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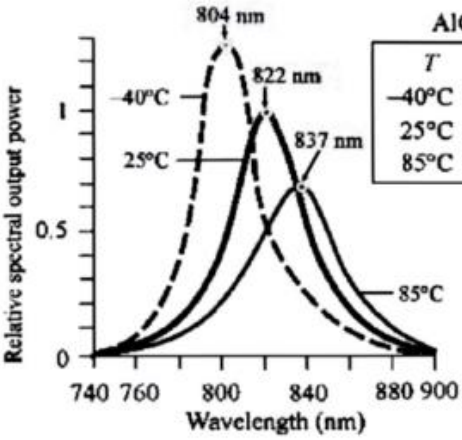
FACULTY OF ENGINEERING AT SHOUBRA

Optical Comm.
4^{th} level_credit

Sheet 3

1. Consider the three experimental points in the table shown in the Figure to the right. From problem 2, ***Δλ*** varies **linearly** with ***T***, that is: **$(\Delta\lambda/\lambda_o^2)$ =mKT/hc**. By a suitable plot find ***m*** and verify the relation of the linewidth ***Δλ*** of the previous problem.

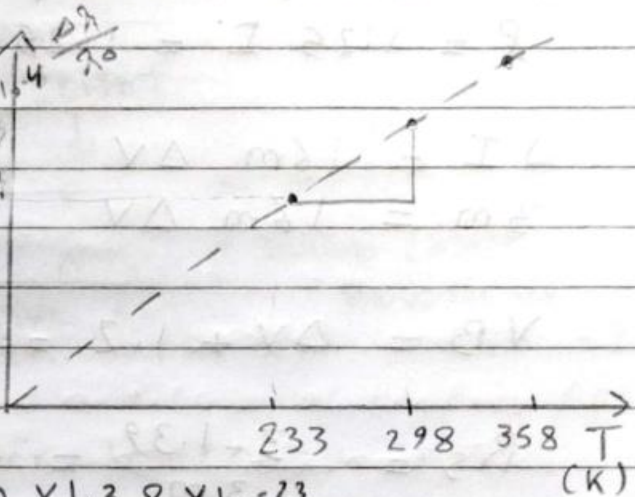


AlGaAs IR LED

T	λ_o	$\Delta\lambda$
−40°C	804 nm	30 nm
25°C	822 nm	40 nm
85°C	837 nm	48 nm

3) $\Delta E = \frac{hc}{\lambda^2}\Delta\lambda = mKT$

$\frac{\Delta\lambda}{\lambda^2} = \frac{mKT}{hc}$



$\text{Slope} = \frac{(5.9-4.6)\times10^{-4}}{298-233}$

$= 200$

$200 = \frac{mK}{hc} = \frac{m\times1.38\times10^{-23}}{6.625\times10^{-34}\times3\times10^{8}}$

$m = 2.88$

2) We know that the spread of the **wavelengths** in the emission spectrum of an LED is related to the spread in the emitted **photon energies**. The emitted photon energy $h\nu = hc/\lambda$. Assume that the spread in the photon energies $\Delta(h\nu) \approx 3kT$ between the half intensity points. Show that the corresponding linewidth $\Delta\lambda$ between the half intensity points in the output spectrum is:

$$\Delta\lambda = \lambda_o^2 \frac{3KT}{hc} \quad \text{where "K" is the Boltzmann constant}$$

and λ_o is the peak emission wavelength.
What is the spectral linewidth of an optical communications LED operating at **1310 nm** and at **300 °k ?** (Note °k means degree Kelvin)

2) $\Delta E = \frac{hc}{\lambda^2} \Delta\lambda = 3KT$

$\Delta\lambda = \lambda^2 \frac{3KT}{hc} = (1310\,nm)^2 \times \frac{3 \times 300 \times 1.38 \times 10^{-23}}{6.625 \times 10^{-34} \times c}$

$\Delta\lambda = 1.07 \times 10^{-7}\,m$

3) Using the expression $E = hc/\lambda$, show why the Full Width at Half Maximum (FWHM) power spectral width of LEDs become wider at longer wavelengths.

