CT-3.

PART-B.

1. Demonstrate the principle of a photonic switch based on self electro optic Device (SEED)

A → SEED is a type of Semiconductor Device that can be used as a photonic switch.

→ The principle operation is based on quantum-confined Stark effect (QCSE), which is the change in the energy levels of a quantum well under an applied E.F

How it works:

→ When the incident light enters the SEED Device, it absorbed by a quantum well layer (QCSE)

→ The Applied E.F changes the absorption properties of quantum well layer (transparent/ opaque based on Direction of E.F).

→ the incident light then passes or blocked based on the direction of E.F

→ the O/P of SEED Device sent to the Detector, then it measures the intensity of O/P light.

→ By varying the Applied E.F, the seed Device can be switched bet. (trans/opa) allowing it act as an optical switch.

→ useful in optical communications & computing Applications.

2. Explain about Electro-optic modulators:

A. Electro-optic effect:-

→ The application of an electric field across a crystal may change its R.I.

→ This E.F may induce birefringence in an isotrophic crystal or change the birefringent property of doubly refractive crystal

→ This is known as electro-optic effect.

→ If R.I varies linearly with the applied electric field, K.A Pocket's effect.

→ if the variation in R.I is proportional to the sq. of the Applied E.F K.A Kerr effect

→ The change in R.I n as a func. of applied E.F (E) can be gn. as

$$\Delta\left(\frac{1}{n^2}\right) - rE + PE^2$$

E → Applied E.F

r → Linear electro-optic coefficient.

P → quadratic electro " "

3. Monolithic integration. [OEIC → optoelectronic integrated circuits]	Hybrid integration.
→ A single chip is used to integrate both optical & electronic components.	Separate chips, assembled on single package
→ Limited by the no. of materials that can be grown on a single substrate	More complex designs are possible as each component can be optimized independently before assembly.
→ Lower cost due to simpler fabrication process	higher cost → separate chips & assembly process
→ low performance by material & growth tech.	high performance by ability to optimize individual component.
→ Limited by defects in the substrate & growth process.	higher yield due to ability to select & test individual components before assembly.
Application: Simple OEICs with a limited no. of components	Complex OEICs with high performance requirements.

4. Discuss about the materials & processing of

OEICs :- → opto electronic integrated circuits are electronic Devices that integrate optical & electronic Components on a single chip, allowing transmission, processing in some Device.

Choice of Materials used to Synthesis

→ operating wavelength
→ lattie matching conductor.
→ Choice of Devices

→ The local area n/w comp. interconnects & optical info processing Depends on GaAs materials
→ P - based material applicable to OEICs for long dist. fiber communication
→ hetero epitaxy or cue of mismatched material that include III - V or II - VI compounds of similar semi-cond. or GaAs & InP based compounds on Si
→ The fabrication of lower -Dimensional quantum confinement structure such as quantam wires & quantum boxes will involve epitaxy followed by nanolithography.
→ Devisable feature size (100 - 400 A°) by electro beam lithography
→ fabrication of optical Devices on chip → Advanced Dry etching capabilities.
→ planar circuits fabricated → regrowth.
→ larger Density of Defects → Conventional regrowth.
Alternative ⇒ etching, patterning, processing followed by growth

5. Active Couplers:

→ that are Devices used in OEICS to couple optical signals bet. Diff components such as waveguides, Photo Detectors, lasers.

→ unlike Passive rely on evanescent coupling bet. adjacent ~~wavelength~~ waveguides, active uses active material. Such as semiconductor optical amplifier (SOA) to actively amplify & Direct the optical signal

Ad:

→ have higher coupling efficiency. achieve stronger coupling.

→ can compensate for losses due to material absorption & waveguide propagation.

→ can be integrated to other active component as amplifiers & modulators.

6. Ad. of Erbium Doped fiber Amplifiers (EDFA)

→ the optical fiber amplifier use optical pumping In this process one uses photons to Directly raise electrons into excited states

→ The optical pumping process requires 3 or more energy levels.

Ad:

→ Wideband Amplification:

bet. 1530 & 1620nm.

→ high gain: → high gain levels upto 30db or more.

→ long transmission dist.

→ Low noise:

→ they can amplify optical signals without introducing significant noise into the signal

→ Low cost:

→ Easy integration

→ integrated into existing optical n/w.

→ Power pumping:

→ Pumped with relatively low-power lasers.

