LD Physics Leaflets
P5.4.2.1

Birefringence and polarization with calcite (Iceland spar)

Objects of the experiment

- Observing the splitting of a light bundle when passing through a spar crystal.
- Verification that the two light bundles are polarized perpendicularly to each other.

Principles

The validity of Snell's law of refraction is based on the premise that light propagates in the refracting medium at the same velocity in all directions. However, there are transparent substances where this condition is not fulfilled. These media display "anisotropic" optical properties.

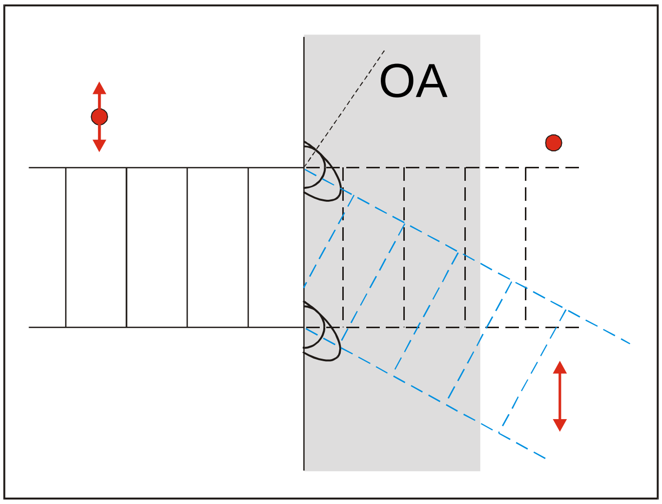
In anisotropic media birefringence (or double refraction) is observed due to the decomposition of the light ray into two rays (the ordinary ray and the extraordinary ray). These rays propagate with different refractive behavior and with different polarization. We will restrict in the following to crystals which possess exactly one symmetry axis (e.g. calcite: $CaCO_3$).

The spatial separation of ordinary and extraordinary ray can be explained by Huygen's principle. The light beam strikes the surface of a single axis crystal perpendicularly. The optical axis runs obliquely with respect to its surface into the drawing plane. The elementary waves of the ordinary waves are spherical waves. Their envelope and thus the wave fronts are parallel to the crystal surface in each case. Therefore the ordinary ray passes the crystal without refraction.

In the case of the extraordinary ray the elementary waves are ellipsoid waves. Their envelope is again parallel to the boundary surface. However, the wave fronts are laterally shifted. The direction of the extraordinary waves thus deviates from the direction of the ordinary ray.

The polarization plane is indicated in Fig. 1 by a double arrow or a point. The polarization plane of the extraordinary ray is defined by the direction of propagation and the optical axis and thus lies in the drawing plane. The polarization plane of the ordinary ray is perpendicular to this.

Fig. 1: Propagation of ordinary and extraordinary rays in the crystal. OA: optical axis of the crystal. The polarization of the rays is indicated by a double arrow or a point.



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Apparatus

1 Iceland spar crystal 472 02
1 Prism table on stand rod 460 25
1 Iris diaphragm 460 26
1 Polarization filter 472 401
1 Lens in frame f = +50 mm 460 02
1 Lens in frame f = -100 mm 460 06
1 Translucent screen 441 53
1 Optical bench, standard cross section 1 m 460 32
7 Optics rider 60/34.. 460 370
1 Halogen lamp housing 12 V, 50/90 W................ 450 64
1 Halogen lamp, 12 V / 90 W 450 63
1 Picture slider 450 66
1 Transformer 2 to 12 V, 120 W........................... 521 25
1 Pair cables 100 cm, red/blue............................. 501 46

Setup

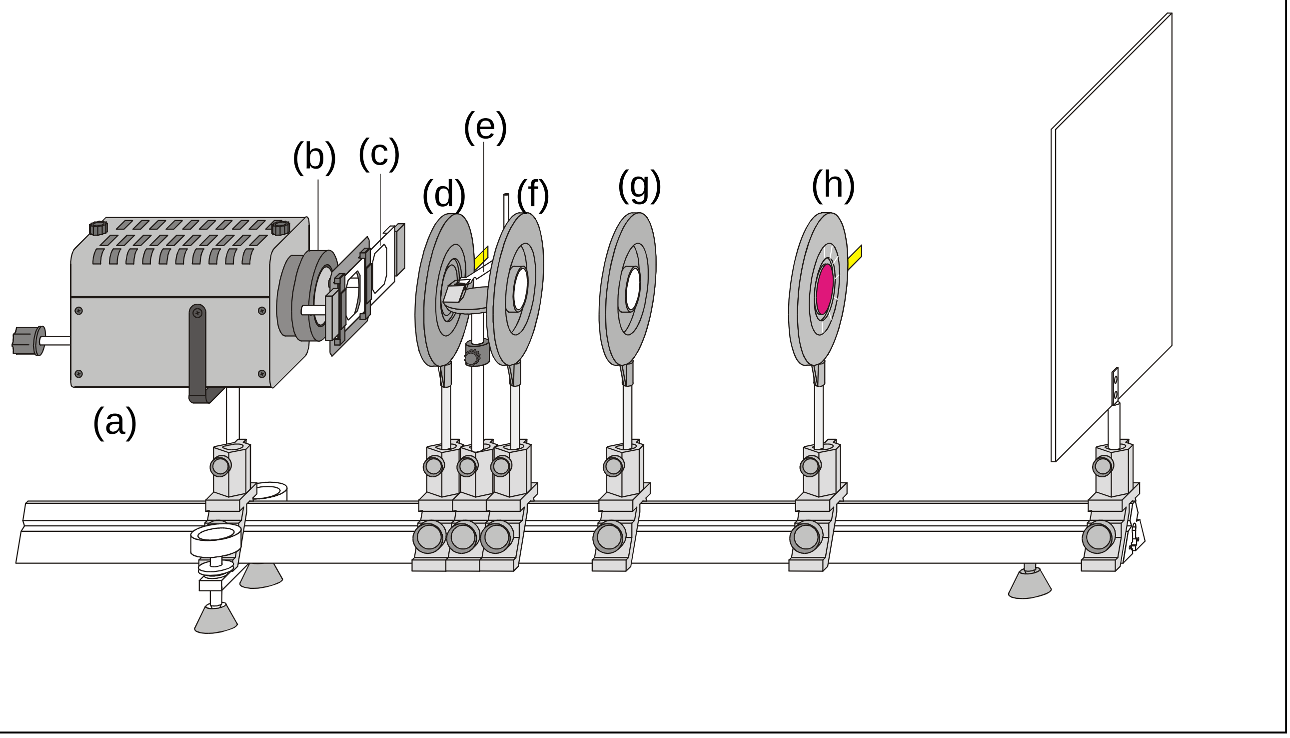
Setup the experiment like shown in Fig. 2. Do not yet position the spar crystal in the beam path.

