day 18 pg 1

— quizzes
— review question

— review of matrices for linear polarizers

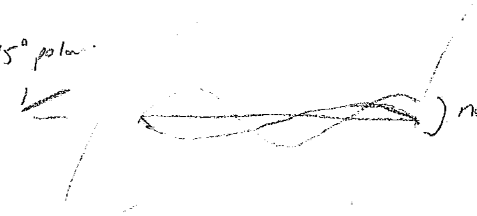
<u>Waveplate</u>: As EM wave goes through material, the index of refraction is larger for one polar. than the other

aka "Optical Retarder"

→ different λ inside material

ex: 45° polar.

(discussed in last chapter)



) now out of phase with each other!

if 90° → circular polarization!

otherwise, elliptical

Such materials called bi<u>fringent</u>

example: calcite $n_o = 1.658$, $n_e = 1.486$

or even ice $n_o = 1.309$, $n_e = 1.313$

happen in materials (esp. crystals) that don't look the same in all directions

(already did this) Calcite Structure

o = ordinary = slow = ⊥ to axis of anisotropy

e = extraordinary = fast = ∥ to axis of anisotropy aka "optical axis"

⇓

different n

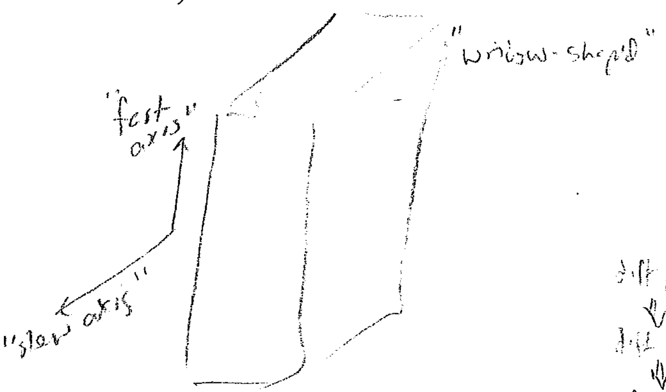
⇓

diff Snell's law angles

⇓

different paths

picture on wikipedia



diff λ's inside

⇓

diff phase by end

⇓

a phase shift!

thickness determines amount of phase shift

$\Delta\text{phase} = \Delta k \cdot d$

$= \frac{2\pi}{(\lambda_{vac}/n_{slow})} - \frac{2\pi}{(\lambda_{vac}/n_{fast})}$

typical applications:

<u>quarter wave plate</u> $\Delta\text{phase} = \frac{\pi}{2} + 2\pi m$

<u>half wave plate</u> $\Delta\text{phase} = \pi + 2\pi m$

<u>quarter wave plate</u> - used for transforming linear to circ. (and vice versa)
needs linear pol @ 45° to fast axis

proof. Jones matrix for $\lambda/4$, fast axis @ 0° = $\begin{pmatrix} 1 & 0 \\ 0 & i \end{pmatrix}$

(see why??)

send in 45° light, $\begin{pmatrix} 1/\sqrt{2} \\ 1/\sqrt{2} \end{pmatrix}$

get out $\begin{pmatrix} 1 & 0 \\ 0 & i \end{pmatrix}\begin{pmatrix} 1/\sqrt{2} \\ 1/\sqrt{2} \end{pmatrix} = \begin{pmatrix} 1/\sqrt{2} \\ 1/\sqrt{2}\, i \end{pmatrix} = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 \\ e^{i90°} \end{pmatrix}$

= LCP !

What would you get w/ -45° light? (1 guess!)

matrix for $\lambda/4$, fast axis @ 45°

$$M = \frac{e^{i\pi/4}}{\sqrt{2}}\begin{pmatrix} 1 & -i \\ -i & 1 \end{pmatrix}$$ (proved in book)

Matrix for $\lambda/4$, fast axis @ θ

$$M = \begin{pmatrix} \cos^2\theta + i\sin^2\theta & \sin\theta\cos\theta - i\sin\theta\cos\theta \\ \sin\theta\cos\theta - i\sin\theta\cos\theta & \sin^2\theta + i\cos^2\theta \end{pmatrix}$$

Good problem: send in RCP to $\lambda/4$, 0°. Get out linear @ 45° ?
-45° ?
other ?

If linear pl not at 45° to fast axis, probably get some sort of elliptical out.

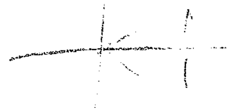
<u>half wave plate</u> - used mainly for <u>rotating</u> linear pol.

proof: matrix for $\frac{\lambda}{2}$, fast axis @ 0° = $\begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$ see why??

let's send in eg 30° linear: $\begin{pmatrix} \sqrt{3}/2 \\ 1/2 \end{pmatrix}$

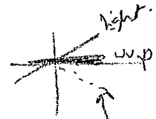
out = $\begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}\begin{pmatrix} \sqrt{3}/2 \\ 1/2 \end{pmatrix} = \begin{pmatrix} \sqrt{3}/2 \\ -1/2 \end{pmatrix}$

$= -30^\circ$!



☆ Rule: if you consider the light to be at 0° and $\lambda/2$ at θ relative to that then final light = 2θ

Did that just happen?



matrix for $\lambda/2$ fast axis @ 45°: $M = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$

matrix for $\frac{\lambda}{2}$ @ θ $M = \begin{pmatrix} \cos^2\theta - \sin^2\theta & 2\sin\theta\cos\theta \\ 2\sin\theta\cos\theta & \sin^2\theta - \cos^2\theta \end{pmatrix} = \begin{pmatrix} \cos 2\theta & \sin 2\theta \\ \sin 2\theta & -\cos 2\theta \end{pmatrix}$

"rotation matrix! (high school!?)"

(Quiz) Final

Jones matrices

(have students guess)

reflection: $m = \begin{pmatrix} -r_p & 0 \\ 0 & r_s \end{pmatrix}$

if "p" means in x-direction
"s" in y direction

why the negative sign?
"handedness inversion"
→ circ. polar = conservation of angular momentum!

transmission $m = \begin{pmatrix} t_p & 0 \\ 0 & t_s \end{pmatrix}$

~~Summary chart~~

~~[illegible]!~~

~~(Quiz)~~

~~[illegible]~~

"Class designed Problem"

incident polar → $\lambda/4$ @ 30° → $\frac{\lambda}{2}$ @ 50° → polar @ 60°

What fraction of original light?