Optic Sign Detemination

Biaxial Minerals

Biaxial Interference Figures

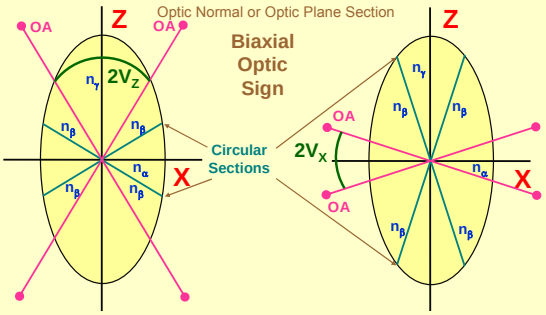
- Now that the interference figures have been attained and identified, the Optic Sign of the Biaxial mineral can be determined
- First recap conventions used to determine the Biaxial Optic Sign from an earlier lecture, followed by
- How the Optic Sign can be determined

Biaxial Minerals

- Biaxial optic sign is dependant on whether the **X** or **Z** indicatrix axis is the **Acute Bisectrix (Bxa)**
  - If **X** = **Bxa**, mineral is optically negative
  - If **Z** = **Bxa**, mineral is optically positive

Biaxial Indicatrix

Optic Normal or Optic Plane Section



Biaxial Positive
Acute Bisectrix (Bxa) = **Z**
Obtuse Bisectrix (Bxo) = **X**
$2V_Z$ = acute angle between **OA**s

Biaxial Negative
Acute Bisectrix (Bxa) = **X**
Obtuse Bisectrix (Bxo) = **Z**
$2V_X$ = acute angle between **OA**s

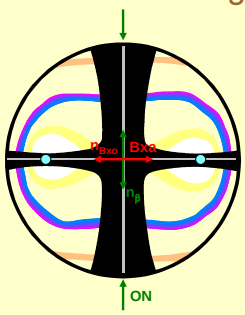
Biaxial Indicatrix

- Another convention used to identify the angle between the **OA**s bisected by:
  - the **X** axis as the $2V_X$ angle
  - the **Z** axis as the $2V_Z$ angle
- Angle can vary from 0 to 180°, where:
  $$2V_X + 2V_Z = 180°$$
- If $2V_Z$ < 90°, mineral is positive
- If $2V_Z$ > 90°, mineral is negative
- If $2V_Z$ = 90°, mineral is neutral

Biaxial Optic Sign

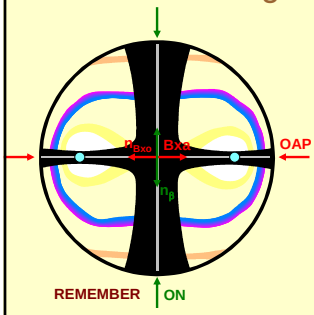
- In determining the Optic Sign of a biaxial mineral we need to determine whether the **X** or **Z** indicatrix axis is the **Bxa** and from that the corresponding optic sign
- Will look at various biaxial interference figures, beginning with the Bxa Figure

Determining the Optic Sign



- In a centred **Bxa** figure two rays of light propagate along the acute bisectrix, and emerge in the centre of the figure
- At extinction the two rays vibrate parallel with the upper and lower polarizers forming centre of cross.
- One ray vibrates parallel to the **Optic Normal** (**Y** indicatrix axis) has index n_β.
- Other ray vibrates parallel to the **Obtuse Bisectrix** and has an index n_{Bxo}.

Determining the Optic Sign



- This ray vibration direction is also parallel to the **OAP** (thinner arm) and contains the **Melatopes**.
- For optically positive minerals, the **Bxo** is the **X** axis and $n_{Bxo} = n_\alpha$, and corresponds to the fast ray ($n_\alpha < n_\beta < n_\gamma$).
- For optically negative minerals, **Bxo** is the **Z** axis and $n_{Bxo} = n_\gamma$, and corresponds to the slow ray.
- **Must determine whether the ray vibrating parallel to the obtuse bisectrix is the fast or slow ray**.

Determining the Optic Sign

Steps

1. Obtain an acute bisectrix interference figure.
2. Rotate the stage so that the trace of the **OAP** is oriented NE-SW, i.e., the isogyres split and move into the NE and SW quadrants.
   - if 2V is small, isogyres stay in field of view
   - if 2V is large, isogyres leave field of view
3. Insert accessory plate, with slow vibration direction oriented NE-SW; observe colour change or movement direction of isochromes.

