University of Technology
Department of Laser & Optoelectronics Engineering
Final Examination 2011-2012

Subject: optoelectronics *Class: fourth year*
Division: optoelectronics *Time: 3 hours*
Examiner: Dr. Salah Aldeen Adnan *Date: 22 / 5 / 2012*

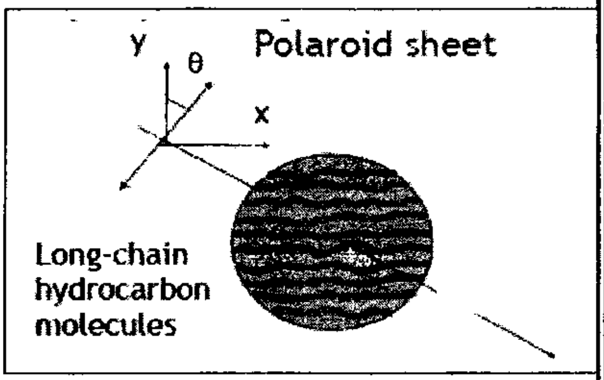
Answer only five questions

Q.1: Compute the approximate length of (KDP) SHG crystal to be used with a 2MW (Q-switch) Ndi-YAG laser that has abeam diameter with the crystal of 5mm. Assume that we want 20% Conversion Efficiency when properly phased matched. Where second order coefficient =$5x10^{-24}$, index of refraction =1.44, beam area =$2x10^{-5}$, Permittivity & permeability = $8.85x10^{-12}$, $4\pi x10^{-7}$? [20 M.]

Q.2: Express the equation of electromagnetic wave $\varepsilon(x, t) = \varepsilon_o \cos[\omega t - kx + \Phi]$ in Alternative Forms such as (a) $\varepsilon = \varepsilon_o \cos 2\pi (t/T - x/\lambda) = \varepsilon_o \cos k(vt - x)$, (b) write down the equation of the wave which is 180° out of phase with these equations, (c) when Traveling in the negative(x-direction) with (+ 270°) phase shift ? [20 M.]

Q.3 :(a) For the superposition of two waves of the same frequency, different phase and in the same direction ,derive the value of irradiance (ε^2_o), (b) Show that the irradiance of the resulting of adding (5) waves of equal amplitude (ε_o) and phase constant are (o, $\pi/4$, $\pi/2$, $3\pi/4$, π) is [$\varepsilon^2_o (3 + 2\sqrt{2})$] [20 M.]

Q.4: Derive MALUS Law from fig. below. [20M]



Q.5: For Longitudinal effect modulator device of Amplitude (m) and frequency (f) with Varying voltage applied to the modulator, prove that

$$\frac{I}{I_o} = 0.5 + \frac{\pi m}{2} \sin 2\pi f t \quad [20M]$$

Q.6: Find the net phase shift or total retardation between two wave resulting from the Application of the voltage (V) across an optical medium. [20M]

good Luck V.1

opto electronics (V.1) / 2011-2012
for (Laser)

Q.1
Thermal devices

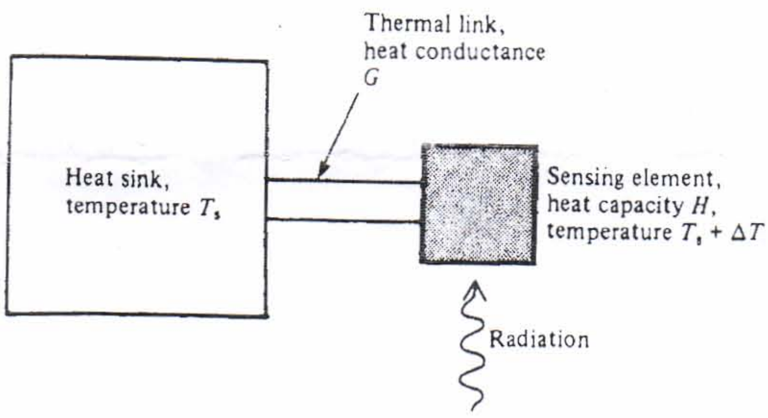


FIG. 7.2 Model of a thermal detector used to derive the frequency response characteristics. The incoming radiation causes the instantaneous temperature of the sensing element to be $T_s + \Delta T$. The element is connected via a conducting link (of conductance G) to a heat sink which remains at the temperature T_s.

