IV/IV B.Tech Regular/Supplementary Degree Examination, Nov 2022

Scheme of Evaluation

Subject code:- 18EC703

Subject Name:- Fiber Optic Communications

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18EC703

Hall Ticket Number:

IV/IV B.Tech (Regular/Supplementary) DEGREE EXAMINATION

November,2022 **Electronics & Communication Engineering**

Seventh Semester **Fiber Optic Communications**

Time: Three Hours **Maximum:** 50 Marks

Answer Question No. 1 Compulsorily. (10X1 = 10 Marks)

*Answer **ANY ONE** question from each Unit.* (4X10=40 Marks)

1.	a)	What is Snell's law?	CO1(BL1)	
	b)	Define Numerical Aperture of the fiber	CO1(BL1)	
	c)	List the salient features of expanded beam connector.	CO2(BL1)	
	d)	What are the different types of bending losses occur in Optical fibers?	CO2(BL1)	
	e)	What is insertion loss?	CO2(BL1)	
	f)	What are the applications of LED?	CO3(BL1)	
	g)	Define Responsitivity of Photodiode.	CO3(BL1)	
	h)	List the different current confinement methods for LASER.	CO3(BL1)	
	i)	What are the applications of OTDR?	CO4(BL1)	
	j)	Define the Sensitivity of Optical Receiver.	CO4(BL1)	
		Unit - I		
2.	a)	Explain about Optical fiber communication system with the help of a block diagram.	CO1(BL4)	**5M**
	b)	Compare the advantages and disadvantages of Optical Communication System with Conventional Communication System.	CO1(BL4)	**5M**
		(OR)		
3.	a)	Discuss i) 'Total Internal Reflection' and 'Acceptance angle' in ray optics. ii) Illustrate various advantages of optical fiber communication.	CO1(BL2)	**5M**
	b)	i)Compute the numerical aperture of a plastic step-index fiber having refractive index of n1=1.6 and a Cladding index n2=1.49. ii) Illustrate single mode fibers and their mode- field diameter.	CO1(BL3)	**5M**
		Unit - II		
4.	a)	Explain in detail about Linear scattering losses in optical fiber.	CO2(BL4)	**5M**
	b)	Compare the differences between intramodal and intermodal Dispersion.	CO2(BL4)	**5M**
		(OR)		
5.	a)	Explain various fiber splicing techniques.	CO2(BL2)	**5M**
	b)	Describe in detail about Joint losses occur in Single mode and Multimode fibers.	CO2(BL2)	**5M**
		Unit - III		
6.	a)	Explain the construction and working of high radiance surface emitting LED With a neat diagram.	CO3(BL4)	**5M**
	b)	Discuss the structures of fabry perot LASER diode and distributed feedback (DFB) LASER diodes with necessary diagrams.	CO3(BL2)	**5M**
		(OR)		
7.	a)	Sketch the structure of Avalanche photo diode and describe its working as optical detector.	CO3(BL3)	**5M**
	b)	Interpret in detail about optical detection principles.	CO3(BL3)	**5M**
		Unit - IV		
8.	a)	Describe the functioning of every element of a fiber optic receiver with the help of a suitable block diagram	CO4(BL2)	**5M**
	b)	Explain in detail about Optical time division multiplexing (OTDM).	CO4(BL4)	**5M**
		(OR)		
9.	a)	Explain the principle, requirement and applications of WDM.	CO4(BL2)	**5M**
	b)	Describe the working principle and operation of OTDR.	CO4(BL2)	**5M**

Answer QUESTION No.1 compulsorily **1X10=10M**

1.

a) snell's law:

Snell's law states that the ratio of the sines of the angles of incidence and refraction is equivalent to the ratio of phase velocities in the two media.

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1}$$

b) The light gathering capability of an optical fiber is defined as a NA of fiber.

c) Expanded Beam (EB) connectors are ideal for use in harsh environment applications where optical interfaces can become contaminated potentially jeopardising system performance. The increased size of the optical beam reduces susceptibility of the interconnect to contamination and allows for easy cleaning / maintenance in the field.

d) Micro and Macro are the two types of bending losses

e) The insertion loss is the amount of light that is lost as the signal arrives at the receiving end of the link. Insertion loss is measured in decibels (dB).

f) LEDs are simple, inexpensive as well as rugged sources. LEDs find use in most of the modest short length links, as well as in LANs. Laser diodes are the sources of choice for all telecommunication applications because of their higher optical powers, small spectral width, and high data rate modulation capability.

