Conoscopic Viewing

A condensing lens below the stage and a Bertrand lens above it

Arrangement essentially folds planes → cone

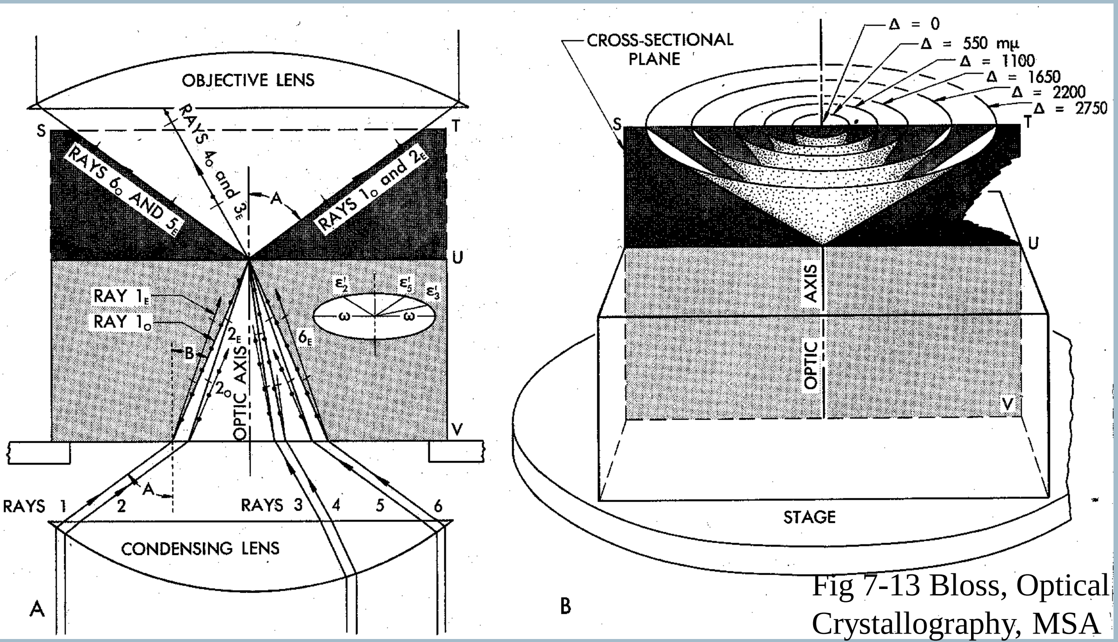
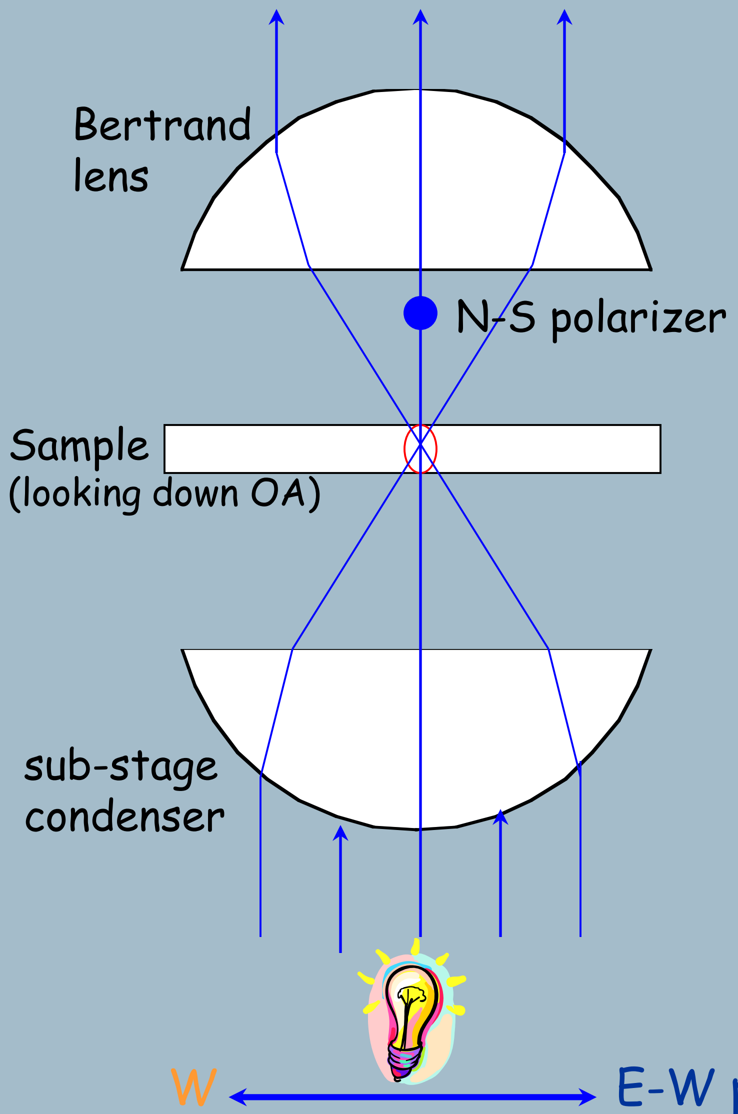


Fig 7-13 Bloss, Optical Crystallography, MSA

- Light rays are refracted by condensing lens & pass through crystal in different directions
- Thus different properties
- Only light in the center of field of view is vertical & like ortho

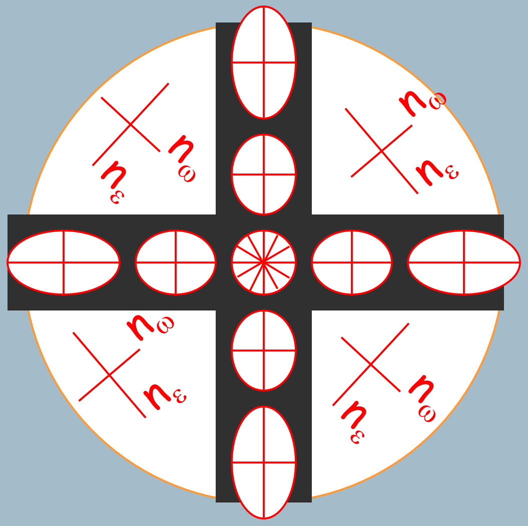
→ **Interference Figures** Very useful for determining optical properties of xl

How interference figures work (uniaxial example)



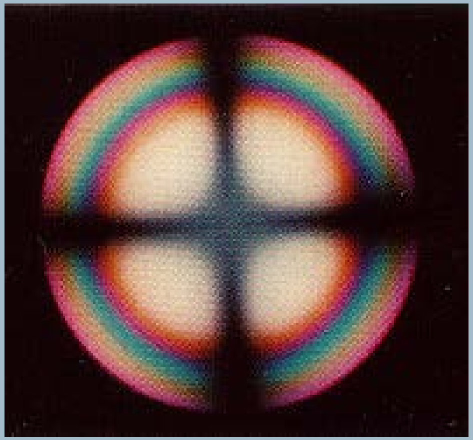
Converging lenses force light rays to follow different paths through the indicatrix

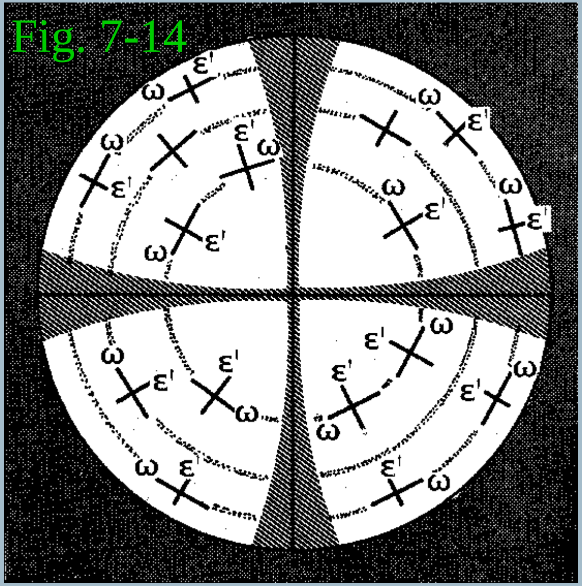
What do we see??

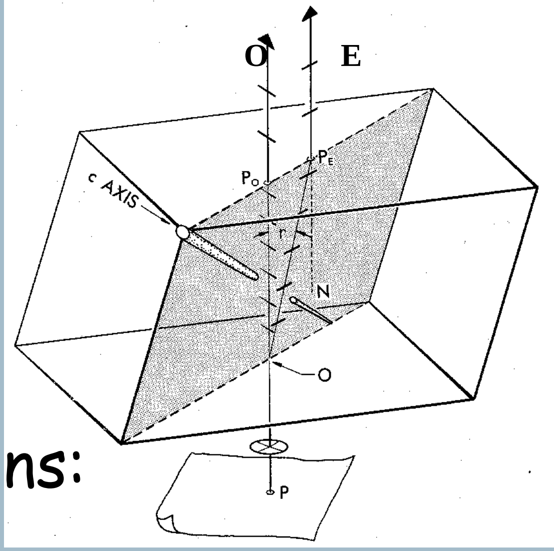


Effects of multiple cuts through indicatrix

Uniaxial Interference Figure

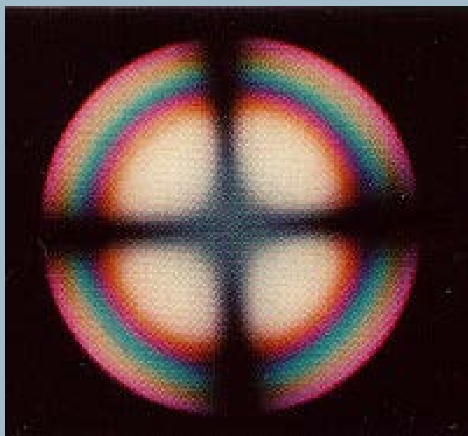






- Circles of **isochromes**
- Note vibration directions:
  - ω tangential
  - ε' radial & variable magnitude
- Black cross (**isogyres**) results from locus of extinction directions
- Center of cross (**melatope**) represents optic axis
- Approx 30° inclination of OA will put it at margin of field of view

