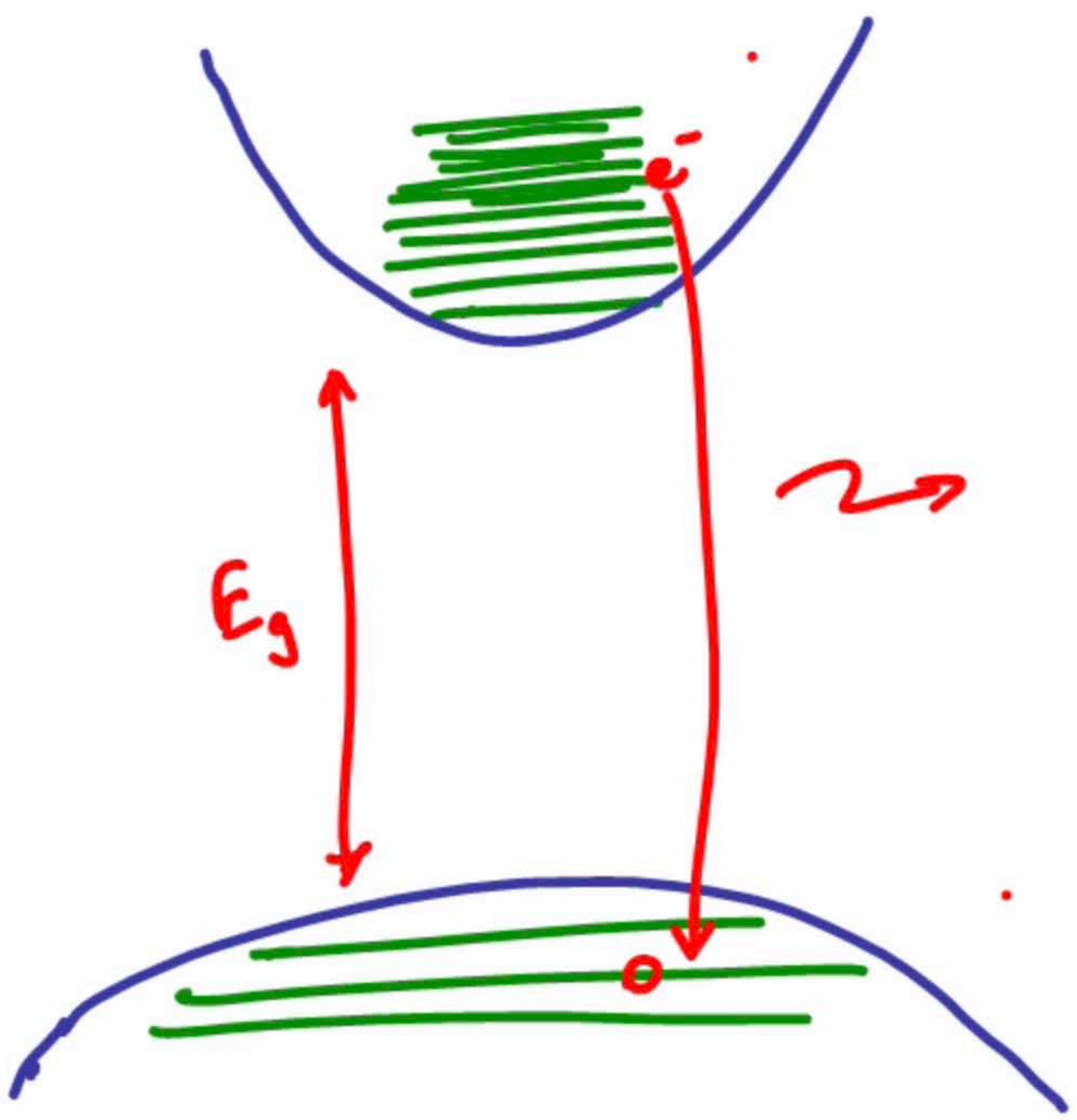
Spectral Characteristics



$$R_{spon}(\nu) = \int_{E_c}^{\infty} A \cdot f_c(E_2)\left[1 - f_v(E_1)\right] \rho_{cv} \, dE_2$$

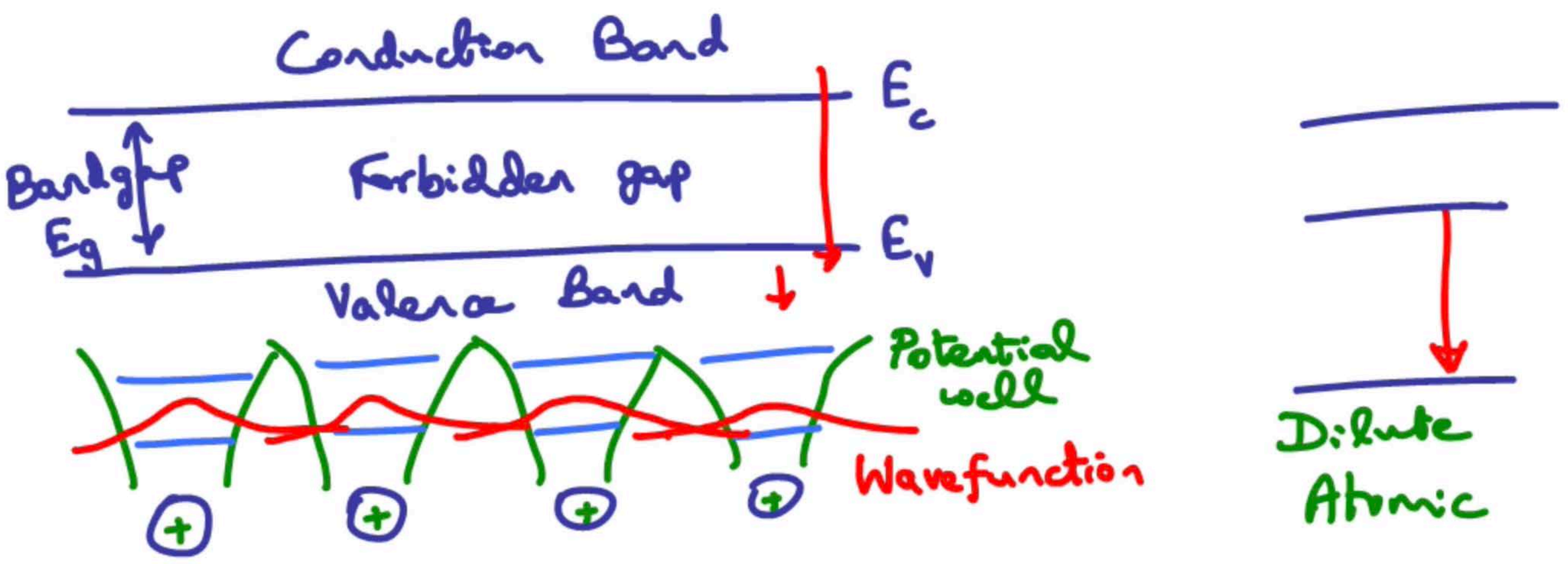
$$= A_0 (h\nu - E_g)^{1/2} \exp\left(-\frac{h\nu - E_g}{k_B T}\right)$$

At $T = 300^\circ K$

$\Delta\nu = 11\ THz$

Learning Objective: Identify fundamental principles of semiconductor light sources & detectors

