DEPARTMENT OF PHYSICS AND NANOTECHNOLOGY
SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

18PYB103J –Semiconduuctor Physics

Concepts of optical transition in bulk semiconductor

Dr. V. Ganesh

- For the optical properties of semiconductors, the photons should interact with charge carriers.
- In the process of interaction three process occurs
    - Absorption
    - Recombination
    - Emission

i.e the photons are absorbed and emitted , these processes are important in photonic devices using semiconductors

There are several type of transition possibilities are occur

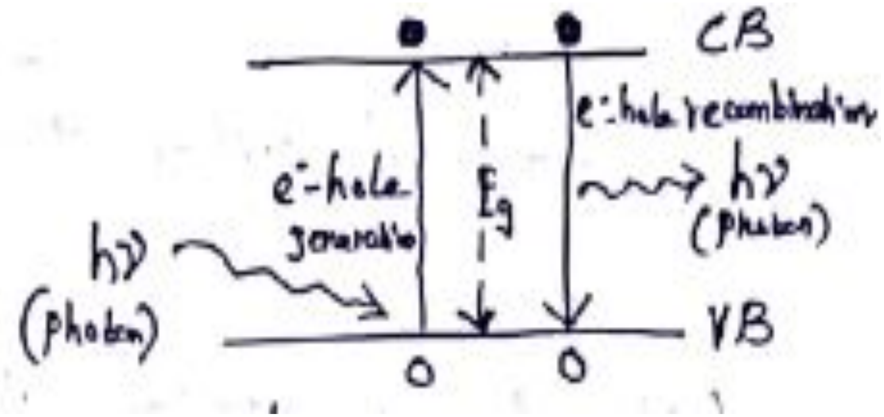
1. Band to band transition (Inter band transition)
2. Impurity level to band transition
3. Free carrier transition (Intra band transition)

In semiconductors electrons can make transitions between two energy states and create or destroy photons in the process.

1. Band to band transition (Inter band transition)

An absorbed photon can result in an electron in the valence band making an upward transition to conduction band. This results electron-hole pair generation, followed by this electron-hole recombination takes place by the emission of Photon

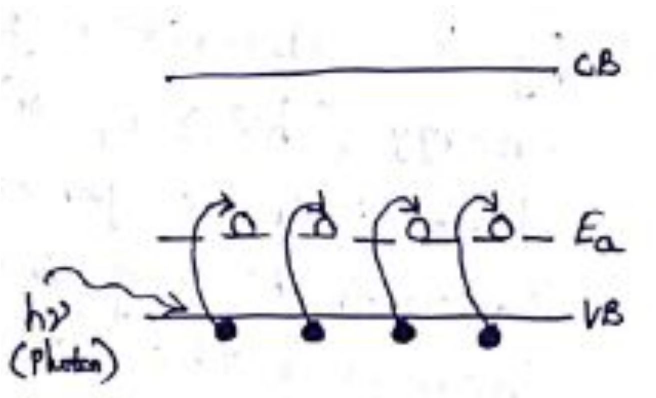
Eg: Band to Band transition in GaAs can results absorption and emission of photons with wavelength of 0.087 µm or (E_g = 1.42 eV)



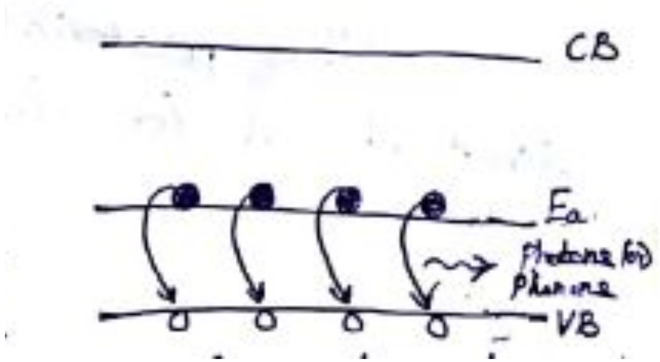
2. Impurity level to band transition:

An absorbed photon results in a charge carriers transition between a donor (or) acceptor level to a band in semiconductor, mostly observed in doped semiconductors.

