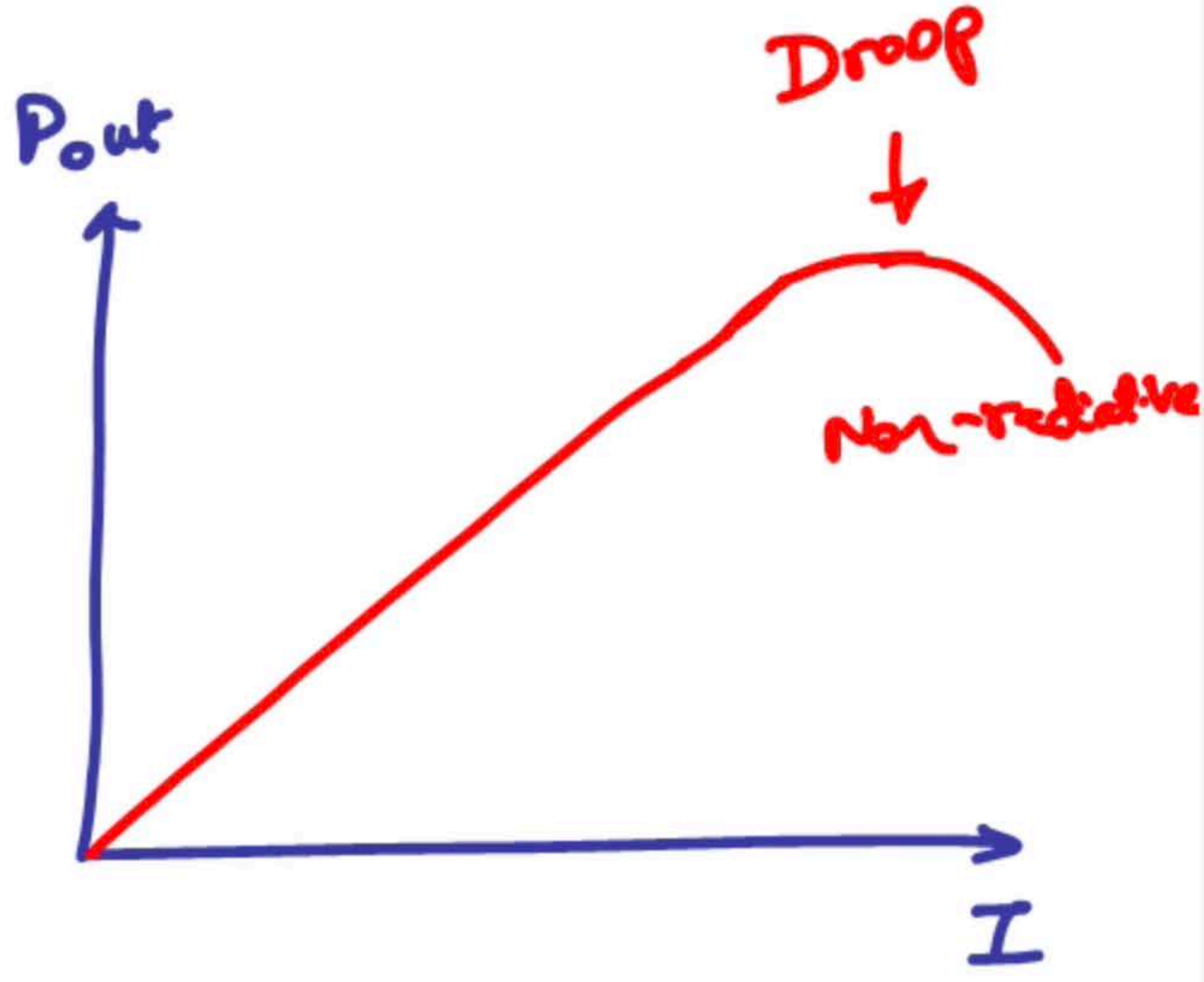
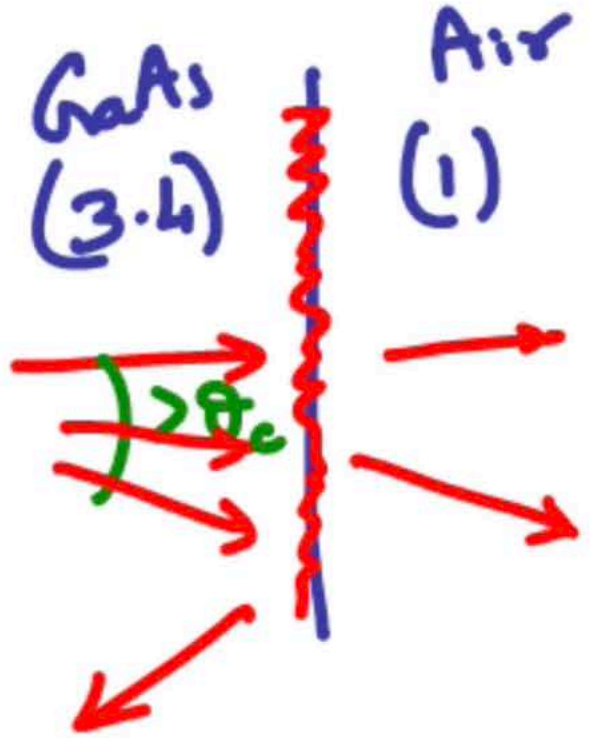
Light Emitting Diodes

