SRM Institute of Science and Technology
College of Engineering and Technology
DEPARTMENT OF ECE

SRM Nagar, Kattankulathur – 603203, Chengalpattu District, Tamil Nadu

Academic Year: 2022-23 (Even)

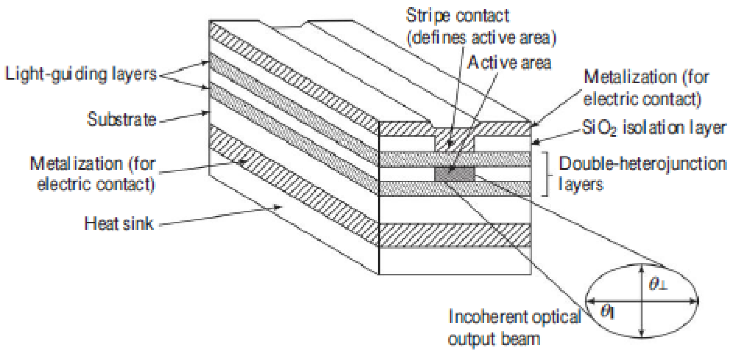
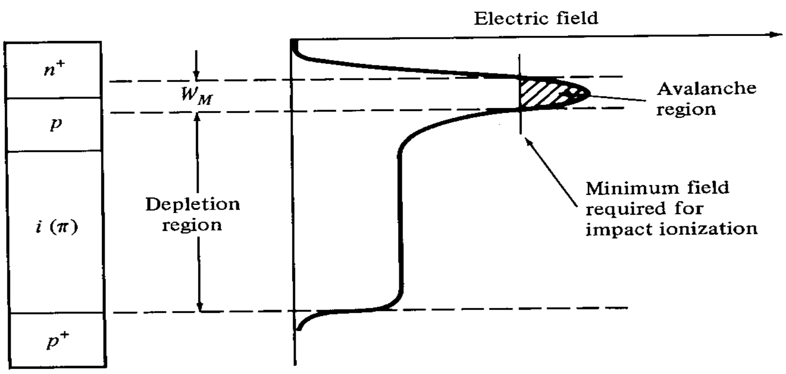
SET-A

Test: CLAT-2	**Date: 04-04-2023**
Course Code & Title: 18ECC302J–Microwave and Optical Communication	**Duration: 12.30PM–02.15PM**
Year & Sem: III / VI	**Max. Marks: 50**

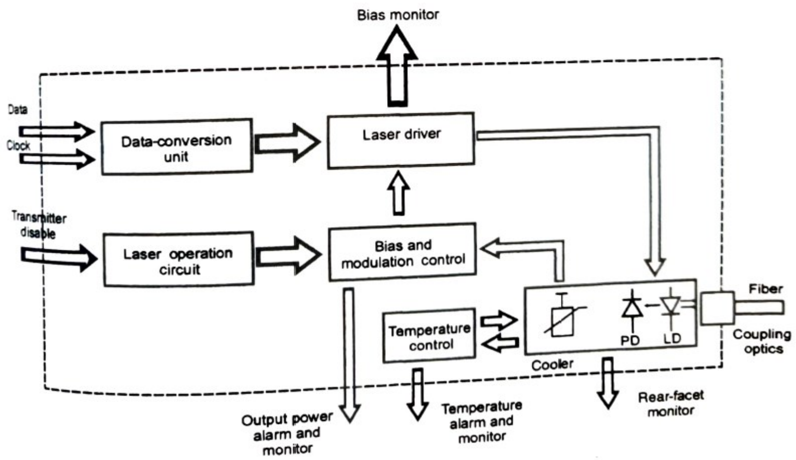
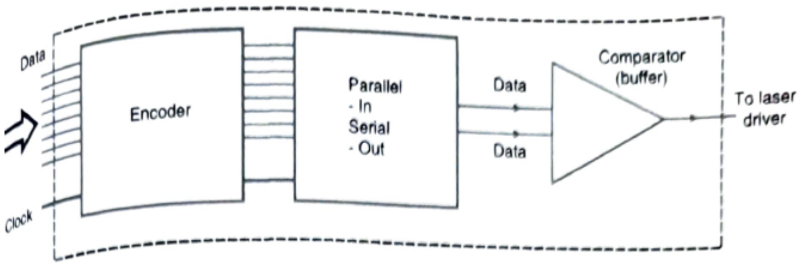
	18ECC302J - Microwave & Optical Communications	**Program Outcomes (POs)**														
		Graduate Attributes												**PSO**		
S. No.	**Course Outcomes (COs)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**1**	**2**	**3**
1	Demonstrate the knowledge on the theory of microwave transmission, microwave generators and associated components	3	-	-	3	-	-	-	-	-	-	-	-	-	-	1
2	Analyse the microwave passive devices and components	-	2	-	3	-	-	-	-	-	-	-	-	2	-	-
3	Incorporate microwave measurements and associated techniques with equipment	-	-	3	2	-	-	-	-	-	-	-	-	-	-	3
4	Gain knowledge of the fundamentals on light transmission through fiber	-	3	-	2	-	-	-	-	-	-	-	-	-	-	1
5	Develop a basic optical communication system	-	3	-	-	3	-	-	-	-	-	-	-	2	-	-
6	Implement the working principle of microwave components, microwave measurements, optical sources, detector and fibers	-	-	3	-	3	-	-	-	-	-	-	-	-	-	3

