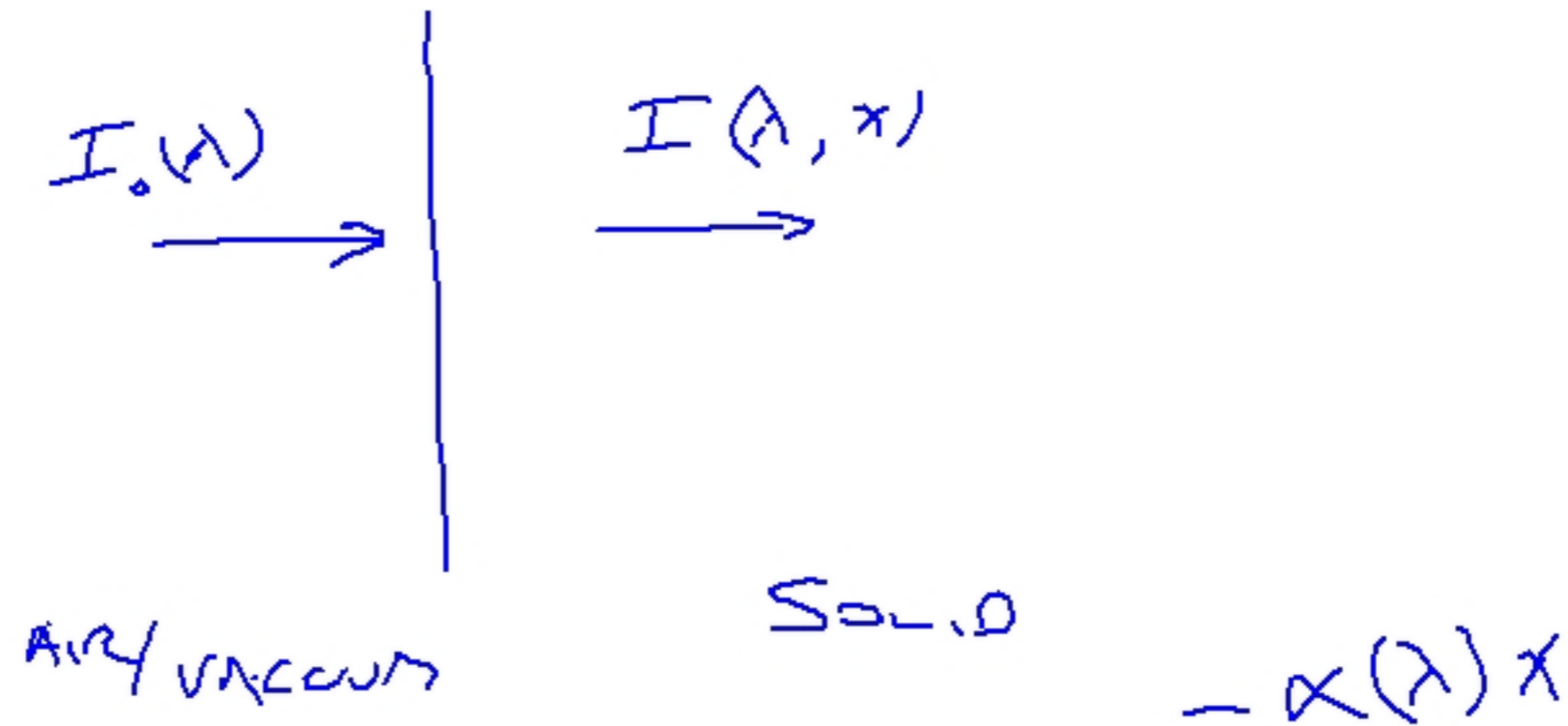


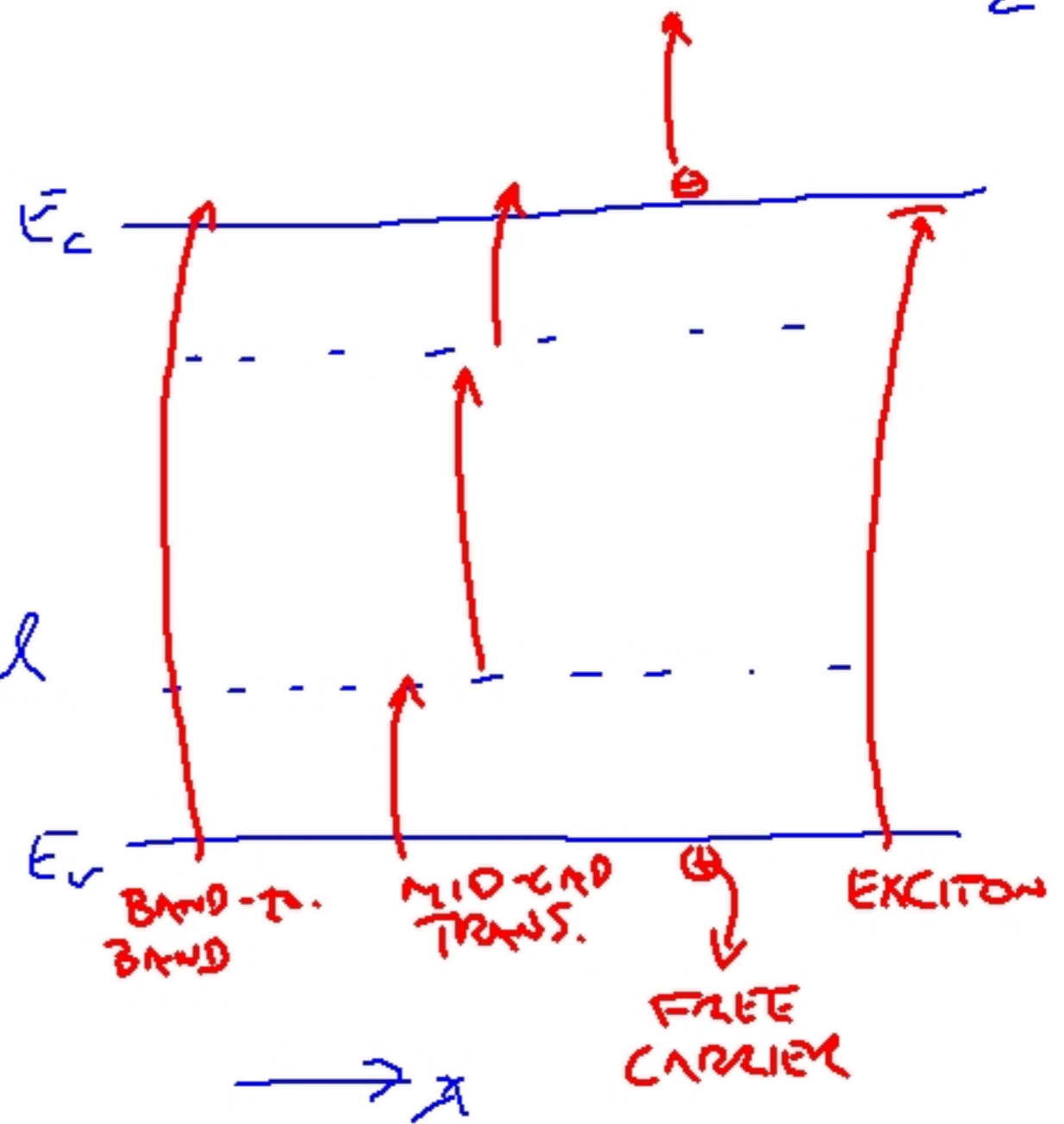
