CBCS SCHEME

USN 15EC82

Eighth Semester B.E. Degree Examination, November 2020
Fiber Optic and Networks

Time: 3 hrs. Max. Marks: 80

Note: Answer any FIVE full questions irrespective of modules.

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages. 2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. With relevant diagrams, explain the different types of optical fibers, considering the number of the modes and material composition of the core. (08 Marks)
b. Describe what is implied by the term Photonic Crystal Fiber (PCF) and explain the guidance mechanism for electromagnetic modes in such optical fibers. (08 Marks)

2 a. Explain the ray theory of the optical fiber, with the help of neat sketch. (08 Marks)
b. Explain mode field diameter of single mode fiber. (04 Marks)
c. A multimode step index fiber with core diameter of 80 μm and relative index difference of 1.5% is operating at a wavelength of 0.85μm, if the core RI is 1.48. Estimate :
i) The normalized frequency for the fiber ii) The number of guided modes. (04 Marks)

Module-2

3 a. Discuss the followings for optical fibers :
i) Fiber bend loss ii) Material absorption. (08 Marks)
b. Define fiber splicing. Explain electric arc fusion splicing with neat sketches. (08 Marks)

4 a. Describe linear scattering losses in an optical fiber. (08 Marks)
b. A four port multimode fiber FBT coupler has 60 μw optical power launched into port 1. The measured output powers at ports 2, 3 and 4 are 0.004, 26.0 and 27.5 μw respectively. Determine the excess loss, insertion losses between input and output ports, the cross talk and split ratio for the device. (08 Marks)

Module-3

5 a. Explain the 3 factors, which affects the response time of photodiode. (08 Marks)
b. Derive an equation for optical receiver sensitivity. (08 Marks)

6 a. What are the characteristic requirements of an optical source? With the help of diagram, describe the operation of surface emitting LED. (08 Marks)
b. Explain the different amplifiers used in optical receiver. (08 Marks)

Module-4

7 a. Describe the principles of working of isolators and circulators with a neat diagram. (08 Marks)
b. Briefly discuss Raman amplifiers. (08 Marks)

8 a. Write a note on : i) Diffraction gratings ii) MEMS technology. (08 Marks)
b. With the aid of neat diagram, explain three possible EDFA configurations. (08 Marks)

Module-5

9 a. Explain public telecommunications network review with neat diagram. (08 Marks)
b. Explain an optical packet switched network with neat diagram. (08 Marks)

10 a. Explain the concept of optical burst switching. (08 Marks)
b. Explain the different types of optical networking node elements. (08 Marks)

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Scheme & Solution Prepared by Prof. V. M. Chougale

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Page 1 of 1	Rev. Dt: 01/08/2020
Solution and Scheme and award of marks	

AY: 2020-21

Department:Electronics & Communication Engg.
Semester / Division: 8^{TH} (A&B)

Subject with Sub. Code: Fiber optics &network (15EC82) (15EC82)
Faculty Name: v.m.chougala

November. 2020 Module 1

Q No	Solution and Scheme	Marks
1.a	With relevant diagrams, explain the different types of optical fibers, considering the number of the modes and material composition of the core.	8 marks
	* Fiber cables are also classified as per their mode. Light rays propagate as an electro-magnetic wave along the fiber. * The two components, the electric field and the magnetic field form patterns across the fiber. These patterns are called modes of transmission. * The mode of a fiber refers to the number of paths for the light rays within the cable.	

* According to modes optic fibers can be classified into two types.

i) Single mode fiber ii) Multimode fiber.

* Multimode fiber was the first type to be manufactured and commercilized. The term multimode simply refers to fact that numerous modes (light rays) are carried simultaneously through the waveguide.

* Multimode fiber has a much larger diameter, compared to single mode fiber, this allows large ~~diameter, compared to single~~ number of modes.

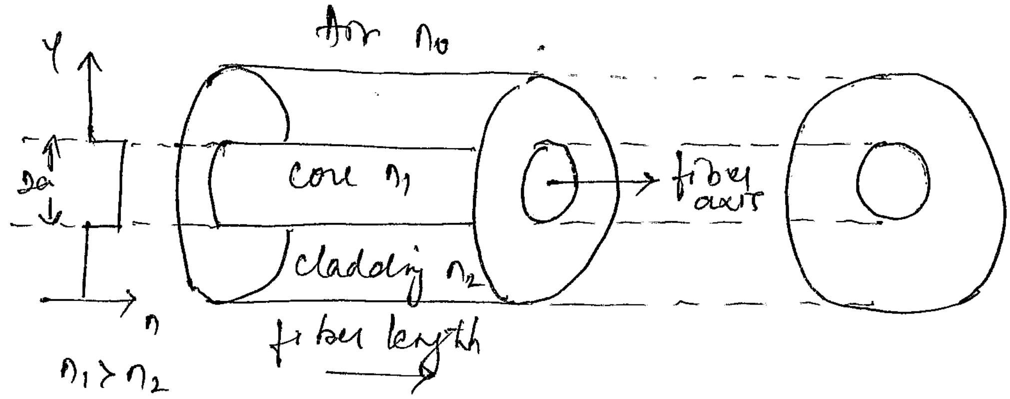
* Single mode fiber allows propagation to light ray by only one path. Single mode fibers are best at retaining the fidelity of each light pulse over longer distance also they do not exhibit dispersion caused by multiple modes.

* Single mode fiber has higher bandwidth compared to multimode fiber.

* Disadvantage of single mode fiber are smaller core diameter makes coupling light into the core more difficult. Precision required for single mode connector and splices are more demanding.

Step Index Fiber

* The step index (SI) fiber is a cylindrical waveguide core with central or inner core has a uniform refractive index of n_1 and the core is surrounded by outer cladding with uniform refractive index of n_2.
* The cladding refractive index (n_2) is less than core refractive index (n_1).



* The propagation of light wave within the core ~~typically~~ of step index fiber takes the path of meridional ray. i.e. zig zag path.
* The core typically has diameter of 50-80 μm and the cladding has 125 μm diameter.

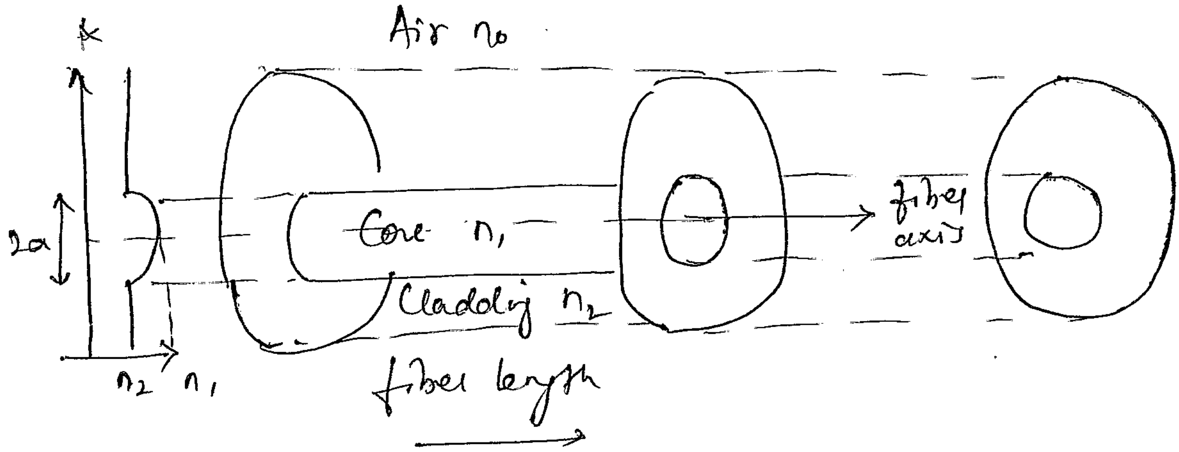
∴ RI profile is defined as

$$n(r) = \begin{cases} n_1 & r < a \text{ (core)} \\ n_2 & r \geq a \text{ (cladding)} \end{cases}$$

4 + 4

7. Graded Index Fiber.

* the graded index fiber has a core made from many layer of glass.
* there refractive index is not uniform within the core.
*



* In graded index fiber light wave are bent by refraction towards the core axis and they follow the curved path down the fiber length.
* A graded index fiber has lower coupling efficiency and higher bandwidth than step index fiber.
* The refractive index variation in core is given by.

$$n(r) = \begin{cases} n_1\left(1 - 2\Delta\left(\frac{r}{a}\right)^n\right), & r < a \text{ (core)} \\ n_1(1-2\Delta)^{1/2} \simeq n_2, & r \geq a \text{ (cladding)} \end{cases}$$

r = radial distance from fiber axis

a = core radius

n_1 = refractive index of core

n_2 = refractive index of cladding

1b.	Describe what is implied by the term Photonic Crystal Fiber (PCF) and explain the guidance mechanism for electromagnetic modes in such optical fibers.	

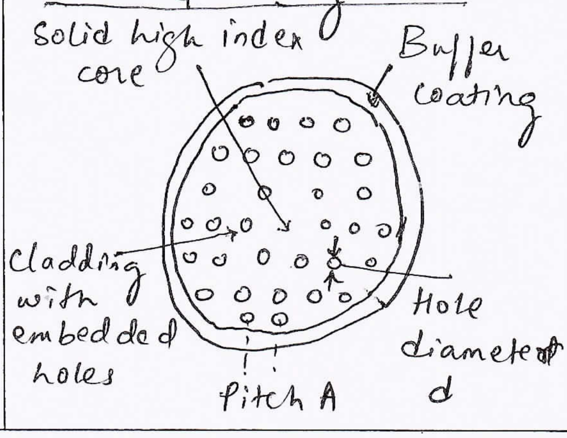
* It is called as Holey fiber or microstructured fiber.
* Difference between photonic crystal fibers and conventional fibers is that the cladding.
* In some cases the core region of PCF also contains holes and it runs along the length of the fiber.
* The light guiding characteristics of PCF is determined by size and shaping of holes in microstructure and R.I of its constituent material.

