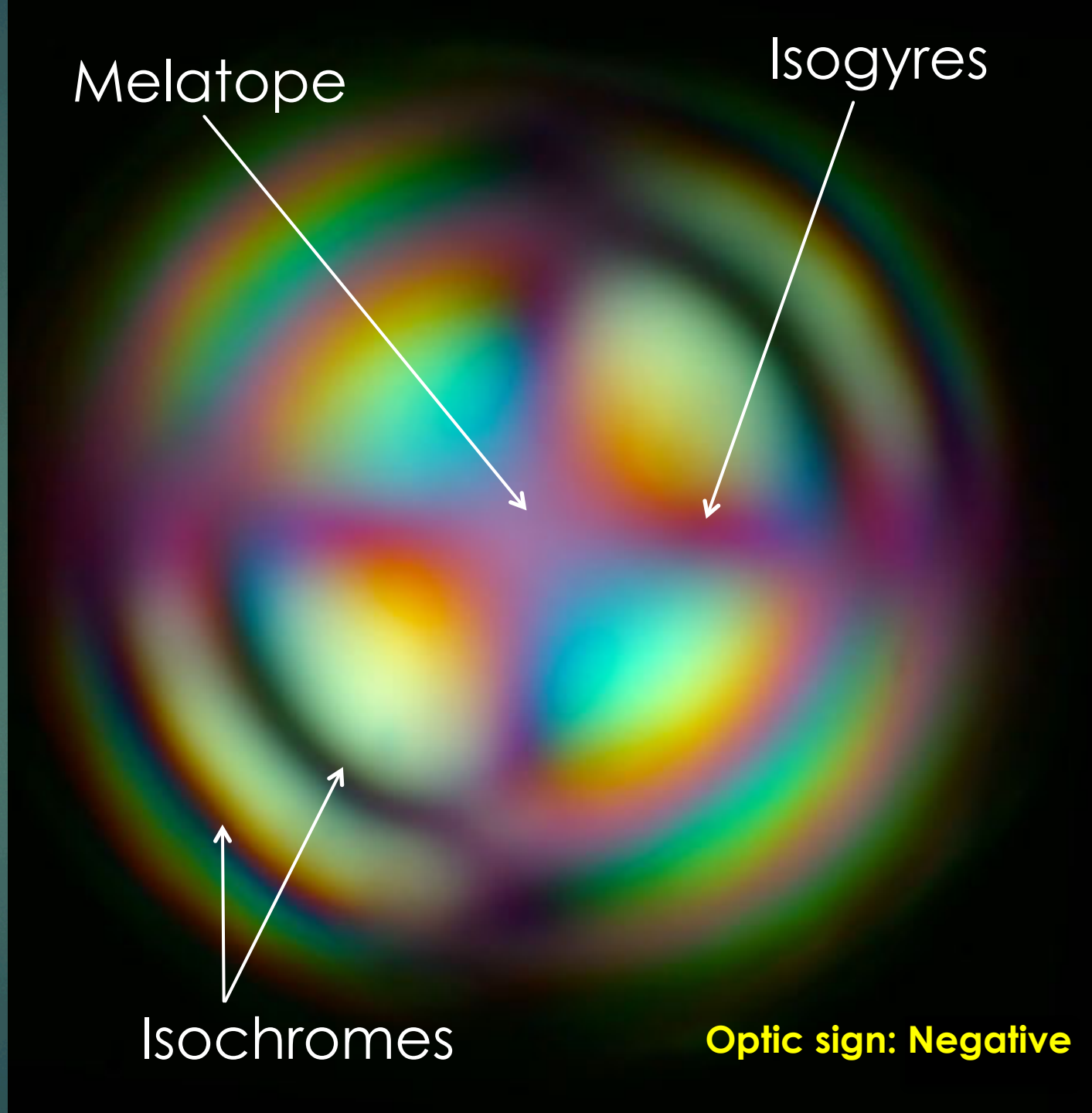
Chapter 4: Optics of Uniaxial minerals

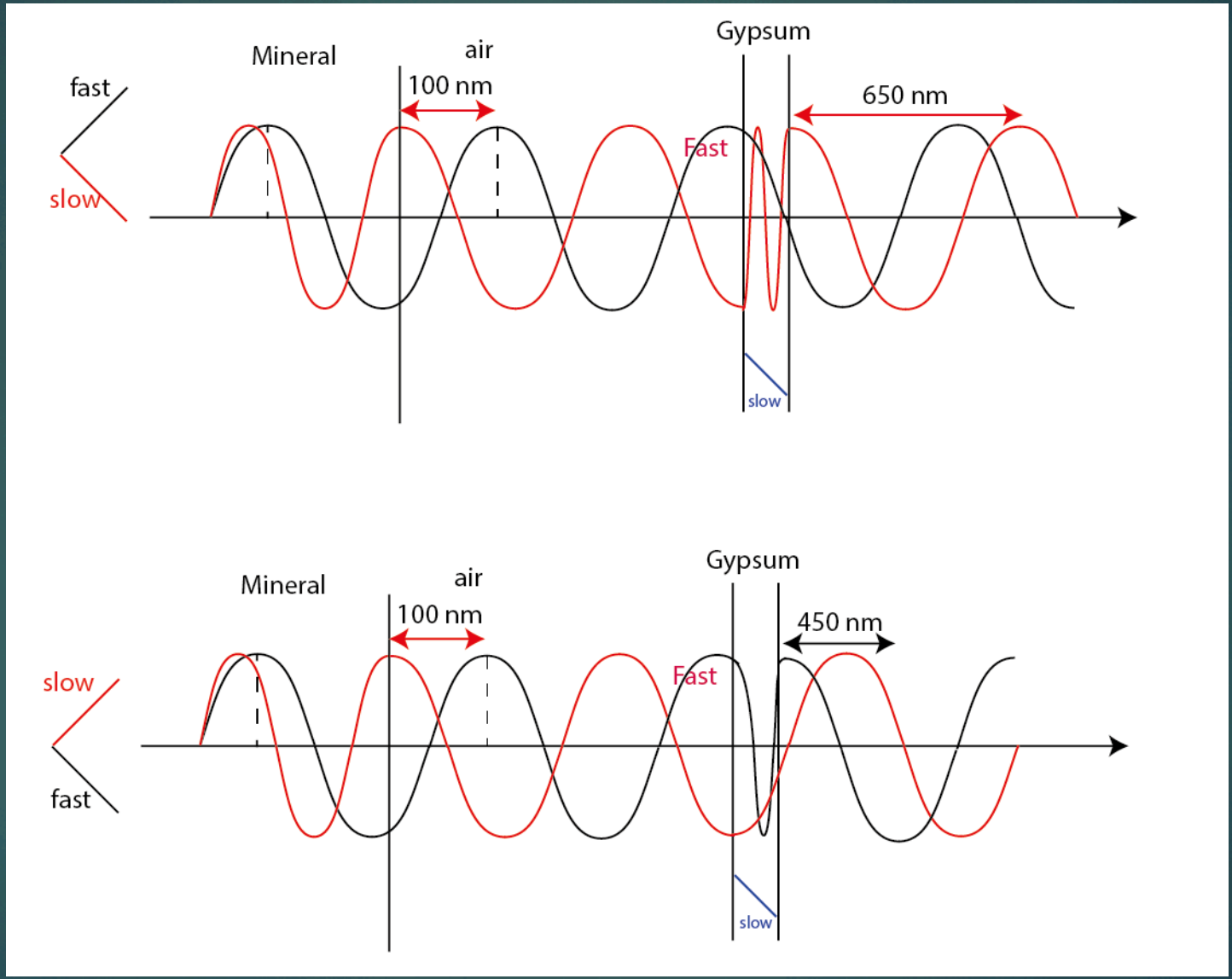
SARAH LAMBART



Recap chapter 3

- **Optics of anisotropic minerals**
  - **Interference phenomena**
    - **Retardation** $\Delta = d * (n_s - n_f)$
    - **Birefringence** $\delta = n_s - n_f$
  - **Birefringence color** (use of the birefringence plate)
  - **Extinction: every 90°**
    - Extinction angle
    - Parallel, inclined, symmetrical, no angle
  - **Accessory plates :** induce a retardation
  - **Sign of elongation**: addition (along the slow ray) or subtraction (along the fast ray)

ACCESSORY PLATES



* Not to scale

ACCESSORY PLATES

- **Sign of elongation**
- Length slow: the slow ray vibrates more or less parallel to the length of elongation (or cleavage) = positive elongation.
- Length fast: the fast ray vibrates more or less parallel to the length of elongation (or cleavage) = negative elongation.

