UNIAXIAL INDICATRIX

- The indicatrix is a geometric figure, constructed so that the indices of refraction are plotted as radii that are parallel to the vibration direction of light.
- In isotropic minerals the indicatrix was a sphere, because the refractive index was the same in all directions.
- In uniaxial minerals, because n omega and n epsilon are not equal, the indicatrix is an ellipsoid, the shape of which is dependant on its orientation with respect to the optic axis.

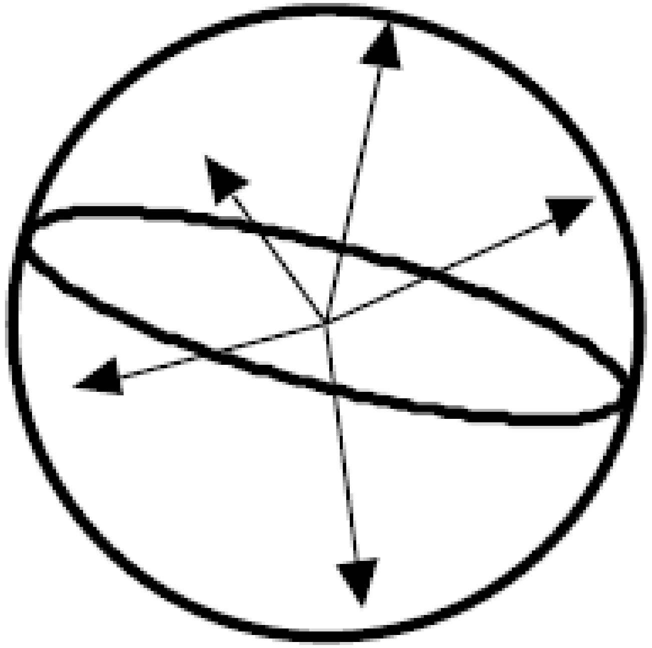
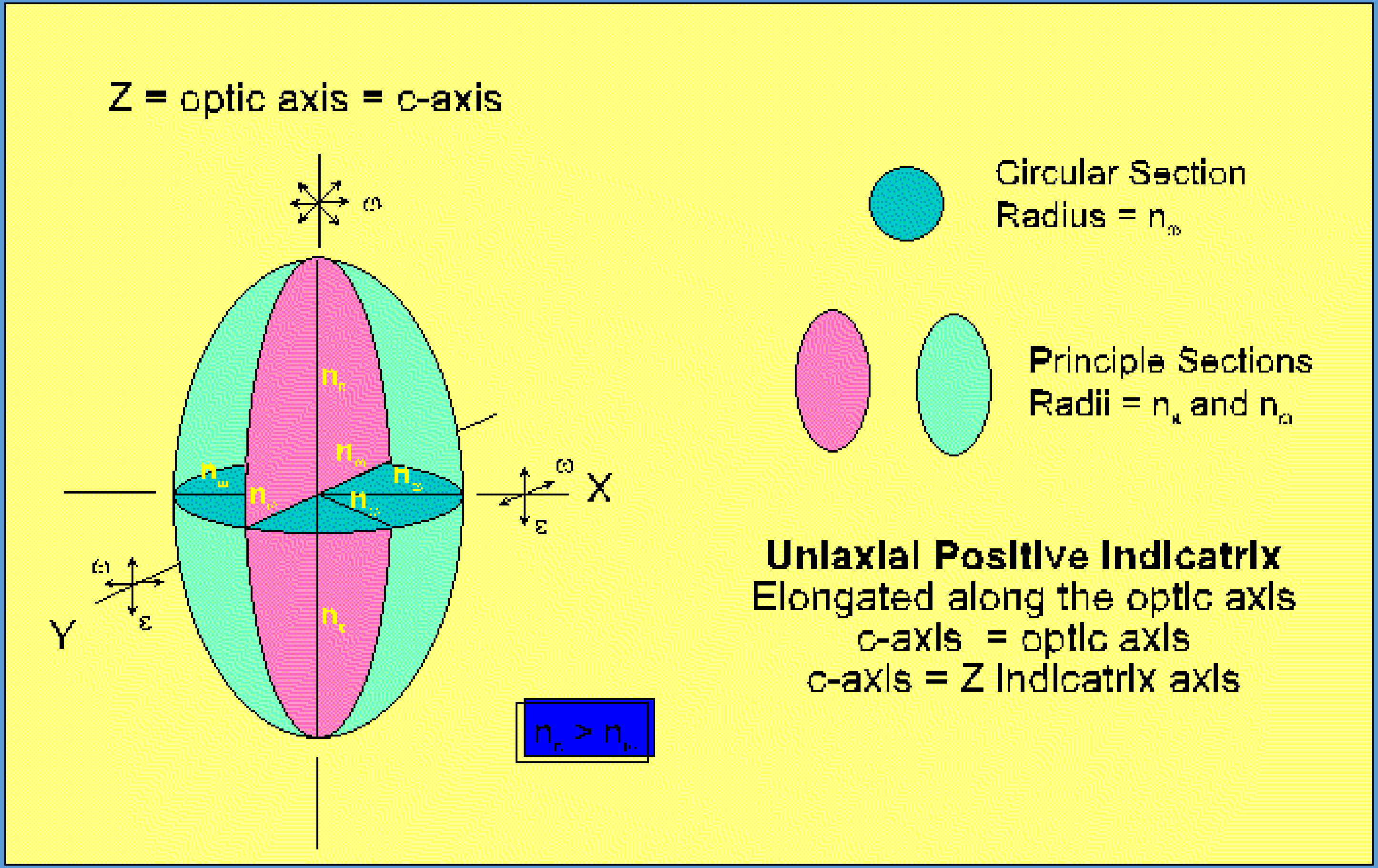
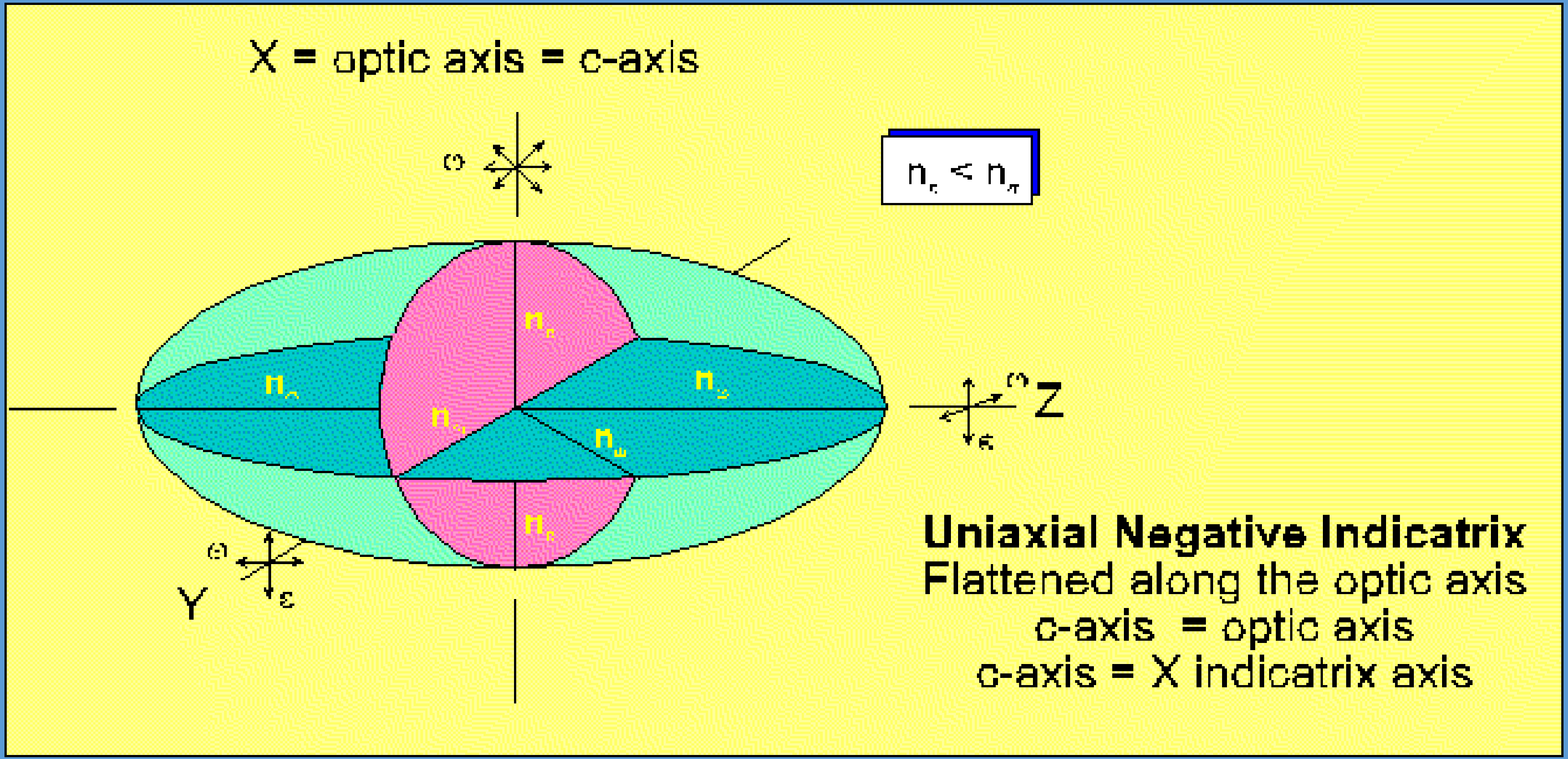


Figure 5. Optical indicatrix for isotropic minerals. A series of vectors, whose length is proportional to n, is constructed from a common origin. The surface the tips of these vectors describe, in this case a sphere, is the optical indicatrix.