Determining the Optic Sign

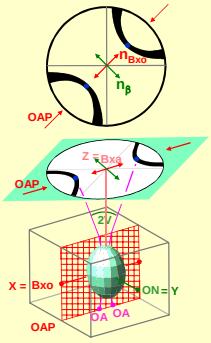
Steps (continued)

4) Interpretation

- If the interference colours between the **Melatopes** decreases, the ray vibrating parallel to **Bxo** (parallel to **OAP**) must be the fast ray so **Bxo** = **X** axis (**X** = fast ray) and **Bxa**, which is vertical, must be the **Z** axis. **Mineral is +ve**.
- If the interference colours between the **Melatopes** **increases**, the ray vibrating parallel to **Bxo** must be the slow ray, so **Bxo** = **Z** axis, and **Bxa** = **X** axis. **Mineral is -ve**.

NOTE: If the OAP is placed NW-SE, the areas of addition and subtraction observed for the interference colours will be reversed.

Determining the Optic Sign



For an Optically Positive Mineral

Bxa = Z axis

Bxo = X axis

ON = Y Axis

Therefore $n_{Bxo} = n_\alpha$ and must be the Fast Ray

Determining the Optic Sign

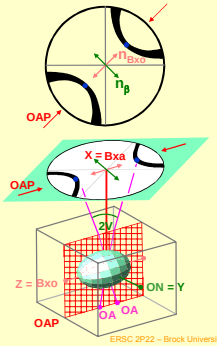
For an Optically Negative Mineral

Bxa = X axis

Bxo = Z axis

ON = Y Axis

Therefore $n_{Bxo} = n_\gamma$ and must be the Slow Ray

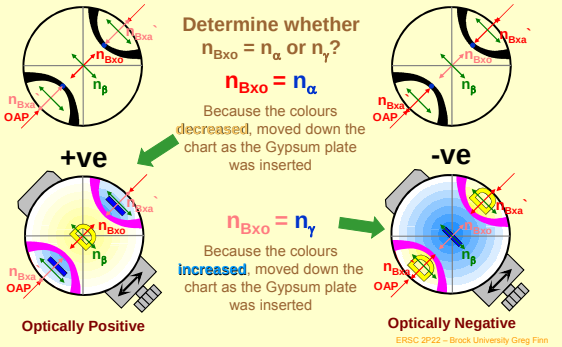


Determining the Optic Sign

- How do we determine whether the ray which vibrates parallel to the **OAP** in the biaxial interference figure and has an index of refraction = n_{Bxo} is the **Fast** or **Slow** ray?
- ie. whether:
  - $n_{Bxo} = n_{\alpha}$, or
  - $n_{Bxo} = n_{\gamma}$

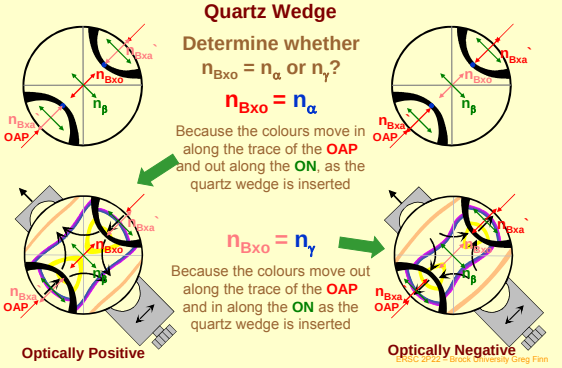
Determining the Optic Sign

Gypsum Plate



Determining the Optic Sign

Quartz Wedge



Determining the Optic Sign

Which accessory plate to use?

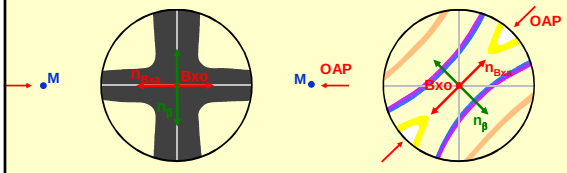
- If the interference figure displays few to no isochromes use the gypsum plate
  - Look for increases or decreases in colours by 550 nm
- If there are numerous isochromes use the quartz wedge and watch the directions in which the isochromes move with respect to the isogyres.
  - Where colours increase, the isochromes move into the figure towards the melatopes, to be replaced by higher order colours from the edge of the figure.
  - Where the colours decrease the isochromes move out of the figure away from the melatopes, to be replaced by lower order colours.

