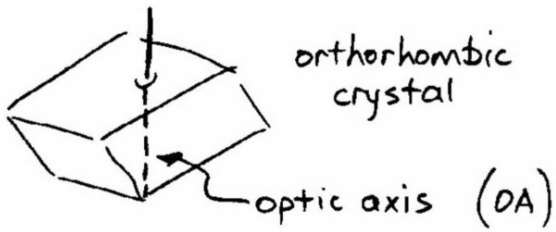
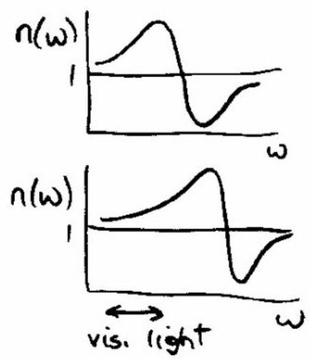
calcite:



different absorption bands for polarization parallel or perpendicular to OA.



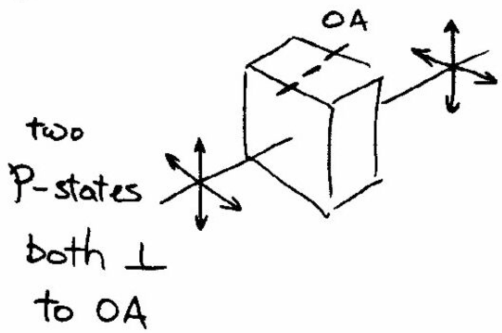
eg $\lambda = 589$ nm (Na)

$n_{\parallel} = 1.486$

$n_{\perp} = 1.658$

$\Rightarrow v_{\parallel} > v_{\perp}$

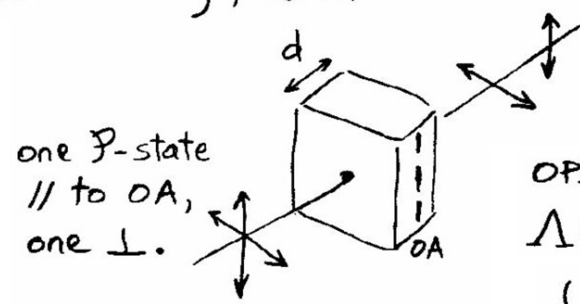
say, have:



<u>no</u> effect

both $\mathcal{P}$-states have polar. ⊥ to OA

alternatively, with

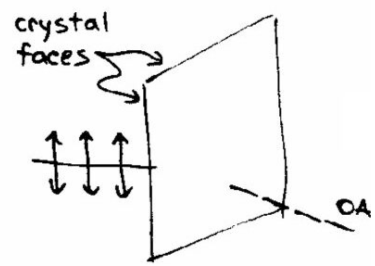


OPD

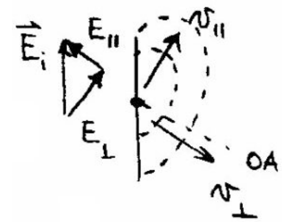
$\Lambda = d(n_{\perp} - n_{\parallel})$

$\delta = k\Lambda$

for polarization neither // or ⊥ to OA, things are more complicated:

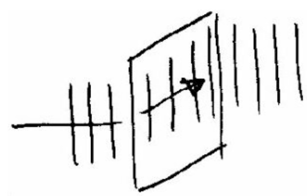


use Huygen's principle:



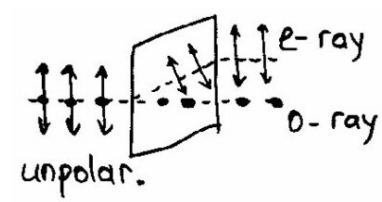
secondary wavefronts are ellipsoidal!

wavefront propagation:



($\vec{k}$ <u>not</u> ⊥ to wavefront!)

in general:



matrix for phase retarder: $\begin{bmatrix} e^{i\varepsilon_x} & 0 \\ 0 & e^{i\varepsilon_y} \end{bmatrix}$

such that:

$$\begin{bmatrix} e^{i\varepsilon_x} & 0 \\ 0 & e^{i\varepsilon_y} \end{bmatrix} \begin{bmatrix} E_{ox} e^{i\phi_x} \\ E_{oy} e^{i\phi_y} \end{bmatrix} = \begin{bmatrix} E_{ox} e^{i(\phi_x + \varepsilon_x)} \\ E_{oy} e^{i(\phi_y + \varepsilon_y)} \end{bmatrix}$$

multiplied by $e^{i(kz-\omega t)}$ $\rightarrow e^{i(kz-\omega t + \phi_i + \varepsilon_i)}$

$$= e^{i(kz - (\omega t - \varepsilon_i) + \phi_i)}$$

$\Rightarrow$ $\varepsilon_x, \varepsilon_y$ are <u>phase</u> <u>lags</u>.

