FODE U-4

Part C

① Raman Nath Modulator

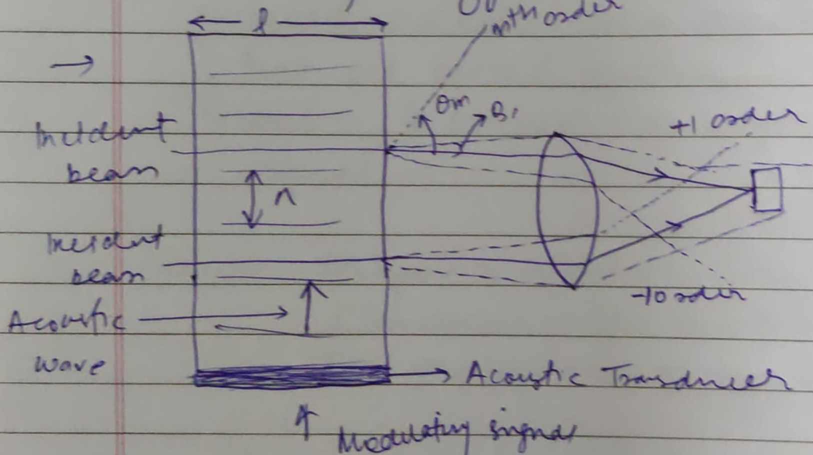
→ In Raman Nath modular, the acousto diffraction grating is so thin that it almost behaves like plan transmission grating

→ The m^{th} order diffracted wave propagates along a directing making an angle θ_m.

$$\sin \theta_m = m\left(\frac{\lambda}{n_0 \Lambda}\right)$$

n_0 is refractive index of medium
m is order number

→ Raman Nath modular is electro-optic device that modulates the intensity of light using electro-optic effect

→


Working:

→ Here the signal is carrying the information of the acoustic wave propagating through the medium.

→ The light beam incident on acousto optic medium gets diffracted and 0th order ~~beam~~ of the diffracted output is blocked using a STOP.

→ The relative intensity in the order is given by

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

Δn is peak change in refractive index of medium
L is the length of acoustic beam

→ The diffraction efficiency ~~[illegible]~~ is given by

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

P_a is small Acoustic power
M is merit of acousto optic device
L and H are length & height.

→ Thus the intensity of diffracted beam is directly propotional to acoustic power

$$\Lambda = \frac{\text{Velocity of Acoustic wave}}{\text{frequency}}$$

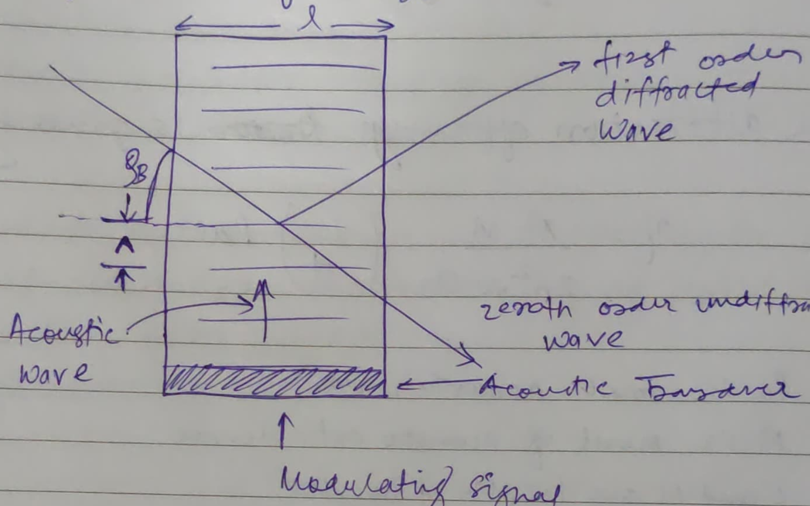
Bragg Modulator

→ In Bragg Modulator, there is thick acousto diffraction grating

→ Condition:

$$\sin \theta_B = \frac{\lambda}{2 n_0 \Lambda}$$

→ Configuration of Bragg Modulator



→ ~~Working~~ Also uses the principle of acousto optic modulation to modulate the intensity of light

→ They are mostly used in fiber communication

Working:

