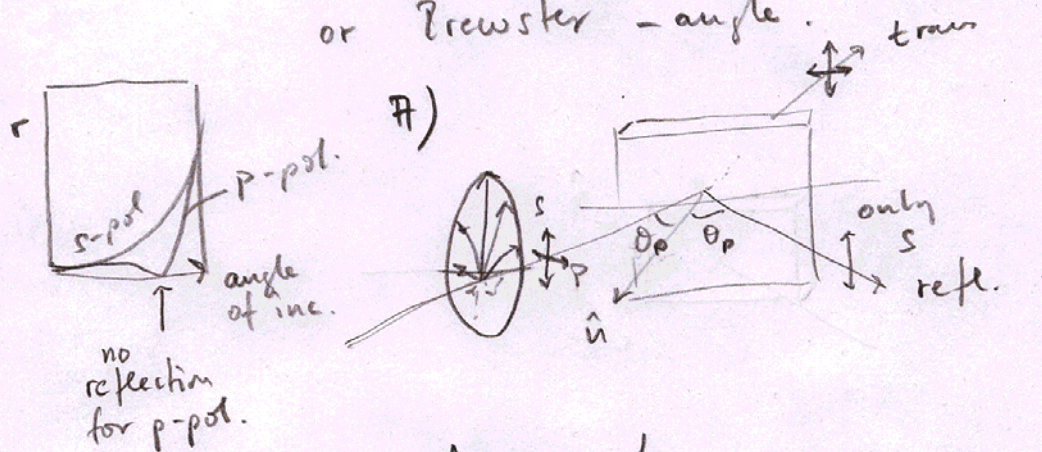


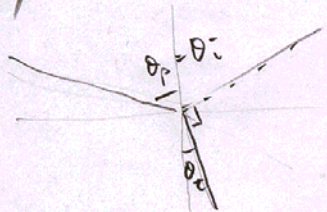
Del A: 1. Use the phenomenon of "polarization" or "Brewster" - angle.



Arrangement.

Hecht eq. 8.25. $\tan \theta_p = \frac{n_t}{n_i} = \frac{4}{1} \Rightarrow \theta_p \approx 76^\circ$

B) Snell $n_i \sin \theta_i = n_t \sin \theta_t \Rightarrow \sin \theta_t = \sin 76^\circ \cdot \frac{1}{4}$



$\theta_t = 14.04^\circ$

check: $r_{\parallel} = \frac{\tan(\theta_i - \theta_t)}{\tan(\theta_i + \theta_t)} = 0$ OK.

$r_{\perp} = -\frac{\sin(\theta_i - \theta_t)}{\sin(\theta_i + \theta_t)} = -\sin(76^\circ - 14^\circ) = -0.8829$

$I_{\perp} \propto r_{\perp}^2 = 0.78$

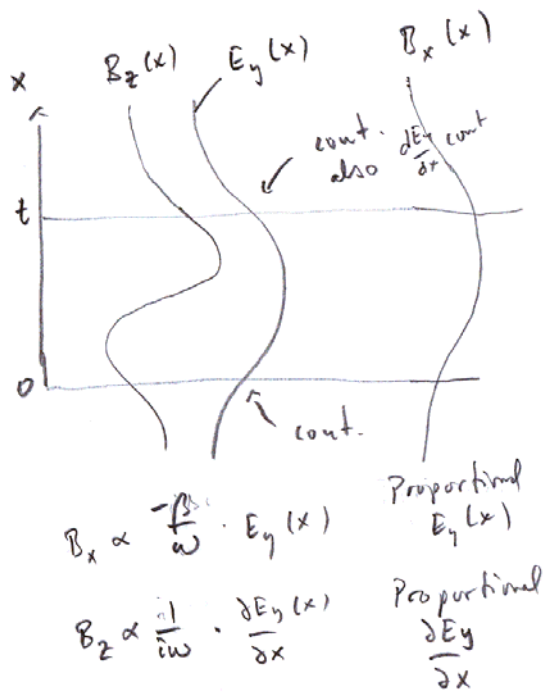
almost 80% reflected as s-pol.

efficiency: $\frac{I_{\perp}}{I_{\parallel} + I_{\perp}} = \frac{0.5 \cdot 0.78}{0.5 + 0.5} \approx 0.39$

