5045

SCHEME OF VALUATION

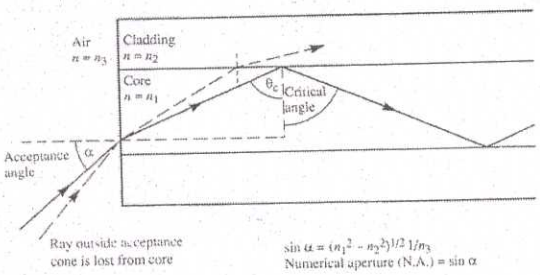
Scoring Indicators

Course Code: 5045

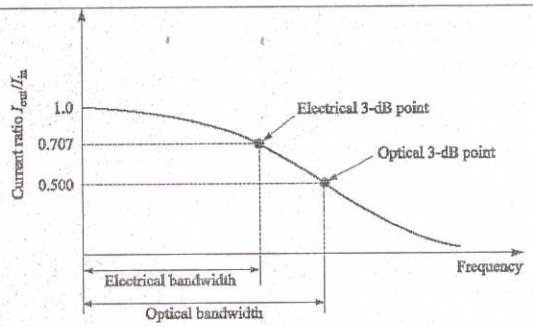
Revision : 2015

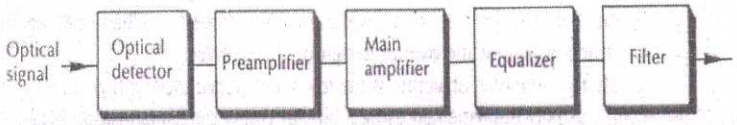
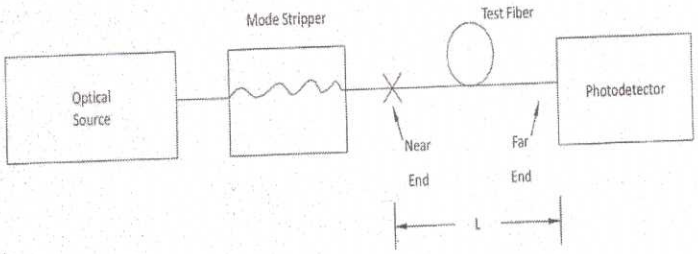
Course Title : OPTICAL FIBRE COMMUNICATION

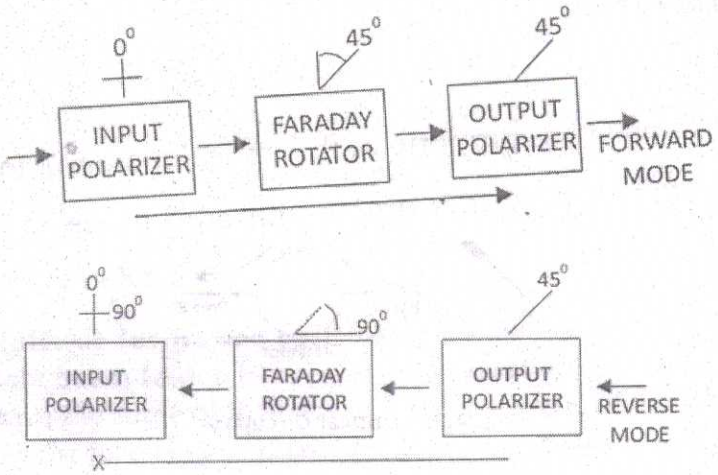
Version :