Schroedinger wave equation



$E_g \gg k_B T$

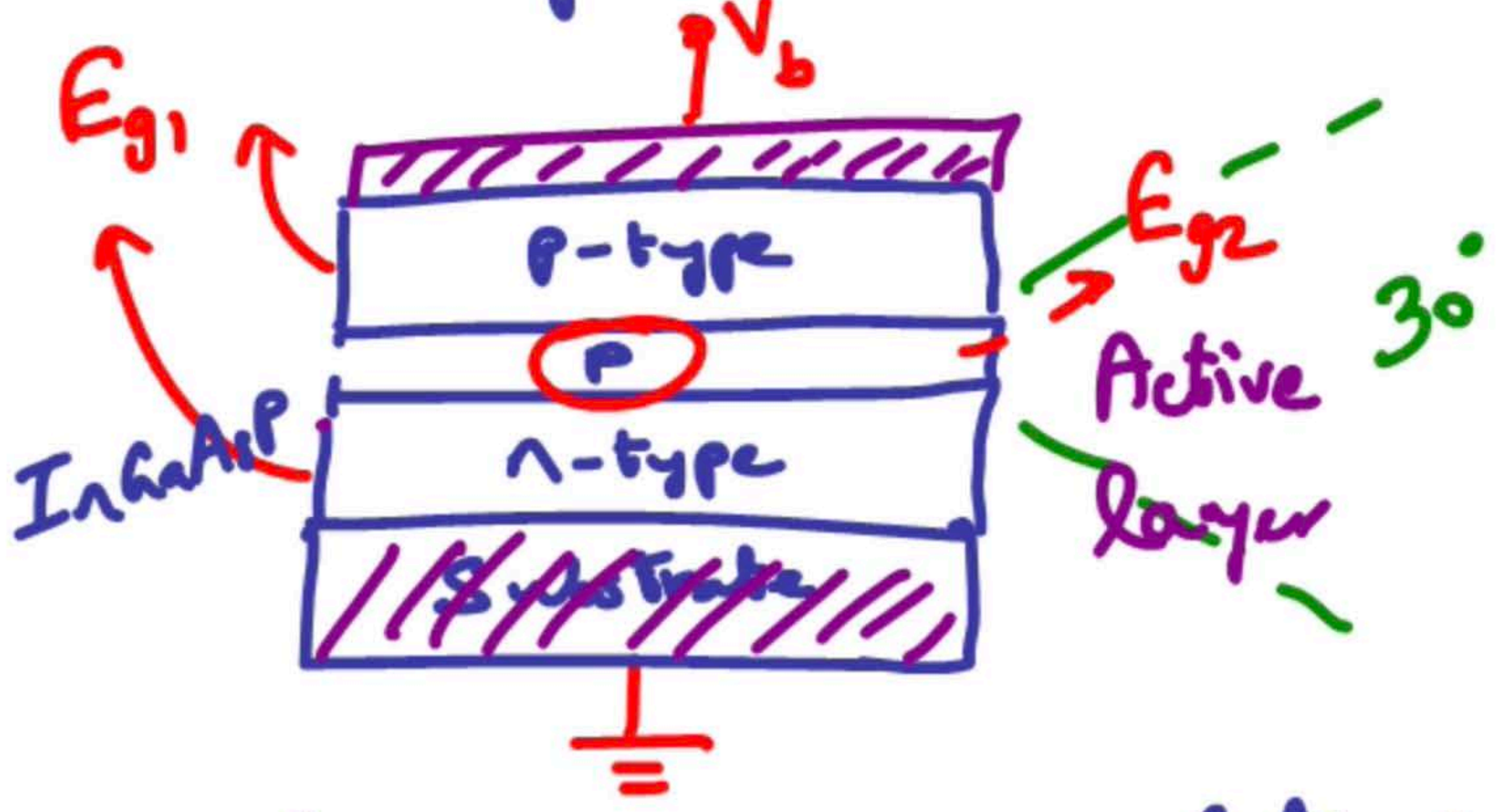
25 meV

Kronig-Penney Model

Light Emitting Diodes

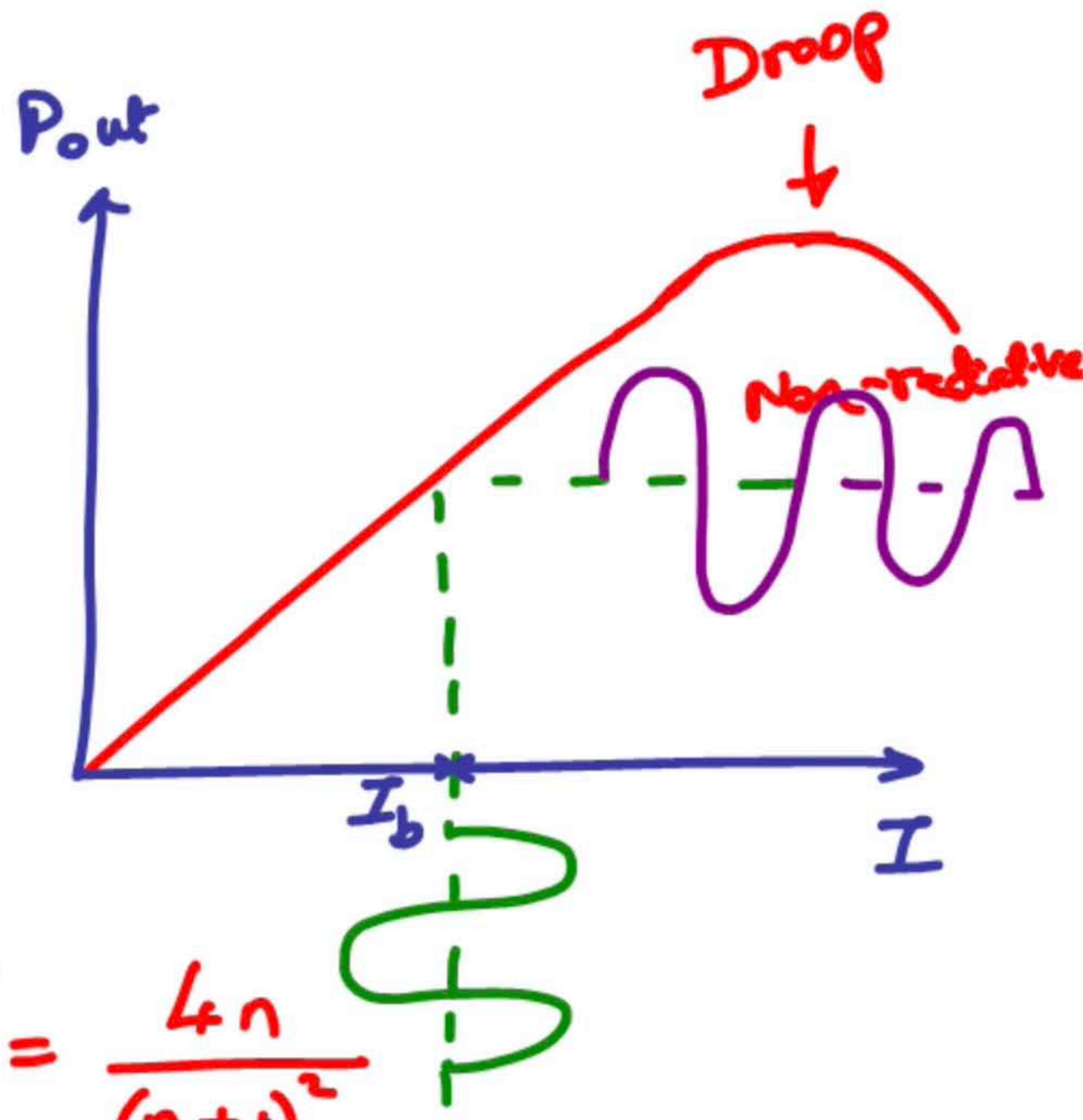
Edge-emitting LED

Epitaxial

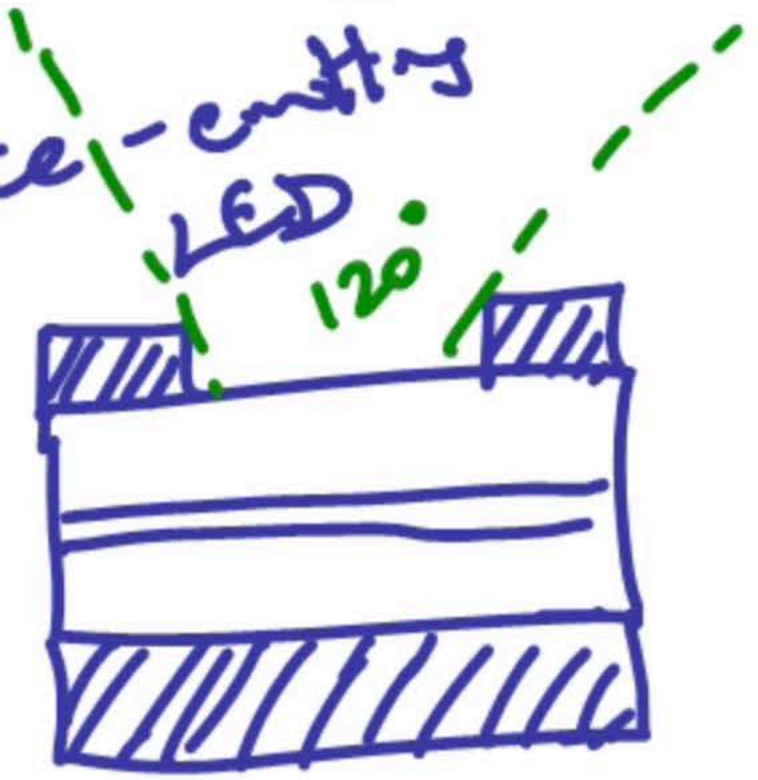


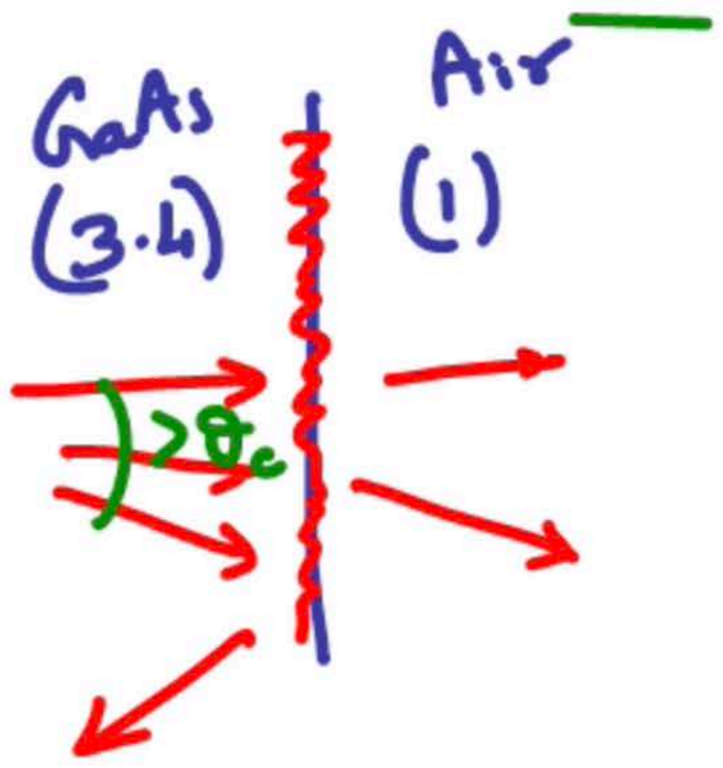
