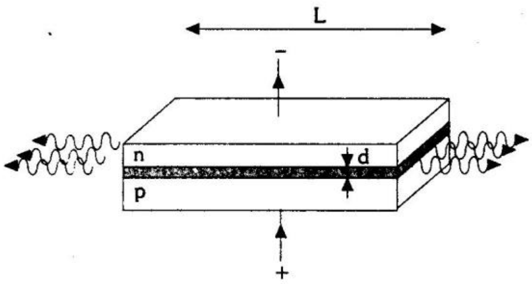
Homework 3 **DIODE LASER BASICS**

1. Solve the following exercises from Coldren's book:
2.6 (20%)
2.7 (20%)
2.9, question (a) only (20%)

2. What is the photon lifetime in a 500μm cleaved-mirror InP cavity with internal losses $<\alpha_i>=10cm^{-1}$? (20%)

3. Consider the P-I-N laser diode of the schematic below, having a single quantum well (QW) of thickness L_1 as active medium. The laser emits at $\lambda=1\mu m$, the cavity length is L=0.5mm, the effective index of refraction in the waveguide is $\eta=3$, and $\partial\eta/\partial\lambda=-1\mu m^{-1}$. Assuming that the injection current produces carriers in the active region without leakage, and ignoring non-radiative recombination or other parasitic phenomena, the threshold current can be written as $I_{th}=eV_1BN_{th}^2$, where V_1 the volume of the QW, B the bimolecular recombination coefficient, and N_{th} the threshold carrier density in the QW. If the gain coefficient in the QW is given by $g(N)=g_0\ln(N/N_0)$, where N the carrier density and g_0, N_0 constants, (a) write down the equation relating the threshold current with V_1 and Γ_1, where Γ_1 the confinement factor of the QW. (b) Next, assume that we have M QWs instead of one, equally pumped by the injection current. Find which M minimizes the threshold current, if $g_0=100cm^{-1}$, L=0.5mm, the mirror reflectivities $R_1=R_2=0.3$, $\Gamma_1=0.1$, and the cavities losses $\alpha_i=10cm^{-1}$. (20%)



In 1 and 2, you will need the following parameters:
cleaved mirror reflectivity for InP, R=0.32
bimolecular recombination coefficient $B= 10^{-10}\ cm^3/s$
group velocity $u_g=c/(\eta+\omega\cdot\theta\eta/\theta\omega)$ where $\theta\eta/\theta\lambda=-1\mu m^{-1}$

Deadline: **Tuesday 24th of November**

<u>OPTIONAL- (ΠΡΟΑΙΡΕΤΙΚΑ)</u>

<u>Bonus +1 in the final grade</u>

Rate equations and operating characteristics of laser diodes

Starting from Eqs. 2.15 and 2.16 (Coldren), solve for and plot the steady-state solutions of N and N_P as a function of current, from below to above threshold current values. Neglect non-radiative or other carrier-leakage effects, and consider $\eta_i=1$, $\Gamma=0.2$, $\tau_P=1ps$, $B= 10^{-10}$ cm^3/s, $\beta_{SP}=10^{-5}$, and the group velocity $u_g=c/(\eta+\omega\cdot\theta\eta/\theta\omega)$ where $\eta=3.2$ and $\theta\eta/\theta\lambda=-1\mu m^{-1}$**.** Also the thickness of the active region is 200nm, the cavity length is 0.5mm and the metal contacts have a width of 50μm. Further, assume that $g=a\ (N-N_{tr})$ where $a=2.5x10^{-16}cm^2$ and $N_{tr}=2x10^{18}$ cm^{-3}. The semiconductor material of the active region is InP and the operating temperature 300K.

(Hint: the steady-state condition on Eqs. 2.15 and 2.16 leads to a third degree polynomial in N which can be used to solve for N as a function of current. The expected curves look similar but are not identical to those shown in the attached Figs. 6.1 and 6.2)

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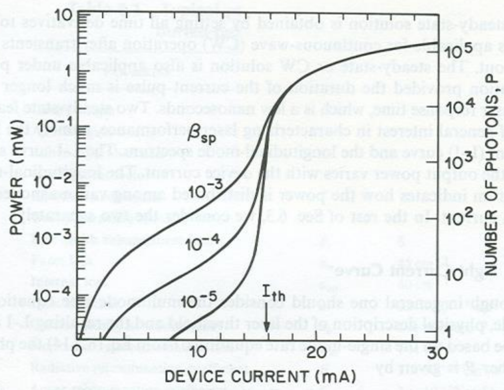

Fig. 6.1 Calculated L-I curves for a 1.3-μm InGaAsP laser showing the dramatic increase in laser power near threshold. The parameter β_{sp} governs the fraction of spontaneous emission that contributes to the lasing model. Other parameters used are given in Table 6.1.

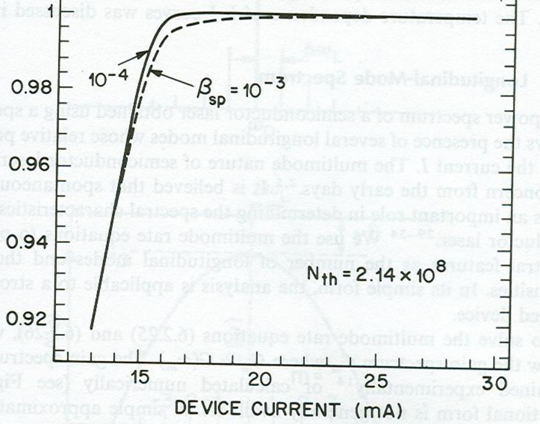

Fig. 6.2 Variation of the carrier population N with device current I corresponding to the L-I curves shown in Fig. 6.1. The curves for $\beta_{sp} = 10^{-5}$ and $\beta_{sp} = 10^{-4}$ are indistinguishable on this scale, so the curve for $\beta_{sp} = 10^{-5}$ is not given.

sharply defined. Figure 6.1 shows that the transition from the nonlasing to