3 x 0.25	5/3 x 0.16
Parallesism:	< 1 second	< 30 seconds	< 10 seconds
Temperature dependence:	low order – 0,1 nm/K zero order – 10^{-5} nm/K		
Measurement unit of wavelenght:	in nm	in nm	in nm
Dimensions:	up to maximum of Ø 120 mm	up to maximum of Ø 150 mm, also other geometries available	up to maximum of Ø 50 mm
Shape:	round, rectangular square, other on request	round, rectangular square, freeform surface, other on request	
Retardation:	$\lambda/2$, $\lambda/4$ other on request	$\lambda/2$, $\lambda/4$ other on request	$\lambda/2$, $\lambda/4$ other on request
Retardation tolerance:	i.e. $\lambda/200$ at 266 nm	± 5 % other on request	depends on wavelength range, up to 10 %
AR coating:	R < 0.25 % or customer's requirements	R < 0.25 %	R < 0.25 % or customer's requirements
Mounting:	typical Ø 25 mm other on request	Ø 25 mm other on request	Ø 25 mm other on request

Quality in the STEEG & REUTER tradition

Polarization prisms

Polarization prisms are optical components that split beams breaking unpolarized light into two linear polarized waves oscillating perpendicularly to each other. These prisms impress with excellent optical qualities over a wide spectral range and ensure very good birefringence. They consist of several single prisms, which are either cemented together or mounted with an air gap.

As the refraction index of the material is direction-dependent, that is birefringent, the two orthogonal components of light in the prism diverge in different ways. Either they leave the prism at a defined divergence angle or the prism is formed so that one component is completely mirrored by total reflectance and is fade out separately.

Polarization prisms are in widespread use wherever higher levels of light polarization is required, for example in photometers, polarimeters and interference microscopes.

Specially selected materials of the highest quality are used for the manufacturing of prisms, whereby calcite and quartz are preferred. The following types of prisms, which differ in their design and function, are available:

• Wollaston prism
• Glan Thompson prism (long or short)
• Glan Taylor prism (with or without a side window),
• Rochon prism
• Foster prism
• others, such as Nomarski.

Wollaston prism

A Wollaston prism consists of two right-angled prisms which are cemented together along their hypotenuse surfaces. These prisms consist of uniaxial birefringent crystals such as calcite and quartz.

The Wollaston prism splits the incident beam into an ordinary ray and an extraordinary ray. These are linear polarized and perpendicularly to each other and exit the prism at a divergence angle of up to 20°. The crystal axes are perpendicular to each other and perpendicular to the propagation of the incident light.

Technical specifications for calcite

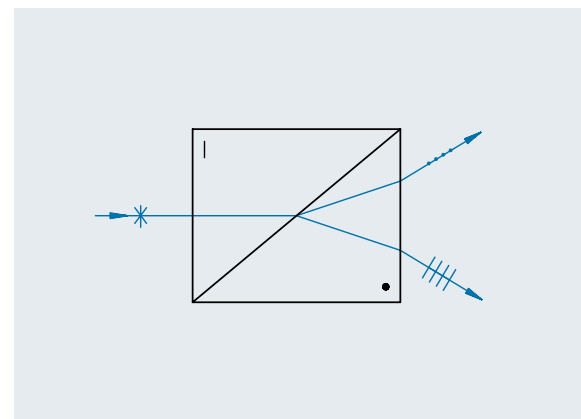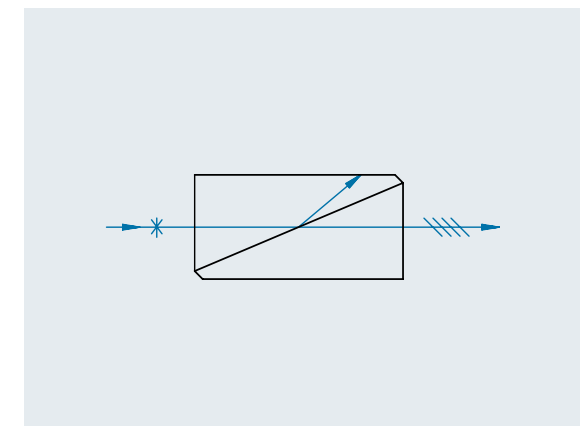|	
Material:	high quality calcite
Spectral range:	300 nm – 2,2 µm
Typical extinction ratio:	10^{-6}
Deflection aberration:	< 2 min
Planity of the defelctor:	$\lambda/4$
Typical divergence angle:	2° / 5° / 10° / 20°
Clear aperture:	5 up to 20 mm
AR-coating incident and emergent face:	< 0,5 %
Mounting diameter:	25 mm