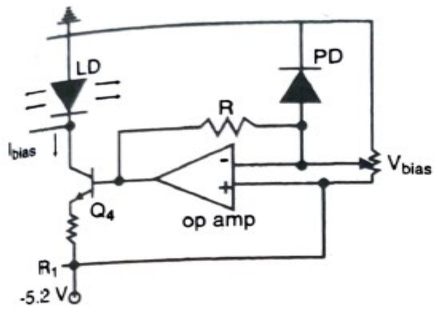
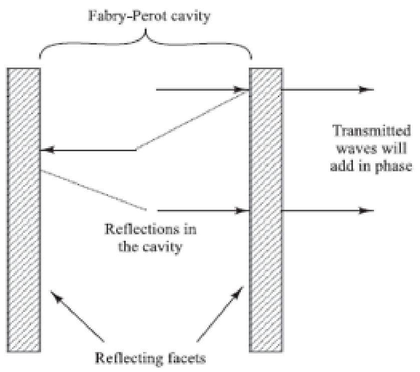
Part – A
(5 × 10 = 50 Marks)
Instructions: Answer any FIVE Questions.

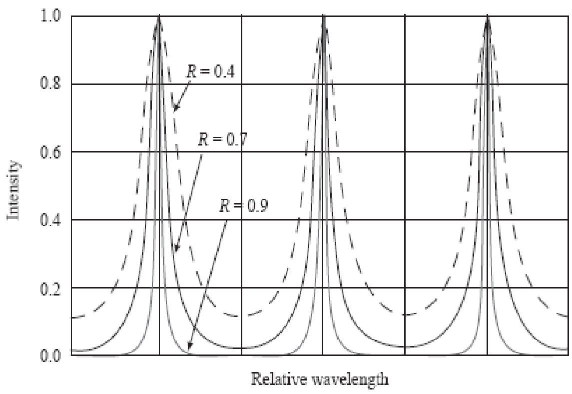
Q. No.	Question	Marks	BL	CO	PO
1	i) Which of the following dispersion arises from the variation of the refractive index of the core material as a function of wavelength (a)Waveguide dispersion **(b)Material dispersion** (c) Group velocity dispersion (d) Modal dispersion	1	1	4	2
	ii) Consider a multimode step index fiber with 60.5µm core diameter and a core-cladding index difference of 1.2%. If the core refractive index is 1.43, estimate the numerical aperture, normalized frequency of the fiber and the total	4	4	4	2
	1. ii) $a = \text{radius} = \frac{\text{diameter}}{2} = \frac{60.5\times10^{-6}}{2} = 30.25\times10^{-6}\,m$ $\Delta = 1.2\% = 0.012$ Numerical aperture $= n_1\sqrt{2\Delta}$ $= 1.43\sqrt{2(0.012)}$ (1 Mark) $= 0.221$ $\lambda = 850nm$ Normalised frequency $V = \frac{2\pi a}{\lambda}(NA)$ $= \frac{2\times\pi\times(30.25\times10^{-6})(0.221)}{850\times10^{-9}}$ $V = 49.39$ (2 mark) Number of modes supported $N = \frac{V^2}{2}$ $N = \frac{(49.39)^2}{2} \simeq 1219$ (1 Mark)				