ACCESSORY PLATES

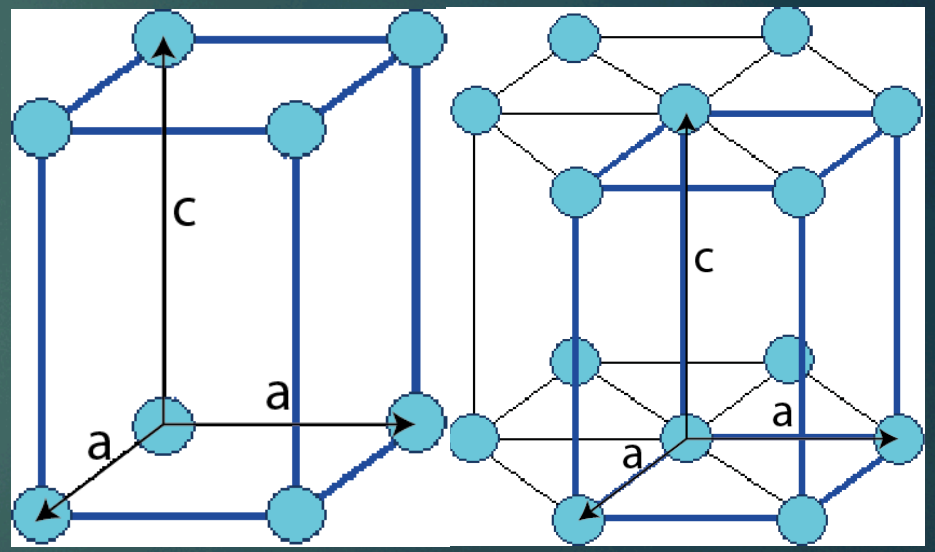
- **Sign of elongation**
- In practice
  - 1) if the direction in which the degree of the interference color increases when we the gypsum plate is inserted, is more or less parallel to the direction of elongation or cleavage: **positive elongation**
  - 2) If the direction in Δ decreases when we the gypsum plate is inserted, is more or less parallel to the direction of elongation or cleavage: **negative elongation**

Content Chapter 4

- **Optics of Uniaxial minerals**
  - **Uniaxial mineral: definition**
  - **Optical indicatrix: definition**
    - Uniaxial indicatrix
    - Use of uniaxial indicatrix
  - **Conoscope light**
  - **Determination of the optic sign**
  - **Extinction angle and sign of elongation**
  - **Pleochroism**

UNIAXIAL MINERALS

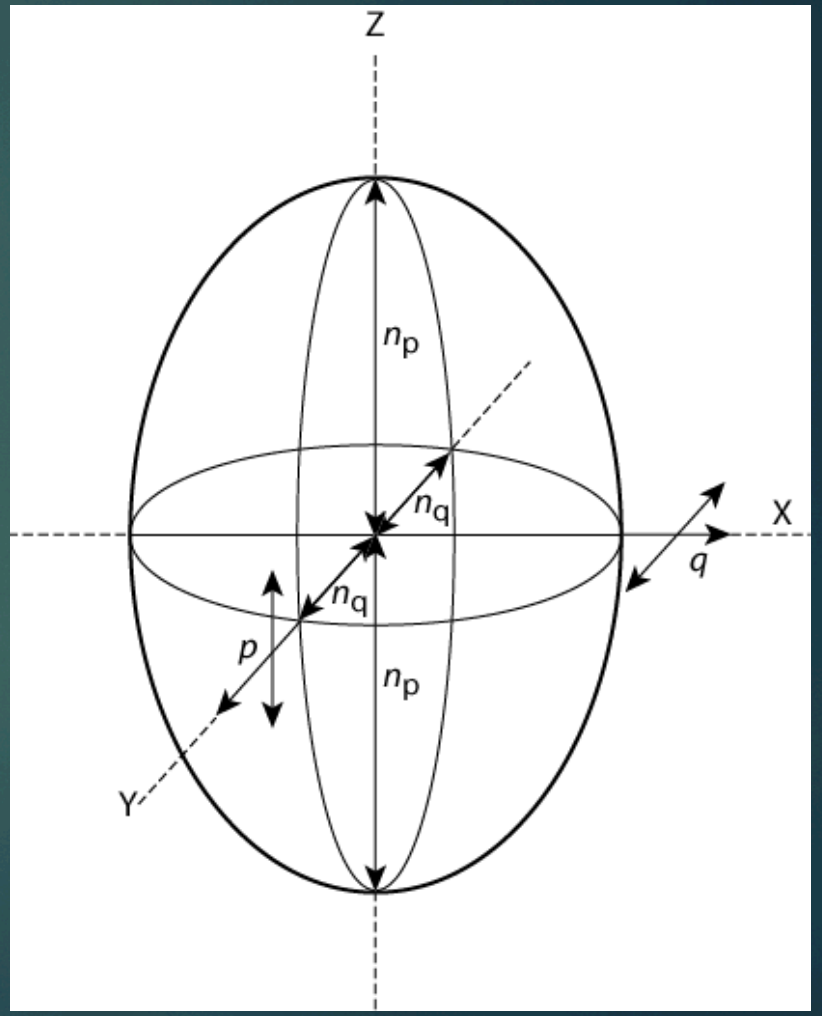
- **Uniaxial minerals:** anisotropic minerals that crystallized in the hexagonal and the tetragonal systems. They are called uniaxial because they have **a single optic axis** ⇔ c-crystallographic axis.



- **Refractive index**: ε ' - between *ω* and ε

OPTICAL INDICATRIX

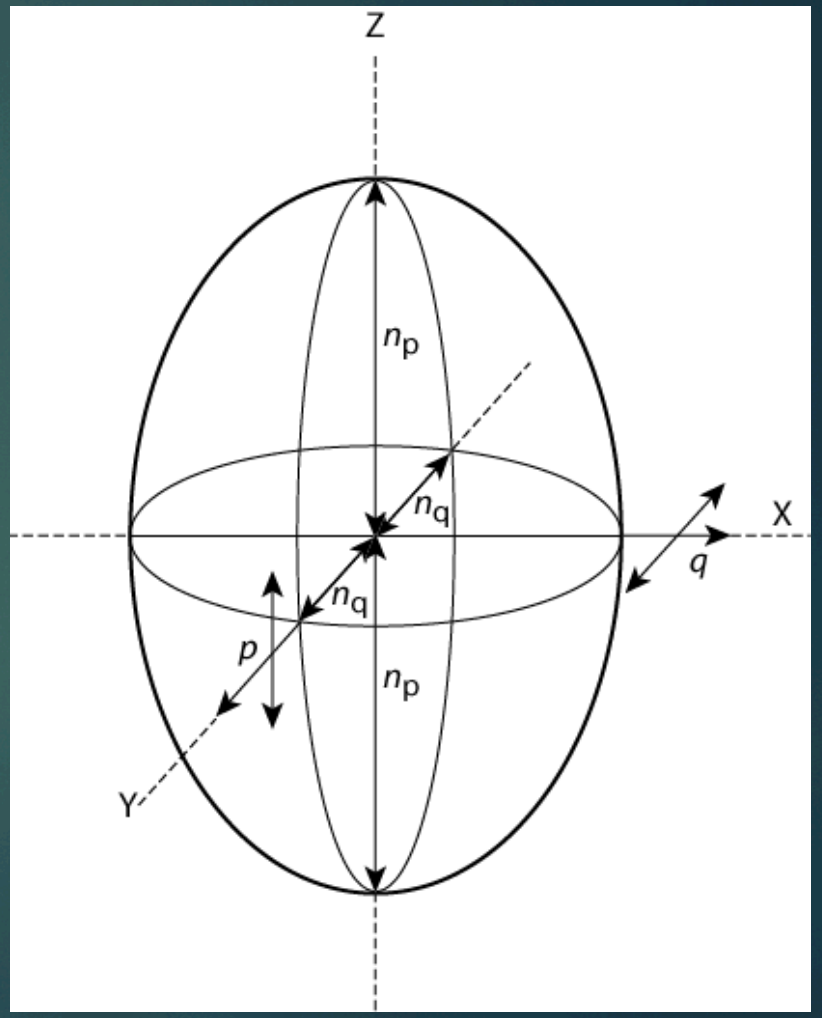
- **Optical indicatrix:** 3D representation (ellipsoidal) of the variations of the refractive index in a substance. Each vector defining the ellipsoidal is proportional to n in the same direction.