<u>special cases:</u>

a) Quarter Wave Plate $|\Delta\varepsilon| = \pi/2$

eg/ $\varepsilon_y - \varepsilon_x = \pi/2$, SA on y-axis

$$\underset{\approx}{M} = \begin{bmatrix} e^{-i\pi/4} & 0 \\ 0 & e^{i\pi/4} \end{bmatrix} = e^{-i\pi/4} \begin{bmatrix} 1 & 0 \\ 0 & i \end{bmatrix}$$

then,

$$\underset{\approx}{M} \begin{bmatrix} 1 \\ 1 \end{bmatrix} = e^{-i\pi/4} \begin{bmatrix} 1 \\ i \end{bmatrix}$$

left circ. polar. ($\mathcal{L}$-state)

b) Half Wave Plate $|\Delta\varepsilon| = \pi$

eg/ $\varepsilon_x - \varepsilon_y = \pi$, SA on x-axis

$$\underset{\approx}{M} = \begin{bmatrix} e^{i\pi/2} & 0 \\ 0 & e^{-i\pi/2} \end{bmatrix} = e^{i\pi/2} \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$$

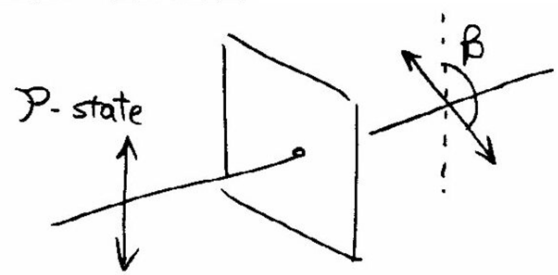
then,

$$\underset{\approx}{M} \begin{bmatrix} 1 \\ 1 \end{bmatrix} = e^{i\pi/2} \begin{bmatrix} 1 \\ -1 \end{bmatrix}$$

rotates plane of polarization (for this input)

another device:

<u>phase</u> <u>rotator</u>



$$\underset{\approx}{M} = \begin{bmatrix} \cos\beta & -\sin\beta \\ \sin\beta & \cos\beta \end{bmatrix}$$

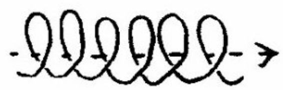
rotate ccw by β

eg/ "optically active" materials

- optical activity occurs in "chiral" materials, i.e. which can be right-handed or left-handed.

eg/ structures like DNA:

right-handed (dextrorotary)



left-handed (levorotary)

} enantiomorphs

also: quartz, sugar, ...

view $\mathcal{P}$-state as linear comb. of $\mathcal{R}$ and $\mathcal{L}$-states:

$$\begin{bmatrix}1\\0\end{bmatrix} = \frac{1}{2}\begin{bmatrix}1\\-i\end{bmatrix} + \frac{1}{2}\begin{bmatrix}1\\i\end{bmatrix}$$

experience diff. indices, $n_{\mathcal{R}}, n_{\mathcal{L}}$
("circular birefringence")

result after propagation: $\Delta\phi_i = k d n_i$

$$\frac{1}{2}e^{+i\Delta\phi_{\mathcal{R}}}\begin{bmatrix}1\\-i\end{bmatrix} + \frac{1}{2}e^{+i\Delta\phi_{\mathcal{L}}}\begin{bmatrix}1\\i\end{bmatrix}$$

$$= \frac{1}{2}\begin{bmatrix}e^{i\Delta\phi_{\mathcal{R}}} + e^{i\Delta\phi_{\mathcal{L}}}\\ -ie^{i\Delta\phi_{\mathcal{R}}} + ie^{i\Delta\phi_{\mathcal{L}}}\end{bmatrix}$$

$$= \frac{1}{2}e^{i(\Delta\phi_{\mathcal{R}}+\Delta\phi_{\mathcal{L}})/2}\begin{bmatrix}e^{i(\Delta\phi_{\mathcal{R}}-\Delta\phi_{\mathcal{L}})/2} + e^{-i(\Delta\phi_{\mathcal{R}}-\Delta\phi_{\mathcal{L}})/2}\\ -ie^{i(\Delta\phi_{\mathcal{R}}-\Delta\phi_{\mathcal{L}})/2} + ie^{-i(\Delta\phi_{\mathcal{R}}-\Delta\phi_{\mathcal{L}})/2}\end{bmatrix}$$

$$= e^{ikd(n_{\mathcal{R}}+n_{\mathcal{L}})/2}\begin{bmatrix}\cos kd(n_{\mathcal{R}}-n_{\mathcal{L}})/2\\ -\sin kd(n_{\mathcal{R}}-n_{\mathcal{L}})/2\end{bmatrix}$$