In positive uniaxial minerals, the Z indicatrix axis is parallel to the c-crystallographic axis and the indicatrix is a prolate ellipsoid, i.e. it is stretched out along the optic axis.



For optically negative minerals the X indicatrix axis corresponds to the optic axis and the indicatrix is an oblate ellipsoid, i.e. flattened along the optic axis, and n omega > n epsilon



- In each case, for positive and negative minerals the circular section through the indicatrix is perpendicular to the optic axis and has a radius = nomega.

- The radius of the indicatrix along the optic axis is always nepsilon.

- Any section through the indicatrix which includes the optic axis is called a principal section, and produces an ellipse with axes nomega and nepsilon.

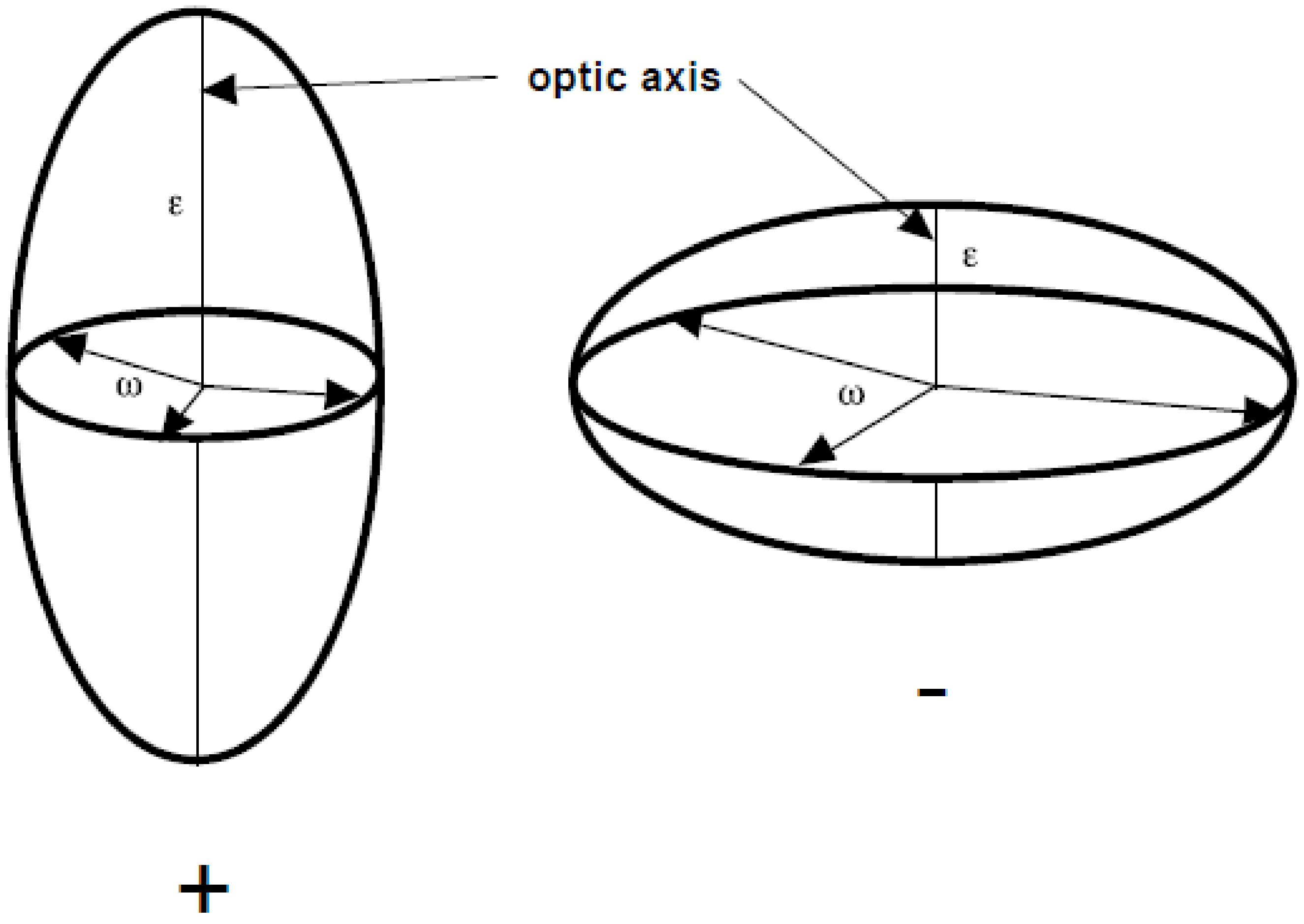
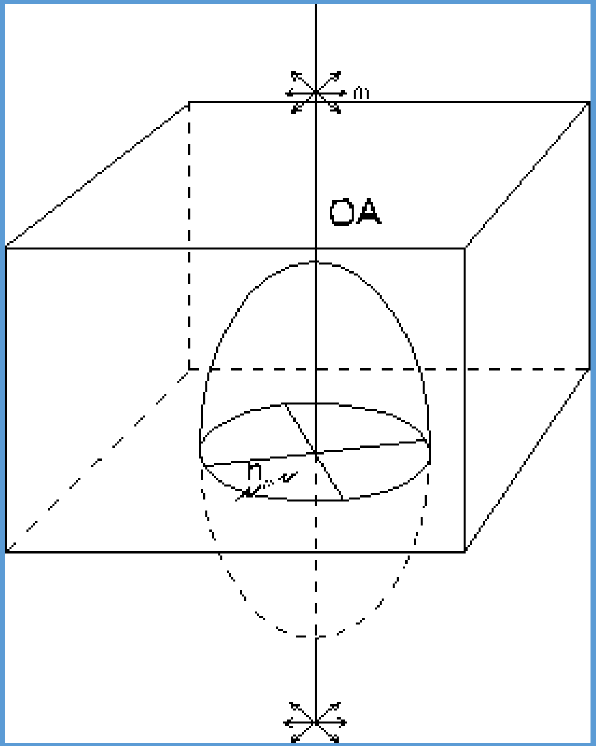