OPTICAL INDICATRIX

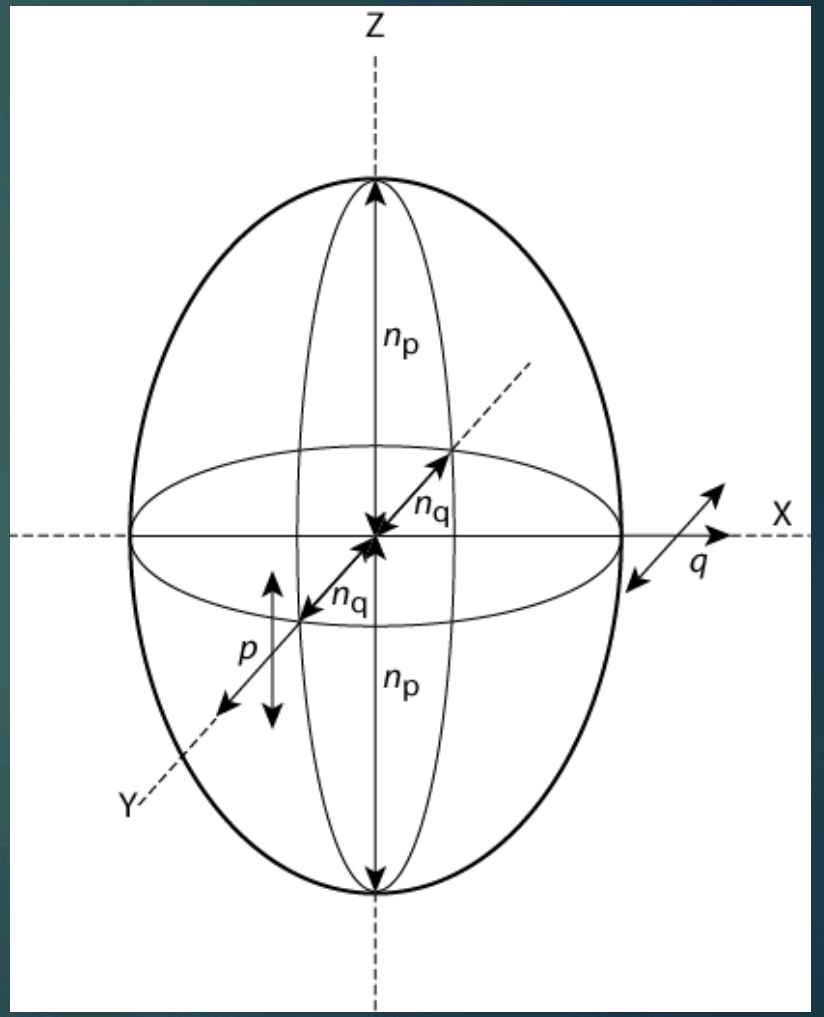
- **Optical indicatrix:** 3D representation (ellipsoidal) of the variations of the refractive index in a substance. Each vector defining the ellipsoidal is proportional to n in the same direction.

- **Notation:** Ray p, propagating along Y, vibrates parallel to the Z-axis so its index of refraction (n_p) is plotted as radii along Z.



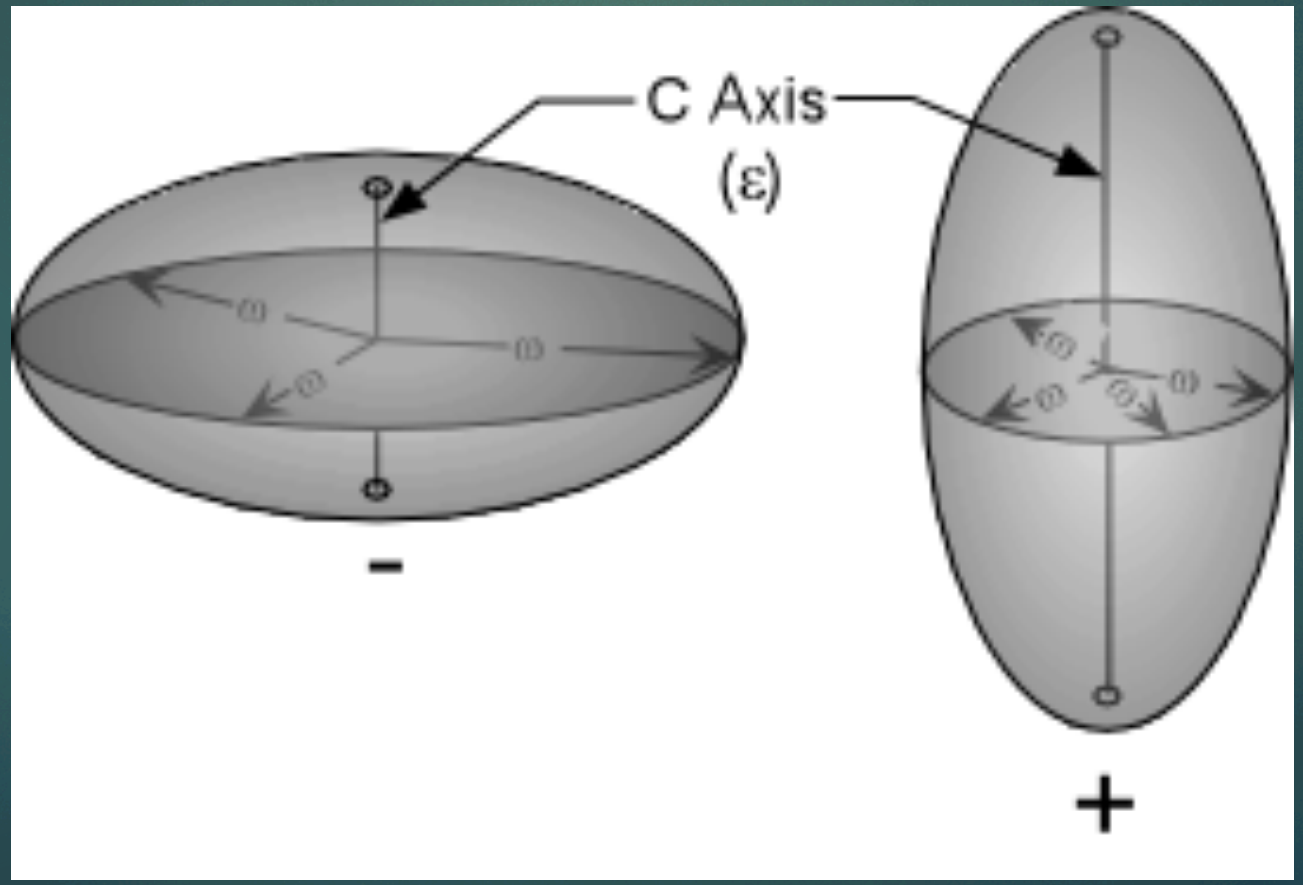
OPTICAL INDICATRIX

- **Notation:**
  - Ray p, propagating along Y, vibrates parallel to the Z-axis so its index of refraction (n_p) is plotted as radii along Z.
  - Ray q, propagating along X, vibrates parallel to the Y-axis so its index of refraction (n_q) is plotted as radii along Y.
- **Shape depends on the crystal symmetries**



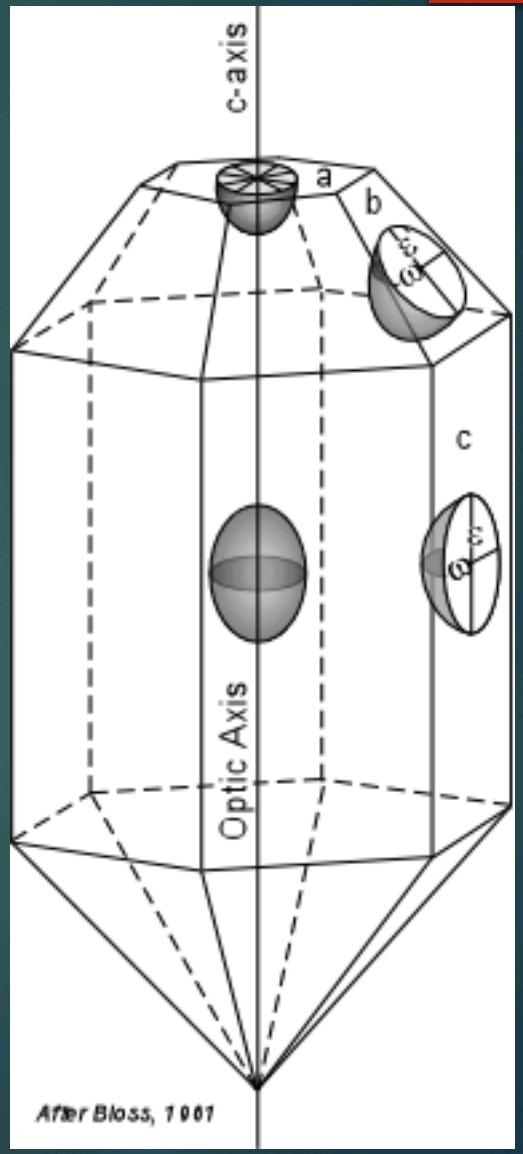
UNIAXIAL INDICATRIX

- **Optic sign**
- If $\omega > \varepsilon$, the optic sign is **negative**
- If $\varepsilon > \omega$, the optic sign is **positive**