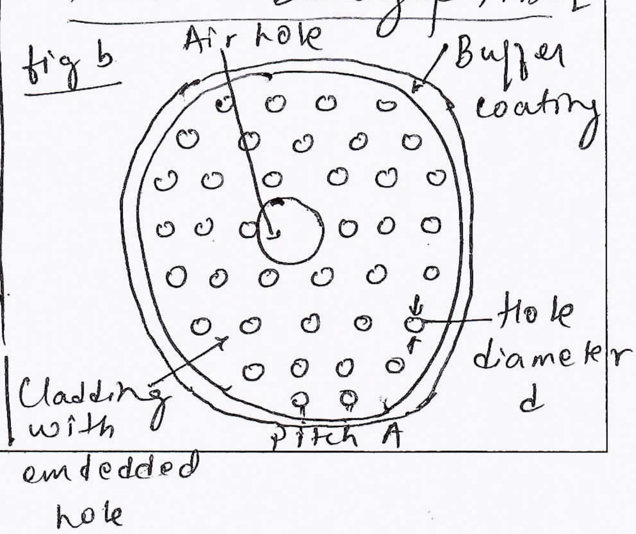
[8M]

PCF types   4+4

Index Guiding fiber | Photonic Bandgap Fiber

fig a





Index Guiding Fiber :

* As shown in fig(a), fiber has a solid ~~cage~~ core and cladding contains air holes running along the length of the fiber.
* Core and cladding are made up of same material only but holes in cladding has lower the effective RI of cladding.
* $n_1 = 1.45$ for silica and $n_2 = 1$ for air then microstructure arrangement is equivalent to step index fiber.
* The holes in microstructure arrangement has a diameter 'd' and pitch or distance between two adjacent holes is 'Δ'.

*

Advantages of pure silica core in Index guiding fiber over conventional are :

- Very low losses
- Transmits high optical power.
- High resistance to darkening effect from nuclear radiation

* It supports single mode operation over 300nm to more than 2000nm wavelength range.

Photonic Bandgap Fiber :-

* This fiber has hallow core as shown in fig(b), cladding contains air holes running along the length of fiber.

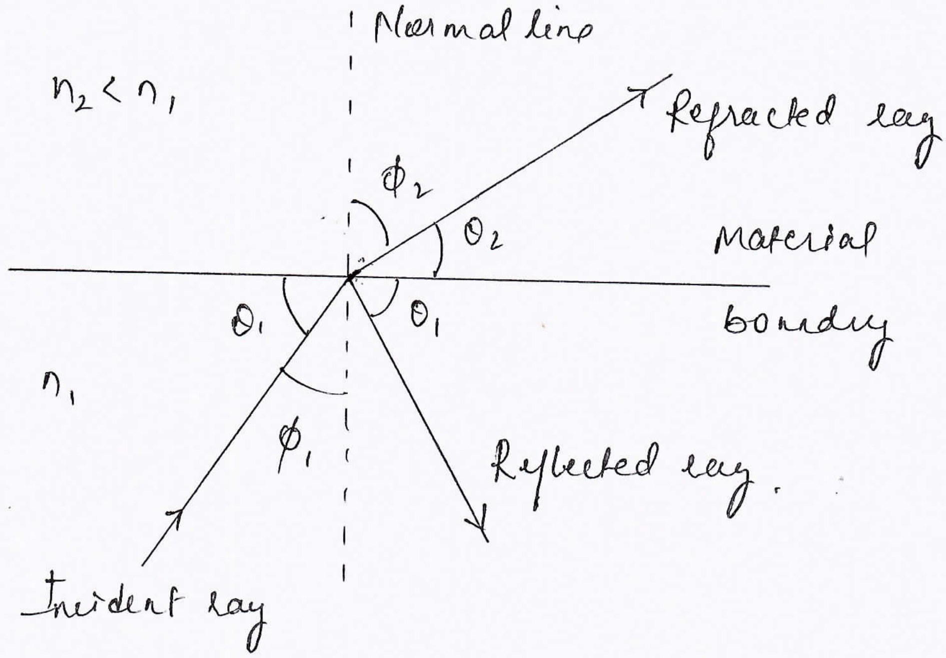
* It guides the light by photonic bandgap effect.

* The functional principle is similar to the role of periodic crystalline lattice in a semiconductor.

* Hollow core ~~as~~ will act as a defect in a photonic bandgap structure through which light propagate.

2a. Explain the ray theory of the optical fiber, with the help of neat sketch.

a) Refractive Index :-

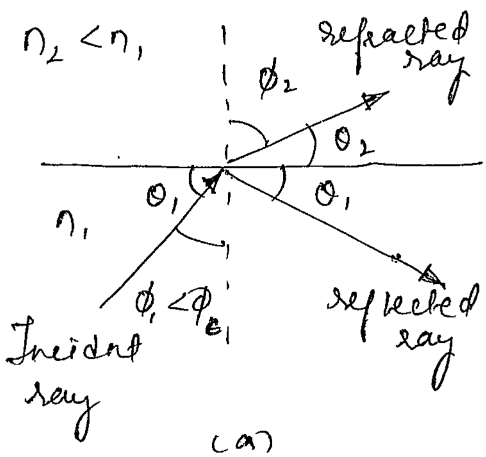


It is defined as ratio of velocity of light in vaccum to velocity of light in material.

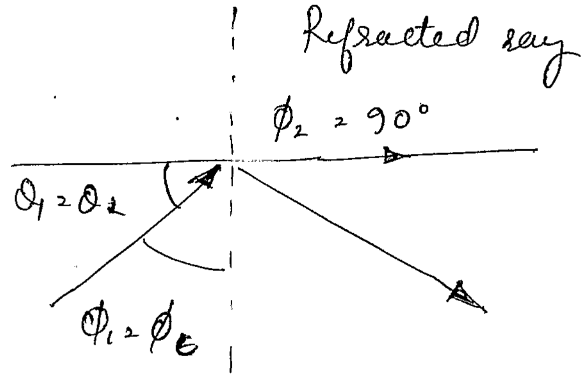
$$n = \frac{c}{v}$$

Angle of rays are measured w.r.t normal. This is line drawn at right angle to boundry line between two refractive indices. The angles of incoming and outgoing rays are called angle of incidence and refraction respectively.

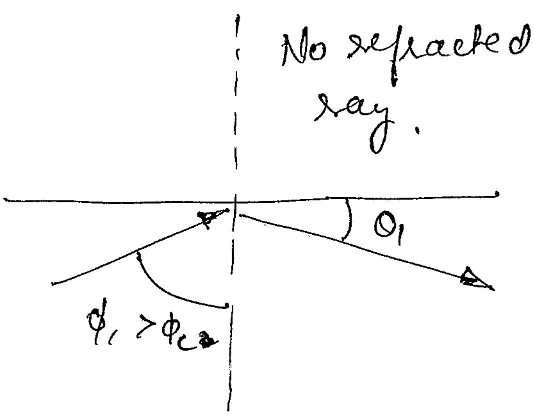
b). Snells law.



(a)



(b)



c

When a light ray encounters a boundry separating two different medium, part of ray is reflected back into first medium and remaining is refracted as it enters second material.

It is shown in figure here $n_2 < n_1$. The relationship at the interface is known as Snell's law and is given by

$$n_1 \sin\phi_1 = n_2 \sin\phi_2$$

$n_1 < n_2 \rightarrow$ Bent towards normal

$n_1 > n_2 \rightarrow$ Bent away from normal.

Critical Angle:

The angle of Incidence at which the angle of refraction becomes 90° is called critical angle (fig b).

From Snell's law $\phi_1 = \phi_c$, $\phi_2 = 90°$ **8M**

$$n_1 \sin\phi_c = n_2 \sin 90°$$

$$\sin\phi_c = \frac{n_2}{n_1}$$ **4+4**

$$\phi_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$

Total Internal Reflection:-

If the angle of incidence is beyond (greater) the critical angle, then the entire light ray gets reflected within the denser medium. This is called Total internal Reflection (TIR). (fig c)

Acceptance cone :-

If we rotate acceptance angle around axis of fiber, we get a cone like structure which is called acceptance cone. If cone is large then light can be launched easily into fiber.

The cone of acceptance is the area of light gathering at input side of the optical fiber.

Numerical Apperature :-

+ It is light figure of merit which represents light gathering capacity of Fiber and is a unitless quantity.

$$NA = \sqrt{n_1^2 - n_2^2} = \sin \theta_0$$

where n_1 and n_2 are refractive index of core and cladding respectively, θ_0 is acceptance angle.

Acceptance Angle:

The maximum angle at which a light ray be incident upon a fiber and accept for transmission is called Acceptance angle θ_0

$$\text{Acceptance angle } \theta_0 = \sin^{-1} NA = \sin^{-1}\sqrt{n_1^2 - n_2^2}$$

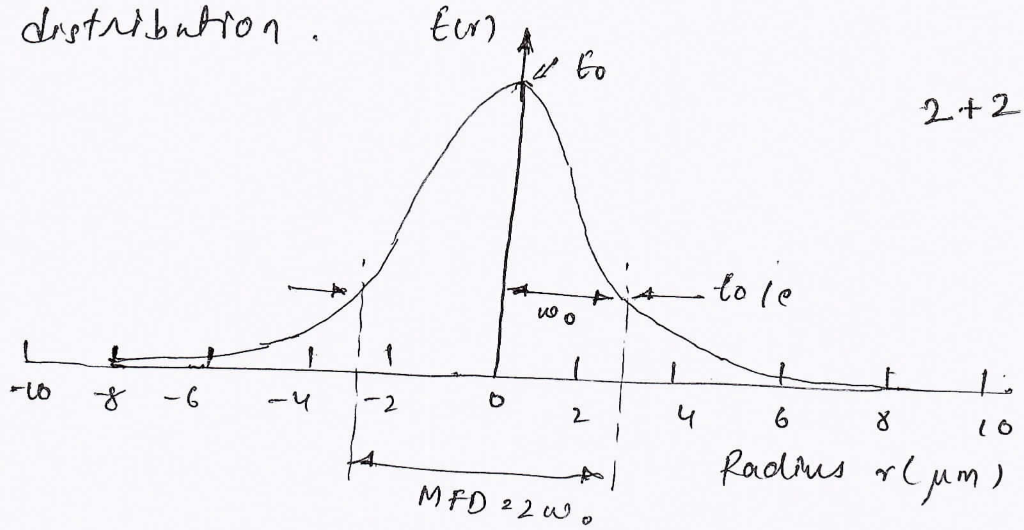
2b Explain mode field diameter of single mode fiber.

