Spring 2021

Laser Physics II (PHYS 564)
Take Home Midterm Exam

Assigned: April 22, 2021
Due: April 26, 2021 (12:30pm)

Please return your exam to Mr. Edward Davis at the P&A reception desk
Or
Scan (using high quality pdf format) and email the instructor

NAME ...................................... ........................................
last                                   first

NOTE to STUDENTS
• You may consult class notes, HW solutions and any other printed/electronic references but not each other for this exam. The solution-set to HW4 is helpful.

• Please append a printout (copy) of your computer simulation program.

• In case you cannot complete a numerical calculation, clearly but briefly describe and set-up the governing equations (together with qualitative plots) for partial credit.

• Please start each part of the problem [(a) through (i)] on a new page.

Good Luck!
Design of an Optically –Pumped Semiconductor Laser (OPSL)

You are asked to design and analyze a MQW gain structure for an OPSL as depicted in Figure above.

The QWs are In$_x$Ga$_{1-x}$As having a width $L_w=7$nm, and the barriers are GaAs with width $L_b$. (We ignore the strain due to lattice mismatch). Assume the operation is at slightly elevated temperature of $T=320K$ for which $E_g^{GaAs}=1.394eV$, $E_g^{InGaAs}(x=0.355)=0.91eV$. Furthermore, for the QW, take $m_e=0.05m_0$, $m_{hh}=0.5m_0$, $m_{lh}=0.06m_0$, $n$ (refractive index)=3.5, and assume equal band offsets for both valence and conduction bands ($\Delta E_c=\Delta E_v=0.5\Delta E_g$).

(a) Calculate the bound QW energy levels (sub-bands) for the conduction and valence bands. Give your answers in eV (relative to the top of the valance band in QW). (20 points)

(b) Graph all the sub-band dispersion diagrams $E_n(k_z)$ for both conduction and valence bands. Choose your energy range (vertical axis) from -0.25 eV to 1.25eV. Identify the allowed interband transitions; mark them in your graph with a vertical arrow between each allowed band-pair. (15 points)

(c) Calculate and plot the absorption of a single QW versus wavelength (within a reasonable 400 nm range) under zero pumping. (15 points)

(d) Calculate the transparency e-h density $N_{eh}$ (use all sub-bands if you can). (15 points)

(e) Calculate and plot the gain/absorption coefficient vs. wavelength when pumped with $N_{eh}=4 \times 10^{18} cm^{-3}$. Give your calculated quasi-Fermi levels in eV. (15 points)

(f) Give the barrier thickness that ensures a resonant periodic gain (RPG) structure. What should be the thickness of the first barrier layer (closest to DBR) assuming the reflection from the DBR introduces a $\pi$ phase shift? (5 points)

(g) If the number of QWs ($N_{QW}$) is 20, what is the integrated gain (upon reflection -in a roundtrip) at $\lambda_L=1178$nm in part (f)? Ignore Fresnel reflections. (5 points)

(h) As shown in the Figure above, it is often desirable to in-well pump these lasers (as oppose to barrier-pumping) to minimize “quantum defect” and thus heat generation. Calculate the total absorbance (per roundtrip, assuming the DBR is broadband to reflect the pump) of the your MQW structure for a pump laser at $\lambda_P=1070$nm. What is the CW pump power required to sustain the population (in part f) if the recombination time is $\approx 1$ ns and the pump spot size $w_{P}=100 \mu m$? (10 points)