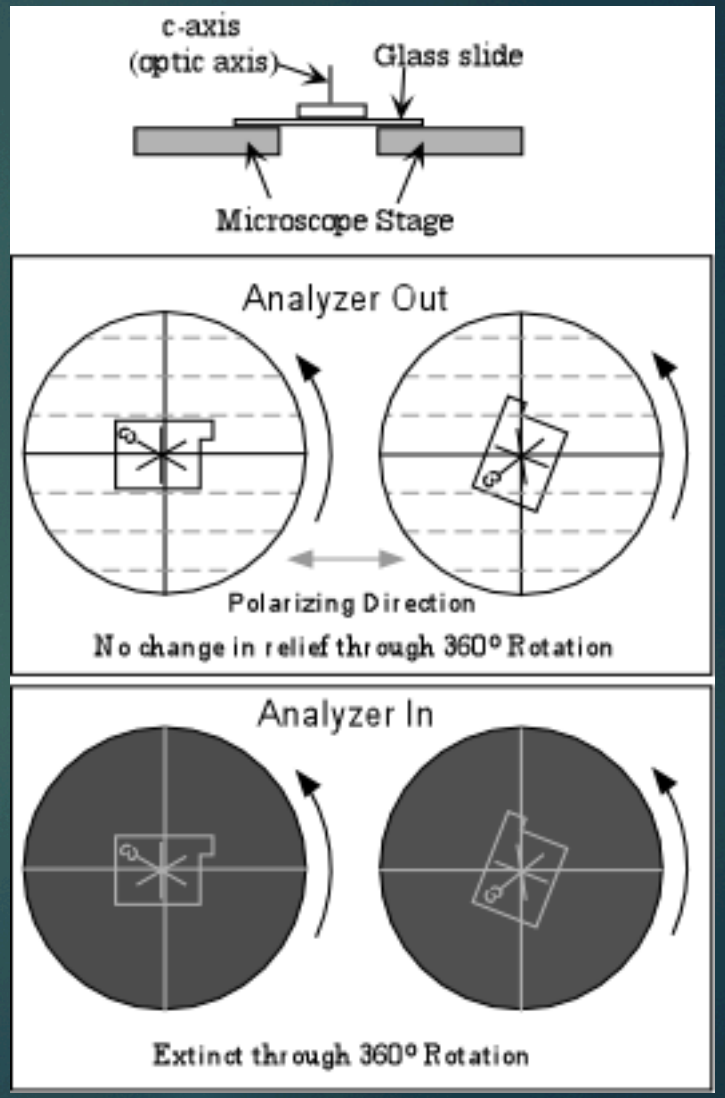
UNIAXIAL INDICATRIX

- **Application**
- Ex.: Tetragonal crystal with positive optic sign
  - Optical axis perpendicular to the stage: circular section of the indicatrix with a radius ω
  - Optical axis parallel to the stage: oval section with radii ω and ε
  - Random orientation: oval section with radii ω and ε '



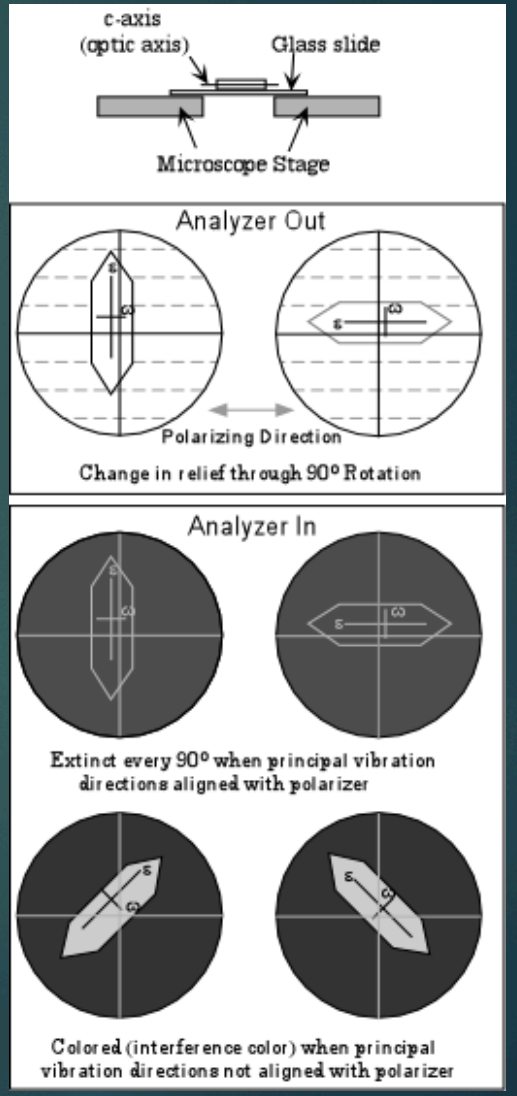
UNIAXIAL INDICATRIX

- **Application:** Ex.: Tetragonal crystal with positive optic sign
  - **Circular section**: the crystal behaves as an isotropic mineral:
    - Transmitted light:
      - No change of relief with the rotation of the stage
      - refractory method ⇒ ω
    - Analyzed light: mineral is extinct.



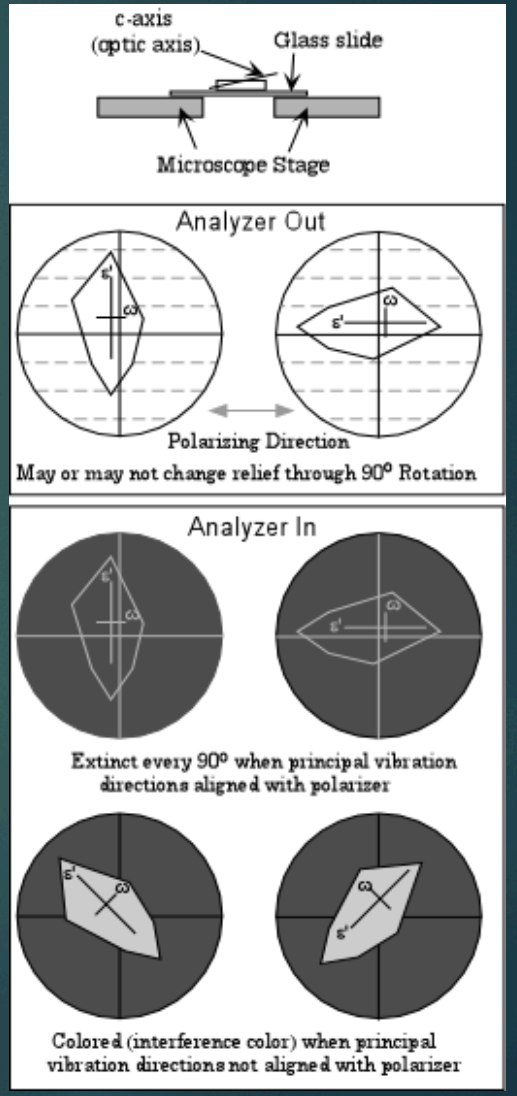
UNIAXIAL INDICATRIX

- **Application:** Ex.: Tetragonal crystal with positive optic sign
  - **Principal section**: c-axis parallel to the stage
    - Transmitted light:
      - if ω direction is aligned E-W (as the polarizer) ⇒ measure of ω
      - if ε direction is aligned E-W (as the polarizer) ⇒ measure of ε
      - change in relief when it's rotated by 90°
- Analyzed light: mineral extinct only when ε or ω direction is oriented E-W.



UNIAXIAL INDICATRIX

- **Application:** Ex.: Tetragonal crystal with positive optic sign
  - **Random section**: c-axis parallel to the stage
    - Transmitted light:
      - if ω direction is aligned E-W (as the polarizer) ⇒ measure of ω
      - rotation of 90° ⇒ measure of ε '
      - change in relief when it's rotated by 90°
- Analyzed light: mineral extinct only when ε or ω direction is oriented E-W.



