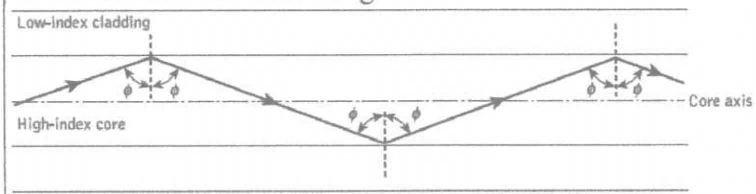
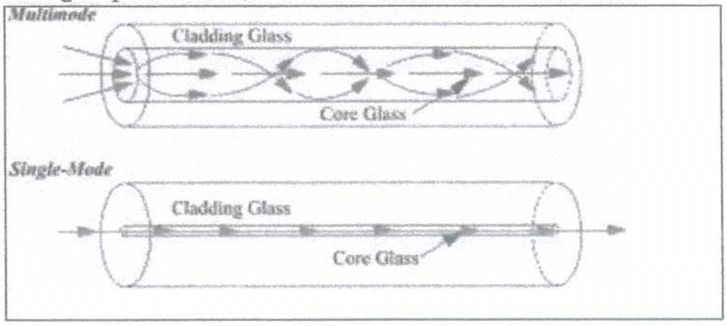
Scoring Indicators

COURSE NAME : OPTICAL COMMUNICATION AND NETWORKING (REV 2021)

COURSE CODE : 5043A QID : 2109230092

Q No	Scoring Indicators	Split score	Sub Total	Total score
	PART A			**9**
I. 1	Step Index, Graded Index	0.5+ 0.5	1	
I. 2	Given, Angle of incidence θi=25° Angle of refraction θr=32° Refractive index of air, n2= 1 According to Snell's Law, $n1 \sin \theta i = n2 \sin \theta r$ n1sin 25° =1xsin32° n1x0.423 =0.53 Refractive index of glass, n1=1.25	1	1	
I. 3	Population inversion is a condition of the laser medium, where a system consisting of a group of molecules or atoms exists in a higher excited state than that of the lower energy state of a laser transition.	1	1	
I. 4	PIN Photodiode, Avalanche Photo Diode (APD), PN Photodiode (Any two)	1	1	
I. 5	PIN photodiode does not have gain whereas APD has gain. PIN photodiode does not have a high-intensity electric field region. whereas APD have a high-intensity electric field region. The responsivity of a PIN diode is limited whereas responsivity of APD can have much larger values. Response time of PIN is half that of APD. APD operation is more noisy than PIN diode. (Any one)	1	1	
I. 6	1) Semiconductor Optical Amplifier 2) Erbium Doped Fiber Amplifier (Any two) 3)RAMAN Amplifier	0.5+ 0.5	1	
I. 7	Scattering losses in optical fibers are due to microscopic variations in the material density, compositional fluctuations, structural inhomogeneities and manufacturing defects.	1	1	
I. 8	To allow transmission in one direction through it but block all transmission in the other direction. Isolators are used in systems at the output of optical amplifiers and lasers primarily	1	1	

	to prevent reflections from entering these devices, which would otherwise degrade their performance.			
I. 9	Synchronous Digital Hierarchy (SDH).	1	1	
	PART B			24
II. 1	At angles of incidence greater than the critical angle the light is reflected back into the originating dielectric medium (total internal reflection). Total internal reflection occurs at the interface between two dielectrics of differing refractive indices when light is incident on the dielectric of lower index from the dielectric of higher index, and the angle of incidence of the ray exceeds the critical value. This is the mechanism by which light at a sufficiently shallow angle (less than 90°) may be considered to propagate down an optical fiber with low loss. Figure below illustrates the transmission of a light ray in an optical fiber via a series of total internal reflections at the interface of the silica core and the slightly lower refractive index silica cladding. 	1.5(Exp) 1.5(Fig)	3	
II. 2	From definition, the refractive index of a medium, n=c/v Where v is the Speed of light in the medium and c is the Speed of light in air. Therefore $v = \frac{3 \times 10^8 \text{ m/s}}{1.33}$ $= 2.26 \times 10^8$ m/s	3	3	
II. 3	When a ray is incident on the interface between two dielectrics of differing refractive indices (e.g. glass–air), refraction occurs, as illustrated in Figure 2 The ray approaching the interface is propagating in a dielectric of refractive index *n*1 and is at an angle ϕ1 to the normal at the surface of the interface. If the dielectric on the other side of the interface has a refractive index *n*2 which is less than *n*1, then the refraction is such that the ray path in this lower index medium is at an angleϕ2 to the normal, whereϕ2 is greater than ϕ1. The angles of incidence ϕ1 and refraction ϕ2 are related to each other and to the refractive indices of the dielectrics by Snell's law of refraction which states that: $n1 \sin \phi 1 = n2 \sin \phi 2$	1.5+ 1.5	3	
II. 4	Based on the number of modes that propagates through optical fiber, they are classified as 1. Single mode fibers- In a fiber, if only one mode is transmitted through it then it is said to be a single mode fiber. 2. Multimode fibers- If more than one mode is transmitted	1.5(Fig) 1.5(Exp)	3	