→ Here, the interaction length 'L' is larger, so acoustic field creates a thick grating inside the medium

→ When light beam incident is incident at an angle θ, it is reflected by successive layer of acoustic gating

→ Diffraction occurs for angle of incidence $\theta = \theta_B$

→ The $(\Delta n)^2$ is proportional to Acoustic power

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

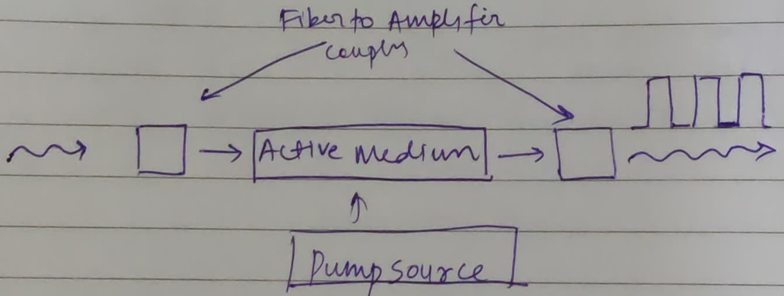
② Optical Amplifier

→ It is a device that amplifies optical signal without converting to electrical signal

→ To amplify optical signal we need to perform
* photon to electron conversion
* electrical amplification
* retiming pulse shaping
* electron to photon conversion

→ Three fundamental types

(1) Semiconductor Optical Amplifier (SOA)
(2) Doped Fiber Amplifier
(3) Raman Amplifier



→ Semiconductor Optical Amplifier

→ It is an essential InGaAsP laser that is operating below its threshold value

→ The Gain can be selected by varying composition of the InGaAsP

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→ The optical signal passes through the device only once, and during the single passage the signal gains energy

→ SOA construction:

* It has an active region of length 'L', width 'W' and height 'd'

* The low reflection are achieved by depositing thin layer of Silicon oxide, Silicon nitride or titanium oxide

→ External Pumping

* It is the method used to create population inversion

* The sum of injection, stimulated emission and spontaneous recombination gives the rate eqn.

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

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

$R_p(t)$ is external pumping rate
τ_r is combined time constant
$J(t)$ is active layer of thickness

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

Γ is optical confinement factor
a is gain constant
n_{th} is threshold

N_{ph} is photon density
g is overall gain

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→ Amplifier gain

It is defined as

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

$$G = \exp[\Gamma (g_m - \alpha) L] = \exp g(z) L$$

P_s out and P_s in are input and output powers of optical signal

Γ → optical confinement factor | α → absorption coefficient

g_m → gain coefficient | $g(z)$ → gain length

→ SOA Bandwidth

The general expression is given by:

$$G_e(f) = \frac{(1-R_1)(1-R_2)G}{(1-\sqrt{R_1R_2G})^2 + 4\sqrt{R_1R_2G}\sin^2\phi}$$

G → single pass gain

R_1, R_2 → i/p and o/p reflectivities

$\phi = \pi(f - f_0) / \Delta f_{FSR}$

f_0 = cavity resonance frequency

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Ans

① SEED is the type of semiconductor device that can be used as photonic switch.

Principle of SEED is based on quantum confined Stark effect.

Working

→ when the incident light enters into SEED Device it is absorbed by quantum layers

→ It is then passed or blocked based on the direction

→ The o/p is sent to the detector the then it measures the intensity of o/p light.

SEED is useful in optical communications and computing Applications.

② Electro optic Modulators

→ The application of electric field across a crystal may change its refractive index
→ This electric field may induce birefrigence in isotropic crystal of doubly refracting crystal
→ This is known as electro optic effect
→ The change in Refractive index is given by

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

quadratic electro optic coef
Applied electric field
linear electro optic coefficient

→ If RI varies linearly to ef, it is ~~poo~~ pocket's effect
→ If RI varies proportionally to ef, it is kerr effect

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③ Advantages of Erbium Doped Fiber Amplifiers

(1) High Gain : can have high gain upto 30dB

(2) Wide Bandwidth : wide range of wavelengths

(3) Low noise figure : has low noise, less than 4dB

(4) long lifetime : have long service life

(5) Compatibility : It is compatible with other components

(6) Relaibility : highly reliable

④

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① PIN

→ A PIN diode integrated HBT is a device that converts optical signals into electrical signals

→ The photodetector is a PIN diode, which has heavily doped p-type region on one side and heavily dope n-ptype on other side.