* The mode field diameter (MFD) is an important parameter for characterizing single mode properties which take into account the wavelength dependant field penetration into the fiber cladding.

* It is a function of optical source wavelength, core radius and R.I profile of the fiber.

* This is used to predict fiber properties such as splice loss, bending loss, cut off wavelength and wavelength dispersion.

* For step index and graded single mode fiber operating near the cut off wavelength λ_c, the field is appropriate by Gaussian distribution.



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* MFD is generally taken as distance between opposite

$\frac{1}{e} = 0.37$ field amplitude points and power

$\frac{1}{e^2} = 0.135$ in relation to values on fiber axis.

* Another parameter related to MFD is spot size w_0

$$MFD = 2w_0$$

$w_0 \Rightarrow$ nominal half width of input excitation.

Module - 2

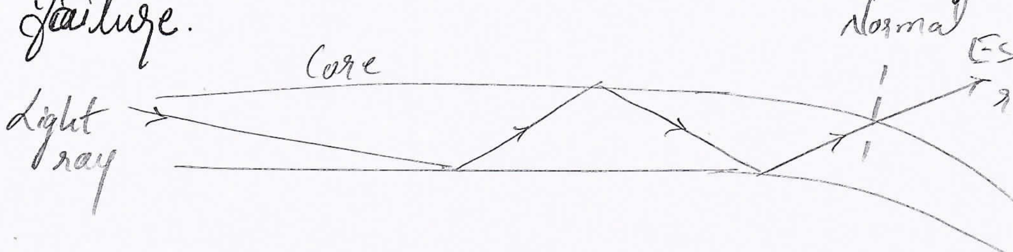
3a. Discuss the followings for optical fibers:
i) Fiber bend loss   ii) Material absorption.

[8m]

→ i) Fiber bend loss -

* Losses due to curvature and losses caused by an abrupt change in radius of curvature are referred to as 'bending losses'.

* The sharp bend of a fiber causes significant radiative losses and there is also possibility of mechanical failure.



4+4

* As the core bends the normal will follow it and the ray will now find itself on the wrong side of critical angle and will escape. The sharp bends are therefore avoided.

* The higher order modes are less tightly bound to the fiber core, the higher order modes radiate out of fiber firstly.

* For multimode fiber, the effective number of modes that can be guided by curved fiber is given expression

$$N_{eff} = N_{\infty}\left\{1 - \frac{\alpha+2}{2\alpha\Delta}\left[\frac{2a}{R} + \left(\frac{2}{2n_2kR}\right)^{2/3}\right]\right\}$$

where,

α is graded index profile.

Δ is core-cladding index difference.

n_2 is refractive index of cladding.

k is wave propagation constant $\left(\frac{2\pi}{\lambda}\right)$

N_{∞} is total number of modes in a straight fiber.

$$N_{\infty} = \frac{\alpha}{\alpha+2}(n_1 k a)^2 \Delta$$

ii) Material absorption -

* Absorption loss is related to the material composition and fabrication process of fiber.

*	Absorption loss results in dissipation of some optical power as heat in the fiber cable.
*	Although glass fibers are extremely pure, some impurities still remain as residue after purification.
*	The amount of absorption by these impurities depends on their concentration and light wave length.
*	Absorption is caused by three different mechanisms.
1)	Absorption by atomic defects in glass composition.
2)	Extrinsic absorption by impurity atoms in glass matts.
3)	Intrinsic absorption by basic constituent atom of fiber.
3b.	Define fiber splicing. Explain electric arc fusion splicing with neat sketches.
→	A permanent or semipermanent connection between two individual optical fibers is known as fiber splice. And the process of joining two fibers is called as splicing.

* Fusion splicing involves butting two cleaned fiber and faces and heating them until they melt together or fuse.

* Fusion splicing is normally done with a fusion splicer that controls the alignment of the two fibers to keep losses as low as 0.05 dB.

* Fiber ends are first prealigned and butted together under a microscope with micromanipulators. The butted joint is heated with electric arc or laser pulse to melt the fiber ends so can be bonded together

8M

4+4 —

4a. Describe linear scattering losses in an optical fiber?

→ * Scattering losses exists in optical fibers because of microscopic variations in the material density and composition.

* As glass is composed by randomly connected network of molecules and several oxides these are the major cause of compositional structure fluctuation.

* These two effects results to variation in refractive index and rayleigh type scattering of light. [8M]

* Rayleigh scattering of light is due to small localized changes in the refractive index of the core and cladding material.

* There are two causes during the manufacturing of fiber.

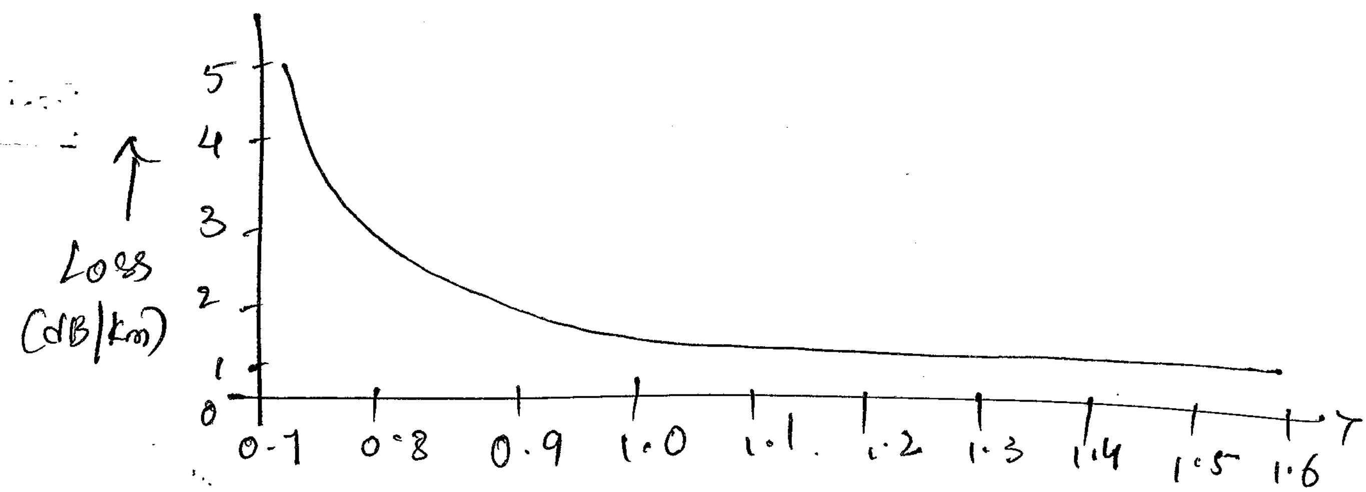
* The first is due to slight fluctuation in mixing of ingredients. The random changes because of this are impossible to eliminate completely.

* Scattering loss for single component glass is given by,

$$\alpha_{scat} = \frac{8\pi^3}{3\lambda^4}(n^2-1)^2 K_B T_f \beta_T \text{ nepers}.$$

* Scattering loss for multicomponent glasses is given by,

$$\alpha_{scat} = \frac{8\pi^3}{3\lambda^4}(\delta n^2)^2 \delta V.$$



4b. A four port multimode fiber FBT Coupler has 60 μw optical power launched into port 1. The measured output powers at ports 2, 3 and 4 are 0.004, 26.0 and 27.5 μw respectively. Determine the excess loss, insertion losses between input and output ports, the cross talk and split ratio for the device.

Excess loss — $10 \log_{10} \frac{P1}{(P3+P4)} = 10 \log_{10} \frac{60}{53.5}$ — 2m

$= 0.5$ db

Insertion loss (port 1 to 3) $= 10 \log_{10} \frac{P1}{P3} = 10 \log_{10} \frac{60}{26}$ 8M

$= 3.63$ db — 2m

Insertion loss (port 1 to 4) $= 10 \log_{10} \frac{60}{27.5} = 3.39$ db

Crosstalk $= 10 \log_{10} \frac{P2}{P1} = 10 \log_{10} \frac{0.004}{60}$ — 2

$= -41.8$

Splitting Ratio $= \left[\frac{P3}{P3+P4} \times 100 \right] = \frac{26}{53.5} \times 100$

$= 48.6\%$ — 2m

5.a	Explain the 3 factors, which affects the response time of photodiode.

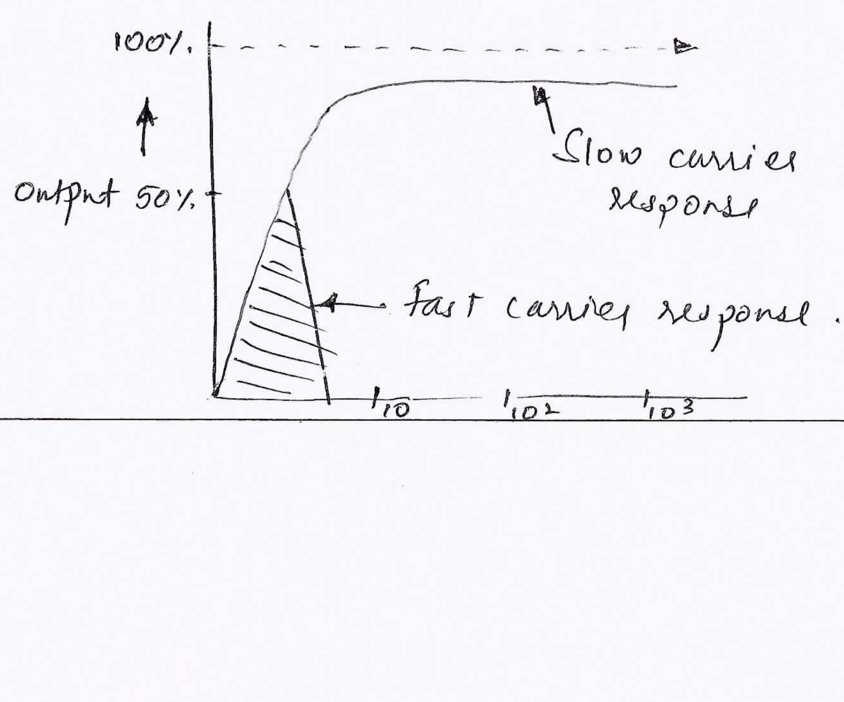
* Factors that determine the response time of a photodiode are:
  i) Transit time of photocarriers within the depletion region.
  ii) Diffusion time of photocarriers outside the depletion region.
  iii) RC time constant of diode and external circuit.