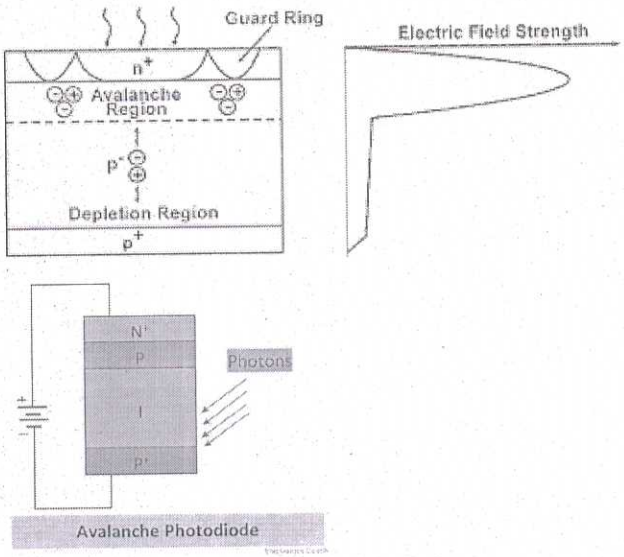
Question No.	Scoring Indicators	Split Score	Sub Total	Total
I 1	Acceptance angle is the maximum angle of a ray (against the fiber axis) hitting the fiber core which allows the incident light to be guided by the core. Or  $\sin \alpha = (n_1^2 - n_2^2)^{1/2} 1/n_3$ Numerical aperture (N.A.) = $\sin \alpha$	2	2	2
I 2	Step Index fiber Graded Index fiber	1 1	2	2
I 3	Optical sources : LED LED LASER DIODE Optical detectors PIN photo diode Avalanche photo diode Photo transistor *(Any two)*	1 1	2	2
I 4	Three types: semiconductor optical amplifiers, Raman Amplifiers and fiber doped amplifiers	2	2	2
I 5	Optical source Optical fiber Detector Optical amplifiers	0.5 0.5 0.5 0.5	2	2

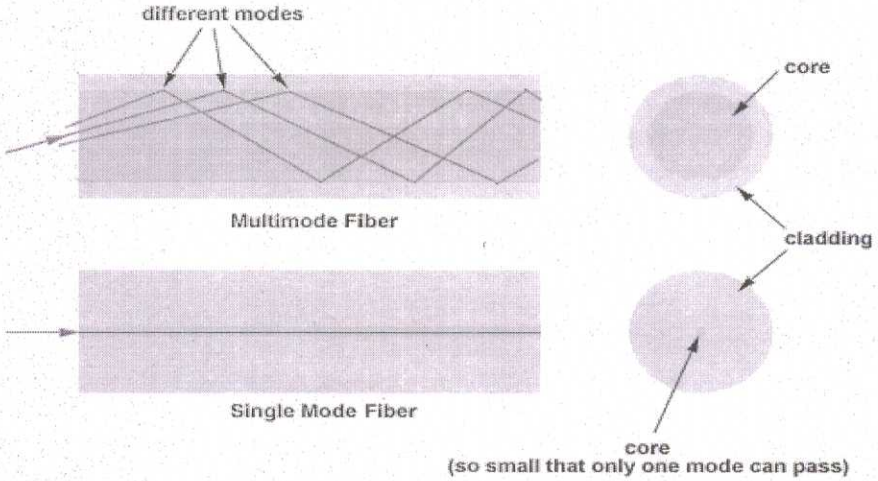
	fiber connector and splicer Fiber couplers Optical isolators and circulators Beam splitters Optical modulators **(Any four)**			
II 1	• Enormous potential Bandwidth • Small size and weight • Electrical isolation • Immunity to interference and crosstalk • Signal security • Low transmission loss • Ruggedness and flexibility • System reliability and ease of maintenance • Potential low cost *(8*.75 mark)* (any six)	6	6	6
II 2	The frequency response of an LED depends on: 1- Doping level in the active region 2- Injected carrier lifetime in the recombination region, . 3- Parasitic capacitance of the LED • If the drive current of an LED is modulated at a frequency of ω the output optical power of the device will vary as $P(\omega) = \frac{P_0}{\sqrt{1+(\omega\tau_i)^2}}$ • Electrical current is directly proportional to the optical power, thus we can define electrical bandwidth and optical bandwidth, separately.: $\text{Electrical BW} = 10\log\left[\frac{p(\omega)}{p(0)}\right] = 20\log\left[\frac{I(\omega)}{I(0)}\right]$ p : electrical power, I : electrical current $\text{Optical BW} = 10\log\left[\frac{P(\omega)}{P(0)}\right] = 10\log\left[\frac{I(\omega)}{I(0)}\right]$ No need	6	6	6

