SRM Institute of Science and Technology
College of Engineering and Technology

DEPARTMENT OF ECE

SRM Nagar, Kattankulathur – 603203, Chengalpattu District, TamilNadu

ANSWER KEY
OFFLINE
SET A

Academic Year: 2021-2022 (EVEN)

Test: CLAT- 2 **Date:** 25-05-2022
Course Code & Title: 18ECE322T – Optoelectronics **Duration:** 12:30 – 2.15 PM
Year & Sem: 2nd Year / 4th Sem **Max. Marks:** 50

Course Articulation Matrix with PI:

	18ECE322T- Optoelectronics		Program Outcomes (POs)																								PSO		
COs	Course Outcomes	BL	1	PI	2	PI	3	PI	4	PI	5	PI	6	PI	7	PI	8	PI	9	PI	10	PI	11	PI	12	PI	1	2	3
CO-1:	Define the basic concepts of optics and semiconductor optics.	1	3	1.4.1	-		-		-																				1
CO-2:	Demonstrate the working principle of various photonic sources and display devices.	3	3	1.2.1	3	2.1.2	-		2	4.1.1																			3
CO-3:	Analyze the principle and operation of various detectors and noise associated with it.	4	-		3	2.1.3	2	3.1.1	3	4.1.2																			3
CO-4:	Interpret the various optoelectronic modulators, switches, and interconnects.	3	3	1.3.1	2	2.2.1	3	3.2.1	-																				2
CO-5:	Apply the concepts of integrated optoelectronic components and its application in various fields.	3	3	1.4.1	-		3	3.2.2	3	4.2.1																			3

Part - A
(10 x 1 = 10 Marks)
Instructions: Answer ALL the Questions

Q.No	Question	Marks	BL	CO	PO	PI
1	In characteristic luminescence materials, the excitation and emission of light radiation occurs very rapidly in less than _____ s Answer: (d) 10^{-8}	1	1	2	1	1.2.1
2	For N elements the number of external wiring connections required for coordinate connected matrix display method is Answer: (d) $\sqrt{N}$	1	2	2	2	2.1.2
3	The band gap of red, blue, and green LEDs is E_r, E_b, and E_g, respectively. Which of the following is true? Answer: (c) Eb > Eg > Er	1	2	2	2	2.1.2
4	In the population Inversion Answer: (c) The number of electrons in higher energy state is more than the ground state	1	1	2	1	1.2.1
5	The distance between planes having the same director direction is called _____ Answer: (c) Pitch	1	1	2	1	1.2.1
6	The phototransistor construction normally allows the incident radiation to be absorbed in the ______ junction space charge layer. Answer: (a) base–collector	1	1	3	3	3.1.1
7	The responsivity of a given p-i-n diode is 0.5A/W for a wavelength of 850nm. What is the output photocurrent when optical power of 0.2 μW is incident on it? Answer: (a) 0.1μA	1	4	3	2	2.1.3
8	The basic building block of a charge-coupled device (CCD) is called Answer: (c) Metal-oxide semiconductor capacitor	1	1	3	3	3.1.1
9	Which of the following is an inherent property of an optical signal and cannot be eliminated even in principle? Answer: (b) Shot noise	1	1	3	3	3.1.1
10	If the external photocurrent is due to more than one electron flow per absorbed photon, then it is termed as. Answer: (b) photoconductive gain	1	1	3	3	3.1.1

Part – B
(4 x 10 = 40 Marks)
SECTION B1
Instructions: Answer ANY 2 Questions

11 (a) Differentiate phosphorescence and fluorescence. Calculate penetration depth of an electron beam (with energy = 10 keV) on a ZnS screen that produce cathodoluminescence. (Note: For ZnS, K = 1.2 x 10-4, b = 1.75).

Phosphorescence	Fluorescence
1. It is the absorption of energy by atoms or molecules followed by immediate emission of light or electromagnetic radiation.	It is the absorption of energy by atoms or molecules followed by delayed emission of electromagnetic radiation.
2. The emission of light suddenly stops on removal of source of excitation.	The emission of radiation remains for some time even after the removal of source of excitation.