* The transit time is given by -

$$t_d = \frac{w}{v_d}.$$

3M

* The diffusion process is slow and diffusion times are less than carrier drift time. By considering the photodiode response time the effect of diffusion can be calculated.



4 marks

* The detector behaves as a simple low pass RC filter having passband of

$$N = \frac{1}{2\pi R_R C_T}$$

where,

R_T is combination input resistance of load and amplifier

C_T is sum of photodiode and amplifier capacitance.

5b Derive an equation for optical receiver sensitivity.

* To calculate optical receiver sensitivity, total noise in the receiver is calculated.

Substituting these values and solving equation, we get

$$(V_N^2) = \{V_{shot}^2(t)\} + (V_R^2(t)) + (V_1^2(t)) + (V_E^2(t)) \quad \text{—— (*)}$$

$$B_{bae} = \frac{I_2}{T_b} = I_2 B$$

and

$$B_e = I_2 B + (2\pi C)^2 I_3 B^3$$

Substituting these values and solving equation (*) gives

$$(V_N^2) = R^2 A^2 \left\{ 2q(i_0) M^{2+x} + \frac{4k_B T}{R_b} + S_1 + \frac{S_E}{R^2} \right\} I_2 B + (2\pi C)^2 A^2 S_E I_3 B^3 \quad \text{—— (1)}$$

— 2M

$$\therefore (V_N^2) = (qRAB)^2 (2q(i_0) M^{2+x} T_b I_2 + W) \quad \text{—— (2)}$$

where,

$$W = \frac{1}{q^2 B}\left(S_1 + \frac{4k_B T}{R_b} + \frac{S_E}{R^2}\right) I_2 + \frac{2\pi C^2}{q} S_E I_3 B \quad -(3)$$

This equation is known as thermal noise characteristic of an optical receiver.

* The optimum gain to achieve desired BER for receiver is given by -

$$M_{opt}^{1+x} = \frac{2w^{1/2}}{xQI_2} \pi r^2$$

Assuming no ISI ie $\gamma = 1$ — 2M

where,

Q is parameter related so S/N ratio to acheive desired BER.

w is thermal noise characteristic of receiver.

X is photodiode factor.

I2 is normalized BW.

8M eq

Mean Square Input Noise Current

* The mean square input noise current is given as.

$$\langle i_N^2 \rangle = \langle i_g^2 \rangle + \langle i_g^2 \rangle + \langle i_I^2 \rangle + \langle i_g^2 \rangle$$

i) Shot noise current :-

$$\langle i_s^2 \rangle = 2q\langle i_o \rangle \langle m^2 \rangle A^2 I_2 B$$

ii) Thermal Noise :

$$\langle i_g^2 \rangle = \frac{4 k_B T}{R_b} A^2 I_2 B$$

iii) ~~Shunt~~ Series Noise :-

$$\langle i_g^2 \rangle = S_E A^2 \left[\frac{I_2 B}{R^2} + (2\pi C)^2 I_3 B^3 \right]$$

iv) Shunt Noise :-

$$\langle i_I^2 \rangle = S_I A^2 I_2 B$$

v) Total Noise :-

$$\langle i_N^2 \rangle = \langle i_s^2 \rangle + \langle i_g^2 \rangle + \langle i_I^2 \rangle + \langle i_g^2 \rangle$$

$$\langle i_N^2 \rangle = A^2 (2q\langle i_o \rangle \langle m^2 \rangle I_2 B + q^2 W B^2)$$

$$\langle i_N^2 \rangle = \left(S_I + \frac{S_g}{R_m^2} \right) B I_2 + (2\pi C)^2 S_E B^3 I_3 \quad \text{— 4M}$$

6a. What are the characteristics requirements of an optical source? With the help of diagram describe the operation of surface emitting LED.

Characteristics of Light Source of Communication

* To be useful in an optical link, a light source needs the following characteristics.

i) It must be possible to operate the device continuously at a variety of temperature for many years.

ii) It must be possible to modulate the light output over a wide range of modulating frequencies.

iii) For fiber links, the wavelength of the output should coincide with one of transmission windows for the fiber types used.

iv) To couple large amount of power into a optical fiber, the emitting area should be small.

v) To reduce material dispersion in an optical fiber link, the output spectrum should be narrow.

vi) The power requirement for its operation must be low.

vii) The light source must be compatible with the modern solid state devices.

viii) The optical output power must be directly modulated by varying the input current to the device.

ix) Better linearity of prevent harmonics and intermodulation distortion.

x) High coupling efficiency.

xi) High optical output power.

xii) High reliability.

xiii) Low weight and low cost.

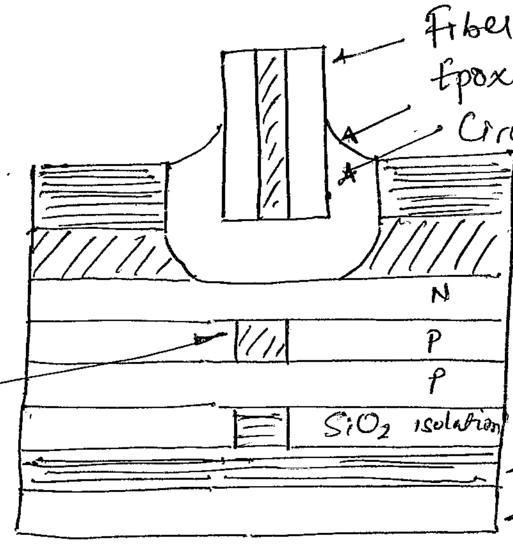
* Surface Emitting LED

* In surface emitting LEDs the plane of active light emitting region is oriented perpendicularly to the axis of the fiber. A DH diode is grown on an N-type substrate at the top of the diode as shown in figure. A circular well is etched through the substrate of the device. A fiber is then connected to accept the emitted light.

* At the back of device is a gold heat sink. The current flows through the p-type material and forms the small circular active region resulting in the intense beam of light.

Diameter of circular active area = 50 μm
thickness of circular active area = 2.5 μm
Current density = 2000 A/cm² half power
Emission pattern = Isotropic, 120° beamwidth.

fig 1.



HM

SM

* The isotropic emission pattern from surface emitting LED is of Lambartian pattern. In Lambartian pattern, the emitting surface is uniformly bright, but its projected area diminishes as cos θ, where θ is the angle between the viewing direction and the normal to the surface as shown in fig 2. The beam intensity is maximum along the normal.

4+4

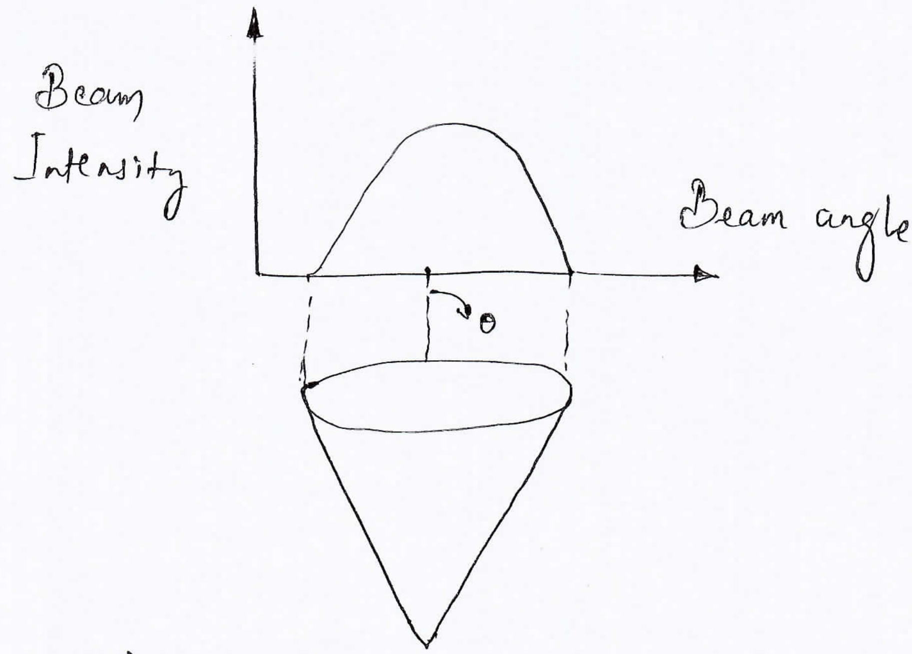


fig 2. Lambartian radiation

* The power is reduced to 50% of its peak when $\theta = 60°$, therefore the total half power beamwidth is 120°. The radiation pattern decides the coupling efficiency of LED.

6.6 Explain different ~~types~~ amplifiers used in optical receiver.

Front end amplifier.

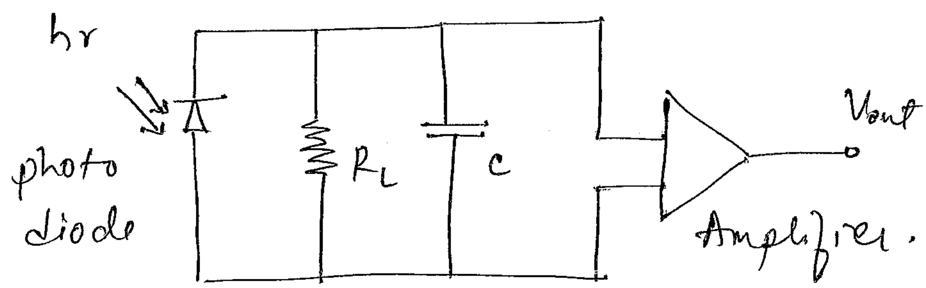
* Noise sources at the front end of a receiver dominates the sensitivity and bandwidth, so it is necessary to design a low noise front end amplifier.

* Front end amplifier is used for
  - → increasing receiver sensitivity
  - → maintaining suitable bandwidth

* Types
  - → High Impedance design
  - → Trans Impedance design.