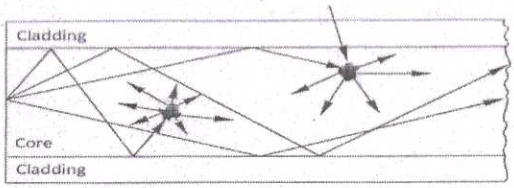


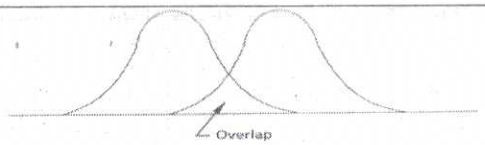
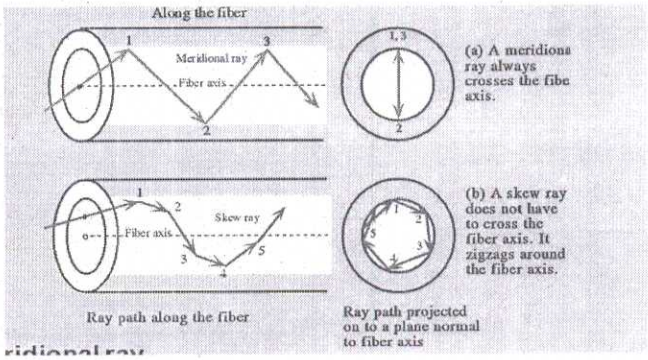
II 3	 Figure 11.16 Block schematic showing the major elements of an optical fiber receiver. Brief explanation of each block	3 3	6	6
II 4	 Fig. 4.6 Cut-Back Method • Optical source launches optical energy to a known length of Optical fiber and ouput optical energy detected using an optical detector • Node stripper – filter unwanted modes • Loss in dB/Km = 10/L Log Pin/ Pout • Very accurate • Can't be used in the working link	3 3	6	6

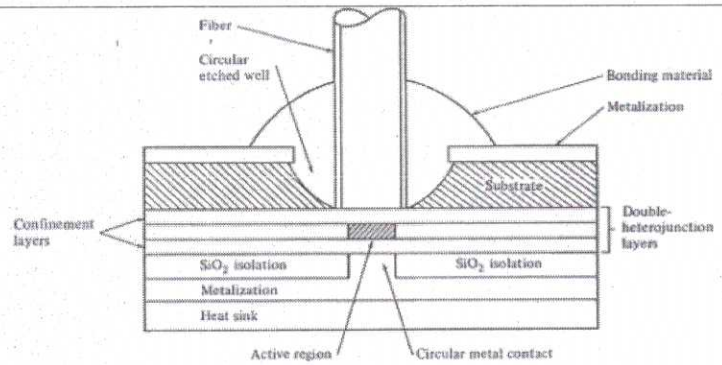
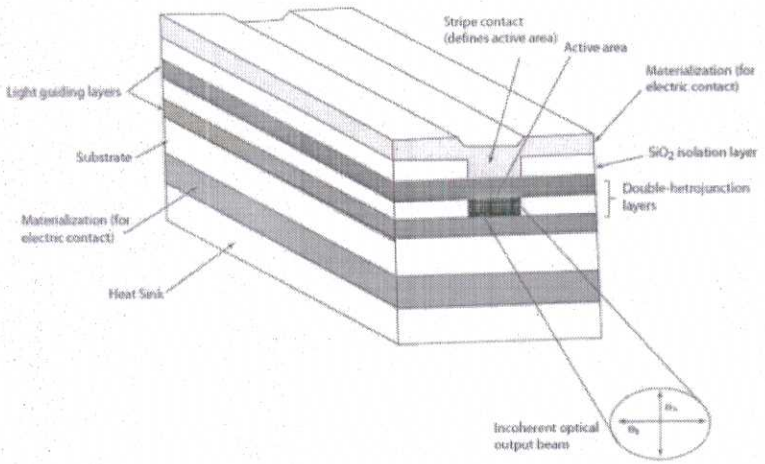
II 5	Optic device that only allows light to travel in one direction • Used to protect a source from back reflections or siganls that may occure after the isolator • Based on Faraday effect - Faraday rotation  Reverse Mode	6	6	6
II 6	Most optical amplifiers use stimulated emission • An optical amplifier is basically a laser without feedback • Optical gain is realized when the amplifier is pumped optically (or electrically) to achieve population inversion • Gain depends on wavelength, internal light intensity and amplifier medium • Three types: semiconductor optical amplifiers, Raman Amplifiers and fiber doped amplifiers	6	6	6