Output Power. $P_{out} = \frac{I}{e} h\nu \, \eta_{int} \, \eta_{out}$

$$\frac{R_{rad}}{R_{rad} + R_{non\text{-}rad}} = \frac{\tau_{nr}}{\tau_r + \tau_{nr}} \sim 80\text{-}90\%$$



Surface-emitting LED





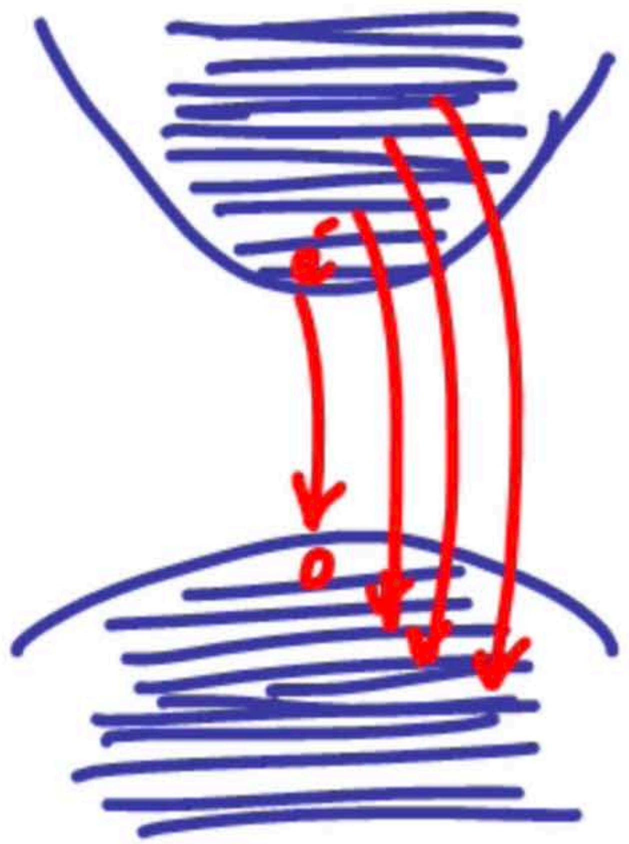
$$R = \left(\frac{n-1}{n+1}\right)^2 \Rightarrow T = 1 - \left(\frac{n-1}{n+1}\right)^2 = \frac{4n}{(n+1)^2}$$

