CHEM 524 -- Outline (Part 5) – 2011 update

For html Version of This Set of Notes with Linked Figures from 2005 CLICK HERE

Text: Chapter 3, Sect 2-3 directly relates to this lecture, added material needed

III. C. Special Topics in optics

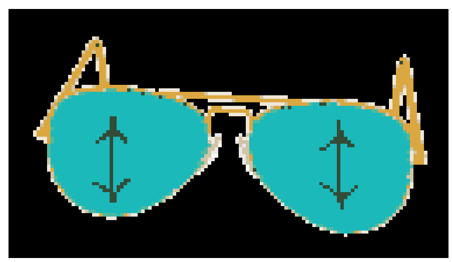
1. Linear Polarizers -- random polarization in - linear out (i.e. **E** field with specific orientation)

   a. Absorptive (or reflective -- for metal): Aligned dipole transitions select polarization

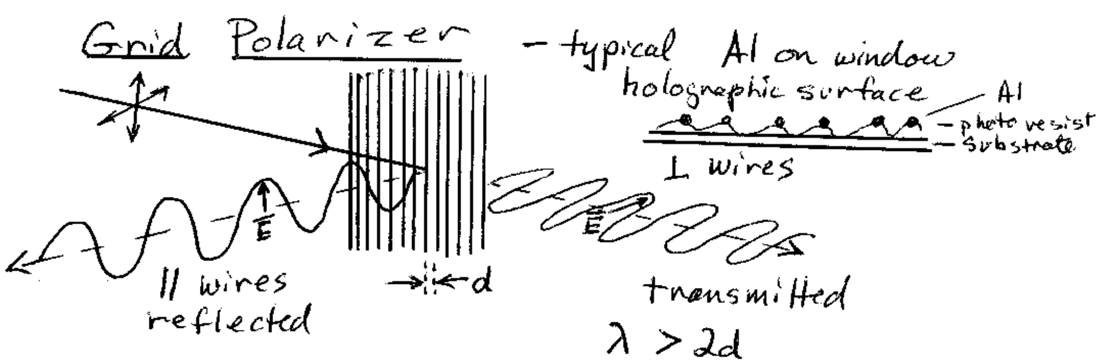
   -- vis & uv, absorbing (Polaroid, stretched film impregnated with dye, can be big, orient by binding to oriented polymer)—"glare" is polarized, sheets of Polaroid make sunglasses

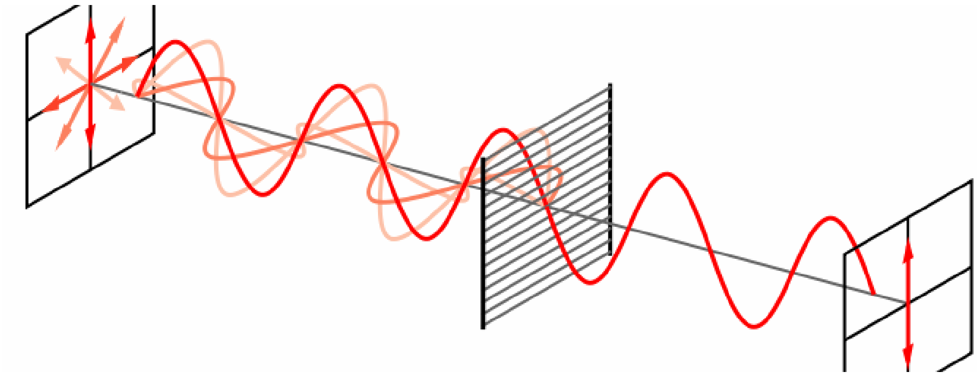






-- IR: reflection: wire (grid) --made like a grating (narrow spacing $\lambda > 2d$), use hologram, expose photo resist, evaporate metal across ridges, minimize d for near IR





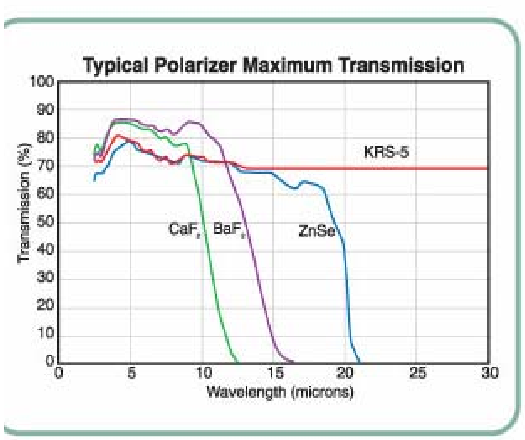
Wire array by first photoetch a coating with hologram, highest groove density for best near IR.

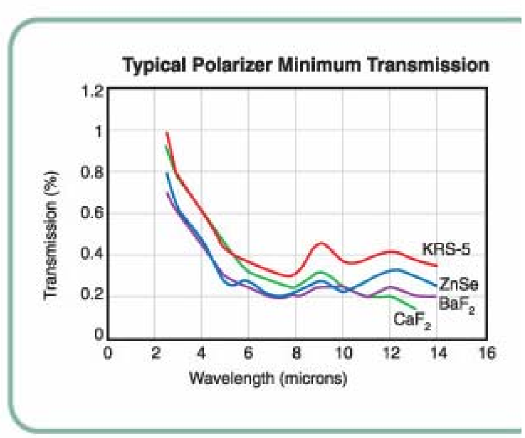
Al is vapor deposited on ridges by tilting substrate to flow direction,

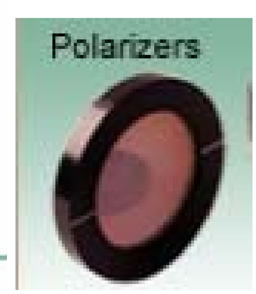
Cambridge Physical Science (sold under various names) – Now Thorlabs.com lists them

