EE 232 | **Midterm Examination-2** | Fall 2005
11/9/2005 | **EE 232 – Lightwave Devices** | Prof. Ming Wu

- If you need additional conditions, write down your assumptions explicitly.

15 pts.

1. a) to d) are multiple choice problems:

a) An InGaAs/InP quantum well laser with TE output polarization is (A) compressively strained, (B) tensile strained, (C) unstrained, (D) insufficient to draw conclusion.

b) An InGaAs/InP quantum well laser with TM output polarization is (A) compressively strained, (B) tensile strained, (C) unstrained, (D) insufficient to draw conclusion.

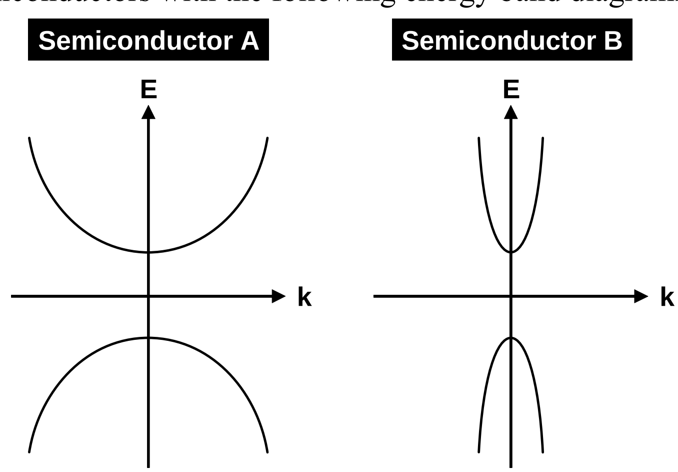
c) Double heterostructures (DH) provide (A) confinement of electrons, (B) confinement of holes, (C) optical waveguiding, (D) optical feedback.

d) Quantum well lasers have lower threshold currents than DH lasers because they have (A) lower threshold carrier concentration, (B) lower transparency carrier concentration, (C) larger optical matrix elements, (D) smaller active volume

e) Rank the order of the spectral width for the following light sources:
(A) surface-emitting LED, (B) edge-emitting LED, (C) semiconductor laser, (D) incandescent light bulb

20 pts.

2. Consider two semiconductors with the following energy band diagrams:



$m_e^* = m_h^* = 0.4m_0$ $\quad\quad$ $m_e^* = m_h^* = 0.1m_0$

Both semiconductors have the same bandgap energy (1 eV) and the same optical matrix elements. This problem deals with the transparency carrier concentration, N_{tr}. This is the carrier concentration at which the *peak* gain is equal to zero. [Note that when peak gain is just equal to zero, the corresponding photon energy is equal to bandgap energy].

a) If these two semiconductors are used as active layers of double heterostructure (DH) lasers, which semiconductor has lower transparency carrier concentration? Explain your choice.
[Credit is given only when both the answer and the reason are correct].

b) Find the ratio of their transparency carrier concentrations, $\frac{N_{tr,A}}{N_{tr,B}}$.

c) If these two semiconductors are used as the well materials of quantum well lasers, which semiconductor has lower transparency carrier concentration? Explain your choice.

d) Find the ratio of their transparency carrier concentrations, $\frac{N_{tr,A}}{N_{tr,B}}$.

20 pts.

3. Consider a semiconductor quantum well laser with the following parameters:

Optical gain: $g(N) = g_0 \ln(N/N_{tr})$, where g_0 = 2000 cm^{-1}, N_{tr} = 10^{18} cm^{-3}

Confinement factor Γ = 1% per quantum well

Intrinsic loss α_i = 20 cm^{-1}

Laser dimensions: width w = 1 μm, length l = 500 μm

Quantum well thickness = 10 nm

Facet reflectivity = 30% for both facets

Internal quantum efficiency η_i = 90%

Assume the total carrier lifetime at threshold = 1 nsec

Laser wavelength = 1550 nm

a) Find the threshold gain of the single quantum well (SQW) laser.

b) Find the threshold carrier concentration of the SQW laser.

c) Find the threshold current density and threshold current of the SQW laser.

d) Plot the L-I curve of the SQW laser. Please note the scale of both current and power axes. What is the quantum efficiency?

20 pts.

4. Use the parameters as in Problem 2:

a) What is the *modal* gain expression of the laser with n_w quantum wells?

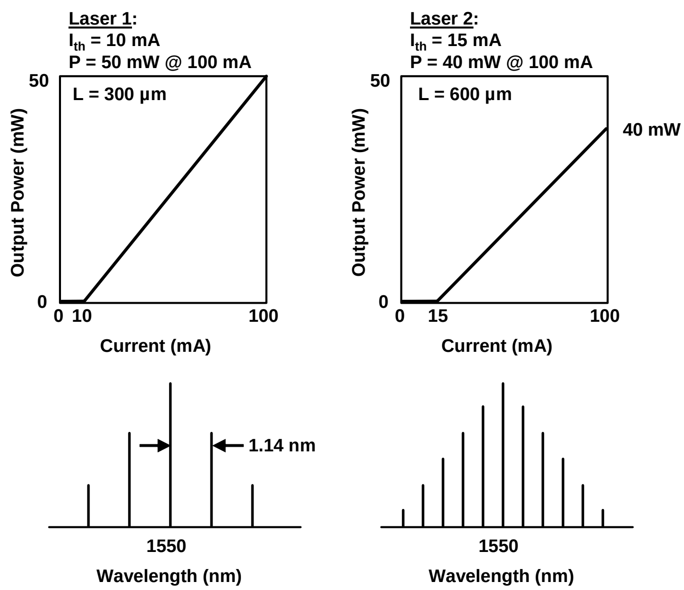
b) Assume the confinement factor of a multi-quantum well (MQW) laser is proportional to the number of quantum wells, what would be the optimum number of quantum wells that will result in the *lowest threshold current*?

25 pts.

5. You will be doing a crime scene investigation of a dead laser:

Crime scene:	a dead semiconductor laser, burned when it is biased to produce an output power of 50 mW
Suspect:	an innocent graduate student who claimed he followed the instruction and did not apply current higher than 200 mA, the maximum allowed by the intruction.
Evidence:	Two surviving lasers from the same batch as the dead laser. They have identical parameters except their lengths.

The two surviving lasers were analyzed thoroughly in Berkeley CSI laboratory. Under microscope, it was found that Laser 1 is 300 μm long, and Laser 2 is 600 μm long. The dead laser is 1000 μm long. It was also determined that all the facets are uncoated, i.e., their reflectivity is 30%. The L-I characteristics and the optical spectra of two surviving lasers are shown below (the output power is collected from both facets):



a) What are the quantum efficiencies (in %) of Lasers 1 and 2, respectively?

b) Find the internal quantum efficiency of these lasers. [Note: all lasers should have the same internal quantum efficiency].

c) Find the intrinsic loss of these lasers [Note: all lasers should have the same intrinsic loss].

d) Find the additional current needed beyond threshold to bias the dead laser to generate 50 mW of output power.

e) Is the graduate student innocent or guilty?