Wollaston Prism

Glan Thompson and Glan Laser Prism

The Glan Thompson prism is a special polarization prism where only the extraordinary ray leaves the prism without deflection. The ordinary ray is deflected on the layer separating the parts of the prism by total reflectance and is absorbed on a blackened surface.

The distinctive, special feature of Glan Laser prisms is their utilization of both polarization directions and of higher laser performances. In addition they can also be used reversely. The ordinary ray refracts so that it exits the body through two specially created windows and can be used separately. The extraordinary ray, which is polarized horizontally, leaves the polarization prism without being deflected.

Glan Laser prisms cut at the Brewster angle are manufactured on request.

Technical specifications for calcite

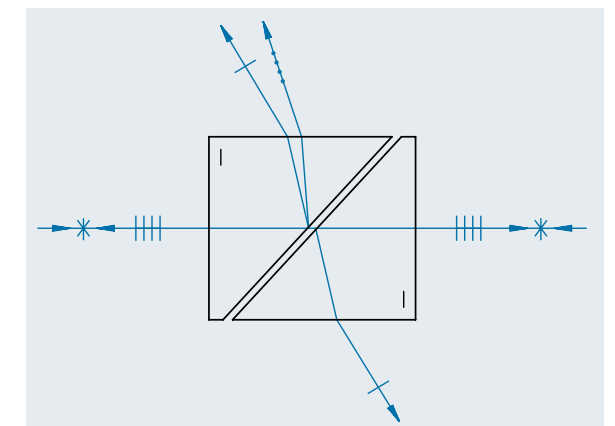|	
Material:	high quality calcite
Spectral range:	300 nm – 2.7 µm
Typical extinction ratio:	10^{-6}
Deflection aberration:	< 2 min
Planity of the defelctor:	$\lambda/4$
Clear aperture:	5 up to 20 mm
Glan Thompson:	max. 30 W/cm^2 for the absorbing beam; 200 W/cm^2 for the transmitted beam
Glan Laser (air):	300 W/cm^2 cw at 1064 nm; 300 MW/cm^2 for 20 ns Puls at 1064 nm
Mounting diameter:	25 mm

Glan Thompson Prism

Glan Laser Prism

Quality in the ◤ STEEG & REUTER tradition
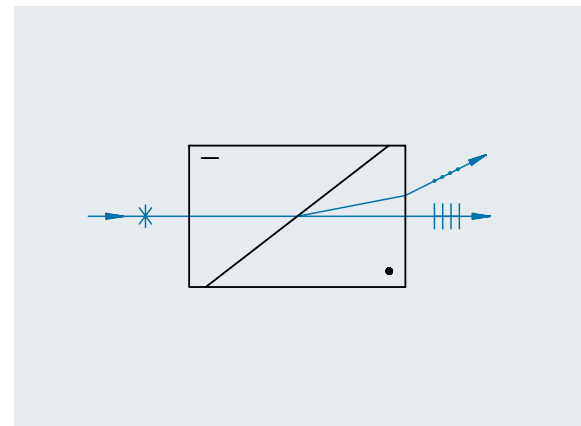
Polarization prisms

Rochon Prism

The Rochon prism operates in a similar way to the Wollaston prism. It is a two-part prism with a divided field of view and consists of two right-angled prisms. These prisms are made from high-quality calcite or quartz.

