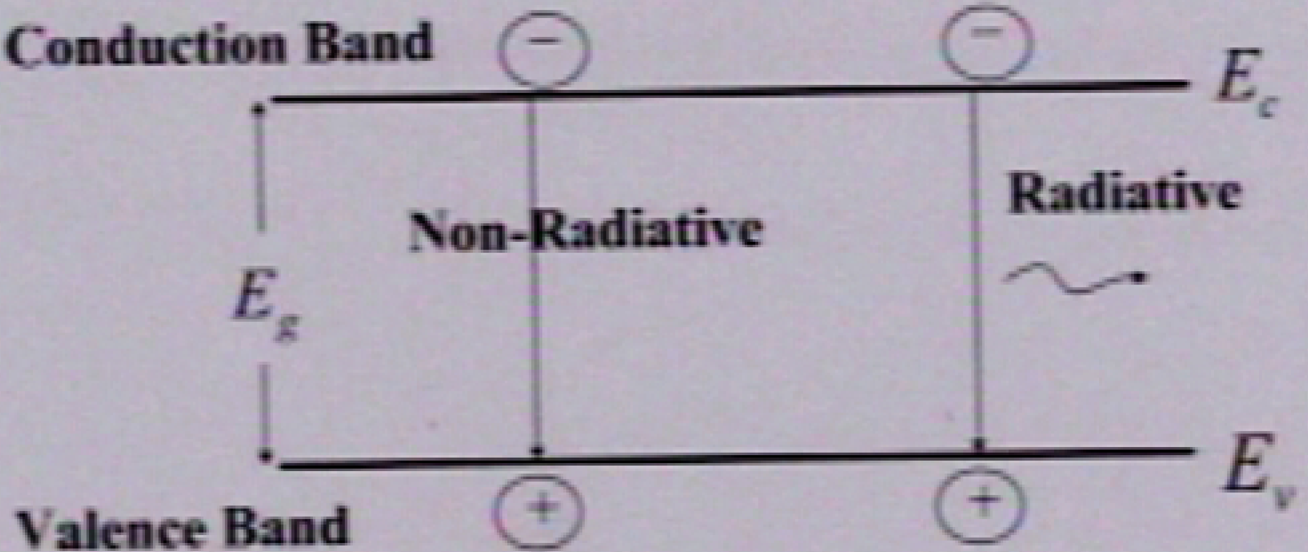
Desirable Characteristics of Optical Sources

- Emission within low loss window of the fiber
- Narrow spectral width
- Capability to couple adequate power to fiber
- Ease of coupling to fiber
- Ease and linearity of modulation
- High modulation speed
- High reliability
- Ruggedness for field use

Various Optical Sources

- Gas Sources (Lasers)
  - High power
  - Narrow spectral width
  - Highly directional
- Semiconductor Sources (Light Emitting Diode (LED), Injection Laser Diode (ILD))
  - Low power
  - Large spectral width
  - Non-directional radiation

