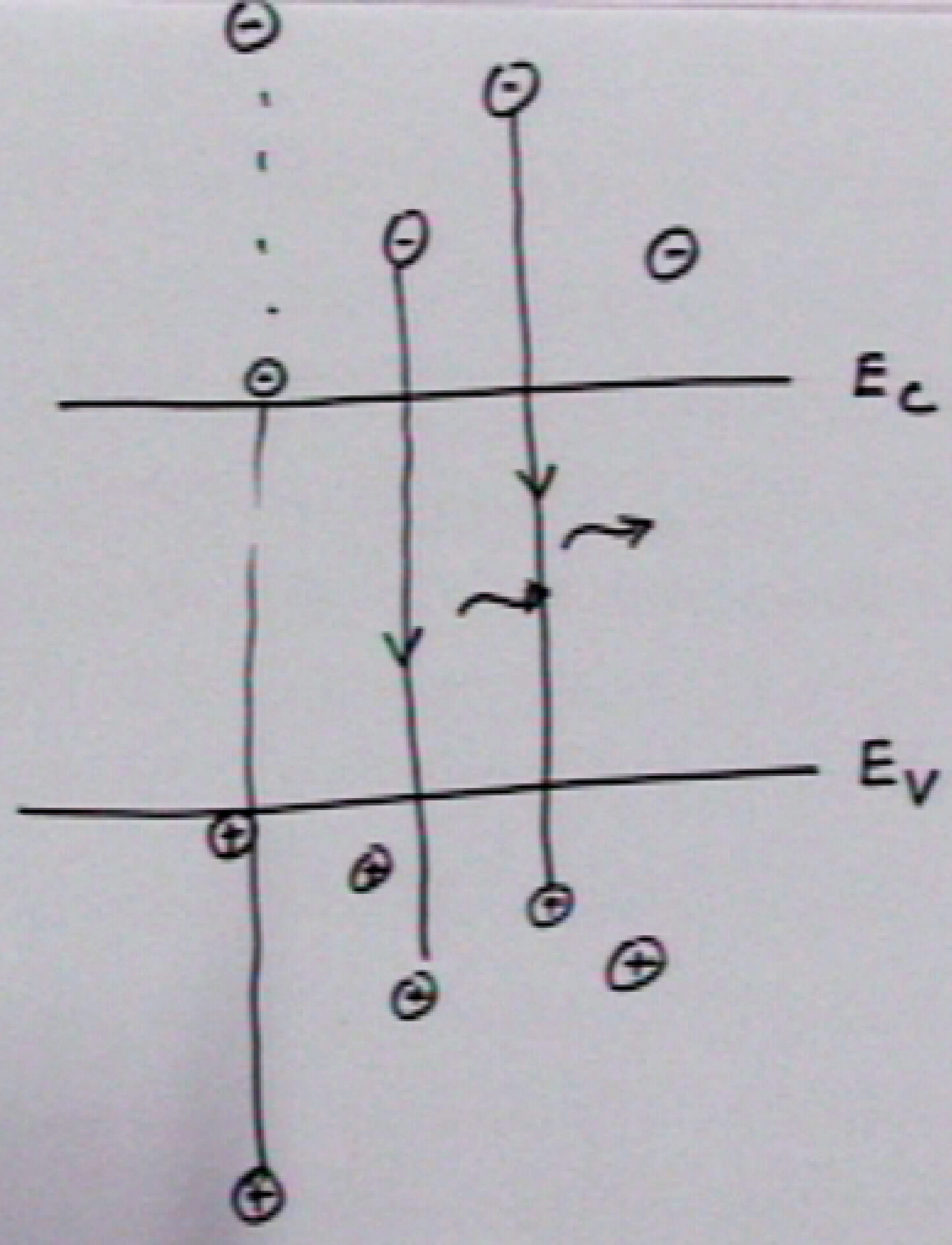

E_c
E_V

Prob. of photon generation

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

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