3. The excited atom has comparatively short lifetime before its transition to low energy state.	The excited atom has comparatively long lifetime before its transition to low energy state.

Any two points – 2 Marks

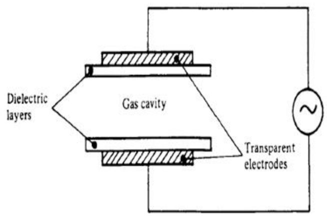
Marks	CL	CO	PO	PI
4	4	CO2	PO2	2.1.2

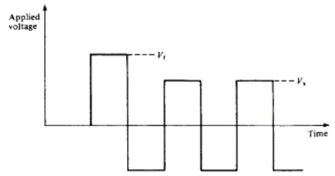
The penetration depth of the electron, $R_c = kE_B^b$ - 1 Mark

$= \left(1.2\times10^{-4}\right)\times\left(1.602\times10^{-15}\right)^{0.151} = \left(1.2\times10^{-4}\right)\times\left(5.833\times10^{-3}\right)$ - 1 Mark

$= 6.99979\times10^{-7} = 0.7\,\mu m$

(b) Explain the construction and working of Plasma Display and a.c. electroluminescent device.





i. Principle: Glow is produced when an electric current is passed through a gas (neon).
ii. Electrodes are placed external to the gas cavity.
iii. Gas cavity is 10-4 m in width with transparent electrodes on the outside of the containing dielectric layers.
iv. Gas gets ionized.
v. Free electrons increases their kinetic energy and collide with atoms exciting them.
vi. During recombination- Photons

Diagram 1 Mark + Explanation – 2 Marks

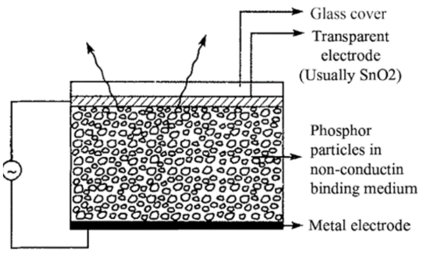


Diagram 1 Mark + Corresponding explanation – 2 Marks

i. The phosphor particles namely ZnS: Cu are suspended in a nonconducting transparent insulating binding medium of high dielectric constant.
ii. This medium is sandwiched in between two electrodes namely, highly transparent (SnO_2) and a metal electrode.
iii. As a result, there is no complete conduction path between the two electrodes and hence, the excitation cannot take place.
iv. When an ac voltage is applied between the electrodes, a short burst of light is emitted for every half cycle for a period of 10^{-3} s.
v. Due to the application of ac voltage, a high electric field is known to exist within the phosphor particle.

Marks	CL	CO	PO	PI
6	2	CO2	PO1	1.2.1

12

(a) Explain the optical feedback and threshold condition for laser oscillation.

The standing wave exists only for wavelengths for which the distance of the mirrors is an integral number of the half of the wavelength.

$L = k\cdot\frac{\lambda}{2n}$ Resonance condition

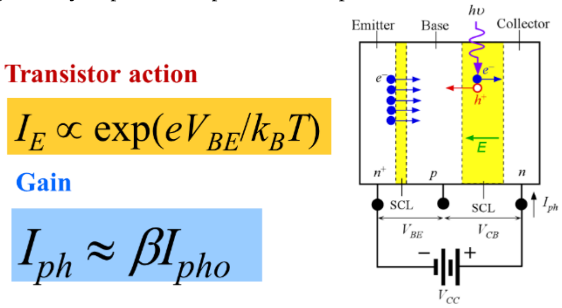
Based on the resonance condition the spectral width of the amplified signal can be determined to be