Photon Wavelength



Conduction Band

E_c

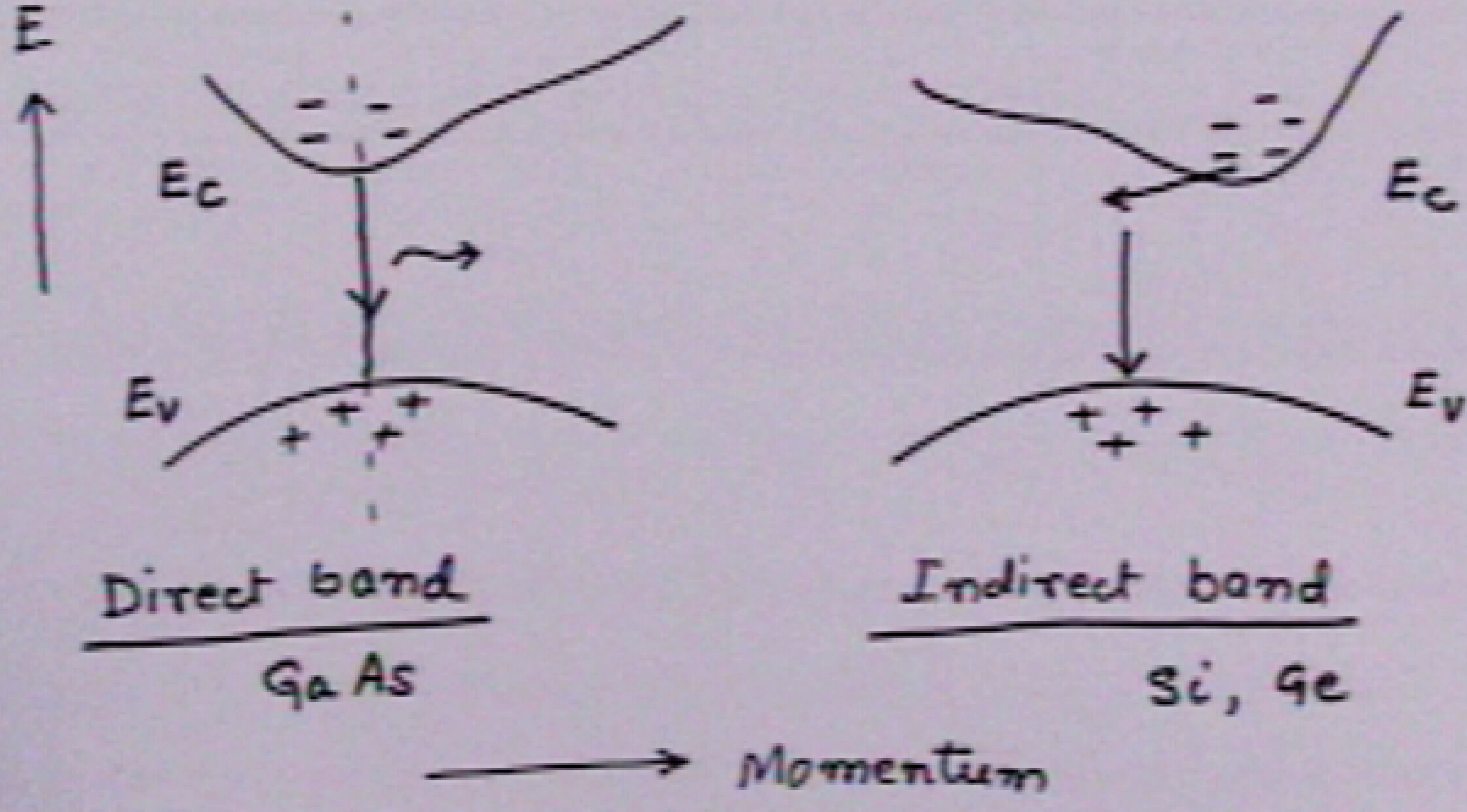
Non-Radiative

Radiative

E_g

E_v

Valence Band



Direct band

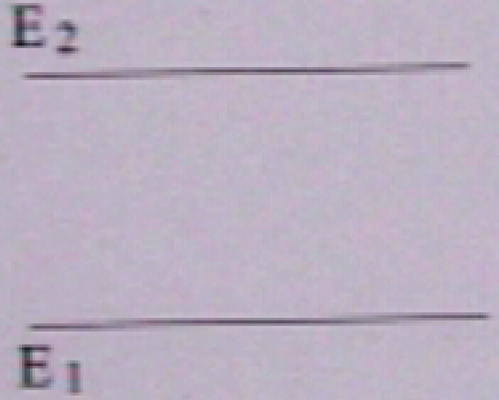
GaAs

Indirect band

Si, Ge

Optical Sources

Direct Band gap Material



$$E = E_2 - E_1 = h\nu = \frac{hc}{\lambda}$$

$$\lambda\,(\mu m) = \frac{1.24}{E\,(eV)}$$

For GaAs $E = 1.4$ eV

$\Longrightarrow$ $\lambda = 0.8\ \mu m$

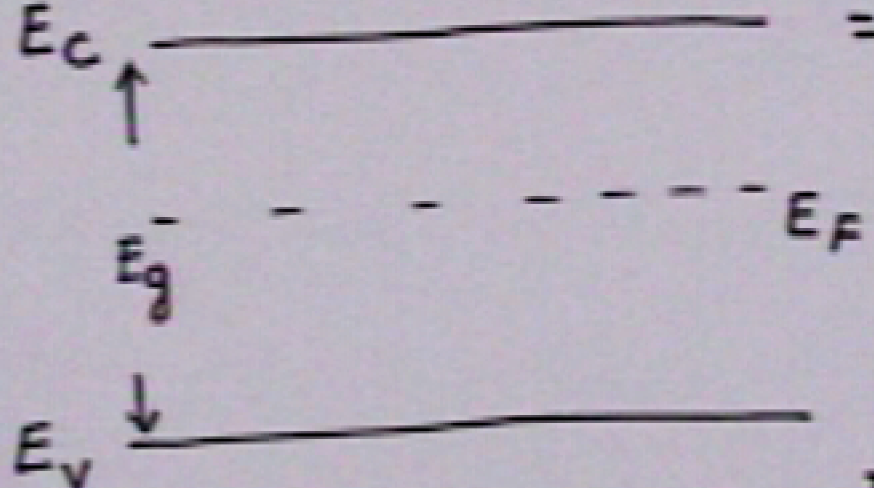
For $Ga_x\,Al_{1-x}\,As$ $E\,(eV) = 1.424 + 1.266x + 0.266x^2$ $0 < x < 0.37$

For $In_{1-x}Ga_x\,As_y\,P_{1-y}$ $E\,(eV) = 1.35 - 0.72y\ 0.12y^2$ $y = 2.2x,\ 0 < x < 0.47$