In the first prism, the optical axis runs parallel to the crystal axis. The crystal axis in the second prism on the other hand is perpendicular to the optical axis. This arrangement means that optical birefringence is not possible in the first prism, as the light enters along the optical axis. At the interface between the two parts of the prism, the light is split into an ordinary ray and an extraordinary ray. The ordinary ray exits from the Rochon prism without being deflected and is achromatic. Both rays leave the prism at a divergence angle, so that the extraordinary ray can be fade out.

Technical specification for calcite

Material:
high quality calcite

Spectral range:
300 nm – 2.2 µm; above 2 µm absorption is setting in

Typical extinction ratio:
10^{-6}

Deflection aberration:
< 2 min

Planity of the deflector:
λ/4

Typical divergence angle:
2° / 5° / 10° / 20°

Clear aperture:
5 up to 20 mm

AR-coating incident and emergent face:
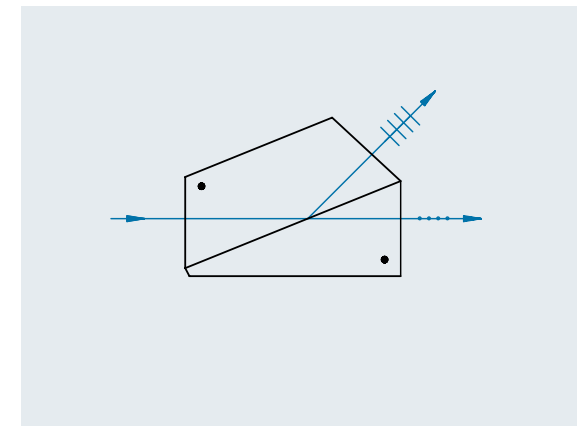< 0,5 %

Mounting diameter:
25 mm

Foster Prism

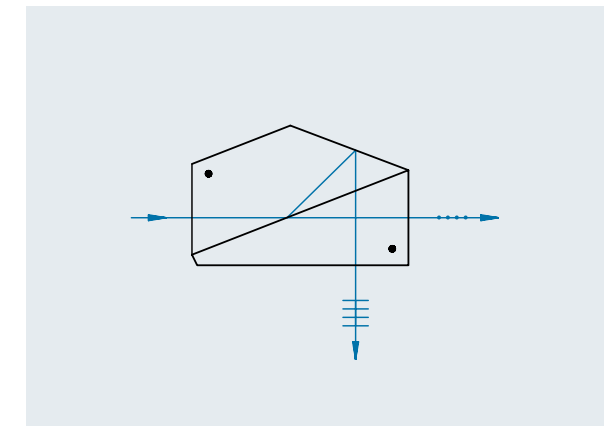Foster polarization prisms are two-part prisms and are made of high-quality calcite.

When a beam hits a Foster prism, it creates two polarized beams perpendicular to each other. The angle between them is either 45° or 90° in the spectral range of 300 – 2.7 µm. Absorption of the diffracted ray starts at 2 µm. Special prisms can be made to meet customer requirements. For example, another wave plate with λ/2 can be cemented to the side window, so that the direction of oscillation turns through 90° and both exiting rays are polarized in the same direction.

Technical specifications for calcite

Material:
high quality calcite

Spectral range:
300 nm – 2.2 µm; above 2 µm absorption of the deflected beam is setting in

Typical extinction ratio:
10^{-6}

Deflection aberration:
< 2 min

Planity of the deflector:
λ/4

Typical divergence angle:
2° / 5° / 10° / 20°

Clear aperture:
5 bis 20 mm

AR-coating incident and emergent face:
< 0,5 %

Mounting diameter:
25 mm

Rochon Prism

Foster Prism 1

Foster Prism 2

Our designs and specifications are in constant development. We reserve the right to make changes that reflect technological progress.

Depolarizers

Rotation plates

Depolarizers are optical components that convert polarized light into virtually unpolarized light by combining the polarization states.

Depolarizers are made from birefringent materials such as quartz, calcite or magnesium fluoride.

A distinction is made between the Hanle, Lyot and Cornu types.

Hanle type

Hanle type depolarizers consist of two optically contacted wedges, of which at least one is birefringent. The second wedge compensates the prismatic deflection. The retardation varies with expansion giving different polarization states. Experiments must be undertaken to find the best orientation. The effect increases with the diameter of the beam.

