HW#1 Solutions

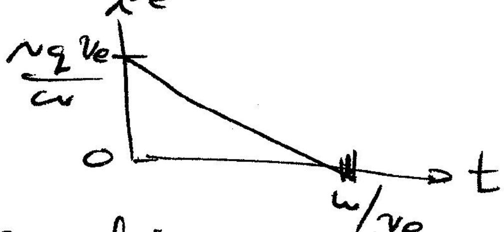
Problem 1 : 10 pts

Assuming photocarriers are generated uniformly throughout the sc, when electrons reach $x = w$ and holes reach $x = 0$, they stop contributing to photo current.

For N electrons generated uniformly at $t = 0$, the initial current is

$$i_e = \frac{Nq v_e}{w}$$

Assuming that at time $t = \frac{w - x}{v_e}$ all electrons generated at x have ceased contributing to current, independent of x, we must have



which is a line described by

$$i_e = -\frac{Nq v_e^2}{w^2} t + \frac{Nq v_e}{w}, \quad 0 \le t \le w/v_e$$

For holes, same situation

$$i_h = -\frac{Nq v_h^2}{w^2} t + \frac{Nq v_h}{w}, \quad 0 \le t \le w/v_h$$

And total current is sum

$$i_{total}(t) = \frac{Nq}{w}\left[(v_h + v_e) - \frac{1}{w}\left(v_h^2 + v_e^2\right)t\right]$$

for $0 \le t \le w/v_e$

$$= \frac{Nq}{w}\left[v_h - \frac{v_h^2}{w} t\right] \quad \frac{w}{v_e} \le t \le \frac{w}{v_h}$$

problem 2

$$\eta = \frac{3\times10^{12}}{8\times10^{12}} \frac{\text{electrons}}{\text{photon}} = 37.5\%$$

$$R = \frac{\eta q}{h\nu} = \frac{(.375)(1.6022\times10^{-19}J)}{(6.62\times10^{-34}J\cdot s)(3\times10^{8}m/s)} \times \lambda\,(\mu m) \times10^{-6}$$

$R(0.83) = .251$
$R(1.3) = .394$
$R(1.55) = .469$

At $1\mu m$ thickness, $In_{.7}Ga_{.3}As_{.64}P_{.36}$ has $\alpha \doteq 3000\ cm^{-1}$

Now $\eta = R(1 - e^{-\alpha\cdot10^{-4}})$
$= R(.74)$
$\eta(1.3) = (.394)(.74) = .292$

problem 3

(a) rms noise current due to shot noise must consider both photogenerated + dark noise currents

$$\sigma_{rms} = \sqrt{2q(I_p + I_d)\Delta f}$$

where $I_p = \frac{\eta q}{h\nu} P_{in} = 0.4\ mA$

$\sigma_{rms} = \text{Sqrt}(2\cdot 1.6022\times10^{-19}(0.4mA + 1nA)20\times10^{6})$
$= 5.06\times10^{-8} A$

problem 3b (Contd)

(b) SNR due to Shot noise

$$SNR = \frac{I_p^2}{\sigma_{rms}^2} = \frac{(0.4\ nA)^2}{(5.06\times10^{-8})^2} = 6.25\times10^7$$