Wire Grid Polarizer Specifications

Material	CaF_2		BaF_2		ZnSe		KRS-5	
Wavelength	3 µm	8 µm	3 µm	10 µm	3 µm	10 µm	3 µm	15 µm
Typical Extinction Ratio	150:1	300:1	150:1	300:1	150:1	300:1	150:1	300:1
Wire Grid Spacing (Nominal)	2700 Grooves/mm							
Parallelism	≤ 3 arcmin							
Surface Flatness	λ/20 @ 10.6 µm for Ø25 mm Polarizers λ/10 @ 10.6 µm for Ø50 mm Polarizers							
Substrate Thickness	2 ± 0.5 mm for Ø25 mm Polarizers 5 ± 0.5 mm for Ø50 mm Polarizers							
Ring Thickness	5.0 mm ± 0.2 mm							
Ring Diameter Tolerance	+0.0/-0.2 mm							

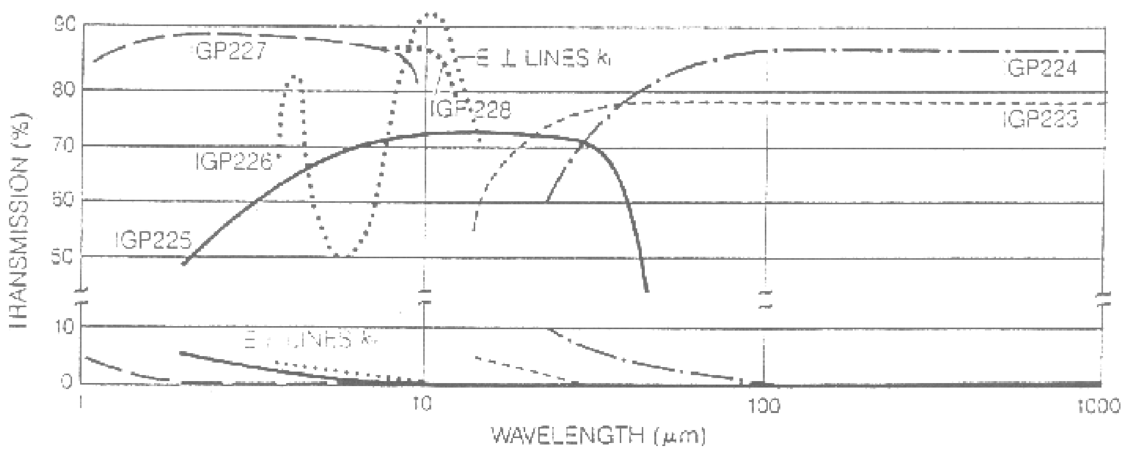






Performance Specifications

MODEL NUMBER	IGP228 (BaF_2)	IGP227 (CaF_2)	IGP226 (Ge)	IGP225 (KRS 5)	IGP224	IGP223
Spectral Range	1-12 µm	1-9 µm	8-14 µm	2-35 µm	50-1000 µm	20-1000 µm
Substrate Material	Barium Fluoride	Calcium Fluoride	AR coated Ge	KRS-5	Polyester	Polyethylene
Substrate Thickness	2 mm	2 mm	2 mm	2 mm	2.5 µm	0.5 mm
Aperture	25 mm dia.	25 mm dia.	25 mm dia.	25 mm dia.	37 mm dia.	25 mm dia.
Transmission (k_1)* Efficiency	85%	85%	90% (10 µm)	70% (10 µm) 50% (3 µm)	90%	80%
Grid Spacings (period)	0.25 µm	0.25 µm (approx)	0.4 µm (approx)	0.4 µm (approx)	10 µm	4 µm
Extinction Ratio*	42 (3.9 µm) 14 (1.5 µm)	42 (3.9 µm) 14 (1.5 µm)	> 190 (10 µm)	> 9 (3 µm) > 140 (10 µm)	> 15	> 12 (20 µm) > 20 (30 µm)
Degree of Polarization*	98% (3.9 µm) 93% (1.5 µm)	93% (1.5 µm) 98% (3.9 µm)	> 99% (10 µm)	> 99% (10 µm) > 88% (3 µm)	> 93%	> 92% (20 µm) > 95% (30 µm)
Holder Diameter	1.625in(4.13cm)	1.625in(4.13cm)	1.625in(4.13cm)	1.625in(4.13cm)	2.125in(54cm)	1.625in(4.13cm)
Holder Thickness	0.25in(0.635cm)	.25in(0.635cm)	.25in(0.635cm)	.25in(0.635cm)	.25in(0.635cm)	.25in(0.635cm)

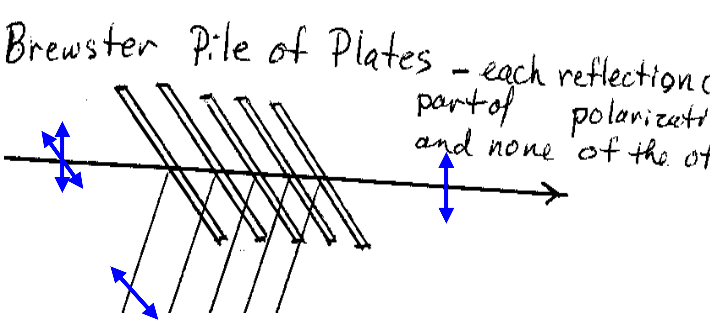


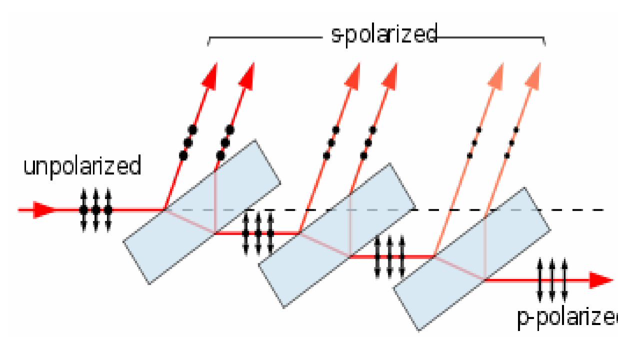
Substrates affect transmission, CaF_2 or BaF_2 for near IR, Ge mid IR,

wire density controls polarization ratio

b. Reflecting (due to index change)