UNIAXIAL INTERFERENCE FIGURES

- **Orthoscope mode**: light is perpendicular to the lower and upper surfaces of the crystals

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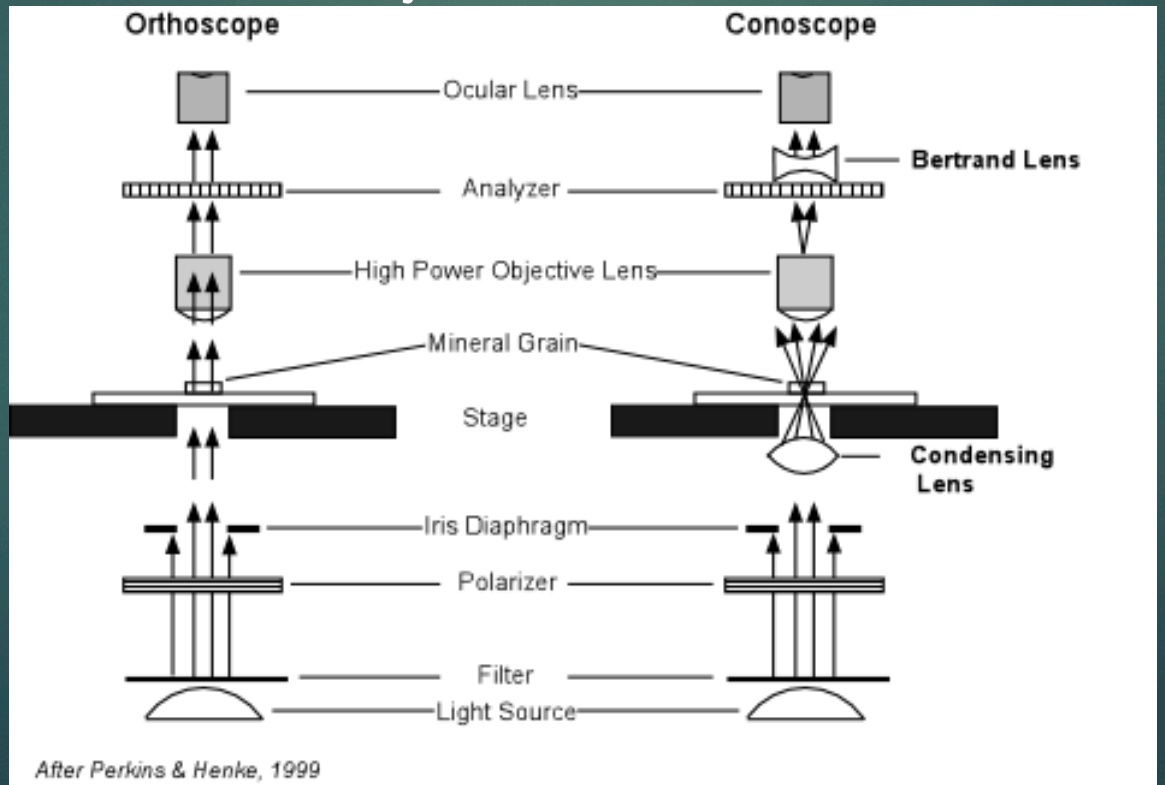
  Conoscope mode: lens is inserted between the source and the crystal ⇒ incident rays cross within the crystal + second lens = **Bertrand lens,** inserted between the objective and the ocular



UNIAXIAL INTERFERENCE FIGURES

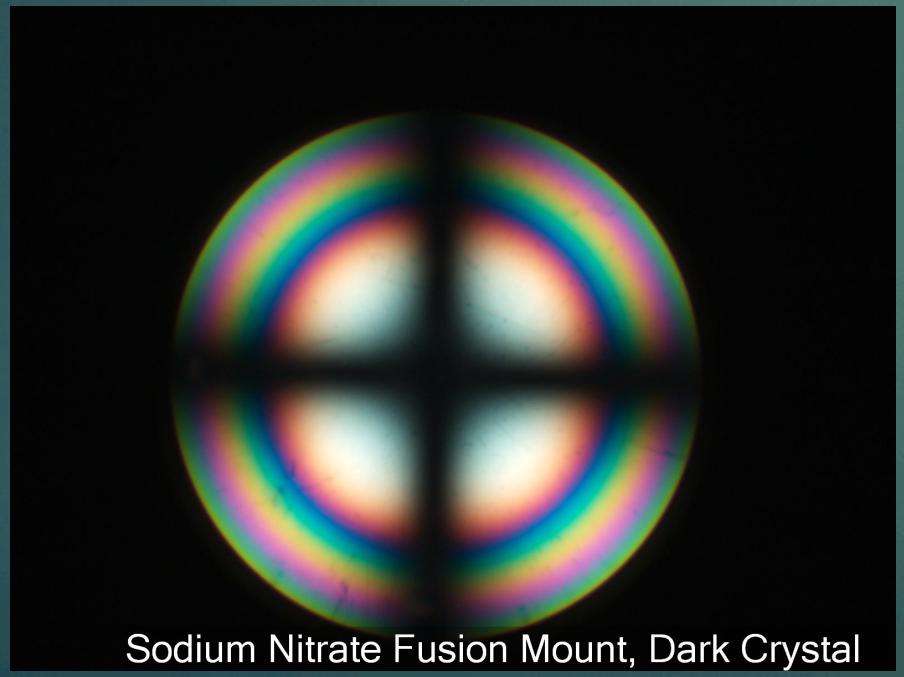
- **Conoscope** mode:
  - 1) highest power objective lens
  - 2) Switch in the condensing lens located beneath the stage, and raise it to a position so that the top is just below the stage.
  - 3) Switch in the Bertrand lens, located just below the ocular lenses.
  - 4) Put the analyzer in.

UNIAXIAL INTERFERENCE FIGURES

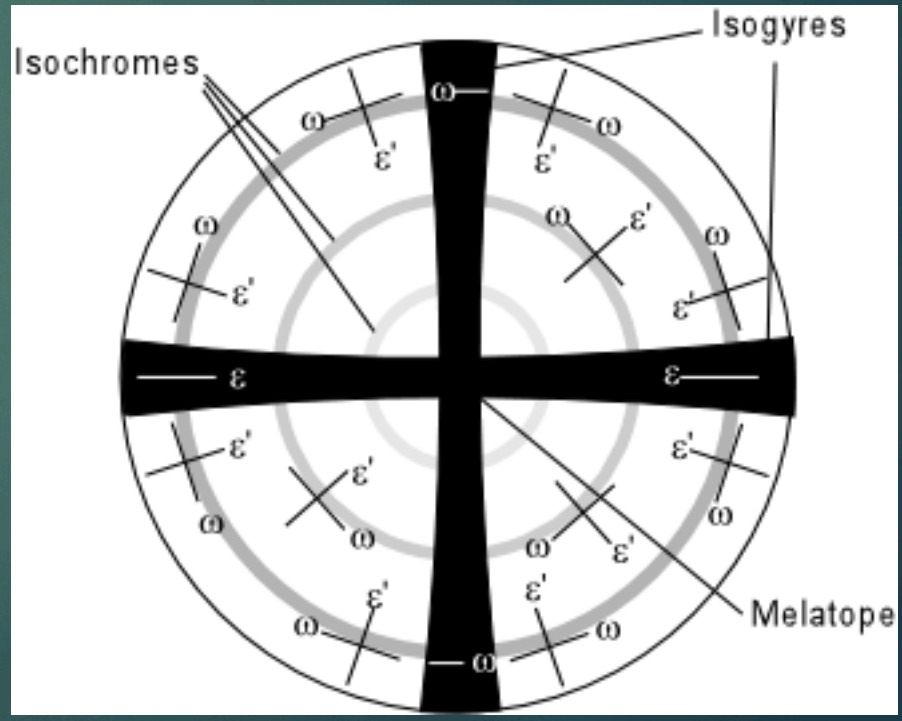
- Optic axis perpendicular to the stage.
  - No change of relief
  - Extinct with analyzed light.