g) **Responsivity:**

Output current per unit incident light power; typically 0.5 A/W

$$R = \frac{\eta e}{h\nu} M$$

h) Optical confinement and carrier confinement are teo types of confinements in LASER.

i) The main application of OTDR is to find fault detection and attenuation measurement

j) Sensitivity is defined as the minimum signal optical power level required at the receiver to achieve a certain BER performance

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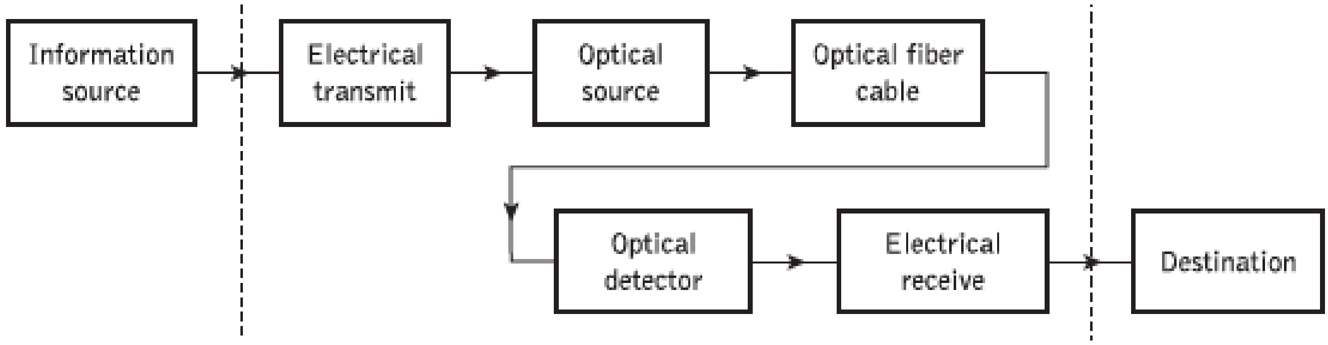
UNIT-I

2.a) Elements of Optical communication system:- **Block diagrams – 3M + Explanation-2M = 5M**



An optical fiber communication system is similar in basic concept to any type of communication System. the function of which is to convey the signal from the information source over the transmission medium to the destination. The communication system therefore consists of a transmitter or modulator linked to the information source, the transmission medium, and a receiver or demodulator at the destination point.

For optical fiber communications the information source provides an electrical signal to a transmitter comprising an electrical stage which drives an optical source to give modulation of the lightwave carrier. The optical source which provides the electrical–optical conversion may be either a semiconductor laser or light-emitting diode (LED). The transmission medium consists of an optical fiber cable and the receiver consists of an optical detector which drives a further electrical stage and hence provides demodulation of the optical carrier. Photodiodes (*p–n*, *p–i–n* or avalanche) and, in some instances, phototransistors and photoconductors are utilized for the detection of the optical signal and the optical–electrical conversion

2)b) **Explanation of differences between them = 5M**

Optical Fiber Communication System	Conventional Communication System
1. Requires a bandwidth of 10^{13} to 10^{16}Hz.	1.Requires a bandwidth of 500 MHz
2 .Light weight.	2. Heavier in weight.
3. Immune to R.F. interference.	3. Needs external shielding.
4. Electrical isolation.	4. Exhibits earthing problems.
5. Low loss of about 0.2 dB/km.	5. Loss of about 10 dB/km.
6. Secure signal propagation.	6. Signal can be tapped easily.

(OR)

3)a) **Explanation of TIR -3M + Advantages of OFC- 2M= 5M**

i) **Total Internal Reflection:-**

The phenomenon which occurs when the light rays travel from a more optically denser medium to a less optically denser medium. Consider the following situation. A ray of light passes from a medium of water to that of air. Light ray will be refracted at the junction separating the two media. Since it passes from a medium of a higher refractive index to that having a lower refractive index, the refracted light ray bends away from the normal. At a specific angle of incidence, the incident ray of light is refracted in such a way that it passes along the surface of the water. This particular angle of incidence is called the critical angle.