→ Compatibility with wavelength Division multiplexing (WDM)

multiple signals transmitted over a single optical fiber.

7. how longitudinal electro optic modulator differs from transverse electro optic modulator?

L-com:

The effect of an electric field across a crystal showing pockel's or linear electro optic effect Depend on the crystal structure and symmetry.

T-EOM:

where the Direction of propogation of light is perpendicular to the Direction of the applied field.

Diff. the 2 lies in the Direction of applied E.F with respect to the direction of the optical wave propagation.

L-EOM	T-EOM
Applied E.F parallel to Direction of optical wave propagation. ↳ longitudinal direct.	perpendicular. ↳ transverse Direct.
→ change in R-I of material in the same Direct.	→ perpendicular Direct.

8. Short note on Raman Nath Modulator.

→ In Raman Nath modulator, the acousto optic diffraction grating is so thin that it behaves almost like a plane transmission grating

→ The mth order diffraction wave propagates along a direction making an angle θ_m the direction of incident beam

$$\sin \theta_m = m \left(\frac{\lambda}{n_o \lambda} \right)$$

$n_o \rightarrow$ R.I of medium in the absence of acoustic wave

$m = 0, \pm 1, \pm 2, \pm 3, \pm 4 \ldots,$

m = order no.

9. Derive the expression for optical amplifier gain.

→ The gain of an optical amplifier is a measure of the amplification factor that it provides to an optical signal passing through it.

Amplifier gain:

is Defined

$$G = \frac{P_{s\,out}}{P_{s\,in}}$$

$P_{s,in} \rightarrow$ i/p power of optical signal being amplified

$P_{s,out} \rightarrow$ o/p powers

$$G = \exp\left[\Gamma (g_m - \bar{\alpha}) L\right] = \exp g(z) L$$

where

$\Gamma \rightarrow$ optical confinement factor in cavity

$g_m \rightarrow$ material gain coefficient

$\bar{\alpha} \rightarrow$ absorption coefficient

$g(z) \rightarrow$ gain /unit length

10. Challenges met by Optoelectronic integrated circuit.

→ OEICs → that integrate both optical & electronic components on a single chip.

→ It has many Advantages as high speed data transfer, reduced power consumption.

Challenges:

→ Devices may have Different layer structure & it shd be of high quality.

→ Compatability
→ shd be compatable to be integrated in one same chip.
→ limit range of materials.

→ fabrication complexity:
→ Precise alignment of optical components

→ Thermal management:
→ integration results in increasing heat dissipation.

→ Crosstalk:
→ Signal interference.

→ cost: → complexity of Design & fabrication.

11. What do you mean by front end photo receivers?

→ In the Design of an optical fiber Communication sys, the key ele. is receiver

→ Basic principle of receiver:

↳ to Detect the incident light & Convert it into an electrical signal containing the info impaired in the light at the transmitting end.

⇒ Performance Characteristics:

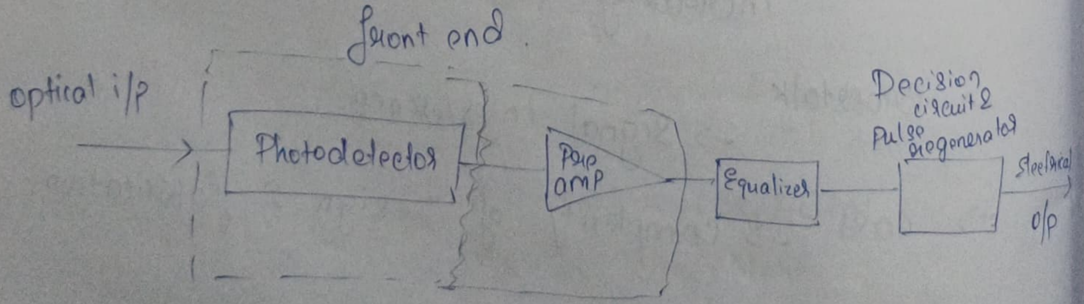
→ operating bandwidth

→ Sensitivity → no. of repeaters in long range communication

→ dynamic rang.

⇒ Receiver Sensitivity:

→ Minimum amt of optical power level needed at the receiver i/p so that Signal to noise ratio (SNR) is greater than gn. value.



