Laser Physics II (PHYC/ECE 564)

Midterm Exam, Take Home, Due Nov. 22

Fall 2016

Please return your exam by 10 AM (Tuesday) to Michael at the P&A Reception Desk

NAME ....

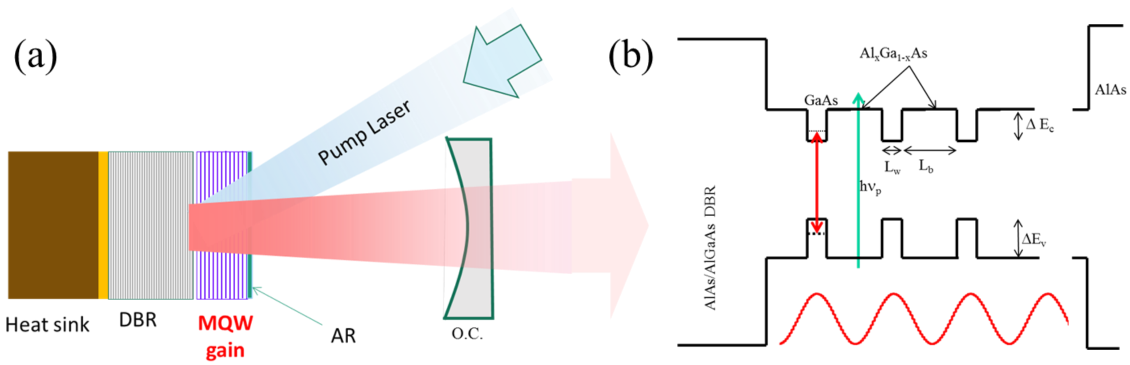
last *first*

NOTE to STUDENTS

You may consult class notes and any other printed/electronic references but NOT each other on this exam.

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 Fig.(a) below.



The QWs are made from GaAs and the barriers are $Al_xGa_{1-x}As$ which is lattice matched to GaAs (i.e. no strain). Assume the operation is at room temperature (T=300K) where

$$E_g^{GaAs} = 1.424 \text{ eV} \quad \text{and} \quad E_g^{AlGaAs}(x) = E_g^{GaAs} + 1.247x$$

Furthermore, the QW spacing should satisfy resonant-periodic-gain (RPG) structure; thus each QW should be placed at the antinode of the laser field inside the cavity (Fig. b).

(a) This laser is to be pumped in the barrier of MQW by a laser at λ_p=750 nm . Therefore choose the barrier bandgap to be 1.5kT below the photon energy of the pump. *5pts*

(b) Calculate the band offsets for both conduction and valence bands between the QW and its barrier. Note: For this part you need to read Appendix D in S.L Chuang's "Physics of Optoelectronic Devices" and using data in Appendix K in the same reference (see the assignment webpage). *15pts*

(c) Knowing ΔE_C from part (b), choose the largest QW thickness (L_w) that allows only one QW bound state (n=1) in its conduction band. What is the energy of this level (relative to the top of the GaAs conduction band) *10pts*

(d) Knowing L_w from part c), obtain the number of bound-states (m) in the valence band for both heavy-hole (hh) and light-holes (lh). Find the energy of each bound state. Note: For parts c and d you may have to use simple numerical/graphical solutions. *20pts*

(e) Qualitatively plot equilibrium absorption coefficient (i.e. no pumping) versus wavelength of the QW structure assuming the transition selection rule follows the infinite barrier case: $I_{nm}=\delta_{nm.}$ Please be quantitative in your wavelength axis. *10pts*

(f) Repeat part (e) under nonequilibrium condition, that is assuming there is moderate population inversion (gain). Identify the spectral region that this structure may lase. *10pts*

(g) Calculate the carrier density required to bring this structure to transparency (F_c-F_v=$E_e^{n=1}$-$E_{hh}^{m=1}$). For this part, first set-up the equations considering all sub-bands (levels). For numerical estimation, however, only take into account one sub-band in the valence band corresponding to m=1 heavy-hole level. *15pts*

(h) Pick a reasonable laser wavelength and then design the separation of QWs to satisfy RPG condition. *5pts*

(i) How many QWs will we have if wish to have only ~60% of the pump laser absorbed in the barrier region (in a single pass). Assume an absorption coefficient of ~10^4 cm^{-1} for AlGaAs at 750 nm. What may be the downside of having more QWs in order to have close to 100% pump absorption in single pass? *10pts*