Ans. if unpol light is used, ca 40% is reflected as s-pol @ incident angle $\sim 76^\circ$

Del A. 2:

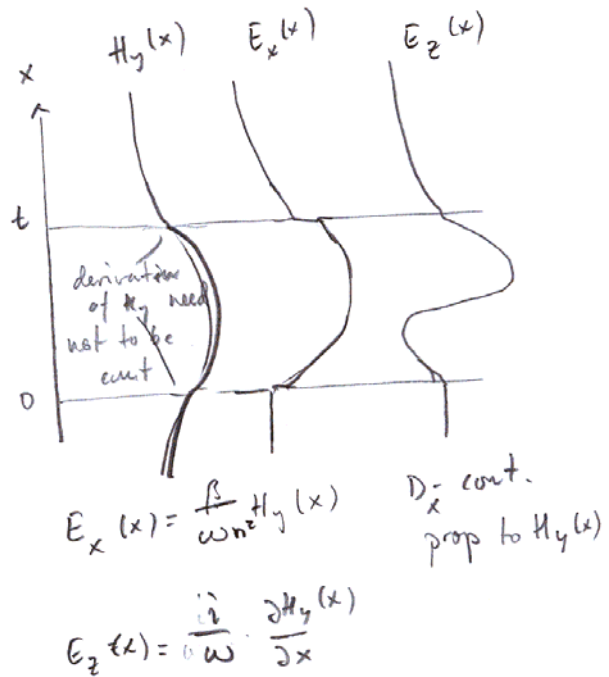
TE: we know E_y



use: $\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$
 $\rightarrow i\beta \quad \rightarrow -i\omega$

all field prop. $e^{i(\beta z - \omega t)}$

TM: we know H_y



use $\vec{\nabla} \times \vec{H} = \frac{\partial \vec{D}}{\partial t} = n^2 \frac{\partial \vec{E}}{\partial t}$
 $\rightarrow i\beta \quad \rightarrow -i\omega$

Del A3!

A: $n_E > n_o$

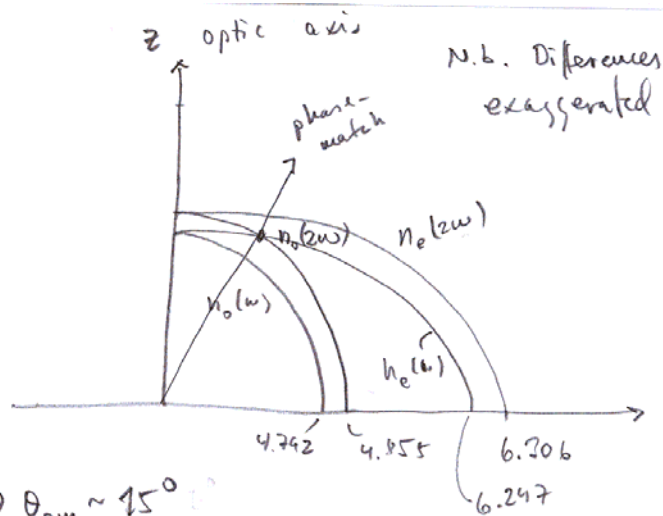
phase-matching when

$$\frac{1}{4.855^2} = \frac{\cos^2 \theta}{4.742^2} + \frac{\sin^2 \theta}{6.247^2}$$

$\uparrow 2\omega$
(5 μm)

$\uparrow \omega$
(10 μm)

$\Rightarrow \theta_{pm} \sim 15^\circ$



B: $\begin{matrix} \omega\omega & 2\omega \\ ee \rightarrow & o \end{matrix}$ ans.