<table>
<tr><td></td><td>through optical fiber, then it is said to be multimode fiber.

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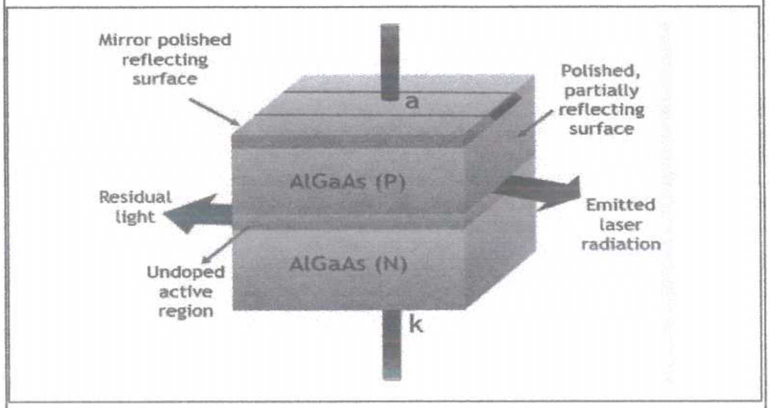
<tr><td>II. 5</td><td>
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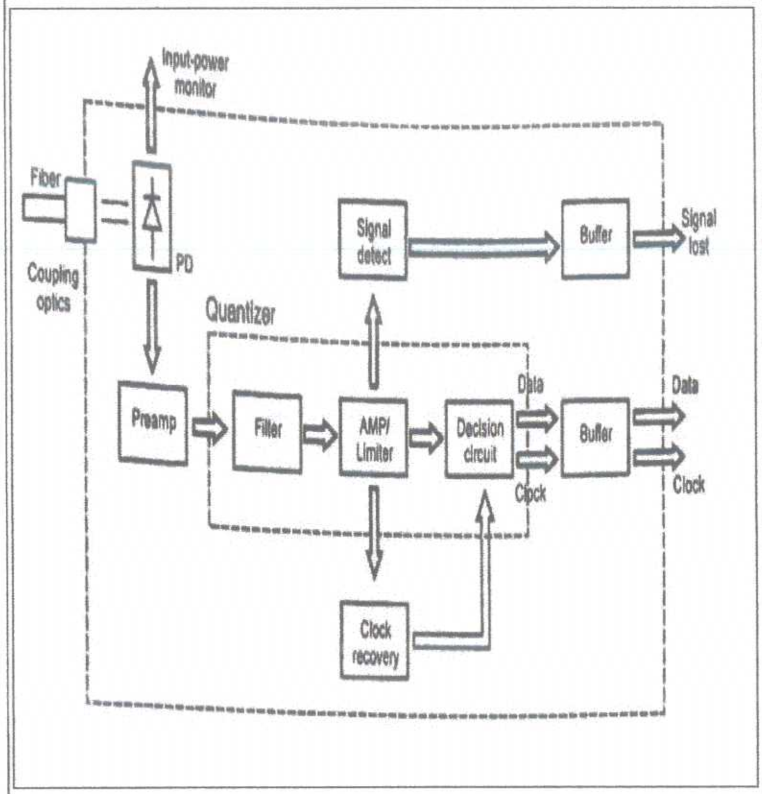
<tr><td>II. 6</td><td>
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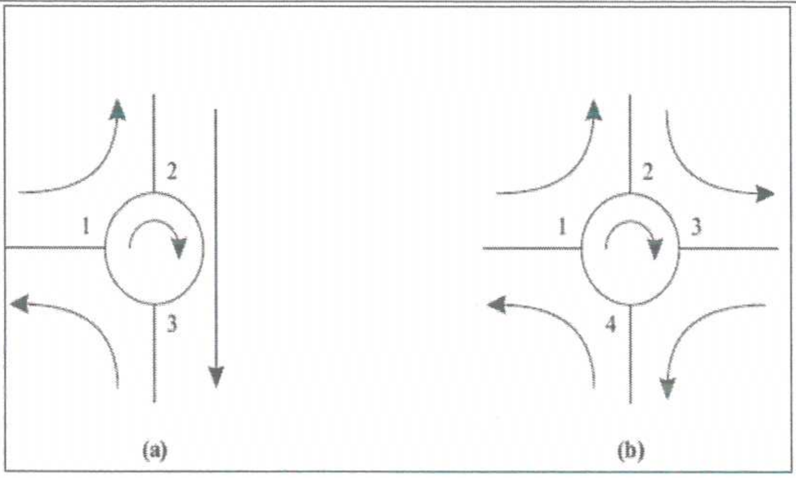
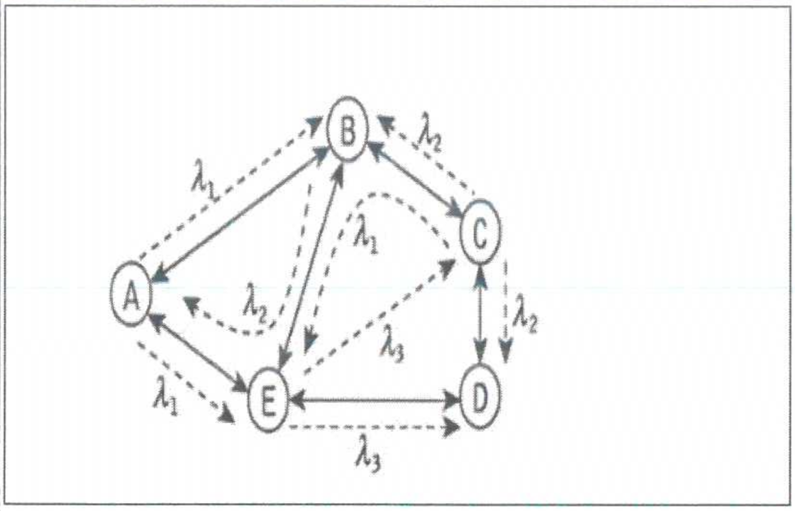
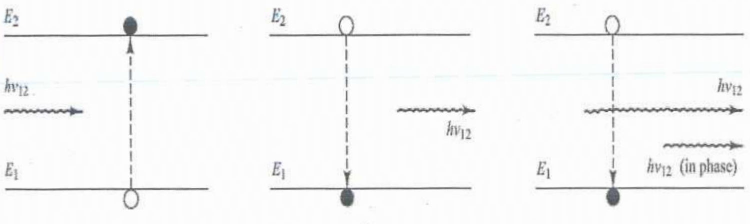
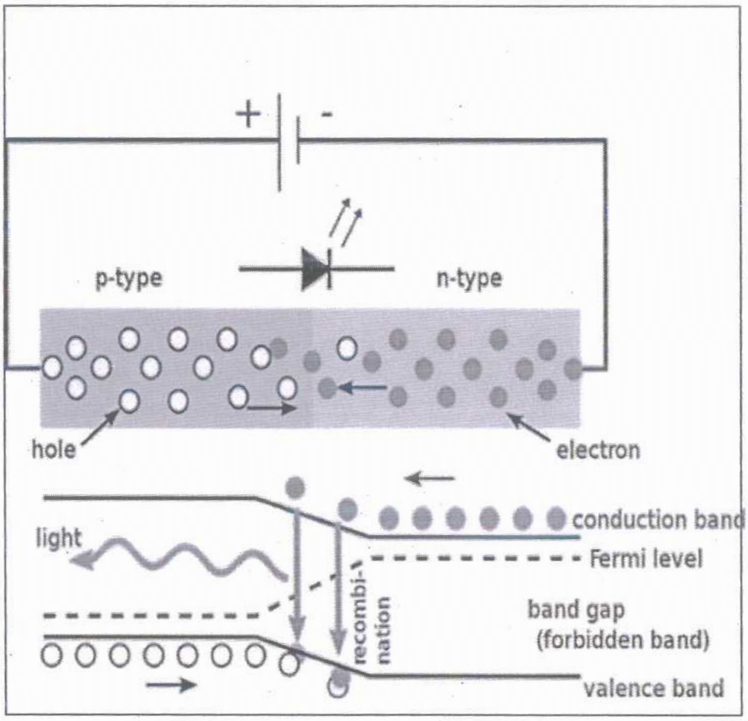
II. 7	 (a) three-port circulators (b) four-port circulators (any one)	3	3	
II. 8	(i) Optical coupler: Couplers are simple components used to combine or split optical signals. (ii) Beam splitter: Beam splitters are a basic element of many optical fiber communication systems often providing a Y-junction by which signals from separate sources can be combined, or the received power divided between two or more channels. (iii) Optical modulator: They are devices used to modulate any of the properties of light such as power, phase or polarization.	1+1+1	3	
II.9	 	3	3	
II.10	SONET stands for Synchronous Optical Network. SONET is a communication protocol, developed by Bellcore – that is used to transmit a large amount of data over relatively large distances using optical fibre. With SONET, multiple digital data streams are transferred at the same time over the optical fibre. • Developed by Bellcore • Used in North America	3	3	