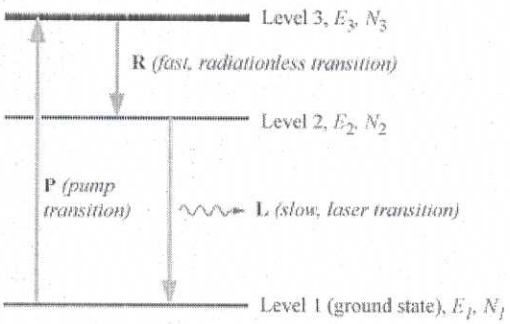
II 7	**Principle** - An **avalanche photodiode** (**APD**) is a highly sensitive semiconductor electronic device that exploits the photoelectric effect to convert light to electricity. APDs can be thought of as photodetectors that provide a built-in first stage of gain through avalanche multiplication. It operates under a high reverse bias condition to able **avalanche multiplication** of the holes and electrons created by the initial hole electron pairs created by the photon / light impact. The **avalanche** action enables the gain of the diode to be increased many times, providing a much greater level of sensitivity. **Structure :** 	3 3	6	6
III a	**Numerical aperture** is the light gathering capacity of an **optical fibre**. **Numerical Aperture** is defined as the Sine of half of the angle of **fibre's** light acceptance cone. i.e. NA= Sin θ_a where θ_a, is called acceptance cone angle.	2	8	1

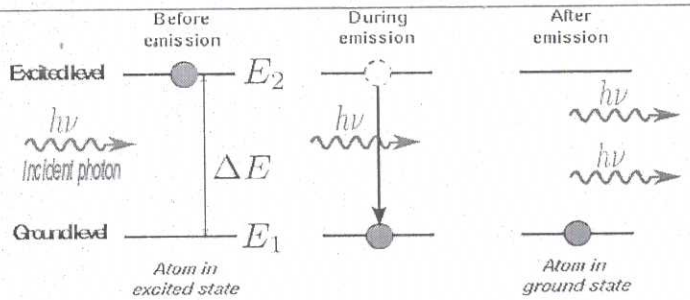
	From Snell's Law, $n_{CO}\sin\theta_1 = n_{CL}\sin\theta_2$ For total internal reflection, θ_2=90° $\theta_1 = \theta_c = \sin^{-1}\left(\frac{n_{CL}}{n_{CO}}\right)$ What value of φ_1 corresponds to θ_c? That is the maximum acceptance angle for the fiber. $\varphi_2 = 90°-\theta_c$ $\sin\varphi_2 = \cos\theta_c$ $\sin\theta_c = \frac{n_{CL}}{n_{CO}}$, so $\cos\theta_c = \frac{\sqrt{n_{CO}^2 - n_{CL}^2}}{n_{CO}}$ $n_{CO}\sin\varphi_2 = n_{CO}\left(\frac{\sqrt{n_{CO}^2 - n_{CL}^2}}{n_{CO}}\right) = \sqrt{n_{CO}^2 - n_{CL}^2} = NA$	6		
III b	The propagation of light along a waveguide can be described in terms of a set guided electromagnetic waves called modes of the waveguide Configuration and modes – Single mode and multi mode fibers  	4	7	
	Explanation	3		

