Chapter 2 Introduction to Optoelectronic Device Principles

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QUESTION 1: A solar cell under illumination of 500 W/m^2 has a short circuit current of I_{sc} = 15 mA and an open circuit voltage of V_{oc} = 0.6 V. Calculate I_{sc} and V_{oc} for double the light intensity assuming a diode ideality factor of $m=1$.

SOLUTION 1: The solar cell current-voltage characteristic is given by Eq. (12). The open circuit voltage is obtained for $I=0$ and $V_{oc} >> mkT/e$ as

$$V_{oc} = \frac{mkT}{e}\ln\left(\frac{I_{ph}}{I_o}\right)$$

The short circuit current is equal to the photocurrent which is proportional to the light intensity. Double the intensity gives I_{sc2} = 30 mA and

$$V_{oc2} = V_{oc1} + \frac{mkT}{e}\ln\left(\frac{I_{sc2}}{I_{sc1}}\right) = 0.6V + 0.0259V \times \ln(2) = 0.618V \; .$$

QUESTION 2: The LED emission wavelength λ is sensitive to the temperature T which is mainly related to the band gap shift $E_g(T)$. Consider an LED with an emission wavelength of 870 nm at 20 ^{o}C that red-shifts by 2.8 nm for 10 ^{o}C temperature increase. What is the band gap E_g and its temperature sensitivity $\Delta E_g/\Delta T$?

SOLUTION 2: The band gap – wavelength relation is given in Eq. (1). At 20

^{o}C, the wavelength of 870 nm gives a band gap of E_g = 1241/870 = 1.426 eV. The thermal shift of the band gap is calculated as

$$\frac{\Delta E_g}{\Delta T} = \frac{1241}{10}\left(\frac{1}{870} - \frac{1}{867.2}\right) = -0.46 \times 10^{-3} \frac{eV}{K}.$$

QUESTION 3: Consider a Mach-Zehnder modulator as in Figure 23 with a Pockels coefficient $r = 3.4\ 10^{-12}$ m/V and a branch thickness $d = 5$ µm. For a maximum half-wave voltage of $V_\pi = 10$ V, what should be the minimum branch length L for modulator operation at 1.55 µm wavelength ($n_r = 2.2$) ?

SOLUTION 3: The half-wave voltage is given by Eq. (35), which leads to

$$L = \frac{d}{V_\pi}\frac{\lambda}{r n_r^3} = \frac{5 \times 10^{-6} m}{10V} \frac{1.55 \times 10^{-6} m}{3.4 \times 10^{-12} m/V \times 2.2^3} = 2.14 cm.$$