Lyot type

Lyot type depolarizers consist of two retardation plates cut parallel to the optical axis with a thickness ratio of 2:1. The plates are optically contacted at 45° and create elliptical, circular and linear polarized light. This type cannot be used for monochromatic light.

Cornu type

Cornu type depolarizers consist of two quartz prisms, counter-clockwise rotating and clockwise rotating respectively, which are cut perpendicularly to the optical axis (rotation plate) and therefore rotate linear polarized light depending on the location.

Rotation plates are based on the principle of optical activity or rotation dispersion. That is, when a polarized beam passes through crystals (of monocrystalline quartz in particular), the polarization plane rotates perpendicularly to the polished surface.

The rotation of the beam is proportional to the length of the substrate through which the beam passes. A solid optical substance rotates the polarization plane of linearly polarized light by the angle: $\alpha = [\alpha] \times d$

d is the length of the light path in the substance, $[\alpha]$ the specific rotatory power. The specific rotary power is positive for clockwise and negative for counter-clockwise substances. It is dependent on the wavelength.

Technical specifications

Material:
Quartz crystall, monocrystalline

Wavefront deformation:
λ/10 at 633 nm

Surface quality:
5/3 x 0.16

Typical diameter tolerance:
+ 0.0 mm; – 0.1 mm

Parallesism:
< 0.5 seconds possible

Rotation angle:
45°; 90°; other on request, please specify wavelength
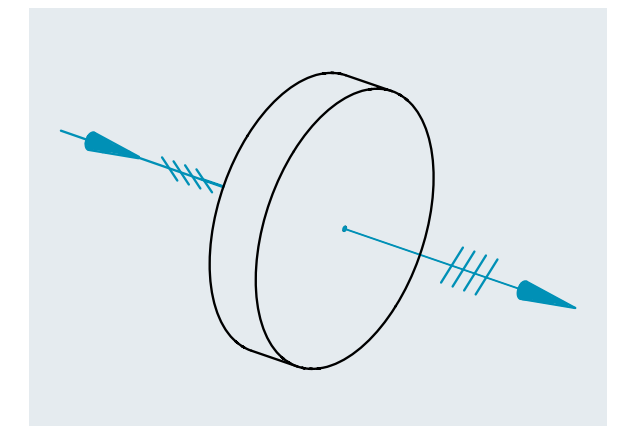
Typical thickness tolerance:
< 0.003 mm

Typical damage ratio:
10 J/cm^2, 8 nsec. pulse; 1 MW/cm^2, cw at 1064 nm

Other information:

Production of quartz control plates.
According to customers' requirements, the optics can be refined with AR coatings and fitted in special mounts. We are able to manufacture any desired shape.

Rotation plate

Quality in the STEEG & REUTER tradition

Compensators

Compensators are variable or multi-stage retardation plates. As in the case with retardation plates, quartz, mica and magnesium fluoride are widely used for the manufacturing of compensators due to their excellent optical properties.

Compensators are used for measuring processes that operate with varying retardation values, for the examination of different polarization states and in areas in which work with polariscopes or continuity testers requires a reference standard.

A distinction is made between step compensators and continuously variable compensators.

Step compensator type

In the step compensator, mica plates of different thicknesses, and therefore different retardation, are cemented together on a base.

Continuously variable compensators

Continuously variable compensators such as the Babinet and the Soleil Babinet have a "wedge-shaped retardation plate" that can be adjusted with a screw. The Soleil Babinet type also features a wedge to compensate beam deflection. This yields a retardation that can be defined consistently within the free aperture, thereby facilitating the calibration and measuring of defined retardation values.

