SRM Institute of Science and Technology
College of Engineering and Technology

SET B

DEPARTMENT OF ECE

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

Academic Year: 2024-25 (ODD)

ANSWER KEY

Test: FT-II **Date: 27/02/2025**

Course Code & Title: 21ECC304TR Microwave and Optical communication Duration: 8.00-9.40 AM

Year & Sem: III & VI **Max. Marks: 50**

Course Articulation Matrix:

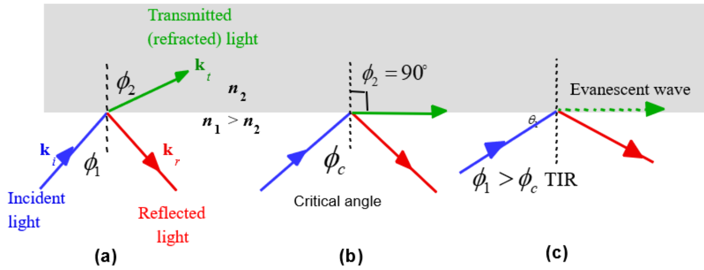
21ECC304TR- Microwave and Optical communication		Program Outcomes (POs)														
		Graduate Attributes												PSO		
COs	Course Outcomes (COs)	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
CO-1:	familiarize the concept of microwave transmission and generation	3	2	-	-	-	-	-	-	-	-	-	-	3	-	-
CO-2:	realize systematic methods to design, analyze S-parameters of microwave devices	3	2	-	-	-	-	-	-	-	-	-	-	3	-	-
CO-3:	identify different measurement techniques for determining various parameters and to gain knowledge on microwave measurements and the techniques with associated equipment	2	-	-	3	-	-	-	-	-	-	-	-	3	-	-
CO-4:	discover complete information on the fundamentals of light transmission through fiber and their characterization and mechanism	3	2	-	-	-	-	-	-	-	-	-	-	3	-	-
CO-5:	recognize the link power budget design considerations of optical communication system	3	-	2	-	-	-	-	-	-	-	-	-	-	2	-

Q. No	**PART-A (1*20=20)** **Answer all questions**	**Marks**	**BL**	**CO**	**PO**
1(a)	(i) An optical system deploy single mode fibers, which would be the most beneficial index profile? (a) Step index **(b) Graded index** (c) Coaxial cable (d) Step and graded index	**1**	**1**	**CO4**	**PO2**
	(ii) Multimode step index fiber has a large core diameter of range is (a)100 to 300 nm **(b)100 to 300µm** (c)200 to 500 µm (d)200 to500 nm	**1**	**1**	**CO4**	**PO2**
	(iii) The key system requirement for the point to point link analysis using optical fiber component is **(a) Data rate** (b) Core size (c) Spectral line width (d) Responsivity	**1**	**1**	**CO5**	**PO1**
	(iv) For a biomedical short range optical communication system, the below mentioned parameter plays a vital role in predicting a cleaner signal with less noise disruption. **(a)Carrier to noise ratio** (b)Optical Gain (c)Efficiency(d)Thermal noise	**1**	**1**	**CO5**	**PO1**
1(b)	(i) As a part of Digital India Initiative, a rural area has been identified by the government and a communication system will have to developed for the local people to enable a standard network communication. Optical engineers are organized for the same and they are in the process of analyzing the area to deploy an efficient optical communication. Assume	**8**	**1**	**CO4**	**PO1**

yourself to be one of the optical engineer in the team and analyze the challenges and effects of the light propagation through medium over various launch angle of the optic source. Provide mathematical illustrations for the same scenario.