* The important design parameter in front end amplifier is to choosing of R_L (load resistance).
* Because thermal noise is inversly proportional to R_L (ie) thermal noise $\propto \frac{1}{R_L}$.
* So R_L should be as large as possible to minimize thermal noise.

High Imdedance amplifier:



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* System Bandwidth is also $\propto \frac{1}{R_p}$
  where R_p → Resistance seen by photodiode
* So for this design a trade off must be done between noise and bandwidth ($\because R_p = R_L$)

* Equalizers can be used to increase the system bandwidth. but if bandwidth is less than the bit rate then it is not useful front end amplifier.

<u>Trans impedance amplifiers</u>.

* The drawbacks of the previous amplifiers is overcame by using R_L as the negative feedback for an inverting amplifier.

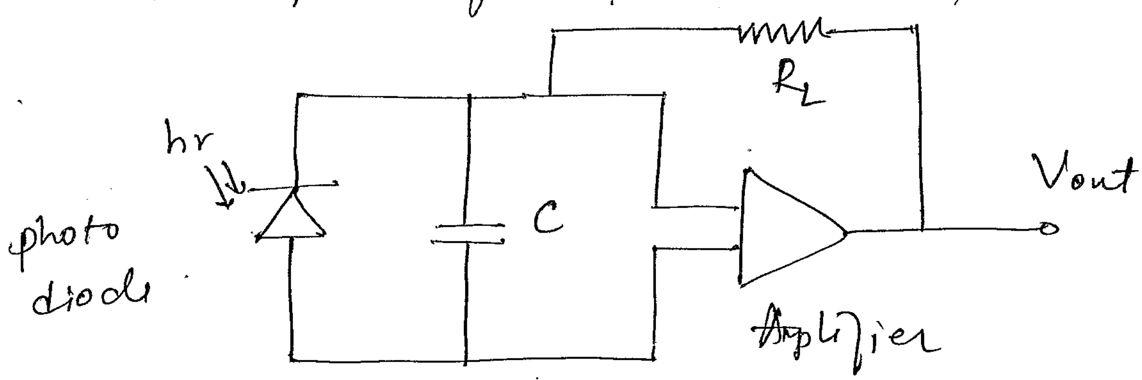
* Now the effective resistance seen by the photodiode is reduced by a factor of G

ie $R_p = \frac{R_L}{G+1}$ G → gain of amplifier

* So the bandwidth increases by a factor "G+1"

* Also noise is increased but this amount of noise can be tolerated easily.

* This is the optimum choise of amplifier to be used in optic fiber transmission link.



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Module-4

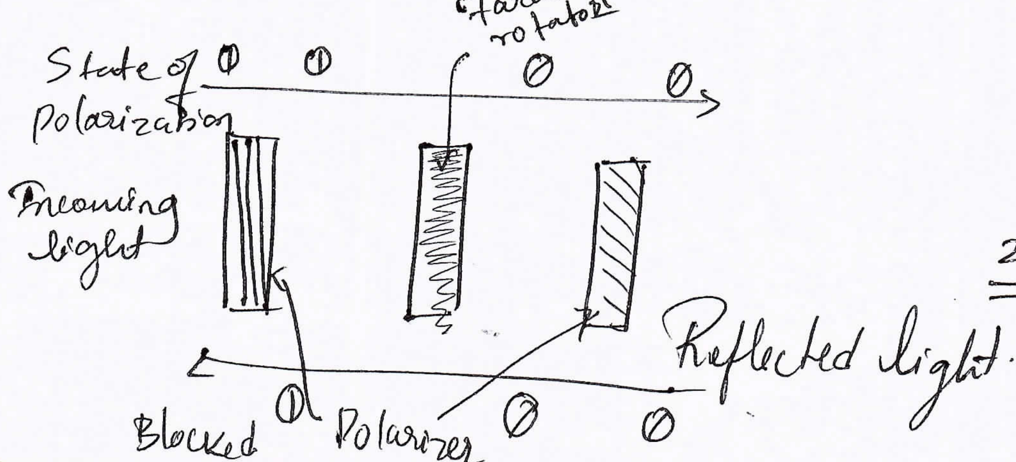
7a. Describe the principles of working of isolators and Circulators with a neat diagram.

→ Isolators:

* Isolator works on the principle of state of polarization (SOP) refers to the orientation of its electric field vector on a plane that is orthogonal to its direction of propagation.

* The electric field can be expressed as linear Combination of two orthogonal linear polarization supported by fiber.

* These two polarization modes are horizontal and vertical modes.



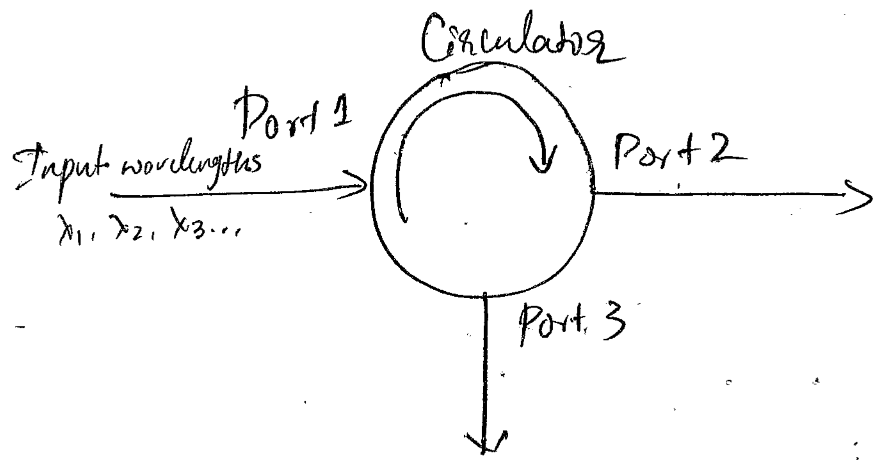
2M

* Let input light signal has vertical state of polarization and blocks energy in horizontal SOP. The polarizer is followed by Faraday rotator.

* Faraday rotator is an asymmetric device which rotator passes only SOPs with 45° orientation.

Circulator:

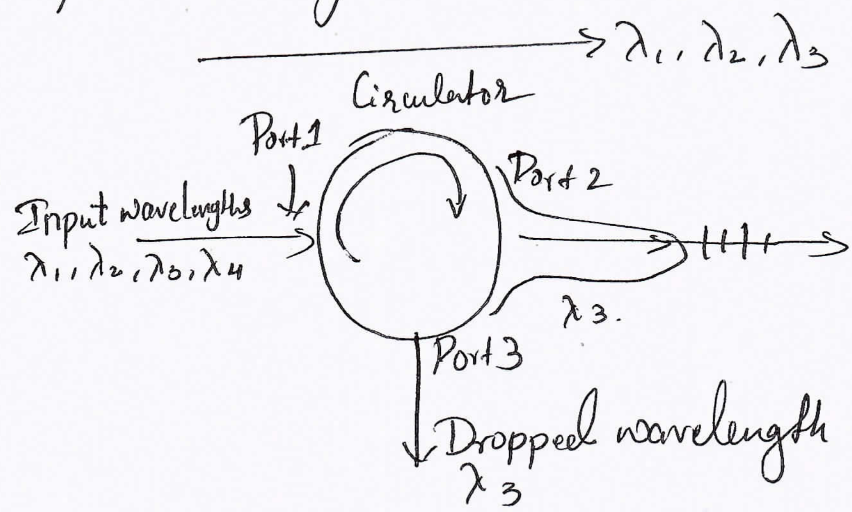
* A three port circulator signals of different wavelengths are entered at a port and sends them at next port.



2M

* All the wavelengths are passed to port-2. If port-2 absorbs any specific wavelength then remaining wavelengths are reflected and sends them to port-3.

* Circulators are used to implement demultiplexer using ∂ the fiber Bragg grating for extracting a desired wavelength



8M

* The circulator takes four wavelengths $\lambda 1, \lambda 2, \lambda 3$ and $\lambda 4$ from input port-1 tunable filter operedes on similar principle as passive devices. 4M

7b Briefly discuss Raman amplifiers?

→ *An EDFA requires a specially Constructed optical fiber for its operation a Raman amplifier makes use of the transmission fiber itself as the amplification medium.

* A Raman amplifier is based on an effect called Stimulated Raman Scattering. This effect is due to an ~~effect called Stimulate~~ interaction between an optical energy field and the vibration modes of the lattice structure in a material.

* The energy difference between the absorbed and the released photons is transformed to a phonon, which is a vibration mode of the material. The power transfer results in an upward wavelength shift of 80 to 100nm, and the shift to a longer wavelength is refferied to as the Stokes Shift.

* Raman gain Spectrum from a pump laser operating at 1445nm. Here a signal at 1535nm, which is 90nm away from the pump wavelength, is amplified.

* Raman amplifier ~~a~~ This process transfers optical energy from a strong laser pump beam to a weaker transmission signal that has a wavelength which is 80 to 100nm higher than the pumping wavelength.

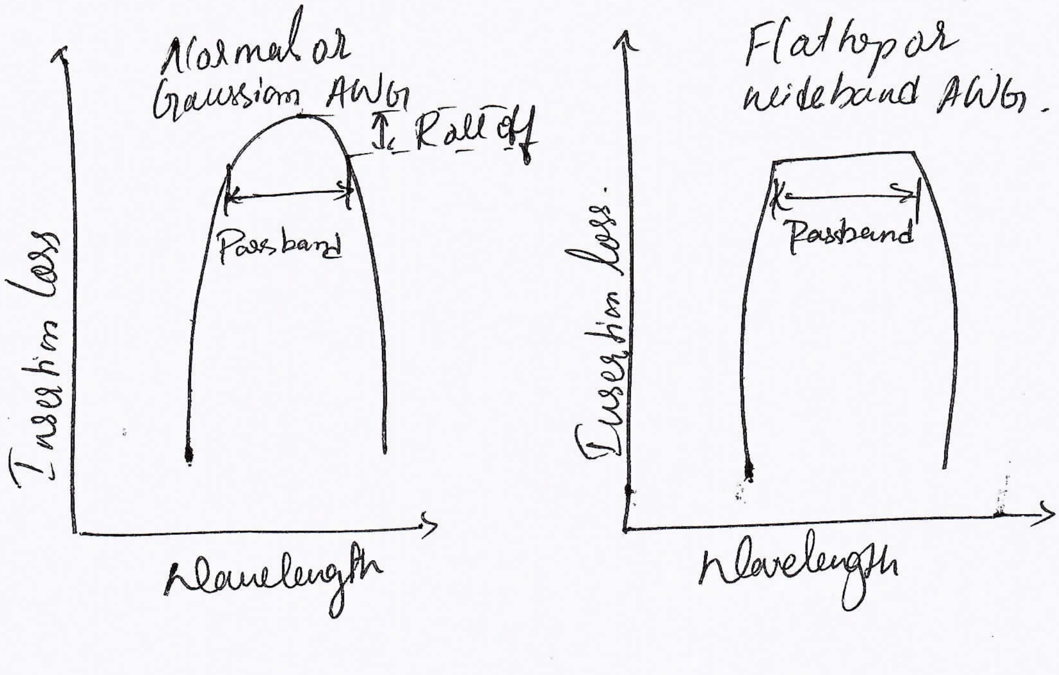
4+4 [8M]

8a. Write note on : i) Diffraction gratings ii) MEMS technol-
-ogy.