IV a	**1. Absorption**: Major cause of signal loss in the optical fiber communication. Portion of attenuation resulting from the the conversion of optical power in to another energy form Imperfections in atomic structure The intrinsic or basic material properties The extrinsic fiber material properties –(presence of impurities) **Intrinsic Absorption** Caused by basic fiber material properties If OF material absolutely pure all absorptions should be intrinsic **Extrinsic Absorption** Due to impurities - Iron, Nickel, Chromium Also due to hydroxyl ions (OH) introduced in fiber water in silica glass –Silicon Hydroxyl Si-OH	3	9	1
	2. Scattering • Caused by interaction of light by density fluctuations within the fiber • Commercial fibers(700 to 1600 nm) – Main loss – Rayleigh scattering • If size of defect is less than /10^{th} of operating wavelength of light – **Rayleigh scattering** • If greater – **Mie scattering**	3		
				
	• **Dispersion** • Leads to pulse spreading – Energy overlapped, limits the information capacity	3		

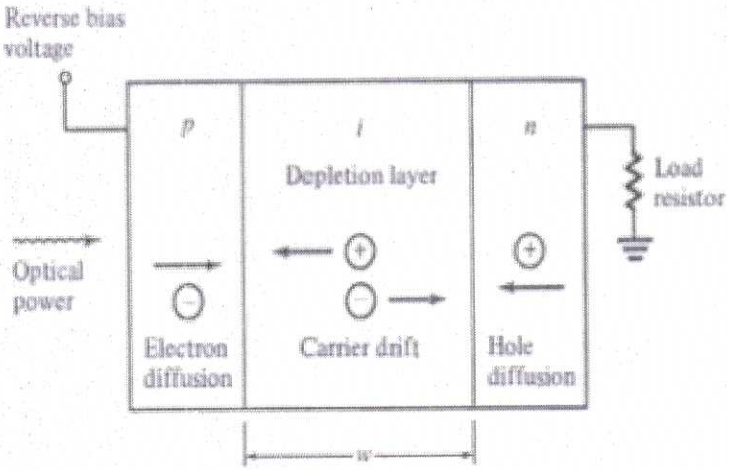
	 Pulse Overlap • Intramodal/ chromatic dispersion - In all types of fibers • Intermodal or modal dispersion – in multimode fibers		
IV b	2 types of rays propagate along the optical fiber cable: **Meridional rays:** Rays that pass through the center axis} of the core. Skew rays: Rays that travel through the fiber without} passing through the center axis of the core Can be classified as: Bound: Rays that propagate through the fiber by total} internal reflection. Unbound: Rays that are refracted from the core} **Skew rays** The acceptance angle of skew rates is larger than the acceptance angle of meridional rays. Most rays entering the} core are skew rays. The contribute to the} amount of light capacity of the fiber optic (especially in case of high NA). However, they contribute} also the amount of light losses of the fiber **(with figure)**  optic ridional ray	3 3	6

V a	 **Surface emitting LED - Explanation**  **Edge emitting LED - explanation**	4 2 4 2	12	1

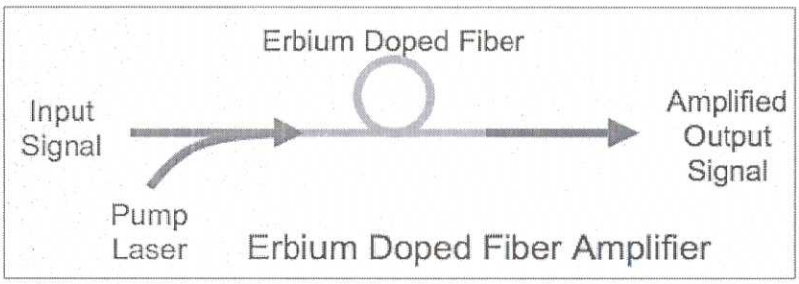
V b	. Principle of operation of a Photo Detector: A photodiode is a PN junction or PIN structure. When a Photon of sufficient energy strikes the diode, it excites an electron, thereby creating a free electron and a hole. A **detector** is one which converts light into either current or voltage	3	3	
VI a	• **population inversion:** If there are more atoms in the upper level (N2) than in the lower level (N1), the system is not at equilibrium. In fact, at thermodynamic equilibrium, the distribution of the atoms between the levels is given by Boltzmann's Law: n this case, N2 is always less than N1. A situation not at equilibrium must be created by adding energy via a process known as "pumping" in order to raise enough atoms to the upper level. his is known as **population inversion** and is given by N2-N1 . Light is amplified when the population inversion is positive. Pumping may be electrical, optical or chemical.  • **Stimulated emission** is the process by which an incoming photon of a specific frequency can interact with an excited atomic electron (or other excited molecular state), causing it to drop to a lower energy level.	4.5 4.5	9	1