	• Similar to SDH (Synchronous Digital Hierarchy) which is used in Europe and Japan. A single clock (Primary Reference Clock, PRC) handles the timing of transmission of signals & equipments across the entire network. 1. STS Multiplexer: • Performs multiplexing of signals • Converts electrical signal to optical signal 2. STS Demultiplexer: • Performs demultiplexing of signals • Converts optical signal to electrical signal 3. Regenerator: • It is a repeater, that takes an optical signal and regenerates (increases the strength) it. 4. Add/Drop Multiplexer: • It allows to add signals coming from different sources into a given path or remove a signal.			
	PART C			42
III	1)The numerical aperture (NA) of an optical system is dimensionless number that characterizes the range of angles over which the system can accept or emit light. $n_0 \sin \theta_a = (n_1^2 - n_2^2)^{\frac{1}{2}}$ $NA = n_1(2\Delta)^{\frac{1}{2}}$ 2)For rays to be transmitted by total internal reflection within the fiber core they must be incident on the fiber core within an acceptance cone defined by the conical half angle θa. Hence θa is the maximum angle to the axis at which light may enter the fiber in order to be propagated, it is known as the acceptance angle for the fiber. $\theta a = \text{Sin}^{-1}(\text{NA})$ 3)The refractive index of a medium (n) is defined as the ratio of the velocity of light in a vacuum to the velocity of light in the medium. (n=c/v)	2.5+ 2.5+ 2	7	7
IV	*(a) Enormous potential bandwidth.* The optical carrier frequency in the range 10^{13} to 10^{16} Hz (generally in the near infrared around 10^{14} Hz or 10^{5} GHz) yields a far greaterpotential transmission bandwidth than metallic cable. *(b) Small size and weight.* Optical fibers have very small diameters which are often no greater than the diameter of a human hair. Hence, even when such fibers are covered with protective coatings they are far smaller and much lighter than	7 (Any five)	7	7