element. Hence we may write

$$W\delta t - G\Delta T\delta t = H\delta(\Delta T)$$

If we take the limit $\delta t \rightarrow 0$ we obtain

$$W = H\frac{d(\Delta T)}{dt} + G\Delta T$$

1.Thermoelectric Detector

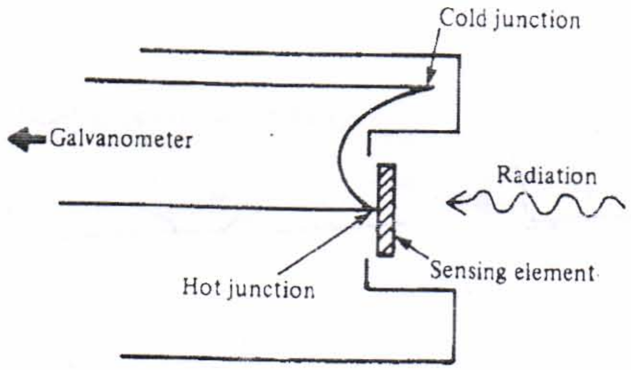


FIG. 7.3 Thermoelectric detector: the temperature change of the sensing element induced by the absorption of radiation is detected using a thermocouple, one junction of which is attached to the sensing element, and the other shielded from the radiation.

2.The Bolometer Detector

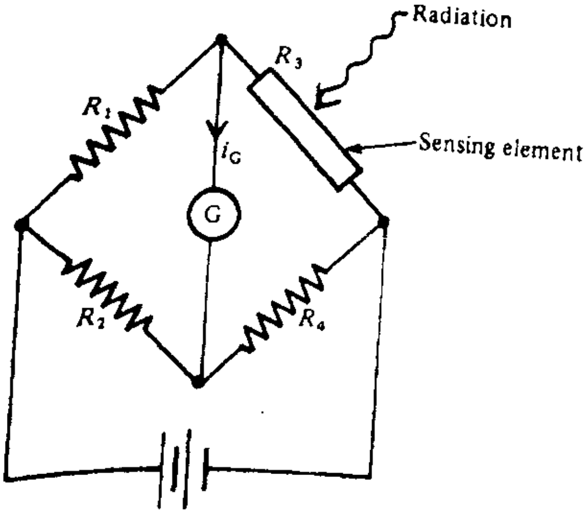


FIG. 7.4 Wheatstone bridge circuit incorporating a bolometer radiation sensing element. When the resistance values are such that $R_1/R_2 = R_3/R_4$ then the current i_G through the galvanometer is zero. If, however, the sensing element resistance changes slightly then a current will flow which is proportional to the resistance change.