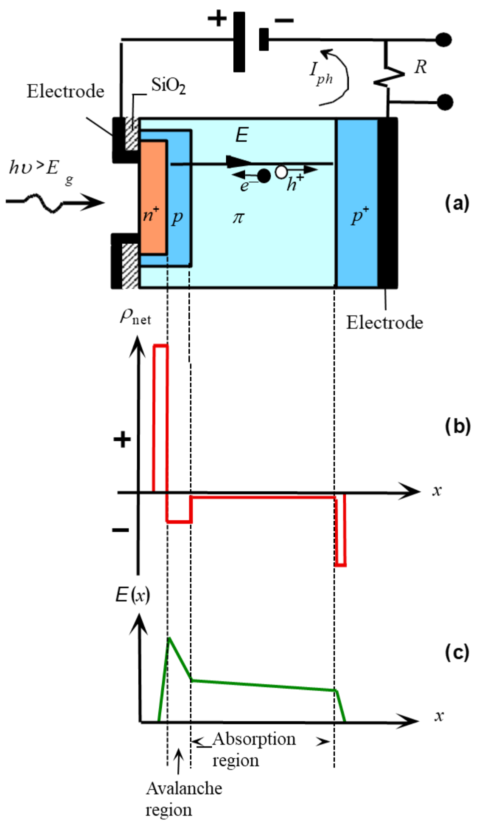
$\Delta\lambda = \frac{\lambda^2}{2nL}$ Spectral width

$$Fractional\ loss = R_1R_2\exp\left(-2\alpha\cdot L\right)$$

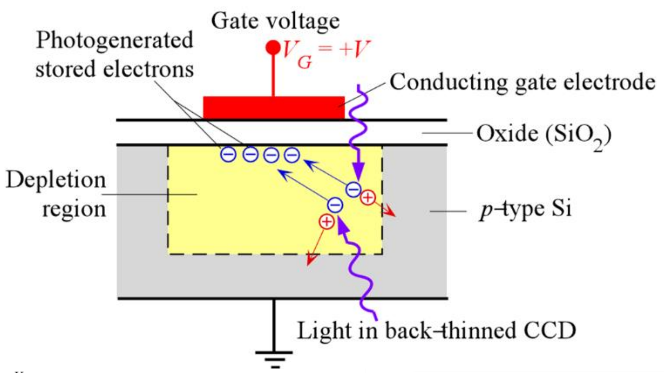
$\overline{g}_{th} = \overline{\alpha} + \frac{1}{2L}\cdot\ln\left(\frac{1}{R_1R_2}\right)$ Threshold gain