UNIAXIAL INTERFERENCE FIGURES

- Optic axis perpendicular to the stage.
  - No change of relief
  - Extinct with analyzed light.
  - Conoscope mode: **centered uniaxial interference figure**

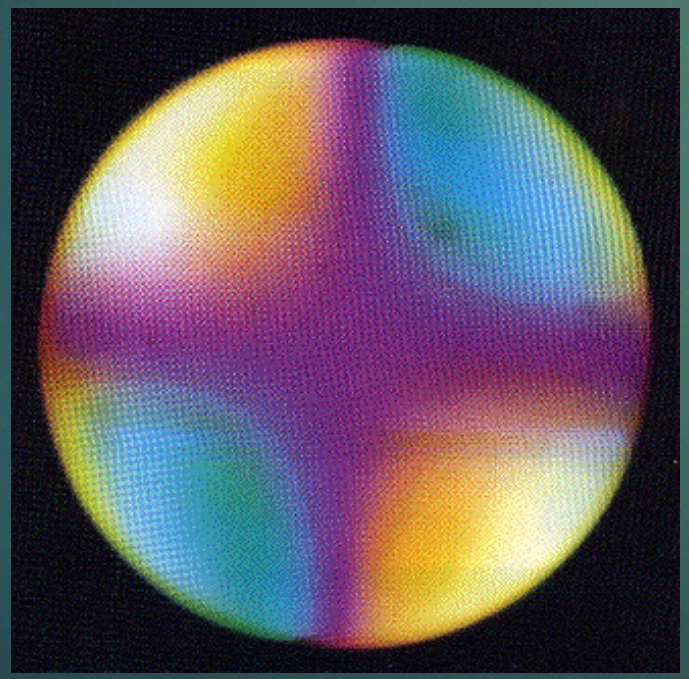


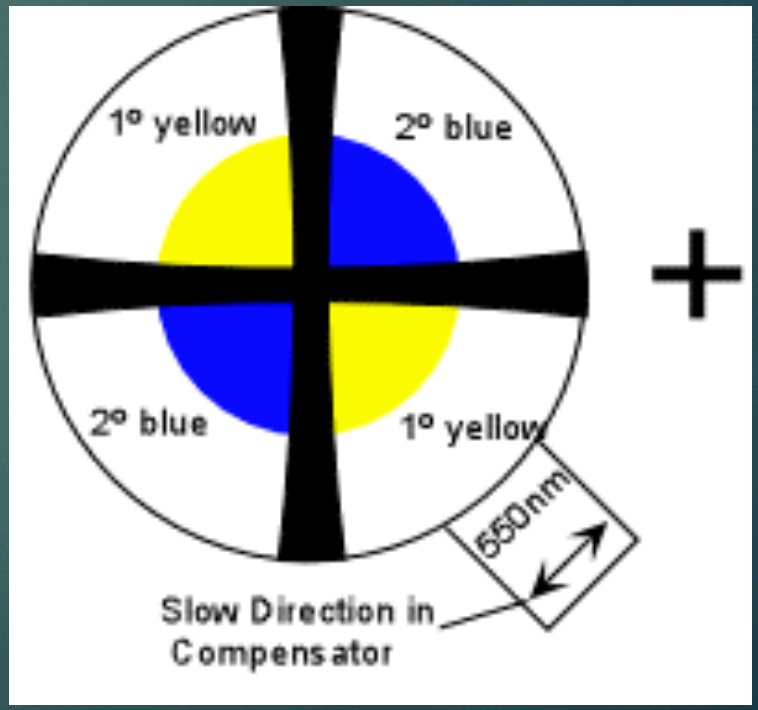
Sodium Nitrate Fusion Mount, Dark Crystal



UNIAXIAL INTERFERENCE FIGURES

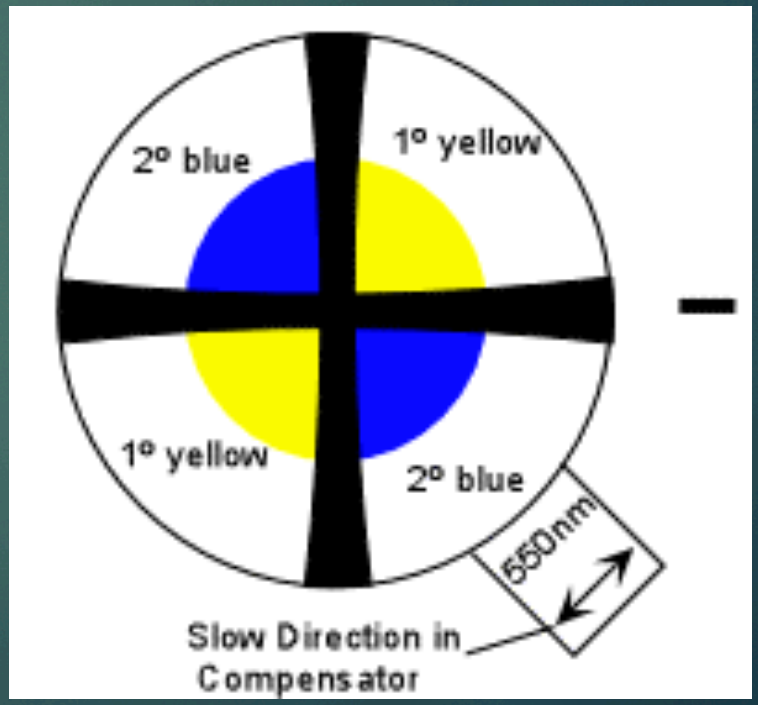
- Determination of the optic sign: addition of the gypsum plate
  - **Positive**: the NE and SW quadrants of the interference figure turn **2nd order blue** (addition), **t**he NW-SE quadrants turn 1st order yellow, (subtraction).





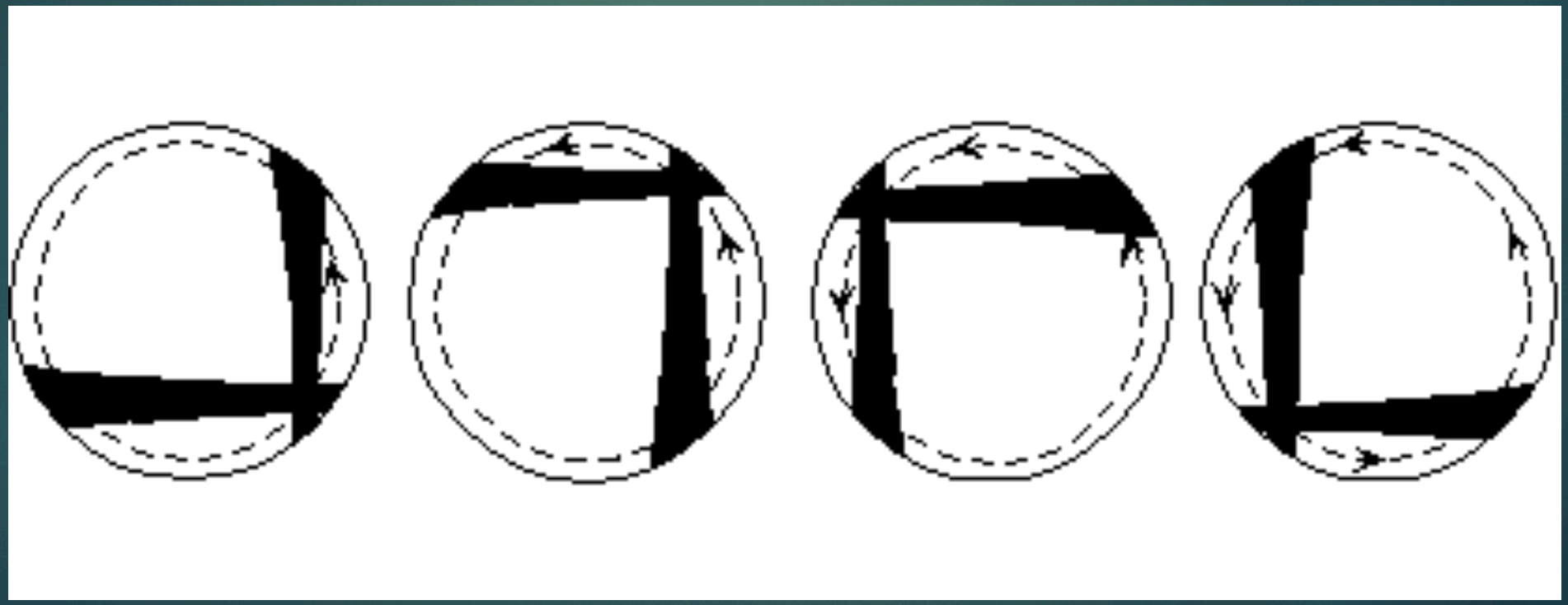
UNIAXIAL INTERFERENCE FIGURES

- Determination of the optic sign: addition of the gypsum plate
  - **Negative**: the NE and SW quadrants of the interference figure turn 1st order yellow (subtraction), **t**he NW-SE quadrants turn **2nd order blue** (addition).