	corresponding copper cables. *(c) Electrical isolation.* Optical fibers are fabricated from glass, or sometimes a plastic polymer, are electrical insulators and therefore, unlike their metallic counterparts, they do not exhibit earth loop and interface problems. Furthermore, this property makes optical fiber transmission ideally suited for communication in electrically hazardous environments as the fibers create no arcing or spark hazard at abrasions or short circuits. *(d) Immunity to interference and crosstalk.* Optical fibers form a dielectric waveguide and are therefore free from electromagnetic interference (EMI), radio-frequency interference (RFI), or switching transients giving electromagnetic pulses (EMPs). *(e) Signal security.* The light from optical fibers does not radiate significantly and therefore they provide a high degree of signal security. *(f) Low transmission loss.* Optical fiber cables exhibit very low attenuation or transmission loss in comparison with the best copper conductors. Fibers have been fabricated with losses as low as 0.15 dB km−1 and this feature has become a major advantage of optical fiber communications. *(g) Ruggedness and flexibility.* Although protective coatings are essential, optical fibers can be manufactured with very high tensile strengths. The fibers, a glassy substance, may also be bent to quite small radii or twisted without damage. Furthermore, cable structures have been developed which have proved flexible, compact and extremely rugged. *(h) System reliability and ease of maintenance.* These features primarily stem from the low-loss property of optical fiber cables which reduces the requirement for intermediate repeaters or line amplifiers to boost the transmitted signal strength. Hence with fewer optical repeaters or amplifiers, system reliability is generally enhanced in comparison with conventional electrical conductor systems. *(i) Potential low cost.* The glass which generally provides the optical fiber transmission medium is made from sand – not a scarce resource. So, in comparison with copper conductors, optical fibers offer the potential for low-cost line communication.			
V	Laser action is the result of three key processes: photon absorption, spontaneous emission, and stimulated emission. These three processes are represented by the simple two-energy-level diagrams in Fig. shown, where E1 is the ground-state energy and E2 is the excited-state energy. According to Planck's law, a transition between these two states involves the absorption or emission of a photon of energy hv12 = E2 – E1.	4(Exp) 3(Fig)	7	7

	Normally, the system is in the ground state. When a photon of energy hν12 impinges on the system, an electron in state E1 can absorb the photon energy and be excited to state E2, as shown in Fig. a. Since this is an unstable state, the electron will shortly return to the ground state, thereby emitting a photon of energy hν12. This occurs without any external stimulation and is called spontaneous emission. These emissions are isotropic and of random phase, and thus appear as a narrowband gaussian output The electron can also be induced to make a downward transition from the excited level to the ground state level by an external stimulation. As shown in Fig. c, if a photon of energy hν12 impinges on the system while the electron is still in its excited state, the electron is immediately stimulated to drop to the ground state and give off a photon of energy hν12. This emitted photon is in phase with the incident photon, and the resultant emission is known as stimulated emission. In thermal equilibrium the density of excited electrons is very small. Most photons incident on the system will therefore be absorbed, so that stimulated emission is negligible. Stimulated emission will exceed absorption only if the population of the excited states is greater than that of the ground state. This condition is known as population inversion. Since this is not an equilibrium condition, population inversion is achieved by various "pumping" techniques. In a semiconductor laser, population inversion is accomplished by injecting electrons into the material at the device contacts or through an optical absorption method by means of externally injected photons.  (a) Absorption (b) Spontaneous emission (c) Stimulated emission			
VI	i) Excitation Process ii) Recombination Process iii) Photon Extraction Excitation Process The process of injecting minority carriers through a forward biased PN junction. Other methods like tunnelling and avalanche excitation may also be used Recombination Process Excess electron hole pairs are injected on the appropriate sides of the PN junction. The recombination process of electron hole	4(Exp) 3(Fig)	7	7

<table>
<tr>
<td></td>
<td>pairs is a radiative recombination
Photon Extraction
The photons are generated in LEDs within a few millimeter of the junction. The emitted light has to pass through semiconductor for reaching its surface and from there it has to reach fiber or observer's eyes. The amount of light reach there is less than the light actually generated at the surface.