1. Brewster angle ([stack of plates]), each one loses some intensity from (horizontal, ⊥) polarization and transmits all of the other (vertical, | |) polarization at Brewster angle





2. **Prism** uses birefringence properties--different index two polarizations —
   - o result: total internal reflection of one polarization, other transmit (Glan Prism)
   - o one polarization is transmitted with some reflection loss, the other totally reflected (but angle sensitive, narrow angle of acceptance),

a. Glan Taylor has air gap, narrow angle of acceptance, capable of high power

Typically calcite ($CaCO_3$) big difference in n_x, n_y, but far-uv and IR absorbance

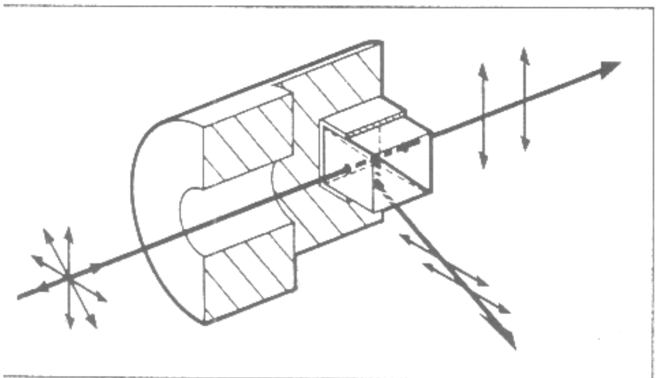


Fig. 1 Oriel Glan-Taylor Polarizer with exit window.

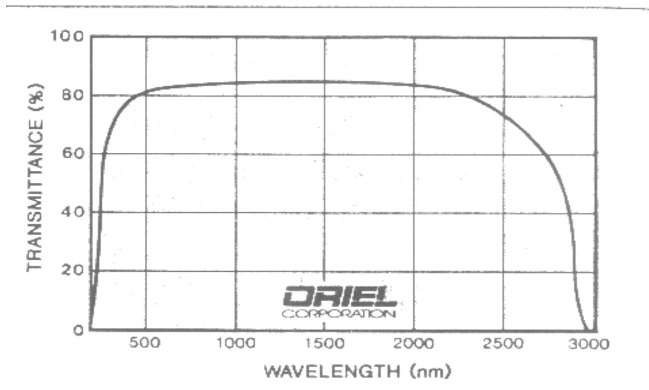
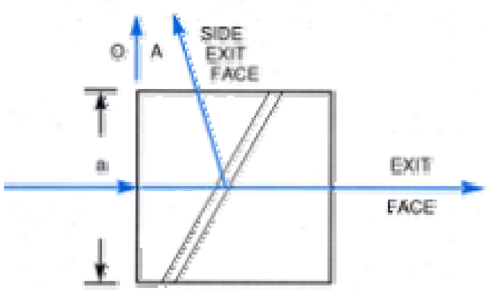
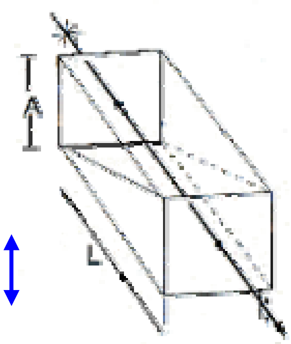
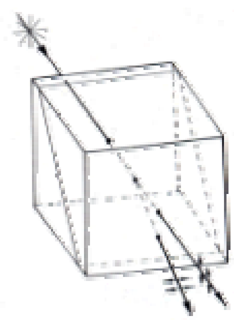


Fig. 2 Transmittance (k_1) of Oriel Standard Glan-Taylor Polarizers for polarized light.







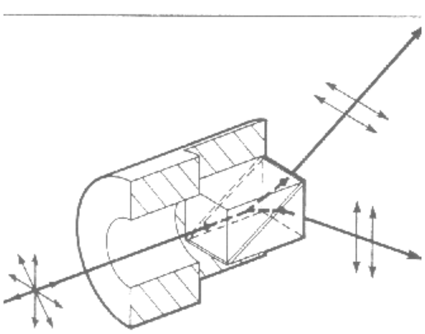
b. Glan Thompson has glue in gap, much larger acceptance angle, lower power, longer λ

c. -- Beam splitting prism (Rochon, Wollaston etc.), transmit both,

but divergent angle between polarizations,

if beam is collimated, can separate at a distance,

MgF_2 used in vac-uv as Rochon, $LiIO_4$ (goes into IR) sometimes as a Wollaston



. 1 Oriel Wollaston Cube Polarizer.