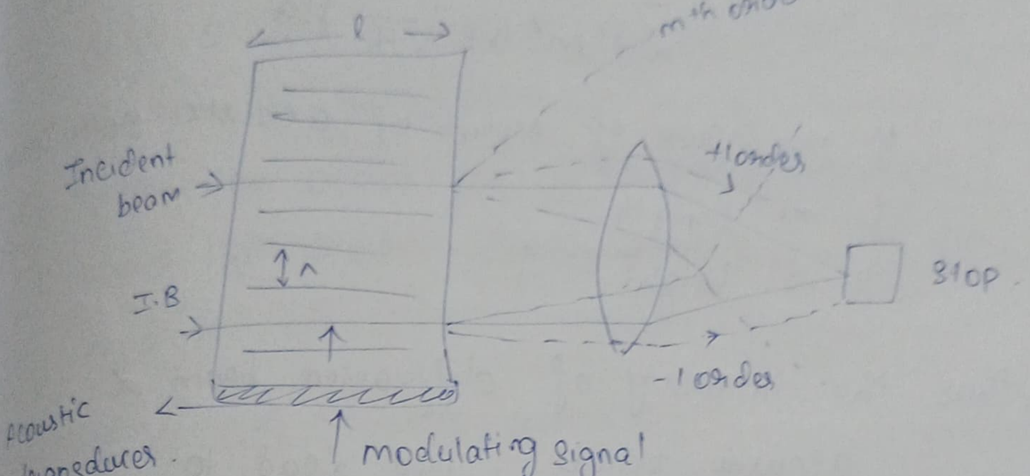
PART-C :

→ An optical modulator is a device which can be used for manipulating a property of light

→ used in optical fiber communications, displays, optical metrology etc.

1. Raman Nath & Bragg modulator

Raman Nath:



→ Acoustic optic modulator based on Raman Nath Diffraction

→ In this configuration, the signal carrying the info modulates the amplitude of the acoustic wave propagating through the medium.

→ The light beam incident on the acoustic optic medium gets diffracted & the 0th order beam of the diffracted o/p blocked by stop

for small acoustic power,

$$\eta = \frac{(\Delta n)^2 L^2 \pi^2}{\lambda^2}$$

Δn → peak change in R.I. of medium due to acoustic wave

L → width of acoustic beam = length

→ for small acoustic power P_a, the diffraction efficiency for an angle of incidence θ_B may be gn by.

$$\eta = \frac{\pi^2 M}{2 \lambda^2 \cos^2 \theta_B} \left(\frac{L}{H}\right) P_a .$$

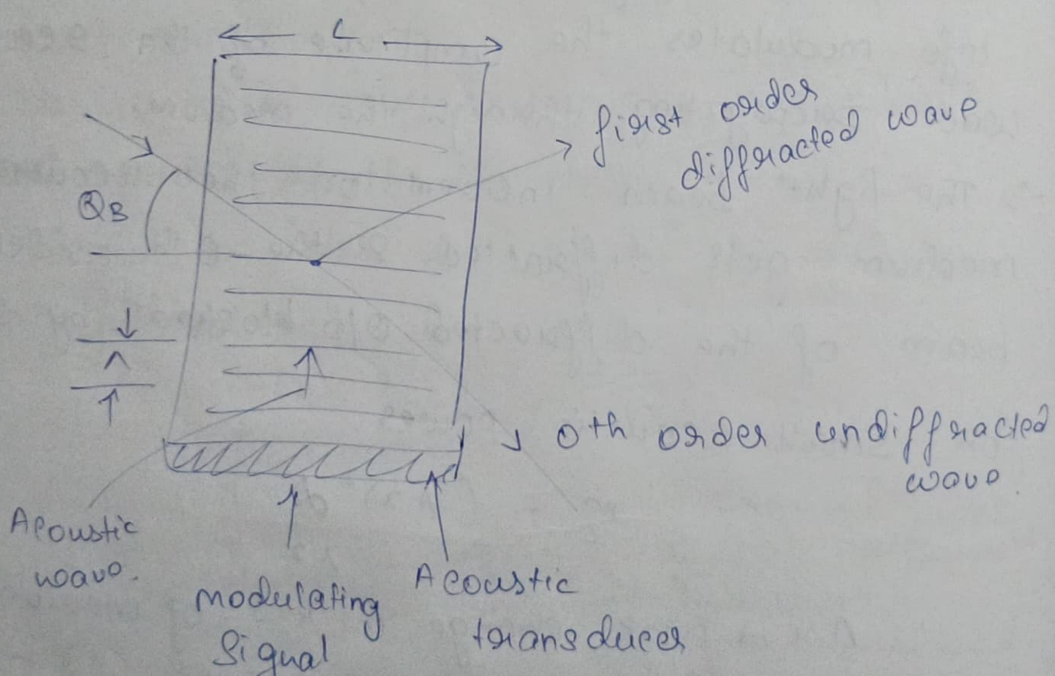
M → figure of Merit of acoustic optic Device

L → Length

H → height.