Uniaxial Figure



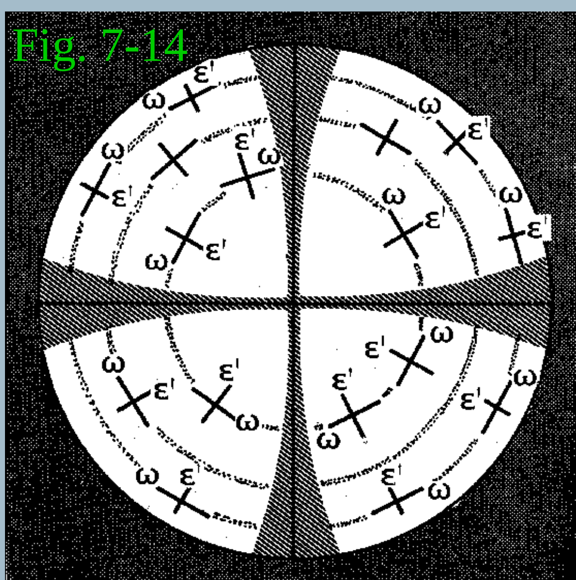
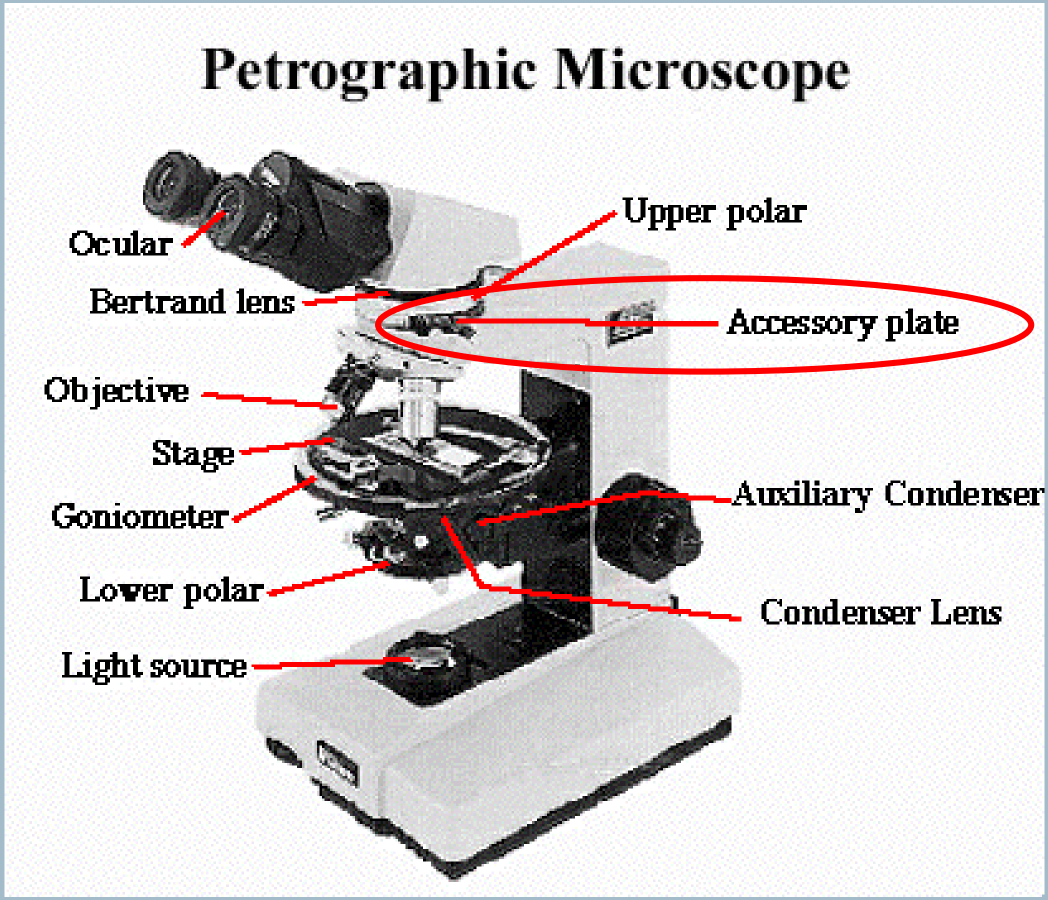


Fig. 7-14

- **Centered** axis figure: when rotate stage cross does **not** rotate
- **Off center:** cross still E-W and N-S, but **melatope** rotates around center
- **Melatope outside field:** bars sweep through, but **always** N-S or E-W at center
- **Flash Figure:** OA in plane of stage Diffuse black fills field brief time as rotate

Accessory Plates

We use an insertable 1-order red (gypsum) plate



Accessory Plates

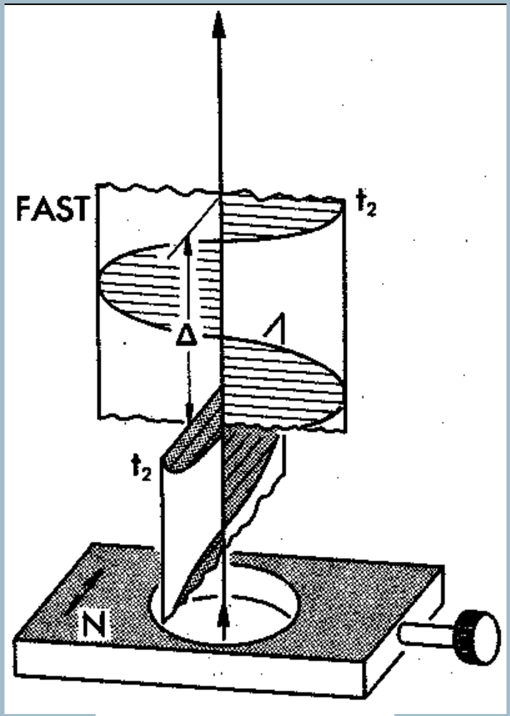


Fig 8-1 Bloss, Optical Crystallography, MSA

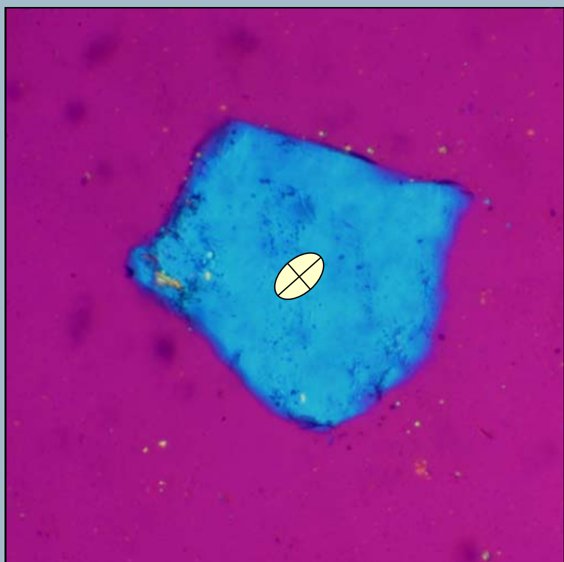
- We use an insertable 1-order red (gypsum) plate
- Slow direction is marked N↕ on plate
- Fast direction (n) || axis of plate
- The gypsum crystal is oriented and cut so that $\Delta = (N-n) \rightarrow$ **550nm retardation**

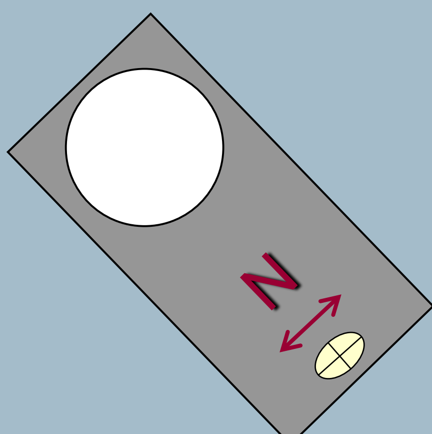
← it thus has the effect of retarding the **N** ray 550 nm behind the **n** ray

- If insert with no crystal on the stage → 1-order red in whole field of view

Accessory Plates

Suppose we view an anisotropic crystal with
Δ = 100 nm (1-order gray) at 45° from extinction



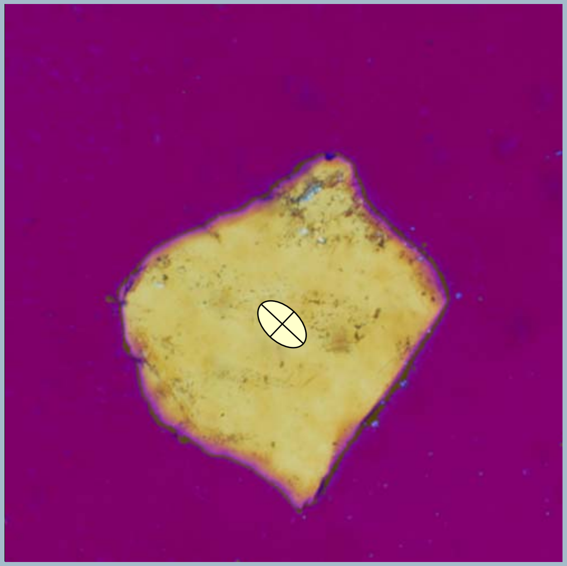


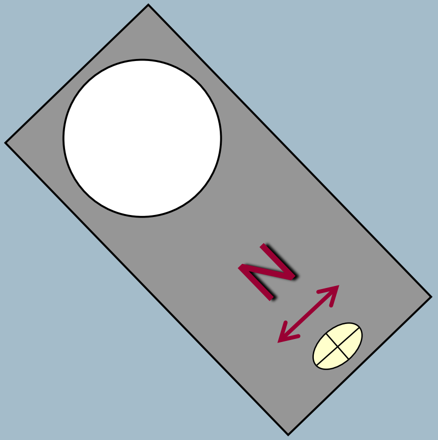
If N_{gyp} || N_{xl} $\rightarrow$ **Addition**

- Ray in crystal || N_{gyp} already behind by 100nm & it gets **further retarded** by 550nm in the gypsum plate
- 100 + 550 $\rightarrow$ 650nm
- What color (on your color chart) will result?
- Original 1° grey $\rightarrow$ **2° blue**

Accessory Plates

Now rotate the microscope stage and crystal 90° → N_{gyp} || n_{xl} (Δ still = 100 nm)