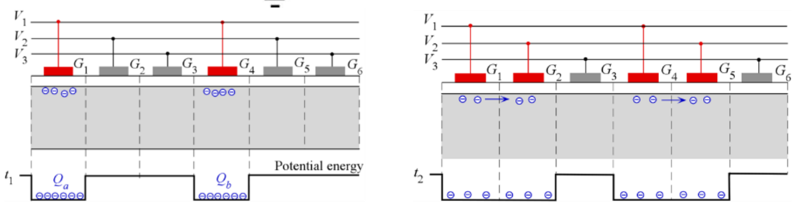
Marks	CL	CO	PO	PI
6	3	CO2	PO4	4.1.1

	(b) An injection laser has active cavity losses of 25 cm-1and the reflectivity of each laser facet is 30%. Determine the laser gain coefficient for the cavity it has a length of 500μm. Gain threshold for a laser diode is given by $g_{th}=\bar{\alpha}+\frac{1}{2L}\ln\left(\frac{1}{R^2}\right)$ $\bar{\alpha}=25cm^{-1}, R=30\%=0.3, L=500\mu m$ $=25+\frac{1}{2(500\times10^{-4})}\ln\left(\frac{1}{(0.3)^2}\right)=49.07cm^{-1}$	4	4	CO2	PO2	2.1.2
13	(a) Consider a particular green LED based on InGaN MQW active region. The emission wavelength is 528 nm. At an LED current of 350 mA, the forward voltage is 3.4 V. The emitted luminous flux is 92 lm. Find the power conversion efficiency, external quantum efficiency, luminous efficacy, and the emitted optical power (radiant flux)? The luminous flux Φ_υ is defined by $\Phi_\upsilon = P_o\times$ (683 lm W^{-1}) × $V(\lambda)$ Where P_o is the radiant flux (Watts) and $V(\lambda)$ is the relative luminous efficiency i. Output optical power = $P_o = \Phi_\upsilon$ / [(683 lm W^{-1}) V(528 nm)] *[V(528 nm) = 0.90]* = (92 lm) / [(683 lm W^{-1}) × (0.90)] = (92 lm) / (614.7 lm W^{-1}) = 0.15 W **Emitted Optical power = 0.15 W - 2 Marks** ii. Luminous efficacy (efficiency) = $\eta_{LE}=\frac{\Phi_v}{IV}$ = (92 lm) / [(0.35 A)×(3.4 V)] = 92 / 1.19 = 77.31 lm/W **Luminous efficacy (efficiency) = 77.31 lm / W - 2 Marks** iii. Power conversion efficiency = $\eta_{PCE}=\frac{P_o}{IV}\times100\%$ = (0.15 W) / (0.35 A × 3.4 V) = 0.126 = 12.6 %**Power conversion efficiency = 12.6 % - 2 Marks** iv. External quantum efficiency = $\eta_{EQE}=\frac{P_o/h\upsilon}{I/e}\times100\%$ hν = 1.24 / 0. 528 = 2.35 eV $\eta_{EQE}=\left(\frac{0.15W/(2.35eV\times1.6\times10^{-19}JeV^{-1}}{0.35A/1.602\times10^{-19}C}\right)\times100\%$ $=\left(\frac{3.98936\times10^{17}}{2.1875\times10^{18}}\right)\times100\%$ = 18.23% **External Quantum Efficiency = 18.23 % - 2 Marks**	8	4	CO2	PO2	2.1.2
	(b) Why silicon is not preferrable for the fabrication of optical sources. Justify your answer. Ans: Silicon is an Indirect Bandgap Semiconductor material. Hence, we cannot use it for the fabrication of optical sources.	2	2	CO2	PO1	1.2.1
	SECTION B2 **Instructions: Answer ANY 2 Questions**					
14	(a) Briefly explain the operation of a phototransistor. 	4	2	CO3	PO3	3.1.1

	(b) A Si APD has a QE of 70 % at 830 nm in the absence of multiplication, (M =1). The APD is biased to operate with a multiplication of 100. If the incident optical power is 10 nW what is the photocurrent? The unmultiplied responsivity is given by, $R = \eta_e \frac{e\lambda}{hc}$ $= (0.70)\frac{(1.6\times10^{-19}\ \mathrm{C})(830\times10^{-9}\ \mathrm{m})}{(6.626\times10^{-34}\ \mathrm{J\ s})(3\times10^{8}\ \mathrm{m\ s^{-1}})}$ R = 0.47 A/W - 2 Marks The unmultiplied primary photocurrent from the definition of R is $I_{pho} = RP_o = (0.47\ \mathrm{A/W}) \times (10\times10^{-9}\ \mathrm{W}) = 4.7\ \mathrm{nA}$ The multiplied photocurrent is $I_{ph} = MI_{pho} = (100) \times (4.67\ \mathrm{nA}) = 470\ \mathrm{nA}$ or $0.47\ \mu\mathrm{A}$ - 2 Marks	4	4	CO3	PO2	2.1.3
	(c) Define noise equivalent power (NEP) and detectivity of a photodetector with relevant expression. NEP is defined as the required optical input power to achieve a SNR of 1 within a bandwidth of 1 Hz $\mathrm{NEP} = \frac{\text{Input power for SNR} = 1}{\sqrt{\text{Bandwidth}}} = \frac{P_1}{B^{1/2}}$ - 1 Mark $\text{Detectivity} = \frac{1}{\mathrm{NEP}}$ - 1 Mark	2	3	CO3	PO3	3.1.1
15	(a) Briefly discuss the construction and working of Avalanche photodiode (APD).  Diagram 2 Marks + Operation – 3 Marks – (Impact Ionization & Avalamche Multiplication)	5	3	CO3	PO3	3.1.1.

(b) With a neat diagram explain the concept of charge coupled device (CCD) in detail.