Here the angle of refraction is 90 degrees. When the angle of incidence is greater than the critical angle, the incident ray is reflected back to the medium. We call this phenomenon total internal reflection.

ii) **Advantages:**

Enormous Potential Band Width

- Small Size and Weight
- Electrical Isolation
- Immunity to interference and crosstalk(emi,rfi,emp)
- Signal Security
- Low transmission loss
- Ruggedness and flexibility
- System reliability and Ease of maintenance
- Potential low cost

3)b) i) **Calculating Numerical Aperture=2M**

ii) **Single mode fibers:-** **Block diagram and Explanation = 3M**

Single-mode optical fiber (SMF), also known as fundamental- or mono-mode,[1] is an optical fiber designed to carry only a single mode of light - the transverse mode. Modes are the possible solutions of the Helmholtz equation for waves, which is obtained by combining Maxwell's equations and the boundary conditions.

The advantage of the propagation of a single mode within an optical fiber is that the signal dispersion caused by the delay differences between different modes in a multimode fiber may be avoided. For single-mode operation, only the fundamental LP01 mode can exist. Hence the limit of single-mode operation depends on the lower limit of guided propagation for the LP11 mode. The cutoff normalized frequency for the LP11 mode in step index fibers occurs at V_c =2.405. Thus single-mode propagation of the LP01 mode in step index fibers is possible over the range:

$0 < V < 2.405$

UNIT-II

4.a) <u>Linear Scattering loss:</u> **Explanation of both scattering losses = 5M**

Linear scattering mechanisms cause the transfer of some or all of the optical power contained within one propagating mode to be transferred linearly into a different mode. This process may give the attenuation of the transmitted light in the form leaky or radiation mode. It must be noted that as with all linear processes there is no change of frequency on scattering. The linear scattering losses are categorized based on the physical properties variations. They are Rayleigh and Mie scattering loss.

<u>Rayleigh Scattering loss:</u>

It is the dominant intrinsic loss mechanism between uv and IR region.It is due to in homogeneities of a random nature occurring on a small scale compared with the wavelength of light. The in homogenities manifested as RI fluctuations due to density and compositional variations. The compositional variations are reduced by improved fabrication process and other are not.The scattering due to density fluctuations almost in all directions produces attenuation.

$$\gamma_R = \frac{8\pi^3}{3\lambda^4} n^8 p^2 \beta_c K T_F$$

From the mention Rayleigh scattering coefficient we understand that, ΎR=1/λ4. The transmission loss factor (Transmitivity) of the fiber Z=e(-ΎRL). From the above equation ΎR can be reduced by operating at largest wave lengths. Theoretically attenuation due to Rayleigh scattering in silica at o.63, 1.00, 1.3µm are 5.2, 0.8, 0.3 db/km. respectively.

<u>Mie Scattering loss:</u>

These are due to non perfect cylindrical structure of waveguide(fiber).Imperfections like irregularities in

1. core-cladding interface,
2. core-cladding RI differences along fiber length
3. Diameter fluctuations
4. Strains and bubbles.

The scattering occurs in forward direction and the Mie scattering losses are reduced significantly by,

1. Removing imperfections due to glass manufacturing process,
2. Carefully controlled extrusion and cladding of the fiber,
3. Increasing the fiber guidance by increasing the Δ.

4)b) **Difference between Intermodal and Intramodal Dispersion=5M**

<u>Intramodal Dispersion (Chromatic Dispersion)</u>

Intramodal dispersion may occur in all types of optical fibers. As we know that optical sources emit a band of frequencies so do not emit just a single frequency. Therefore different spectral components present in the optical source take different propagation delay while travelling through the optical fiber. This phenomena results in the broadening of each transmitted mode and is responsible for the intramodal dispersion. Intramodal dispersion is also popular by another name 'chromatic dispersion'.

Intramodal dispersion (chromatic dispersion) is found more in LED sources in comparison to LASER sources. This delay difference may be caused by the dispersive properties of the material of the waveguide (material dispersion) and also guidance effects within the fibre structure (waveguide dispersion).

Intermodal Dispersion (Modal or Mode Dispersion)

Intermodal dispersion is found in multimode optical fibres. Multimode fiber are the fibres that allow various modes to propagate through it. Therefore it is not observed in single mode fibers as only a single mode is allowed to propagate through the single mode fibre. But single mode fibres suffer from the intramodal dispersion(chromaticdispersion).

The intermodal dispersion results due to propagation delay difference between various modes propagating through the optical fibre. Intermodal dispersion is found more in case of multimode step index fibres in comparison to graded index fibres. As in case of multimode step index fibres, the refractive index of the core is uniform. Because of this same refractive index throughout the core of the multimode step index fibre, different modes propagating through the core travel with same speed. Because of this same speed, different light rays launched into the optical fibre at different angles at the transmitting end takes different times to reach to the other end of the optical fibre as their propagation path (path length) changes with change in angle while launching.