$$= 77.95\ dB$$

(c) $SNR = 100 = \dfrac{I_p^2}{2q(I_p + I_d)\Delta f}$

$$I_p^2 - 2q100\Delta f\, I_p - 2q100\Delta f I_d$$

Solving for root

$$I_p = 1.18\,nA$$

$$\therefore P_{in} = \frac{hc}{\eta q \lambda} I_p$$

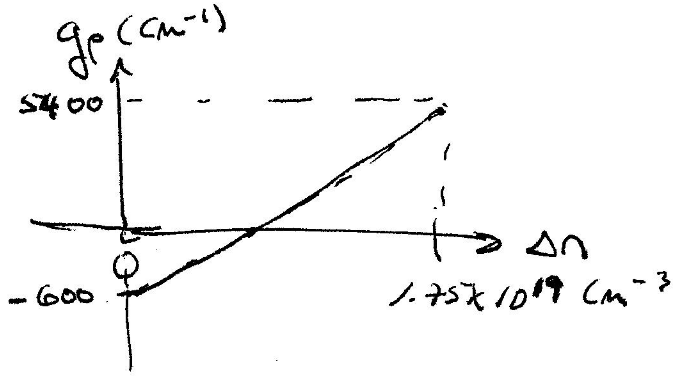
$$= \frac{(6.626\times10^{-34})(3\times10^8)}{(.65)(1.6022\times10^{-19})(0.8\times10^{-6})}\ 1.18\,nA$$

$$= 2.81\,nW$$

problem 4

(A)

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



(B) Mode Separation $\Delta\lambda_m = -\dfrac{\lambda^2}{2nL} = -\dfrac{(1.31)^2\mu m^2}{2\cdot4\cdot380\mu m} = .613\ nm$

(C) # Modes oscillate $= \dfrac{5nm}{.613\,nm} \cong 8$ Modes

(D) Mode peak is at $M=0$

Problem 5

400 μm long grating
$n_{eff} = 3.5$
$\Lambda = .22 \mu m$

$\therefore \lambda_B = (2)(.22 \mu m)(3.5) = 1.54 \mu m$

From Fig assume nearest modes to $\Delta\beta = 0$,
or $KL = 0.5$

$$\Rightarrow \Delta\beta L \cong 2$$

Solving

$$\Delta\beta L = 2 = 400 \mu m \cdot 2\pi \cdot 3.5 \left(\frac{1}{\lambda} - \frac{1}{\lambda_B} \right)$$

$$\frac{1}{\lambda} = \frac{1}{1.54} \pm 7.1 \times 10^{-4}$$

OR two lasing modes

$$\lambda = 1.538 \mu m, 1.542 \mu m$$

With $\lambda/4$ phase shift in grating

$\Delta\beta L = 0$ and

$$\lambda_{lasing} = \lambda_B = 1.54 \mu m$$

problem 6

Active Volume $V = 400\,\mu m \cdot 2\,\mu m \cdot 0.3\,\mu m$

$= 2.4 \times 10^{-10}\ cm^3$

Current vs. carrier concentration is obtained from rate eqn.

$$\frac{I_g}{qV} = BN^2 + CN^3$$

$$I_g = (1.6022 \times 10^{-18})(2.4 \times 10^{-10}) \cdot \left[10^{-10} N^2 + 3 \times 10^{-29} N^3\right]$$

Solving for N for I_g from 0 mA to 100 mA

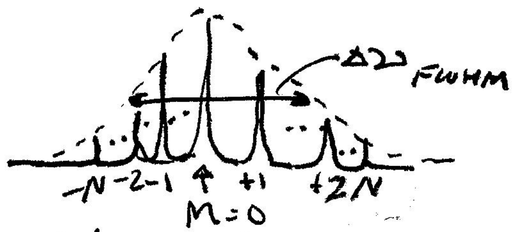
I_g (mA)	N	Δd (nm)
10	1.35×10^{18}	-1.7
20	1.83×10^{18}	-2.3
30	2.17×10^{18}	-2.8
40	2.45×10^{18}	-2.8
50	2.68×10^{18}	-3.1
60	2.89×10^{18}	-3.7

Using $\Delta d = \dfrac{\beta_{pe}\, d_g\, \Gamma_t N}{n_{eff}} = \dfrac{(-1.3 \times 10^{-20})(1300\,nm)(0.3) N}{4}$

See next page

problem 7

Assume the gain curve and modes look something as follows



Total # modes
$M = 2N+1$

pulse width: The gain line shape has a FWHM of $\Delta\nu$, so

$$\tau_{pulse} \approx \frac{1}{\Delta\nu}$$

number of modes is given by mode separation ν_m and linewidth

$$M = \frac{\Delta\nu}{\nu_m}$$

Mean intensity

$$\bar{I} = M|A|^2 = MP$$

peak intensity

$$I_p = M\bar{I} = M^2 P$$