Time	V_1	V_2	V_3
t_1	$+V$	0	0
t_2	$+V$	$+V$	0
t_3	0	$+V$	0

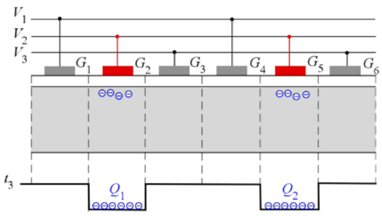


Diagram 2 Marks + Corresponding Explanation – 3 Marks

5	3	CO3	PO3	3.1.1.

16

(a) Consider an InGaAs pin photodiode used in a receiver circuit with a load resistor of 27 kΩ. The total capacitance of the detector and the input of the amplifier together is 16 pF. The photodiode has a dark current of 2 nA. The incident radiation is 5 nW at 1550 nm where the responsivity is 0.8 A/W. Assuming that the amplifier is noiseless, calculate the SNR at 300K.

$$\text{Bandwidth} = \frac{1}{2\pi R_L C_{in}} = \frac{1}{2\pi\times(27\times10^3\Omega)\times(16\times10^{-12}F)} = 368.4 \text{ kHz}$$

Incident Optical Power (P_o) = 5nW

∴ Photocurrent $I_{ph} = RP_o = (0.8\ A/W)\times(5\times10^{-9}W)$

$= 4$ nA

Shot noise current from the detector = $[2e(Id + Iph)B]^{1/2}$

=

$$\left\{(2\times1.6\times10^{-19})\times\left[2\times10^{-9}+4\times10^{-9}\right]\times368.41\times10^{3}\right\}^{\frac{1}{2}}$$

$$=\sqrt{7.073472\times10^{-22}} \qquad = 2.66\times10^{-11}\text{ A} = 0.0266\text{ nA}$$

Thermal noise current from RL = $\left[\frac{4k_B TB}{R_L}\right]^{\frac{1}{2}}$

$$=\left[\frac{4\times1.380648\times10^{-23}\times300\times368.41\times10^{3}}{27\times10^{3}}\right]^{\frac{1}{2}} = \left[\frac{6.10373\times10^{-15}}{27\times10^{3}}\right]^{\frac{1}{2}} =$$

$$\sqrt{2.2606\times10^{-19}}$$

$= 4.7546\times10^{-10}$ A = 0.47546 nA

$$\text{SNR} = \frac{\text{Signal Power}}{\text{Noise Power}} = \frac{I_{ph}^2 R_L}{i_n^2 R_L + 4k_B TB} = \frac{I_{ph}^2}{\left[2e(I_d + I_{ph})B\right] + 4k_B TB / R_L}$$

8	4	CO3	PO2	2.1.3

<table>
<tr>
<td></td>
<td>

$$= \frac{(4nA)^2}{(0.0276nA)^2 + (0.47546nA)^2} = \frac{1.6\times10^{-17}}{7.0756\times10^{-22} + 2.2606\times10^{-19}}$$

$$= \frac{1.6\times10^{-17}}{2.2676\times10^{-19}} = 70.56$$

Generally SNR is quoted in decibels. We need 10log (SNR), or 10log (70.56) i.e., 18.485 dB

The Signal to Noise Ratio Value is 18.485 dB

(b) Explain in brief about metal-semiconductor-metal (Schottky) photodetector.

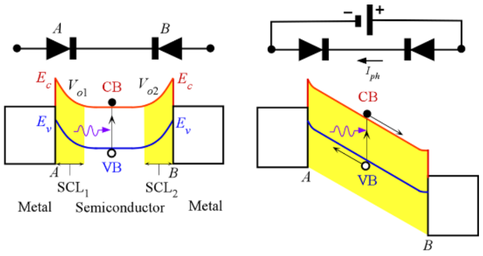


Diagram 1 Mark + Explanation – 1 Mark

</td>
<td>2</td>
<td>2</td>
<td>CO3</td>
<td>PO3</td>
<td>3.1.1</td>
</tr>
</table>