Compensator wedges

Compensator

1) Babinet-compensator   2) Soleil-Babinet-compensator
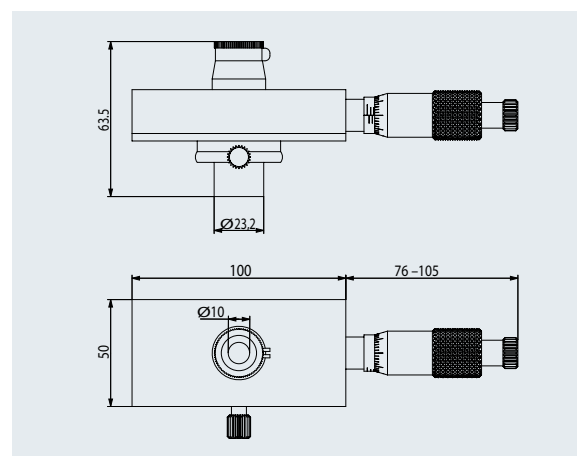
Optical windows

Optical windows are components in the form of a parallel plate. Depending on their application and specification, they can be called windows, flats or substrates. Depending on the application, they can be made of widely differing crystalline materials such as sapphire, calcite or calcium fluoride.

The installation of windows of crystalline material can protect sensitive surfaces from mechanical impacts and also from humidity and chemical reagents such as mica. Used as protective glass, these windows make it possible for vacuums, combustion chambers (heat, pressure) etc., to be observed under the most adverse conditions, as they are robust enough to resist stress and also allow long wave radiation and visible light to penetrate for the purposes of visual observation.
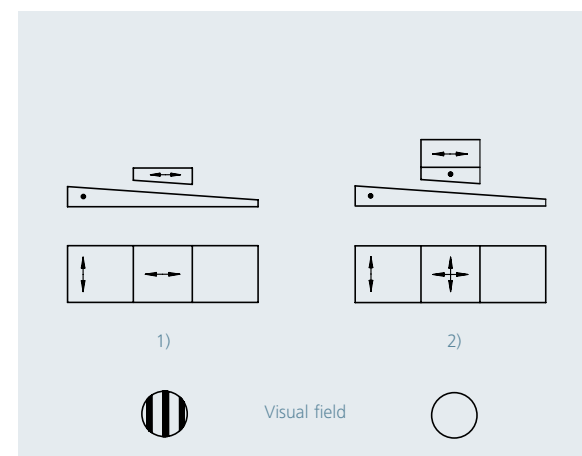
Crystalline windows can be made in almost any form and can therefore be utilized in a wide range of applications. For example, hard, scratch-resistant sapphire is used as watch glass or as inspection window through which thermal processes can be observed.

Windows made from calcium fluoride are mostly deployed in the UV range and windows of germanium are opted for the IR range, in thermography and security and defense technology, for example. Flats can be dimensioned to resist certain pressures. They can also be used as filters or as the base substrate for filters.

Jenoptik has all the essential technologies, and is able to manufacture customized crystalline optics as prototypes and for subsequent series production as well.

Quality in the STEEG & REUTER tradition

Lenses made of crystalline material

The use of crystal instead of amorphous materials offers a special advantage in that crystal optics have high transmission levels, are resistant to high-energy lasers and also are free of tension. Properly aligned, they exhibit a homogeneous refraction index.

Machining three-dimensional, periodically arranged structures of anisotropic crystals requires extensive methods to meet the high demands for optical cleanness and surface accuracy.

New manufacturing technologies harnessing light sources with increasingly short wave-lengths require accurate, high-end optical components. The semiconductor industry, where increasing use is being made of calcium fluoride optics, is a salient example. In the long wave spectral range, lenses made of germanium are used which can then be found in the lenses of thermal imaging cameras.

The production of crystal optics require many years of experience in the development and manufacturing of tools and in the development of manufacturing processes, as it is only possible to create a homogenous surface when creating a lens if material is removed from different angles, which must be done on a curved surface.

Jenoptik has all the required technologies, and is able to manufacture customized crystalline optics as prototypes for subsequent series production.

Technical parameters

Jenoptik develops and manufactures customized opical solutions from crystalline materials. These include spherical, aspherical, cylindrical and toroid components, lenses and freeform shapes.
The Optical Systems Division is able to manufacture customized components. Cylinder surfaces should be considered as special forms of the toroid surface, whereby the radius of the meridian section can be made with an infinite radius of curvature.