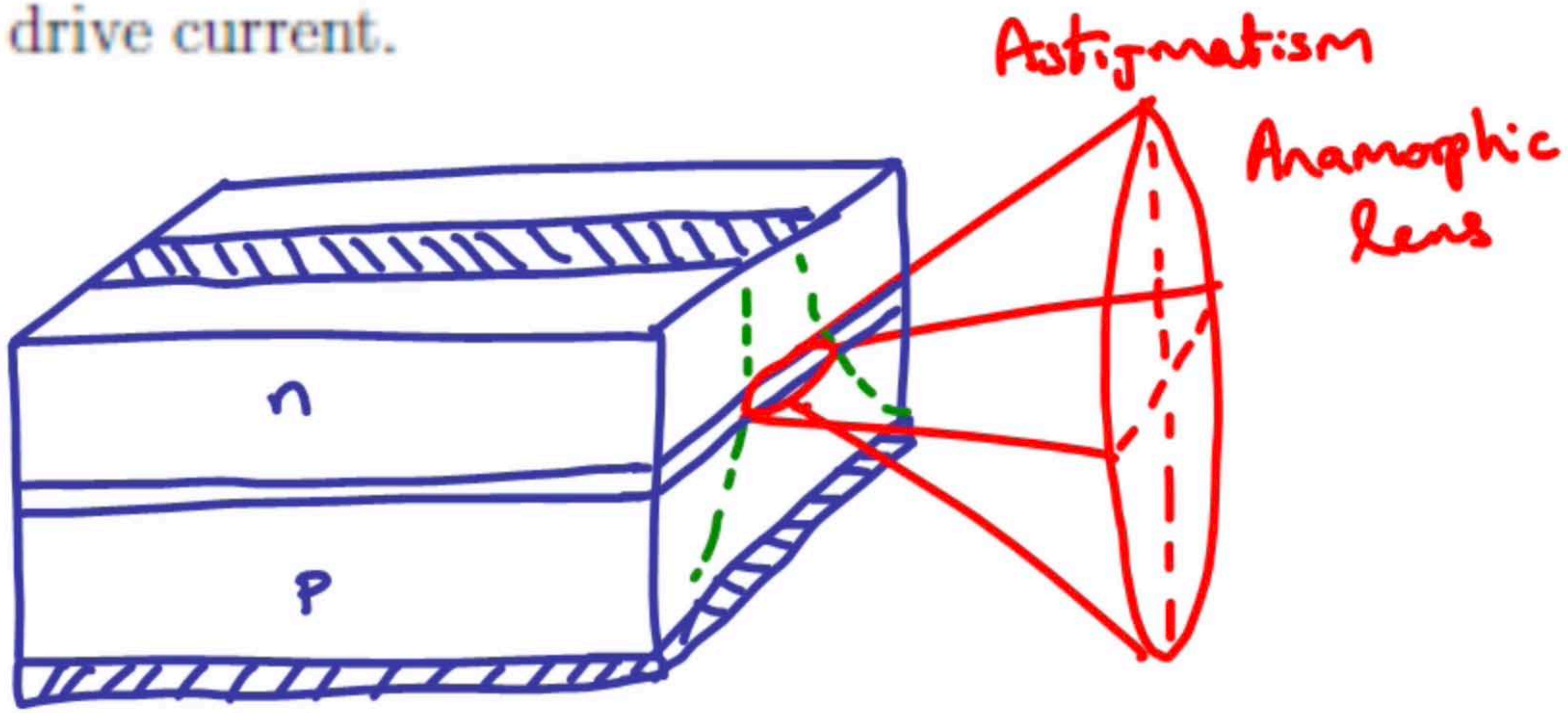
$$\left.\begin{array}{l}\text{Fraction of light}\\ \text{escaping}\end{array}\right\} = 1 - \cos\theta_c = 1 - \sqrt{1 - \left(\frac{1}{n}\right)^2} \simeq \frac{1}{2n^2}$$

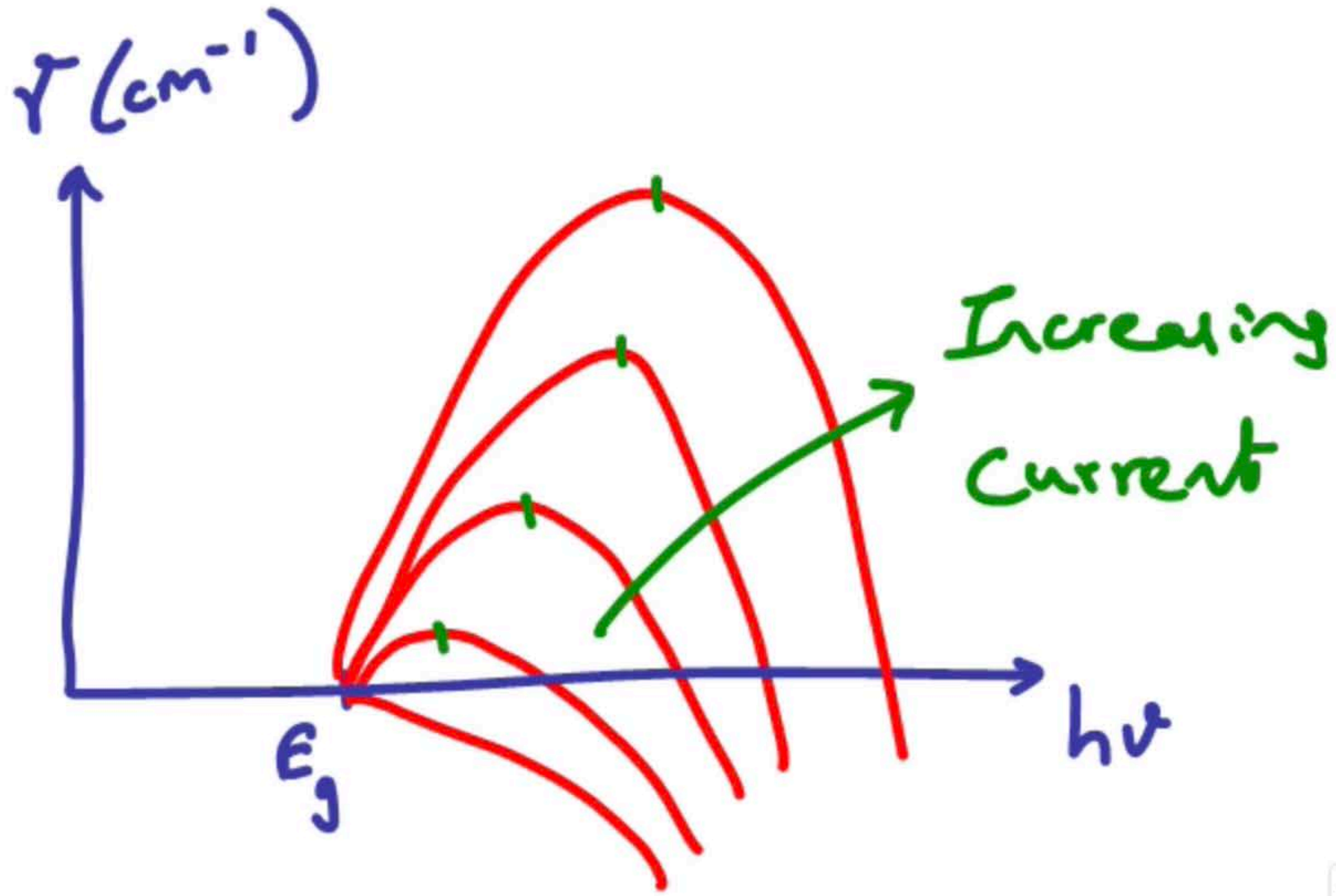
$$\eta_{out} = \frac{4n}{(n+1)^2} \cdot \frac{1}{2n^2} = \frac{2}{n(n+1)^2}$$

