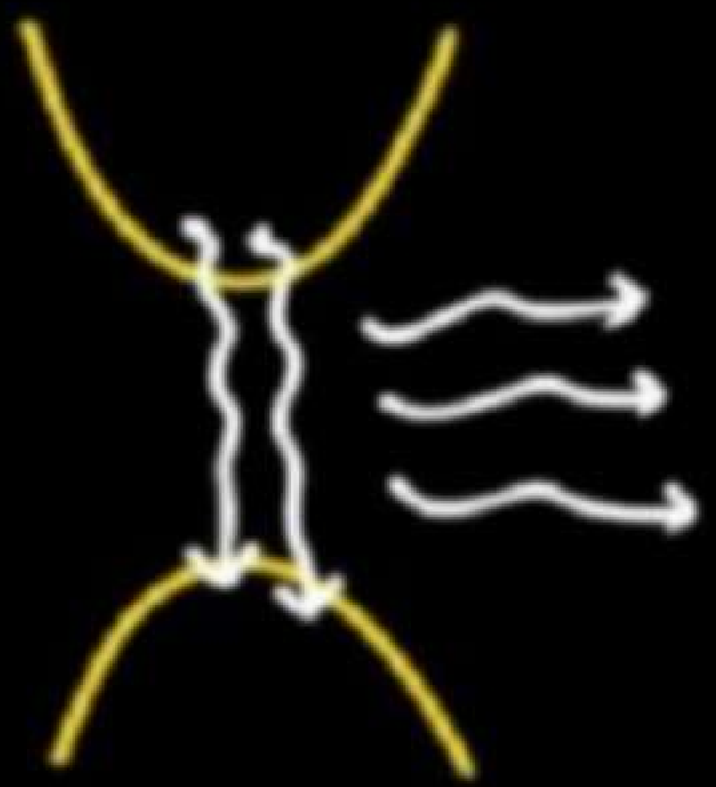
LED → I/P → Electric power.
O/P → light power.

Need Direct band gap.



$h\nu \geq E_G$

$\Rightarrow \frac{1.24}{\lambda(\mu m)} eV \geq (E_G) eV$

* Recomb. Must be in the Dep. region
  ⇒ Emission from dep. region
  ⇒ F. Biased.

* Emission @ only one λ
  → Monochromatic.
  [LED is Not Monochromatic].

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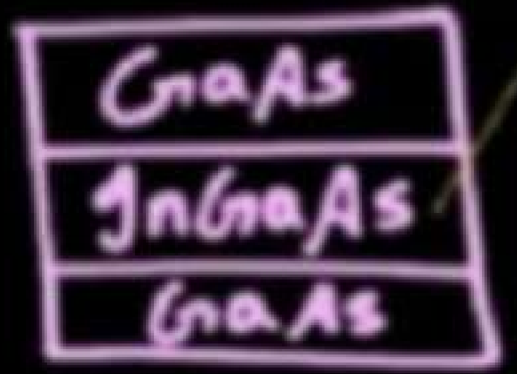
For proper & good Recombinations LED is made up of Material which has a Quantum well.

Smaller E_g than GaAs



Quantum Well.

So an Electron in a Well is tough to Escape Outside.

$\because \; V_D \cong V_{bi} = \frac{KT}{q} \log_e \left| \frac{N_D N_A}{n_i^2} \right|$

$\because \; n_i^2 = A_0 T^3 \exp\left(\frac{-E_{G_0}}{KT}\right)$

$\because \; E_{G_0} \propto 1/\lambda$

If $\lambda \rightarrow$ high

$\Rightarrow E_G \downarrow \longrightarrow n_i \uparrow \longrightarrow V_0 \downarrow$

$\therefore \; \lambda \rightarrow$ high

$\Rightarrow V_0 \downarrow$.

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Since we know

Rate of Recombination $\propto \frac{1}{\text{lifetime}}$

$\Rightarrow R_{rad} \propto \frac{1}{\tau_{rad}}$

$R_{nonrad} \propto \frac{1}{\tau_{nonrad}}$

$\therefore$ less $\tau \Rightarrow$ More Prob. for light

$\Rightarrow$ Shorter lifetime Indicates More Recombination.

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$$\frac{\text{O/P Optical power}}{\text{I/P Electric power}} = \frac{P_{opt}}{P_{in}} \longrightarrow \text{Radiative Efficiency.}$$

(Wall plug Efficiency).
(WPE).

$$\frac{\text{Number of Photons Emitted (into free Space per second)}}{\text{Number of Carriers injected by Electric power Supply}} = \text{External Quantum Efficiency [EQE].}$$

$$EQE = \frac{P_o/hc/\lambda}{P_{in}/Vq} = \frac{P_o}{P_{in}} \times \frac{q\lambda}{hc} \times V$$

$$\therefore \frac{EQE}{WPE} = \left(\frac{q\lambda}{hc}\right)V \geq 1$$

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If $\theta_i < \theta_c \rightarrow$ light comes out

If $\theta_i > \theta_c \rightarrow$ Light Reflects back.

If Recombination Occurs After Completion of life time

$\rightarrow$ Emission of light is called Spontaneous Emission (LED).

If Recombination Occurs before Completion of life time during an External disturbance of injected photon

$\rightarrow$ Stimulated Emission (LASER).

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How many photons are generated internally & how many come out

$\longrightarrow$ Extraction Efficiency.