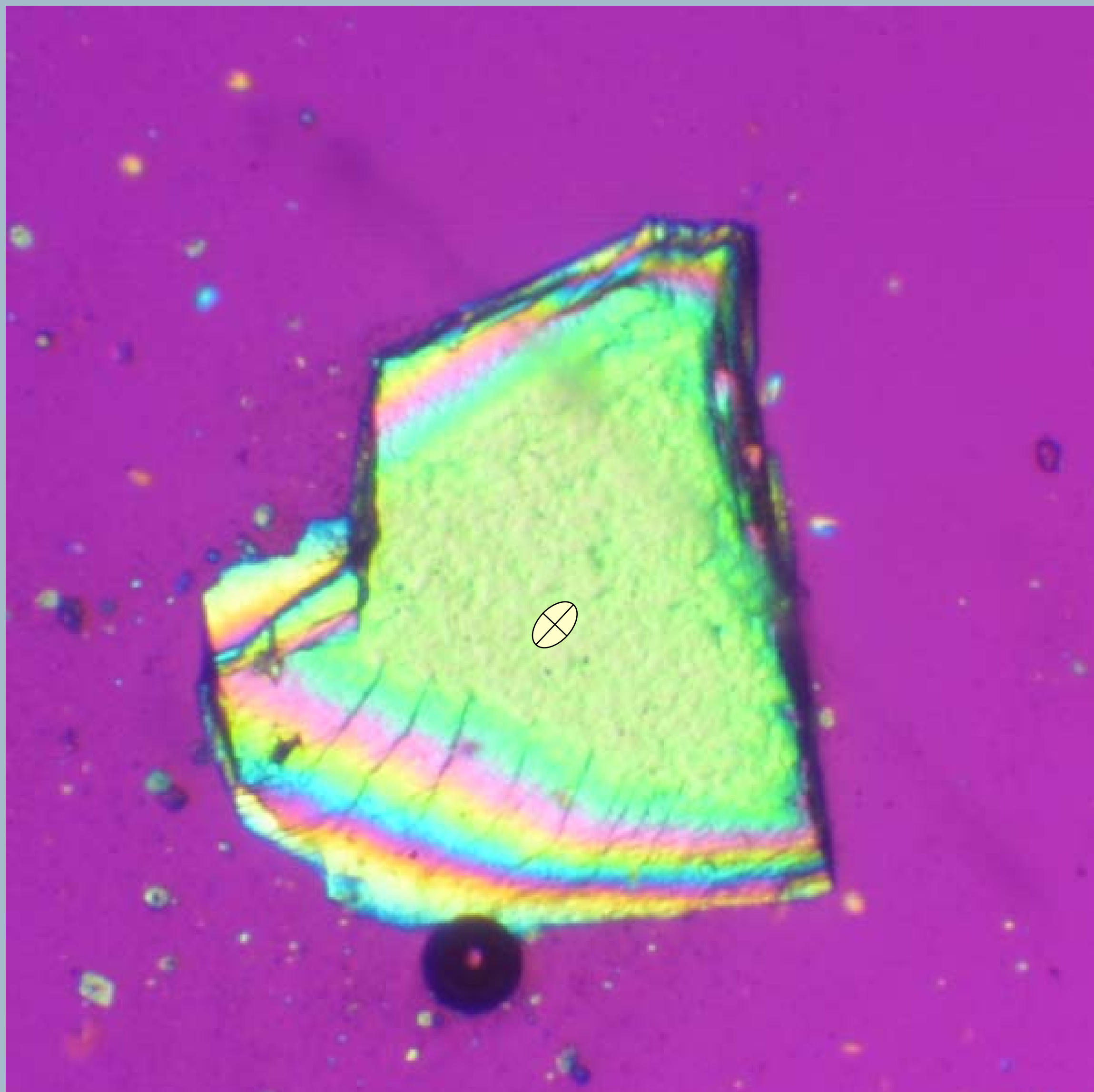


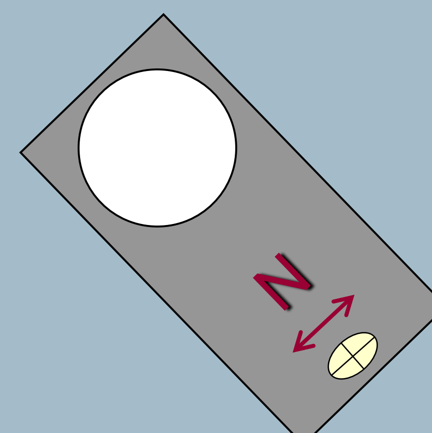


N_{gyp} || n_{xl} → Subtraction

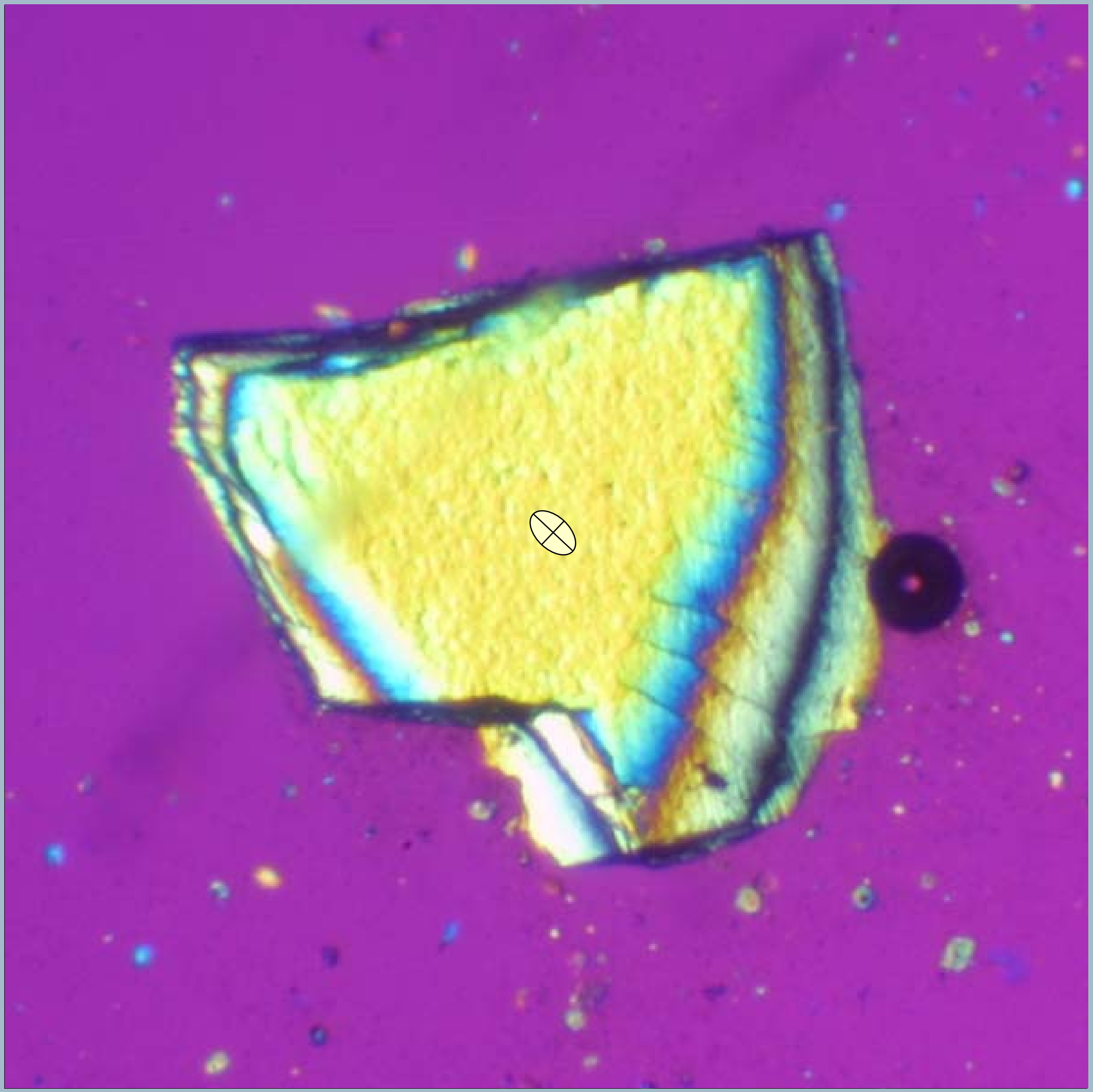
- Ray in the crystal that is parallel to N_{gyp} is ahead by 100nm
- 550μm retardation in gypsum plate → 450nm behind
- What color will result?
- 1° orange

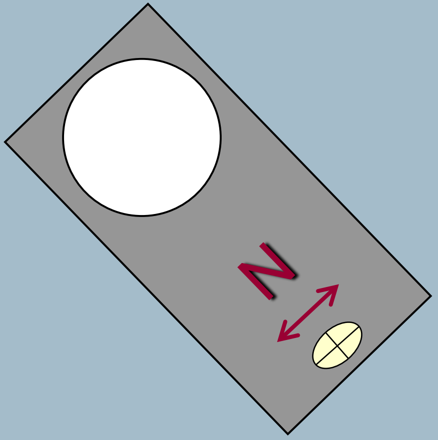
What will happen when you insert the gypsum plate?



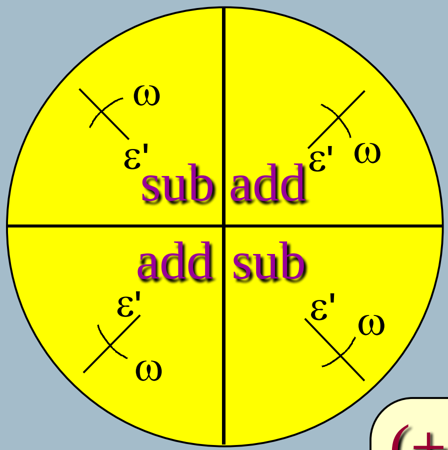


What will happen when you insert the gypsum plate?

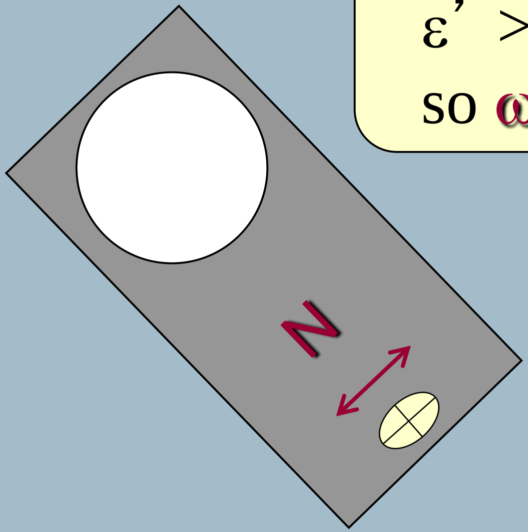




Optic Sign Determination



(+) crystal:
ε' > ω
so ω faster



Inserting plate for a (+) crystal:

→ subtraction in NW & SE where n||N

→ addition in NE & SW where N||N

Whole NE (& SW) quads add 550nm

- isochromes shift up 1 order

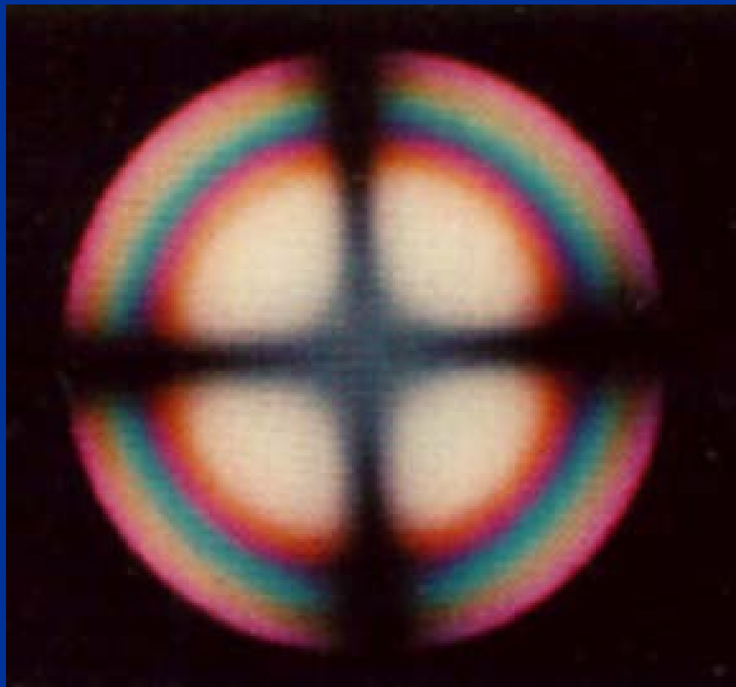
Isogyre adds → red

In NW & SE where subtract

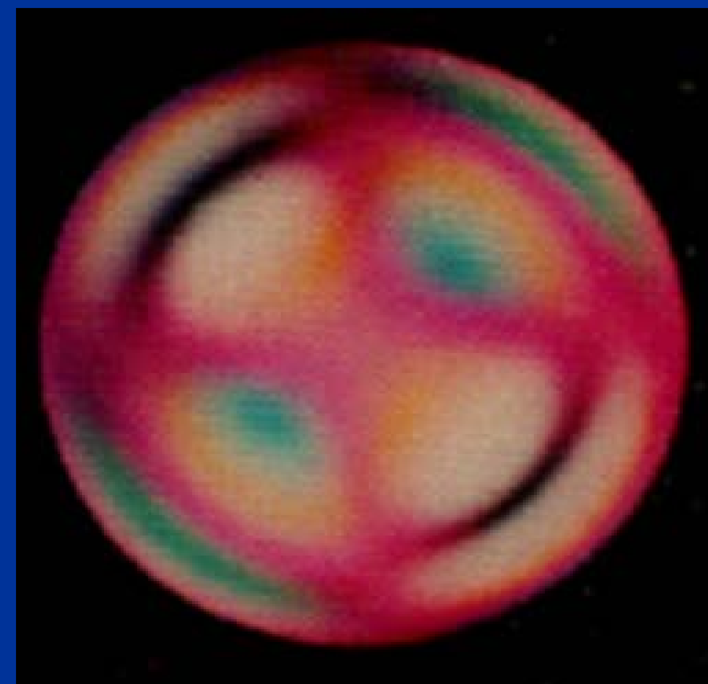
- Each isochrome loses an order

Near isogyre (~100nm)

- get 450 yellow in NW & SE (100-550)
- and 650 blue in NE & SW (100+550)

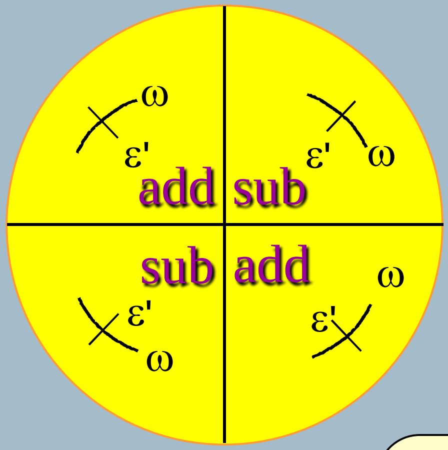


(+) OA Figure without plate

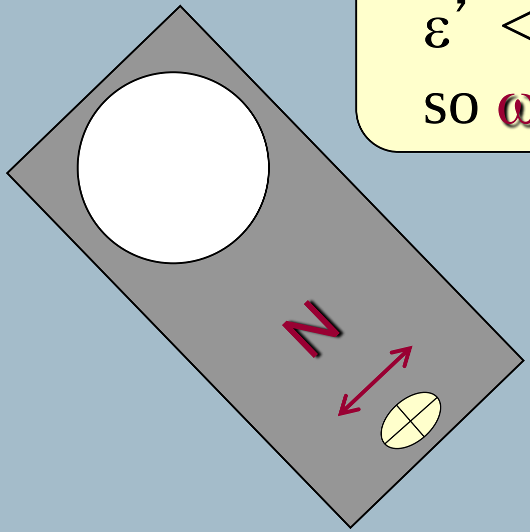


(+) OA Figure with plate
Yellow in NW is (+)