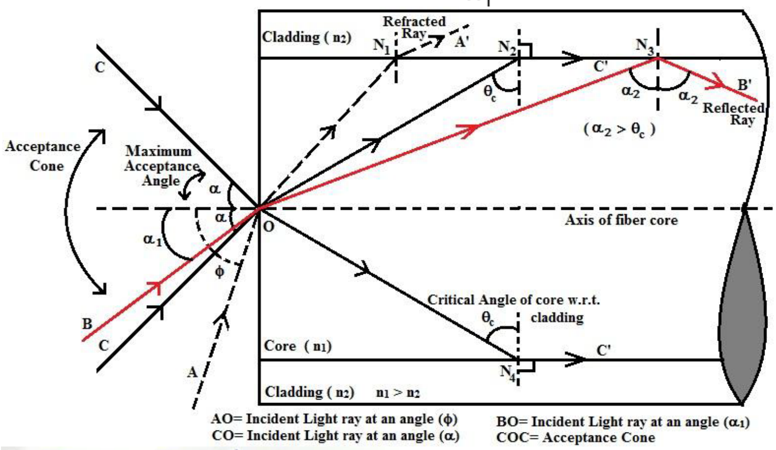
(i)
Identification as Light propagation through medium – 1 Mark
Briefing about the Total Internal Reflection – 2 Marks
Diagrammatic Illustration – 3 Marks
Mathematical illustrations – 2Marks

The continuation or escape of light in a medium is primarily governed by total internal reflection (TIR), which depends on the critical angle and the refractive indices of the materials. When light travels from a higher refractive index medium (n_1) to a lower refractive index medium (n_2), it bends away from the normal at the interface. If the incidence angle (θ) is greater than the critical angle ($\theta c = \sin^{-1}(n_2/n_1)$), light undergoes total internal reflection, remaining confined within the medium. If $\theta < \theta c$, the light refracts out of the medium, leading to signal loss.



$\phi_1 < \phi_c$ $\qquad$ $\phi_1 = \phi_c$ $\qquad$ $\phi_1 > \phi_c$

$n_1 \sin\phi_1 = n_2 \sin\phi_2$ $\qquad$ $\sin\phi_c = \dfrac{n_2}{n_1}$



From Snell's Law,

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

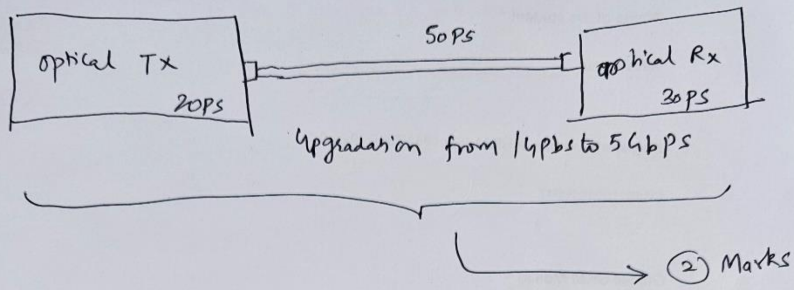
At critical angle,

$\phi_1 = \phi_c$ and $\phi_2 = 90°$

$n_1 \sin\phi_c = n_2 \sin 90°$

$n_1 \sin\phi_c = n_2 \Rightarrow \sin\phi_c = \dfrac{n_2}{n_1}$

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

	(ii) There is a demand for the usage of applications and gadgets that require higher data rates. At your home you are planning to advance your data package from 1 Gbps to 5 Gbps. If the rise time components are Transmitter rise time = 20 ps, Fiber dispersion rise time = 50 ps, receiver rise time = 30 ps, sketch an optical communication layout first with the aforementioned data and analyze the concept of rise-time budget analysis for the high-speed upgradation with the calculation of total system rise time and what may be the allowed rise time for a Non Return to Zero kind of transmission. **(ii)** Tx rise time = 20ps Dispersion rise time = 50 ps Rx rise time = 30ps  Risetime budget Calculation $t_{sys} = \sqrt{t_{tx}^2 + t_D^2 + t_{Rx}^2}$ → (2) Marks $= \sqrt{(20)^2+(50)^2+(30)^2}$ $= \sqrt{400+2500+900}$ $= 61.644$ ps → (1) Mark Maximum allowable rise time for NRZ $t_{max} = \frac{0.7}{\text{Bit rate}}$ → (1) Mark $= \frac{0.7}{5\times10^9} = 140$ ps → (1) Mark $\boxed{t_{sys} < t_{max}}$ for 5Gbps } (1) Mark The upgradation is possible and will support	8	3	CO5	PO1
	PART-B (2*15=30) **Answer Any Two Questions**				
2(a)	In a complete multipath wireless environment, optical fiber communication plays a positive role in a guided medium efficient communication with almost nil multipath signal scenario in a dense wireless architecture. Under this context, elaborate on the choice of an optical receiver that needs to detect very weak signals in the architecture layout. **Optical Receiver Choice – APD and Justification– 2 Marks** **Diagram – 2 Marks** **Explanation – 3 Marks** Avalanche Photodiode (APD) - APDs provide internal gain through avalanche multiplication, which amplifies weak optical signals before conversion to electrical form. They have high sensitivity, making them suitable for detecting weak signals in long-distance or low-power	7	2	CO4	PO1

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<td>applications. APDs operate efficiently in high-speed communication systems, such as long-haul fiber-optic networks and free-space optical communication.

