ELEC 425/6261; Sample of Final Exam

Planck's constant, $h = 6.625 \times 10^{-34}$J-s
Boltzmann's constant $k = 1.38 \times 10^{-23}$ J/K
Effective electron mass: $m^*/m_o = 0.067$ in Ga As and 1.1 in silicon
$m_o = 9.11 \times 10^{-31}$ Kg (free electron mass)
$q = 1.6 \times 10^{-19}$ C (electronic charge)
$E_g = 1.42$ eV for Ga As, and 1.12eV for silicon
Index of refraction n(GaAs) = 3.66, n(Si)=3.45, n(air) =1
Light speed = 3×10^8 m/s

1) Consider a pn junction GaAs LED. Assume that photons are generated uniformly in all directions in a plane perpendicular to the junction of a distance of 0.50 micron from the surface. a) Taking into account total internal reflection, calculate the fraction of photons that have the potential of being emitted from the semiconductor. b) Using the results of part (a) and including Fresnel loss, determine the fraction of generated photons that will be emitted from the semiconductor into air. (Neglect absorption losses).

2) Consider a silicon photoconductor at T = 300K with the following parameters: $N_d=10^{16}$ cm^{-3}, $N_a = 10^{15}$ cm^{-3}, $\mu_n = 1000$ cm^2/V.s, $\mu_p = 450$ cm^2/V.s, $\tau_n = 10^{-6}$s, $\tau_p = 10^{-7}$s, A =10^{-3}cm^2, and L=10 microns. Assume that a voltage of 5 volts is applied and assume the excess electrons and holes are uniformly generated at a rate of 10^{20} cm^{-3}-s^{-1}. Calculate a) the steady state excess carrier concentration, b) the photoconductivity, c) the steady state photocurrent, and d) the photocurrent gain.

3) Consider an EDFA power amplifier that produces optical signal output of 27 dBm for an input signal of 2 dBm at 1542 nm. a) find the amplifier gain, b) what is the minimum pump power required?, c) If a 100mA bias current is applied what will be the pumping rate?, d) what is the zero signal gain?, e) what will be the saturation photon density?, f) if 1 μW signal at 1550 enters the amplifier what will be the photon density?(Assume: an active area with dimensions of w x d x L = 5 x 0.5 x200 μm^3. Confinement factor = 0.3, time constant = 1 ns, gain coefficient = 1×10^{-20} m^2, group velocity = 2×10^8 m/s, and electron threshold density = 1 x ^{24} m^{-3})

4) Design a phase modulator based on $LiNdO_3$. Choose the orientation of the crystal to achieve maximum phase modulation with an applied field. Assume the operating wavelength is 1µm. The design parameters should be practical and feasible. For your design what voltage is needed to achieve a $\pi/4$ phase shift?

For E_a parallel to y-axis : $n_x = n_0 + (1/2)n_0^3 r_{22} E_a$; $n_y = n_0 - (1/2)n_0^3 r_{22} E_a$

For E_a parallel to z-axis : $n_x = n_0 - (1/2)n_0^3 r_{13} E_a$; $n_y = n_0 - (1/2)n_0^3 r_{13} E_a$; $n_z = n_0 - (1/2)n_e^3 r_{33} E_a$

Assume: n_0 =2.29, n_e =2.20; and (r_{13} = 9.6, r_{22} = 6.8, r_{33} = 31) x 10^{-12} m/V

5) The rate equations govern the interaction of photons and electrons in the active region of a laser are given as:

$$\frac{d\phi}{dt} = Bn\phi + R_{sp} - \frac{\phi}{\tau_{ph}}$$ **= stimulated emission + spontaneous emission + photon loss**

which governs the number of photons Φ, and

$$\frac{dn}{dt} = \frac{J}{qd} - \frac{n}{\tau_{sp}} - Bn\phi$$ **= injection + spontaneous recombination + stimulated emission**

which governs the number of electrons n.

In these equations,
- d - is the depth of carrier-confinement region
- B - is a coefficient (Einstein's) describing the strength of the optical absorption and emission interactions,;
- Rsp - is rate of spontaneous emission into the lasing mode;
- τ_{ph} – is the photon lifetime;
- τ_{sp} – is the spontaneous recombination lifetime;
- J – is the injection current density;

By solving these equations for steady state condition find the PI characteristic of a laser diode.