ECE 536 Integrated Optics and Optoelectronics

SPRING 2022 Problem Set No. 2   Due Friday, February 11, 2022

When using software for plots and calculations, please attach code to end of homework.

1. Consider an $In_{0.53}Ga_{0.47}As/InP$ quantum well, assuming the following parameters:

	InGaAs region	InP region
m_e*	$0.041m_0$	$0.077m_0$
m_{hh}*	$0.50m_0$	$0.60m_0$
m_{lh}*	$0.0503m_0$	$0.12m_0$
E_g	0.75eV	1.344eV

where m_0 is the free electron mass.

The band edge discontinuities are $\Delta E_c=0.40\Delta E_g$ and $\Delta E_v=0.60\Delta E_g$.

(a) Consider a well width $L_w=100A$. Estimate the number of bound states in the conduction band assuming an infinite barrier model. How many bound heavy-hole and light-hole subbands are there under the same assumptions?

(b) Find the lowest bound state energies for the conduction subband (C1), the heavy-hole (HH1) and the light-hole (LH1) subbands in part (a). What are the C1-HH1 and C1-LH1 transition energies?

(c) Do you expect the actual transition energies to be higher or lower than those calculated in part (b) above? Why?

(d) Repeat part (b) using the full finite-barrier model and compare the results to your answer in part (c).

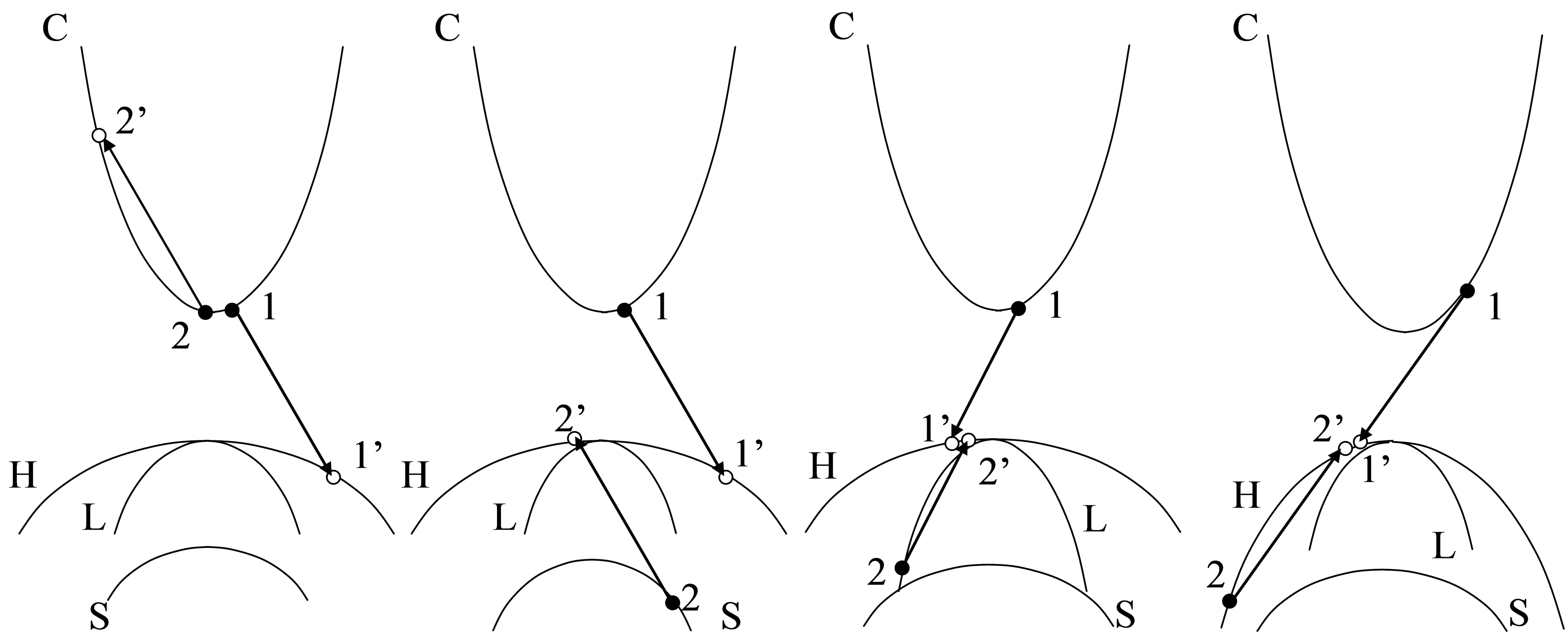
2. Provide in your own words a description of the Auger recombination processes in k-space by considering CHCC, CHSH, CHLH, and CHHH processes. Discuss briefly how the transitions need to take place in order to conserve energy e momentum. Please, refer to the sketches in k-space as in Figure 2.7 of the textbook by Prof. Chuang (pdf file of the revised figure will be included with this homework).

3. For this problem you will consider a realistic 2D electron gas structure, that is a system which could be defined as a 2D quantum well with confinement (quantization) along the *z*-direction (which becomes the transverse direction with respect to the motion, with a finite thickness of the quantum well, L_z) and two degrees of freedom along the *x* and *y* directions.

(a) Derive an expression for the density of states for electrons for this two-dimensional quantum well system, which accounts for the presence of a number of quantized states in the *z* direction. Be sure to describe your assumptions and show each step in your derivation.

(b) By using the density of states in the general expression for carrier density which includes the Fermi-Dirac distribution (where you are able to use the quasi-Fermi level in case the system is out of equilibrium, under the assumption that the 2D density of states does not depend on the quasi-Fermi level) you should be able to arrive at a close form integration result for the carrier density (remember that this is not possible in 3D, in which case the Fermi integral needs to be solved numerically). Once you have found this expression, then you have could determine the quasi-Fermi level if you are given the value of given carrier density *n*. Looking at the result obtained, when the carrier density is increased what happens to F_n?

(c) Is it possible to find an analytical expression for the quasi-Fermi level, from the result obtained above, in terms of the carrier density in general or in some particular condition, for the case of multiple subbands? (*Hint: consider the temperature dependence*). What is the expression for only a single occupied sub-band?



(a) CHCC process (b) CHSH process (c) CHLH process (d) CHHH process