$\Longrightarrow$ $\lambda = 0.92 - 1.65\ \mu m$

$S_c(E_2)$ = Distribution of energy states in conduction band

$$= \frac{4\pi(2m_e)^{3/2}}{\hbar^2}(E_2 - E_c)^{1/2}$$

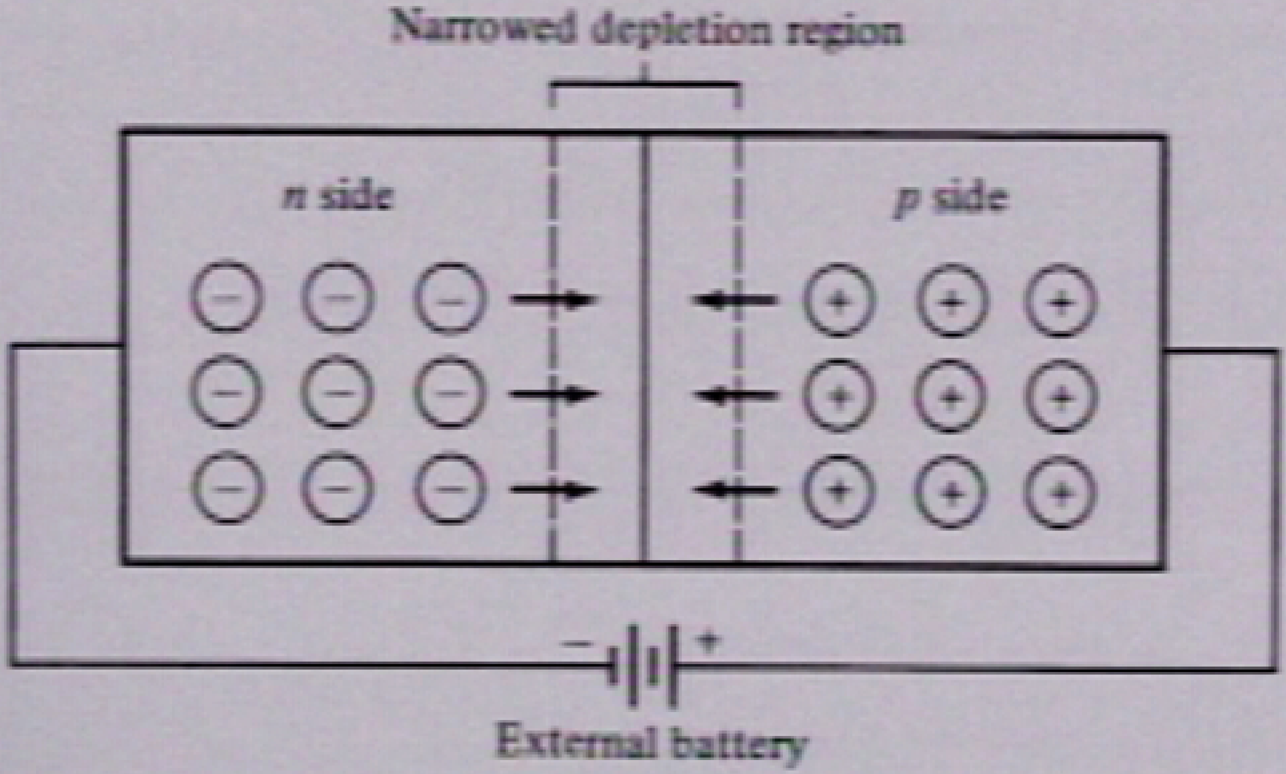


$S_v(E_1)$ = Distribution of energy states in valence band.

$$= \frac{4\pi(2m_h)^{3/2}}{\hbar^2}(E_v - E_1)^{1/2}$$

$$F(E) = \frac{1}{1 + e^{(E-E_F)/kT}}$$

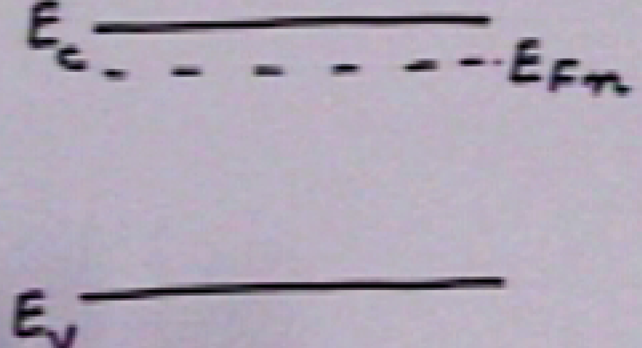
Forward bias condition



n-type material

E_{Fn}

$$F(E_2) = \frac{1}{1 + e^{(E_2 - E_{Fn})/kT}}$$



$$\simeq \frac{1}{e^{(E_2 - E_{Fn})/kT}}$$

$$\simeq e^{-(E_2 - E_{Fn})/kT}$$

Prob of electron in conduction band

$$n(E_2) \simeq e^{-(E_2 - E_{Fn})/kT}$$