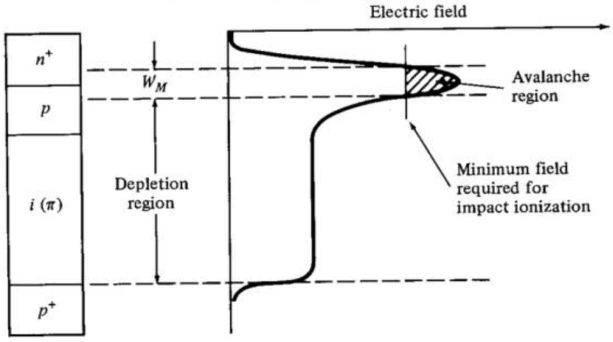
Avalanche Photodiodes

- 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.

Avalanche Photodiodes



Reach-through avalanche photodiode structure and the electric fields in the depletion and multiplication regions.

Impact Ionization:

The photo generated carriers traverse a region where a very high electric field is present. These carriers can gain enough energy under high electric field and excite new electron-hole pairs. This phenomenon is called Impact Ionization

Avalanche Effect:

During Ionization new generated carriers also accelerated by high electric field and gain enough energy to cause further impact ionization. This phenomenon is called avalanche effect.</td>
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<td>**2(b)**</td>
<td>Consider a multimode step index fiber that has a core radius of 50 μm, a core index of 1.48 and an index difference of 0.2%. What are the number of modes in the fiber at wavelengths of 860 nm, 1310 nm and 1550 nm. Also find the percentage of optical power that propagates in the cladding at 860nm.

ξ → 0.5 marks

Core radius = 50 μm , Core index = 1.48 , $\boxed{\Delta = 0.02}$

$\boxed{V = \frac{2\pi a}{\lambda} n_1 \sqrt{2\Delta} \quad , \quad m = \frac{V^2}{2}}$ → 2 marks

$V_{860} = \frac{2\pi \times 50 \times 10^{-6} \times 1.48 \sqrt{2 \times 0.02}}{860 \times 10^{-9}} = \frac{92.944 \times 10^3}{860}$