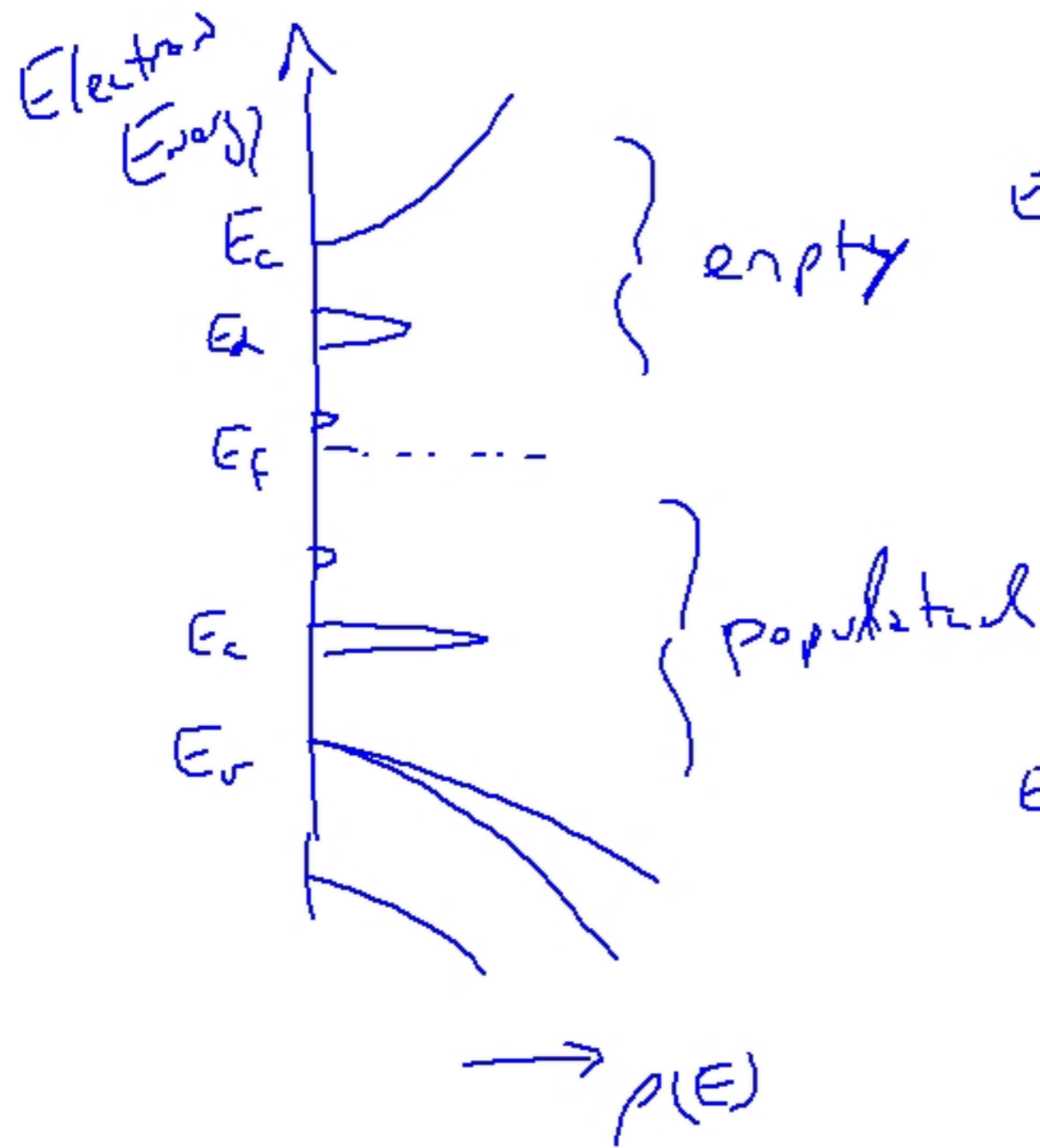
# LECTURE 15 — OPTICAL PROCESSES