4)b) **Splicing techniques:** **Explanation = 5M**

A permanent joint formed in between two individual optical fibers in the field or factory is known as a fiber splice. Fiber splices may be divided into two broad categories depending upon the splicing technique utilized

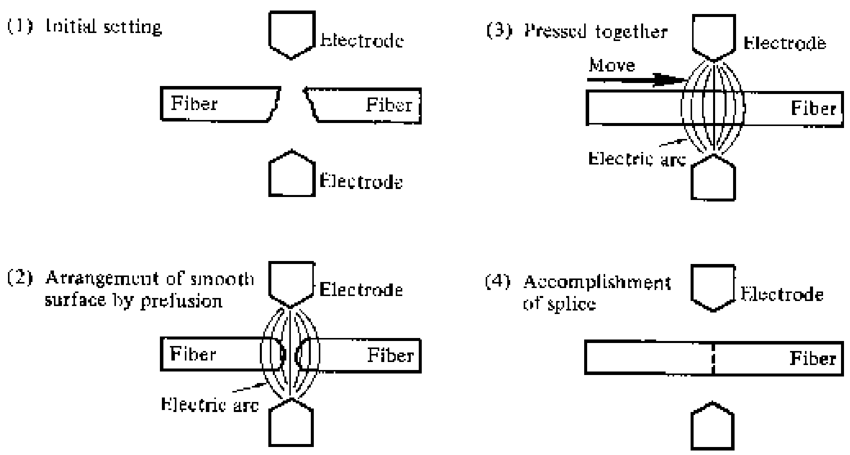
- Fusion Splicing
- Mechanical Splicing

Fusion splicing is accomplished by applying localized heating (by flame) at the interface between two butted, prealigned fiber ends causing them to soften and fuse.

Mechanical splicing , in which the fibers are held alignment by some mechanical means, may be achieved by various methods including the use of tubes around the fiber ends(tube splices).

All these techniques seek to optimize the splice performance(reduce the insertion loss: 0.1 to 0.2 db for MM fibers).

Fusion Splicing:



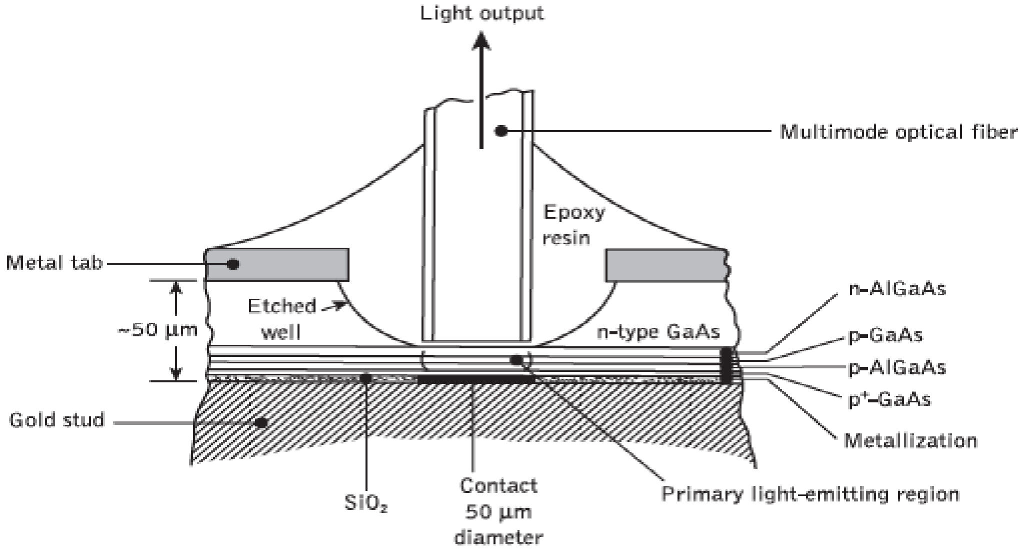
5)b) Fiber joint losses in Singlemode and multimode:- **Explanation = 5M**