For example if a p-type material is considered, the low energy photon absorbed by p-type semiconductor material leads transition of electron from valence band to acceptor level where its trapped by acceptor atom. Thus hole is created in Valence band and acceptor atom is ionized.



Similarly a hole may be trapped by an ionized acceptor atom. The result may be the electron decay from its acceptor level to recombine with hole. The energy may be released radiatively (photons) or non-radiatively (phonons)

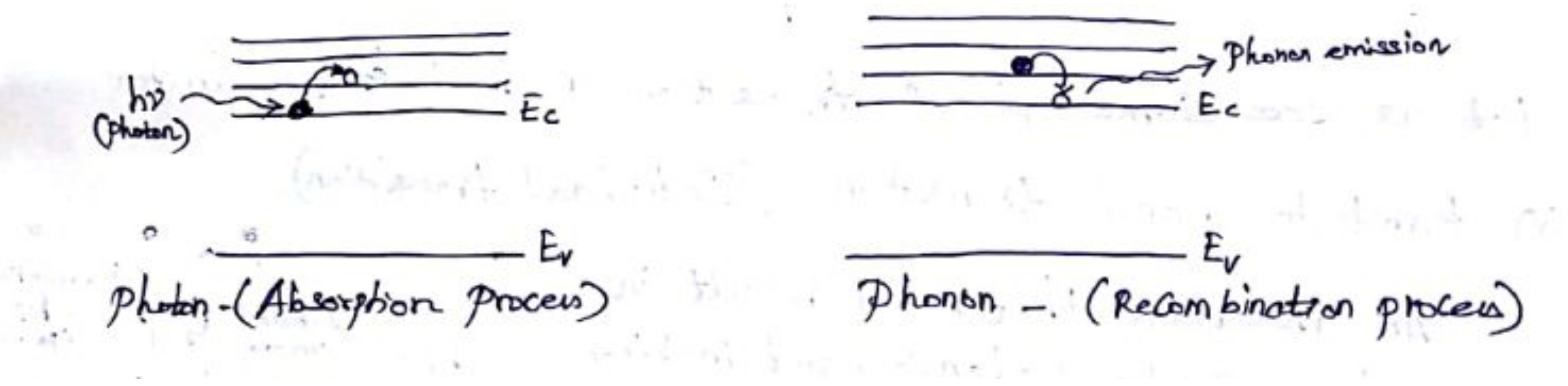


Eg: In Hg doped Ge thw wavelength of absorption and emission between valence and conduction band is 14 μm

3. Free carrier transition (Intra band transition):

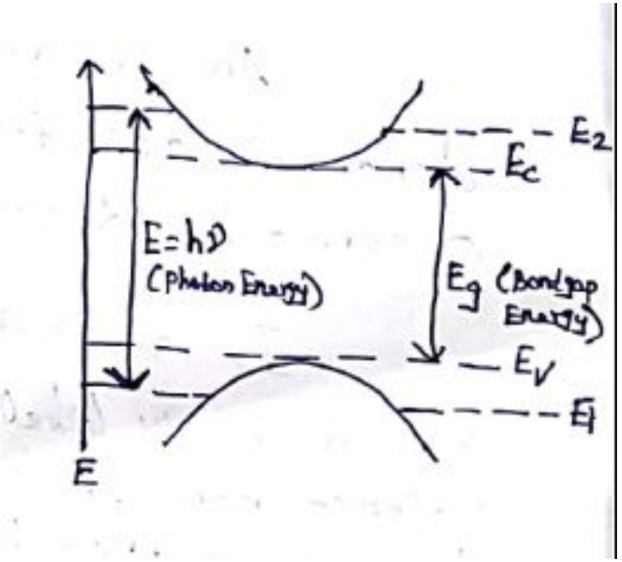
An absorbed photon can impart its energy to an electron in a given band, causing it to move higher level in that band. If a lower level conduction band is considered, by absorbing photon energy the electron moves to next higher energy level in the same conduction band.