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

$$\propto e^{-(E_2 - E_1)/KT} \qquad A - \text{const}$$

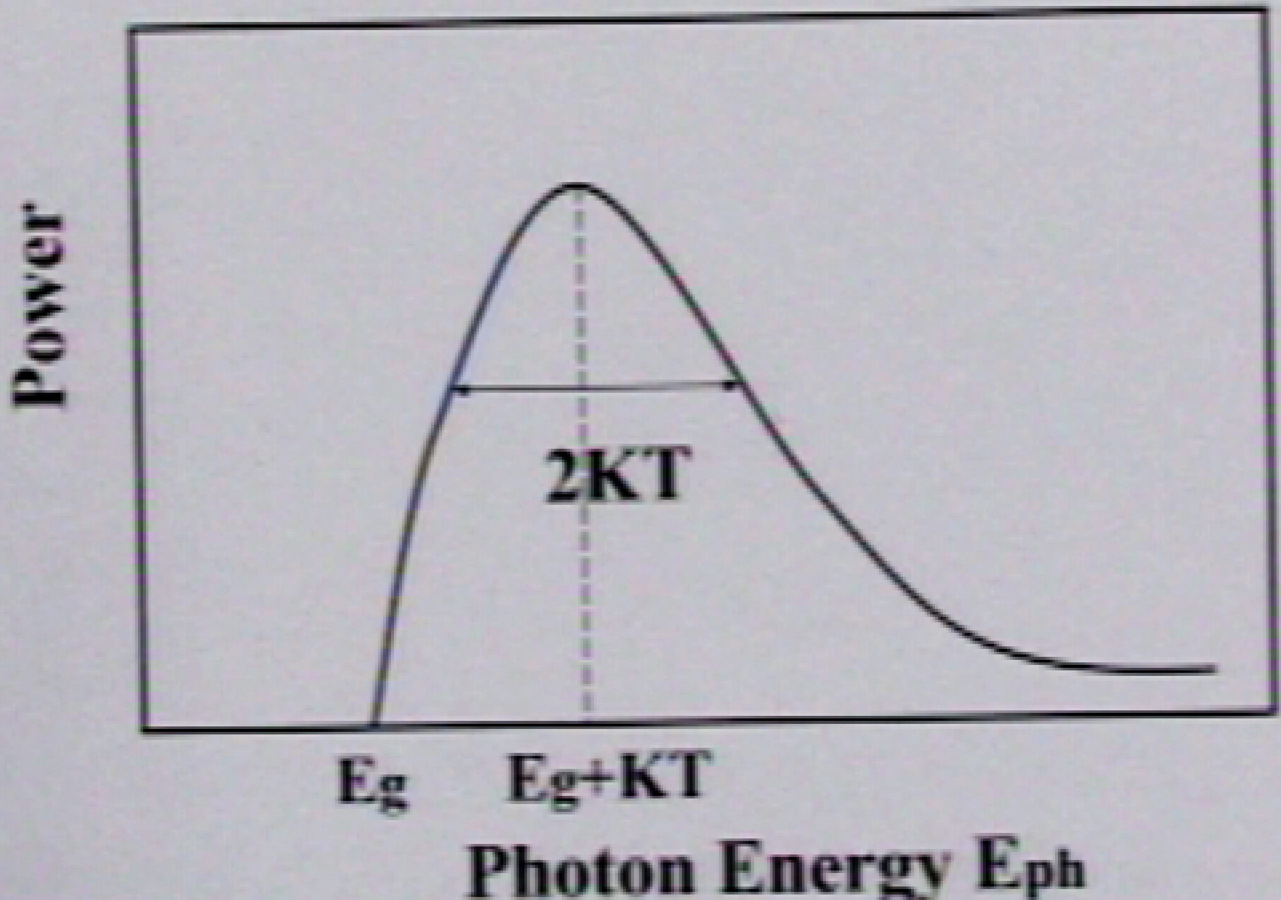
$$\text{Total photons} \propto \int_{E_c}^{E_v + E_{ph}} e^{-E_{ph}/KT} \, dE_2$$