UNIT-III

6)a) Surface Emitting LED (SLED):- **BLockdiagram-3M+ Explanation-2M=5M**

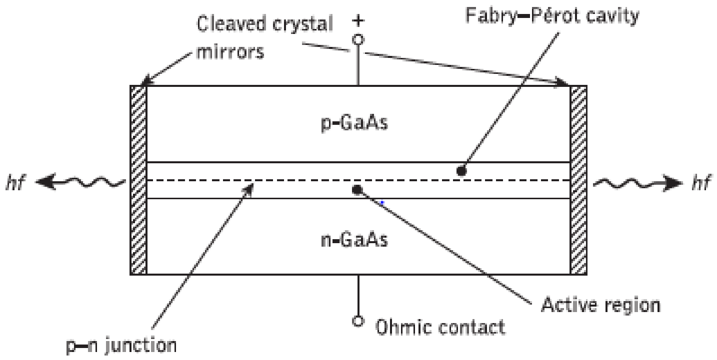
A method for obtaining high radiance is to restrict the emission to a small active region within the device. The technique pioneered by Burrus and Dawson with homostructure devices was to use an etched well in a GaAs substrate in order to prevent heavy absorption of the emitted radiation, and physically to accommodate the fiber. These structures have a low thermal impedance in the active region allowing high current densities and giving high-radiance emission into the optical fiber. Furthermore, considerable advantage may be obtained by employing DH structures giving increased efficiency from electrical and optical confinement as well as less absorption of the emitted radiation.This type of surface emitter LED (SLED) has been widely employed within optical fiber communications.

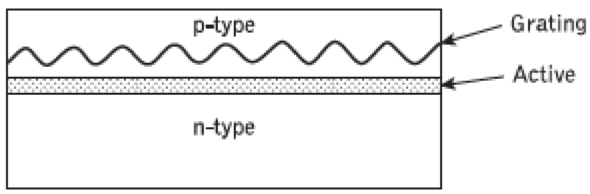
The structure of a high-radiance etched well DH surface emitter* for the 0.8 to 0.9 μmwavelength band The internal absorption in this device is very low due to the larger bandgap-confining layers, and the reflection coefficient at the back crystal face is high giving good forward radiance. The emission from the active layer is essentially isotropic, although the external emission distribution may be considered Lambertian with a beam width of 120° due to refraction from a high to a low refractive index at the GaAs–fiber interface.



6)b) **Fabry Perot LASER:-** **Block diagram& Explanation=3M**

Distributed Feedback LASER (DFB) **Block diagram& Explanation=2M**



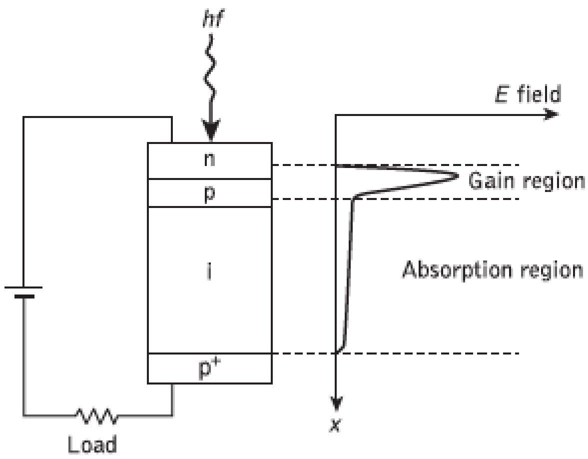


In the DFB laser the optical grating is usually applied over the entire active region which is pumped, whereas in the DBR laser the grating is etched only near the cavity ends and hence distributed feedback does not occur in the central active region. The unpumped corrugated end regions effectively act as mirrors whose reflectivity results from the distributed feedback mechanism which is therefore dependent on wavelength. In addition, this latter device displays the advantage of separating the perturbed regions from the active region but proves somewhat lossy due to optical absorption in the unpumped distributed reflectors. It should be noted that the grating is shown in a passive waveguide layer adjacent to the active gain region for both device structures. This structure has evolved as a result of the performance deterioration with earlier devices (at temperatures above 80 K) in which the corrugations were applied directly to the active layer

(OR)

7)a) Avalanche Photodiode(APD):- **Diagram 3M + Explanation - 2M=5M**

The second major type of optical communications detector is the avalanche photodiode(APD). Therefore, as well as the depletion region where most of the photons are absorbed and the primary carrier pairs generated, there is a high-field region in which holes and electrons can acquire sufficient energy to excite new electron–hole pairs. This process is known as impact ionization and is the phenomenon that leads to avalanche breakdown in ordinary reverse-biased diodes. It often requires high reverse bias voltages (50 to 400 V) in order that the new carriers created by impact ionization can themselves produce additional carriers by the same mechanism



