4.4: Single crystals- Optical properties

Quartz crystals are birefringent, so they exhibit optical anisotropy. Consider plane polarised light passing through a birefringent crystal. Inside the crystal, the light is split into two rays travelling along permitted vibration directions (p.v.d.s). The two rays are subject to different refractive indices, so the light travelling along each p.v.d. reaches the opposite side of the crystal at a different time. When the two rays recombine, there is a phase difference between the two rays that causes the polarisation state of the transmitted light to be different from that of the incident light.

Optical anisotropy in thin samples can be observed by placing the sample between crossed polarising filters in a light box. The bottom filter, between the light source and the sample, is called the polariser. The top filter, between the sample and the observer, is called the analyser. The polariser and analyser have polarising directions perpendicular to one another.
The apparatus used for examining optical anisotropy consists of a white-light source, two polarising filters and a frame to hold them apart so creating a working space.

When no sample is in place the light that reaches the analyser is polarised at 90° to the analyser’s polarisation direction, so no light is transmitted to the observer. When a quartz sample (with favourable orientation, see later) is placed between the filters, the crystal changes the polarisation state of the light that is transmitted through it. When this light reaches the analyser, some component of it lies parallel to the polarisation direction of the analyser, and therefore some light is transmitted to the observer.

If a quartz slice shows optical anisotropy, the intensity of light transmitted through the analyser varies as a function of the angle of rotation of the quartz sample in the plane of the filters. At certain orientations, no light is transmitted. These 'extinction positions' are found at 90° intervals.
https://www.doitpoms.ac.uk/tplib/at..._animation.mp4

Video animation of anisotropic quartz rotated between crossed polarisers

When the same experiment is done using a piece of glass, it is found that light is not transmitted for any orientation. This is because the glass is optically isotropic, and does not change the polarisation state of the light passing though it.

In quartz, there is one direction of propagation for which no birefringence is observed. If a sample is cut so that the
incident light is parallel to this direction, the sample behaves as if it is optically isotropic and no light is transmitted. The crystallographic direction that exhibits this property is known as the *optic axis*.

When the quartz sample is cut so that the incident light is parallel to the optic axis, no light is transmitted in any orientation.

This experiment demonstrates that some single crystals, such as quartz, show anisotropic optical properties. The phenomenon depends on the crystallographic orientation of the crystal with respect to the incident light. Amorphous materials like glass have no 'distinct' crystal directions, so anisotropic properties are generally not observed.