effective mass → average
transport mass → harmonic mean

$$\mu = \frac{e\tau}{m^*}$$

mobility (μ)
τ → relaxation
m^* → effective mass

Carrier generation and Recombination Process

- Photogeneration — light
- Phonon generation
- Impact Ionization — collision

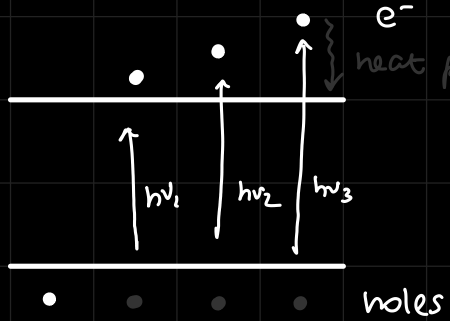
→ Carrier generation: Process through which holes and e^- are generated

→ Recombination: Process in which e^- and holes are annihilated

Temp ↑ $\xrightarrow{\text{how?}}$ Energy ↑ → e^- move to diff E states

① **Photogeneration** : light energy ($h\nu$) is absorbed by e^- and if $h\nu > E_g$, e^- jump from VB to CB and an e^--hole pair is formed

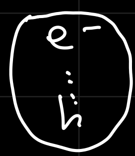
if $h\nu > E_g$



heat produced due to e^- wanting stability which is degrading for solar cells

$V_3 > V_2 > V_1$

exciton : e^- and hole pair



if $E_g < h\nu$ → This coulomb attraction is overcome and this pair breaks

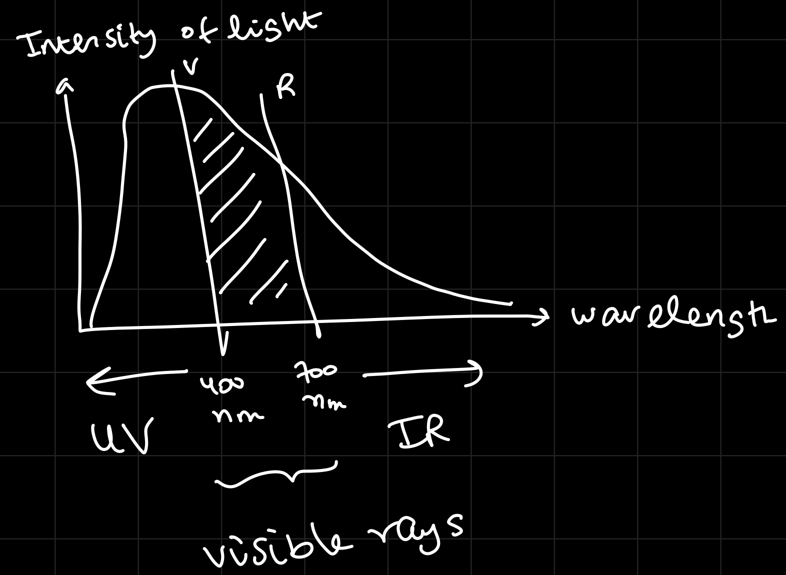
IP	M2	IHCI	DC	com	DSA	BE	P&S	CO	ISA	ELD	M4	S&S	CTD	API	FNW	IF	PSD	ESD	APA
9	7	8	9	7	7	5	6	8	7	10	8	7	8	9	8	10	8	10	7

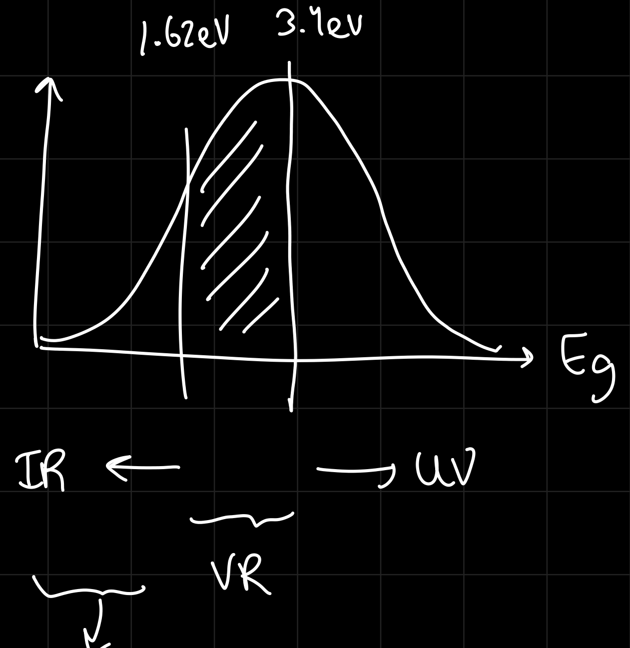
?

SOLAR CELL

solar spectrum

$$E = h\nu = \frac{hc}{\lambda}$$





the order flips because

$$E \propto \frac{1}{\lambda}$$

energy loss → absorption of light energy ↓

e⁻ and hole generation less

for Si, $E_g = 1.12$ eV

not good enough

PHONON GENERATION

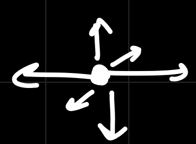
occurs when a semiconductor is under thermal exitation.
Temp ↑ → lattice vibrations increase leading to more photons

due to more lattice vibrations, covalent bonds in semiconductors break and hence e⁻-hole pairs are generated

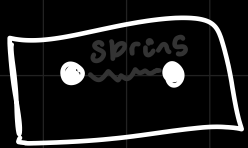
phonons → quantized quasi particles like electrons

