Lecture 11

Material and Homework

Read:

Chapter 12 Sections 12.3 - 12.5

Chapter 15 Yariv and Yeh

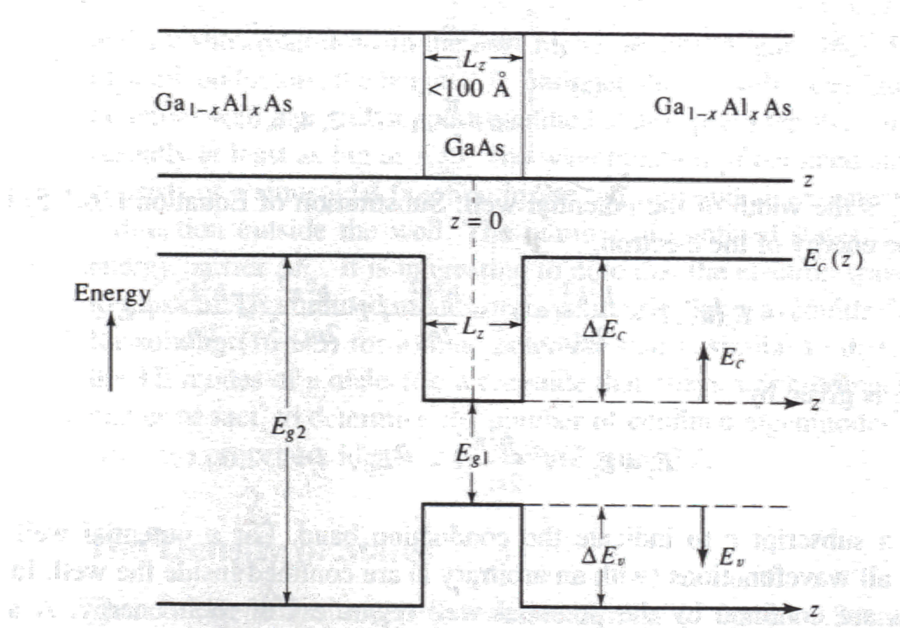
Chapter 16 Yariv and Yeh

Quantum Well Active Media

• Quantum well semiconductor gain material differs from bulk material (which we have looked at so far) in terms of the density of states.

• An electron in a quantum well is free to move in 2-dimensions and is confined in the 3rd dimension (normal to the junction plane).

• For an infinite barrier ΔE_c approximation, the electron wavefunction is described by the time-independent Schrodinger equation with electron energy E and $V(z)=E_c(z)$ being the potential function confining the electron



$$V(z)u(\mathbf{r}) = -\frac{\hbar^2}{2m_c}\left(\frac{\partial^2}{\partial z^2} + \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right)u(\mathbf{r}) = Eu(\mathbf{r})$$

Electron Energy

• Using z invariance, assuming a Bloch wavefunction for the electron motion in xy-plane and homogeneity in the xy-plane (no barriers), and inserting the Bloch wavefunction into the time-independent Schrodinger equation, we can solve for the energy of the electron (this is left as an exercise for the class)

$$E_c(k_\perp, l) = \frac{\hbar^2 k_\perp^2}{2m_c} + E_z = \frac{\hbar^2 k_\perp^2}{2m_c} + l^2 \frac{\hbar^2 \pi^2}{2m_c L_z^2} \equiv \frac{\hbar^2 k_\perp^2}{2m_c} + E_{lc}$$

$$E_z \equiv l^2 \frac{\hbar^2 \pi^2}{2m_c L_z^2} = l^2 E_{1c}, l = 1,2,3\ldots$$

• Subscript *c* indicates the conduction band; *l* is the index of the wavefunctions confined to the well; E_{1c} is the energy of the lowest state (ground state). Zero energy is referenced to the bottom of the conduction band.

• A similar function is defined for the valance band

$$E_v(k_\perp, l) = \frac{\hbar^2 k_\perp^2}{2m_v} + E_z = \frac{\hbar^2 k_\perp^2}{2m_v} + l^2 \frac{\hbar^2 \pi^2}{2m_v L_z^2} \equiv \frac{\hbar^2 k_\perp^2}{2m_v} + E_{lv}$$

Quantum Well Wavefunctions

• The complete wavefunctions for electrons in the conduction band and holes in the valance band are given by, and are shown in the figure below.

$$\psi_c(r) = \sqrt{\frac{2}{L_z}}\psi_{k\perp c}(r_\perp)CS\left(l\frac{\pi}{L_z}z\right)$$

$$\psi_v(r) = \sqrt{\frac{2}{L_z}}\psi_{k\perp v}(r_\perp)CS\left(l\frac{\pi}{L_z}z\right)$$

$$\psi_c(r)_{groundstate} = \sqrt{\frac{2}{L_z}}\psi_{k\perp c}(r_\perp)Cos\left(\frac{\pi}{L_z}z\right)$$

$$\psi_v(r)_{groundstate} = \sqrt{\frac{2}{L_z}}\psi_{k\perp v}(r_\perp)Cos\left(\frac{\pi}{L_z}z\right)$$