A4: Kleinmann does not change anything in this case (!).

$$\begin{pmatrix} d_{11} & -d_{11} & 0 & d_{14} & 0 & 0 \\ 0 & 0 & 0 & 0 & -d_{14} & -d_{11} \\ 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} \bar{E}_x^2 \\ \bar{E}_y^2 \\ \bar{E}_z^2 \\ 2\bar{E}_x\bar{E}_y \\ 2\bar{E}_x\bar{E}_z \\ 2\bar{E}_y\bar{E}_z \end{pmatrix} \rightarrow$$

$\rightarrow d_{11} (\bar{E}_x^2 - \bar{E}_y^2) + 2d_{14} \bar{E}_y \bar{E}_z : \hat{x}$

$-d_{14} \bar{E}_x \bar{E}_z - 2d_{11} \bar{E}_x \bar{E}_y : \hat{y}$

apply ee $\uparrow$

$e: \begin{pmatrix} \cos \theta \cos \phi \\ \cos \theta \sin \phi \\ -\sin \theta \end{pmatrix}$

project onto o: $\begin{pmatrix} -\sin \phi \\ \cos \phi \\ 0 \end{pmatrix}$
ans.

$\Rightarrow d_{eff}(\theta, \phi) = \pm (d_{11} \cos^3 \theta \sin 2\phi + d_{14} \sin 2\theta)$

AS: Apply C_2 around x

$$\Rightarrow \begin{array}{l|l|l} r_{11} \rightarrow r_{11} & r_{12} \rightarrow -r_{12} & 0 \\ r_{21} \rightarrow r_{21} & r_{22} \rightarrow -r_{22} & 0 \\ r_{41} \rightarrow r_{41} & r_{42} \rightarrow -r_{42} & 0 \\ r_{51} \rightarrow -r_{51} & r_{52} \rightarrow r_{52} & 0 \\ r_{61} \rightarrow -r_{61} & r_{62} \rightarrow r_{62} & 0 \end{array} \quad \begin{array}{l} 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{array} \quad \left| \begin{array}{ccc} r_{11} & 0 & 0 \\ -r_{11} & 0 & 0 \\ 0 & 0 & 0 \\ r_{41} & 0 & 0 \\ 0 & -r_{41} & 0 \\ 0 & -r_{11} & 0 \end{array} \right|$$

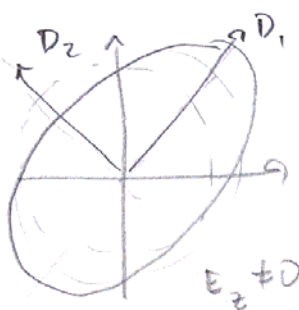
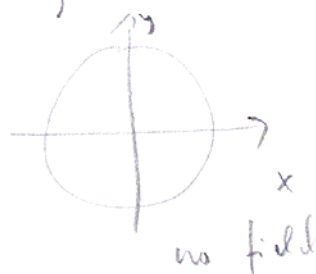
ans. $\uparrow$

Prob: $\begin{pmatrix} r_{11} & 0 & 0 \\ -r_{11} & 0 & 0 \\ 0 & 0 & 0 \\ r_{41} & 0 & 0 \\ 0 & -r_{41} & 0 \\ 0 & -r_{11} & 0 \end{pmatrix} \begin{pmatrix} E_x \\ E_y \\ E_z \end{pmatrix} \Rightarrow \Delta \eta_{ij} = \begin{pmatrix} r_{11} E_x - r_{11} E_z - r_{41} E_y \\ -r_{11} E_z - r_{11} E_y & r_{41} E_x \\ -r_{41} E_y & r_{41} E_x & 0 \end{pmatrix}$

$\uparrow$ arbitrary static field

ans. I would apply static $E_z \Rightarrow \Delta \eta_{ij} = \begin{pmatrix} 0 & -r_{11} E_z \\ -r_{11} E_z & 0 \end{pmatrix}$

propagating along z, then would split the degenerate modes



With input vertical (or horiz) these would be a phase shift along D_1 & D_2 $\rightarrow$ pol. rotation depends on L/λ

87:

$S_{out} = M \cdot S_{in}$
 we measure S_{out} comp. S_0 (int) use Mueller mat in Table 8.6

1 exp.

$$\frac{1}{2} \begin{pmatrix} 1 & -1 & 0 & 0 \\ -1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} S_0 \\ S_1 \\ S_2 \\ S_3 \end{pmatrix} = \frac{1}{2} \begin{pmatrix} S_0 - S_1 \\ -S_0 + S_1 \\ 0 \\ 0 \end{pmatrix} \leftarrow$$

2 exp

$$\frac{1}{2} \begin{pmatrix} 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} S_0 \\ S_1 \\ S_2 \\ S_3 \end{pmatrix} = \frac{1}{2} (S_0 + S_2) \leftarrow$$

↑ we measure int. S_0

3 exp

$$\frac{1}{2} \begin{pmatrix} 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} S_0 \\ S_1 \\ S_2 \\ S_3 \end{pmatrix} = \frac{1}{2} (S_0 + S_1)$$

4 exp.