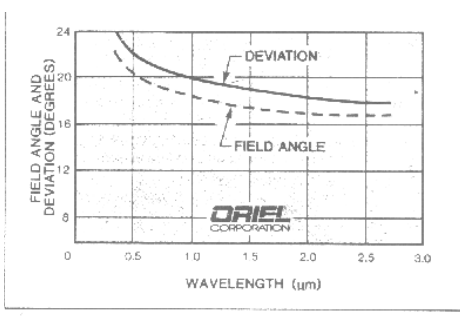
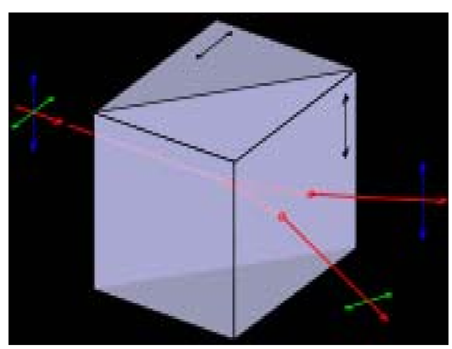
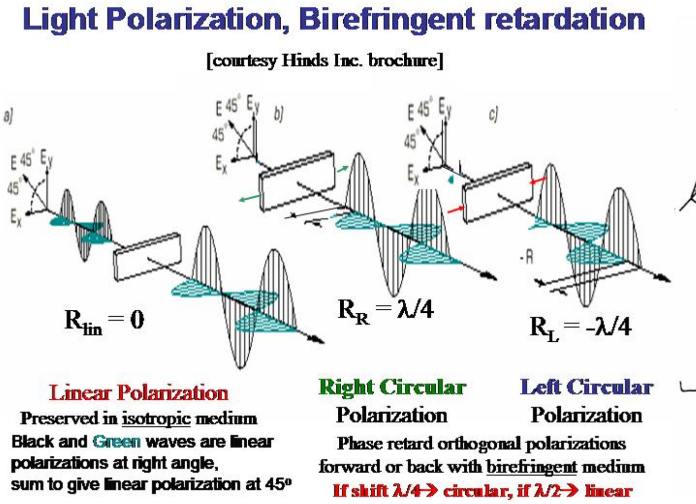


Fig. 2 Beam Deviation and Field Angle vs. Wavelength of Oriel Wollaston Polarizers.



2. Circular polarization

a. Wave plate, slides as example of retardation, use difference in n_x, n_y to retard E_x, E_y



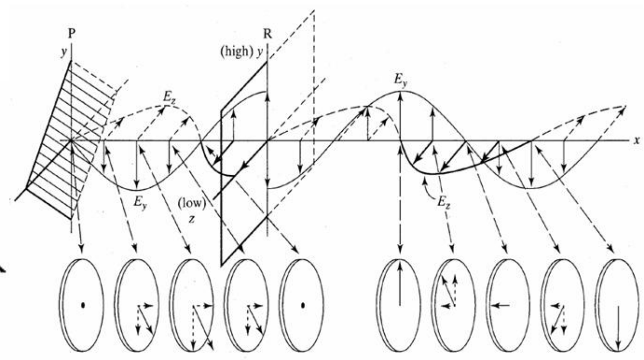


Figure 10.6 The optics for making circularly polarized light uses a linear polarizer P and a quarter-wave retarder R. Circularly polarized light can be decomposed into the sum of two mutually perpendicular linearly polarized waves that are one quarter of a wavelength out of phase. With E_y retarded one quarter of a wave relative to E_z, we have right circularly polarized light as diagrammed here. If E_z were retarded one quarter of a wave relative to E_y, then the circularly polarized light would be left-handed.

-- birefringence retardation, δ, depends on wavelength, λ, the difference in refractive index, $\Delta n = n_x - n_y$ and thickness, z, cause a phase shift of E_x,E_y – need both, input lin. pol.at 45º

$$\delta = (2\pi/\lambda)\,\Delta n\, z$$

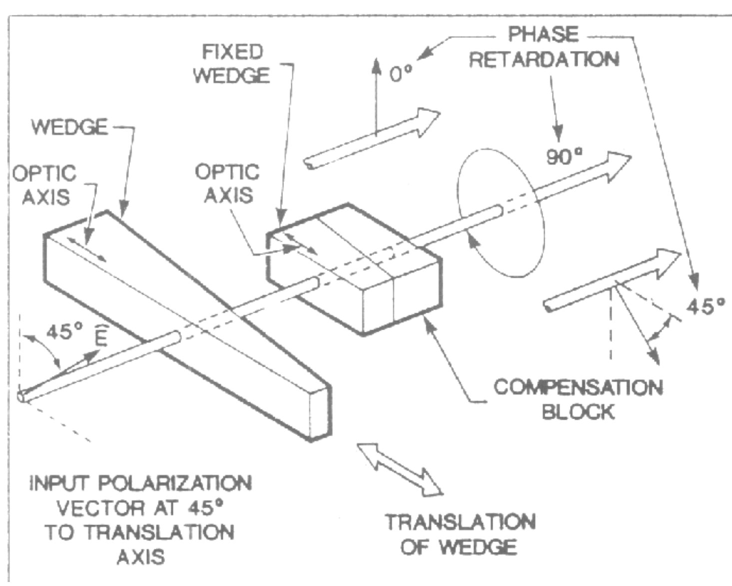
-- as light passes through crystal, shift phase of two orthogonally polarized beams (x,y), when recombine, if $\lambda/4$ shift ($\delta = \pi/2$) then circular (left or right), if $\delta = \pi$ (or $\lambda/2$) then perpendicular linear polarization results–other values give elliptically polarized light

--single plate can be $\lambda/4$ (circ) or $\lambda/2$ (lin), or multi: $(4n+1)\lambda/4$ - work in narrower λ region

--variable – can change index difference by applying stress, static or dynamic,

stress direction gives retardation add left or right circularity, oscillate—modulator (PEM)

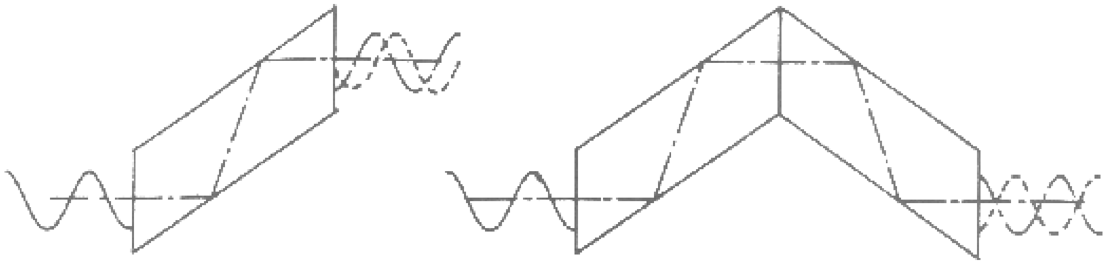
-- Soliel-Babinet compensator - vary z by sliding a wedge into the beam to vary δ