	iii) Identify the incoherent light source which uses a double hetero junction structure to confine the carrier and the light to an active layer and produces a more directional beam whose bandwidth is less. Explain its construction and operation. Edge emitting LED (1 mark) • Active junction region is the source of the incoherent light and two guiding layers • Guiding layers both have a refractive index lower than that of active region but higher than index of surrounding material • Contact stripes for the edge emitter 50 – 70 μm wide and length of the active regions range from 100 to 150 μm • Emission pattern is more directional than surface emitter • In plane parallel to junction, the emitted beam is lambertian with a half power width of θ‖ ≈ 120° • In the plane perpendicular to the junction, the half power θ⊥ is 25-35° (operation 3marks)  Diagram (1 mark)	5	3	4	2
2	i) Identify the ray which is confined to the plane of optical axis (a) Skew ray (b) Refracted ray **(c) Meridional ray** (d) Diffracted ray ii) Identify the device used in the receiver side of the optical fiber communication which has its own internal gain which in turn increases its responsivity. Explain its operation with a neat diagram. Avalanche photodiode (1 mark)  Diagram (1 mark)	1 6	1 3	4 4	2 2

	When a p-n junction diode is applied with high reverse bias, breakdown can occur by two separate mechanisms. 1. Direct ionization of the lattice atoms → Zener breakdown 2. High voltage carriers causing Impact Ionization of the lattice atoms → Avalanche breakdown. APDs uses the avalanche breakdown phenomenon for its operation. The APD has its internal gain which increases its responsivity. The fig. shows the schematic structure of an APD. By virtue of the doping concentration and physical construction of the n^+ p junction, the electric field is high enough to cause impact ionization.Under normal operating bias, the I-layer is completely depleted.This is known as reach through condition, hence APDs are also known as Reach through APDs or RAPDs. In normal usage, the RAPD is operated in the fully depleted mode. Light enters the device through the p+ region and is absorbed in the p material, which acts as the collection region for the photo-generated carriers. The photo-generated electrons drift through the p region in the pn+ junction, where a high electric field exists. It is in this high-field region that carrier multiplication takes place. The average number of electron-hole pairs created by a carrier per unit distance traveled is called the ionization rate. Most materials exhibit different electron ionization rates α and hole ionization rates β. The ratio k = β/α of the electron and hole ionization rates is a measure of the photo-detector performance. APDs constructed of materials in which one type of carrier largely dominates impact ionization exhibit low noise and large gain-bandwidth products. Similar to PIN photodiode, light absorption in APDs is most efficient in I-layer. In this region, E-field separates the carriers and the electrons drift into the avalanche region where carrier multiplication occurs.If the APD is biased close to breakdown, it will result in reverse leakage current. Thus APDs are usually biased just below breakdown, with the bias voltage being tightly controlled. Operation (4 marks) iii) A particular Ga1-xAlxAs laser is constructed with a material ratio x=0.05. Find the bandgap energy of this material and the peak emission wavelength 2.iii $Ga_{1-x}Al_xAs$ $x = 0.05$ Bandgap Energy $E_g = 1.424 + 1.266x + 0.266x^2$ $= 1.424 + 1.266(0.05) + 0.266(0.05)^2$ $= 1.487\,eV$ (2 marks) Wavelength $\lambda(\mu m) = \frac{1.240}{E_g}$ $= \frac{1.240}{1.487} = 0.8338\,\mu m$ $\lambda = 833.8\,nm$ (1 Mark)	3	4	4	4
3	i) Which of the following loss is minimized by extruding a compressible jacket over the fiber **(a) Micro bending loss** (b) Absorption loss (c) Scattering loss (d) Macro bending loss	1	1	4	2