7)b) Optical Detection Principle:- **Explanation=5M**

The basic detection process in an intrinsic absorber and the device is reverse biased and the electric field developed across the *p–n* junction sweeps mobile carriers (holes and electrons) to their respective majority sides (*p*- and *n*-type material). A depletion region or layer is therefore created on either side of the junction. This barrier has the effect of stopping the majority carriers crossing the junction in the opposite direction to the field. However, the field accelerates minority carriers from both sides to the opposite side of the junction, forming the reverse leakage current of the diode. Thus intrinsic conditions are created in the depletion region.

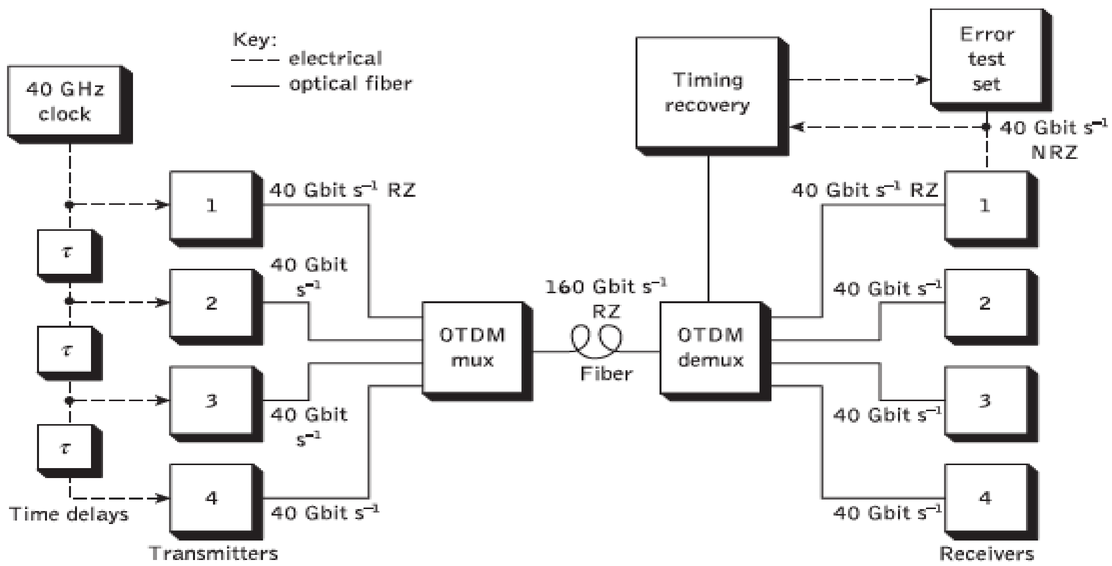
A photon incident in or near the depletion region of this device which has an energy greater than or equal to the bandgap energy Eg of the fabricating material (i.e. $hf \geq E$g) will excite an electron from the valence band into the conduction band. This process leaves an empty hole in the valence band and is known as the photogeneration of an electron–hole(carrier) pair. Carrier pairs so generated near the junction are separated and swept (drift) under the influence of the electric field to produce a displacement by current in the external circuit in excess of any reverse leakage current

8)a) <u>Optical receiver system:-</u> **Block diagram -3M + Explanation-2M = 5M**

- The linear conversion of received optical signal into an electrical current at the detector, it is amplified to obtain suitable signal level.
- The initial amplification is done at the pre-amplifier ckt., where as additional noise is kept minimum in order to avoid corruption of the received signal.
- The main amplifier provides additional low noise amplification of the signal to give an increased signal level.
- The equalizer may precede or follow the main amplifier or may be incorporated in the functions of amplifier and filter.
- The received optical signal may be distorted due to dispersive mechanisms. Hence to compensate this
- distortion and to provide a suitable signal shape using the filter

8)b) <u>Optical Time Division Multiplexing(OTDM):-</u> **Block diagram-3M+ Explanation-2M=5M**

A strategy for increasing the bit rate of digital optical fiber systems beyond the bandwidth capabilities of the drive electronics is known as optical time division multiplexing (OTDM). A block schematic of an OTDM system which has demonstrated 160 Gbit s−1 transmission over 100 km is shown.The principle of this technique is to extend ETDM by optically combining a number of lower speed electronic baseband digital channels. The optical multiplexing and demultiplexing ratio is 1 : 4, with a baseband channel rate of 40 Gbit s−1. Hence the system can be referred to as a four-channel OTDM system.



