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

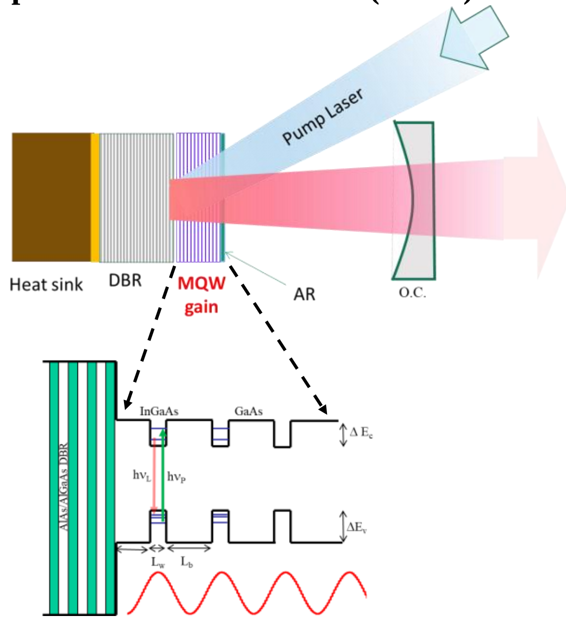
NAME ....
last *first*

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 $In_xGa_{1-x}As$ having a width L_w=7nm, 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 , $E_g^{InGaAs}(x = 0.355) = 0.91\ eV$. 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 $E_n(k_t)$ 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 π 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 λ_L =1178nm 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 λ_P = 1070nm. What is the CW pump power required to sustain the population (in part f) if the recombination time is ≈1 ns and the pump spot size $w_{0P} = 100\ \mu m$? *(10 points)*