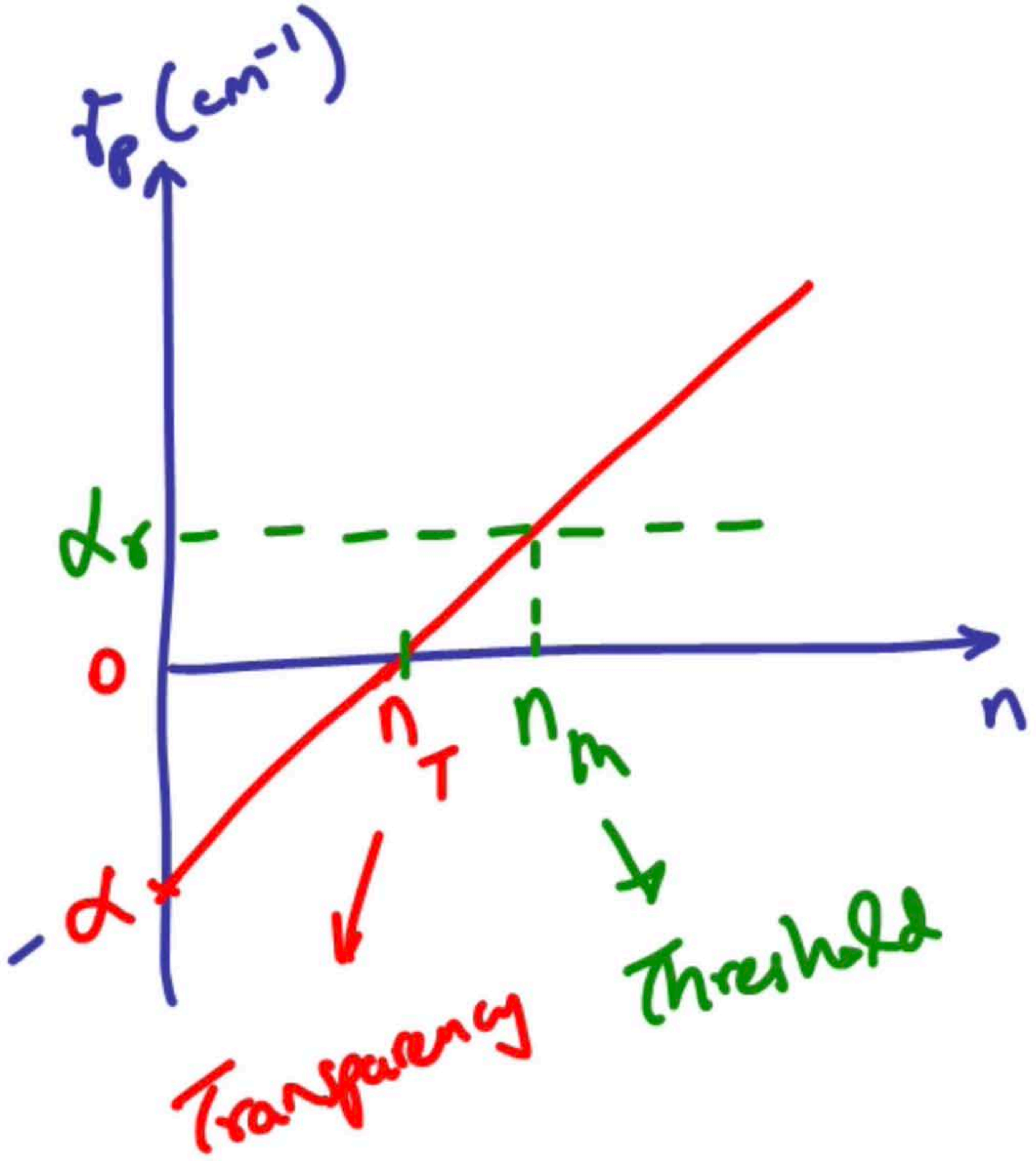
Semiconductor Laser Diodes:

8. Consider an InGaAs semiconductor laser (n = 3.7) emitting 1.3 μm wavelength consists of a 0.4 mm long cavity with internal losses of 40 cm^{-1} and mirror reflectivity of 0.9 at either end.
   (a) Find the frequency spacing between the longitudinal modes of the laser.
   (b) Find the minimum gain required to compensate the losses in the laser cavity.
   (c) Derive an expression for power emitted from the laser in terms of applied current, losses and η_{int}. Assuming $\eta_{int} \approx 1$ and $I_{th} = 50$ mA, find the optical power emitted at 100 mA of drive current.









Peak gain coeff $\quad \gamma_p = \alpha\left(\frac{n}{n_T} - 1\right)$

$$= \alpha\left(\frac{J}{J_T} - 1\right) \quad \text{cm}^{-1}$$

At threshold,

$$\gamma_p = \alpha_r = \alpha\left(\frac{J_m}{J_T} - 1\right)$$

$$\text{(or)} \quad J_m = \frac{\alpha_r + \alpha}{\alpha} \cdot J_T$$

Semiconductor Laser Diodes:

$$\gamma = \alpha_{int} + \frac{1}{2L}\ln\left(\frac{1}{R_1}\right) + \frac{1}{2L}\ln\left(\frac{1}{R_2}\right)$$
$$\simeq 42.5\ \text{cm}^{-1}$$