$$\propto -(E_v + E_{ph} - E_c) e^{-E_{ph}/KT}$$

No. of photons $\propto (E_{ph} - E_g)\, e^{-E_{ph}/KT}$

$$\propto (E_{ph} - E_g)\, e^{-(E_{ph} - E_g)/KT}$$

Spectral Distribution of LED



Due to Impurities, Spectral width is ~ 1.5KT -3.5KT

LED Spectral Width

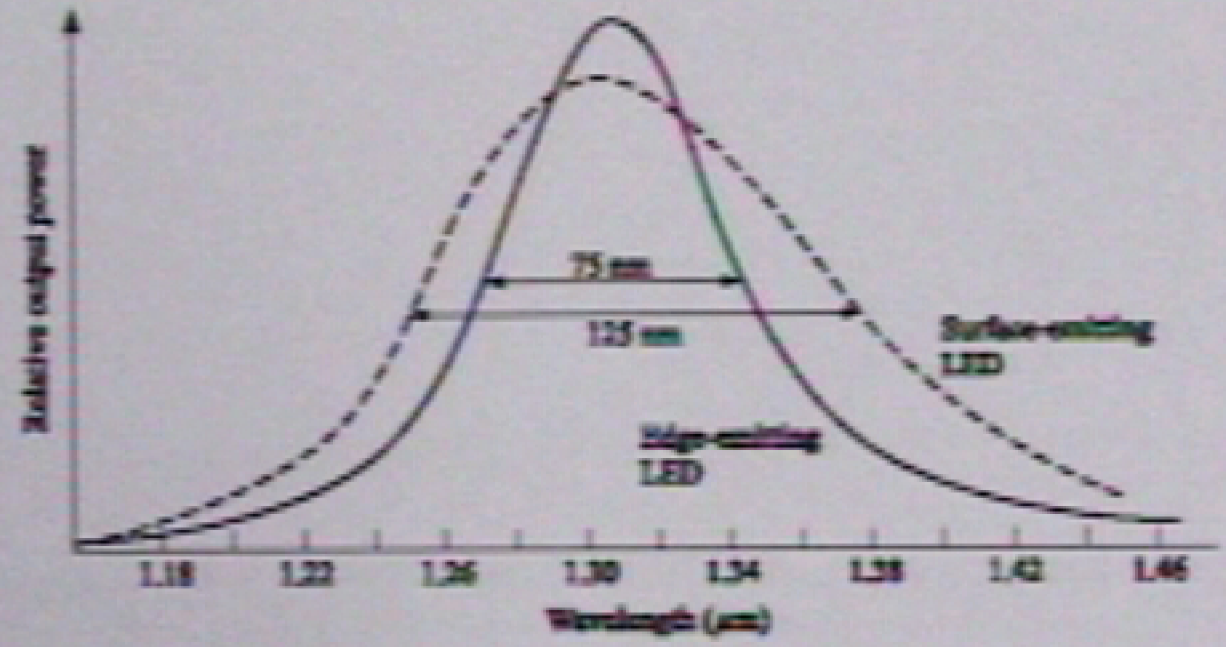
$$\lambda = \frac{hc}{E_{ph}}$$

$$\Delta\lambda = -\frac{hc}{E_{ph}^2}\Delta E_{ph}$$

$$\Delta\lambda / \lambda = \frac{\Delta E_{ph}}{E_{ph}} = \frac{2KT}{E_{ph}}$$

λ	$\Delta\lambda$	$\Delta\lambda/\lambda$
850 nm	30 nm	3.6%
1310 nm	70 nm	5.5%
1550 nm	100 nm	6.5%