The optics of the Soleil Babinet Compensator. The example shows linearly polarized input radiation and three of the possible output polarizations, 0° retardation giving no change in polarization, 90° or 1/4 wave retardation converting the input to circularly polarized light, and 180° or 1/2 wave retardation rotating the polarization through 90°.

b. Fresnel rhomb -- reflection retardation -- broad band circular polarization

RHOMBS FOR UV-VIS-NIR (130nm<λ<2 μm)



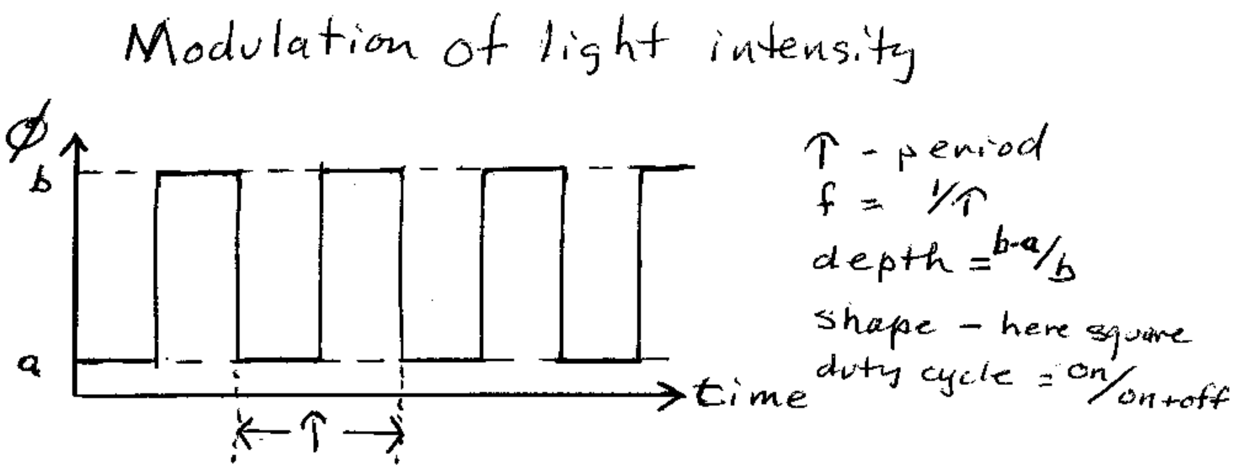
Model No.	Fresnel Rhomb	Air-spaced, Cemented or Optical Contact	Retardation	Aperture	Central Wavelength	Broad Band Coated or Uncoated
	FR	A, C or O*	4 or 2	13, 19 or 25	in nm	BB or UN

* ONLY FOR λ/2 RHOMBS

CENTRAL WAVELENGTH*	MATERIAL	± 2% ERROR RANGE	CENTRAL WAVELENGTH*	MATERIAL	± 2% ERROR RANGE
1080 nm	BK7	500-2000 nm	190 nm	CaF_2	174-205 nm
580 nm	BK7	330-1000 nm	164 nm	CaF_2	154-174 nm
380 nm	FK5	310- 550 nm	148 nm	LiF	142-154 nm
** 272 nm	FUSED QUARTZ	237- 307 nm	136 nm	LiF	130-142 nm
219 nm	FUSED QUARTZ	200- 237 nm			

3. Modulation – *means of improving S/N is signal level low*

a. Characteristics (Figure 1): depth, duty cycle, shape, frequency



This is a square wave modulation with a 50% duty cycle and fairy deep modulation (i.e. b>>a)

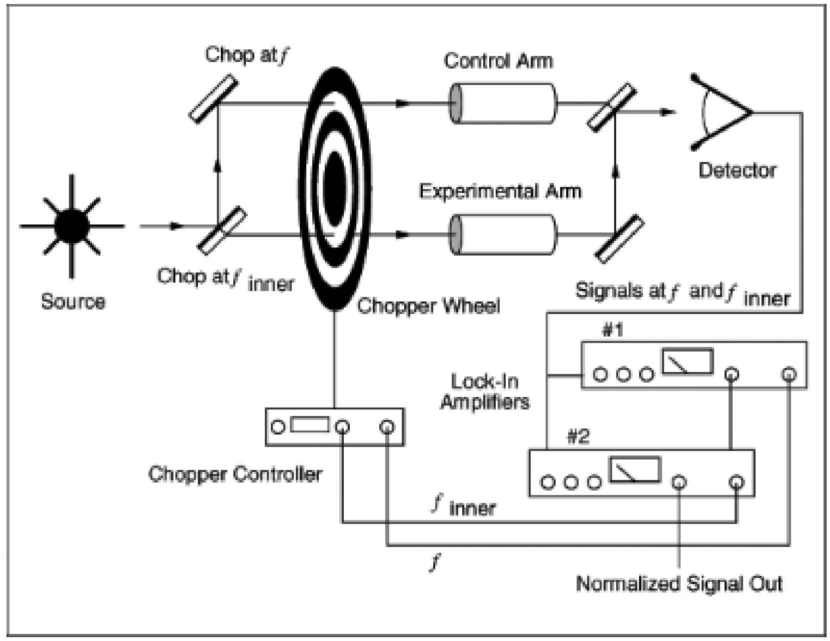
Could be sine wave, triangular, spikes (flash), whatever wanted or device can provide

Period: $\tau = 1/f$, is the repeat time (inverse frequency) assumed regular (or make noise)

Regularity affects duty cycle: $t_{on}/(t_{on}+t_{off})$, on and off same—50%, more off than on <50%, etc.