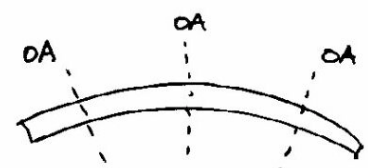
thus $\beta = -kd(n_{\mathcal{R}}-n_{\mathcal{L}})/2$ ($\beta < 0$ here for $n_{\mathcal{R}} > n_{\mathcal{L}}$ since defined it for ccw rot.).

Optical Modulators

- devices with variable influence on polarization

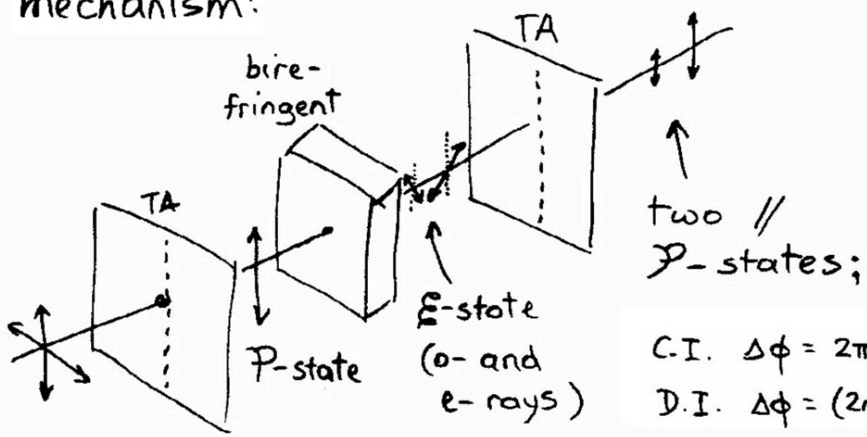
Photoelasticity – stress induced birefringence (nonuniform stress defines an optical axis)

eg



- place between polarizers with // TA and see interference!

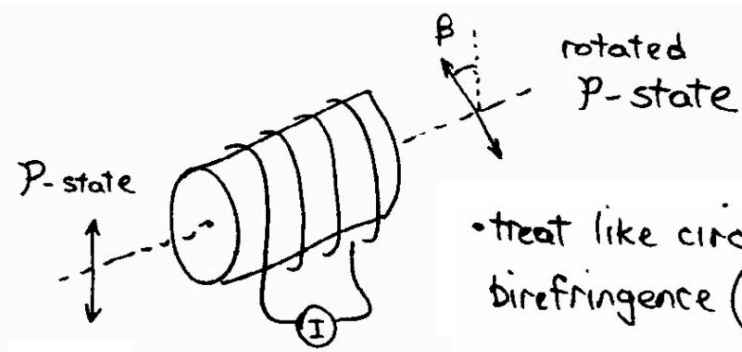
mechanism:



C.I. $\Delta\phi = 2\pi m$

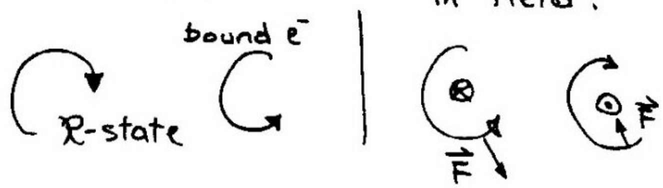
D.I. $\Delta\phi = (2m+1)\pi$

Faraday effect : (magneto-optic) - B-field in material will rotate P-state



• treat like circular birefringence ($n_R \neq n_L$)

mechanism :



opposite mag. force

⇒ diff. elec. polar.