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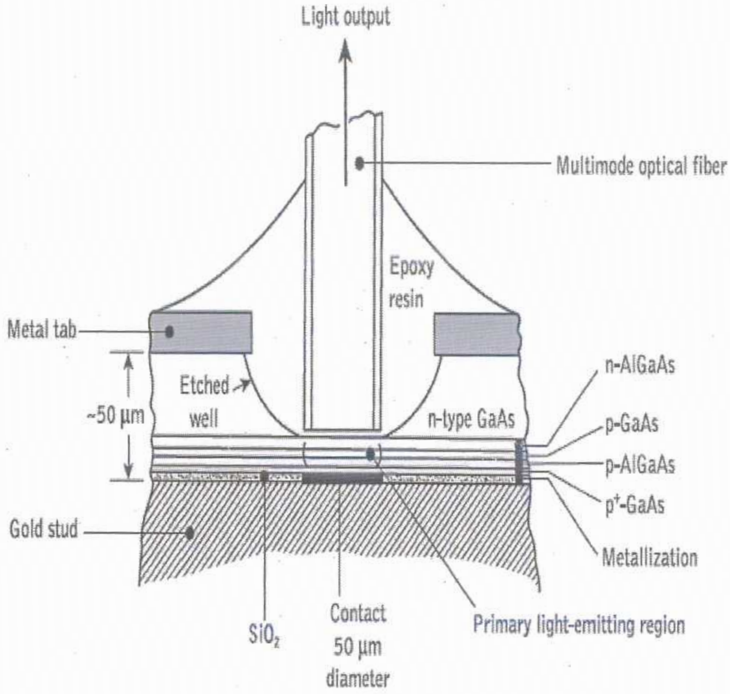
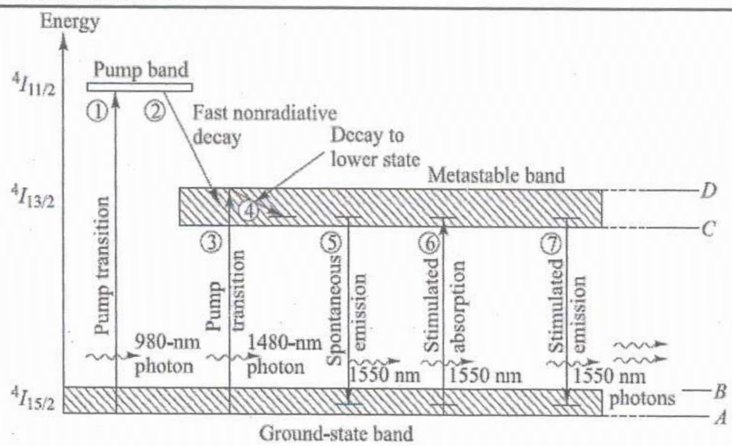
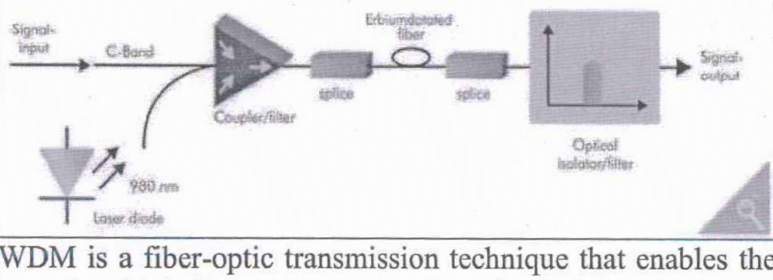
VII		7	7	7
VIII	Avalanche Photo Diode (APD) is a major type of optical communications detector. This has a more sophisticated structure in order to create an extremely high electric field region (approximately $3x10^5$V/cm). Therefore, as well as the depletion region where most of the photons are absorbed 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. In order for carrier multiplication to take place, the photogenerated carriers must traverse a region where a very high electric fi eld is present. In this high-field region, a photogenerated electron or hole can gain enough energy so that it ionizes bound electrons in the valence band upon colliding with them. This carrier multiplication mechanism is known as impact ionization. and is the phenomenon that leads to avalanche breakdown in ordinary reverse-biased diodes. Thus, Avalanche photodiodes (APDs) internally multiply the primary signal photocurrent before it enters the input circuitry of the following amplifier. This increases receiver sensitivity, since the photocurrent is multiplied before encountering the thermal noise associated with the receiver circuit. The newly created carriers are also accelerated by the high electric field, thus gaining enough energy to cause further impact ionization. This phenomenon is the avalanche effect. Below the diode breakdown voltage, a finite total number of carriers are created, whereas above breakdown the number can be infinite. It often requires high	7	7	7

<table>
<tr><td></td><td>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. More recently, devices which will operate at much lower bias voltages (15 to 25 V) have become available.</td><td></td><td></td><td></td></tr>
<tr><td>IX</td><td>

The active medium in an optical fibre amplifier consists of a 10-30m length of optical fibre that is lightly doped with Erbium (Er+). Pump laser using wavelength 980 & 1480nm is used.