Depth: (b+a)/b – affected by "leakage or mechanism for making signal on/off

b. Styles: Chopper mechanical intensity modulation (make dual beam spectrometer)



rectangular holes in wheel — ~square, depend on beam and hole size — circles get ~sin wave

also can make with tuning fork-triangle or trapezoid, shutter, anything interrupt a beam

alternatively use: polarization, frequency modulation (grating dither)--often sinusoidal

transient grating (nonlinear effect, crossed laser beams), Interference, acousto-optic

c. Circular/Linear **polarization Modulator**:

-- Electro-optic — induce birefringence with voltage polarization

(e.g. KDP typical, Pockels Cell) - use as a Q-switch in laser common

can switch between linear polarizations (λ/2 retard) or from linear to circular (λ/4 retard)

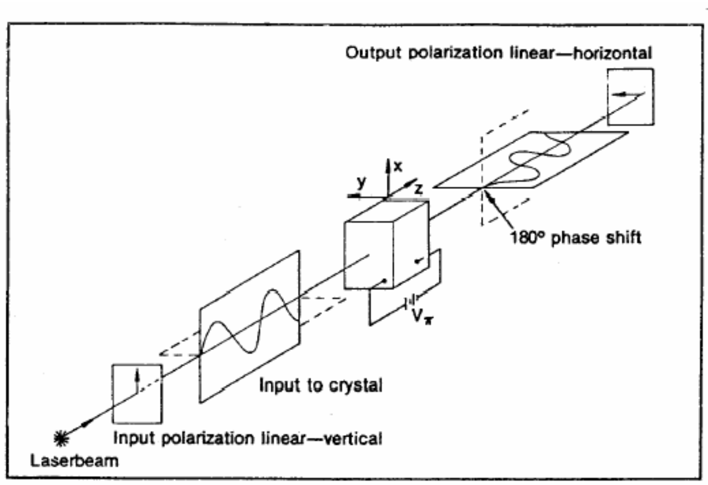
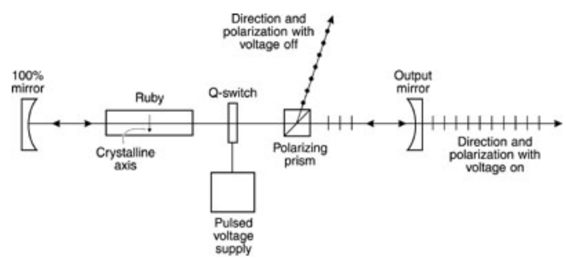
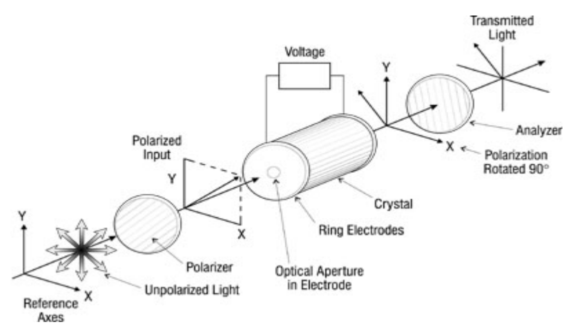
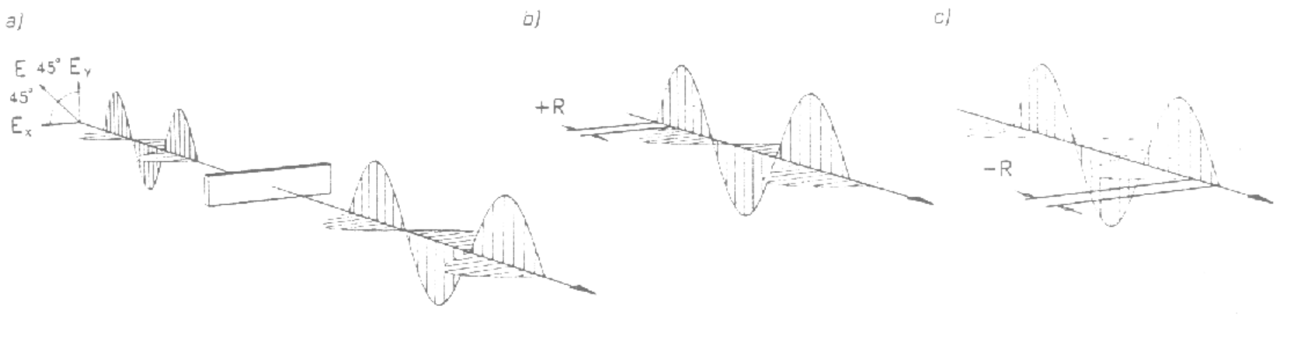


Figure 2. 180° phase shift and 90° rotation of plane of polarization induced by voltage applied to Pockels cell crystal.

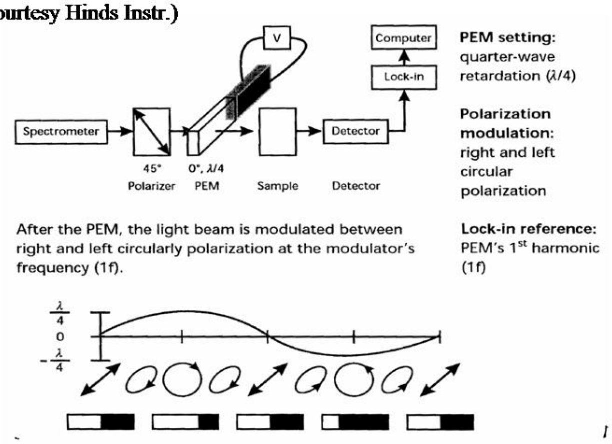




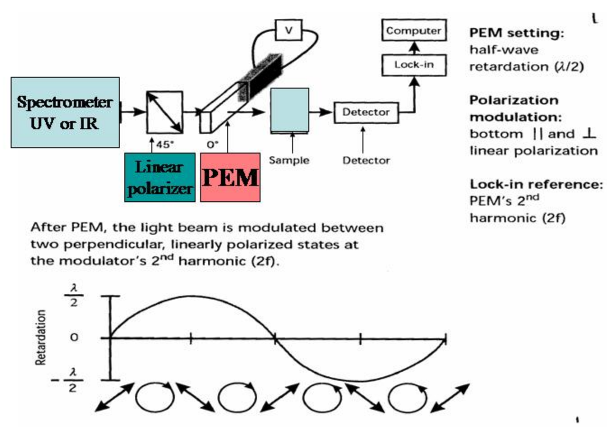
- Photoelastic — periodic stress induce birefringence



Polarization Modulation with PEM for CD (courtesy Hinds Instr.)



