PHYS 564, Laser Physics II

Spring 2021

Homework #2, Due Monday Feb. 15

1. Show that the interband absorption coefficient of semiconductors can be given as:

$$\alpha(h\nu) = A_0 \frac{E_g}{n_0} \frac{\sqrt{x-1}}{x} \quad (1)$$

where α is in cm^{-1}, E_g is in eV and $x=h\nu/E_g$. Evaluate A_0 in the effective mass approximation, and obtain α in GaAs at 800 nm.

2. (a) Derive the formula for thermally-ionized electron-hole concentration in an intrinsic (i.e. undoped) semiconductor in terms of E_g, kT, n_0 and E_p. This is called intrinsic carrier concentration n_i.

(b) Evaluate n_i for InSb (E_g=0.18 eV), GaAs (E_g=1.42 eV) and ZnSe (E_g=2.6 eV) at room temperature (T=300K). Take $E_p \cong 21$ eV for all semiconductors.

3. Strictly speaking, the energy-momentum dispersion relation for a two band (c and v) system is not purely parabolic and is given by the equation (e.g. see S. L. Chuang, 4.1.16):

$$\left[E(k) - \frac{\hbar^2 k^2}{2m_0}\right] \cdot \left[E(k) - \frac{\hbar^2 k^2}{2m_0} - E_g\right] = \frac{\hbar^2}{m_0^2} |p_{cv} \cdot k|^2$$

(a) Show that $E_c(k) - E_v(k) = E_g \sqrt{1 + \frac{4\hbar^2 |k.p_{cv}|^2}{m_0^2 E_g^2}} = E_g \sqrt{1 + \frac{2\hbar^2 k^2 E_p}{m_0 E_g^2}}$ for $k \| p_{cv}$ (light holes)

(b) Calculate the joint density of state $\rho_{cv}(E)$, and the absorption coefficient $\alpha_0(h\nu)$ for such non-parabolic bands. Compare your result with that given by Eq.(1) by plotting the two absorption coefficients versus photon energy.