→ thus, the intensity of diffracted beam $\propto$ acoustic power, will lead to corresponding modulation of diffracted beam

Bragg modulator:



→ In Bragg, the interaction length L is larger, so the Acoustic field creates a thick grating wide the medium

→ when the light beam is incident at an angle θ, it is reflected by successive layer of acoustic grating.

→ Diffraction occurs for an angle of incidence θ = θ_B under the cond. $\sin \theta_B = \lambda / 2 n_0 \Lambda$ of the medium.

$(\Delta n)^2 \propto$ acoustic power.

→ if the acoustic wave is amplitude modulator, the first order diffracted beam will be intensity modulated.

- longitudinal electro - OM (Dia, Construction, working)

- The Basic configuration & gain of Semiconductor optical amplifier (SOA)

→ A SOA is essential InGaAsP laser that is operating below its threshold value & gain can be selected by varying the composition of the InGaAsP. (the optical signal travels through the Device only once)

→ During the single passage the signal gains energy & it emerges at the other end of the amplifier.

(28) → (4)

→ SOA Construction is similar to a resonator structure of a Laser diode.

→ It has a active region of length L & width w & height d.

→ The reflections are lower in order for the optical signal to pass through the amplification cavity.

→ Low reflections are achieved by depositing thin layer of silicon oxide, sili nitride or titanium oxide.

External Pumping:

→ External current injection is the pumping method used to create the population invension needed for having a gain mechanism in SOAs

→ Thus the sum of injection, stimulated Emission & Spontaneous recombinations rates gives the rate eq.

$$\frac{\partial n(t)}{\partial t} = R_p(t) - R_{st}(t) - \frac{n(t)}{\tau_r} \rightarrow (1)$$

τ_r → combined time const

where $R_p(t) = \frac{J(t)}{qd} \rightarrow (2)$

$R_p(t)$ → external pumping rate.

d → active layer of thickness d.

$$R_{st}(t) = \Gamma a v_g (n - n_{th}) N_{ph} = g v_g N_{ph} \rightarrow (3)$$

Γ → optical confinement factor

a → gain const.

n_{th} → threshold carrier density.

N_{ph} → photon density.

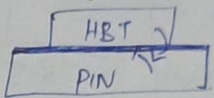
g → overall gain per unit length

→ If the optical amplifier is of width w, thickness d then optical signal of power P_s with photons of energy $h\nu$ & group velocity v_g

photon Density is $N_{ph} = \dfrac{P_s}{v_g h\nu w d}$ → (4)

$$R_p = R_{st} + \frac{n}{\tau_r} \rightarrow (5)$$

5. the operation of a PIN Diode integrated HBT photo receiver with dia. ?



→ Integration of a PIN HBT photo receiver involves a single step epitaxy of the HBT from which the PIN Modulator was selectively defined by processing.

→ The collector region of the HBT also serves as the i-region of the diode.

→ The 2 Devices are Monolithically integrated with the addition of required parse elements here to realize a front-end photo receiver

the PIN Diode serves as the front end photoDetector & HBT as the preamplifier.

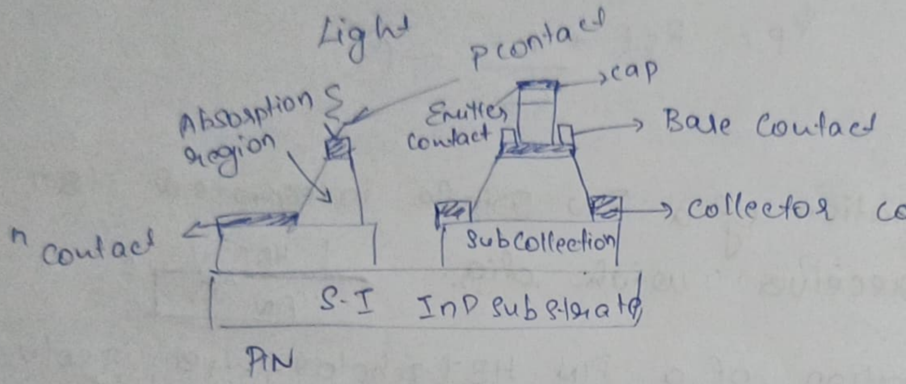
→ Another Ad. of PIN HBT combination is that the Sensitivity of HBT based photo receiver is better than of FET based Photo receiver.