1

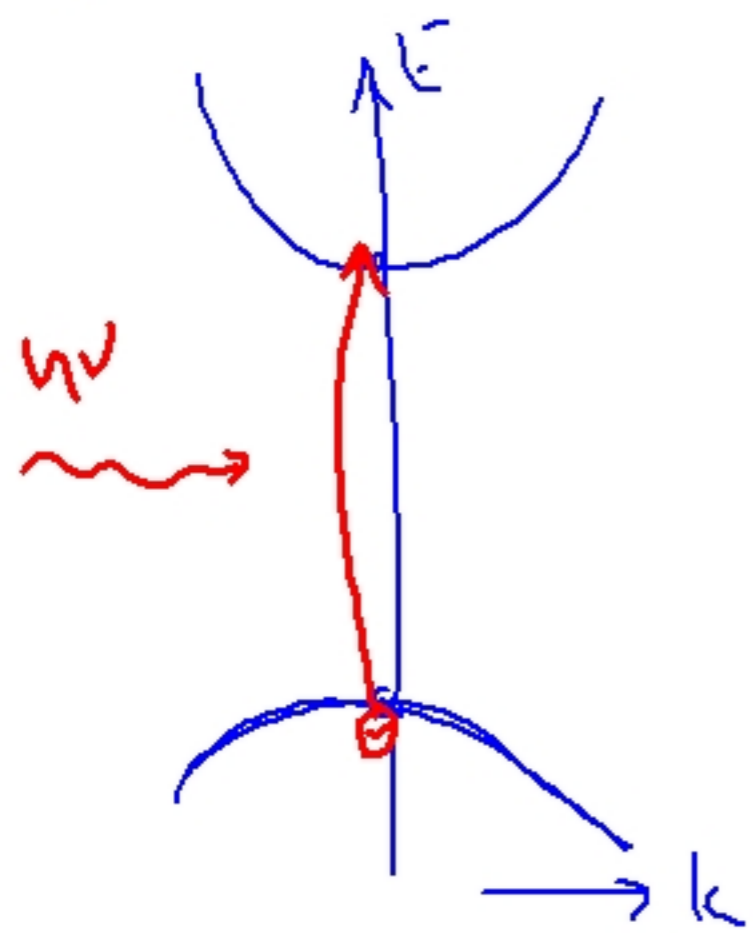


$$I(\lambda, x) = [1 - R(\lambda)] I_0(\lambda) e^{-\alpha(\lambda) x}$$

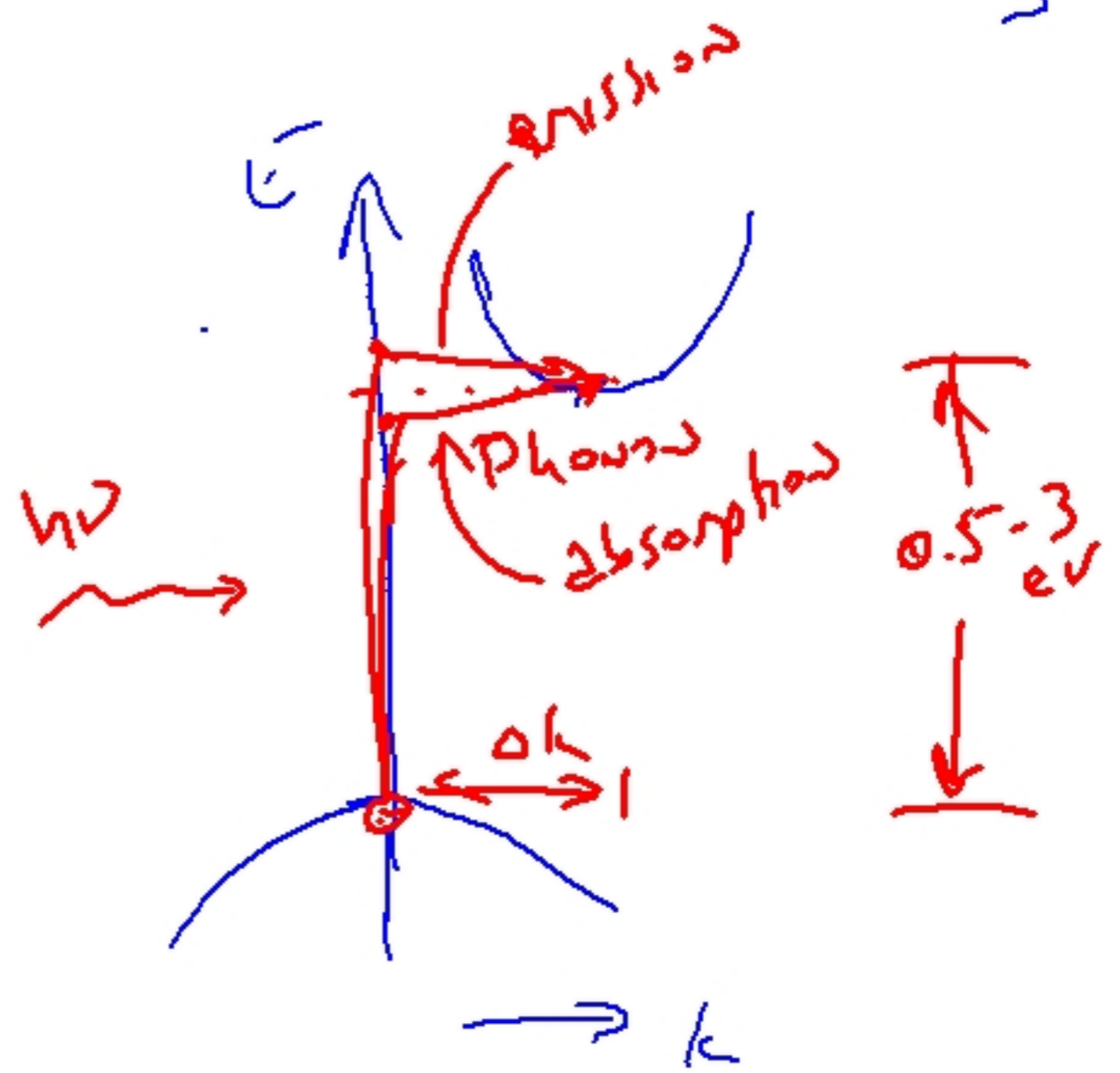
$\alpha(\lambda) \equiv$  absorption coefficient