	ii) Identify the module responsible for converting an electrical information signal in to an optical signal. Draw its block diagram and explain each of its units in detail. Optical transmitter module (1 mark)  (Block diagram -1 mark) Laser driver changes the forward current to modulate the output light radiated by a laser diode **Data conversion unit:**Performs encoding, parallel to serial conversion and reshaping the electric format of the data. Encoding means representing data in a physical format (pulses). Different line codes used are NRZ, Manchester code, Return to zero etc. NRZ- convenient but has poor transmission capability. Transmitter and receiver consumes more electric power because of dc power component  a) (2 Marks) **Laser Driver:** Laser driver convert outside voltage in to current needed to drive the laser. Driving current has to bias a laser diode to provide a bias current.Bias current has to be very stable with threshold current else error occurs.Main factor changing threshold current is temperature.The feedback signal from the temperature sensor that reaches the laser driver through bias control circuit closes the control loop. (2 marks)	9	3	4	2

	 **Modulation Circuit:**Modulation is controlled by changing the driving current from the bias level to maximum**.** When data are represented by a voltage greater than V_{BB}, Q_1 conducts the current and hence laser diode is off**.** When data are represented by a voltage less than V_{BB}, Q_2 conducts the current and hence laser diode is on **Controlling and Monitoring circuits:** Transmitter disable signal allow the user to shut down the transmitter while keeping the module in the stand by mode**.** This can be done by placing high voltage signal at the base of transistor Q1. Voltage across R1 and R2 allow the user to receive the bias and modulation monitoring signals.Photocurrent produced by PD shows whether LD is working. Monitoring signal enables the user to troubleshoot the transmitter**.** Signal from temperature sensor helps to monitor entire ambient temperature**.** Output also provide alarm to signal if any monitored parameters deviate (Modulation, contolling and monitoring 3 marks)				
4	i) An optical window which has very low loss by reducing the concentration of hydroxyl ions and metallic impurities in the fiber material is________. (a) 800-900 nm (b) **1100 -1600 nm** (c) 1550 -1600 nm (d) 900-1100 nm ii) A monochromatic light source uses partially reflecting mirrors to provide optical feedback in longitudinal direction. Find the device. Explain its construction and working with a neat sketch. Fabry-Perot resonator cavity (1 mark)  (diagram1 mark) A Fabry-Perot cavity consists of two flat, partially reflecting mirrors that establish a strong longitudinal optical oscillator feedback mechanism, thereby creating a light-emitting function.	1 5	1 3	4 4	1 2

	The distance between the adjacent peaks of the resonant wavelengths in a Fabry-Perot cavity is the modal separation. If L is the distance between the reflecting mirrors & the refractive index is n, then at a peak wavelength λ the MS is given by $\boxed{\text{Modal Separation } \Delta\lambda = \frac{\lambda^2}{2nL}}$ Working (3 marks)  iii) An optical fiber communication system is deployed in an urban area for 50Km.The system uses 2 connectors, 3 splices and a laser source of power 5dBm.The system possess connector loss of 2dB, splice loss of 0.1 dB and attenuation of 0.7dB /Km. The sensitivity of the receiver is -50dBm. Calculate the total link loss and system margin in dB? 4. iii Total link loss $P_T = P_S - P_R$ $L = 50\,km$ $P_S = 5\,dBm = -25\,dB$ $P_R = -50\,dBm = -80\,dB$ $P_T = -25+80 = 55\,dB$ (2 mark) System Margin $Ma = P_T - \alpha_F L + 2(\text{connector loss}) - 3(\text{splice loss})$ $Ma = 55 - 0.7(50) - 2(2) - 3(0.1)$ $Ma = 15.7\,dB$ (2 mark)	4	4	5	2
5	i) Identify the key system requirement from the following for the point to point link analysis using optical fiber component. (a) Data rate **(b) Core size** (c) Spectral line width (d) Responsivity	1	1	5	2
	ii) Explain the key features of a fiber optic transmission technique that enables the use of multiple light wavelengths to send data over the same medium. Wavelength division multiplexing (1 mark)	4	2	5	2

