3.15 - Problem Set 5 Solutions

Problem 3

a.

$$\begin{aligned} R = rnp &= 10^{-10}(1.8 \cdot 10^6)^2 \text{cm}^3\text{s}^{-1}\text{cm}^{-3} \\ &= 324\text{cm}^{-3}\text{s}^{-1} \end{aligned}$$

b.

Each photon is 1.42 eV approximately. Power = 460 eV/cm^{3}s^{-1}. One eV = $1.6 \cdot 10^{-19}$ Joule $\Rightarrow$ Power = $7 \cdot 10^{-17}$ W/cm^3.

c.

2 μm piece of GaAs will emit $1.4 \cdot 10^{-20}$ W/cm^2. Insignificant.

d.

We have 10^{17} carriers/cm^3 extra, and they recombine in 50 ns. So the recombination rate should be $\frac{10^{17}}{5010^{-9}}\text{cm}^{-3}\text{s}^{-1} = 2 \cdot 10^{24}$/Cr.

e.

This gives $2.8 \cdot 10^{24}$eV/cm^{3}s^{-1} = 450 kW/cm^3.

f.

2 μm thickness $\rightarrow$ 90 kW/cm^2 - high.

g.

It's still 180W, which is very large.

Problem 5

a.

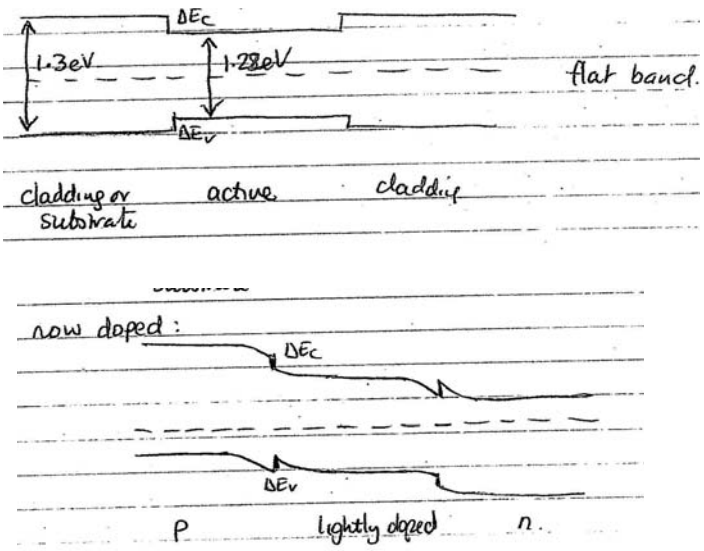
980 nm - several choices of systems. Main concern is to find a suitable substrate. InP or GaAs look good - Need lattice match with active layer plus cladding must have a higher band bap than active layer. Eg:

Option	Substrate	Active	Clad
1	GaAs	(GaIn)As with In $\approx 20\%$	GaAs again
2	GaAs	Ga(As,Sb) with Sb $\approx 20\%$	GaAs
3	InP	In(P,As) with As $\approx 10\%$	GaAs
4	AlAs	(InGa)As with In $\approx 20\%$	AlGaAs

Poor choices: GaSb substrate with $(Ga_{50}Al_{50})Sb$ active layer - GaAlSb is indirect.
InP substrate with (InAl)As active layer - lattice match is worse than option 3.

b.

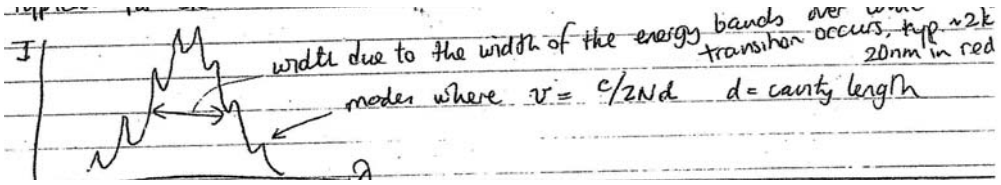
Take option 3 because the lattice match is best. We don't know band offsets but $\Delta E_c + \Delta E_v = 0.2\text{eV}$.



(The cladding thickness doesn't matter too much but you need the active layer to be thin enough so we can get a high density of photons. Also need to avoid dislocations forming due to misfit with substrate. Length of device governed by where you want the nodes due to cavity resonance.)

c.

Typical for slc laser



d.

Really need to know refractive index. Active layer should have a higher RI to confine light inside the quantum well. So a plot of RI vs. comp. would be useful. Also is there thermal expansion mismatch? How do materials cleave or cut? (to make shape for cavity).