8. Consider an InGaAs semiconductor laser ($n = 3.7$) emitting 1.3 μm wavelength consists of a 0.4 mm long cavity with internal losses of 40 cm^{-1} and mirror reflectivity of 0.9 at either end.
   (a) Find the frequency spacing between the longitudinal modes of the laser.
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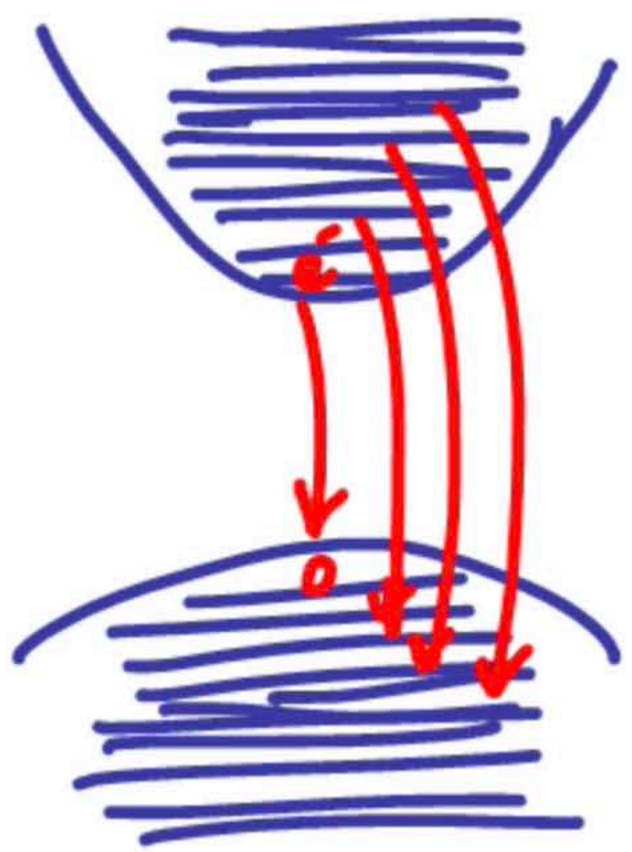
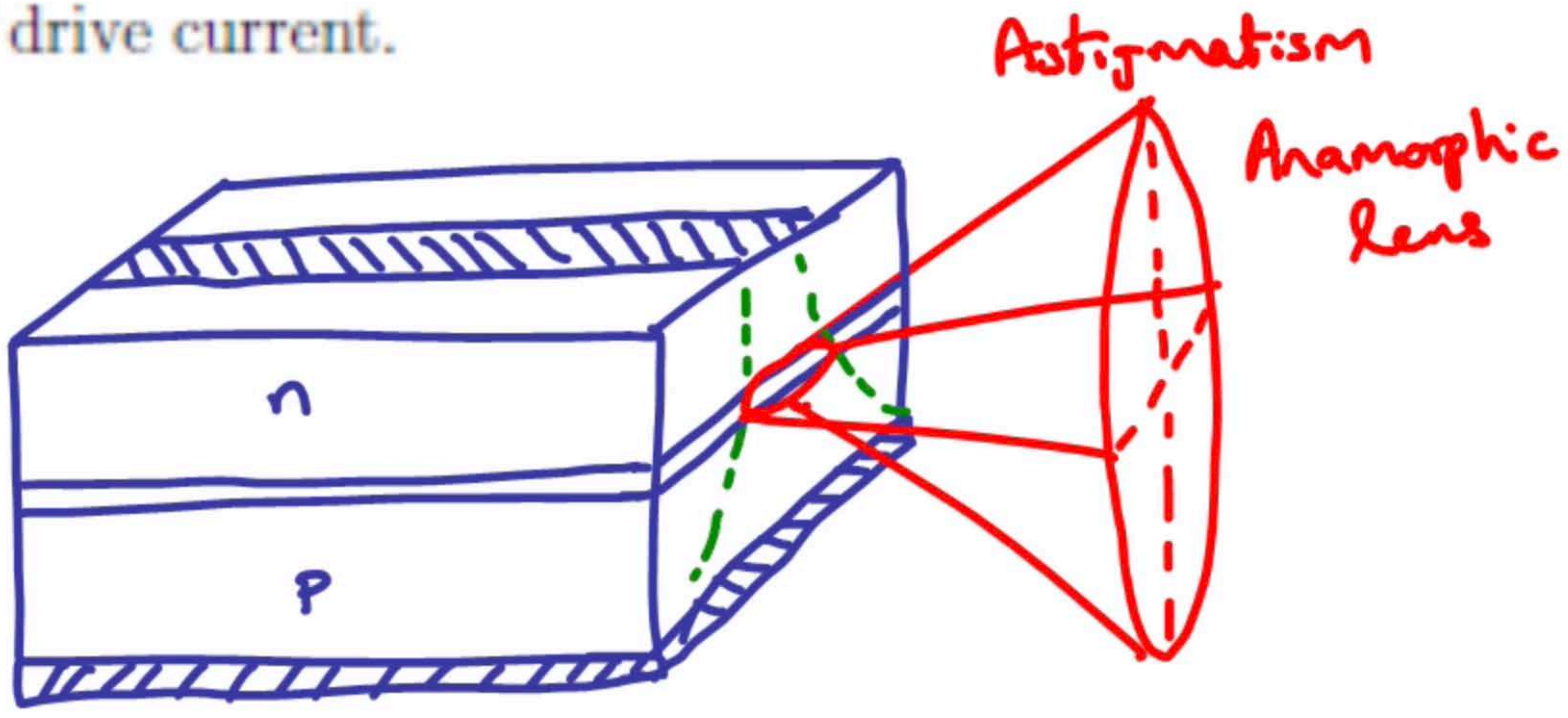
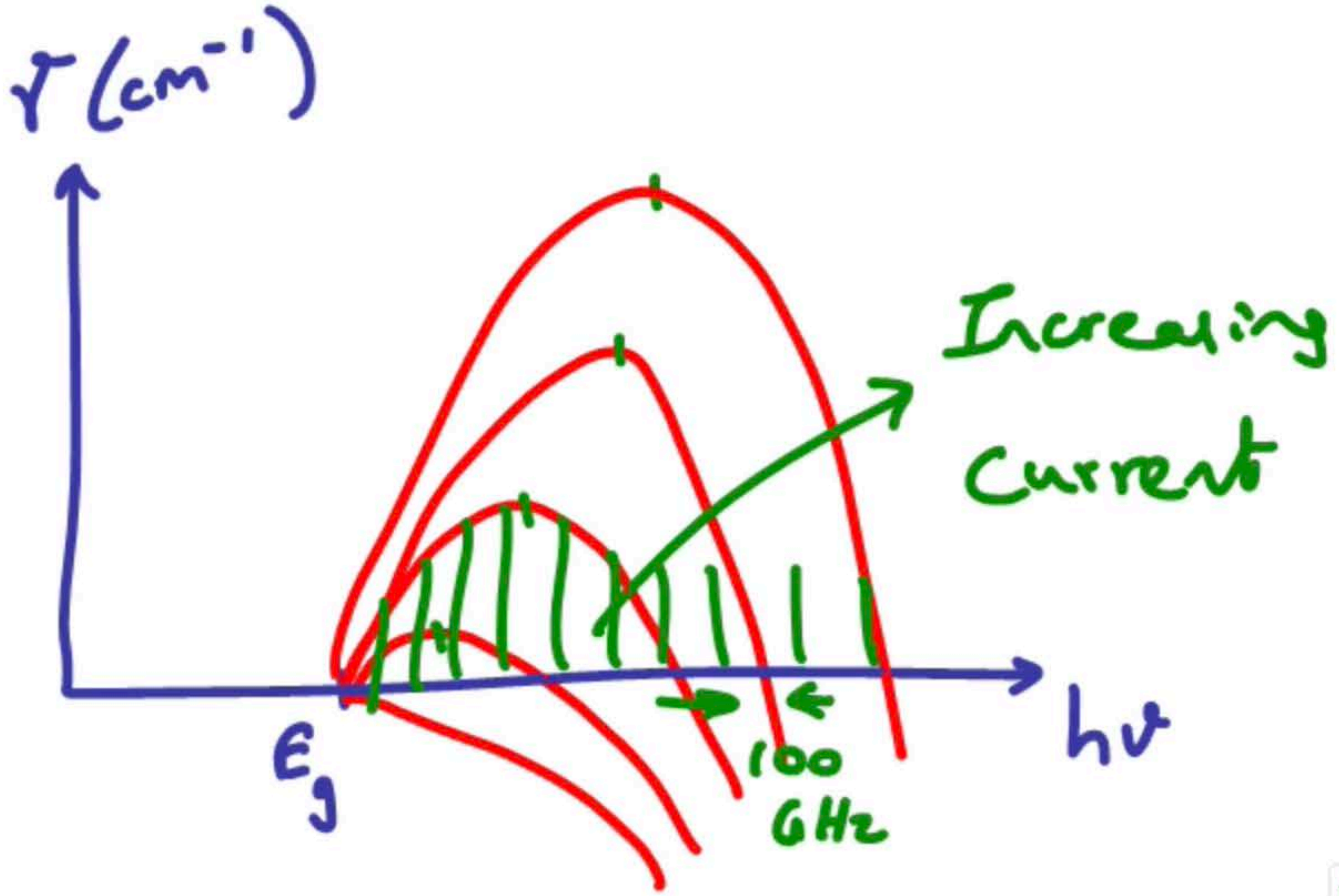
$$\Delta\nu = c/2nL = \frac{3\times10^{8}}{2\times 3.7\times0.4\times10^{-3}}$$
$$\simeq 10^{11}\ \text{Hz}$$
$$= 100\ \text{GHz}$$