Figure 6. Optical indicatrix for uniaxial minerals. When ε > ω the mineral is positive; when ε < ω it is negative. These indicatrices were formed in a similar manner to the isotopic indicatrix. However, because the refractive indices differ, depending upon the vibration direction, they are no longer spheres.

BIREFRINGENCE AND INTERFERENCE COLOURS

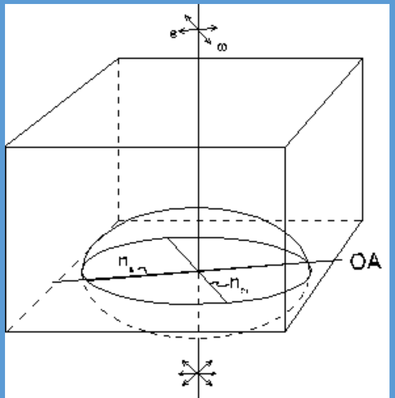
- Birefringence, difference between the index of refraction of the slow and fast rays and the interference colours for uniaxial minerals is dependant on the direction that light travels through the mineral.



1- In a sample which has been cut perpendicular to the optic axis, the bottom and top surfaces will be parallel.

The angle of incidence for the light entering the crystal = 0° and the wave front are not refracted at the interface and remain parallel to the mineral surface.

- A cut through the indicatrix, parallel to the bottom of the mineral, will yield the indices and vibration directions of the light. A slice through the indicatrix is a circular section, with radius nomega.
- No preferred vibration direction, so light passes along the optic axis as an ordinary ray and retains whatever vibration direction it had originally.
- Between crossed polars the light passing through the mineral is completely absorbed by the upper polar and will remain black on rotation of the stage, The birefringence = 0.



2- Cutting the sample such that the optic axis is parallel to the surface of the section the following is observed.

The indicatrix section is a principle section, as it contains the optic axis. The indicatrix forms an ellipse with axes = n omega and n epsilon, with the incident light being split into two rays such that:

- the ordinary ray vibrates perpendicular to the optic axis,
- the extraordinary ray vibrates parallel to the optic axis.

The birefringence is at a maximum, and in thin section this grain orientation will display the highest interference colour.

3- A mineral cut in a random orientation, with normally incident light;

- The ordinary ray produced has an index, nomega and vibrates perpendicular to the optic axis.
- The extraordinary ray has an index nepsilon' and vibrates in the plane containing the optic axis.
- nepsilon' < nomega maximum or minimum, the birefringence is intermediate between the two extremes.

EXTINCTION IN UNIAXIAL MINERALS

- Uniaxial minerals will exhibit all four types of extinction discussed earlier.