# Band to band



Direct  $\Delta E \sim E_g$   
 $\Delta k \sim 0$



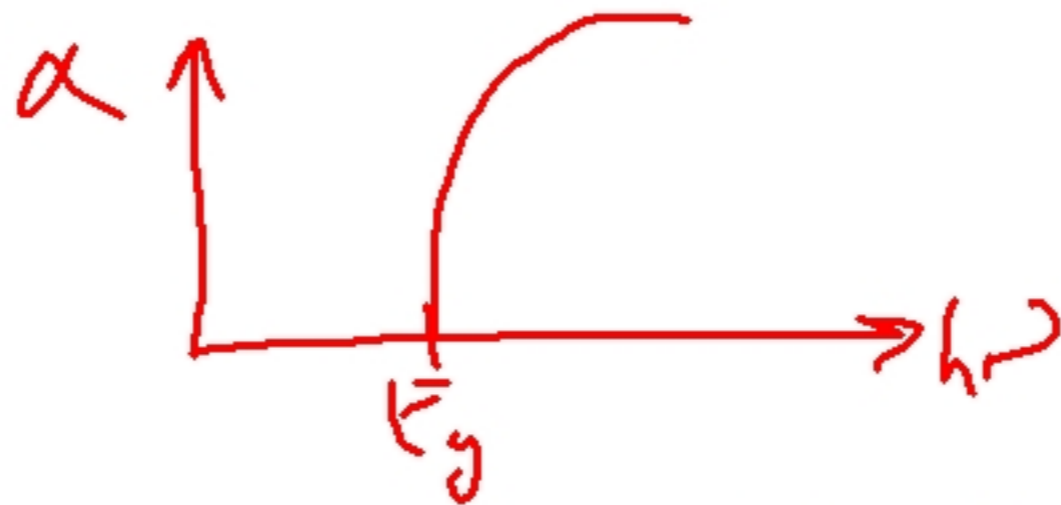
INDIRECT  $\Delta E \sim E_g$   
 $\Delta k \neq 0$

Photon:  $E = h\nu$   
 $k \sim 0$   
 $h\nu \geq E_g$



Direct

$$\alpha(h\nu) = A_{\text{dir}} (h\nu - E_g)^{1/2} \quad a_i (h\nu - E_g)$$

INDIRECT

$$\alpha(h\nu) = A_{\text{indir absorb}} [h\nu - (E - E_{ph})]^2 + A_{\text{indir emission}} [h\nu - (E + E_{ph})]^2$$