→ i) Diffraction gratings -

* A fourth DWDM technology is based on diffraction gratings.

* A diffraction grating is a conventional optical device that spatially separates the different wave lengths contained in a beam of light.



* The device consists of a set of diffracting elements, such as narrow ~~based~~ parallel slits or grooves, separated by a distance comparable to the wavelength of light.

* Adjacent-channel crosstalk in a diffraction grating is very low, usually less than 30dB.

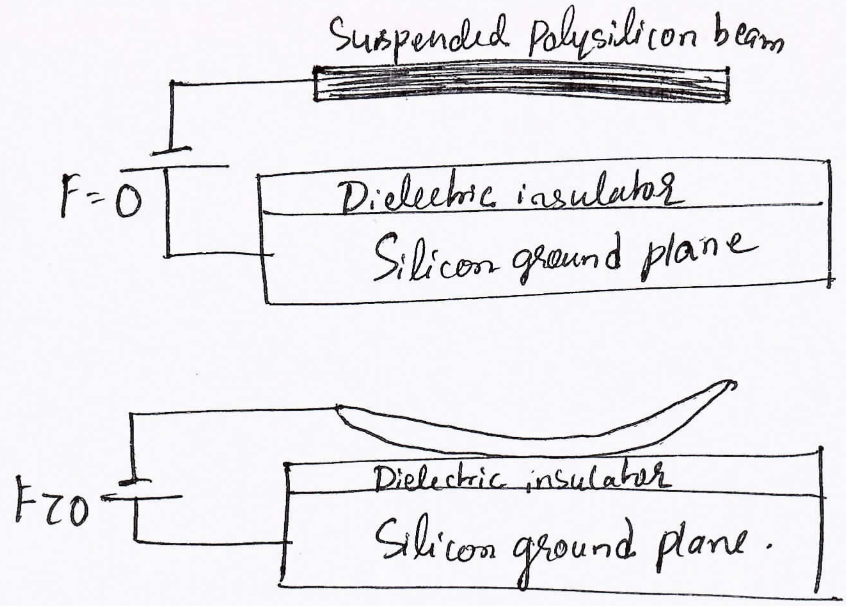
* Reflection gratings are fine ruled or etched parallel lines on some type of reflective surface.

ii) MEMS technology:

* Micro electro-mechanical systems are miniature devices than can combine mechanical, electrical & optical components to provide sensing & optical components to provide sensing & actuator function.

* MEMS are fabricated using integrated circuit & range in size from micrometers to millimeters.

* Application: Air-bag deployment systems, ink-jet printer heads, biomedical applications, variable optical attenuators, tunable lasers, optical add drop multiplexers etc.



4M

* Above figure shows example of MEMS actuation method. 8M
* At top of device there is a thin suspended polysilicon beam that has typical length, width & thickness dimensions of 80μm, 10μm & 0.5μm respectively.
* At the bottom there is a silicon ground plane that is covered by an insulator material.

4M

86. With the aid of neat diagram, explain three possible EDFA Configurations?

→ * There are 3 types of EDFA architectures namely.

(i) Co-Directional pumping

(ii) Counter directional pumping

(iii) Dual pump scheme, these architectures are depending on the direction of signal flow and direction of pump power.

* In co-directional pumping, pump power signal is injected from the same direction as the signal power flow. ~~as~~

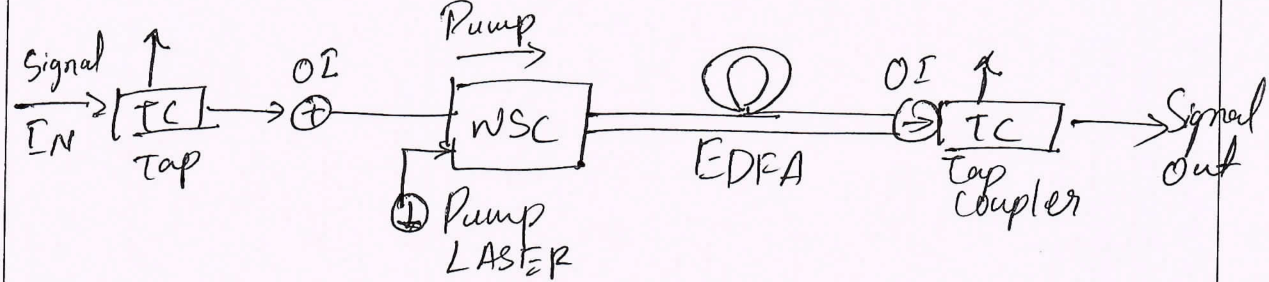
* In counter-directional pumping, pump power signal is injected from the opposite direction to the signal power flow.

* In Dual pump scheme, Two pump Laser Sources are used on the either side of the amplifier/signal power flow.

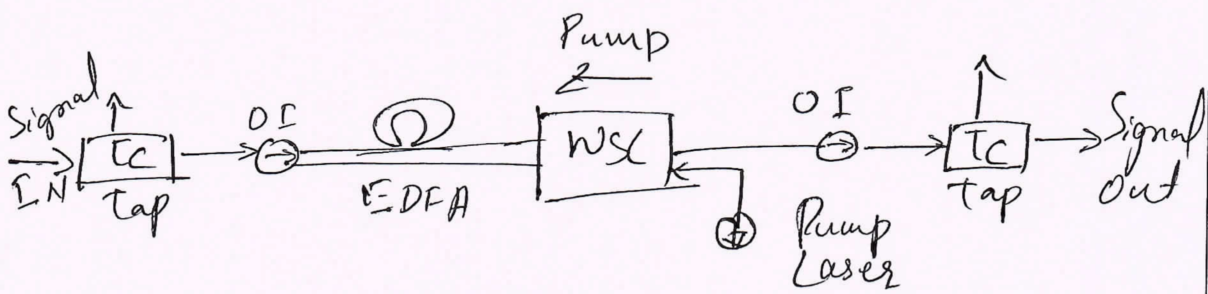
* Along with amplifier (EDFA), these architecture uses.

- One (or) Two pump lasers. 4M
- Passive wavelength Selective Coupler (WSC)

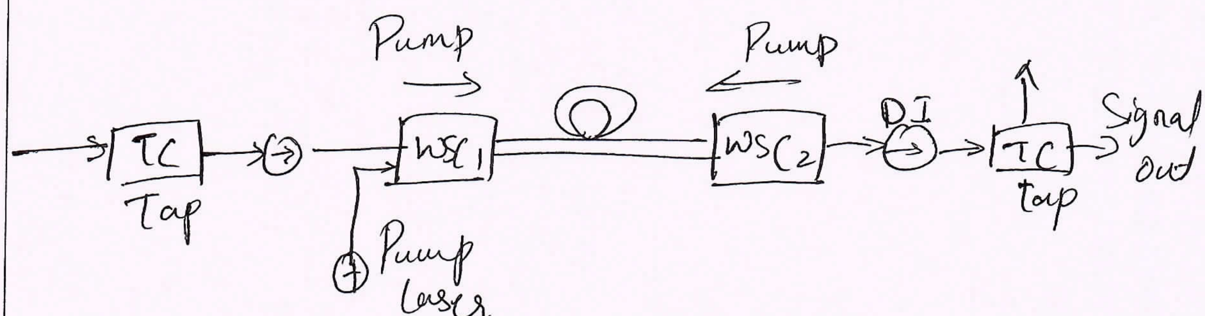
- Optical Isolators (OI)
- Tap Couplers (Tap)