Note: For the optical setup alternatively the small optical bench (460 43) or the optical bench S1 profile (460 310) can be used.

Notes on the beam path:

- The light supplied by the Halogen lamp (a) is concentrated by the condenser (b) and passes through a heat resistance filter (c) to protect the optical components against heating up.
- A thin light bundle is isolated by an iris diaphragm (d) which splits into two bundles corresponding to the ordinary and extra ordinary beam when it passes through the spar crystal (e).
- The ordinary and extraordinary beam pass through a imaging system, consisting of the collective lens (f) and the diverging lens (g).
- Two sharp images of the iris diaphragm are produced on the translucent screen which result from the two light bundles.
- By positioning of a polarization filter (h) between the diverging lens and the translucent screen it can be demonstrated that the ordinary and the extraordinary light beam are polarized perpendicularly to each other.

Fig. 2: Experimental setup for double refraction and polarization at a spar crystal.
(a) Halogen lamp
(b) Condenser lens
(c) Picture slider with heat resistance filter
(d) Iris diaphragm
(e) Spar crystal
(f) Collective lens f = +50 mm
(g) Diverging lens f = -100 mm
(h) Polarizing filter



Safety notes

Mind the safety notes in the instruction sheet of the Halogen lamp.

- Operate with AC voltage only (12 V AC).
- Do not cover the ventilation slits (danger of overheating).

Optical adjustment:

- Set up the Halogen lamp (a) with the reflecting mirror and fit the condenser and picture slider in to the lamp housing.
- Push the iris diaphragm (d) and the collective lens (f) directly up to the prism table (e).
- By turning the lamp insert in the lamp housing produce a sharp image of the lamp coil on a small sheet of paper positioned at the center of the collective lens (f).
- Move the diverging lens (h) in such a manner that a sharp image of the iris diaphragm opening
- Close the iris diaphragm as far as possible (minimum hole size) and place the crystal directly behind diaphragm opening so that one crystal edge is perpendicular to the optical axis.
- Check whether two displayed images of the iris can be seen on the translucent screen. It might be necessary to readjust the intensity of the lamp by turning the lamp insert in the lamp housing.

Note: The two images may slightly overlap (see Fig. 3).

Carrying out the experiment

- Position the polarization filter between the diverging lens and the translucent screen.
- Slowly turn the polarizing filter and observe the screen image.

Note: During the rotation the two images of the iris diaphragm become bright and dark.

- Read of the angles when only one image of the iris diaphragm is observed at the screen.

Measuring example

Positions of polarization filter:

α_1 = -30°

α_2 = +60°

Evaluation and results

Due to the double refraction of the light in the spar crystal two images of the iris diaphragm are observed on the screen.

By rotating the polarization filter the two images become bright and dark alternatively. This shows that two light bundles are polarized perpendicularly with respect to each other.

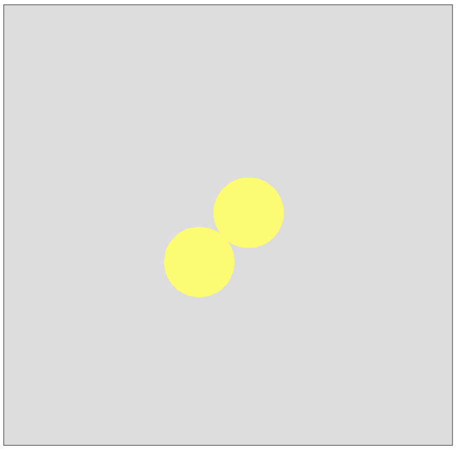


Fig. 3: Experimental result without polarizing filter on the translucent screen schematically. The image of the iris diaphragm due to the ordinary and extraordinary beam.

Supplementary information

Placing the calcite crystal upon a paper with some letters shows the double refraction.