- The type is dependent on:
- the orientation that the mineral is cut
- the presence of cleavage(s) in the grain

PLEOCHROISM IN UNIAXIAL MINERALS

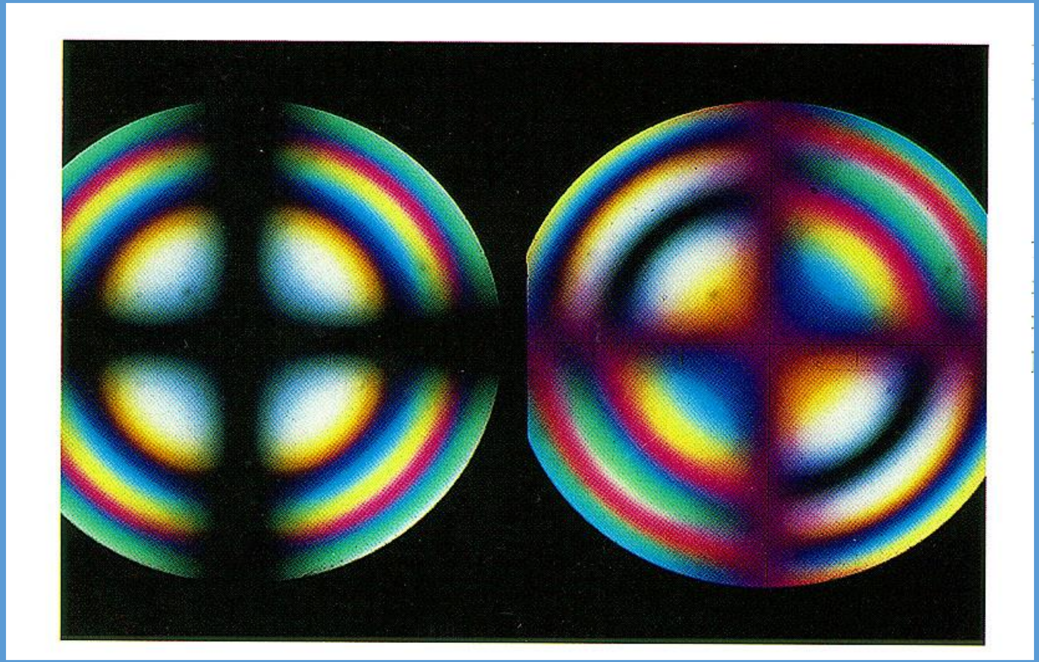
- Pleochroism is defined as the change in colour of a mineral, in plane light, on rotating the stage. It occurs when the wavelengths of the ordinary & extraordinary rays are absorbed differently on passing through a mineral, resulting in different wavelengths of light passing the mineral.

- If the colour change is quite distinct the pleochroism is said to be strong.
- If the colour change is minor = weak pleochroism.
- For coloured uniaxial minerals, sections cut perpendicular to the c axis will show a single colour, corresponding to ordinary ray.
- Sections parallel to the c crystallographic axis will exhibit the widest colour variation as both omega and epsilon are present.

