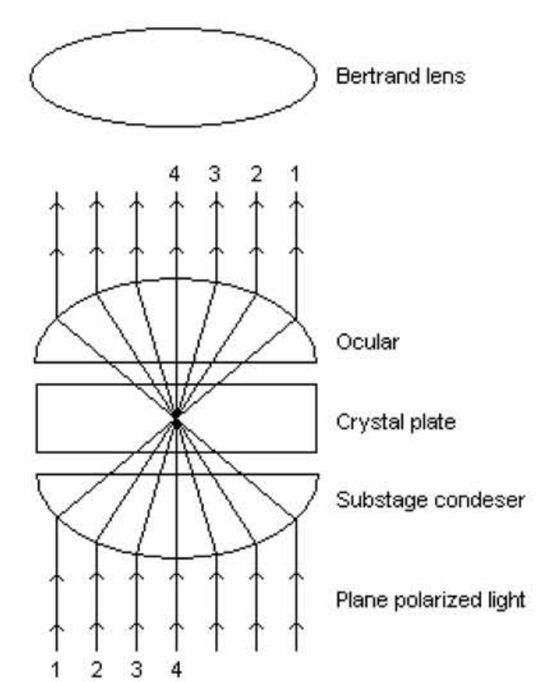
Lecture 12: Optics II

The first lecture on optics explores how to identify isotropic minerals from their refractive index and anisotropic minerals from their birefringence and interference colors. This lecture discusses more powerful tools for identifying anisotropic minerals, including interference figures, optic signs, and 2V angles.

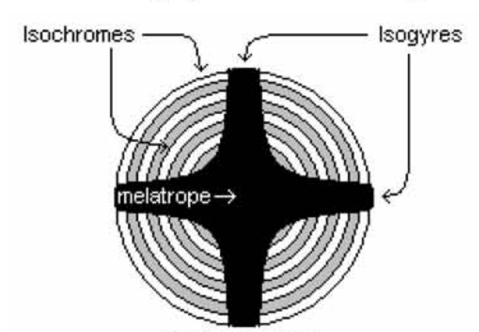
Interference Figures

Interference figures distinguish uniaxial and biaxial minerals and can be used to determine a mineral's optic sign. They are obtained by inserting the analyzer, flipping up the substage condenser, and rotating the Bertrand lens into place. The substage condenser causes the plane-polarized light from the illuminator to converge at the center of the sample, changing the illumination from orthoscopic to conoscopic. This step focuses the image on the plane near the top of the objective lens, and the Bertrand lens is required to refocus it.



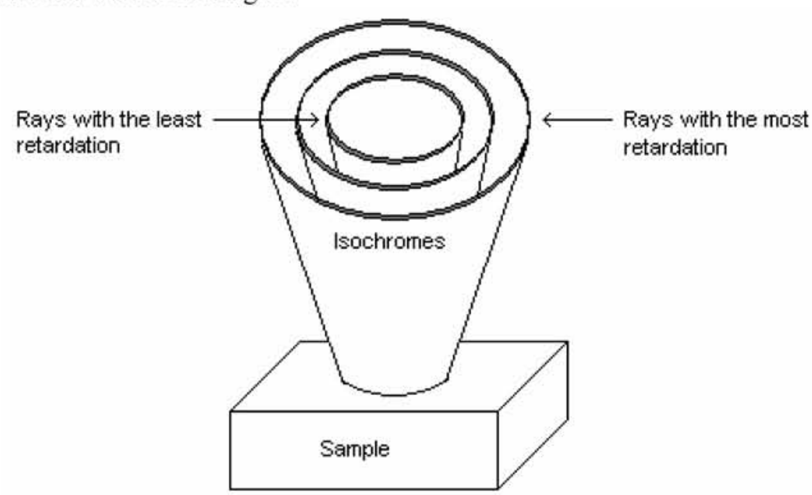
Uniaxial Interference Figures

There are two types of uniaxial interference figures: optic-axis figures and off-center optic-axis figures. Optic-axis figures occur when the c-axis is perpendicular to the stage.

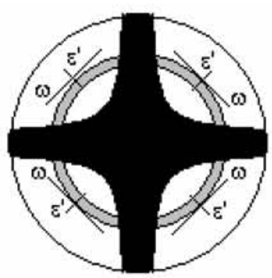


Optic-axis figure

They consist of isochromes, isogyres, and a melatrope. As shown in the picture below, isochromes are concentric color bands formed from cones of light that diverge though the crystal and experience equal amounts of retardation. Note that the outer colors are the faintest because the outermost rays of light have the longest travel path through the crystal and experience the most retardation. This is demonstrated by comparing paths 1 and 4 in the first figure.