It is possible, for example, to manufacture lenses for the use at a wavelength of 193 nm with a surface accuracy of 3/2 (0.4) and a cleanness of 5/3 x 0.063 in a test range of 20 mm x 40 mm.

Technical specifications

Material:
CaF_2, MgF_2, Ge, Si, LiF, etc.

Shapes:
concave, convex, biconcave

Dimensions:
up to 100 mm

Surface quality:
on request

Special coatings:
on request

Technology and manufacturing equipment:
Measuring processes:
• 2D/3D tactile
• Interferometrically for cylinders, aspheres and toroid surfaces with a specially Computer Generated Hologram (CGH)
• Extensive test and measuring facilities to verify resistance to environmental influences

Development:
• In-house and customized design
• Quality and coating as required by customers

Glossary

Anisotropic
Describes materials whose properties depend on the orientation of the crystal, i.e. direction-dependent.

Extraordinary ray
One of the two orthogonal oscillation directions of a wave in a crystal: light speed $\neq n0$.

Birefringence
Property of some crystals through which the two components of a light ray propagate at different speeds, creating a phase shift. Birefringence stems from the anisotropic nature of the refraction index.

Mica
Natural, crystalline, birefringent material from which retardation plates are made. (sheet silicate).

Half-waveplate – $\lambda/2$ plate
Retardation plate that creates a retardation of half a wavelength or an odd multiple thereof. $\Gamma = (2m+1) \times \lambda/2$
(m – ordinal number, λ – wavelength)

Isotropic
Name given to properties of a material that are direction-independent e.g. in optical glass.

Calcite
Natural birefringent crystalline material that is primarily used for polarization prisms ($CaCO_3$), and exhibits a high level of birefringence in the visible and in the near infrared spectrum.

Linearly polarized
One of the possible polarization states in which the oscillation direction of the electric field vector is defined in a specific direction.

Extinction ratio
Ratio of transmission of two polarizers in the "light" and "dark" operate ($\tau o/\tau 90$).

Ordinary ray
One of the two orthogonal oscillation directions of a wave in a crystal: light speed $= n0$

Quartz
Natural crystalline product or synthetically grown material which is used in polarization optics due to its birefringent property (SiO_2).

Streaks
Interference-causing irregularities and inaccuracies in natural optical crystals such as quartz and calcite.

Transmission
The degree to which a component allows optical radiation to penetrate.
T = total radiant flux ϕ – absorption A – reflection R

Quarter waveplate – $\lambda/4$ plate
Retardation plate that creates a retardation Γ of a quarter-wavelength.
$\Gamma = (2m+1) \times \lambda/4$ (m – ordinal number, λ – wavelength)

Wavelength
Space between two similar adjacent phases in an oscillation.

Circular polarization
Special polarization status of a light wave where there is a retardation of $\lambda/4$ between the ordinary and the extraordinary ray.

Quality in the **STEEG & REUTER** tradition

Made by Jenoptik

The performance of the Optical Systems Division depends on the expertise of its highly-qualified employees and on advanced, leading-edge technologies. A comprehensive equipped development section works on new optical concepts, their design and construction, as well as on the development and verification of optical and optical-coating technologies.

Our manufacturing devision accomplish in-depth competence in every technological process, from the processing and manufacturing of optical components, the assembling of optical devices and lenses and up to the optical coating. All manufacturing processes are supported by a quality assurance devision equipped with outstanding measurement and testing technology.

In addition to the manufacturing of standard products in OEM design in a compact modular construction for the integration in existing systems, we also produce individual solutions, providing extensive and consistent customer consulting and support them long-lasting in practice.

Our customers benefit from decisive added value through synergy effects with our additional business units and subsidiaries of Jenoptik. With many years of experience and an extensive network of competence, we accomplish excellence, not only in research and development, but also in manufacturing and in our services.

Set us a challenge! We meet every new task with passion and expertise.

ENVIRONMENTAL MANAGEMENT
Certificate
Voluntary participation in regular monitoring according to ISO 14001

QUALITY MANAGEMENT
Certificate
Voluntary participation in regular monitoring according to ISO 9001