# EXCITONS

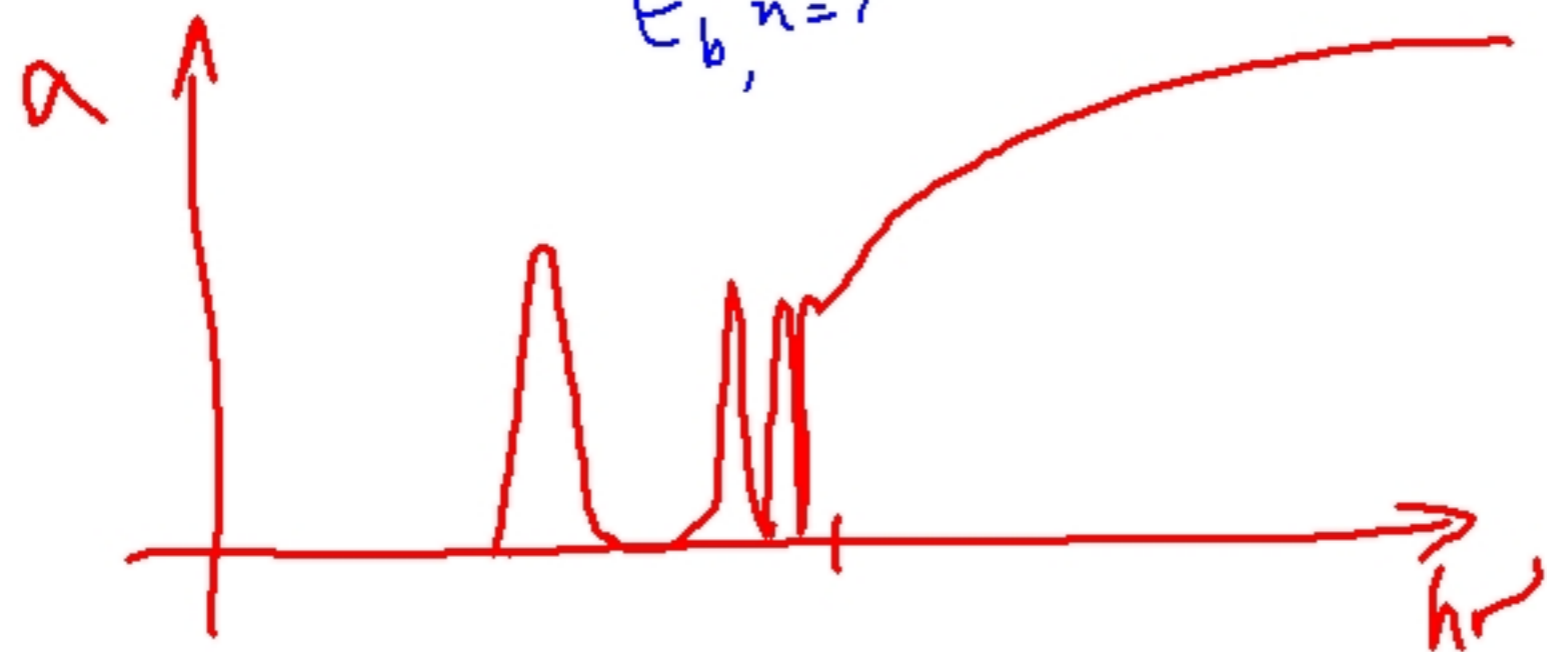
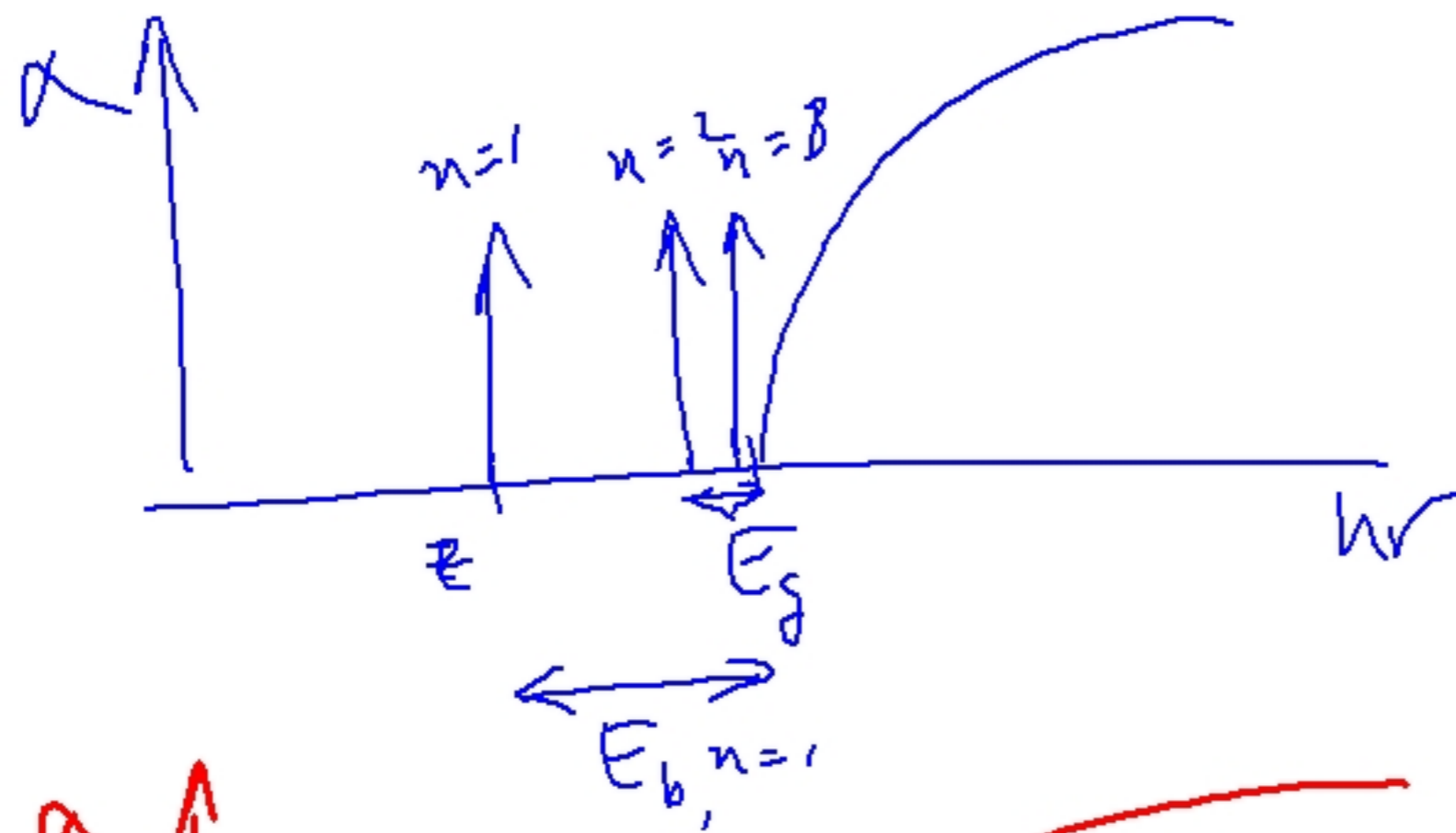


$$E_{\text{binding}} = \frac{13.6 \text{ eV}}{n^2} \cdot \frac{m_r}{m_0} \cdot \frac{1}{\epsilon_r^2}$$