	▪ *Capacity upgrade*. The classical application of WDM has been to upgrade the capacity of existing point-to-point fiber optic transmission links. If each wavelength supports an independent network channel of a few gigabits per second, then WDM can increase the capacity of a fiber system dramatically with each additional wavelength channel. ▪ *Transparency*. An important aspect of WDM is that each optical channel can carry any transmission format. Thus, by using different wavelengths, fast or slow asynchronous and synchronous digital data and analog information can be sent simultaneously, and independently, over the same fiber without the need for a common signal structure. ▪ *Wavelength routing*. Instead of using electronic means to switch optical signals at a node, a wavelength-routing network can provide a pure optical end-to-end connection between users. This is done by means of *lightpaths* that are routed and switched at intermediate nodes in the network. In some cases, lightpaths may be converted from one wavelength to another wavelength along their route. (3 marks) iii) A 2x2 biconical tapered fiber coupler has an input optical power level of P_0=250µW. The output power at other three ports P_1=100µW, P_2=90µW and P_3=7.5nW. Find the coupling ratio, excess loss, insertion loss from port 0 to port 2 and cross talk. 5. iii coupling ratio $= \frac{P_2}{P_1+P_2} = \frac{90}{100+90} \times 100\% = 47.36\%$ (1 Mark) Excess loss $= 10\log\left(\frac{P_0}{P_1+P_2}\right)$ $= 10\log\left(\frac{250}{100+90}\right) = 1.19$ dB (1.5 marks) Insertion loss port 0 to port 2 $= 10\log\left(\frac{P_0}{P_2}\right)$ $= 10\log\left(\frac{250}{90}\right) = 4.43$ dB (1.5 Marks) Cross talk $= 10\log\left(\frac{P_3}{P_0}\right) = 10\log\left(\frac{7.5\times10^{-9}}{250\times10^{-6}}\right)$ $= -45.22$ dB (1 Mark)	5	4	5	2
6	i) Identify the multiplexing technique which has dense channel spacing and allows simultaneous transmission of 16+ wavelengths? (a) Coarse WDM **(b) Dense WDM** (c) TDM (d) FDM	1	1	5	2
	ii) Identify the budget analysis for determining the dispersion limitation of an optical fiber link and derive its four basic elements that limit the system speed. Rise time budget analysis (1 mark) A *rise-time budget analysis* is a convenient method for determining the dispersion limitation of an optical link. This is particularly useful for a digital link. In this approach the total rise time t_{sys} of the link is the root-sum-square calculation of the rise times from each contributor t_i to the pulse rise-time degradation, that is, if there are N components in a link that affect the rise time then $t_{sys} = \left(\sum_{i=1}^{N} t_i^2\right)^{1/2}$ (1 mark)	9	3	5	2

The five basic elements that may limit the system speed significantly are the transmitter rise time t_{TX}, the modal dispersion rise time t_{mod} of multimode fiber, the chromatic dispersion (CD) rise time t_{CD} of the fiber, the polarization mode dispersion (PMD) rise time t_{PMD} of the fiber, and the receiver rise time t_{RX}.

$$t_{RX} = \frac{350}{B_{RX}}$$

(2 marks)

In practice, an optical fiber link seldom consists of a uniform, continuous, jointless fiber. Instead, a transmission link nominally is formed from several concatenated (tandemly joined) fibers which may have different dispersion characteristics. This is especially true for dispersion-compensated links operating at 10 Gbps and higher. In addition, multimode fibers experience modal distributions at fiber-to-fiber joints owing to mechanical misalignments, different core index profiles in each fiber, and/or different degrees of mode mixing in individual fibers. Determining the fiber rise times resulting from chromatic and modal dispersion then becomes more complex than for the case of a single uniform fiber.