3.The Pneumatic Detector

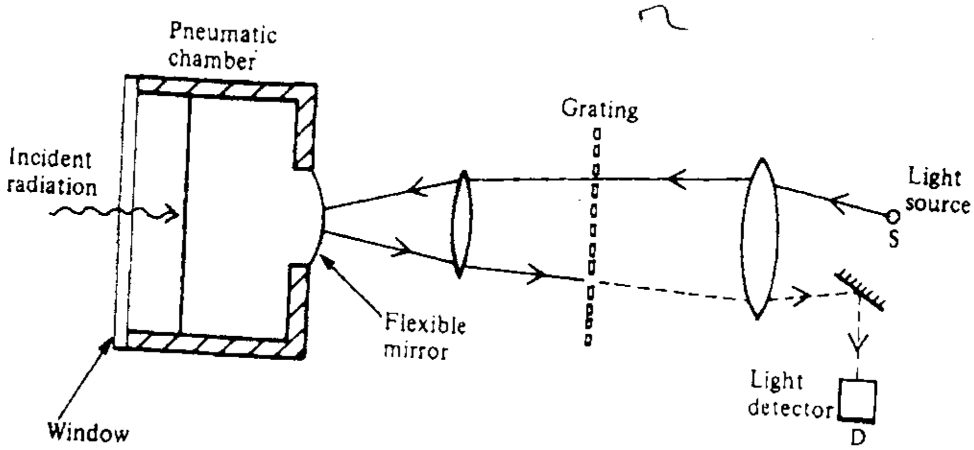


FIG. 7.5 Schematic diagram of a Golay cell detector. A beam of light originating from a source S passes through a grating. It is then reflected from a flexible mirror which forms part of the wall of a pneumatic chamber. The beam subsequently repasses through the grating and is directed onto a light detector D. Radiation absorbed within the chamber causes pressure fluctuations which in turn cause the curvature of the flexible mirror to change.

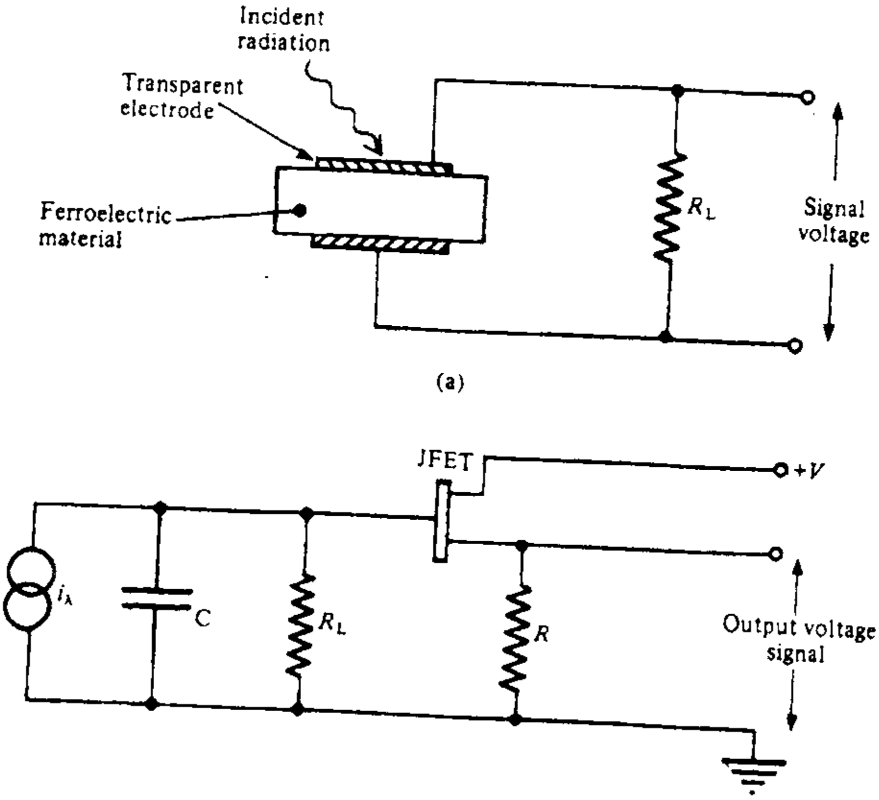


FIG. 7.7 (a) Pyroelectric detector. A slab of ferroelectric material is sandwiched between two electrodes (one being transparent). The electrodes are connected by a load resistor R_L. Radiation absorbed within the ferroelectric material causes it to change its polarization. The induced charge on the electrodes changes and current flows through R_L causing a voltage signal to appear across R_L. (b) Equivalent circuit and typical impedance matching circuitry for a pyroelectric detector. The varying amounts of charge stored on the electrodes are equivalent to a current generator feeding into the electrode capacitance C. The load resistor R_L is in parallel with C. Since R_L is usually very high (about $10^9\ \Omega$ or more), an impedance matching circuit is often employed to reduce the signal source impedance. A typical circuit using a JFET is shown here; the output impedance in this case is then R ($\approx 1\ k\Omega$).