(a) Co-directional pumping



(b) Counter directional pumping. 8M

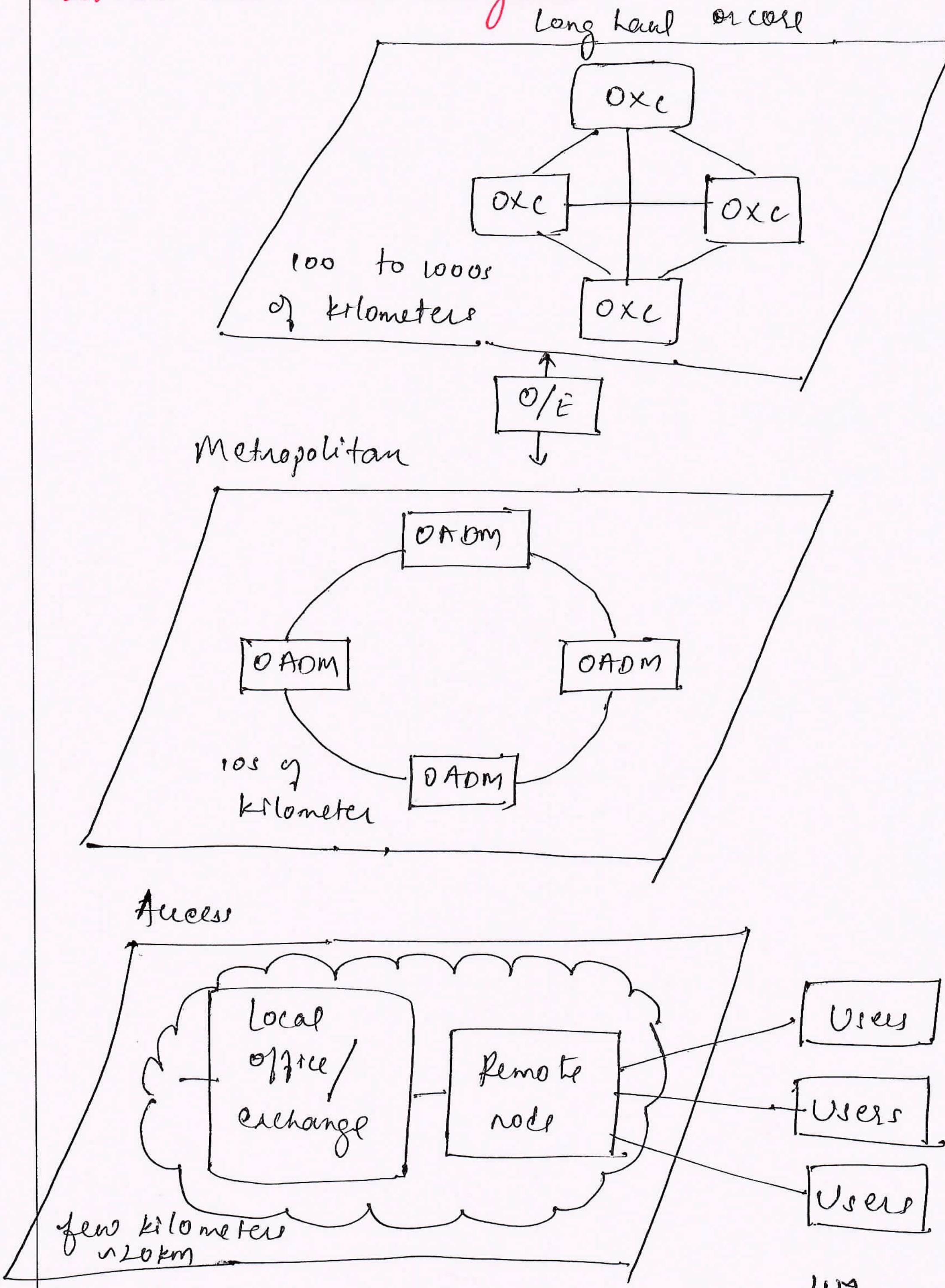


4M

(c) Dual pump scheme.

Module 5.

9.a Explain public telecommunications network review with neat diagram.



4M

figure 1.

* The telecommunication network providing services in the public domain is known as the public telecommunications network where the service providers offer a variety of services for the provision of voice, data and video transmission.

* A simple block hierarchy for the optical public telecommunications network is shown in the figure.

* It is divided into three tiers
  - long haul
  - metropolitan
  - access networks

BM

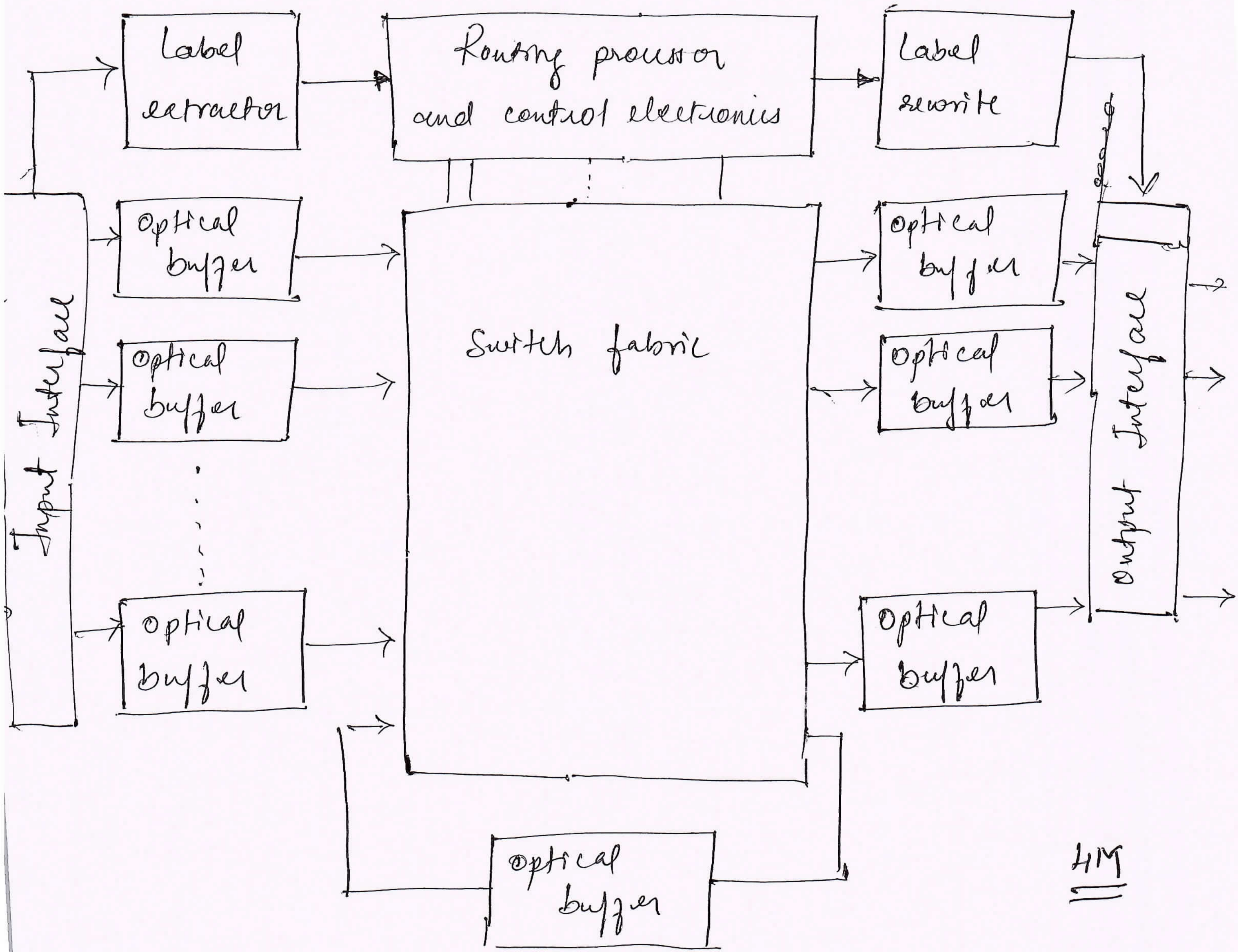
* The long haul network also known as the core sometimes is the backbone network, provides national or global coverage with a reach of thousands of kilometers.

* These networks connect many meteropolitan networks within a country or interconnect together several country wide long haul networks.

* Interconnection between optical nodes is generally accomplished by means of optoelectrical conversion and / or optical switches employing OXC's. HM

* At the next lower hierarchal level resides the metropolitan area network (MAN), often called the metro, or ~~something~~ sometimes the back haul network.

9b. Explain an optical packet switched network with neat diagram.



4M

In an optical packet switched (OPS) network data is transported entirely in the optical domain without intermediate optoelectrical conversions. An optical packet switch performs the four basic functions of routing, forwarding, switching and buffering.

Q No	
	* These networks offer a multiservice platform and maybe confined to a region spreading to tens of kilometers. * At present ~~optical nodes~~ they are largely implemented using the ring topology. * The interconnection between optical node in metro networks are also acheived using OADMs while the larger metro networks can also incorporate OXCs. * The lowest tier in the hierarchy is the local access network which may be extended from few hundreds of meters to 20 kilometers or so. * Hence the access networks provides the initial interface to the telecommunications network for residential and business owners. * These networks can be configured using bus,

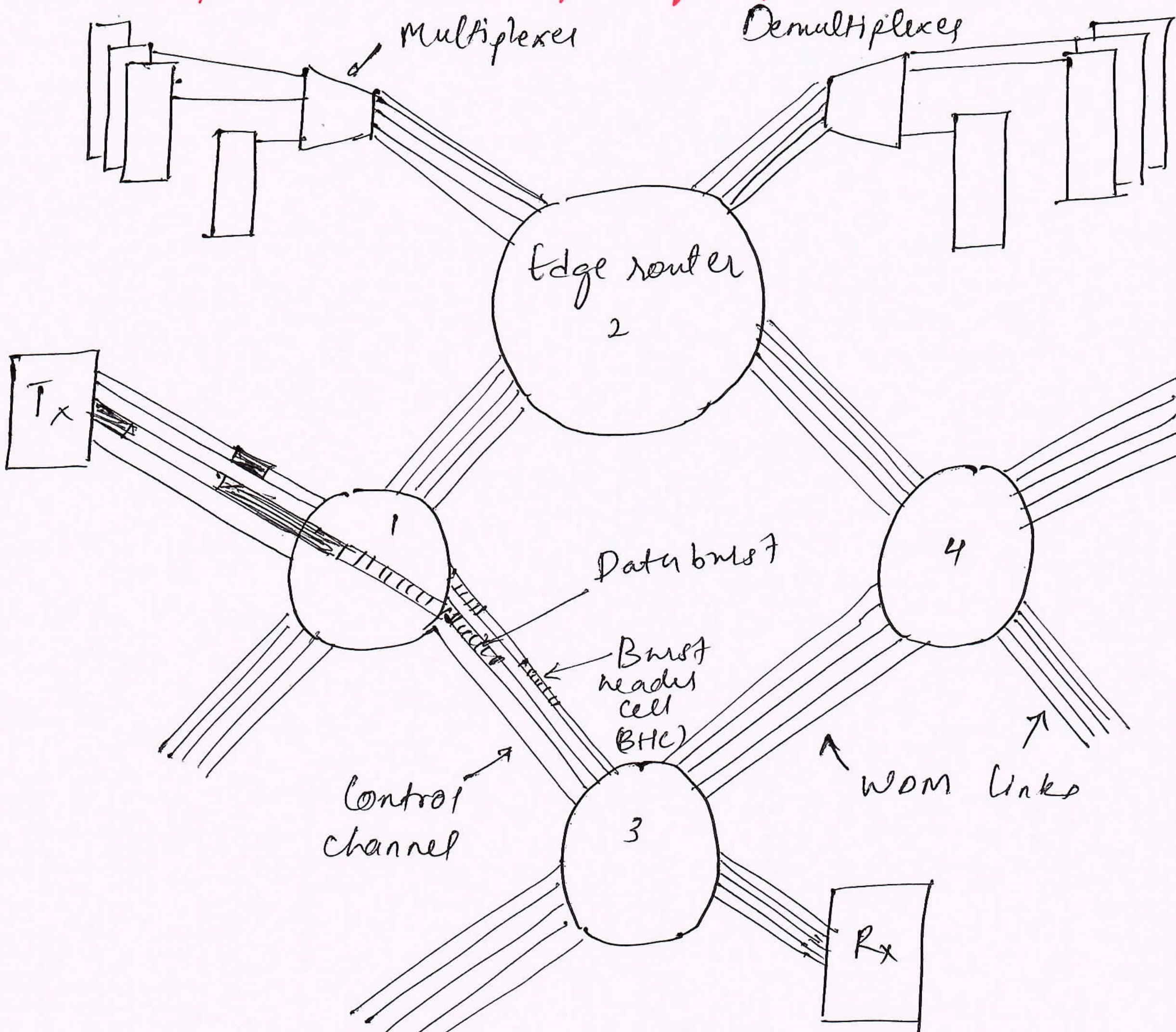
ring or star topology.