If generated Photons break C-Bond's $\longrightarrow$ light is wasted.

Due to Refractive index, $\exists$ Internal reflections $\Rightarrow$ light May not Come Out.

$\therefore$ Need Fiber Dome type.

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How many Recombinations are Radiative → Internal Radiative Efficency.

$$\frac{(\text{Number of Photons Emitted from Active Region Per second})}{(\text{Number of Electrons injected in to LED per Second})}$$

$$\therefore \eta_{int} = \frac{P_{int} \times \lambda q}{hc\, I}$$

$I \rightarrow$ current through LED.

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Total Carrier Recombination life time,

$$\frac{1}{\tau} = \frac{1}{\tau_r} + \frac{1}{\tau_{nr}}$$

+ Since we know $V_D \simeq V_{bi} = \frac{KT}{q} \log_e \left| \frac{N_D N_A}{n_i^2} \right|$

& Also, $n_i^2 = A_0 T^3 \exp\left(\frac{-E_{G0}}{KT}\right)$

& As $\lambda \propto 1/E_G$ $\left[\because \frac{hc}{\lambda} \geq E_G\right]$

$\Rightarrow$ If $\lambda \rightarrow$ high $\Rightarrow E_G$ low $\Rightarrow n_i^2$ high $\Rightarrow V_D \downarrow\downarrow$

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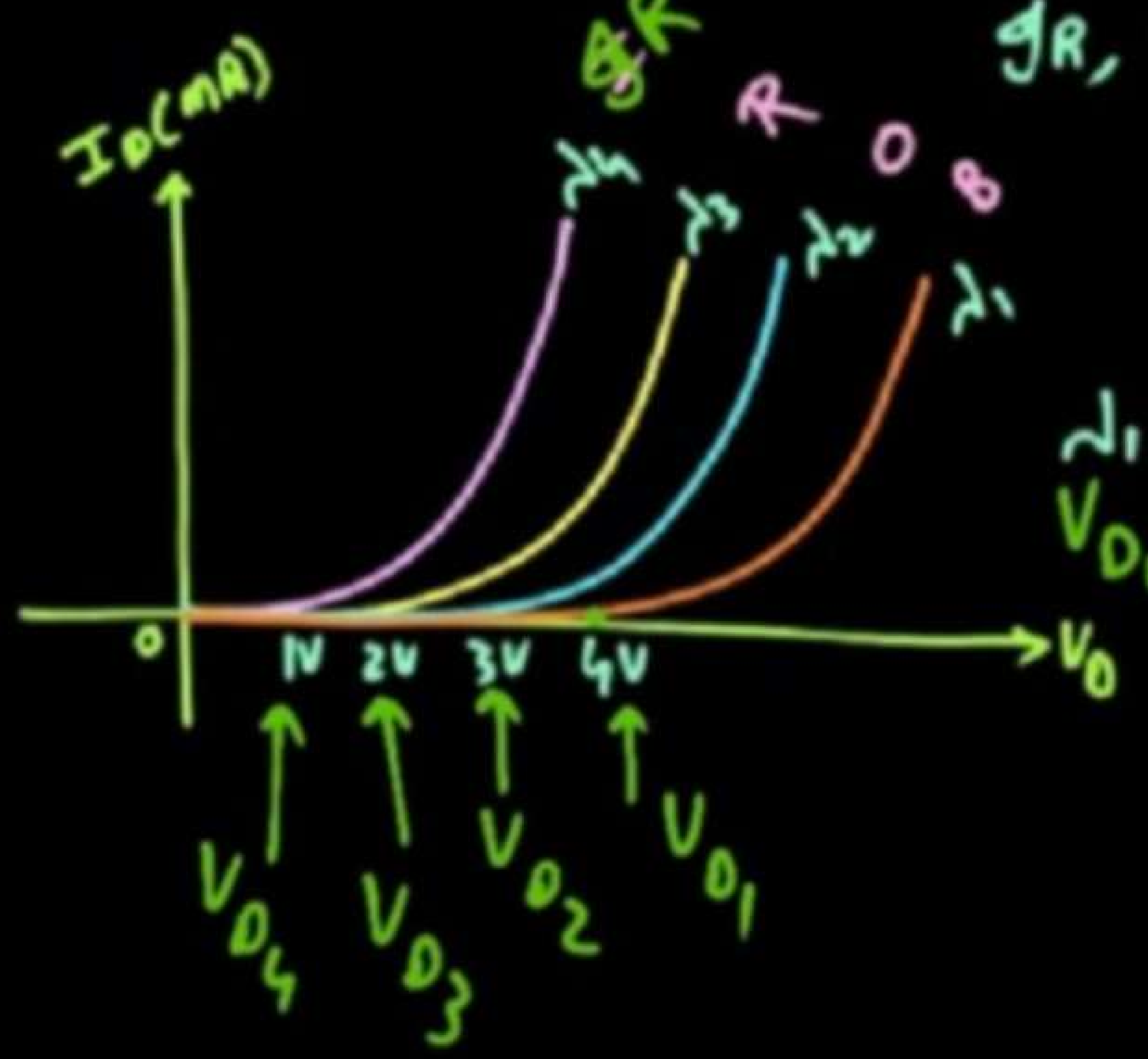
ACE



gR, Red, Orange, Blue.

$\lambda_1 < \lambda_2 < \lambda_3 < \lambda_4$

$V_{D_1} > V_{D_2} > V_{D_3} > V_{D_4}$