4.The Pyroelectric Detector

$$f_c = \frac{1}{2\pi R_L C} \qquad (7.7)$$

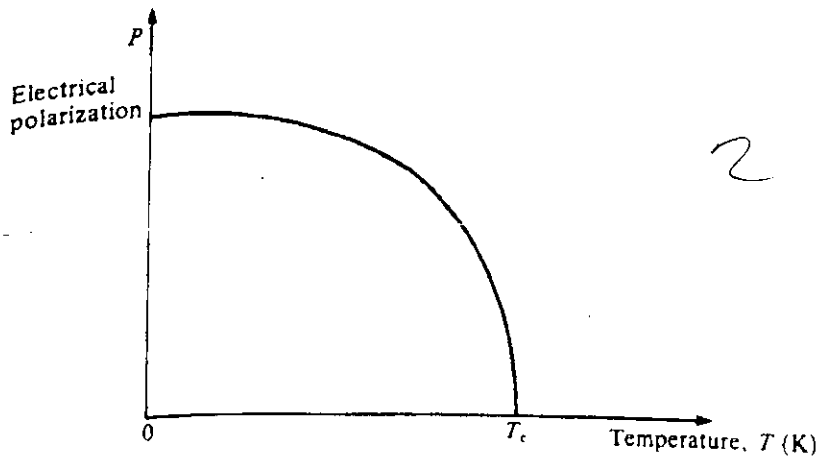


FIG. 7.6 Spontaneous electrical polarization versus temperature for a ferroelectric material (schematic diagram). The polarization falls to zero at the Curie temperature T_c.

Q.2

$$\frac{\pi d}{\lambda}(n_r - n_l) = 29.73^{o}$$

$$(\pi * 10^{-3} / 508.6 * 10^{-9}) * (n_r - n_l) = 29.73^{\circ} * (\pi/180)$$

$$(n_r - n_l) = \mathbf{8.4 * 10^{-5}}$$

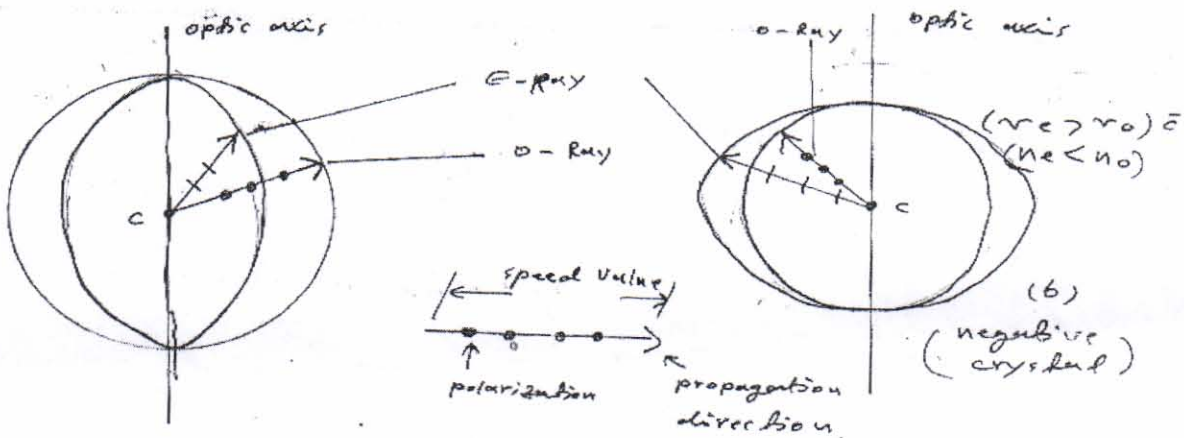
Q.3

a)

* The ordinary ... polarization

* o-ray & E-ray with optical axes By Huygens construction:-

consider a point source of light radiating uniformly inside the crystal. there will be two waves as shown in fig. (3-4 (b) & -(a)).