Similarly due to thermalization, electron relaxes down to the bottom of the conduction band while releasing its energy in the form of phonons.



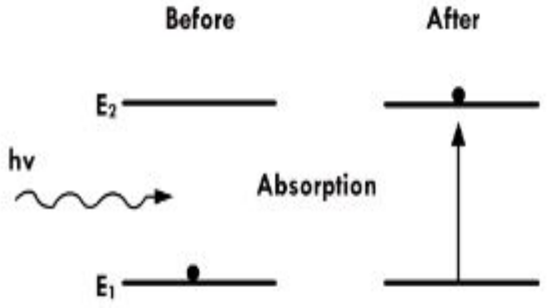
Optical absorption process :

Absorption is the process in which the photons are absorbed by the semiconductor materials causes transition of electron from valence band to conduction band.



Consider direct band to band absorption
The condition for absorption to happen, the incident photon energy must be equal
Or grater than the bandgap i.e $h\nu \geq Eg$, corresponding wavelength $\lambda = hc/Eg$.

The electron hole pairs are generated due to absorption of photon having energy grater Or equal to bandgap.
This leads to the increase of concentration of mobile charge carriers and increase the Conductivity of the material.
So the material behaves as a photoconductor with a conductivity proptaional to photon Flux, the effect is used to detect light.

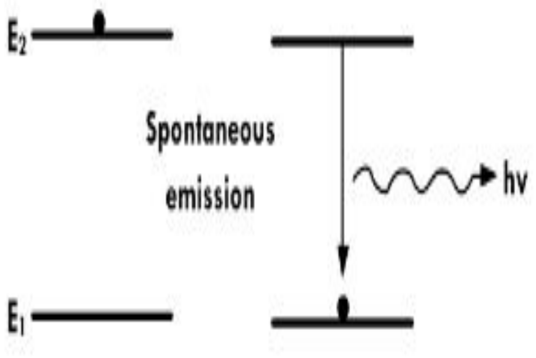


Emission process:

Generally the emission process are takes place in two types in optical devices

1. Spontaneous emission
2. Stimulated emission

Spontaneous emission: spontaneous emission, this process requires a conduction band energy state occupied by an electron and an empty valence band energy state. The electron Itself transit from conduction band to valence band spontaneously by releasing a photon.



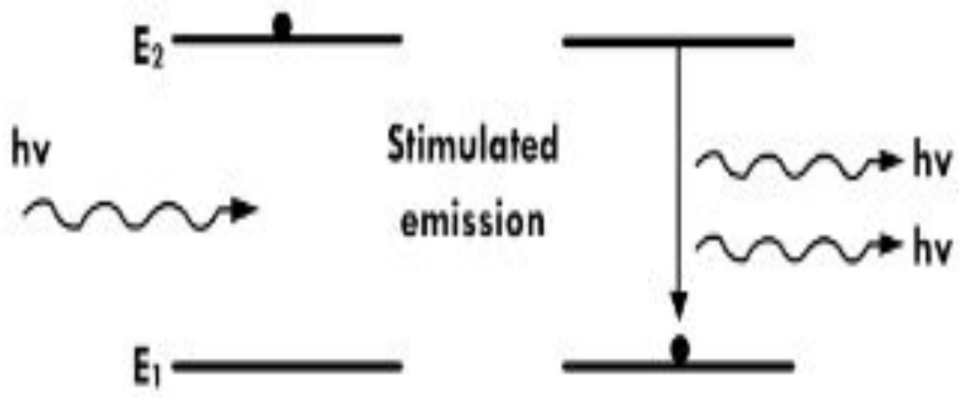
This photon has a random direction and phase.

This is the opposite of the common situation in equilibrium, but at a finite temperature there will be a small number of full states in the conduction band and empty states in the valence band. Also, electrons and holes can be created via optical absorption and other pumping mechanisms.

