

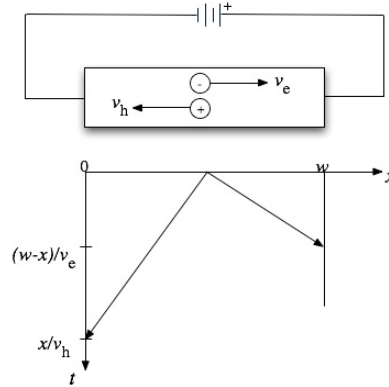
ECE228B

Fiber Optic Components and Systems

Homework #1

Problem 1:

Consider a semiconductor material exposed to an impulse of light at $t=0$ that generates N electron-hole pairs between 0 and w as shown below, with electron and hole velocities v_e and v_h .



Show that the hole and electron currents and total current can be written as follows:

$$i_h(t) = \begin{cases} -\frac{Nqv_h^2}{w^2}t + \frac{Nqv_h}{w}, & 0 \leq t \leq \frac{w}{v_h} \\ 0, & \text{elsewhere} \end{cases}$$

$$i_e(t) = \begin{cases} -\frac{Nqv_e^2}{w^2}t + \frac{Nqv_e}{w}, & 0 \leq t \leq \frac{w}{v_e} \\ 0, & \text{elsewhere} \end{cases}$$

$$i_{total}(t) = \begin{cases} \frac{Nq}{w} \left[(v_h + v_e) - \frac{1}{w}(v_h^2 + v_e^2)t \right], & 0 \leq t \leq \frac{w}{v_e} \\ \frac{Nqv_h}{w} \left[1 - \frac{v_h}{w}t \right], & \frac{w}{v_e} \leq t \leq \frac{w}{v_h} \end{cases}$$

Problem 2:

A p-i-n photodiode is able to convert a pulse of light with 8×10^{12} photons into 3×10^{12} electrons that contribute to the output photocurrent. Calculate the quantum efficiency η and the responsivity R at $\lambda_0 = 0.83 \mu\text{m}$, $1.3 \mu\text{m}$ and $1.55 \mu\text{m}$. Now assume that the photodiode is composed of $\text{In}_{0.70}\text{Ga}_{0.30}\text{As}_{0.64}\text{P}_{0.36}$ and that the intrinsic region perpendicular to the incident photons is $1 \mu\text{m}$ thick. Use the Figure in your class notes for absorption as a function of wavelength for different material systems/compositions to estimate the quantum efficiency and responsivity at $\lambda_0 = 1.3 \mu\text{m}$.

Problem 3:

A silicon p-i-n photodiode operating with 0dBm input at 0.8 μm has 20MHz bandwidth, 65% quantum efficiency, 1nA dark current and 8pf junction capacitance.

- Determine the RMS current noise due to shot noise.
- Determine the SNR due to shot noise.
- If we require and SNR of 20dB, calculate the minimum received optical power when shot noise is the only noise source.

Problem 4:

An InGaAsP-InP FP laser has an optical cavity length of 350 μm , and a gain medium with peak gain coefficient that can be approximated by the linear relation

$$g_p \approx \alpha \left(\frac{\Delta n}{\Delta n_T} - 1 \right)$$

Assume the injected carrier concentration for transparency $\Delta n_T \approx 1.75 \times 10^{18} \text{ cm}^{-3}$ and the semiconductor absorption in the absence of current injection $\alpha = 600 \text{ cm}^{-1}$, a FWHM gain bandwidth of approximately 5nm and a mode refractive index of $n'_{\text{eff}} = 4$.

- Plot the peak gain coefficient as a function of the injected carrier concentration (Δn) from $\Delta n = 0$ to $\Delta n = 10 \Delta n_T$.
- Calculate the separation between mode of the cavity, the number of modes that oscillate in the cavity and the mode integer M of the peak radiation.

Problem 5:

Consider a DFB laser with a 400 μm long grating, an effective mode index 3.5 and a grating corrugation period 0.22 μm . Calculate the symmetric modes (wavelengths) that the laser will operate at assuming no $\lambda/4$ phase shift in the grating. What will be the output wavelength if the grating is fabricated with a $\lambda/4$ phase shift in the grating?

Problem 6:

Calculate and plot the wavelength shift vs. tuning current for a tunable Bragg reflector that operates based on the free-carrier plasma effect. Assume $\lambda_g = 1300\text{nm}$ InGaAsP tuning region operated at 1500 nm, $\beta_{\text{pl}} = -1.3 \times 10^{-20} \text{ cm}^3$, active region with $L = 400\mu\text{m}$, $d = 0.3\mu\text{m}$, $w = 2 \mu\text{m}$ and confinement factor $\Gamma_t = 0.3$. For the material assume an infinite spontaneous recombination time constant, bimolecular recombination constant $B = 10^{-10} \text{ cm}^3/\text{s}$ and Auger recombination constant $C = 3 \times 10^{-29} \text{ cm}^6/\text{s}$.

Problem 7:

For a mode-locked laser, assume the envelopes are given by the expression below and that the phases are equal. v_m is the frequency spacing of mode m , where $m=0$ coincides with the central frequency of the atomic lineshape. Determine expressions for the mean power, peak power and pulse width (defined at the full-width half-maximum FWHM).

$$A_q = \sqrt{P} \frac{\left(\Delta \nu / 2 \right)^2}{\left(m v_m \right)^2 + \left(\Delta \nu / 2 \right)^2}, \quad m = -\infty, \dots, +\infty$$