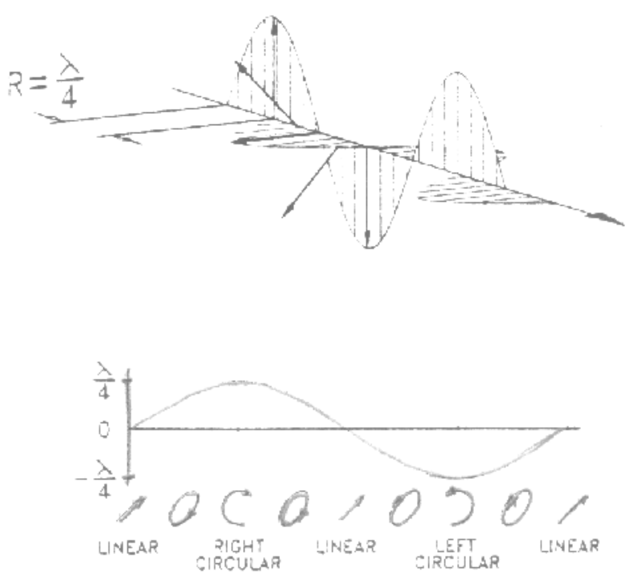
Linear Dichroism Schematic (courtesy Hinds Instr.)

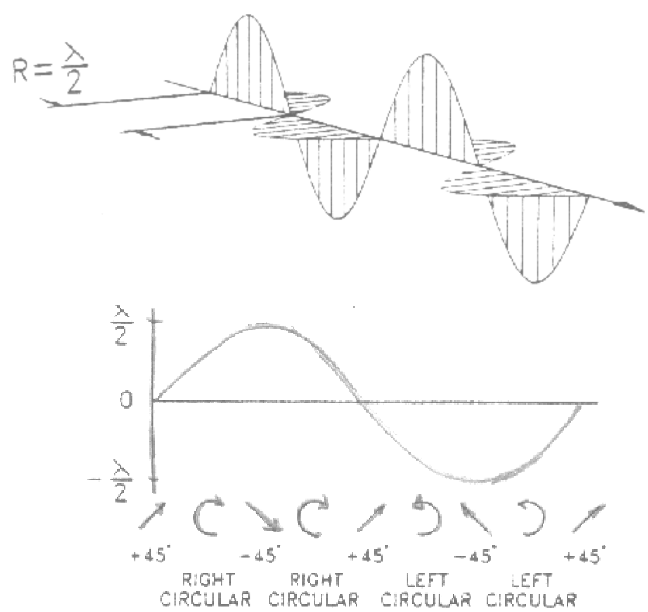


any isotropic material acoustically matched to driver can be basis, wide spectra region possible, results in periodic retardation, sine wave in nature: variable amplitude (see above)

linked slides provide example of CD and LD with polarization modulation

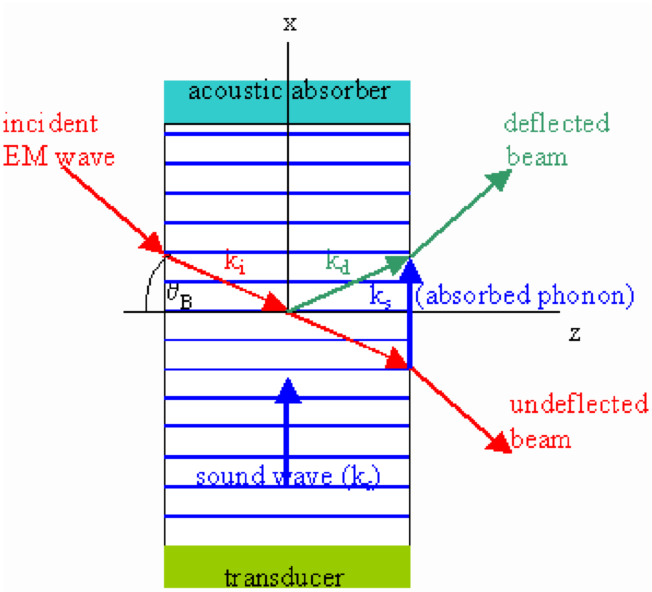
retard wavelength of λ/4 (right to left circular) or λ/2 (parallel to perpendicular linear)





d. Faraday rotator — magnetic field rotate linear (not circ.) polarization to new orientation – analogous to optical rotation by chiral solutions, but tunable angle with **B** field

e. Acousto-optic - acoustic wave sets up diffraction for specific wavelength, key -- use deflected beam, maximum modulaton depth



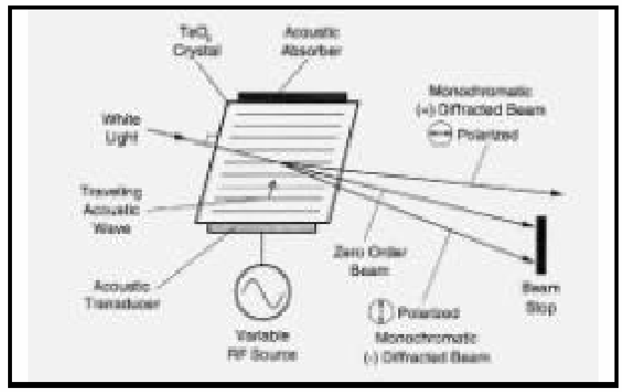
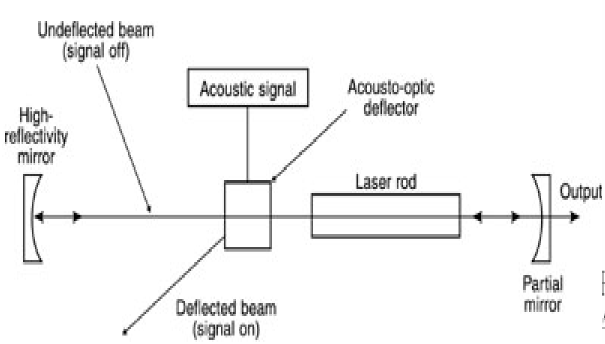


Figure 3. Schematic representation oa a non-collinear AOTF.