Determining the Optic Sign

Obtuse Bisectrix Figure

- The **Bxo figure** can be interpreted in the same way as the **Bxa figure** except that the trace of the **OAP** has an index of refraction equal to n_{Bxa} rather than n_{Bxo}
- If the ray vibrating ‖ to optic plane is the fast ray then the **Bxa** is the **X** axis
  Mineral is -ve
- If the ray vibrating ‖ to optic plane, is the slow ray, then the **Bxa** is **Z** axis.
  Mineral is +ve
- Optic plane lies in the quadrants of FOV into which the isogyres move and leave the FOV on rotation
- If 2V is large, it is difficult to distinguish **Bxa** from **Bxo** figure, sign determination is impractical and new grain should be selected

Obtuse Bisectrix (Bxo) Figure



For a **Bxo figure**, two rays of light propagate along the obtuse bisectrix, and emerge in the centre of the figure

With a 45° rotation, the cross splits and leaves the FOV. The arms of the **Isogyre** lie well outside the FOV and the pattern of the **Isochromes**, if present will be visible

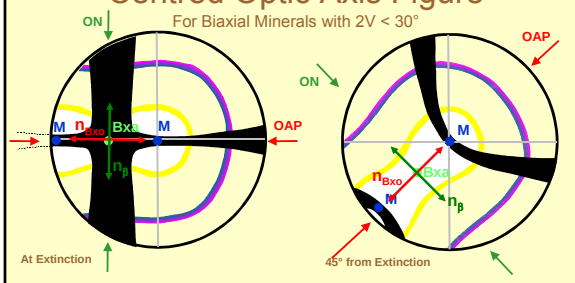
Determine whether:

$n_{Bxa} = n_\alpha$ Fast Ray
➔Optically negative

$n_{Bxa} = n_\gamma$ **Slow Ray**
➔Optically positive

Centred Optic Axis Figure

For Biaxial Minerals with 2V < 30°

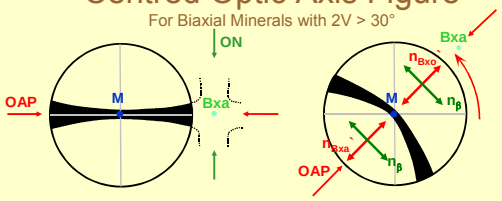


If both melatopes lie in the field of view, the optic axis figure can be treated as an off centered acute bisectrix figure.

With a rotation of 45°, the **Isogyre** splits into two hyperbolae, centred on the **Melatopes**. The Isochromes are rotated, yet retain their tear-drop/Figure '8' shape

Centred Optic Axis Figure

For Biaxial Minerals with 2V > 30°



If one melatope is visible, then it can be considered to be half of **Bxa** figure.

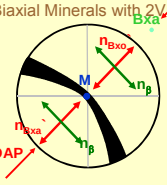
With a 45° rotation, the acute bisectrix lies on the convex side of the isogyre, outside the FOV

Isogyre will be curved, with the degree of curvature reflecting the 2V angle

Centred Optic Axis Figure

For Biaxial Minerals with 2V < 30°

The OAP is parallel to the slow ray direction of the Gypsum Plate. The Convex side of the Isogyre points toward the Bxa.

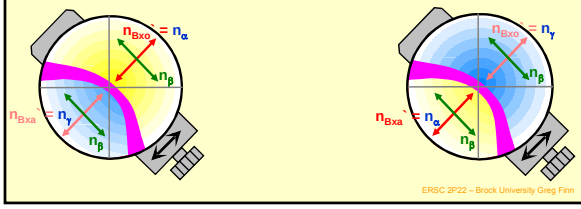


Optically Positive

Interference colours ~~decrease~~ on the convex side of the **Isogyre**

Optically Negative

Interference colours **Increase** on the convex side of the **Isogyre**



Determining the Optic Sign

Optic Axis Figure

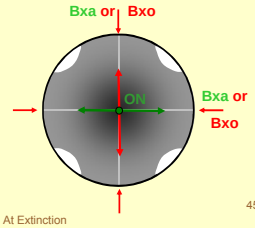
- If 2V = 90°, degree of curvature cannot be determined. The isogyre appears as a straight line parallel to the crosshair when the grain is at extinction. It may be confused with an off-centred uniaxial optic axis figure, however when the stage is rotated the biaxial figure will also rotate while the uniaxial figure will move parallel to the crosshairs.
- With 2V = 90° the mineral is optically neutral and the sign is neither + or -

Determining the Optic Sign

Flash Figure

- Not useful for determining optic sign, because 2V cannot be determined and it cannot be distinguished from a uniaxial flash figure.

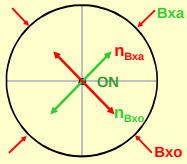
Optic Normal Figure



At Extinction

On rotating the Flash Figure, the isogyre cross splits and leaves the FOV with a rotation of <10°.

The isogyre arms leave the FOV in the quadrants into which the **Bxa** is being rotated.



45° from Extinction

In the 45° position the **Bxa** is oriented NE-SW.