→ Becoz,

Sensitivity of FET photoreceiver $\propto B^3$

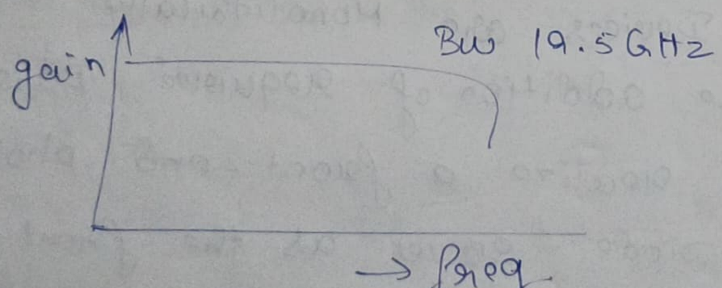
HBT is proportional to B^2 (Bit error rate)

Epitaxial hetero structure:



→ A tech. to Enhance photoreceiver response at high frequences is inductive peaking where an inductor is placed in series with photoDiode. at the I/p of the Diode.

→ Typical values of induction is 2–5 nH.



frequency response of a monolithic PIN HBT photoreceiver

→ guided wave components are required for routing optical Signal on a chip.

→ These are also used for directional coupling, filtering & modulation.

OEIC transmitters:

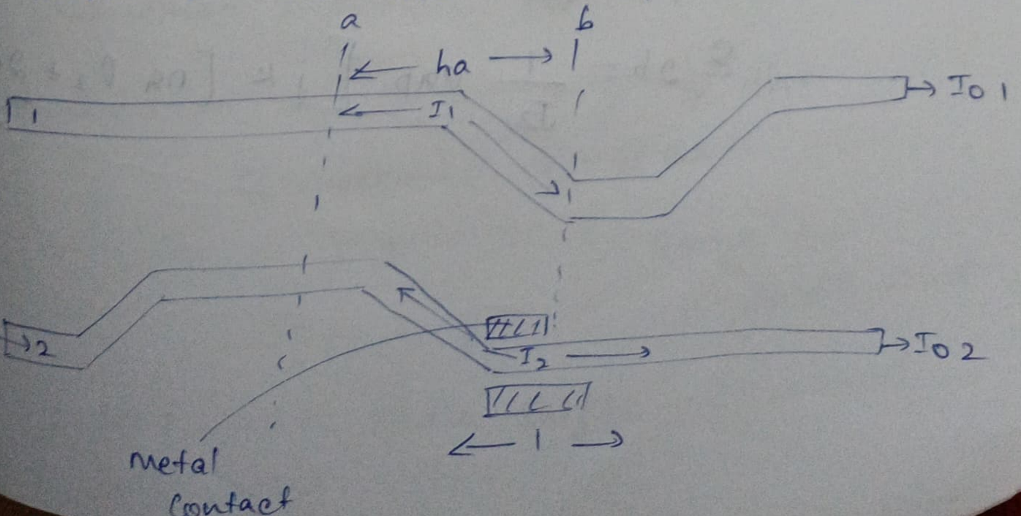
→ The integration of a high power LED are laser with associated electronics is more complicated than the fabrications of a photoreceivers & it is due to the fact that laser has the more strongest material & processing requirements than a photodetector.

neat diag, ~~the construction & working~~ write about the guided wave Mach-Zehnder interferometer.

→ A simple guided wave modulation / switching device based on the electro optic effect is the Mach-Zehnder interferometer.

→ The incoming optical beam is split equally b/w the 2 branches of the i/p coupler & thin recombined at the coupler at the other end.

→ Materials growth & processing is such that the tapers are very gradual to reduce bend losses & that there is spatial uniformity



(34) → (5)

Schematic of guided wave Mach Zehnder interferometer with i/p & o/p 3 dB couplers

→ With no applied bias to the Schottky diode the phase shift in the 2 arms is equal & at the o/p coupler the 2 wave interfere constructively & all the power appears at the o/p.

→ It is assumed that the E.F of the I/p to one arm has onely amplitude & Zero plane.