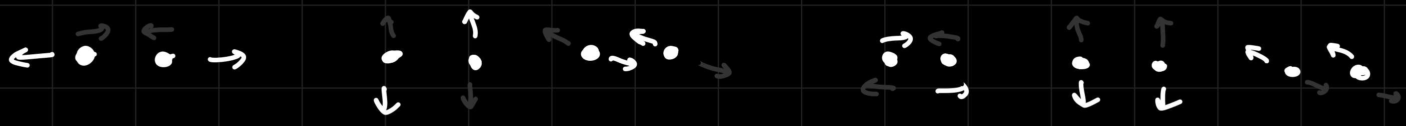
phonon branch/modes

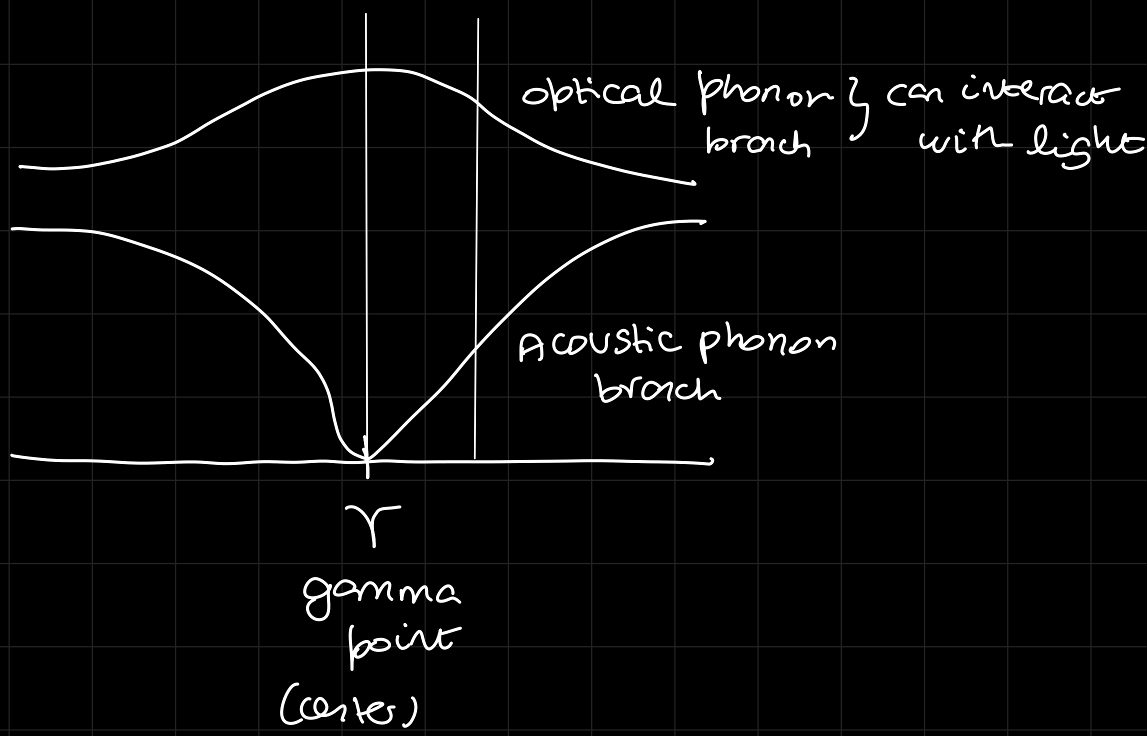
In a 3 dimensional space, a particle can vibrate in atleast 3 directions (x/-x, y/-y, z/-z)



for a two particle system,
6 directions → 3 as a whole body
3 in a harmonic motion wrt each other







③ Impact Ionization :

When a semiconductor is under an Electric Field, e^- gain energy from the applied $\bar{E}$ and hit other atoms.

A bond breaks generating more carriers

Recombination

$$\text{Free } e^- \text{ in conduction band} + \text{Hole} \xrightarrow{\text{recombination}} \text{bound } e^- \text{ in valence band}$$

↳ **Radiative Recombination**

occurs for direct band gap semiconductors like GaAs

e^- from CBM → VBM w/o changing momentum and one photon of energy ($h\nu$) is emitted.

Energy is always released as radiation in case of Radiative Recombination

e^- which are at higher energy states come down to CB by releasing energy as heat. Then from CB, photon is released when coming down to valence band.

Also called direct recombination.

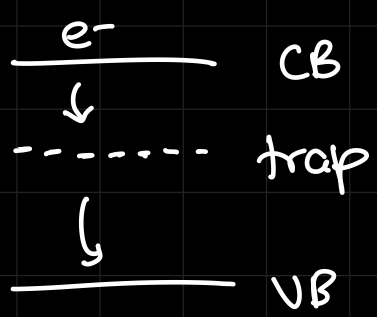
for a blue LED, we need a material with a band gap of 3.4 eV

GaN → E_g = 3.3 / 3.5 eV
↳ p type doping is very difficult because Mg doping can only give P type GaN

Mg is trasient element
↳ has d state
↳ but GaN has p state
↳ defect states are observed
↳ defect states are almost flat
↳ curvature → 0
↳ effective mass → ∞
↳ current → 0

* Instead of jumping from CB_{min} → VB_{max}, e^- might jump to Defect states, stays there for some time and then it jumps down VB_{max}

Shockley Read Hall Recombination



Slow process, generates heat, not ideal for LED since light emitted ↓

(c) Auger Recombination

occurs for heavily doped materials

3 carriers are involved.
an e- and a hole recombine and the energy generated is given to the other e- and it jumps to higher energy state, then it releases heat energy to come back to CB

MOSFET : surface dominating transport device

hence the need to smoothen / minimize the irregularities on the surface

$E\downarrow \rightarrow \mu\downarrow \rightarrow I\downarrow$

for a DBGS → Direct Recombination is efficient since k is conserved
but not for an Indirect Band Gap semiconductor.