In normal operation pump laser emitting 980 nm is used to excite electrons from ground state to pump level by transition1
The excited electrons decay quickly to metastable level as by transition2 which is radiated as mechanical vibrations
The absorption of pump photon excite electron from ground state to metastable state by transition 3.
These electrons tend to move towards the lower end of metastable level by transition4.
Some of electrons at metastable level decays to ground level by spontaneous emission by transition5
Spontaneous absorption by transition 6
Stimulated emission and amplification by transition 7


</td><td>4(Any one Fig)
3(Exp)</td><td>7</td><td>7</td></tr>
<tr><td>X</td><td>WDM is a fiber-optic transmission technique that enables the use of multiple light wavelengths (or colors) to send data over the same medium. It is a technique in which signals of different wavelength are multiplexed together in order to get</td><td>3(Fig)
3(Exp)
1(signi)</td><td>7</td><td>7</td></tr>
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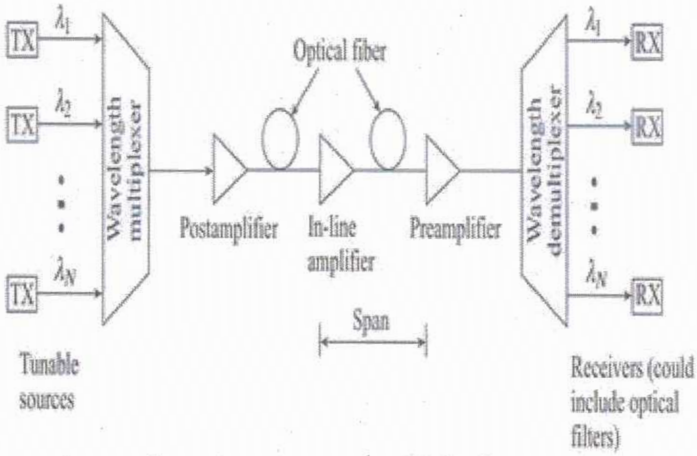
	transmitted over an optical link. The advantages of WDM are: provides greater bandwidth, it allows secured transmission of optical signal, increases the signal carrying capacity of the system.  Dense wavelength-division multiplexing (DWDM) is an optical fiber multiplexing technology that increases the bandwidth of fiber networks. DWDM combines data signals from sources over a single pair of optical fibers and it maintains separation of the data streams.			
XI	<u>Inter Modal Dispersion</u>- Pulse broadening due to intermodal dispersion (sometimes referred to simply as modal or mode dispersion) results from the propagation delay differences between modes within a multimode fiber. As the different modes which constitute a pulse in a multimode fiber travel along the channel at different group velocities, the pulse width at the output is dependent upon the transmission times of the slowest and fastest modes. This dispersion mechanism creates the fundamental difference in the overall dispersion for the three types of fiber. <u>Intramodal Dispersion</u>- Chromatic or intramodal dispersion may occur in all types of optical fiber and results from the finite spectral linewidth of the optical source. Since optical sources do not emit just a single frequency but a band of frequencies (in the case of the injection laser corresponding to only a fraction of a percent of the center frequency, whereas for the LED it is likely to be a significant percentage), then there may be propagation delay differences between the different spectral components of the transmitted signal. This causes broadening of each transmitted mode and hence intramodal dispersion. The delay differences may be caused by the dispersive properties of the waveguide material (material dispersion) and also guidance effects within the fiber structure (waveguide dispersion).	3.5+ 3.5	7	7