1st exp.

$$\frac{1}{2} \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & -1 \\ 0 & 0 & 1 & 0 \end{pmatrix} \begin{pmatrix} S_0 \\ S_1 \\ S_2 \\ S_3 \end{pmatrix} = \begin{pmatrix} S_0 \\ S_1 \\ -S_2 \\ S_3 \end{pmatrix}$$

exp. 4. 2nd. BT cont.

$$\frac{1}{2} \begin{pmatrix} 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} S_0 \\ S_1 \\ -S_3 \\ S_2 \end{pmatrix} = \frac{1}{2} (S_0 - S_3)$$

$$\left. \begin{aligned} \frac{1}{2} (S_0 - S_1) &= 0.25 \\ \frac{1}{2} (S_0 + S_1) &= 0.75 \end{aligned} \right\} \begin{aligned} S_0 &= 1 \\ S_1 &= 0.5 \end{aligned}$$

$$\frac{1}{2} (S_0 + S_2) = 0.5 \Rightarrow S_2 = 0$$

$$\frac{1}{2} (S_0 - S_3) = 0.25 \Rightarrow S_3 = 0.5$$

$$\begin{pmatrix} S_0 \\ S_1 \\ S_2 \\ S_3 \end{pmatrix} = \begin{pmatrix} 1 \\ 0.5 \\ 0 \\ 0.5 \end{pmatrix}$$

Degree of polarization

$$V = \frac{\sqrt{S_1^2 + S_2^2 + S_3^2}}{S_0} \sim 0.707$$

Polarization ellipse for the polarized part.

$S_1 > 0 \Rightarrow$ more horizontal

$S_2 = 0$ not $\nearrow$ or $\nwarrow$

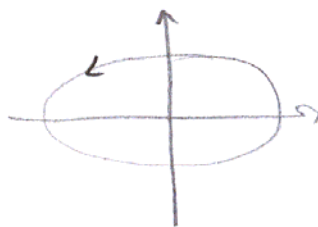
$S_3 > 0$ right circular component larger

∴ polarized part: elliptical, more horizontal than vertical

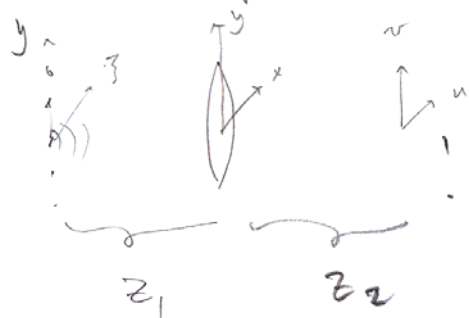
No "kitt"

since

$S_2 = 0$



P.8. A point source emits spherical waves



In the lens plane the emitted wave can be written:

$$U_e(x, y) = U_0 \cdot \frac{1}{z_1} \cdot e^{i \frac{k}{2z_1} \cdot \left((x-0)^2 + (y-0)^2 \right)}$$

Here we used the paraxial approximation and neglect an unimportant phase factor.

depends on where the point source is located

After passing the lens, the field distribution becomes

$$U_e'(x, y) = U_e(x, y) \cdot e^{-i \frac{k}{2f} (x^2 + y^2)}$$

again we neglected an unimportant (constant) phase factor,

Finally, Fresnel diffraction will give the field distribution at the plane u, v at a distance z_2 after the lens

$$U(u, v) = \frac{e^{ikz_2}}{i\lambda z_2} \iint U_e'(x, y) e^{i \frac{k}{2z_2} \left((u-x)^2 + (v-y)^2 \right)} dx dy$$

(again paraxial approx)

BF, cont,

inserting every thing in succumb we obtain:

$$u(u,v) = \frac{e^{ikz_c}}{i\lambda z_c} u_0 \cdot \frac{1}{z_1} \cdot e^{i\frac{k}{z_1}(x^2+y^2)} \cdot e^{i\frac{k}{z_2}(u^2+v^2)} \iint \dots dx dy$$