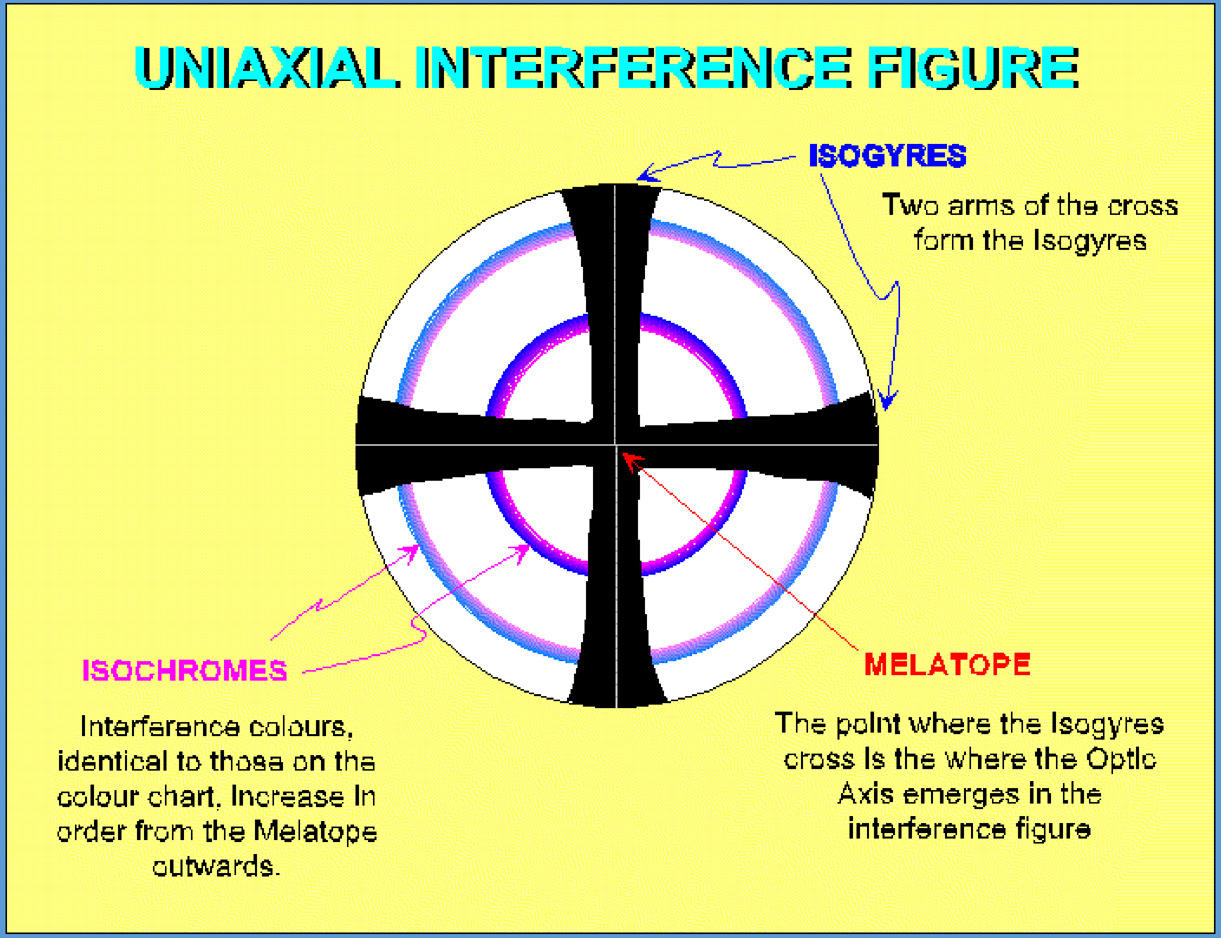
OBTAINING AN INTERFERENCE FIGURE

- To obtain and observe an interference figure using the microscope.
- With high power, focus on a mineral grain free of cracks and inclusions
- Flip in the auxiliary condensor and refocus open aperture diaphragm up to its maximum.
- Cross the polars
- Insert the Bertrand lens or remove the ocular and look down the microscope tube.

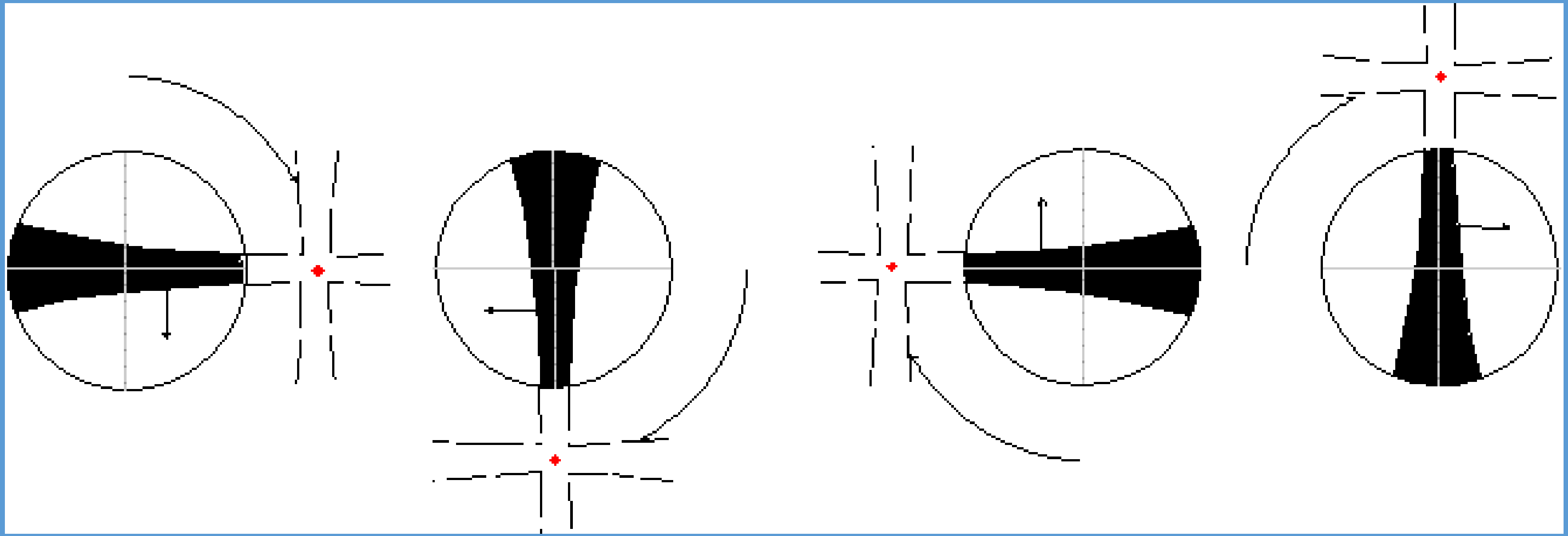
- Will not see the grain, but the interference figure, which appears on the top surface of the objective lense.
- The interference figure consists of a pattern of interference colours and a black band which may form a cross. Nature and pattern for the figure is dependent on the orientation of the grain.