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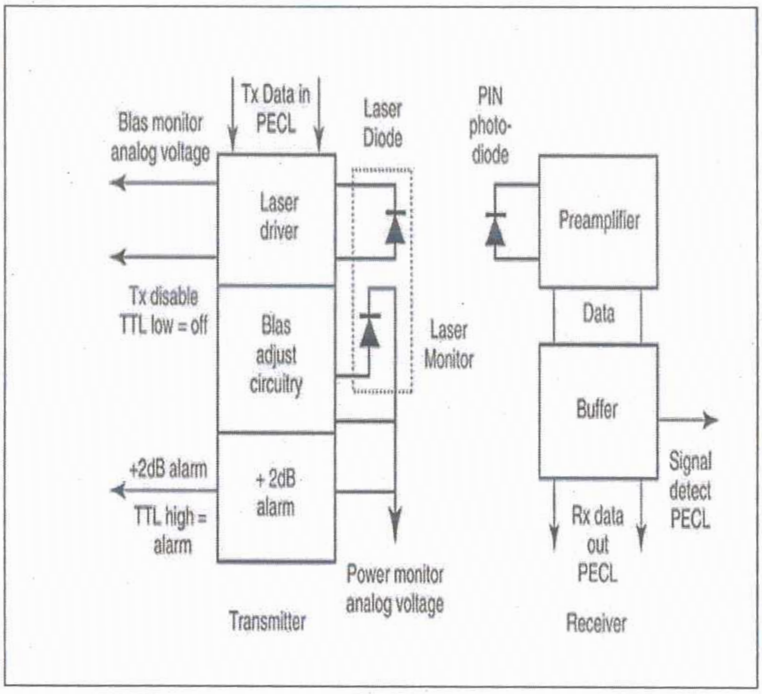
<tr><td>XII</td><td>
</td><td>7</td><td>7</td><td>7</td></tr>
<tr><td>XIII</td><td>A network utilizing optical fiber as a transmission medium provides a connection between many users to enable them to communicate with each other by transporting information from a source to a destination. It may also require an intermediate stage to process the data for control operation. The structure of a simple optical network consists of optical nodes interconnected with optical fiber links. An optical node is a multifunctional element which basically, acts as a transceiver unit capable of receiving, transmitting and processing (if required) the optical signal. Optical fibers provide point-to-point physical connections between network nodes. The point-to-point fiber links can be used to establish logical links where the destination node can be reached by traveling through one (or more intermediate nodes) in a single or multiple hops. Ideally, for an uninterrupted optical signal to reach a destination node using multihops each channel is assigned a specific signal wavelength from source to destination. A signal carried on a dedicated wavelength from source to a destination node is known as a lightpath. The data can be sent over these lightpaths once the connections are set up. In addition, a controlling mechanism is also required to provide for data flow during its transmission in order to authenticate the entire data transportation between each transmitting
and receiving node.</td><td>7</td><td>7</td><td>7</td></tr>
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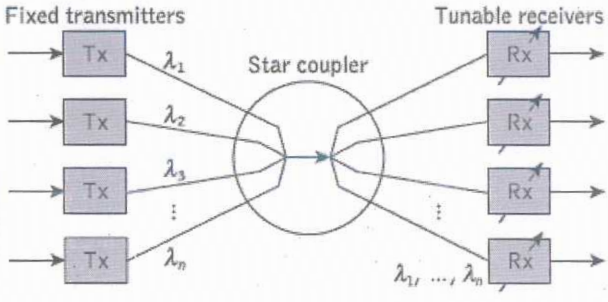
XIV	A broadcast-and-select network strategy based on a star coupler is shown in Figure. The optical transmission is broadcast to all other nodes using fixed transmitters and a tunable receiver at the destination node extracts the desired signal from the entire group of wavelength multiplexed transmitted signals (i.e. $\lambda 1, \lambda 2, \lambda 3, \ldots, \lambda n$). It should be noted that all transmissions are broadcast to all network nodes and hence most of the transmitted power is depleted on the receivers which do not use it. Consequently, as the number of nodes increases, each station receives a small fraction of the overall transmitted power. Alternatively, a wavelength routing network can be used to avoid this wastage of transmitted power where each node within the network is provided with restricted connection(s) to the receiver(s). In wavelength routing, instead of distributing the message over the entire network, the signal is routed to the specific destination through either a single node or using multiple nodes. 	7	7	7