An AOTF acts as an electronically tunable spectral bandpass filter. It is a solid state electro-optical device with no moving parts. It

can mode-lock or Q-switch laser, even has been used as basis for a spectrometer

PRACTICAL AOTF SPECTROMETERS



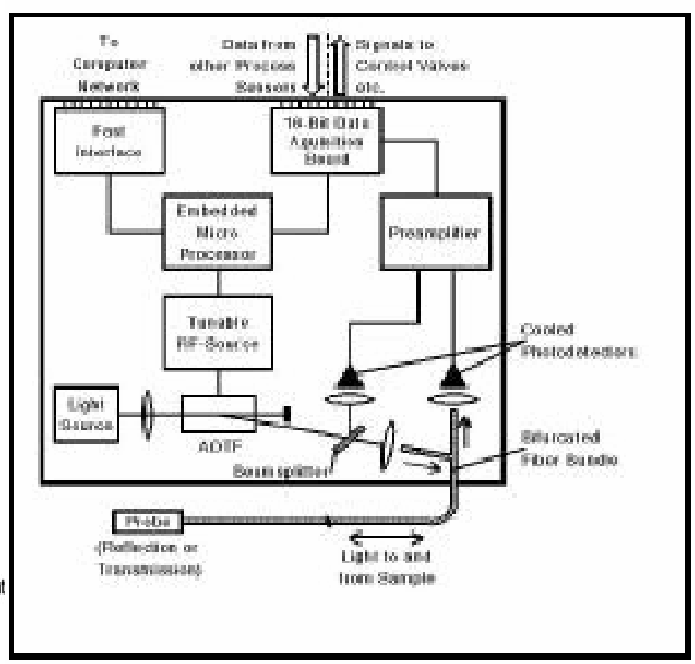


Figure 5. Schematic showing elements of a typical AOTF spectrometer (Brimrose Luminar)

Homework—read in Chap. 3, parts. 1-5 (overlaps Section 4, Optics) and review the modulator tutorials below,

For discussion or thinking: 1. why are wire grids not useful in vis/uv?

2. why are polaroids not useful in farUV or mid IR?

3. what advantage might a 80% duty cycle modulator have? a 20%?

4. if you can modulate with a simple chopper (cheap, low tech) why go to polarization modulation or shutters or ATOF?

5. what is the difference between a magnetic (Faraday) rotator and a electro-optic modulator (Pockels cell) beyond one uses magnetic and the other electric fields?

Problems to hand in: # 3-14, 27 added to assigned work from section 4 (for Problem set #2)

Plus: a. for a wire grid polarizer, if the spacing between wires is 1.0 m, estimate the minimum wavelength for which you can usefully obtain polarized IR light (e.g. 5:1 ratio)

b. For a calcite prism polarizer, if the cut is at 45^o, at what angles of incidence would it be useful as a polarizer (angular aperture is goal)

Links:

Polarizers:

Karl Lambrecht Corp., (local Chicago connection) calcite and other crystal polarizers, retraders etc. (has a neat little diagram)

http://www.klccgo.com/

Polarizer applet, Michigan State

http://lectureonline.cl.msu.edu/~mmp/kap24/polarizers/Polarizer.htm

API Amaerican Polarizers, plastic sheet

http://www.apioptics.com/

Optics for Reserch, crystal polarizers

http://www.ofr.com/oc-22_uv_polarizer.htm

Opto Sigma Corp, wide variety of crystal polarizers and plates

http://www.optosigma.com/miva/merchant.mv?Screen=CTGY&Store_Code=OS&Category_Code=Polarizers

Meadowlark, dichroic polarizers and liquid crystal retarders and modulators

http://www.meadowlark.com/

Thorlabs polarizers, includes prism and wire grid plus others

http://www.thorlabs.com/Navigation.cfm?Guide_ID=24

Edmond Optics, polarizer section, prisms, grids, waveplates etc.

http://www.edmundoptics.com/onlinecatalog/browse.cfm?categoryid=166

Optometrics – ruled grid polarizers, higher power – lower wire density

http://www.optometrics.com/wire_grid_polarizer.html

Modulators:

Explanation of acousto-optic modulation

http://electron9.phys.utk.edu/optics507/modules/m7/acousto.htm

Tutorial from Drexel on E-O and A-O modulators

http://repairfaq.ece.drexel.edu/sam/CORD/leot/course04_mod07/mod04-07.html

Brimrose tech sheet with AOTF, acousto-optic tunable filter description

http://www.brimrose.com/Aointro.pdf

Stanford Research Systems (chopper)

http://www.thinksrs.com/products/SR540.htm

Electro-optical Products Corp, choppers, acousto- and electro-optic modulators

http://www.eopc.com/index.html

Electro-optical components (multi company representative)

Modulators: http://www.eoc-inc.com/electro_optic_modulators.htm

Polarizers: http://www.eoc-inc.com/polarizers_optical_components.htm

Lasermetrics, FAST Pulse, electro-optic modulators

http://www.lasermetrics.com/

(site connects to a descriptive manual of uses

http://www.lasermetrics.com/technotes.html)

Hinds photo elastic polarization modulators

http://www.hindsinstruments.com/PEM_Components/default.aspx