- If the optic axis of the mineral is vertical, the grain will exhibit 0 birefringence and remain black or nearly black upon rotating the stage.



- **OFF CENTRED OPTIC AXIS FIGURE**
- **The interference figure is produced when the optic axis is not vertical, resulting in the interference figure, i.e. the melatope, no longer being centred in the field of view.**

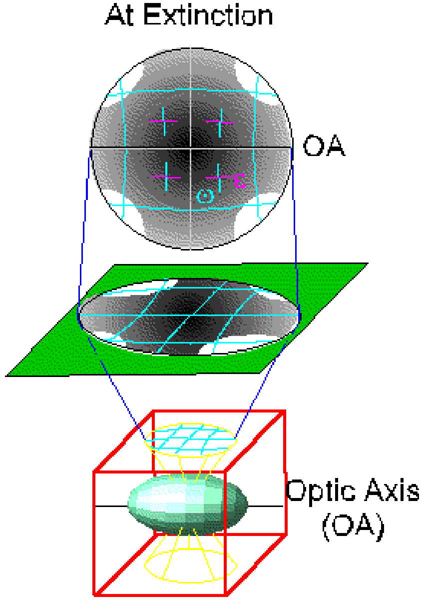


FLASH INTERFERANCE FIGURE

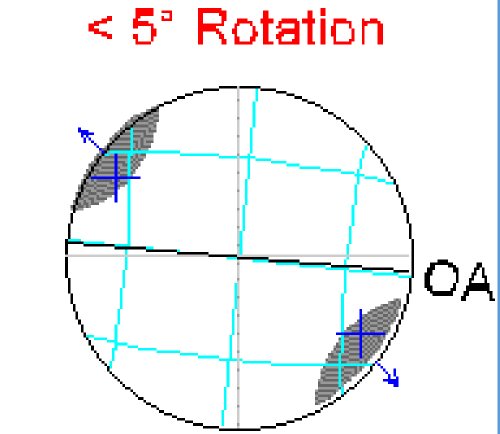
- A mineral grain is oriented with it's optic axis horizontal. This orientation exhibits the maximum birefringence, for this mineral in the thin section, and produces a flash figure. The flash figure results because the vibration directions, of the indicatrix, within the field of view are nearly parallel to polarisation directions of the microscope.

- extraordinary rays vibrate parallel to optic axis
- ordinary rays vibrate perpendicular to optic axis

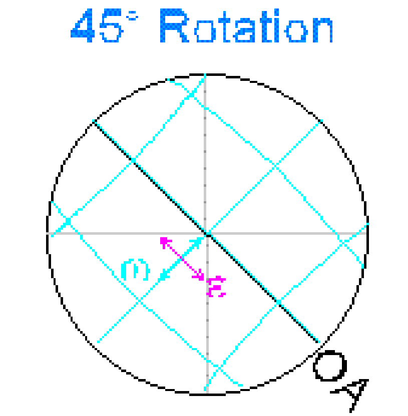
- The c axis is parallel to stage.
  The isogyres split and leave field of view rapidly with only a slight rotation, <10°.
  The maximum interference colour will be observed under crossed polars.



The mineral is oriented with the Optic Axis horizontal, in this case E-W. In this orientation the mineral exhibits its maximum birefringence and highest interference colour. The resulting isogyre is a broad fuzzy cross which nearly fills the field of view because the vibration directions in all but the outer parts of the four quadrants are essentially parallel to the vibration directions of the polars.



With a minor clockwise rotation, the isogyre cross splits and rapidly leave the field of view in the quadrants into which the Optic Axis (OA) is being



With a rotation of 45° the isogyres lie well outside the field of view and the OA is oriented NW-SE. If you rotate in the opposite direction the OA will lie NE-SW.