$\frac{e^{i\phi}}{i\lambda z_c z_1}$ this phase term disappears when we consider intensity
inside intgral is left:

$$\dots \iint_{-\infty}^{\infty} \left[e^{i\frac{k}{2} \left[\left(\frac{1}{z_1} - \frac{1}{f} + \frac{1}{z_2} \right) (x^2 + y^2) \right]} \right] \cdot e^{ik \left[\underbrace{x \left(\frac{x}{z_1} + \frac{y}{z_2} \right)}_{f_x} - \underbrace{y \left(\frac{y}{z_1} + \frac{x}{z_2} \right)}_{f_y} \right]} dx dy$$

FT provided this term vanishes

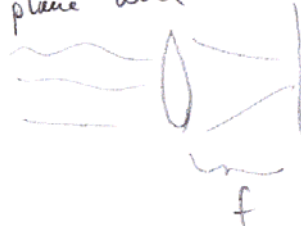
FT-operators with freq f_x, f_y

$$\text{hence } \frac{1}{f} = \frac{1}{z_1} + \frac{1}{z_2}$$

Profound Conclusion: the FT is found where (point) the source is imaged 😊

note:
cf.

plane wave



FT at focal plane

$$\frac{1}{f} = \frac{1}{\infty} + \frac{1}{z_2} \Rightarrow z_2 = \frac{1}{f}$$

89.

$\theta = 53^\circ$ what applies

$$n_{\text{glass}} \cdot \sin 53^\circ = n_{\text{air}} \cdot \sin \theta_{\text{out}} \Rightarrow$$

$$1.5 \cdot \sin 53^\circ = 1.19 \Rightarrow \sin \theta_{\text{out}} \text{ does not exist}$$

TOTAL INTERNAL REFLECTION

$$r_{\perp} = \frac{\cos \theta_i - \sqrt{n_{ti}^2 - \sin^2 \theta_i}}{\cos \theta_i + \sqrt{n_{ti}^2 - \sin^2 \theta_i}}$$

4.70 Hecht

$$r_{\parallel} = \frac{n_{ti}^2 \cos \theta_i - \sqrt{n_{ti}^2 - \sin^2 \theta_i}}{n_{ti}^2 \cos \theta_i + \sqrt{n_{ti}^2 - \sin^2 \theta_i}}$$

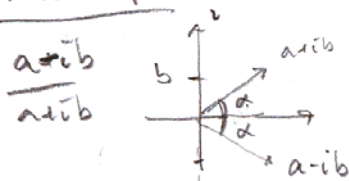
4.71 Hecht

$$n_{ti} = \frac{n_t}{n_i} = \frac{1}{1.5} = 0.66666 \text{ in this case since } n_i > n_t$$

$$\Rightarrow_{\text{TE}} r_{\perp} = \frac{0.602 - \sqrt{(\frac{2}{3})^2 - 0.6378}}{0.602 + \sqrt{(\frac{2}{3})^2 - 0.6378}} = \frac{0.602 - 0.44i}{0.602 + 0.44i} = e^{-i \frac{72.32 \cdot \pi}{180}}$$

$$\text{TM } r_{\parallel} = \frac{0.268 - \sqrt{(\frac{2}{3})^2 - 0.6378}}{0.268 + \sqrt{(\frac{2}{3})^2 - 0.6378}} = \frac{0.268 - 0.44i}{0.268 + 0.44i} = e^{-i \frac{117.31 \cdot \pi}{180}}$$

Phase-shift



$$\alpha = \tan^{-1} \frac{b}{a}$$

$$\left. \begin{aligned} \phi_{\text{TE}} &= -72.32^\circ \\ \phi_{\text{TM}} &= -117.31^\circ \end{aligned} \right\} \phi_{\text{TM}} - \phi_{\text{TE}} = -45^\circ (!)$$

$$\Rightarrow \phi = 2\alpha$$

2 reflection $\Rightarrow 2 \times \phi \Rightarrow -90^\circ$ quarter wave plate

$\Rightarrow E_{\text{in}} = \begin{pmatrix} 1 \\ 1 \end{pmatrix} \rightarrow$ circularly polarized light out

THIS DEVICE IS CALLED A FRESNEL RHOMB see Hecht