Optic Sign Determination



(-) crystal:
ε' < ω
so ω slower



Inserting plate for a (-) crystal:

→ subtraction in NE & SW where n||N

→ addition in NW & SE where N||N

Whole NW (& SE) quads add 550nm

- isochromes shift up 1 order

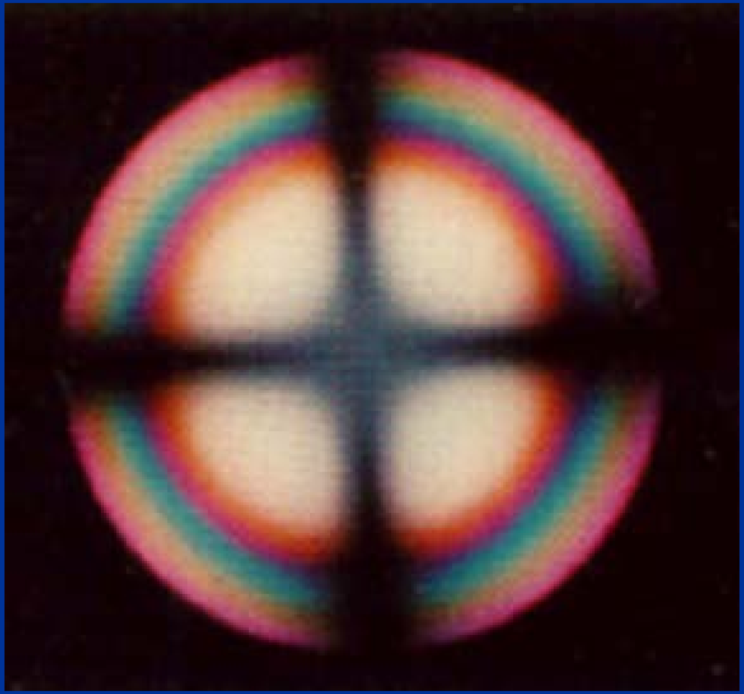
Isogyre still adds → red

In NE & SW where subtract

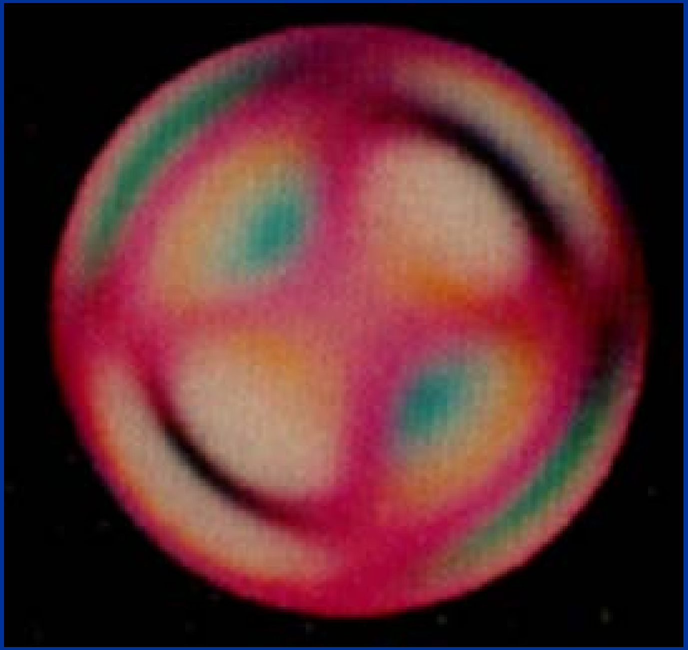
- Each isochrome loses an order

Near isogyre (~100nm)

- get 650 blue in NW & SE
- and 450 yellow in NE & SW



(-) OA Figure without plate
(same as (+) figure)



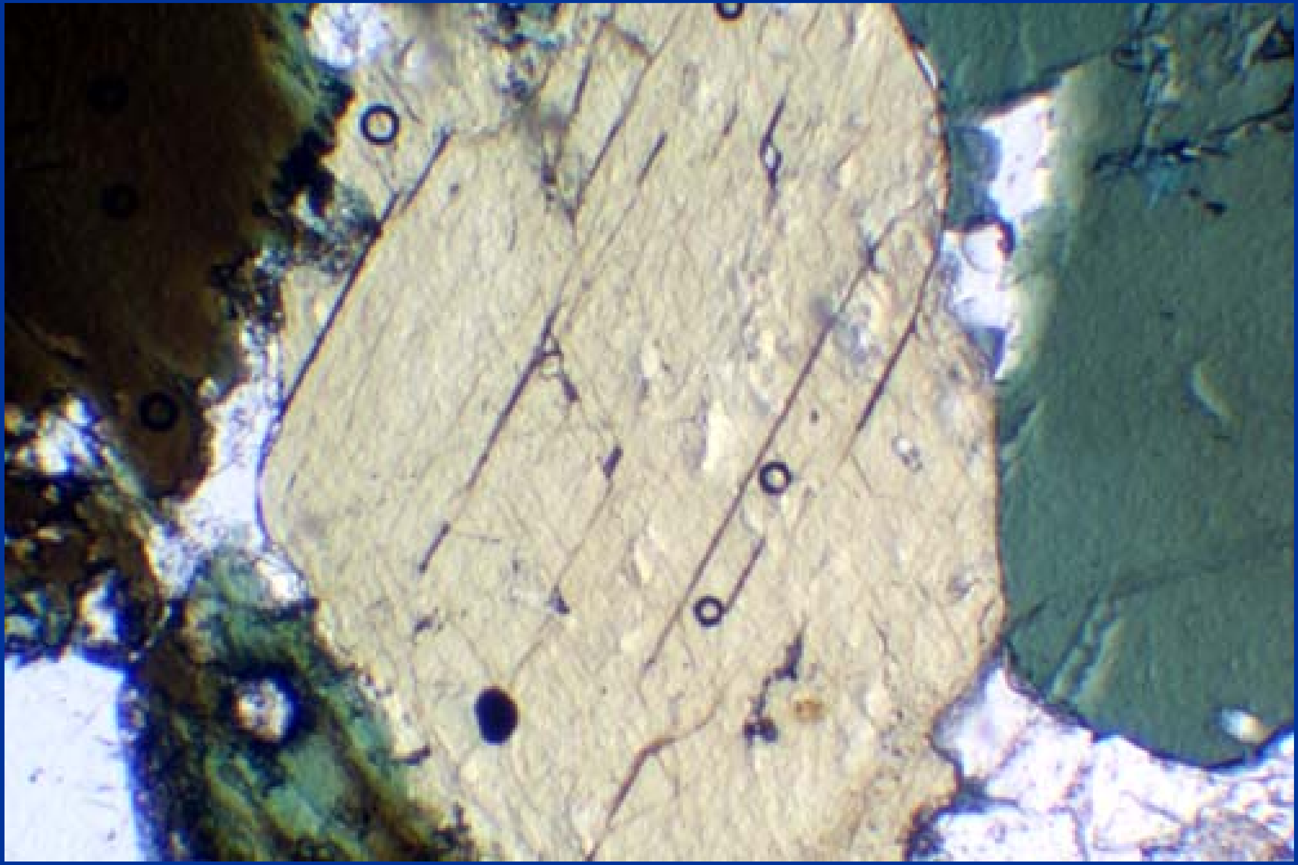
(-) OA Figure with plate
Blue in NW is (-)

Pleochroism

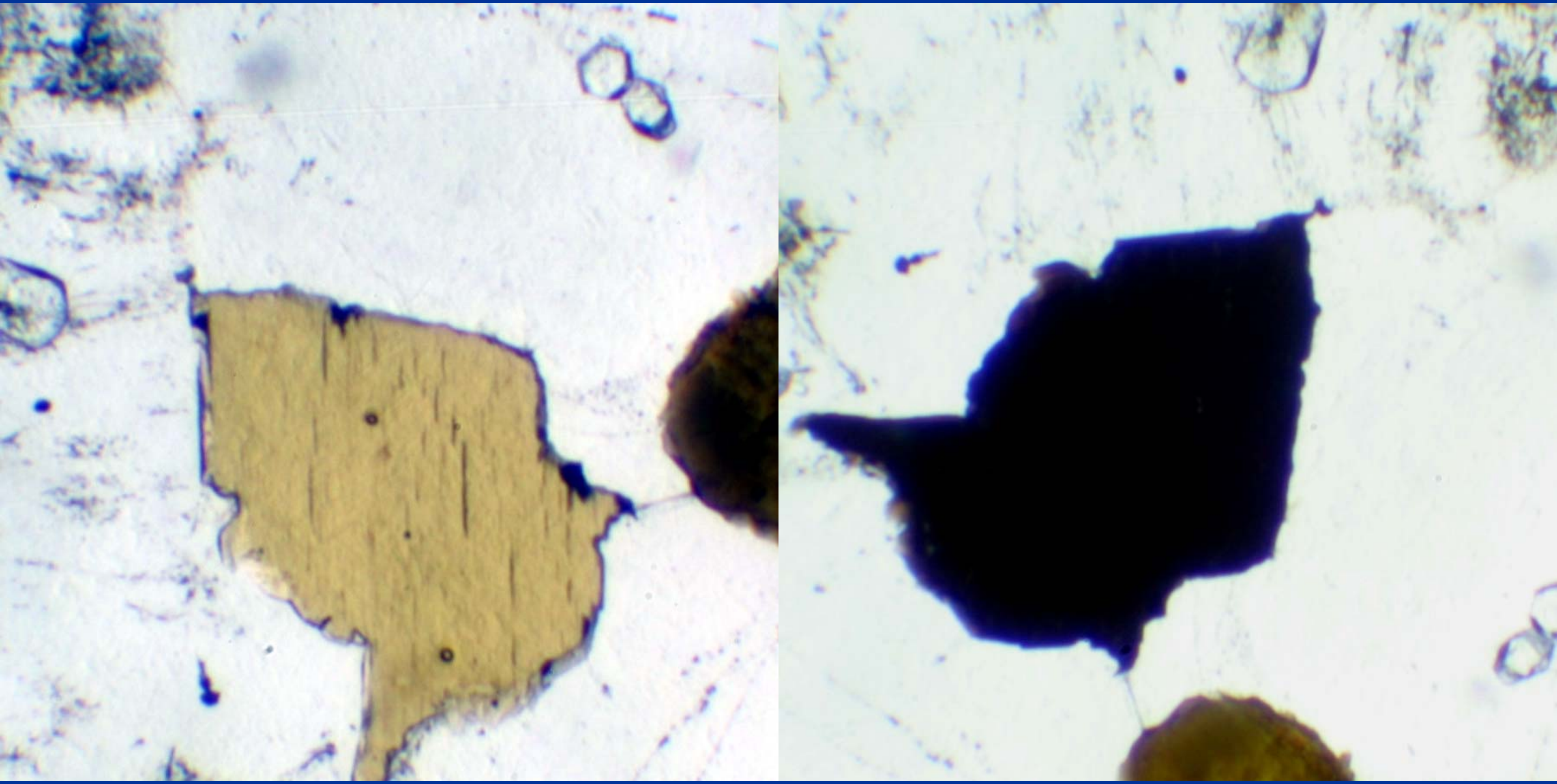
- Changes in **absorption color in PPL** as rotate stage (common in biotite, amphibole…)
- Pleochroic formula:
  - Example: Tourmaline:

    ε = dark green to bluish

    ω = colorless to tan
- Can determine this as just described by isolating first ω and then ε E-W and observing the color



Hornblende as stage is rotated



Biotite as stage is rotated

Biaxial Crystals

Orthorhombic, Monoclinic, and Triclinic crystals don't have 2 or more identical crystal axes

- The indicatrix is a general ellipsoid with three unequal, mutually perpendicular axes
- One is the smallest possible n and one the largest