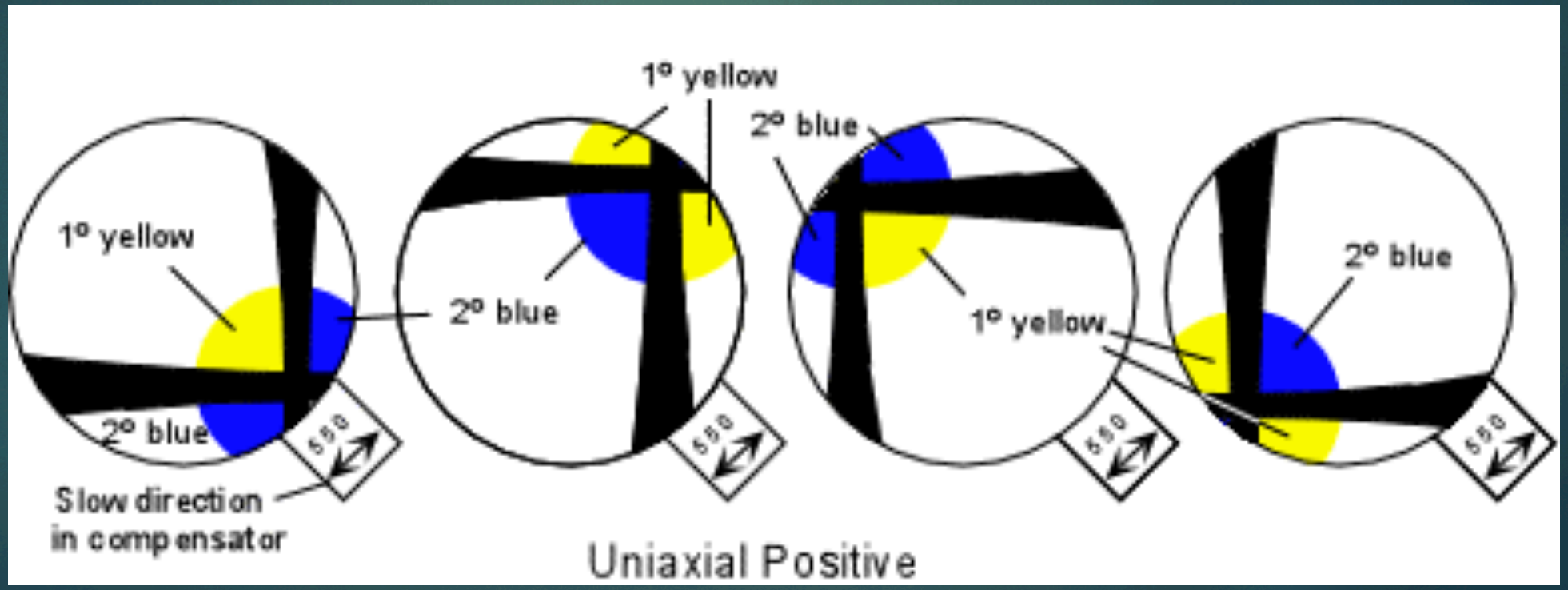
UNIAXIAL INTERFERENCE FIGURES

- Off-center uniaxial interference figure
  - Small change of relief
  - Low order of interference color: ex.: 1st order gray
  - Conoscope mode:



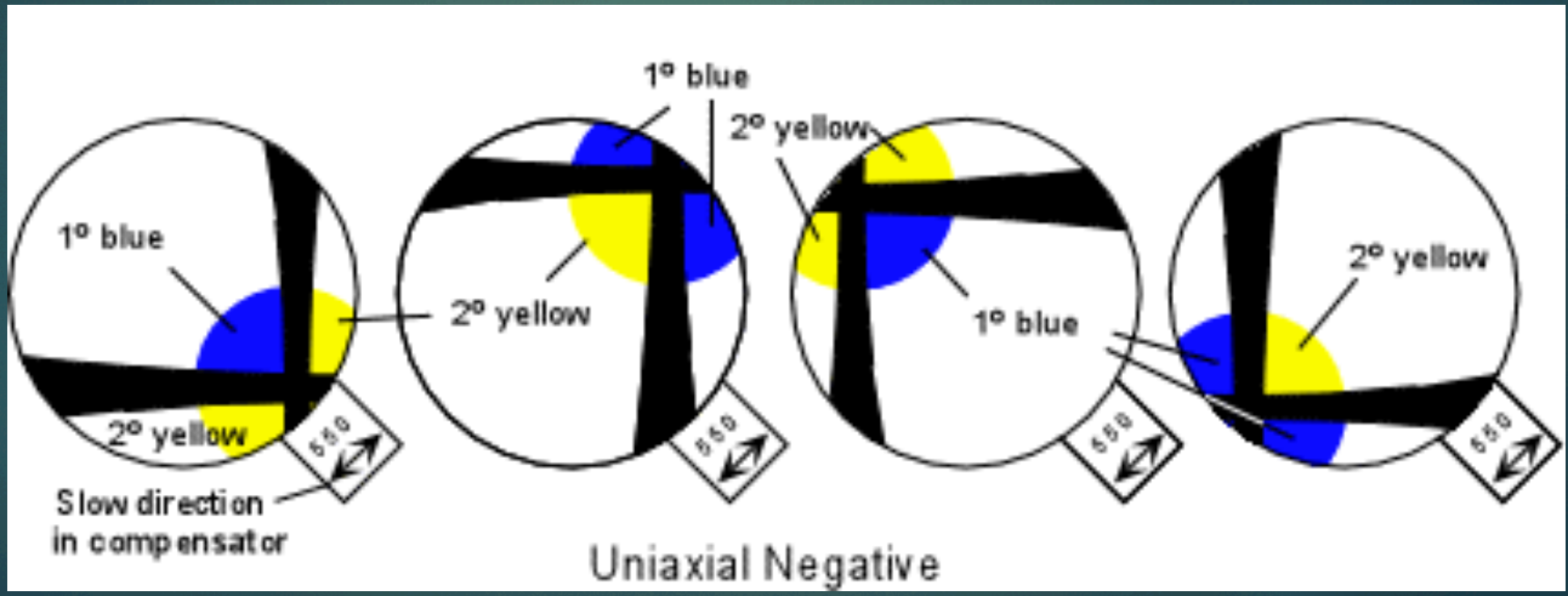
UNIAXIAL INTERFERENCE FIGURES

- Off-center uniaxial interference figure: optic sign

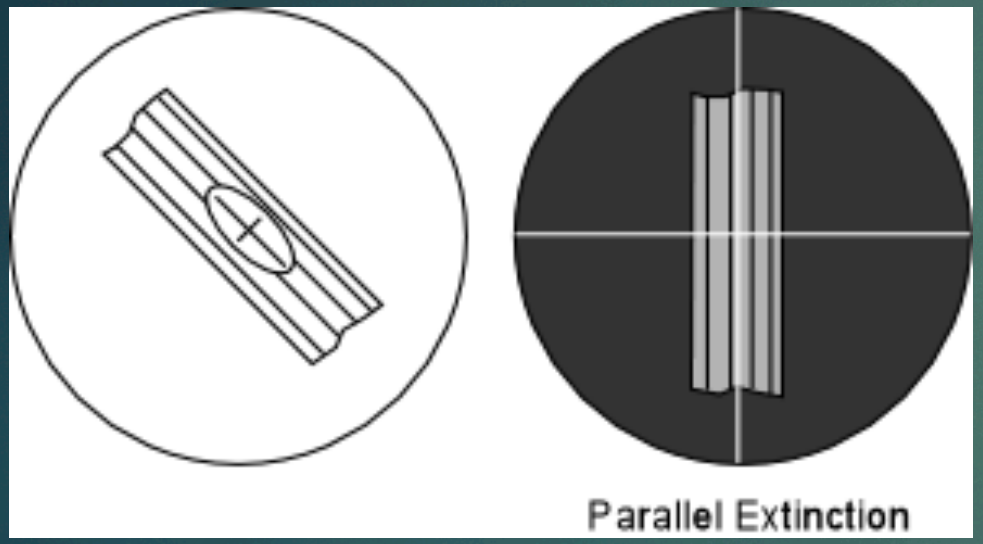


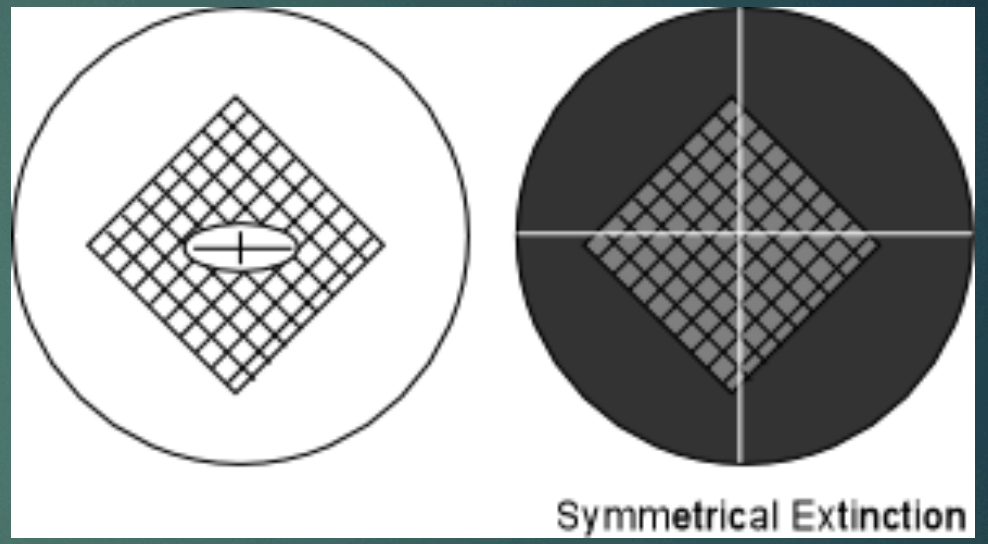
UNIAXIAL INTERFERENCE FIGURES

- Off-center uniaxial interference figure: optic sign



EXTINCTION ANGLE & SIGN OF ELONGATION



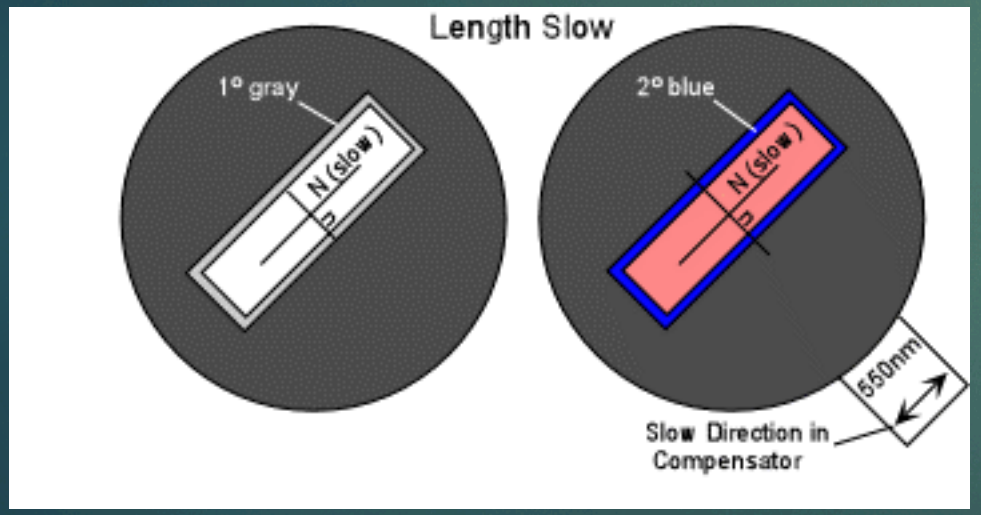


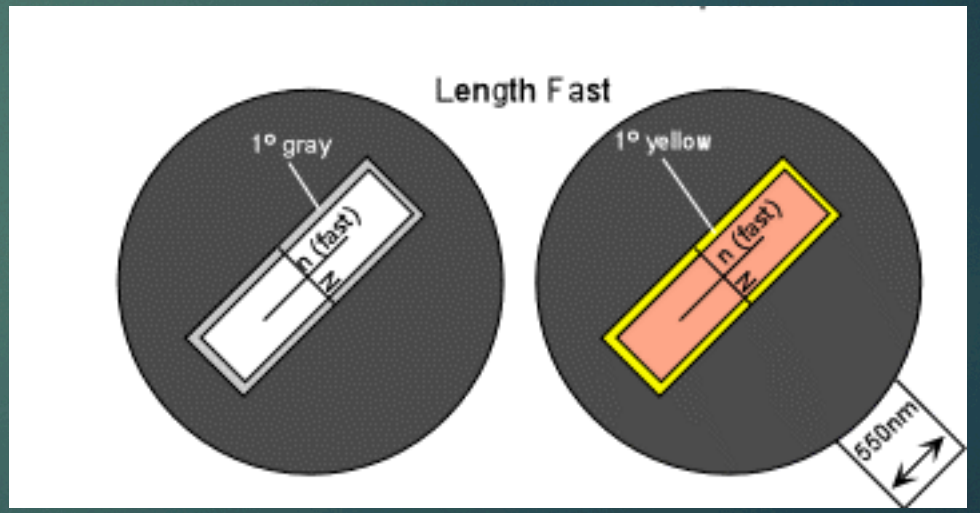
EXTINCTION ANGLE & SIGN OF ELONGATION

- **Sign of elongation:**
  - Crystals elongated **parallel to the slow direction** have a **positive sign** of elongation or are said to be length slow.
  - Crystals that are elongated **parallel to their fast direction** have a **negative sign** of elongation or are said to be length fast.

EXTINCTION ANGLE & SIGN OF ELONGATION

- **Sign of elongation:**
- To determine the sign of elongation, place the crystal so that it is in a position where the long direction of the crystal is parallel to the slow direction in the compensator.



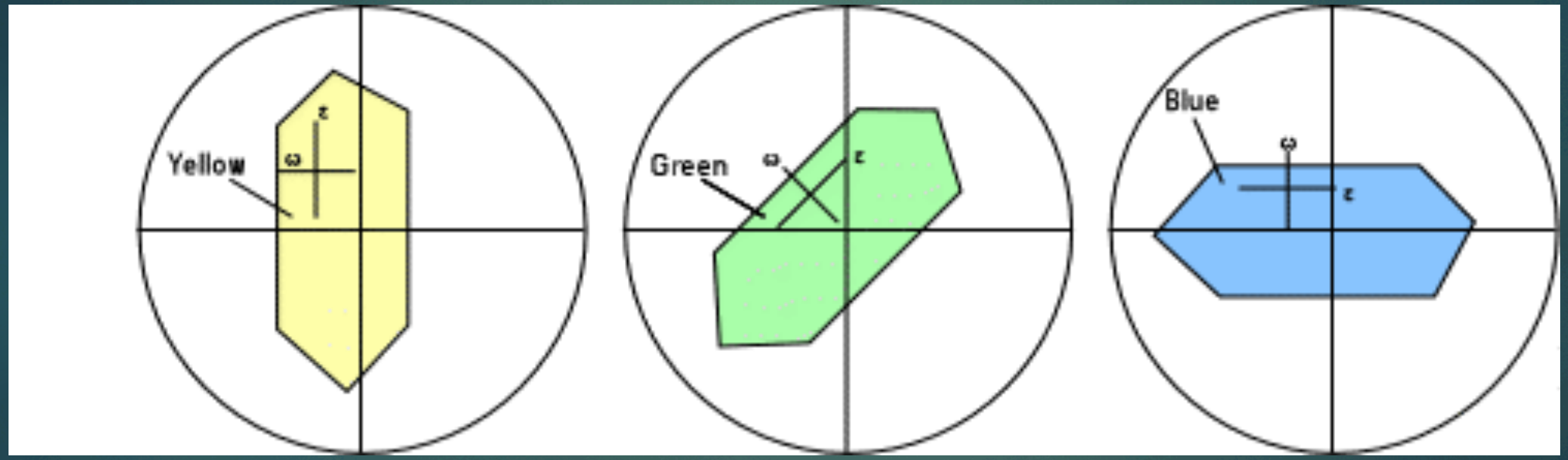


ABSORPTION AND PLEOCHROISM

- In transmitted light:
  - Isotropic mineral: color in transmitted light = absorption color.
  - Uniaxial mineral: several absorption color = pleochroism.

ABSORPTION AND PLEOCHROISM

- Pleochroism formula:
  - Ex: ω = yellow and ε = blue



PLEOCHROISM

- Change of color in transmitted light:
- Different absorptions between the two rays of light as they pass through the colored mineral