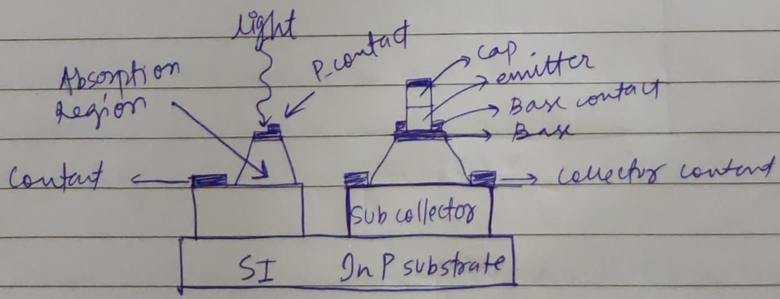
→ The HBT is Heterojunction Bipolar Transistor which amplifies the current generated by photodetector

→ It involves single step epitaxy of HBT from which the PIN modulator was defined by processing.

→ The collector region ~~[illegible]~~ of HBT is used as the i-region of the diode

→ The 2 Devices are monothically integrated with the addition of required passive elents

→ The PIN Diode serves front end photodetector and HBT as preamplifier



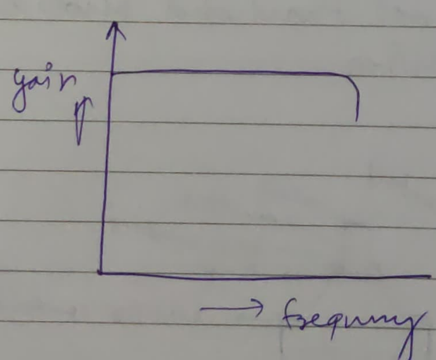
→ The advantage of PIN HBT combination is that it sensitivity is better than other photoreceiver

→ The valuable technique to enhance photoreceiver response at high frequencies is inductive peaking

→ In inductive peaking, the inductor is placed in series after photodiode at input of amplifier

Operation :

→ Light enters the intrinsic region of PIN diode
→ When light is absorbed by the intrinsic region, the electron-hole pairs are generated
→ This generates a current that is proportional to the intensity of incident light
→ The current generated here is amplified by HBT amplifier. HBT provides gain to the overall system
→ It generates the output voltage signal, which can be processed by other electronic circuits.