(a)

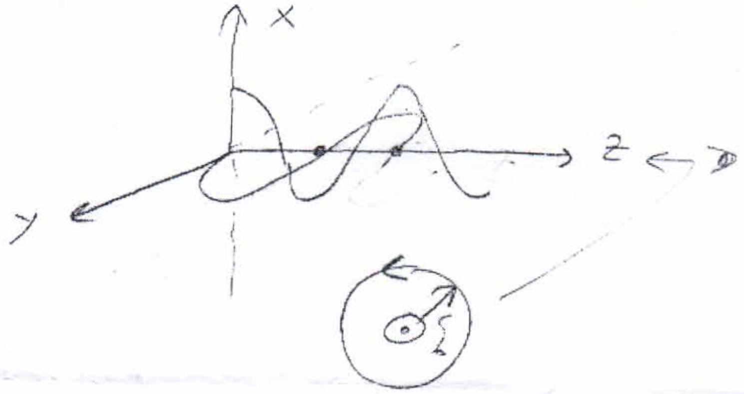
c̄ (ve < vo), (ne > no)

(positive crystal)

b & c :

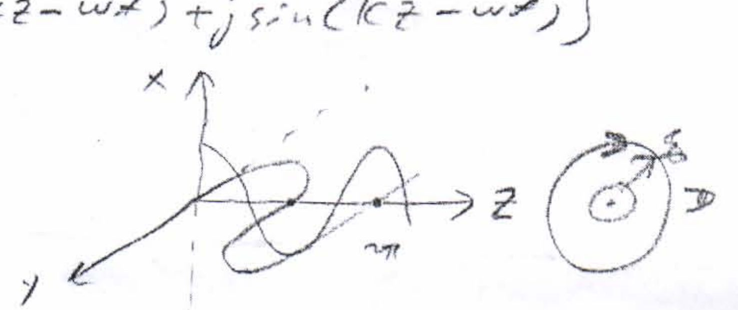
(4) (b) Left circular polarized
or counterclockwise :-

$$\xi = \xi_0 \left[i \cos(kz - \omega t) - j \sin(kz - \omega t) \right]$$



(4) (c) right circular polarization
or (clockwise rotation) :-

$$\xi = \xi_0 \left[i \cos(kz - \omega t) + j \sin(kz - \omega t) \right]$$



(12)

Q.4

$\lambda/4 = (n_o - n_e) * d$

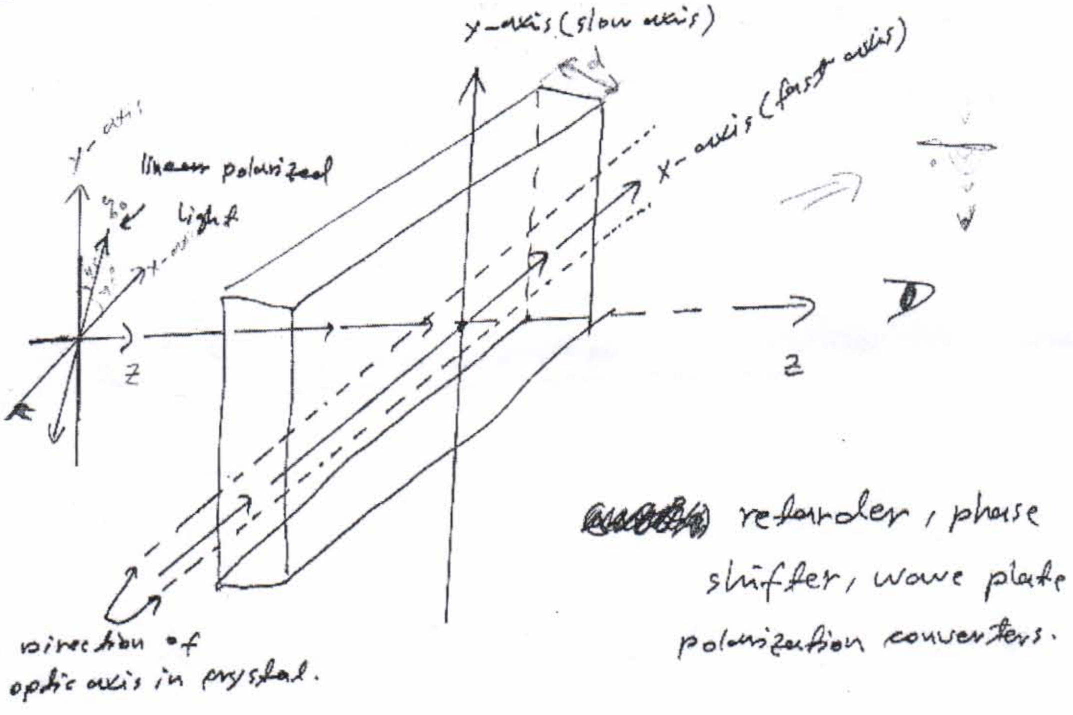
$589.3 * 10^{-9}\,m / 4 = (1.55336-1.54425) * d$