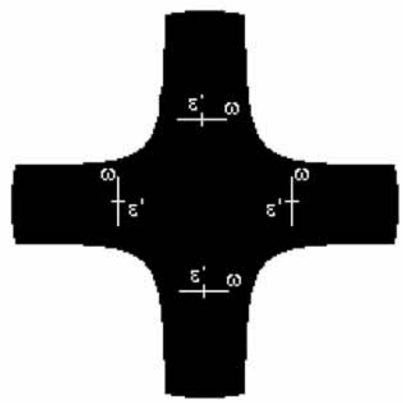


Isogyres are formed where the polarization of the rays that make up the cone is perpendicular to the polarization of the analyzer. The melatrope represents the c-axis and is the point in the center where the two isogyres cross.



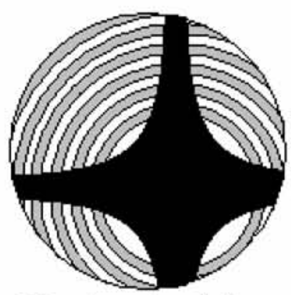
The ω ray vibrates tangentially to the isochromes.

The ε' ray vibrates radially.



Close up of vibration directions in the isogyres.

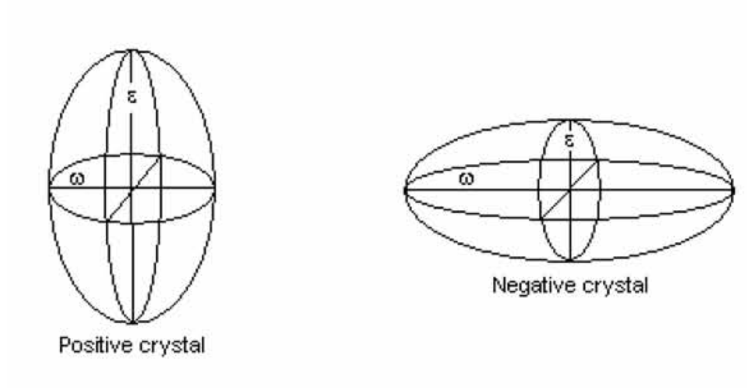
Off-center interference figures have the same characteristics as the optic-axis figure. The have isochromes, isogyres, and a melatrope, but the melatrope is not in the center of the figure because the mineral's c-axis is inclined with respect to the stage.



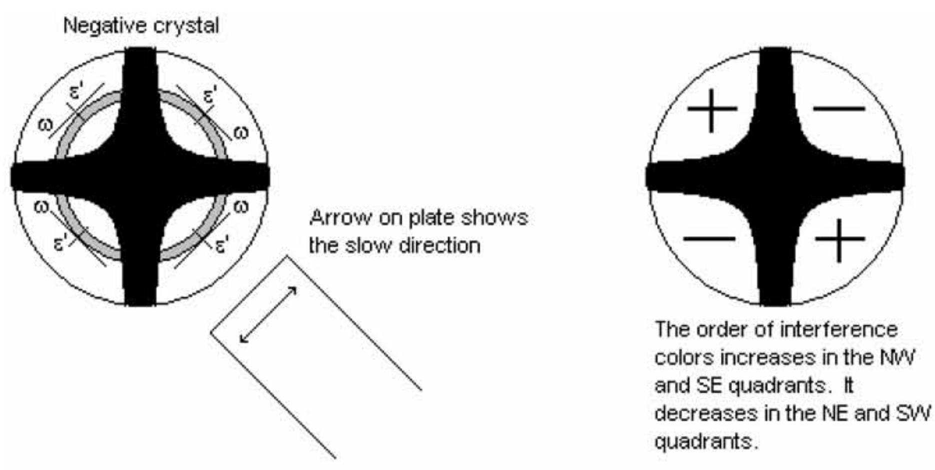
Off-center optic-axis figure

Optic Sign

Uniaxial minerals are designated positive or negative according to the relative magnitudes of their refractive indices. In a positive crystal, ε is larger than ω. In a negative crystal, ω is larger than ε. The sign of a crystal can be determined from its interference figure when a crystal plate is inserted. This plate is usually made out of mica or gypsum. The orientations of its fast and slow vibration directions are known, so viewing an interference figure through it causes the retardation of the light to change in a predictable way and shifts the interference colors.



Consider the interference figure of a negative crystal when the crystal plate is inserted. If the vibration directions of the plate are the same as those shown below, the slow rays in the interference figure are parallel to the slow vibration direction of the plate in the SE and NW quadrants. The fast rays are also parallel to the fast vibration direction of the plate in these quadrants. As a result, the order of the interference colors goes up in these quadrants.

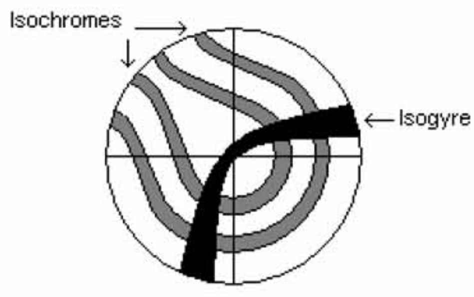


In the NE and SW quadrants, the fast rays in the interference figure are parallel to the slow vibration direction of the crystal plate. The slow rays are parallel to the fast vibration direction of the plate. As a result, the order of the interference colors decreases in these quadrants.