Internal photon flux, $\phi_{in} = \begin{cases} \eta_i \dfrac{I - I_{th}}{e} & I > I_{th} \\ 0 & I \le I_{th} \end{cases}$

$\lambda_B = 2 n_{eff} \Lambda$

Single longitudinal mode

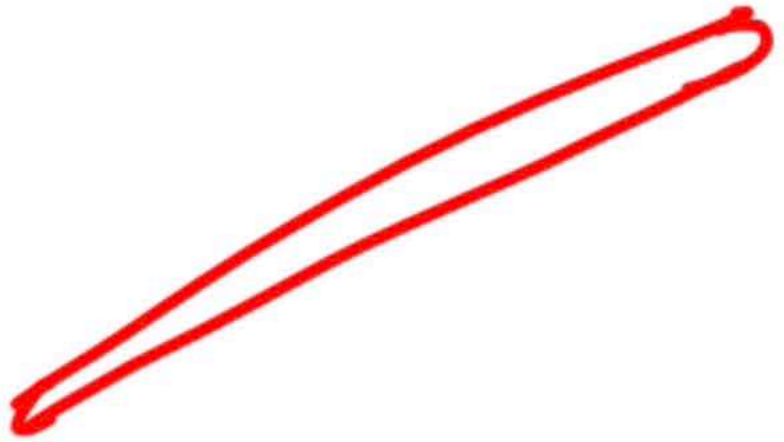
Distributed Feedback Laser (DFB)

Output photon flux. $\phi_{out} = \eta_e \phi_{in}$ where $\eta_e = \dfrac{\alpha_{m2}}{\alpha_r}$

Output power, $P_{out} = \phi_{out} \cdot h\nu = \eta_i \eta_e \cdot \dfrac{I - I_{th}}{e} \cdot h\nu$

