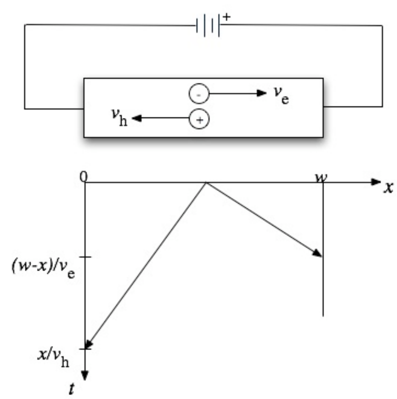
University of California, Santa Barbara — Spring 2009
Department of ECE

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:

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

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

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

Problem 2:

A p-i-n photodiode is able to convert a pulse of light with 8 x 10^{12} photons into 3 x 10^{12} electrons that contribute to the output photocurrent. Calculate the quantum efficiency η and the responsivity R at λ_0 = 0.83 μm, 1.3 μm and 1.55 μm. Now assume that the photodiode is composed of $In_{0.70}Ga_{0.30}As_{0.64}P_{0.36}$ and that the intrinsic region perpendicular to the incident photons is 1 μm 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 λ_0 = 1.3 mm.

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.

(a) Determine the RMS current noise due to shot noise.

(b) Determine the SNR due to shot noise.

(c) 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 $\Delta n_T \approx 1.75 \text{ X } 10^{18}$ cm^{-3} and the semiconductor absorption in the absence of current injection α = 600 cm^{-1}, a FWHM gain bandwidth of approximately 5nm and a mode refractive index of $n'_{eff} = 4$.

(A) Plot the peak gain coefficient as a function of the injected carrier concentration (Δn) from Δn = 0 to Δn = 10 Δn_T.

(B) 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 λ_g = 1300nm InGaAsP tuning region operated at 1500 nm, $\beta_{pl} = -1.3 \times 10^{-20}$ cm^3, active region with L = 400μm, d = 0.3μm, w = 2 μm and confinement factor $\Gamma_t = 0.3$. For the material assume an infinite spontaneous recombination time constant, bimolecular recombination constant B = 10^{-10} cm^3/s and Auger recombination constant C = 3×10^{-29} cm^6/s.

Problem 7:

For a mode-locked laser, assume the envelopes are given by the expression below and that the phases are equal. υ_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).

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