$$m_r = \frac{m_e m_h}{m_e + m_h}$$

IN BULK SEMICONDUCTORS  $E_{\text{binding}} \sim 10 \text{ meV}$





# FREE CARRIER ABSORPTION



Electrons

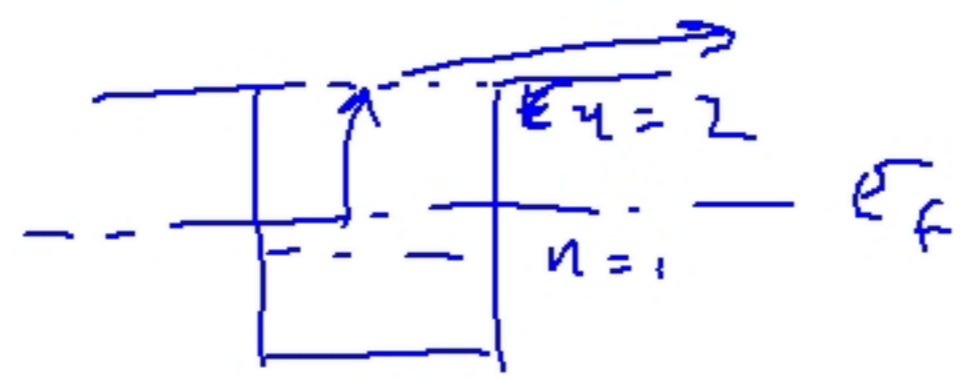
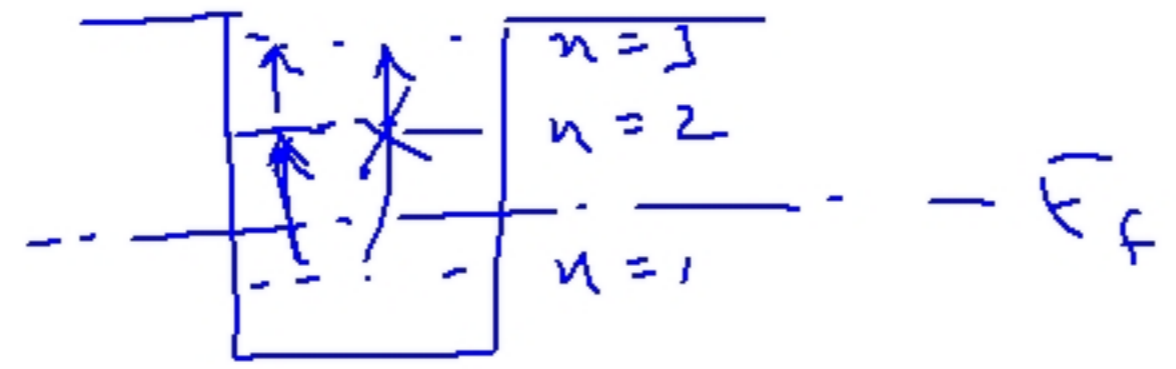
$$\alpha \propto \frac{\lambda_0^2 n}{v \mu_e m_e^2}$$

Holes

same plus transitions to other valence bands

# QUANTUM WELL ABSORPTION

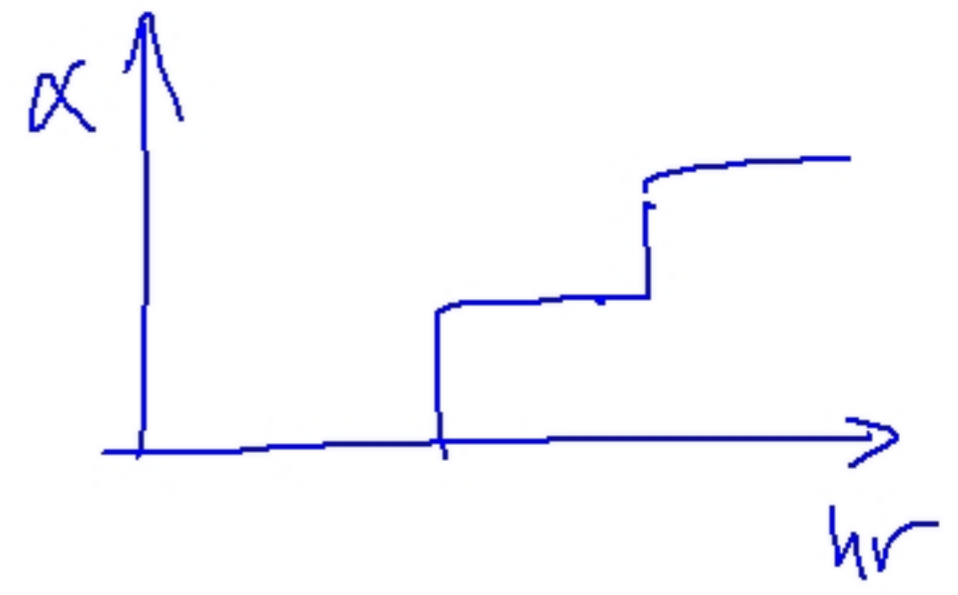
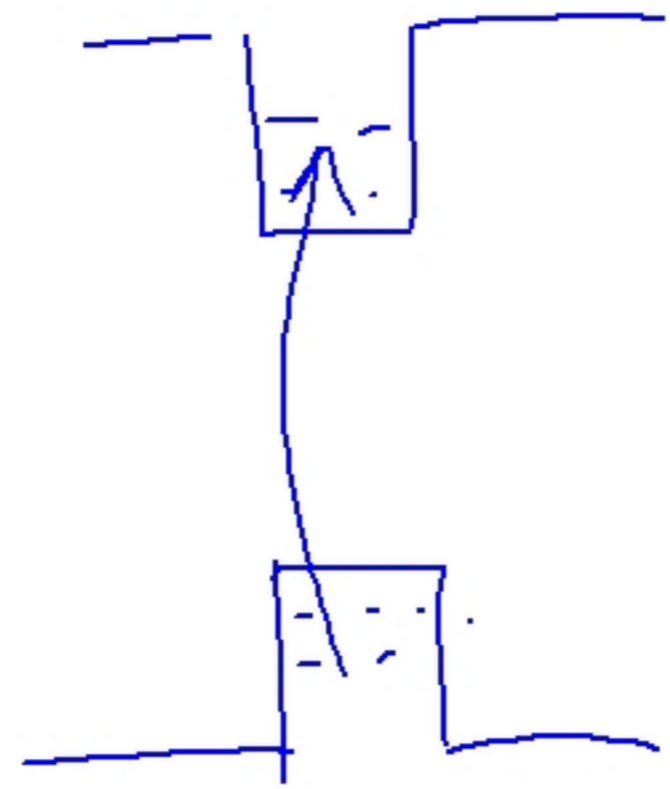
## A. INTRA BAND (CB)



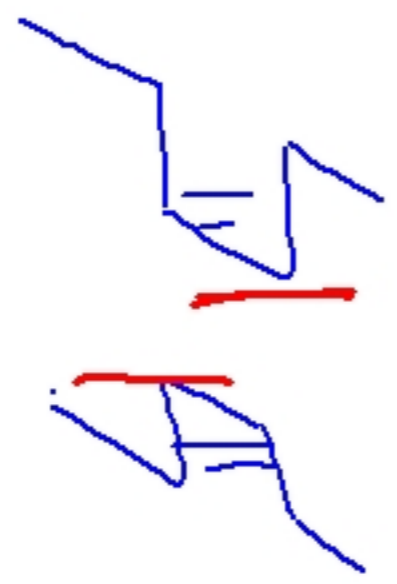
Absorption is only active for light polarized  $\perp$  to plane of well