Fig 10-1 Bloss, Optical Crystallography, MSA

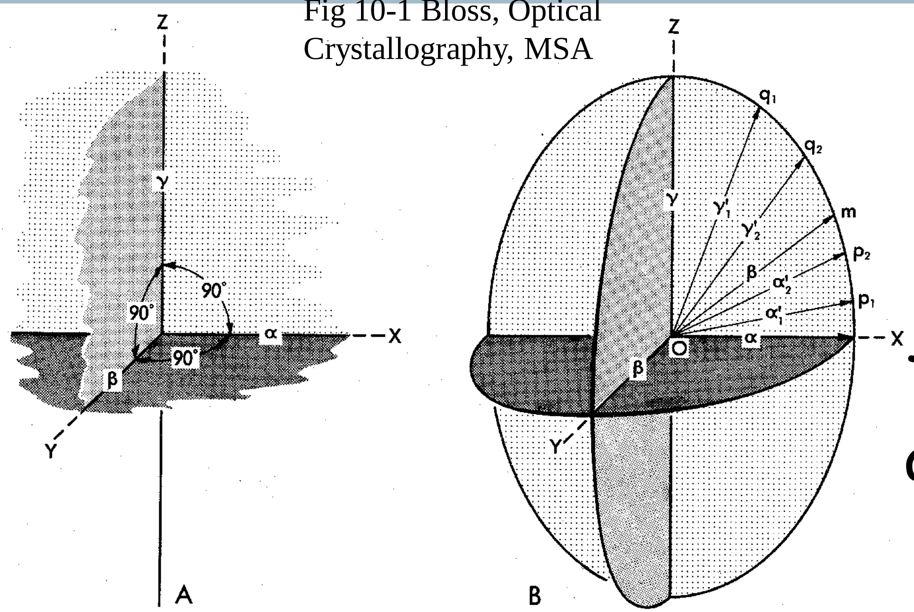


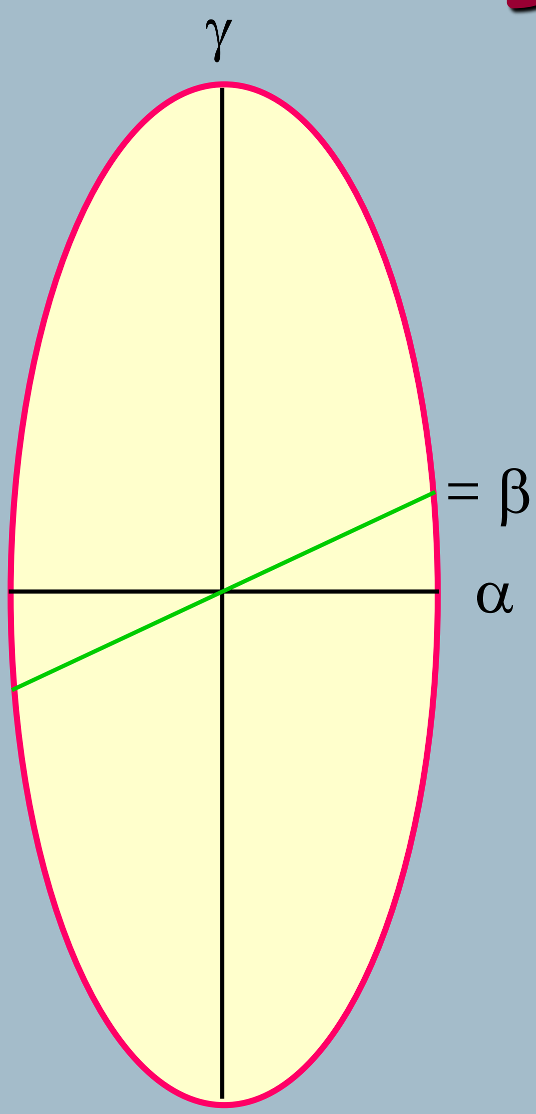
Fig. 9-1. (A) The three, mutually perpendicular, principal vibration axes, *X*, *Υ*, and *Z*, and the common symbols for the indices of refraction of a biaxial mineral for light vibrating parallel to them. (B) Elliptical distribution of the index of refraction (as shown by the vector lengths) for light vibrating parallel to op_1, op_2, om, oq_2, oq_1 within the *ZX* plane.

α = smallest n (fastest)
β = intermediate n
γ = largest n (slowest)

The principal vibration directions are x, y, and z ($x \parallel \alpha$, $y \parallel \beta$, $z \parallel \gamma$)

By definition $\alpha < \alpha' < \beta < \gamma' < \gamma$

Biaxial Crystals



Looking down true β

If α < β < γ then there must be some point between α & γ with n = β

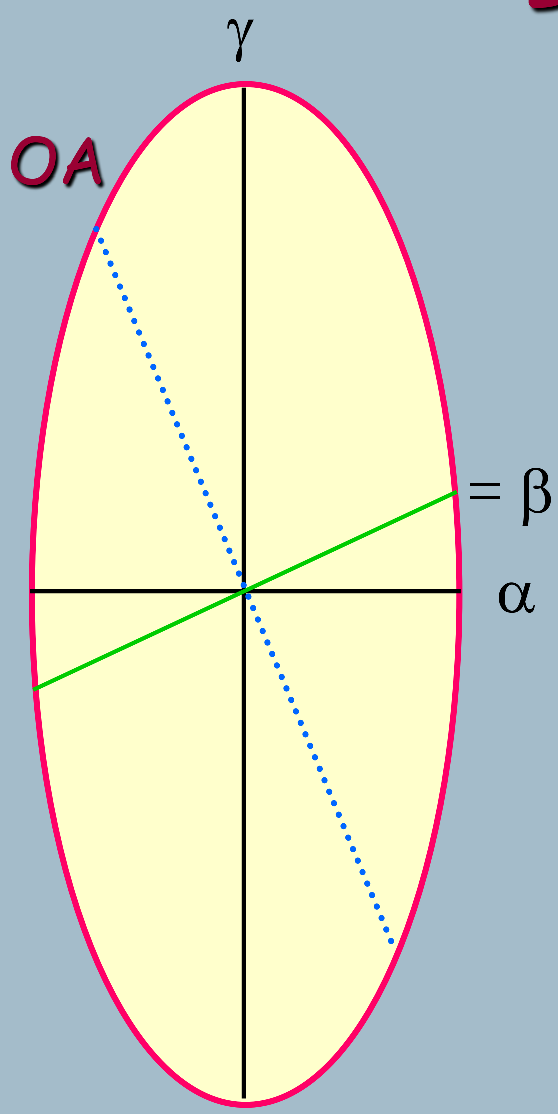
Because = β in plane, and true β is normal to plane, then the section containing both is a circular section

Has all of the properties of a circular section!

If look down it:

- all rays = β
- no preferred vibration direction
- polarized incoming light will remain so
- unpolarized " " " "
- thus appear isotropic as rotate stage

Biaxial Crystals

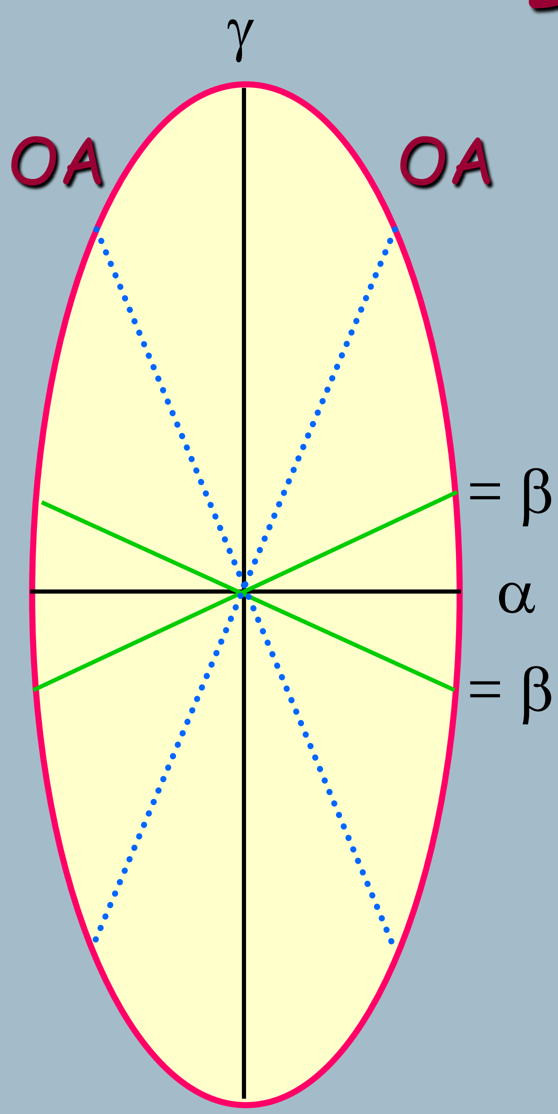


Looking down true β

If α < β < γ then there must be some point between α & γ with n = β

⊥ optic axis by definition

Biaxial Crystals



Looking down true β

If α < β < γ then there must be some point between α & γ with n = β

⊥ optic axis by definition

And there must be two! ⇒ **Biaxial**

Orthorhombic, Monoclinic, and Triclinic minerals are thus biaxial and Hexagonal and tetragonal minerals are uniaxial

Biaxial Crystals

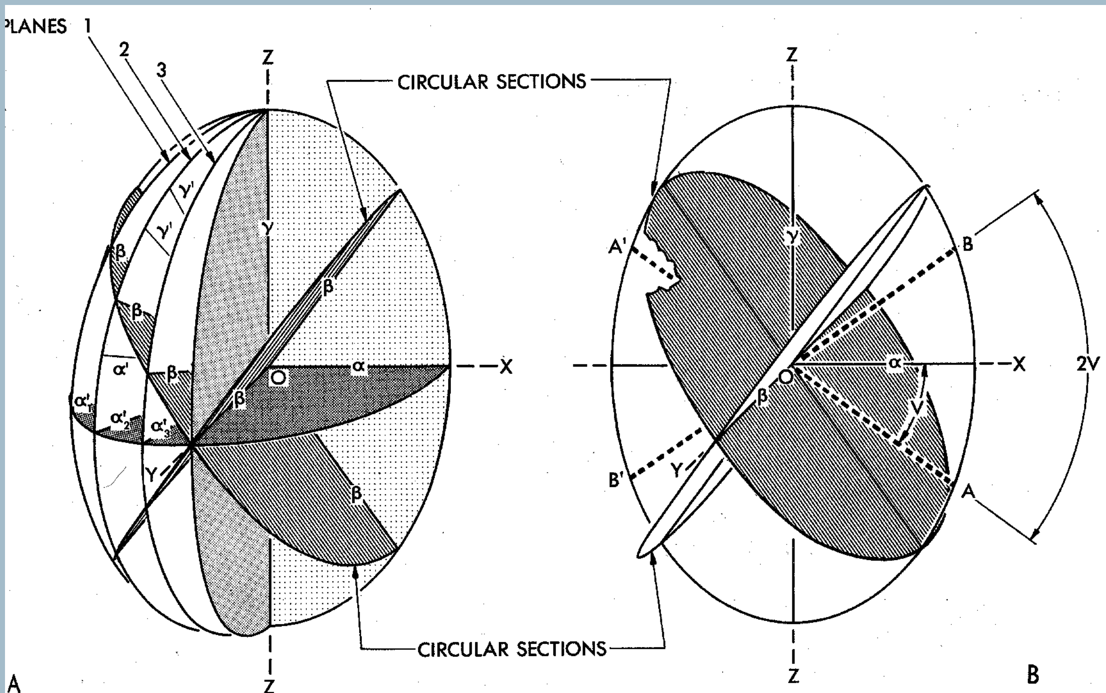


Fig 10-2 Bloss, Optical Crystallography, MSA

Nomenclature:

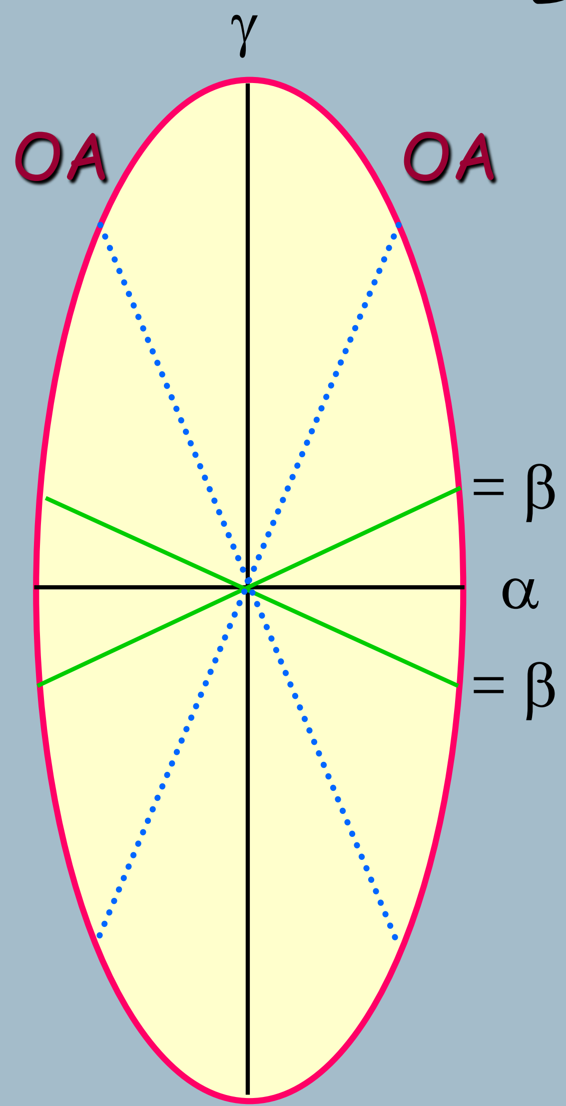
- 2 circular sections → 2 optic axes Must be in α-γ plane = Optic Axial Plane (OAP)
- Y || β direction ⊥ OAP = optic normal

Acute angle between OA's = 2V

The axis that bisects acute angle = acute bisectrix = B_{xa}

The axis that bisects obtuse angle = obtuse bisectrix = B_{xo}

Biaxial Crystals

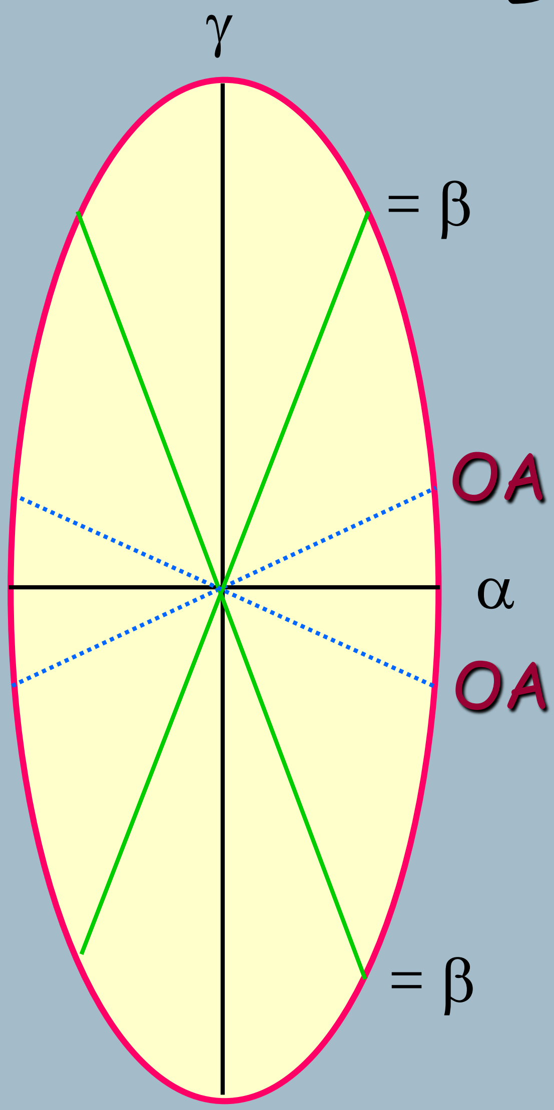


Looking down true β

B(+) defined as Z (γ) = B_{xa}

Thus β closer to α than to γ

Biaxial Crystals



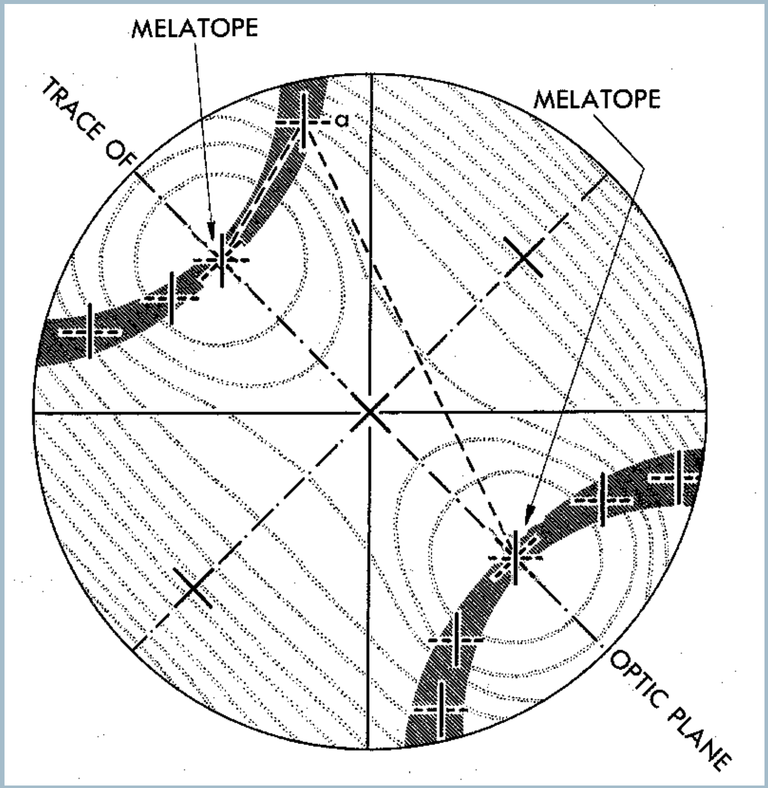
Looking down true β

B(-) defined as X (α) = B_{xa}

Thus β closer to γ than to α

Biaxial Interference Figures

Centered B_{xa} Figure



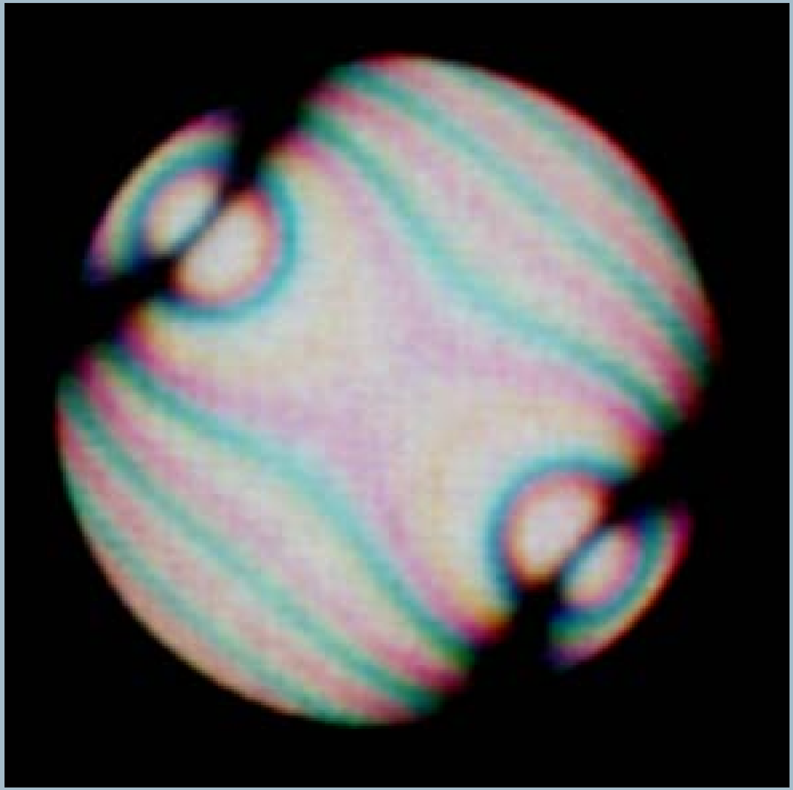


Fig 10-16 Bloss, Optical Crystallography, MSA

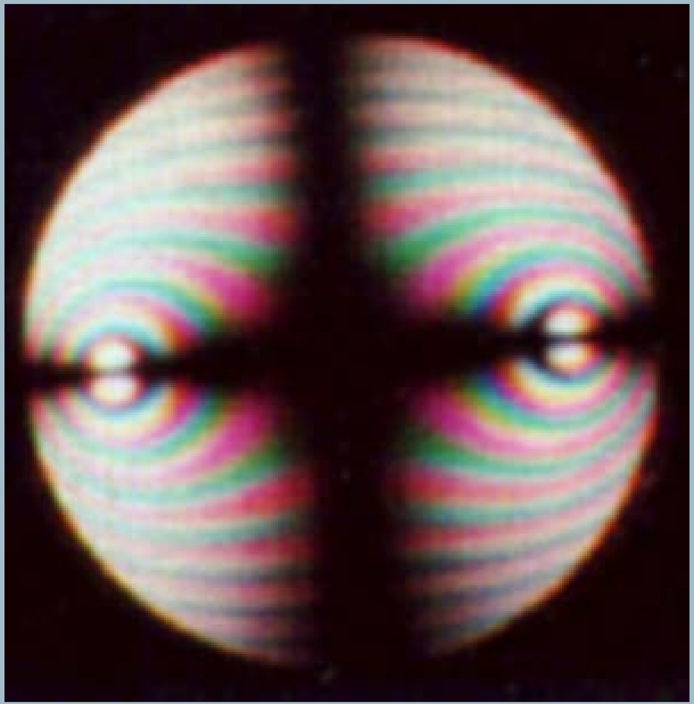
Biaxial Interference Figures

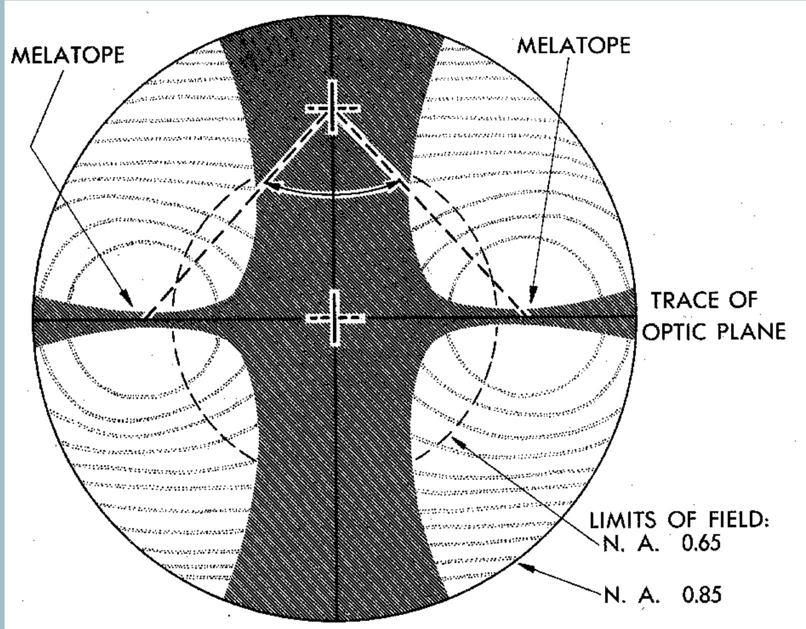
Same figure rotated 45°

Optic axes are now E-W

Clearly isogyres must swing

Demonstration



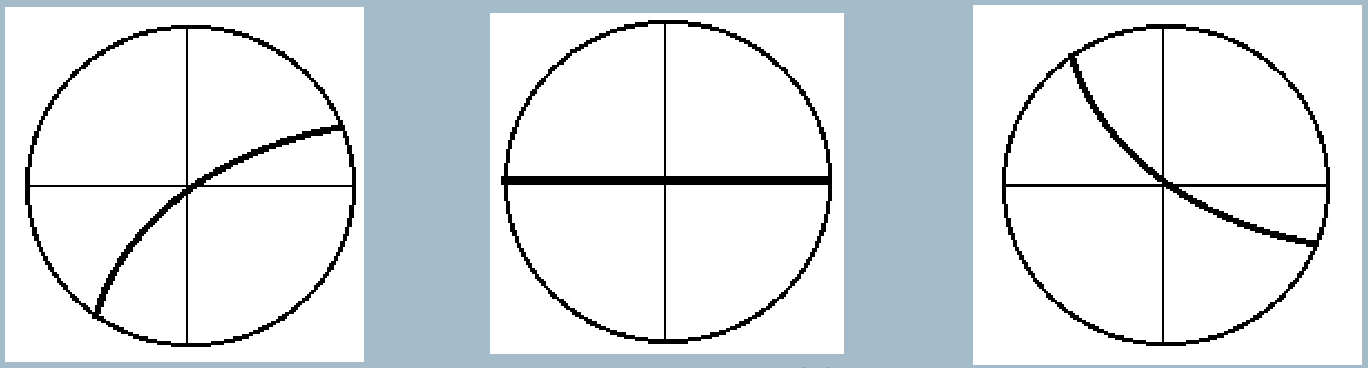


as seen if the microscope stage is rotated 45 degrees counterclockwise. Extinction occurs in the areas where rays emerge that vibrate parallel to the polarizer. The dashed circle marks the limits of the field of view if an objective of N. A. 0.65 is used instead of one of N. A. 0.85.