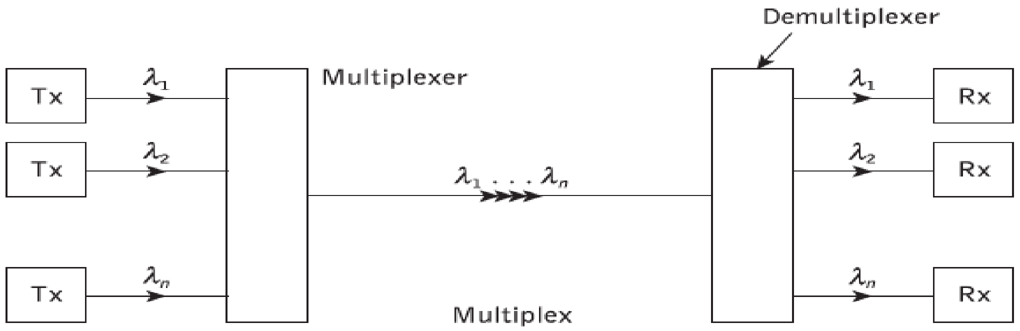
(OR)

9)a) Wavelength Division Multiplexing:- **Block diagrams 3M + Explanation 2M=5M**

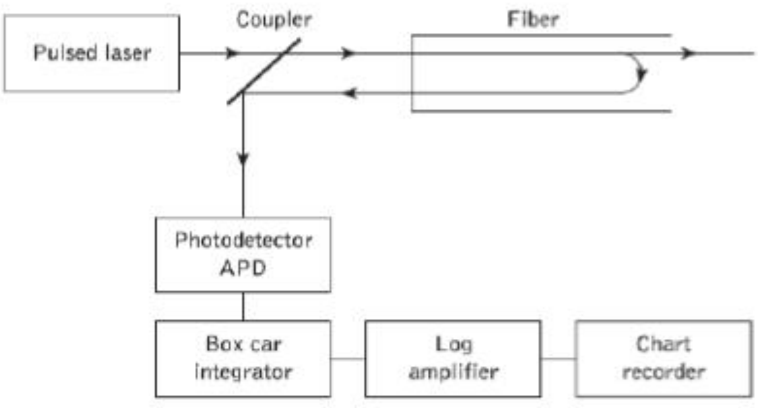
In the basic concept of a WDM, monochromatic optical signals of wavelengths are generated by laser diodes and sent through N fibers to a multiplexer. The MUX combines these input signals in to a polychromatic output signals through the process of multiplexing. The large bandwidth capacity of optical fiber is exploited through the multiplexing process. This multiplexed polychromatic signal is launched in to a single optical fiber for transmission. At the destination a demultiplexer seperates the polychromatic signal into original monochromatic wavelengths.

The DEMUX must be designed such that the centre wavelengths of channels should be same as the original wavwlwngths and the channel spectral widths. Therefore to overlapping of the channels the pass bands should be choosen to accommodate system tolerances.

Depending on application needs, different types of WDM systems are developed such as point to point long distance transmission, local access networks, reconfigurable network etc. Each of these systems needs different WDM components



9)b) Optical Time Domain Reflectrometery (OTDR):- **Diagram 3M + Explanation 2M =5M**



Optical time domain reflectometry or the backscatter measurement

A measurement technique which is far more sophisticated and which finds wide application in both the laboratory and the field is the use of optical time domain reflectometry (OTDR). This technique is often called the backscatter measurement method. It provides measurement of the attenuation on an optical link down its entire length giving information on the length dependence of the link loss.

In this sense it is superior to the optical attenuation measurement methods which only tend to provide an averaged loss over the whole length measured in dB km−1. When the attenuation on the link varies with length, the averaged loss information is inadequate. OTDR also allows splice and connector losses to be evaluated as well as the rotation of any faults on the link. It relies upon the measurement and analysis of the fraction of light which is reflected back within the fiber's numerical aperture due to Rayleigh scattering Hence the backscattering method, which was first described by Barnoski and Jensen [has the advantages of being **nondestructive** (i.e. does not require the cutting back of the fiber) and of requiring access to one end of the optical link only.