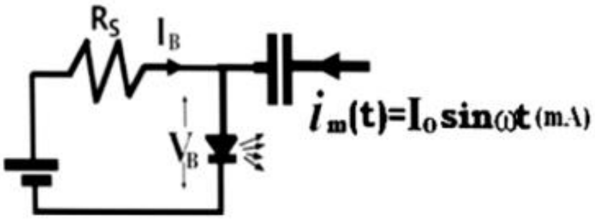
Differentiating the expression for E, we have

$$\Delta E = \frac{hc}{\lambda^2}\Delta\lambda \quad \text{or} \quad \Delta\lambda = \frac{\lambda^2}{hc}\Delta E$$

For the same energy difference ΔE, the spectral width $\Delta\lambda$ is proportional to the wavelength squared. Thus, for example,

$$\frac{\Delta\lambda_{1550}}{\Delta\lambda_{1310}} = \left(\frac{1550}{1310}\right)^2 = 1.40$$

4. Assume that all the modulating current $i_m(t)$ flows through the LED. The bias current $\mathbf{I_B = 6\ mA}$.
At the instant **t=0**, the **instantaneous** emitted output power is **4 mW**. And at **t=3π/2ω,** the instantaneous emitted output power is **1mW**. Calculate:



a) The slope of the output Power-Current characteristic of the LED.
b) The amplitude I_o of the modulating current.
c) The **maximum** instantaneous emitted power.

$I_B = 6\,mA$

at $t = 0 \longrightarrow P = 4\,mw$

at $t = \frac{3\pi}{2w} \longrightarrow P = 1\,mw$

$\rightarrow I_o \sin \frac{3\pi}{2w} w = -I_o$

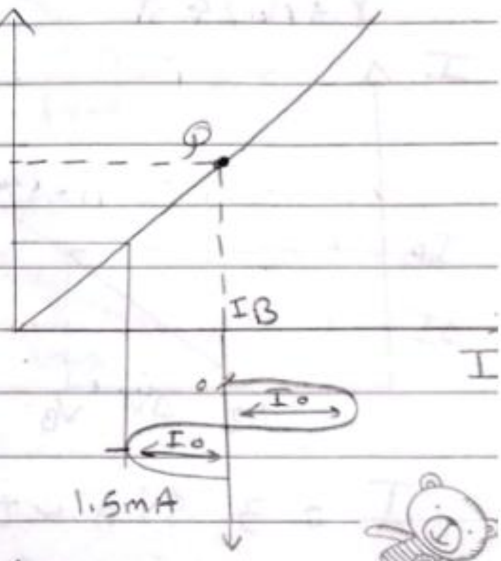
a) $a = \frac{P}{I_B} = \frac{4mw}{6m} = \frac{2}{3}\ mw/mA$

b) $I_{(1mw)} = \frac{1mw}{2/3} = 1.5\ mA$

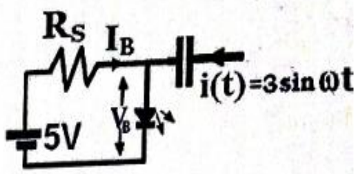
$I_o = 6m - 1.5m = 4.5\ mA$

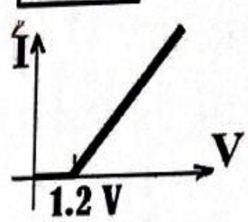
c) $I_{max} = 4.5\ mA + 6m = 10.5mA$

$P = 10.5 \times \frac{2}{3} = 7mw$



5. **It is required to modulate the emitted output power from the LED shown in the figure by an AC current i(t)=3sinωt (mA). Accordingly, the LED must be biased by a DC current I_B such that the output light is not clipped (cutoff) during the negative part of i(t). The LED has the approximate linear I-V characteristic shown in the figure, the slope of the line is 15 mA/V. (Assume that all the AC current i(t) flows through the LED).**





a- What is the "minimum" value of I_B ? (15 marks)
b- Calculate the DC voltage V_B across the LED. (10 marks)
c- Calculate the value of the required resistor Rs. (5 marks)

a) The negative part of the sin wave has an amplitude **-3 mA**. At this operating point the output "Power" decreases to 0 since the P-I characteristic is linear and starts from 0. Therefore, in order that the negative part be unclipped, the **total current** flowing through the LED at that instant should be 0. Thus, at $i(t) = -3$ mA the **total current:**