Fig 10-16B Bloss, Optical Crystallography, MSA

As rotate

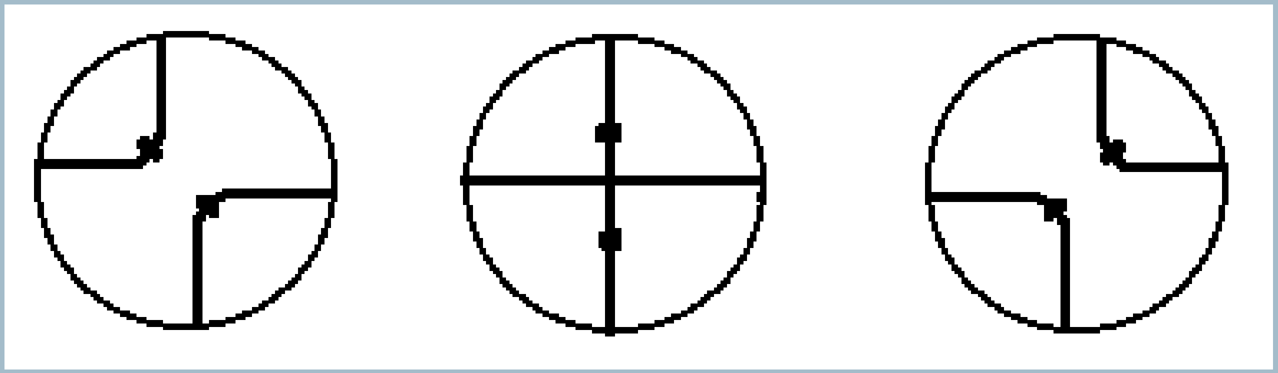
Centered Optic Axis Figure Large 2V:



Not much curvature

Makes use of B_{xa} awful

B_{xa} Figure with Small 2V:



Always use optic axis figures

- Easiest to find anyway. Why?

- B_{xo} looks like B_{xa} with 2V > 90°
- Random Figures: Isogyre sweeps through field (not parallel x-hair at intersection, so can recognize from uniaxial even with this odd direction)
  - Useless if far from OA

Biaxial Optic Sign

B(-) $\alpha = B_{xa}$ thus β closer to γ

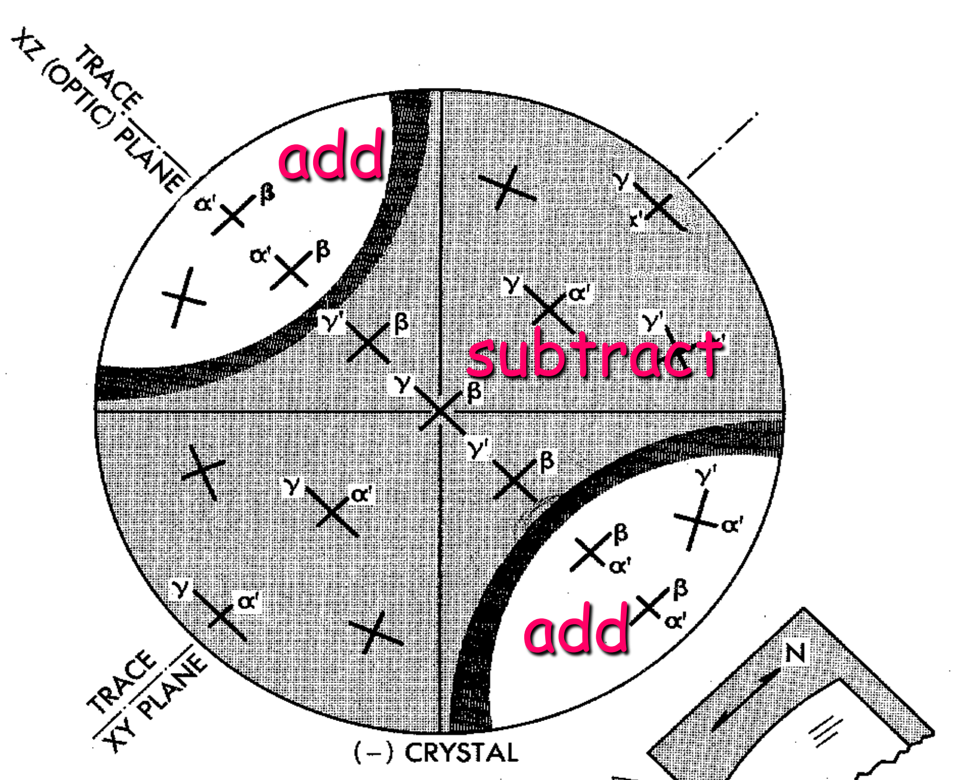
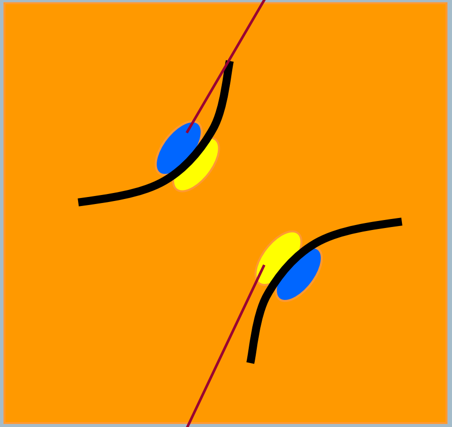


Fig. 11-1A

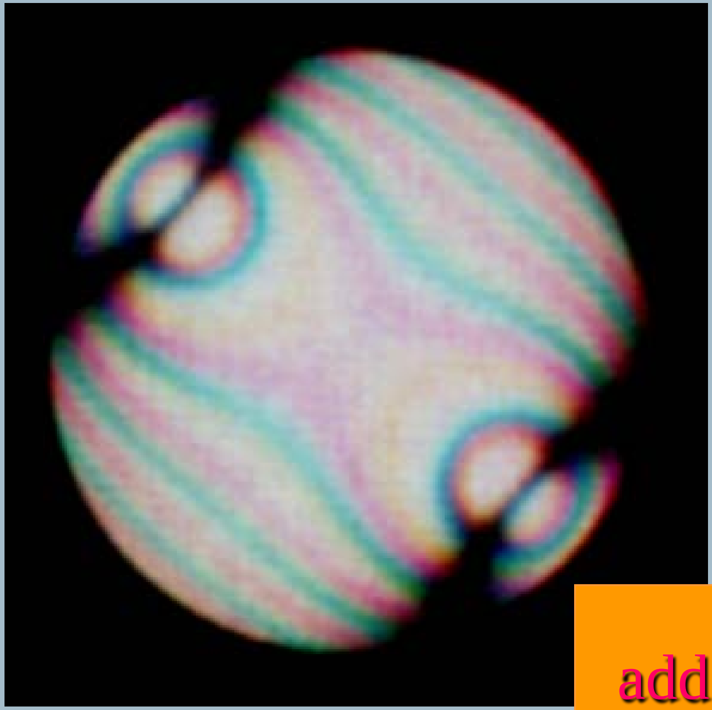
100 gray + 550 → 650 blue



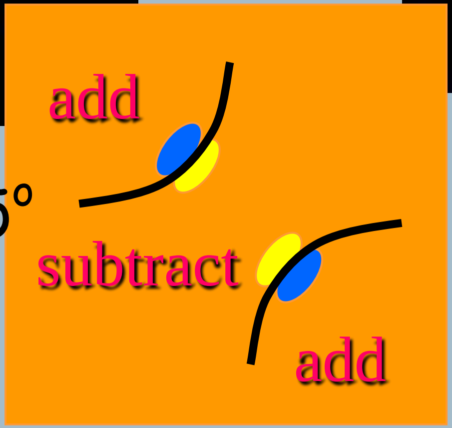
100 gray - 550 → 450 yellow

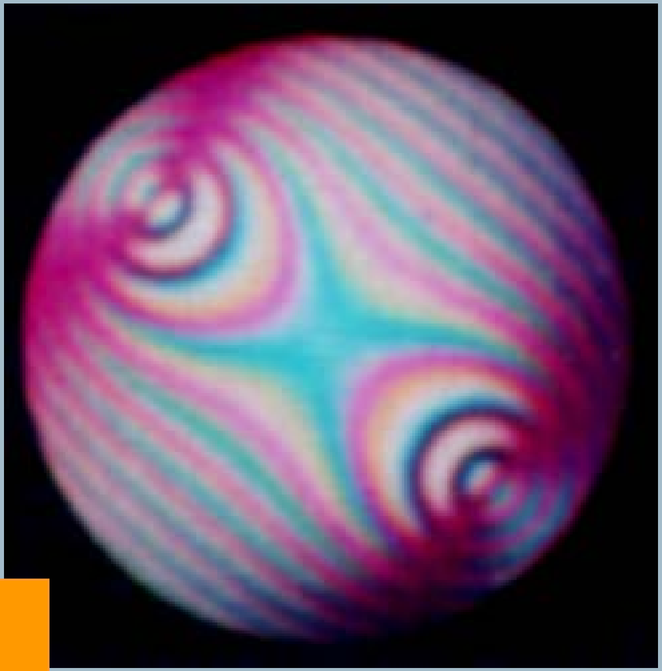
Biaxial Optic Sign

B(-) $\alpha = B_{xa}$ thus β closer to γ (in stage)



Centered B_{xa} 2V = 35°





Centered B_{xa} 2V = 35°
With accessory plate

Biaxial Optic Sign

B(+) $\gamma = B_{xa}$ thus β closer to α (in stage)