p-type material E_{Fp}

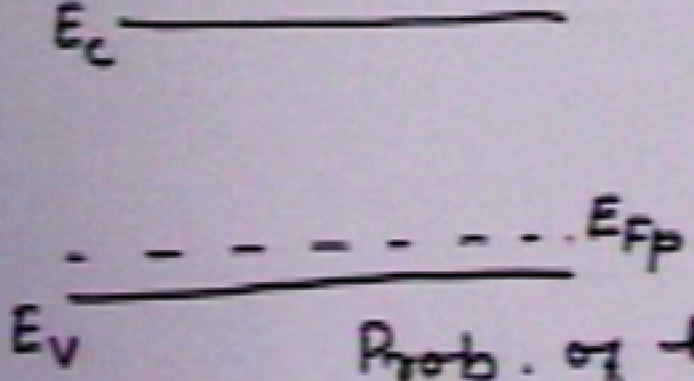
$$F(E_1) = \frac{1}{1 + e^{(E_1 - E_{Fp})/kT}}$$

Prob of absence of electron in the valence band is

$$1 - F(E_1) = 1 - \frac{1}{1 + e^{(E_1 - E_{Fp})/kT}}$$

$$= 1 - \left\{ 1 + e^{(E_1 - E_{Fp})/kT} \right\}^{-1}$$

$$\approx \cancel{1} - \cancel{1} + e^{(E_1 - E_{Fp})/kT}$$



Prob. of hole $p(E_1) \approx e^{(E_1 - E_{Fp})/kT}$

Prob. of photon generation

$$\propto n(E_2) \times p(E_1)$$

$$\propto e^{-(E_2 - E_{Fn})/kT} \cdot e^{(E_1 - E_{Fp})/kT}$$

$$\propto e^{-(E_2 - E_1)/kT} \cdot \boxed{e^{(E_{Fn} - E_{Fp})/kT}}$$

A – const

$$\propto e^{-(E_2 - E_1)/kT}$$