

Polarization

By polarized light we mean optical radiation with its electric field oscillating in a specific regular mode. Any generally polarized electric field can be resolved into two orthogonally polarized components. If the light is plane polarized then the electric field oscillates in a single plane - the plane of polarization, and the two components are in phase. If it is elliptically polarized, the two components have a constant phase difference, and the tip of the electric field vector follows a three dimensional ellipse as the beam propagates.

Circularly polarized light is a special case of elliptically polarized light in which the two components have a 90° phase difference and the electric field vector describes a circular cross section spiral. When viewed looking towards the source, a right circularly polarized beam has a light vector that describes a clockwise circle, while left circularly polarized light describes an anti-clockwise circle.

Linear Birefringence

Linearly birefringent uniaxial crystalline materials are characterised by having a unique axis of symmetry, called the optic axis, which imposes constraints upon the propagation of light beams within the crystal. Two modes are permitted, either as an ordinary beam polarized in a plane normal to the optic axis, or as an extraordinary beam polarized in a plane containing the optic axis. Each of the beams has an associated refractive index, such that both the electric field (wave normal) velocities and the beam (ray) angles of refraction are different. It is this latter property that enables suitably cut and oriented prisms of birefringent materials to act as polarizers and polarizing beam splitters.

Circular Birefringence

If a plane polarized beam propagates down the optic axis of a material exhibiting circular birefringence it is resolved into two collinear circularly polarized beams, each propagating with a slightly different velocity. When these two components emerge from the material, they recombine into a plane polarized beam whose plane of polarization is rotated from that of the incident beam. This effect of producing a progressive rotation of the plane of polarization with path length is called optical activity, and is used to produce optical rotators.

Birefringent Materials

We use various materials out of a fairly wide range of birefringent crystals for the production of our polarizing components - calcite, crystal quartz, magnesium fluoride (MgF_2), YVO_4 and α -BBO.

Calcite (CaCO_3)

Calcite is a widely preferred choice of material, owing to its very high birefringence, wide spectral transmission and the availability of reasonably sized crystals. Unfortunately, calcite cannot be manufactured synthetically. Only natural crystals exist which limits the maximum size with good optical quality. It has the advantage of being non-hygroscopic, so that protection from the atmosphere is not necessary, though it is a fairly soft crystal and is easily scratched. We have perfected a number of proprietary processes for cutting, grinding and polishing perfect optical surfaces on calcite prisms, routinely achieving flatnesses down to $\lambda/8$ over several cm with 10/5 scratch dig. These skills are evident in the high quality of the finished components, and enable our polarizers to be used with very high peak power lasers.

Quartz (SiO₂)

Quartz is an extremely useful birefringent material and is available as either natural crystals or as synthetic boules. Natural crystals occur as rough lumps that require orientation to determine the optic axis before processing, while synthetic crystals have reference surfaces aligned to crystallographic axes. When deciding which sort of quartz should be used for a component, two parameters that differ significantly between the two types should be considered: size and spectral transmission.

In general, components from synthetic quartz are limited to a maximum size in the direction of the optic axis of around 70mm, while natural quartz boules are available large enough to yield working apertures up to 100mm. The other significant discriminant between natural and synthetic quartz is the low wavelength cut-off. Natural quartz has a useful transmission (app. 80%) from 220nm, while synthetic quartz transmits similarly from 190nm. Both transmit out to about 2.6 μ m.

Quartz is very hard (Mohs scale 7) and is very strong. It thus lends itself to the fabrication of very thin low order retardation plates. Unlike calcite or magnesium fluoride, quartz exhibits circular birefringence, and there is no unique direction (optic axis) down which ordinary and extraordinary beams propagate under one refractive index with the same velocity. Instead, the optic axis is the direction for which the two indices are closest: a beam propagates down it as two circularly polarized beams of opposite handedness (chirality). This produces progressive optical rotation of an incident plane polarized beam; which effect is put to good use in rotators.

Magnesium Fluoride (MgF₂)

Single crystal magnesium fluoride is another extremely useful material for the production of polarizers due to its very wide spectral transmission, extending from 120nm in the vacuum ultraviolet to beyond 7.0 μ m in the infra red. Because suitable index matching cements do not transmit below 220nm, magnesium fluoride polarizers are manufactured by optically contacting the two prisms.

Thin plates can be manufactured from this material for use in achromatic retardation plates. In these optical components the spectral dispersion of the magnesium fluoride is used to compensate that of quartz, producing a near uniform retardation over a defined spectral band.

Yttrium Orthovanadate (YVO₄)

Yttrium orthovanadate is useful due to its extended wavelength range. We provide polarizers functional to 4000nm (4 μ m) wavelength. Magnesium Fluoride is also a good candidate, but the separation angle using YVO₄ for Wollaston and Rochon polarizers is much higher.

α -Barium Borate (α -BBO)

The high Temperature form of BBO (α -BaB₂O₄) is a negative uniaxial crystal. It has a large birefringence over the broad transparency range from 190 nm to 3500 nm. Due to its unique UV transparency, good mechanical properties and high damage threshold, α -BBO is an excellent crystal to replace Calcite, TiO₂, and LiNbO₃, etc. in Glan-Taylor and Glan-Thompson Polarizers as well as walk-off beam splitters, especially for high power and UV polarizers. Since the crystal is centrosymmetric, it cannot be used for non-linear optical applications.

We hope this short tutorial has been of use to you. If you require further information on the birefringent materials available or on component possibilities, please contact us.