LED spectral patterns



Re-combinations

Radiative Re-combinations

Non-Radiative Re-combinations

Quantum Efficiency

Internal Quantum Efficiency

$$\eta_{int} = \frac{\text{Number of photons generated}}{\text{Total electron-hole recombinations}}$$

External Quantum Efficiency

$$\eta_{ext} = \frac{\text{Number of photons guided to the fiber}}{\text{Total photons generated}}$$

$$-\frac{\partial n}{\partial t} \propto n$$

$$n(t) = n_0 e^{-t/\tau}$$

↑ Life time of carrier.

$$-\frac{\partial n}{\partial t} = \frac{n}{\tau}$$

τ_{rr} = Life time against Rad. Recom

τ_{nr} = Life time against Non. Rad. Rec.

Total Rate of Recombination

$$-\left.\frac{\partial n}{\partial t}\right|_{total} = -\left.\frac{\partial n}{\partial t}\right|_{Rad} - \left.\frac{\partial n}{\partial t}\right|_{NonRad}.$$

$$\frac{n}{\tau} = \frac{n}{\tau_{rr}} + \frac{n}{\tau_{nr}}$$

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

$$\eta_{int} = \frac{-\left.\frac{\partial n}{\partial t}\right|_{Rad}}{-\left.\frac{\partial n}{\partial t}\right|_{Total}}$$

$$= \frac{n/\tau_{rr}}{n/\tau} = \frac{n/\tau_{rr}}{\frac{n}{\tau_{rr}} + \frac{n}{\tau_{nr}}}$$

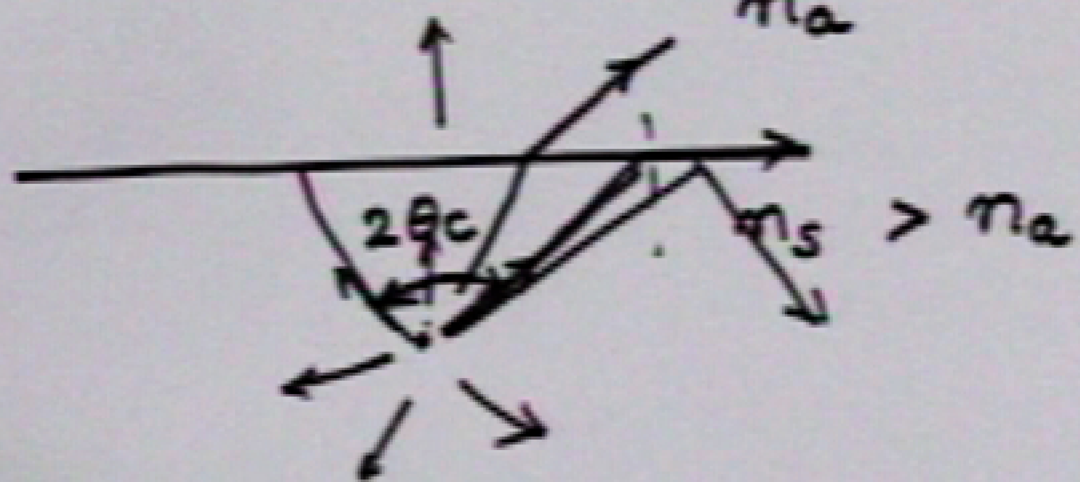
$$\eta_{int} = \frac{1}{1 + \frac{\tau_{rr}}{\tau_{nr}}}$$

If $\tau_{rr} << \tau_{nr} \Rightarrow \eta_{int} \approx 1$

GaAs $\tau_{rr} \sim 100$ nsec

Due to impurities $\tau_{nr} \sim 100$ nsec

$\eta_{int} \sim 0.5$



$$\theta_c = \sin^{-1}\left(\frac{n_a}{n_s}\right)$$

For GaAs $\theta_c \simeq \sin^{-1}\left(\frac{1}{3.6}\right)$

$$\eta_{ext\,1} = \frac{n_a^2}{2 n_s^2} \simeq 0.036$$