→ Then according to coupled mode theory, the fields at pt a gn. by.

$$E_{1a} = 0 + j \sin\frac{\pi}{4} = j/\sqrt{2} \rightarrow (1).$$

$$E_{2a} = 0 + \cos\frac{\pi}{4} = \frac{1}{\sqrt{2}} \rightarrow (2).$$

→ At pt b: phase shifted due to propagation over the length La

$$E_{1b} = \frac{j}{\sqrt{2}} \exp\{j k n_r l_1\}$$

$$E_{2b} = \frac{1}{\sqrt{2}} \exp\left[j k \left[n_r l_2 + \frac{2 n_r}{2V} l_V\right\}\right]$$

→ In the 2nd eq. the electro optic effect is taken into account due to bias V applied to schottky diode over a length l.

∴ unequal lengths l_1 & l_2 will introduce a phase difference

$$\Delta \phi_1 = k n_r (l_2 - l_1)$$

Additional → phase shift.

$$\Delta \phi_{EO} = k l \frac{\partial n_r}{\partial V} V = \frac{\pi l}{\lambda d} n_{ro}^3 r_{ij} V$$

d ↓ thickness of the wave guide.

o/p in arm 1:

$$I_{01} = \frac{1}{2}\left[1 + \cos(\Delta\phi_1 + \Delta\phi_{EO})\right]$$

arm 2:

$$I_{02} = \frac{1}{2}\left[1 - \cos(\Delta\phi_1 + \Delta\phi_{EO})\right]$$

→ The o/p coupler recombines the field E_{1b} & E_{2b} to give the field at o/p at arm 1

→ Taking sq. of magnitude of the field yields the o/p intensity from arm 1.

→ If the Device as lossless.

Sum of $I_{01} + I_{02}$ = i/p intensity.

↳ $l_1 = l_2$ & no bias applied.

↳ $I_{01} = 1$, $I_{02} = 0$.

bias = π ↳ when $\Delta\phi_1 = 0$, $I_{01} = 0$, $I_{02} = 1$.

→ The Modulation index is only & the corresponding bias.

$$V_\pi = \frac{\lambda d}{l\, n_{ro}^3 r_{ij}}$$

∵ same as guide wave

π → half wave phase shift.

V_π → half wave Volt.

$\rightarrow E_s = \frac{1}{2} C V_\pi^2 \rightarrow$ switch energy.

$C \rightarrow$ capacitance of schottky Diode

$\rightarrow$ O/P can be controlled with by varying volt.

$\hookrightarrow w = 2 - 3 \mu m$, $l \rightarrow$ few mms

$\hookrightarrow$ volt. req. $\Rightarrow \Delta \phi = \pi$

5. Longitudinal electro-optic modulator.

Electro-optic effect:

$\rightarrow$ The application of an E.F across a crystal may change its R-I.

$\rightarrow$ This may induce a Phenomena called Birefringence in crystal.

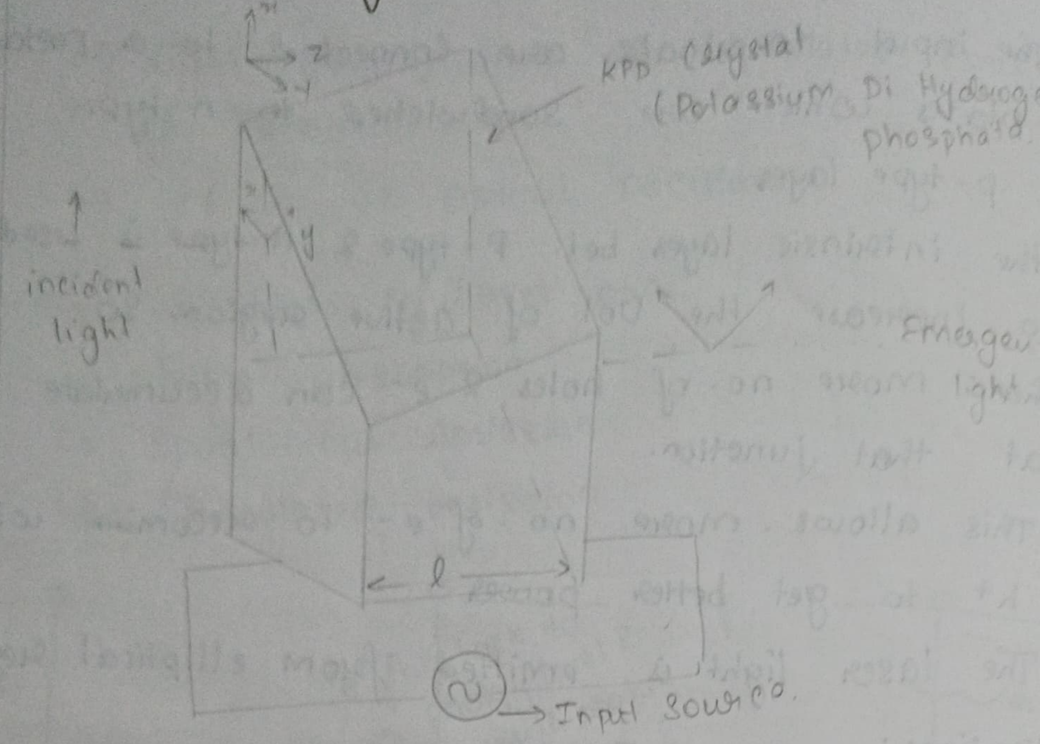
Birefringence:

The R-I of these crystals varies with direction & the crystals called Birefrigent.

+

Class notes.

5/4 UNIT 4 Longitudinal electro-optic modulator



→ Crystalline material when exposed to E.F R.I changes.

→ It is called as Bierfringence or dual R.I

→ This is AKA. electro optic nature.

→ R.I varies linearly → Pockel's effect.

→ R.I varies sq. of applied E F → Kerr effect

$$\Delta\left(\frac{1}{n^2}\right) - \gamma E + P E^2$$

→ exp. of change in R.I with the applied E.F [the light is incident at the horizontal way of the crystal]

→ Longitudinal way of light rays

↳ Polarized medium: Alignment of particles.

↳ unpolarized medium: mix of Diff. Polarization.

↳ polarization: particles align in a particular Direction

→ In crystaline ~~material~~ Material, the incident ray at x, y, z axis.

→ We assume the crystal to be polarised one.

→ The principle of x & y axis, x & y are 45° inclination

$$n_x' = n_o + \frac{1}{2} n_o^3 r_{63} E_z \rightarrow (1)$$

$r_{63} \rightarrow$ electro optic coefficient.

$$n_y' = n_o - \frac{1}{2} n_o^3 r_{63} E_z \rightarrow (2)$$

$$E = E_o \cos(\omega t - kz) \rightarrow (3).$$

↑

the incident light ray has some energy & the energy is given by

$$E = E_o \cos(\omega t - kz) \rightarrow (3).$$

Electronic component along x' & y' direction is

$$E_{x'} = \frac{E_o}{\sqrt{2}} \cos(\omega t - kz) \rightarrow (4)$$

$$E_{y'} = \frac{E_o}{\sqrt{2}} \cos(\omega t - kz) \rightarrow (5)$$

If crystal thickers along propagation direction $z = l$

$$\phi_x' = k n_x' l = \frac{2\pi}{\lambda} n_x' l \rightarrow (6)$$

$$\phi_y' = k n_y' l = \frac{2\pi}{\lambda} n_y' l \rightarrow (7).$$

Sub ① in 6.

$$\phi_{x}' = \frac{2\pi}{\lambda}\left(n_0 + \frac{1}{2} n_0^3 r_{63} E_z\right) l$$

$$= \frac{2\pi l}{\lambda} n_0 \left[1 + \frac{1}{2} n_0^2 r_{63} E_z\right) \rightarrow ⑧$$

Assume:

$$\frac{2\pi l n_0}{\lambda} = \phi_0 \text{ and } \frac{\pi l n_0^3 r_{63} E_z}{\lambda} = \Delta\phi$$

$$\phi_{x}' = \phi_0 + \Delta\phi \rightarrow ⑨$$

$$\phi_{y}' = \phi_0 - \Delta\phi \rightarrow ⑩$$

$$\phi = \phi_{x}' - \phi_{y}'$$ [Superposition of 2 plain polarised wave]

$$\phi = 2\Delta\phi.$$

[Crystallin Material used → Potassium Di Hydrogen phosphate]

6. Discuss the materials & processing tech of OEIC.

An: OEIC circuits:

→ involves integration of electronic & optical components & optical interconnects.

→ This integration of electronic & optical devices will lead to high speed, high sensitivity compactness & reliability all at low cost.

+

4 mark Ans.