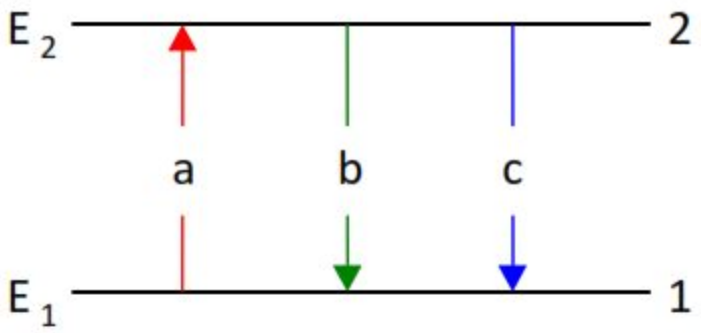
Stimulated emission:

An incident photon causes an upper level atom to decay, emitting a "stimulated" photon whose properties are identical to those of the incident photon.

The term "stimulated" underlines the fact that this kind of radiation only occurs if an incident photon is present



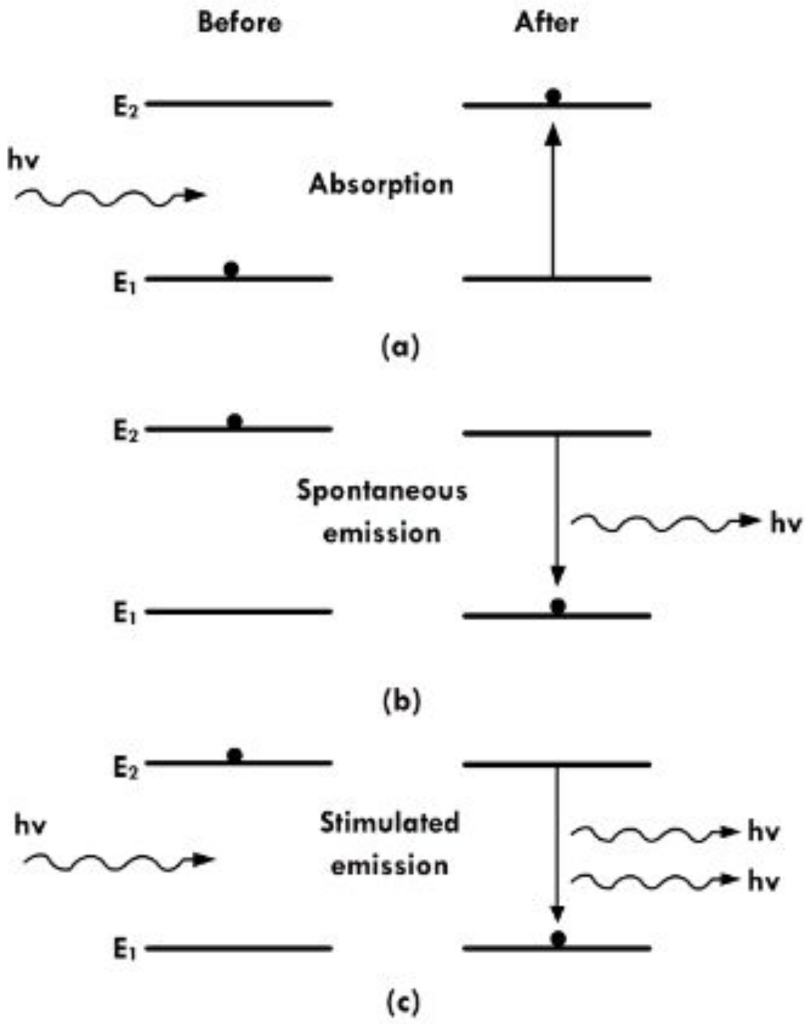
Over all picture of Absorption and emission process



a absorption

b spontaneous emission

c stimulated emission



Absorption

Molecule absorbs a quantum of radiation (a photon) and is excited from 1 to 2.

$$M + h\upsilon \rightarrow M^*$$

(state 1) (state 2)

Spontaneous emission

M* (in state 2) spontaneously emits a photon of radiation.

$$M^* \rightarrow M + h\upsilon$$

Stimulated emission

A quantum of radiation is required to stimulate M* to go from 2 to 1.

$$M^* + h\upsilon \rightarrow M + 2h\upsilon$$