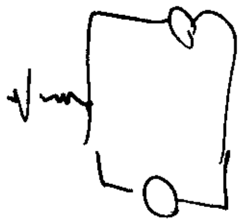
(6)

$d = 2.156 * 10^{-5}\,m$

when plane polarized light is incident on a quarter-wave plate the emergent light is in general elliptical polarized.
if the plane of polarization of incident beam is inclined at (45°) to the privileged direction then the emergent light is circularly polarized.

(6)





Q.5

(12) (1) Ans. optoelectronics / U-1 / 22-5-2012

Q-1) $\eta_{SHG} = 2\left(\frac{\mu_o}{\varepsilon_o}\right)^{3/2} \cdot \frac{d^2 \cdot \omega^2 \cdot \ell^2}{n^3} \cdot \frac{\sin^2\left(\frac{\Delta K \ell}{2}\right)}{\left(\frac{\Delta K \ell}{2}\right)^2} \cdot \frac{P \cdot \omega}{A}$

∵ Assume properly phased matched

$\eta = \frac{P_{SHG}}{P}$

$\therefore \frac{\sin^2 \frac{\Delta K \ell}{2}}{\left(\frac{\Delta K \ell}{2}\right)^2} = 1$

$$\eta_{SHG} = 2\left(\frac{\mu_o}{\varepsilon_o}\right)^{3/2} \cdot \frac{d^2 \cdot \omega^2 \cdot \ell^2}{n^3} \cdot \frac{P \cdot \omega}{A}$$

$\omega = 2\pi f = 2\pi \frac{c}{\lambda} = 2\pi \frac{3\times10^8}{1.06\times10^{-6}} = 1.77\times10^{15}$

$\omega = 1.8\times10^{15}$ rad./sec.

$A = 2\times10^{-5}\ m^2$

$\mu_o = 4\pi\times10^{-7}$ H/m

$\varepsilon_o = 8.85\times10^{-12}$ F/m

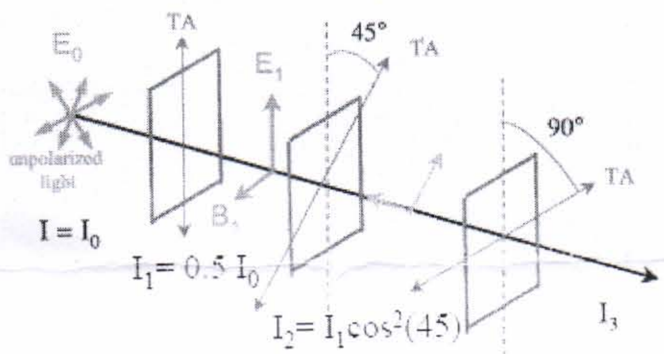
$0.2 = 2\times\left(\frac{4\pi * 10^{-7}}{8.85 * 10^{-12}}\right)^{3/2} * \frac{(5\times10^{-24})^2 * (1.8 * 10^{15})^2 \cdot \ell^2 \times 2\times10^6}{(1.44)^3 \times 2\times10^{-5}}$

$0.2 = 104.7 * 10^6 * 4.8\times10^{-22} * \ell^2 * 10^{11}$

$\therefore \ell = 6.3$ m ?? ** ملاحظة

Q.6

Malus' law. Example



1) Light transmitted by first polarizer is vertically polarized. $I_1 = I_0/2$
2) Angle between it and second polarizer is $\theta=45°$. $I_2 = I_1 \cos^2(45°) = 0.5 I_1 = 0.25\ I_0$
3) Light transmitted through second polarizer is polarized 45° from vertical. Angle between it and third polarizer is $\theta=45°$. $I_3 = I_2 \cos^2(45°) = 0.125 I_0$