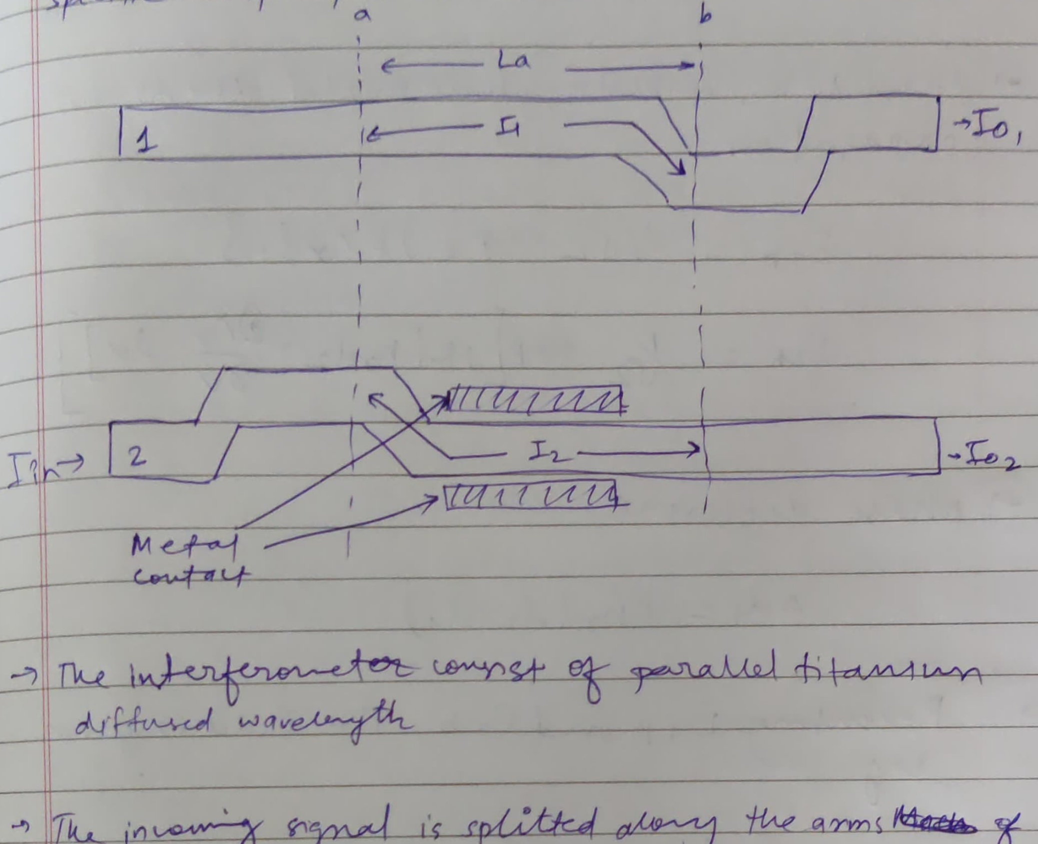


Adv : good sensitivity
: effective device
: wide application

② Mach Zehnder Interferometer.

→ Mach Zehnder Interferometer is a simple guided wave switching device based on electro optic effect

→ It can be used to direct the specific wavelength to specific output port.



→ The interferometer consist of parallel titanium diffused wavelength

→ The incoming signal is splitted along the arms ~~~~ of Mach-Zehnder interferometer and then recombined at the output

→ electrodes are fixed on the arms of Mach-Zehnder ~~~~ Interferometer and two couplers are connected to interferometer.

→ When voltage is applied to electrodes, a specific wavelength is ~~~~ directed to I_{o1} / I_{o2}

→ According to coupled mode theory, the fields at point a is given by

$$E_1 a = 0 + j \sin \frac{\pi}{4} = j/\sqrt{2} \rightarrow (1)$$

$$E_2 a = 0 + \cos \pi/4 = 1/\sqrt{2} \rightarrow (2)$$

→ At point b, field is phase shifted due to propagation,

$$E_{1b} = j/\sqrt{2} \exp\{ jkn_r l_1 \}$$

$$E_{2b} = 1/\sqrt{2} \exp\left[jk \left[n_r l_2 + \frac{\partial n_r}{\partial V} l V \right] \right]$$

→ phase difference

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

→ Recombining $E_1 b$ and $E_2 b$, the field is given by

$$E_{01} = \frac{-j}{2} (jkn_r l_1) \left[1 + e\{ j(\Delta\phi_1 + \Delta\phi E_0) \} \right]$$

→ Output intensity at arm 1,

$$I_{01} = \frac{1}{2} \left[1 + \cos(\Delta\phi_1 + \Delta\phi E_0) \right]$$

→ Output intensity at arm 2,

$$I_{02} = \frac{1}{2} \left[1 - \cos(\Delta\phi_1 + \Delta\phi E_0) \right]$$

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Ans

① Monolithic OEIC	Hybrid OEIC
(i) single chip is used	(i) seperate chip is used
(ii) lower cost	(ii) higher cost
(iii) low performance	(iii) high performance
(iv) Small in size	(iv) large in size
(v) less flexibility	(v) More flexibility
(vi) low power consumption	(vii) high power consumption
(viii) high reliable	(viii) less reliable,

② Active couplers

→ It is the device used in OEICS to couple optical signal between different componts.

→ Active couplers uses Active materials such as semiconductor optical Amplifier

→ It helps to incruse the performce of optical comication system.

Advantages:

→ high coupling efficieny
→ Can be used for signal processing
→ loss is very less
→ flexible

③ Longitudinal electro optic modulator	Transverse electro optic modulator
① it is applied parallel to electric field	① It is applied perpendicular to electric field
② longitudinal dirn	② Transverse Direction
③ phase modulator	③ Amplitude modulator
④ Affects the phase of the waves	④ Affects the Amplitude of the waves
⑤ faster response	⑤ slow response

④ frontend photo receiver

→ It is used to detect the incident light and convert it to electrical signal

→ The performance of the frontend photo receiver depends on:

bandwidth
sensitivity
number of repeats