# B INTERBAND



W. E-field



Band-to-band absorption  
 ⇒ carrier generation  
 hole-electron pair creation

$$g(x) = \alpha I(x)$$

$$\frac{dn}{dt} = G - R$$

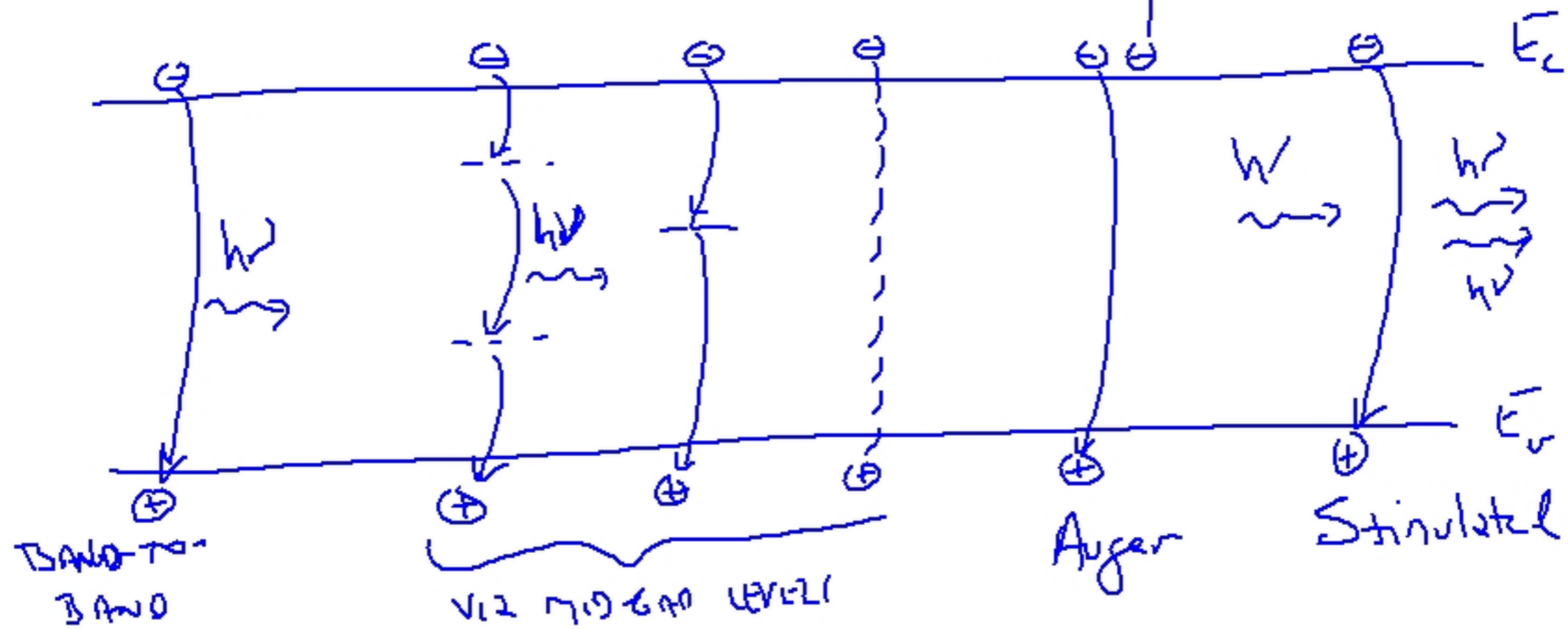
↓  
 $G_0 + g(x)$

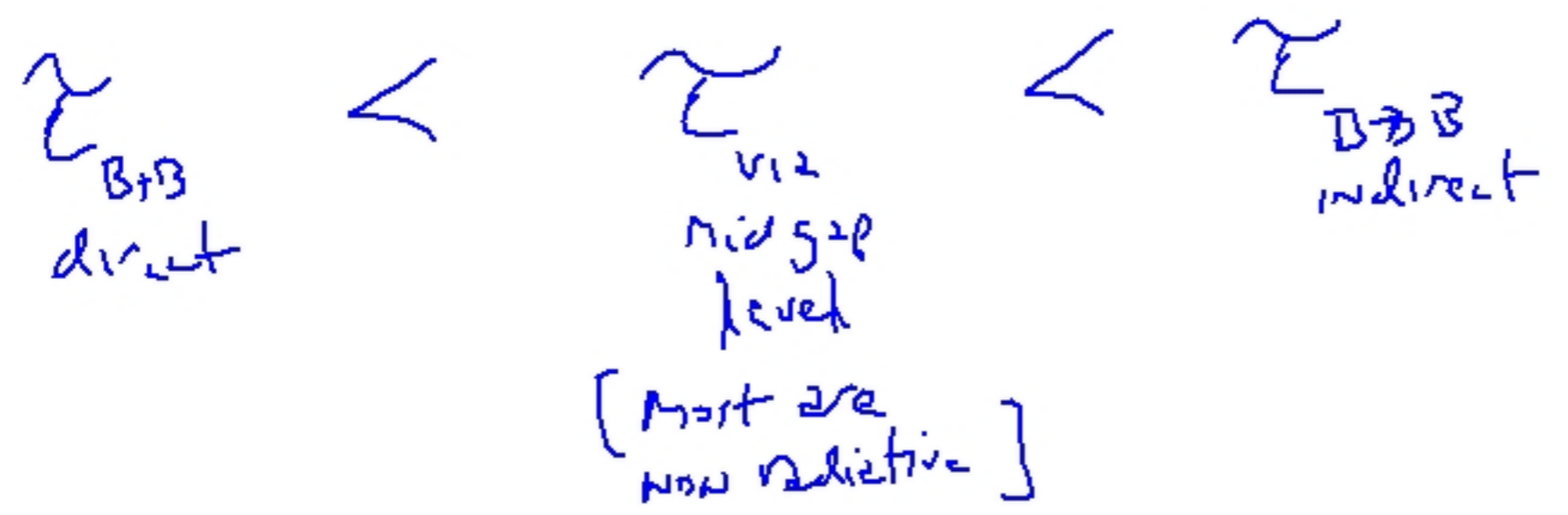
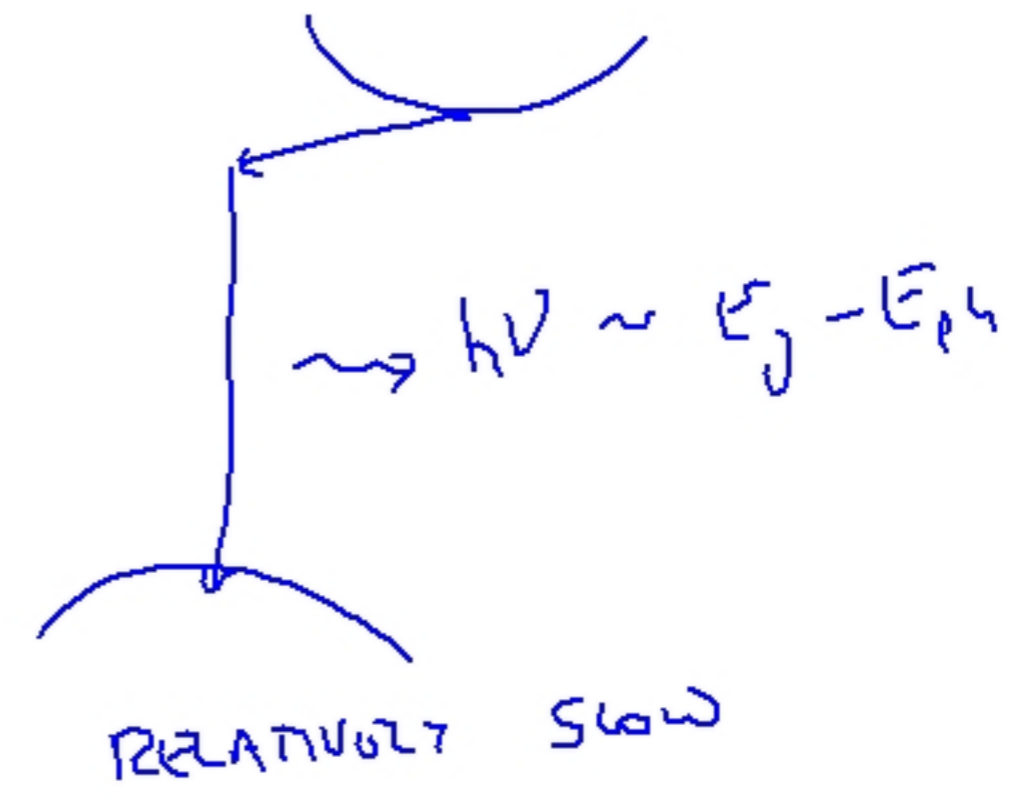
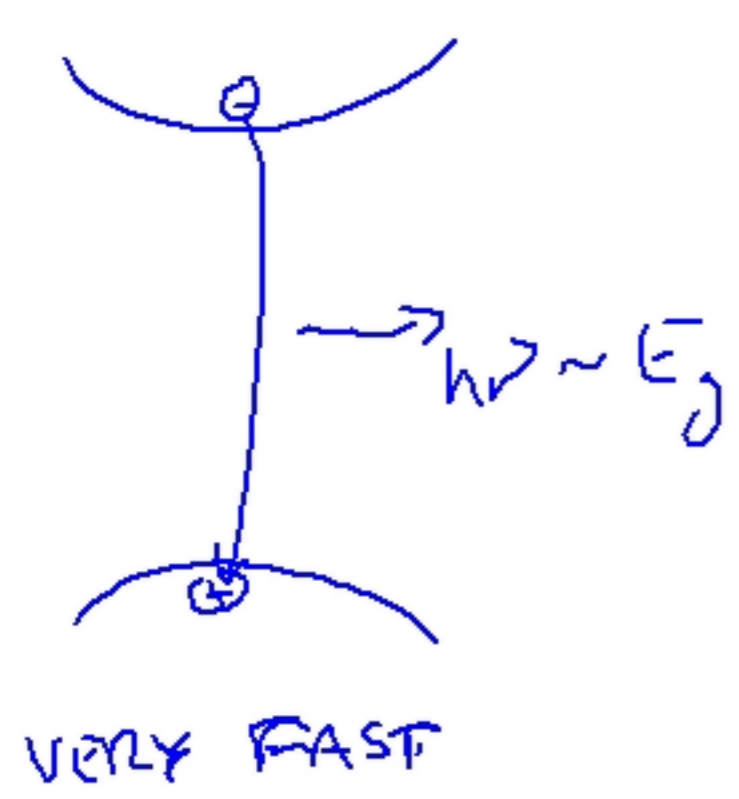
$$\frac{d}{dx} I_0 e^{-\kappa x} = -\alpha \underbrace{I_0 e^{-\alpha x}}_{I(x)} = -\alpha I(x)$$

↑  
Photon Flux

# RECOMBINATION PROCESSES

goal  $\rightarrow$  optical emission





BOTTOM LINE: INDIRECT GAP MATERIALS RELYING ON  $B \rightarrow B$  ARE WEAK LIGHT EMITTERS

FIND

LEDs

—

can use mid gap levels  
if radiative (few  
special cases)

—

direct bandgap materials  
(must have high quality)

LASER DIODES

—

must have high  
quality direct gap  
(today, at least)

INDIRECT GAP w. efficient emission useful