The fiber rise time t_{CD} resulting from chromatic dispersion over a length L can be approximated by

$$t_{CD} \approx |D_{CD}| L \Delta\lambda$$

(2 marks)

For a multimode fiber the *bandwidth*, or *information-carrying capacity*, is specified as a bandwidth-distance relationship with units of megahertz times kilometers. Thus the bandwidth needed to support an application depends on the data rate of transmission; that is, as the data rate goes up (MHz), the distance (km) over which signals can be transmitted at that rate goes down. Multimode fibers with a 50-µm core diameter have about 3 times more bandwidth (500 MHz·km) than 62.5-µm fibers (160 MHz·km) at 850 nm. If B_{mod} is the modal dispersion bandwidth (in MHz·km), then the modal rise time t_{mod} (in nanoseconds) over a fiber of length L km is given by

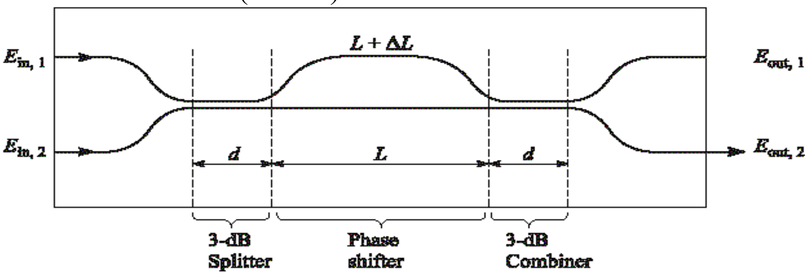
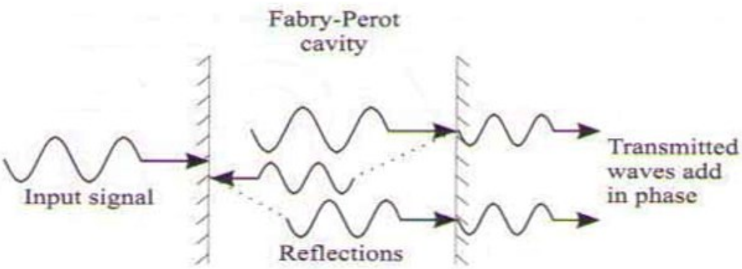
$$t_{mod} = \frac{440L}{B_{mod}}$$

(2 marks)

$$t_{PMD} = D_{PMD}\sqrt{\text{fiber length}}$$

where D_{PMD} is the polarization mode dispersion measured in units of ps/$\sqrt{\text{km}}$.

(1 mark)

7	i) Identify the technique where light is modulated by a radio frequency and transmitted over an optical fiber to access the dead zones. **(a) Radio over fiber** (b) Fiber optic communication (c) Microwave communication (d) Radio communication	1	1	5	2
	ii) An Optical component is used to determine the relative phase shift variations between two collimated beams derived by splitting light from a single source. Identify the device. Explain its construction and operation. MZI interferometer (1 mark)  (diagram 1 mark) Phase shift of the propagating wave increases with *ΔL*, Constructive or destructive interference depending on *ΔL* An interferometric device uses 2 interfering paths of different lengths to resolve wavelengths.Typical configuration: two 3-dB directional couplers connected with 2 paths having different lengths. Phase shift at the output due to the propagation path length difference: $\boxed{\Delta\phi = \frac{2\pi n_{eff}}{\lambda}\Delta L}$ If the power from both inputs (at different wavelengths) to be added at output port 2, then, $\boxed{\pi = 2\pi n_{eff}\left[\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right]\Delta L}$ (Working 3 marks)	5	2	5	2
	iii) Identify the WDM component which work on the principle of partial interference of the incident beam with itself in a mirrored resonant cavity to produce transmission peaks and nulls in the frequency domain.Expalin its principle of operation. Fabry-Perot Filters (1 mark)  (Diagram 1 mark)	4	3	5	2

	Principle of operation: A Fabry-Perot filter consists of the cavity formed by two highly reflective mirrors placed parallel to each other. The input signal is incident on the left surface of the cavity. The output of the filter is the light beam leaving the second mirror. After one pass through the cavity a part of the light leaves the cavity through the right facet and a part is reflected. A part of the reflected wave is again reflected by the left facet to the right facet. For those wavelengths for which the cavity length is an integral multiple of half the wavelength in the cavity—so that a round trip through the cavity is an integral multiple of the wavelength—all the light waves transmitted through the right facet add in phase. Such wavelengths are called the resonant wavelengths of the cavity. (3 marks)				