- **BIAXIAL MINERALS**
- Include orthorhombic, monoclinic and triclinic systems, all exhibit less symmetry than uniaxial and isotropic minerals.
- It is also necessary to specify 3 different indices of refraction for biaxial minerals:
- N alpha, n beta, n gamma are used in text.
- where n alpha < n beta < n gamma
- The maximum birefringence of a biaxial mineral is defined by (ngamma - nalpha)

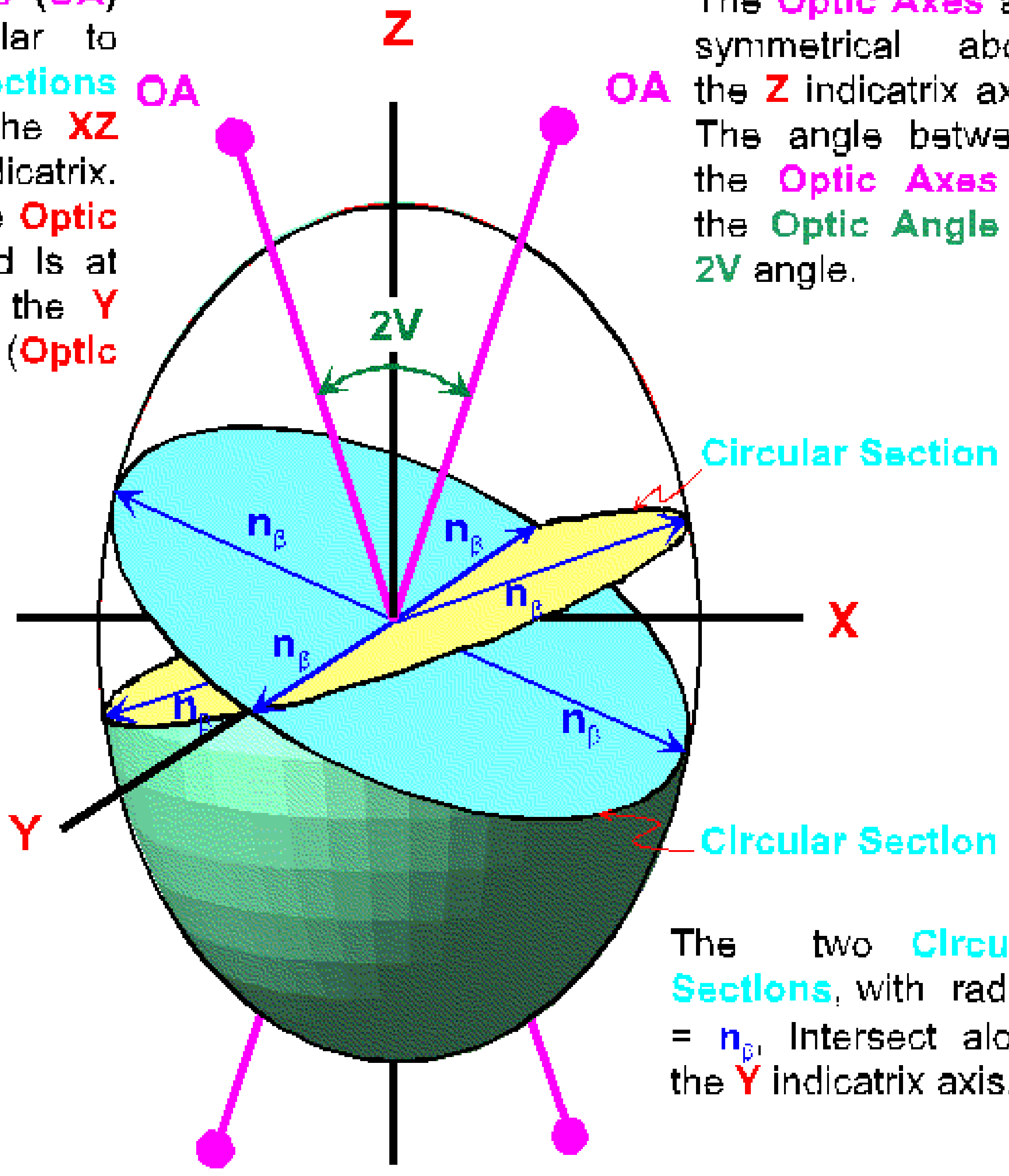
- It takes 3 indices of refraction to describe optical properties of biaxial minerals, however, light that enters biaxial minerals is broken into two rays - **FAST** and **SLOW**.

- The rays are both extraordinary and are referred to as **SLOW RAY** and **FAST RAY**.

  - **N slow** = n gamma' , between n beta and n gamma (**higher RI**)
    - N gamma > n gamma' > n beta

  - **N fast** = n alpha' , between nalpha and n beta (**lower RI**)
    - N alpha < n alpha' < n beta

The **Optic Axes** (**OA**) are perpendicular to the **Circular Sections** and lie within the **XZ** plane of the indicatrix. This plane is the **Optic Axial Plane** and is at right angles to the **Y** indicatrix axis (**Optic Normal**).



The **Optic Axes** are symmetrical about the **Z** indicatrix axis. The angle between the **Optic Axes** is the **Optic Angle** or **2V** angle.

The two **Circular Sections**, with radius = n_β, intersect along the **Y** indicatrix axis.