$$E_2 \quad E_1 = \Delta E = h\nu$$

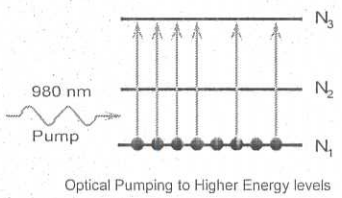
VI b	The PIN diode is a one type of photo detector, used to convert optical signal into an electrical signal. The PIN diode comprises of three regions, namely P-region, I-region and N-region. Typically, both the P and N regions are heavily doped due to they are utilized for Ohmic contacts. The intrinsic region in the diode is in contrast to a PN junction diode. This region makes the PIN diode an lower rectifier, but it makes it appropriate for fast switches, attenuators, photo detectors and applications of high voltage power electronics.	3	6
		3	

VII a	Erbium-doped fiber amplifier (EDFA) is the most widely used fiber-optic amplifiers, mainly made of Erbium-doped fiber (EDF), pump light source, optical couplers, optical isolators, optical filters and other components. Among them, a trace impurity in the form of a trivalent erbium ion is inserted into the optical fiber's silica core to alter its optical properties and permit signal amplification	5	9	1

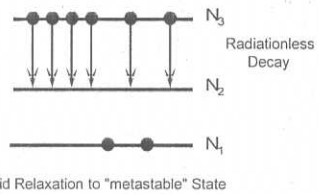


The working principle of the EDFA is to use the pump light sources, which most often has a wavelength around 980 nm and sometimes around 1450 nm, excites the erbium ions (Er3+) into the 4I13/2 state (in the case of 980-nm pumping via 4I11/2), from where they can amplify light in the 1.5-μm wavelength region via stimulated emission back to the ground-state manifold 4I15/2.

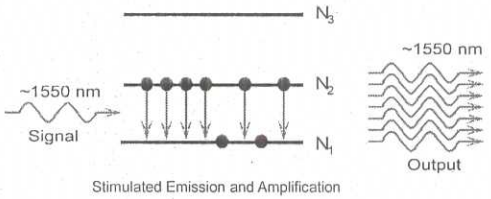
Amplification process



Optical Pumping to Higher Energy levels



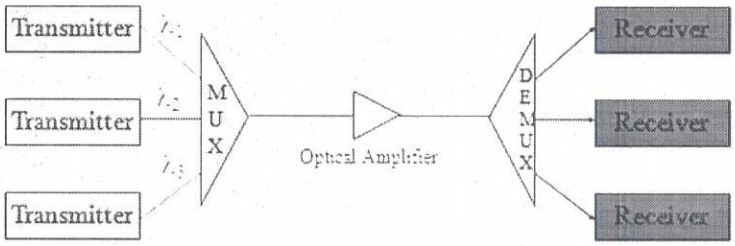
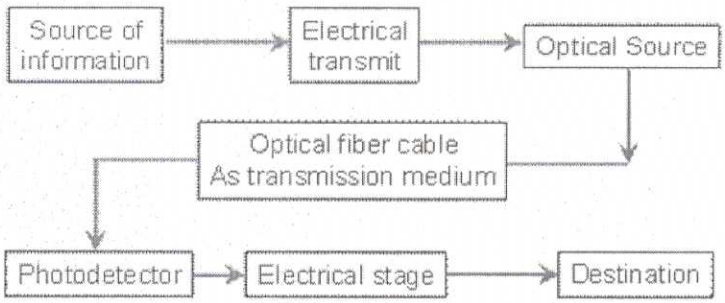
Rapid Relaxation to "metastable" State

