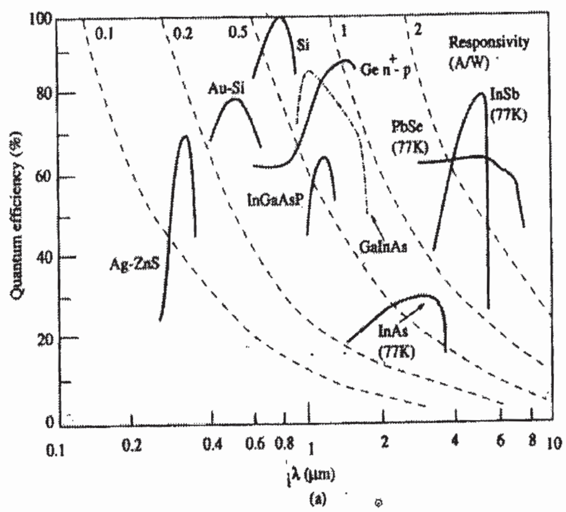
EPL336: SEMICONDUCTOR OPTOELCTRONICS

Time: 2 Hour | Major Test: May 4, 2007 | Max. Marks: 38

1. Answer following briefly;
   (i) What is meant by mean time to failure (MTTF)? List main reasons for gradual failure of LEDs.
   (ii) Why the threshold current and peak optical power of quantum well laser diodes is in general lower than that of double heterojunction laser diodes?
   (iii) What is *photoconductive* and *photocurrent* mode of operation of a photodiode?
   (iv) Figure below shows quantum efficiency and responsivity of some common photodetectors. Give reasons for difference in quantum efficiency and responsivity of Si photodetector with <u>any one</u> of the other photodetectors. [4x2=8]



2. (i) *List* key parameters of a p-i-n photodiode responsible for limiting the response of the detector. [2]
   (ii) *List* sources of noise in semiconductor photodetectors. What is meant by detectivity of a photodetector? [2]
   (iii) Draw energy level diagram of an unbiased metal-semiconductor double heterostructure showing *Fermi level* and *band offsets*: **Gold/p-AlGaAs/n-GaAs/n$^+$-AlGaAs**. [2]

3. (i) A semiconductor of length 2 mm is uniformly illuminated by light. Draw the transit time spread of the total current and calculate *response time* if the electron and hole saturation velocities are 10^7 cm/sec and $3\text{x}10^6$ cm/sec, respectively [3]
   (ii) A shot limited detector has minimum detectable power of 1 pW at the wavelength 1.3 μm, if the bandwidth of the detector is 3 MHz, what are the *signal-to-noise ratio*, *average number of detectable photons* and its *variance*? [3]

4. (i) Draw a neat reach through APD structure with *hole multiplication* by properly marking the photosensitive and avalanche regions. *List* main advantages and limitations of Avalanche Photodiode (APD)? [3]
   (ii) What should be the minimum signal power required in order to detect signal at 0.9 μm from a silicon APD having quantum efficiency of 85 %. It has a dark current of 1 nA and avalanche gain of 50. [3]

5. (i) Responsivity of a green LED ($\lambda = 510$ nm) is 10 μW/mA. When this LED is biased at 2V the current through the device is 100 mA. Calculate *the output optical power*, *the external quantum efficiency* and *the wall plug efficiency* of the LED. [3]

   (ii) An InGaAsP Fabry-Perot laser operating at wavelength of 1.33 μm has a cavity length of 200 μm and α_s, the loss coefficient due to absorption and other scattering mechanisms, is 10 cm^{-1}. Assume that the absorption at the operating wavelength is negligible and light-confining factor is 0.7. The refractive index of InGaAsP is 3.39. If the laser facets are replaced by Bragg reflectors with reflectivity 90%, what should be the cavity length to achieve the same threshold gain and change in the number of oscillating longitudinal modes? [3]

6. Carriers are injected in a GaAs quantum well optical amplifier of dimension 50 Å such that the second quantum levels in conduction and valence bands are filled. Assume recombination lifetime of 5 nsec. Calculate

   (i) No. of electrons that are filling the conduction band states. [2]

   (ii) the peak gain coefficient. [2]

   (iii) The bandwidth of the amplifier. [2]

Useful physical constants:

Electron charge e = 1.602×10^{-19} C
Mass of electron $m_o = 9.109 \times 10^{-31}$ kg
Boltzman constant $k_B = 8.617 \times 10^{-5}$ eV/K
Planck's constant h = 6.626×10^{-34} J-s
Work function Gold Φ = 5.1 eV
Work function p-AlGaAs = 5.32 eV

GaAs $E_g = 1.43$ eV,
$m_e = 0.068\ m_o$, $m_h = 0.56\ m_o$
$m_r = 0.061\ m_o$,
Refractive index = 3.6