8M

4M

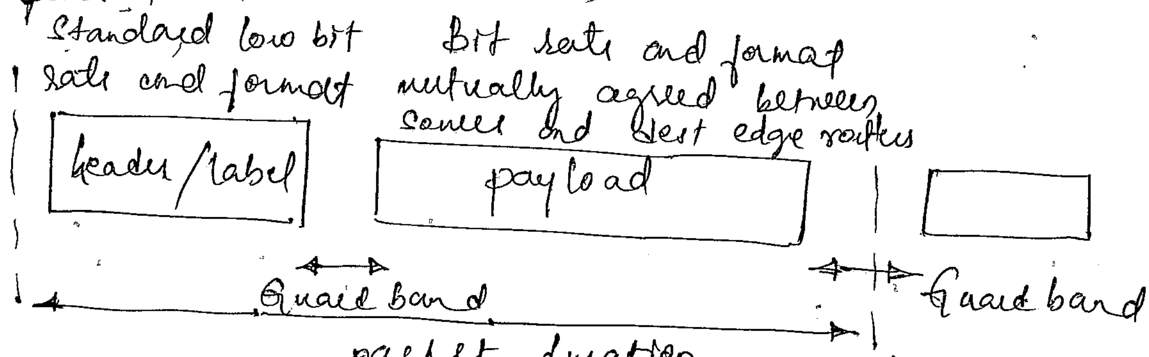
being sent through the optical switch fabric to the desired output buffers. Finally, the sorting processor and control section regenerate the label which is reattached with the data at the output interface.

10a. Explain the concept of optical burst switching.



4M

Above figure illustrates the concept of Optical Burst switching where four edges router of a large network are shown to establish links between data sources (Tx) and receivers (Rx) individually or by using multiplexers or demultiplexers, respectively

Q No	
	* Figure 2 shows the overall structure of a typical packet.  * It contains a header or label and the payload and it requires a guard band to ensure the data is not overwritten. * The label points to an entry in a lookup table that specifies to where the packet should be forwarded. * ~~Such~~ Since labels define the routing criteria it is therefore sometimes ~~of~~ reffered to as label switching.

* The figure 1 depicts a generic OLS network configuration to route packets while also extracting and rewriting labels at input and output interfaces.

* In this particular implementation only the detached label is processed electronically and the payload remains in optical buffers before

Q No	
	* The OADM further adds another wavelength signal λ_4 at intermediate port 3 which is then multiplexed with the transmitted signal wavelengths so that the combined signal leaving port 4 contains wavelength λ_1, λ_3 and λ_4. * Devices which are configured to drop a particular wavelength and add another specific wavelength are also known as OADM. * Figure 1(d) shows a simple 2x2 optical switch with two input and two output ports. * The two optically multiplexed signals comprising wavelengths λ_1 λ_2 and λ_3 λ_4 are present at input ports 1 and at 2 respectively. * At the output ports the wavelengths are required to be switched and multiplexed as λ_1 λ_3 and λ_2 λ_4 emerging at outputs port 3 and 4.

4M

* A combination of an OADM and an optical switch producing a reconfigurable optical add/drop multiplexer (ROADM) is illustrated in figure 1(e).

* This device can drop one or a desired number of wavelength channels after demultiplexing a wavelength multiplexed signal and similarly it can also add a new single or more wavelength channel through optical switch.

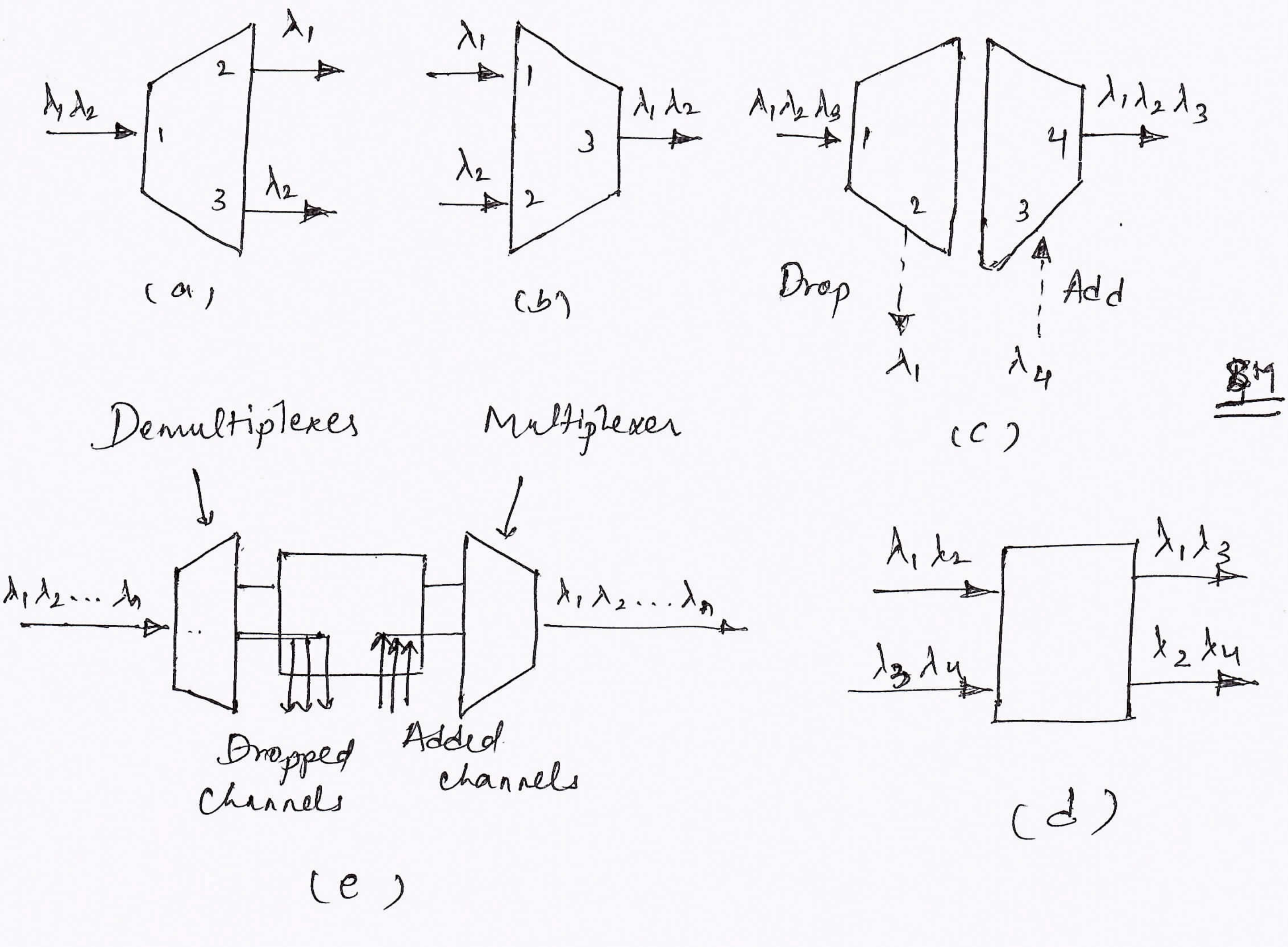
figure 1. Optical networking node elements
a) wavelength demultiplexer
b) wavelength multiplexer
c) optical add / drop multiplexer
d) 2x2 optical switch
e) reconfigurable optical add / drop multiplexer.

* The four different function of an optical router are depicted in figure 1.
* A 1x2 wavelength demultiplexer is shown in figure 1(a) which illustrate the splitting of an optical signal present at input port 1 containing two wavelengths (λ_1 and λ_2) and routing them to ports 2 and 3, respectively.
* A three port wavelength multiplexer combining two wavelength signals is indicated in figure 1(b).
* An optical add / drop multiplexer (OADM) which also comprises a wavelength add / drop (WADD) is shown in figure 1(c) where an incoming multiplexed signal comprising three wavelengths (ie λ_1, λ_2 and λ_3) is partially demultiplexed by dropping the λ_2 signal at an intermediate port 2.

field specifying the time duration of the burst.
on each link can be reserved for control information that is used to control the dynamic assignment of the remaining channels to user data bursts.

+ It should be noted that the WDM transmission links shown in the figure carry a number of wavelength channels and the user data bursts can be dynamically assigned to any of these channels of the OBS router.

10b. Explain the different types of optical networking node elements.



Q No	
	* Optical bursts containing both the data burst and the BHC travel on a control channel. * An idle channel on the access link is selected when a data burst is required to be sent. * Whereas the BHC travels on the control channel ahead of its associated data burst in time and is processed electronically at every node along the path. * The OBS edge router, on receiving ~~and~~ the BHC assigns the incoming burst to an available channel selected to carry the burst. * It also forwards the BHC on the control channel of the selected link. 4M * After modifying the cell to specify the channel on which the burst is being forwarded. * This process is repeated at every routing

node along the path to the destination.

* The BHC also includes an offset field which contains the time between the transmission of the first bit of the BHC and the first bit of the burst and a length field specifying the time duration of the burst.

* One or several channels burst and a length

8M