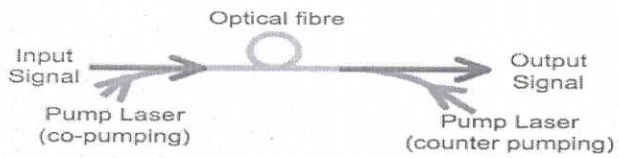


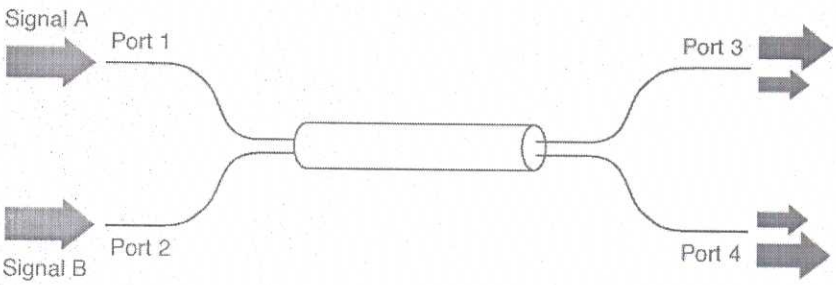
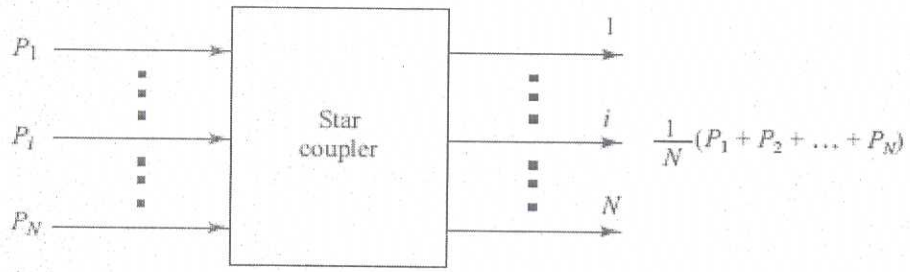
Stimulated Emission and Amplification

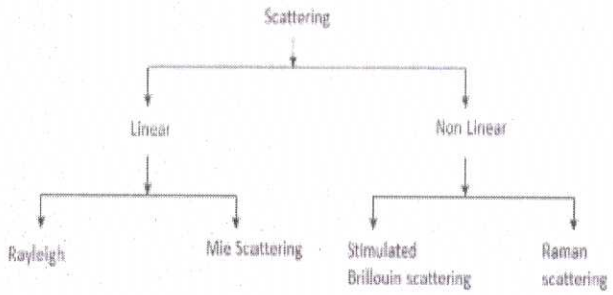
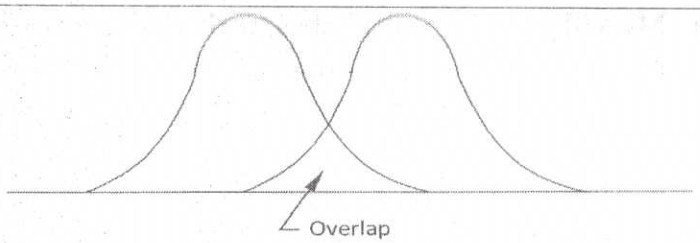
advantages

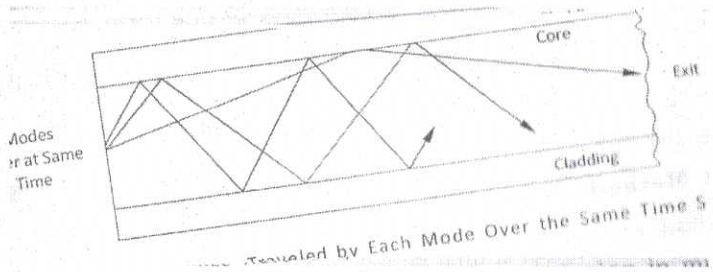
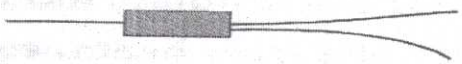
- EDFA has high pump power utilization (>50%)