$\mathbf{i = I_B + i(t) = I_B - 3 = 0}$, THUS: $\underline{\mathbf{I_B = 3\ mA}}$.

b) From the (I-V) c/c of the LED, the voltage across the LED, should be above the cutoff (1.2V) by an amount $\mathbf{\Delta V}$ corresponding to $\underline{\mathbf{I_B = 3\ mA}}$. And since the c/c is linear, then:

$$\text{Since the slope } \mathbf{15}\ (mA/V) = \mathbf{I_B/\Delta V}$$

$$\therefore \mathbf{\Delta V = I_B / 15}\ (mA/V = \mathbf{3}\ mA/\mathbf{15}\ (mA/V) = \mathbf{3/15}\ V = \underline{\mathbf{0.2\ V}}.$$

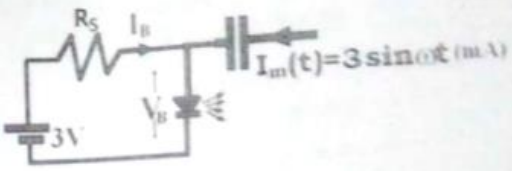
$$\therefore \mathbf{V_B = 1.2 + \Delta V = 1.2 + 0.2 = \underline{1.4\ V}}$$

c) Since the voltage across $\mathbf{R_S}$ is:

$$\mathbf{(V_S - V_B) = 5 - 1.4 = 3.6\ V}$$

$$\therefore \mathbf{R_S = (V_S - V_B)/\ I_B = 3.6\ V/\ 3mA = \underline{1200\ \Omega}}$$

6. **The P-I characteristic of a certain LED is described by: P=aI where a=1.25 mW/mA. Its I-V characteristic is described by:** $\boxed{\begin{array}{ll} I = 0 & \text{for } 0 \le V \le 1.2\ V \\ I = bV & \text{for } \quad V \ge 1.2\ V \end{array}}$.



Assume that b= 16 mA/V, and that all the AC modulating current passes through the LED. Calculate the "lowest" possible value of the LED quiescent point (I_B and V_B) and the resistor R_S.

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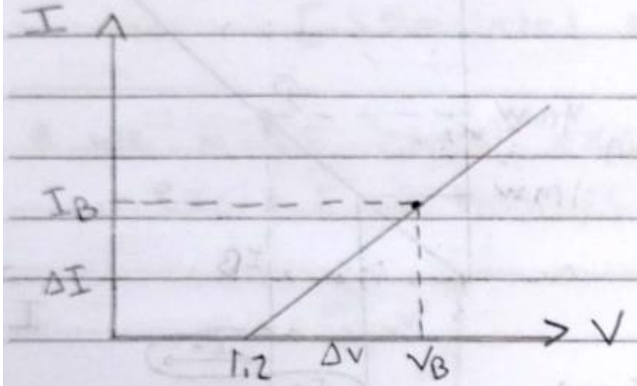
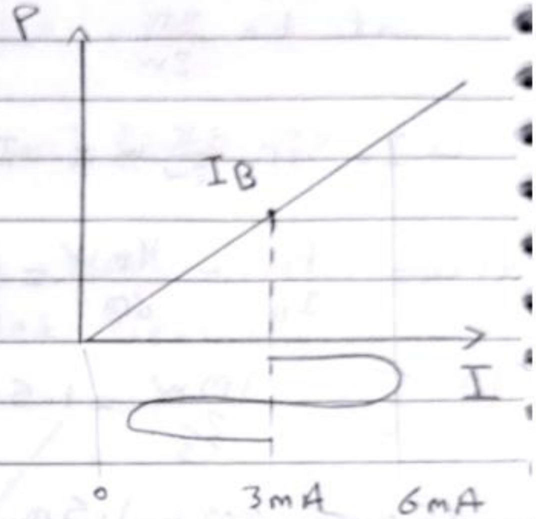
$P = 1.25\, I$





$I = 3 \sin \omega t \ mA$

$I_{max} = 3 \ mA$

P at Q Point ;

$P = 1.25\, I = 1.25 \times 3m = 1.$

$\Delta I = 16m\ \Delta V$

$3m = 16m\ \Delta V$, $\Delta V = 0.19V$

$V_B = \Delta V + 1.2 = 1.39V$

$R_s = \frac{3 - 1.39}{3m} = 537\,\Omega$