$V = 108.1$

$m = \frac{V^2}{2} = 5832$

$V_{1310} = \frac{92944 \times 10^3}{1310}$

$V = 70.9$

$m = \frac{V^2}{2}$

$m = 2513$

$V_{1550} = \frac{92.944 \times 10^3}{1550}$

$V = 59.96$

$m = \frac{V^2}{2}$

$m = 1798$

3 marks for all V numbers

1 marks for all modes

1 marks ← % optical power Calculation</td>
<td>**8**</td>
<td>**3**</td>
<td>**CO4**</td>
<td>**PO2**</td>
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<td>**3(a)**</td>
<td>A networking company needs an optical source for a high speed, short-distance fiber optic link. Justify the choice with suitable technical background so that the choice is a cost effective source and for the company depending upon on the distance of communication, length of</td>
<td>**8**</td>
<td>**2**</td>
<td>**CO4**</td>
<td>**PO1**</td>
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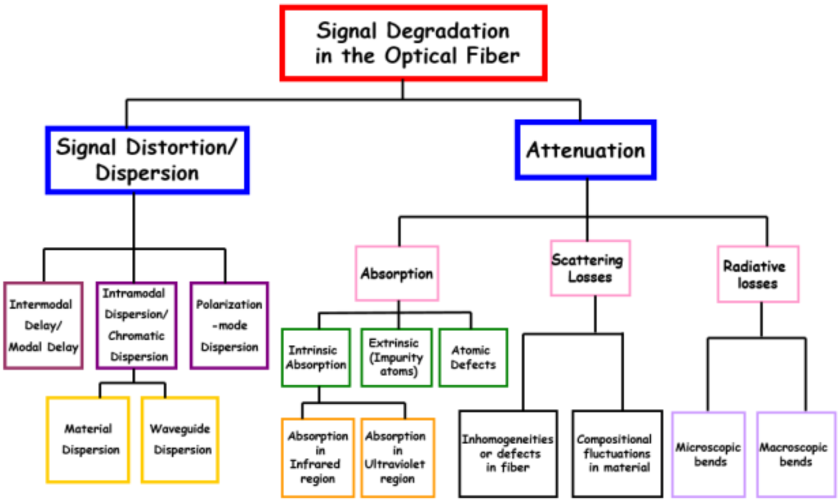
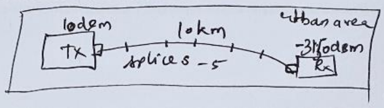
	the cables, intra and inter signal noises, brief on the impact of the optical networking installation over several degradation of signal factors. **Optical Transmitter Choice – LED and Justification– 2 Marks** **Why LEDs - relatively lower power output, wide beam angle, and cost-effectiveness, making them suitable for transmitting data within a limited range where line-of-sight is readily available, cost effective, high speed switching.** **Listing the Degradations - Attenuation and Dispersion – 3 Marks** **Brief Explanation on the attenuation and dispersion types– 3 Marks** 				
3(b)	Propose a device to route optical waves around for coupling different devices and list the parameters associated to the device that may be of interest to the network developers. Also if a 2x2 biconical tapered fiber device for the same purpose is proposed that has a significant input optical power level. The output power at other three ports P1=10µW, P2=9µW and P3=0.75nW. Express the coupling ratio, excess loss, insertion loss from port 0 to port 2 and cross talk in terms of input optical power for the power cases mentioned. **Identification of device as Optical Coupler – 1 Mark** **Listing the parameters – 2 Marks** **Calculations each 1 Mark – 4 Marks** Splitting (Coupling) Ratio = $P_2/(P_1+P_2)$ Excess Loss = $10 \text{ Log}[P_0/(P_1+P_2)]$ Insertion Loss = $10 \text{ Log}[P_{in}/P_{out}]$ Crosstalk = $10 \text{ Log}(P_3/P_0)$ Coupling ratio = $\frac{9}{10+9} = \frac{9}{19} = 0.474$ Excess loss = $10 \log\left[\frac{P_0}{19}\right]$ Insertion loss = $10 \log\left[\frac{P_0}{9}\right]$ Crosstalk = $10 \log\left[\frac{0.75 nW}{P_0}\right]$	**7**	**3**	**CO5**	**PO3**
4(a)	For an urban environment, an optical fiber communication system is deployed for 10 Km range. The system uses 2 connectors, 5 splices and a laser source of power 10 dBm. The system possess connector loss of 2 dB, splice loss of 0.1 dB and attenuation of 0.7dB /Km. The sensitivity of the receiver is -30 dBm. Calculate the total link loss and system margin	**7**	**2**	**CO5**	**PO3**

	in dB. Sketch the urban area blue print of the transmitter and receiver scenario. (2marks) Fiber attenuation Fiber loss = 0.7 dB/km = 0.7 × 10 = 7 dB Splice loss = 5 × 0.1 dB = 0.5 dB Connector loss = 2 × 2dB = 4dB (1mark) ← Total link loss = 7 + 0.5 + 4 = 11.5dB = 41.5dBm (1mark) ← Received power = P_S (10dBm) − link loss = 10 − 41.5 = −31.5 dBm / −61.5dB (1mark) ← Receiver sensitivity = −30 dBm Since −31.5dBm < −30dBm, the signal is not strong enough  → (2)marks				
4(b)	For the same urban area mentioned above, as an optical communication technician ornate on the various devices that may be suitable for a high-speed WDM system for the following purposes (i) to prohibit back-reflection into the laser source, (ii) to filter out 1880 nm wavelengths from a multi-wavelength WDM system and (iii) to split the signals for various users. **Identification of each devices– 3 Marks** **(i)Isolator, (ii) Filter, (iii) Splitter** **Each explanation of isolator and filter – 2 Marks – 4 Marks** **Splitter explanation in brief – 1 Mark**	**8**	**3**	**CO5**	**PO1**

Course Outcome (CO) and Bloom's level (BL) Coverage in Questions