ECE 4300, Fall Semester 2016
Lasers and Optoelectronics

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Assignment 6

Present your solutions *neatly*. Do not turn in rough unreadable worksheets - learn to **take pride in your presentation**. Show the relevant steps, so that partial points can be awarded. BOX your final answers where applicable. Draw figures wherever necessary. **Please print out the question sheet(s) and staple to the top of your homework.** Write your name, email address, and date/time the assignment is turned in on the cover.

Note: Assignment 1 has additional directions on deadlines, and rules for collaborative work.

Posted on: Monday, 11/14/2016. Due on: 11/22/2016, Tuesday

Problem 6.1 (Semiconductor Band Parameters)
Verdeyen Problem #11.5.

Problem 6.2 (Gain Spectrum of Semiconductor)

We discussed the spontaneous emission and small-signal gain spectra $\gamma_0(\nu)$ of semiconductors in class. For this problem, assume the optically active region to be GaAs with bandgap $E_g = 1.4$ eV, conduction band edge effective mass $m_e^\star = 0.067m_0$ where m_0 is the free electron rest mass, valence band edge effective mass $m_h^\star = 0.4m_0$, refractive index $n = 3.3$, and the Einstein A coefficient to be $A = 1$ ns^{-1}.

(a) Calculate and plot the *spontaneous emission* spectrum as a function of the photon energy $h\nu$ for bulk 3D GaAs with the separation of the quasi Fermi levels: $F_n - F_p = 1.4$ eV at 77 K and at 300 K. Explain the spectrum.

(b) Calculate and plot the gain spectrum $\gamma_0(\nu)$ of 3D GaAs at T =300 K as a function of the photon energy $h\nu$ for three injection levels: 1) $F_n = E_c - \frac{E_g}{2}$ and $F_p = E_v + \frac{E_g}{2}$, 2) $F_n = E_c$ and $F_p = E_v$, and 3) $F_n = E_c + 0.1$ eV and $F_p = E_v - 0.05$ eV. Explain what you observe, and identify the gain spectrum, the peak gain, and the gain bandwidth.

(c) Re-do part (b) if instead of 3D GaAs bulk we use a $L_z = 5$ nm 2D GaAs *quantum well* sandwiched between AlAs barriers. Assume for simplicity that the potential barriers for the quantum well are infinite. Do not forget to account for the fact that the band-edges E_c and E_v now have shifted due to quantum confinement. What are the major differences in the gain spectrum of the 3D bulk and the quantum well?

(d) Re-do part (c) for 1D GaAs *quantum wires* of dimensions $L_x = L_y = 3$ nm. Do you see an advantage in going to lower dimension quantum structures? [Contd...]

Problem 6.3 (GaAs Bulk Laser)
Verdeyen Problem #11.15

Problem 6.4 (Optically Pumped Semiconductor)
Verdeyen Problem #11.16

Problem 6.5 (A Quantum Well Laser)
Verdeyen Problem #11.19

Problem 6.6 (Quantum Well Laser as a 4-Level System)
Verdeyen Problem #11.20

Problem 6.7 (Lab Assignment, Due date: TBA)

This problem is Lab assignment # 1, which should be turned in as a *separate* report at a due date to be announced in class. Please form groups of 5. Each lab will take 1:30 hr. Each group will pick a time slot from a few that will be announced. Each group of 5 will submit *one* report. The lab will be set up by Dr. Vladimir Protasenko, who will explain the measurements and help you collect the relevant data.

The goal of this lab is to

a) Measure and plot the spontaneous emission profile $R_{sp}(\nu)$ of a GaN/InGaN/GaN semiconductor quantum well heterostructure. Such quantum well structures are used for blue and green light-emitting diodes (LEDs) and lasers. From the emission spectrum, you will determine the lineshape of emission and the FWHM,

b) Measure the spontaneous emission lifetime A^{-1} of the quantum well structure by time-resolved photoluminsecence (TRPL), and

c) Outline how you would go about making a semiconductor based green laser from what you learn from (a) and (b).