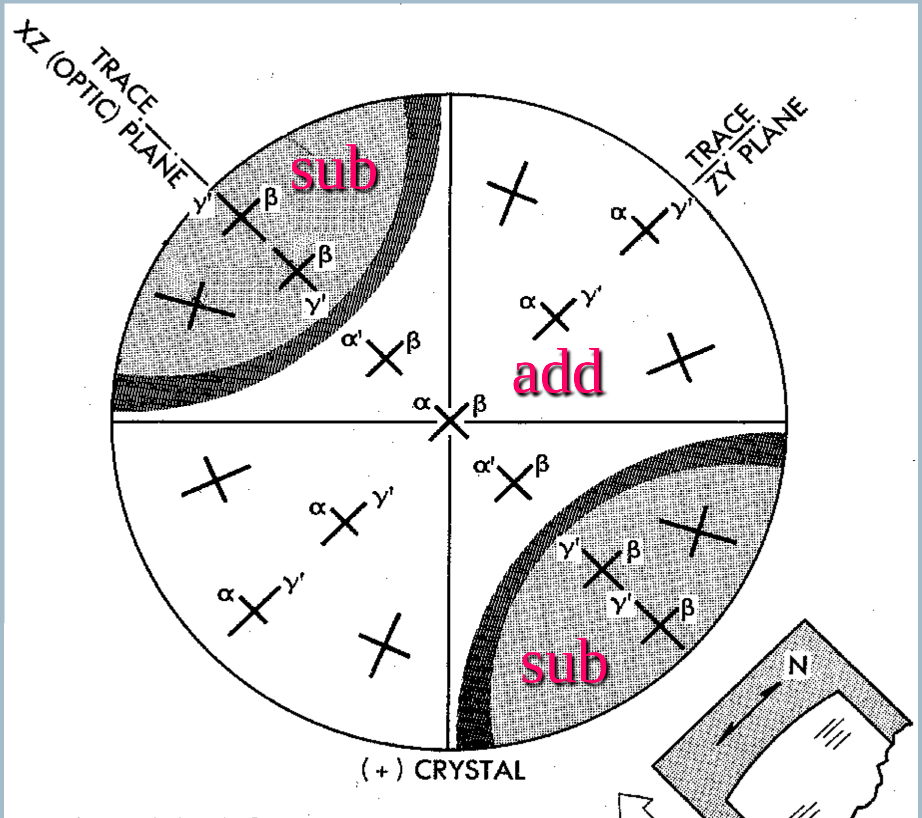
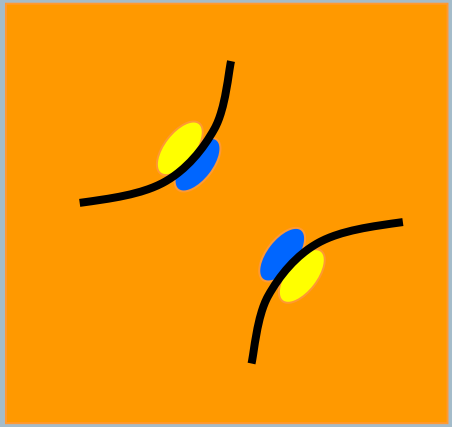
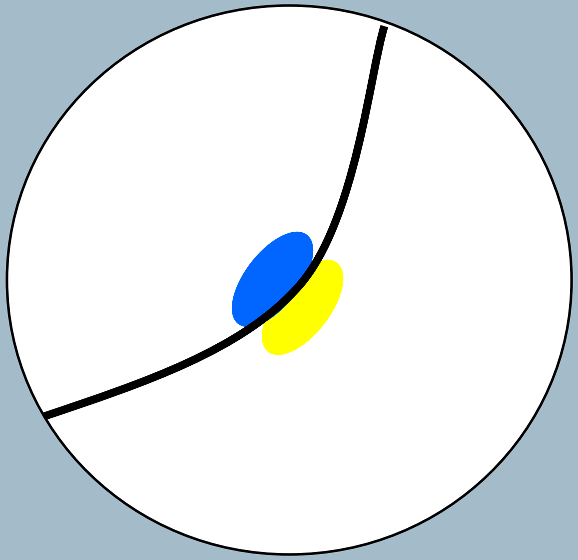


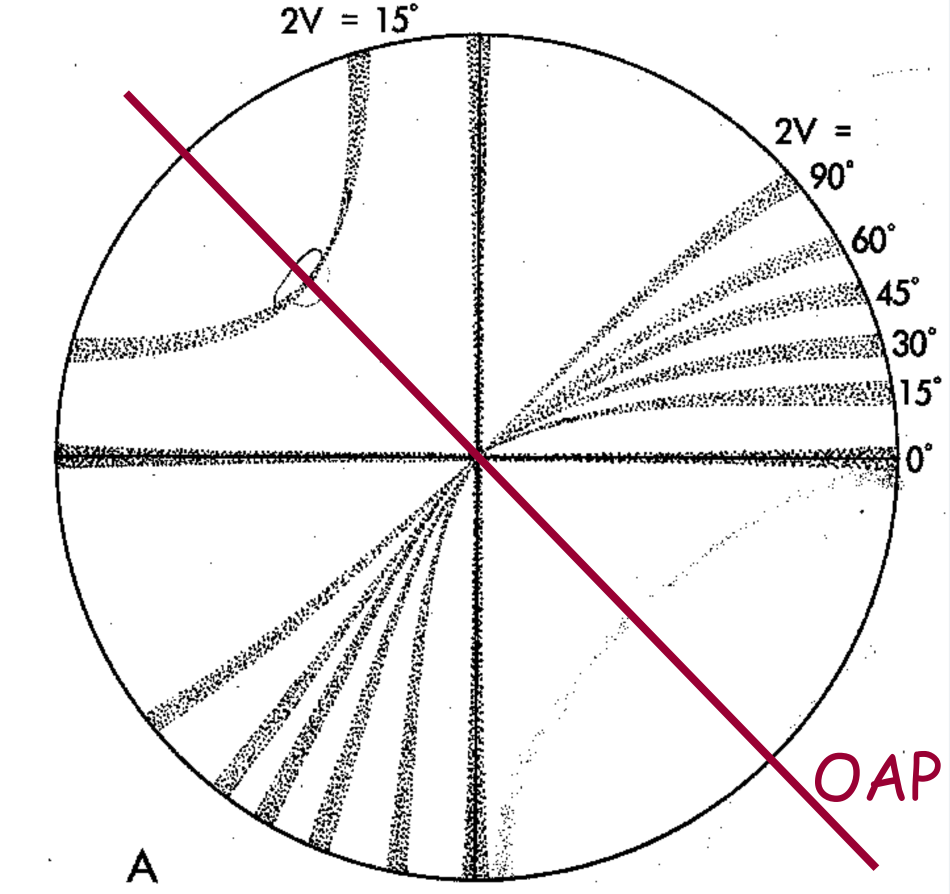
Fig. 11-1A



- Always use Optic Axis Figure & curvature of isogyre to determine optic sign
- How find a crystal for this?
- Blue in NW is (-) still works



Estimating 2V

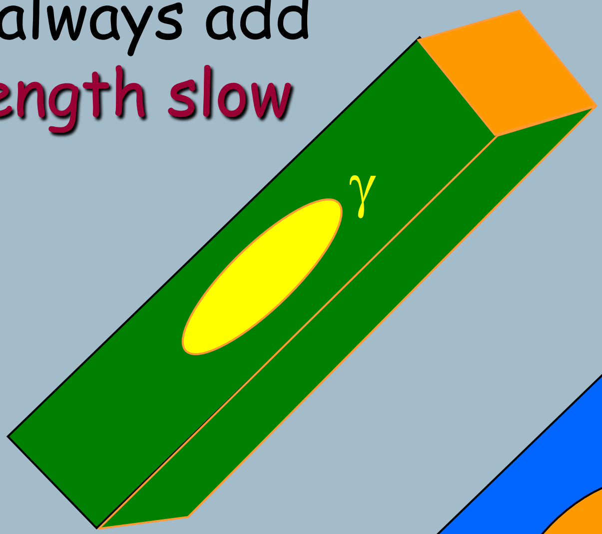


(A) Determination of 2*V* from
optic plane is at 45 degrees (NW-SE) to the

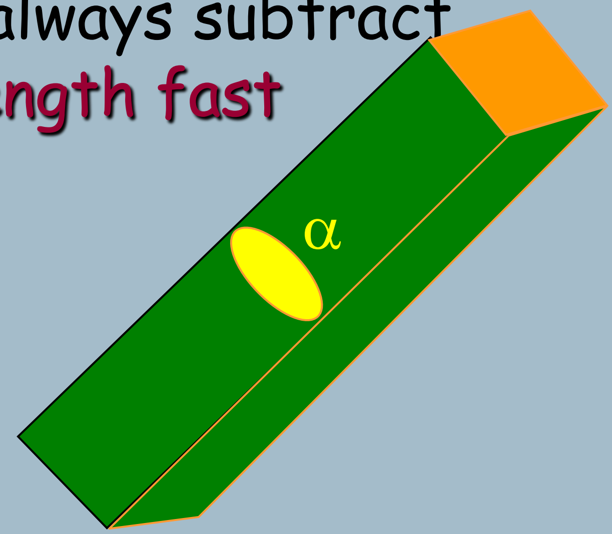
Fig 11-5A Bloss, Optical Crystallography, MSA

Sign of Elongation

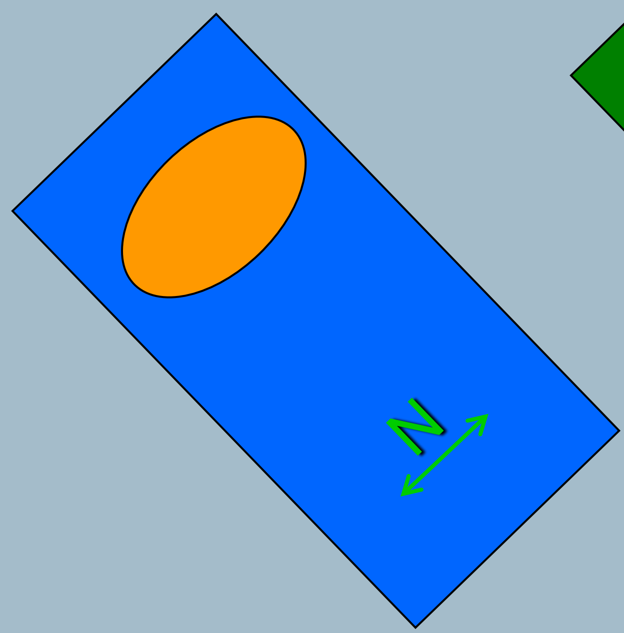
If γ || elongation
will always add
$\rightarrow$ **length slow**



If α || elongation
will always subtract
$\rightarrow$ **length fast**

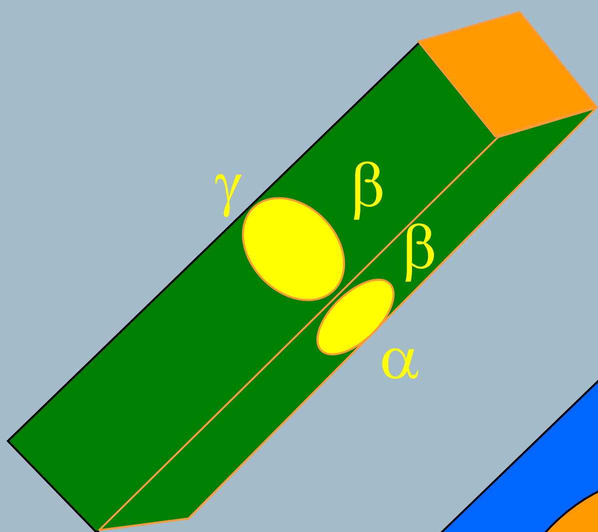


U(+) will also
$\rightarrow$ **length slow**

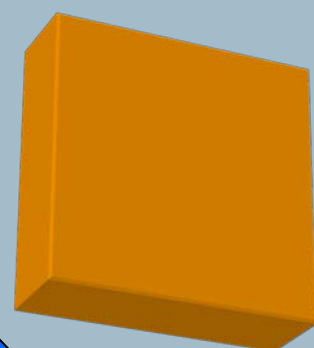


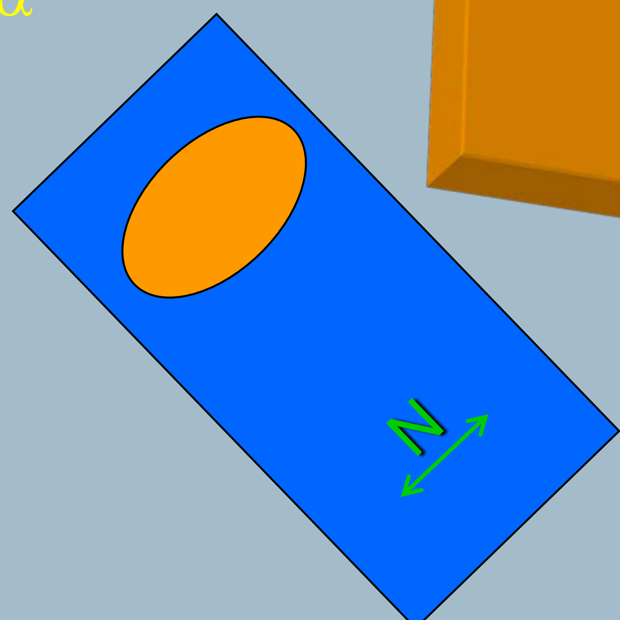
U(-) will also
$\rightarrow$ **length fast**

Sign of Elongation



If β || elongation
Sometimes will add → **length slow**
Sometimes will subtract → **length fast**





Platy minerals may appear elongated too

Can still use sign of elongation on edges