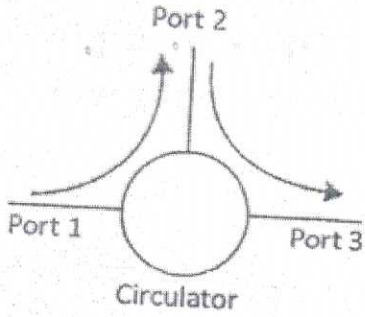
	• Directly and simultaneously amplify a wide wavelength band (>80nm) in the 1550nm region, with a relatively flat gain • Flatness can be improved by gain-flattening optical filters • Gain in excess of 50 dB • Low noise figure suitable for long haul applications	4		
VII b	In fiber-tic communications, **wavelength-division multiplexing (WDM)** is a technology which multiplexes a number of optical carrier signals onto a single optical fiber by using different wavelengths (i.e., colors) of laser light 	6	6	
VIII a		5	10	1

	Information source- it provides an electrical signal to a transmitter comprising an electrical stage. **Electrical transmitter-** It drives an optical source to give a modulation of the light wave carrier. **Optical source-** It provides the electrical-optical conversion .It may be a semiconductor laser or an LED. **Information source-** it provides an electrical signal to a transmitter comprising an electrical stage. **Electrical transmitter-** It drives an optical source to give a modulation of the light wave carrier. **Optical source-** It provides the electrical-optical conversion .It may be a semiconductor laser or an LED.	5		
VIII b	• A **Raman amplifier** is an optical **amplifier** based on**Raman** gain, which results from the effect of stimulated **Raman** scattering.  • • The principle of FRA is based on the Stimulated Raman Scattering (SRS) effect. • The gain medium is undoped optical fiber. Power is transferred to the optical signal by a nonlinear optical process known as the Raman effect. • An incident photon excites an electron to the virtual state and the stimulated emission occurs when the electron de-excites down to the vibrational state of glass molecule. The Stokes shift corresponding to the eigen-energy of a phonon is approximately 13.2 THz for all optical fibers.	5	5	

IX a	A **fiber optic coupler** is a device used in **optical fiber** systems with one or more input fibers and one or several output fibers. Light entering an input **fiber** can appear at one or more outputs and its power distribution potentially depending on the wavelength and polarization. **Types** : Acive and passive couplers N*M coupler **3 port coupler (Y or T coupler, 2*1 coupler)**  **4 port coupler (X coupler, 2*2 coupler)**  **Star coupler** ;  	2 2 2 2	8	1

IX b	• Scattering losses in glass arise from microscopic variations in the material density, from compositional fluctuations and from structural inhomogeneties or defects occurring during fiber manufacture. Mainly classified in to Linear and non linear scattering losses • Brief explanation of linear and non linear scattering losses and types  **Figure 2.5**	2 4	6
X a	 Pulse Overlap • Two types • Intra mode or Chromatic – in all types of fibers • Inter mode or Modal – in multimode fibers • Dispersion mechanism leads to pulse spreading – limits the information capacity of the fiber • **Intra mode dispersion** • Depends primarly on fiber materials • Occures because different colours of light travels through different materials and different waveguide structure at different speeds • Two tpes	3 3	9

	• Material dispersion • Waveguide dispersion • **Inter mode dispersion**  • Causes the input light pulse to spread • Input light pulse is made up of a group of modes • The pulse spreads because each mode propagates along the fiber at different speeds	3		
X b	**Beam splitters** Optical device which can split an incident light beam in to two or more Beams  A Fiber-Optic Beam Splitter with a Single Input Port and Two Output Ports **Optical Modulator** A device that modulates or varies the amplitude of an optical signal in a controlled manner. • Generates desired intensity, color in the passing light by changing optical parameters such as the transmission factor, refractive index, reflection factor, degree of deflection and coherency of light in the optical system according to the modulating signal . Two types Direct and External modulation **Optical circulator** Multi port (minimum three) non reciprocal passive component	2 2 2	6	



Optical Circulator