Multimode

Broad-stripe

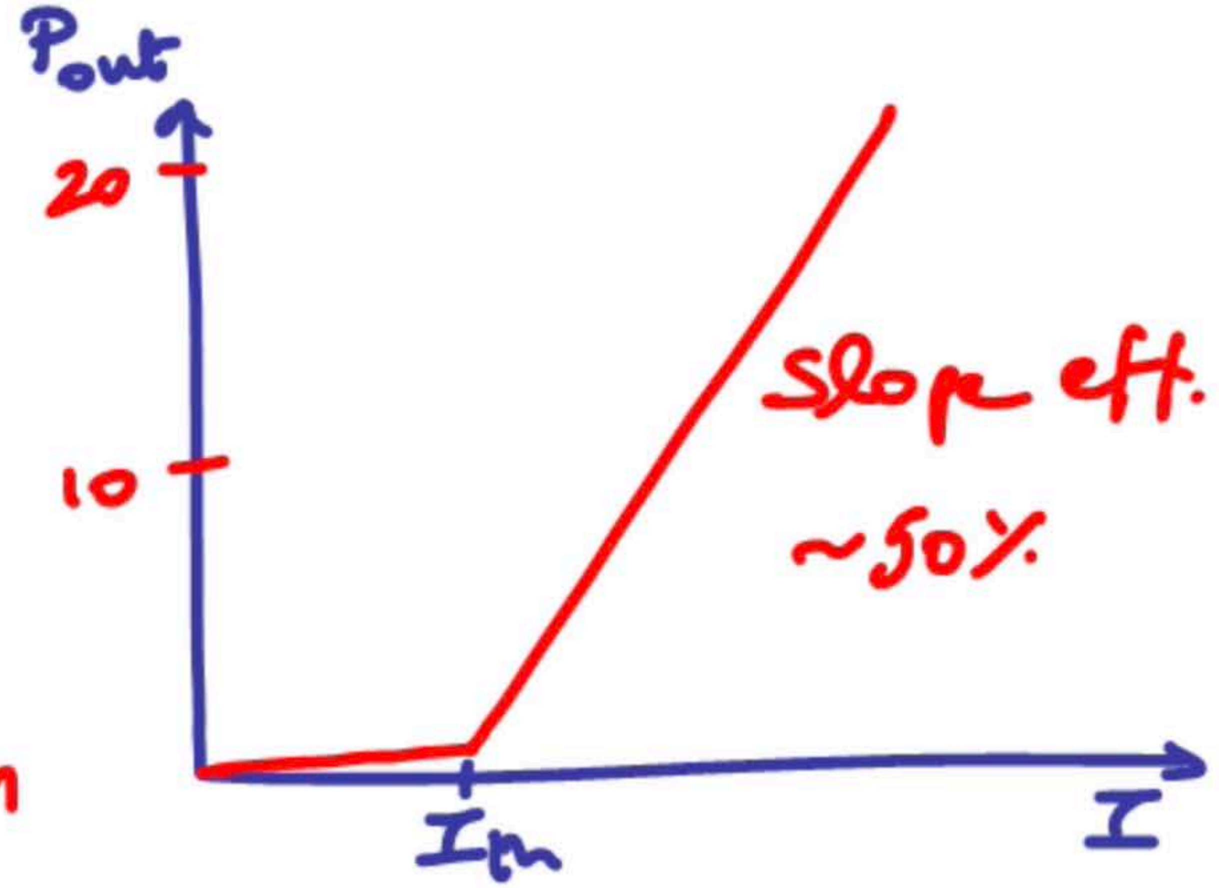


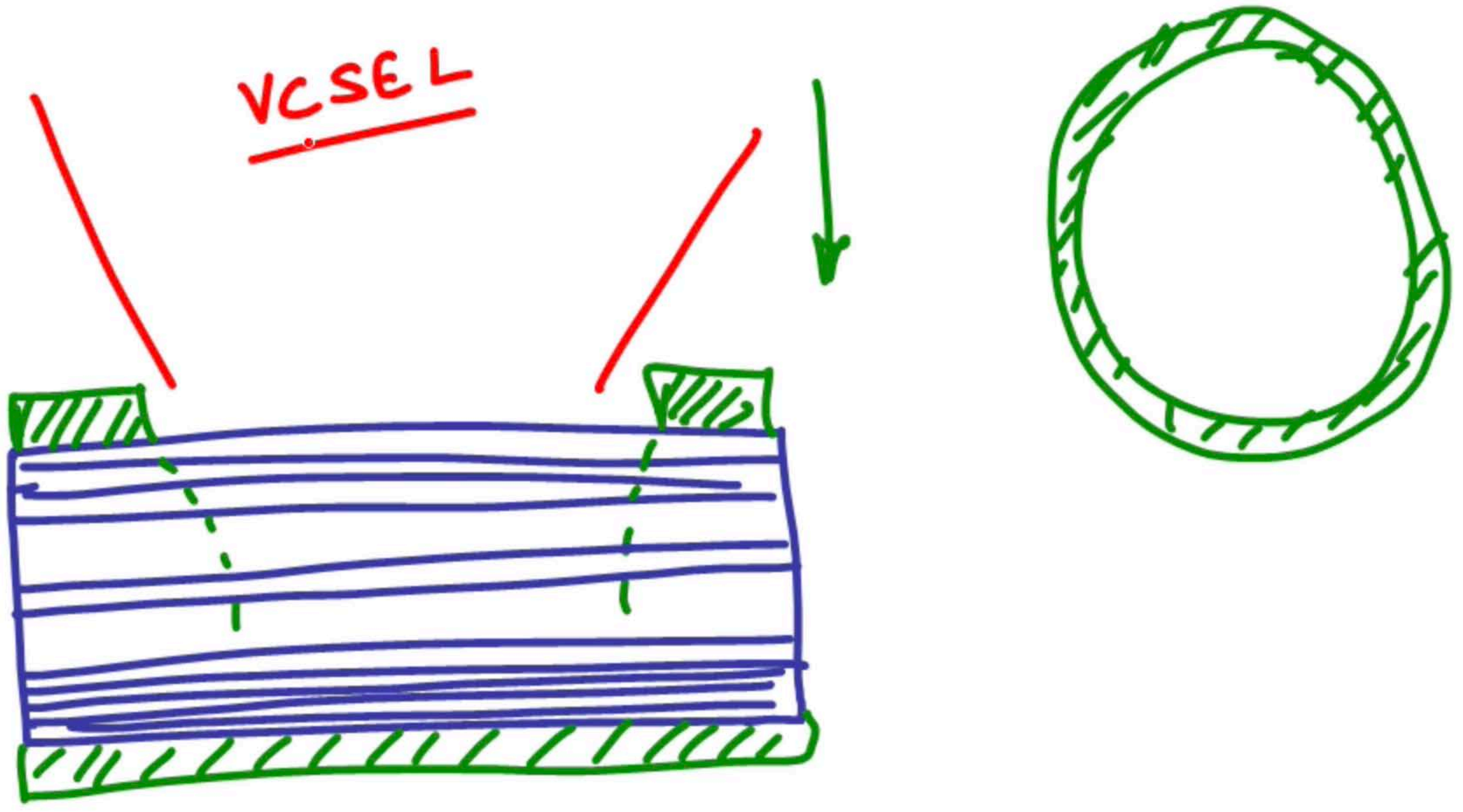
12 emitters

× 10 W (11A, 2V)

= 120 W in

105/125 μm




VCSEL

Internal photon flux, $\Phi_{in} = \begin{cases} \eta_i \dfrac{I - I_{th}}{e} & I > I_{th} \\ 0 & I \leq I_{th} \end{cases}$

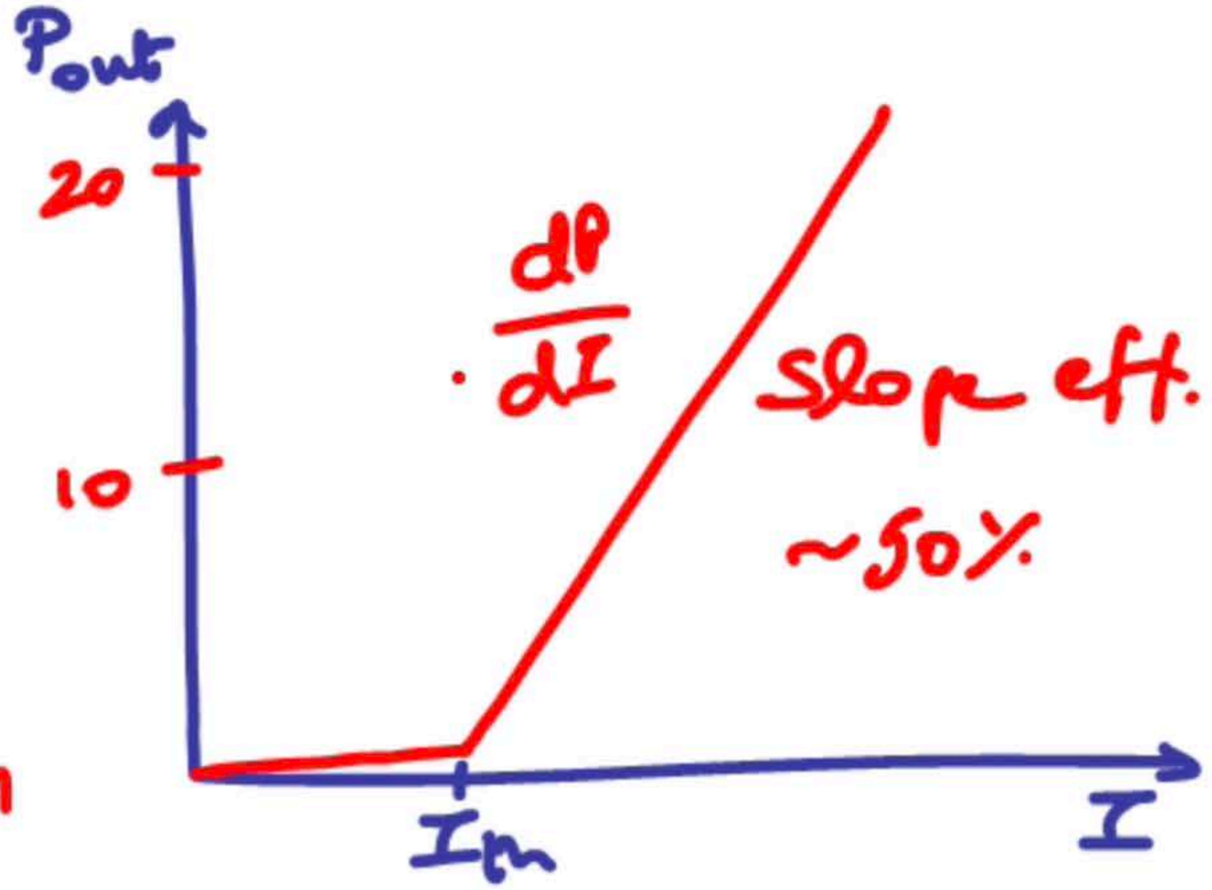
$\lambda_B = 2 n_{eff} \Lambda$

Single longitudinal mode

Distributed Feedback Laser (DFB)

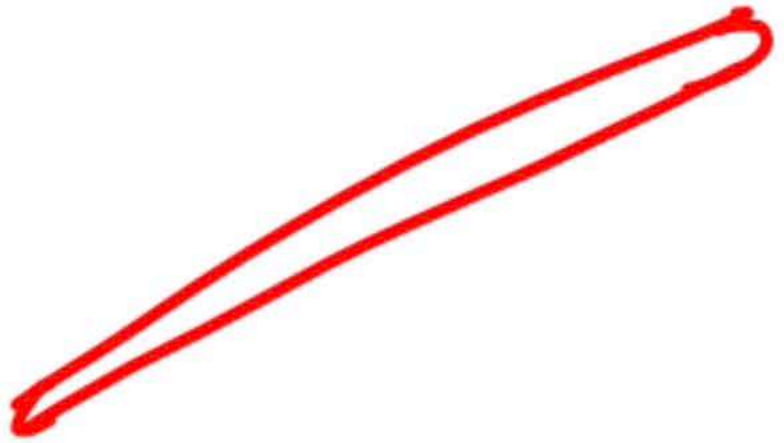
Output photon flux. $\Phi_{out} = \eta_e \Phi_{in}$ where $\eta_e = \dfrac{\alpha_{m2}}{\alpha_r}$

Output power, $P_{out} = \Phi_{out} \cdot h\nu = \eta_i \eta_e \cdot \dfrac{I - I_{th}}{e} \cdot h\nu$



Multimode

Broad-stripe



12 emitters
× 10 W (11 A, 2 V)
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