Similar arguments can be used to show that, in optically positive crystals, the order of the interference colors increases in the NE and SW quadrants and decreases in the NW and SE quadrants.

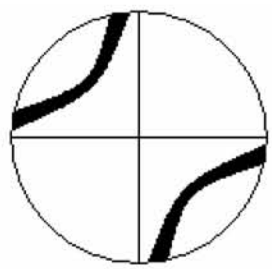
Biaxial Interference Figures

Biaxial interference figures are formed in the same way as uniaxial interference figures and have the same elements: isochromes, isogyres, and melatropes. While a number of different interference figures can be obtained depending on the orientation of the mineral, this discussion will examine only two particular cases. The simplest case arises when one of the optic axes is vertical.



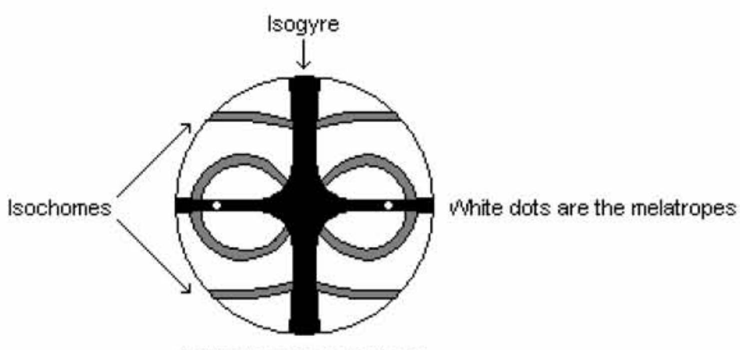
Optic-axis figure

This figure is very similar to the one produced when the optic plane is vertical and at forty-five degrees. The only difference is that, in the latter case, two isogyres are visible. The isochromes keep the same orientations.



Optic plane is vertical and oriented at 45°

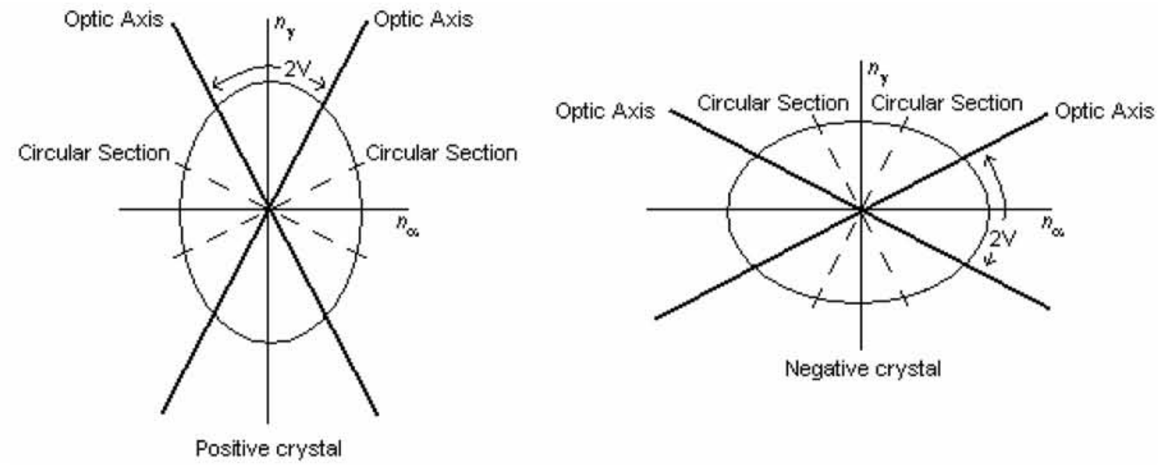
Another simple case arises when the optic plane is vertical and oriented east-west.



Optic plane is vertical and oriented E-W

Optic Sign of Biaxial Minerals

Biaxial crystals are positive if n_γ is the vibration direction that bisects 2V. They are negative if n_α is the vibration direction that bisects 2V.



The procedure for determining the optic sign of biaxial minerals is the same as that for uniaxial minerals: insert the analyzer, flip up the substage condenser, and rotate the Bertrand lens into place. The best interference figure to analyze is the one for which the optic plane is vertical and at forty-five degrees. For this case, the interference colors change in the same way that they do with uniaxial minerals. For a positive crystal, the order of the interference colors increases in the SW and NE quadrants and decreases in the NW and SE quadrants. For a negative crystal, the order of the interference colors increases in the SE and NW quadrants and decreases in the NE and SW quadrants.