Can now test to see whether the **Bxa** is: the **fast ray** (**X** axis, n_α), or

the slow ray (**Z** axis, n_γ)

Which Grains are Suitable to Produce Interference Figures

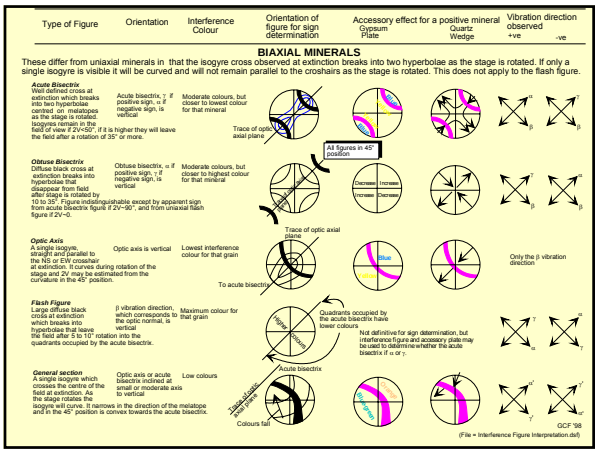
- As with uniaxial minerals, optic axis figures are easiest to identify because of their **low interference colours** due to the optic axis being vertical
- If birefringence for the mineral is low, grains with **OA** vertical will remain extinct with rotation of the stage
- Optic axis figures are used for most routine work because these orientations produce interference figures where the optic sign and 2V can be determined

Which Grains are Suitable to Produce Interference Figures

- Optic Normal Figures (flash figures) have the **Y** indicatrix axis vertical and **X** and **Z** axes horizontal
- Birefringence in this orientation is at a maximum ($n_\gamma - n_\alpha$), and this orientation displays the **highest interference colour** for that mineral
- Not useful for determining 2V or sign.

Which Grains are Suitable to Produce Interference Figures

- The identification of grains which will produce a **Bxa figure** is a matter of trial and error. Many grains and their interference figures must be examined before one with a nearly vertical **Bxa** is obtained
- The interference colour for this section will be in the lower range of that displayed for the mineral in the sample
  - Reason: birefringence for this orientation must be less than $(n_\gamma - n_\alpha)/2$
- Time consuming to search for suitable grain to give **Bxa figure**, but it is essential because these figures give a better estimate of 2V than optic axis figures
- **Bxo figures** in mineral grains is again trial and error procedure. Birefringence is higher than Bxa figure but less than optic normal section, so interference colour will be upper portion for that mineral


Type of Figure
Orientation
Interference Colour
Orientation of figure for sign determination
Accessory effect for a positive mineral
Gypsum Plate
Quartz Wedge
Vibration direction observed
+ve
-ve
BIAXIAL MINERALS
These differ from uniaxial minerals in that the isogyre cross observed at extinction breaks into two hyperbolae as the stage is rotated. If only a single isogyre is visible it will be curved and will not remain parallel to the croshairs as the stage is rotated. This does not apply to the flash figure.
Acute Bisectrix
Well defined cross at extinction which breaks into two hyperbolae centred on melatopes as the stage is rotated. Isogyres remain in the field of view if 2V<50°, if it is higher they will leave the field after a rotation of 35° or more.
Acute bisectrix, γ if positive sign, α if negative sign, is vertical
Moderate colours, but closer to lowest colour for that mineral
Trace of optic axial plane
All figures in 45° position
Obtuse Bisectrix
Diffuse black cross at extinction breaks into hyperbolae that disappear from field after stage is rotated by 10 to 35°. Figure indistinguishable except by apparent sign from acute bisectrix figure if 2V~90°, and from uniaxial flash figure if 2V~0.
Obtuse bisectrix, α if positive sign, γ if negative sign, is vertical
Moderate colours, but closer to highest colour for that mineral
Trace of optic axial plane
Optic Axis
A single isogyre, straight and parallel to the NS or EW crosshair at extinction. It curves during rotation of the stage and 2V may be estimated from the curvature in the 45° position.
Optic axis is vertical
Lowest interference colour for that grain
To acute bisectrix
Only the β vibration direction
Flash Figure
Large diffuse black cross at extinction which breaks into hyperbolae that leave the field after 5 to 10° rotation into the quadrants occupied by the acute bisectrix.
β vibration direction, which corresponds to the optic normal, is vertical
Maximum colour for that grain
Quadrants occupied by the acute bisectrix have lower colours
Not definitive for sign determination, but interference figure and accessory plate may be used to determine whether the acute bisectrix if α or γ.
Acute bisectrix
General section
A single isogyre which crosses at centre of the cross at all times. As the stage rotates the isogyre will curve. It narrows in the direction of the melatope and in the 45° position is convex towards the acute bisectrix.
Optic axis or acute bisectrix inclined at small or moderate axis to vertical
Low colours
Trace of optic axial plane
Colours fall
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