⇒ $n_R \neq n_L$

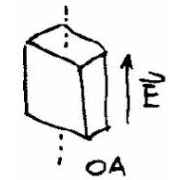
$\beta = V^{\circ} B d$ ← Verdet constant

Kerr effect (electro-optic ; nonlinear)

- applied E-field will induce birefringence

eg. $SrTiO_3$

Δa varies with E



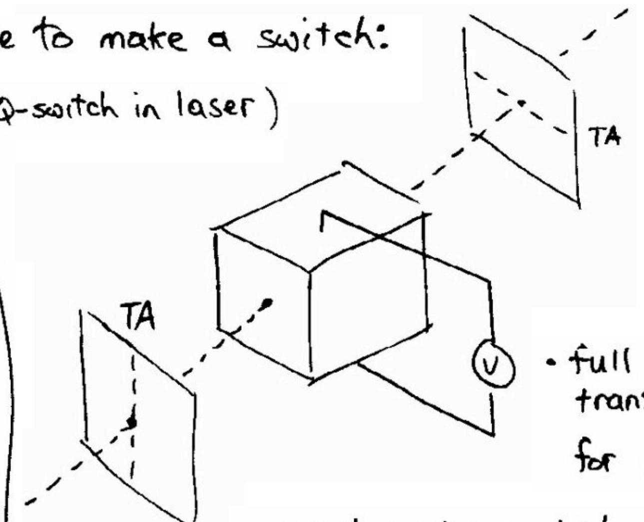
$\Delta n = \lambda_0 K E^2$ Kerr constant

or

$\Delta n \propto E$ Pockel effect

use to make a switch:

(Q-switch in laser)

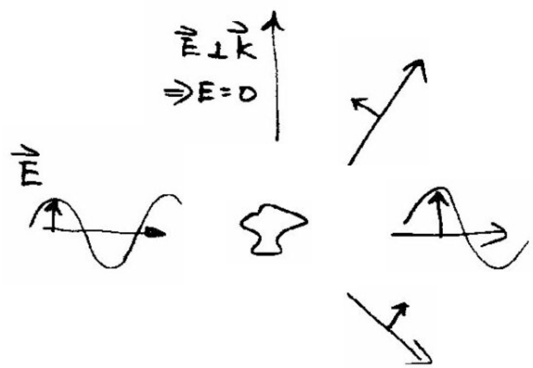


• full transmission for $\beta = \pi$

• operates at very high freq, up to 30 GHz.

Additional Means of Producing Polarized Light:

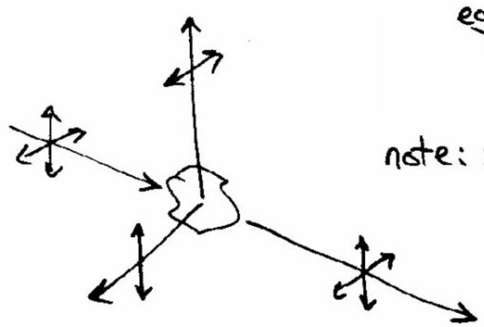
scattering: scattered radiation has same polarization as the incident radiation:



- <u>no</u> scattered radiation in direction of polarization

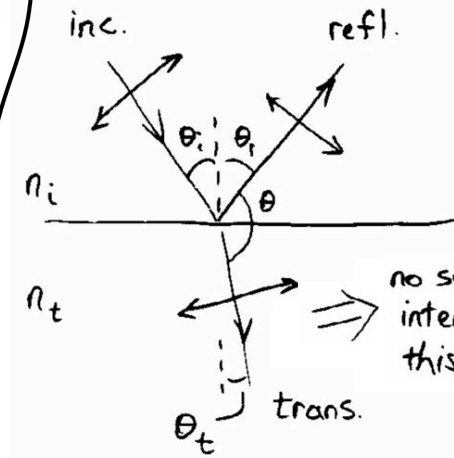
thus, for unpolarized source look normal to the incident direc. and see polarization;

eg/ polarization of light from sky



note: scattered intensity is generally quite <u>weak</u>.

reflection: Brewster's angle (θ_p)



$\Rightarrow$ no scattered intensity in this direction

- zero refl. amp. when

$$\theta = 90^\circ = 180^\circ - (\theta_r + \theta_t)$$

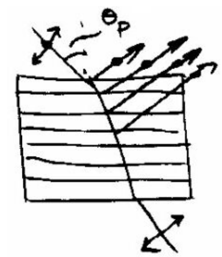
$$\Rightarrow \theta_t = 90^\circ - \theta_i$$

$$n_i \sin\theta_i = n_t \sin\theta_t$$

$$\boxed{\tan\theta_p = \frac{n_t}{n_i}}$$

- reflected wave composed of superposition of scattered wave from medium, which have zero amp. in direction $\perp$ to $\vec{k}_t$.

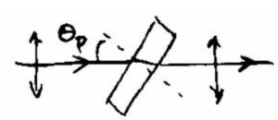
eg/ "pile of plates" polarizer



- reflect only $\perp$ polar.

$\Rightarrow$ trans. beam, after many reflec., has only // polar.

eg/ Brewster window (on laser tube)



no reflec. losses