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



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



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

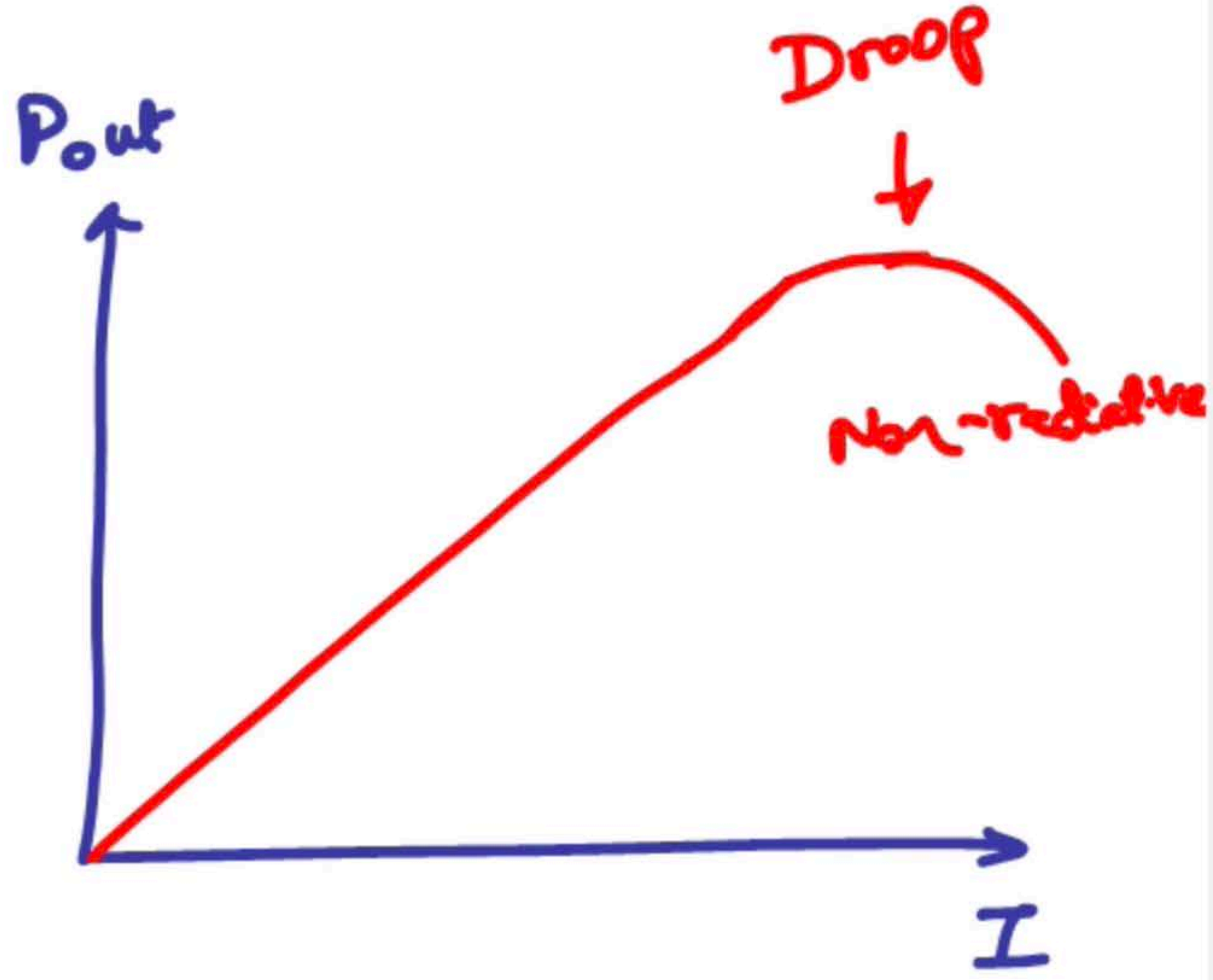
$$\left.\begin{array}{c}\text{Fraction of light} \\ \text{escaping}\end{array}\right\} = 1 - \cos\theta_c = 1 - \sqrt{1 - \left(\frac{1}{n}\right)^2} \simeq \frac{1}{2n^2}$$

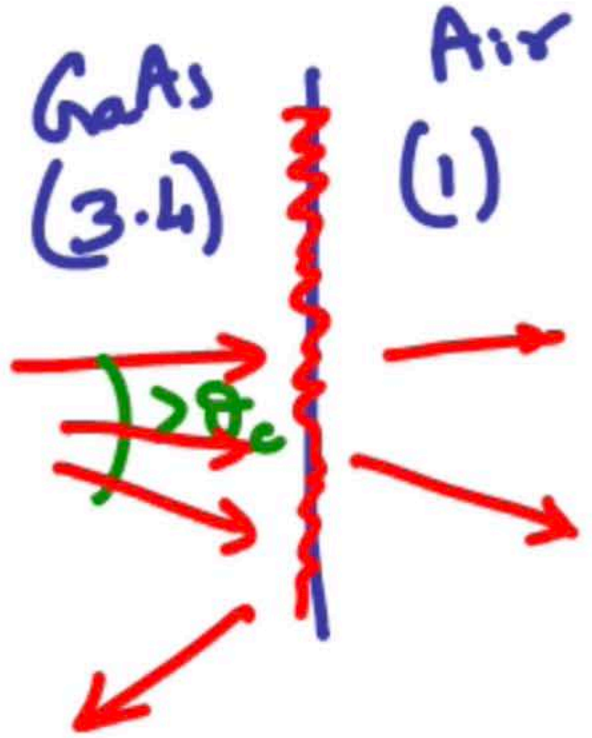
$$\eta_{out} = \frac{4n}{(n+1)^2} \cdot \frac{1}{2n^2} = \frac{2}{n(n+1)^2}$$

Light Emitting Diodes

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

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





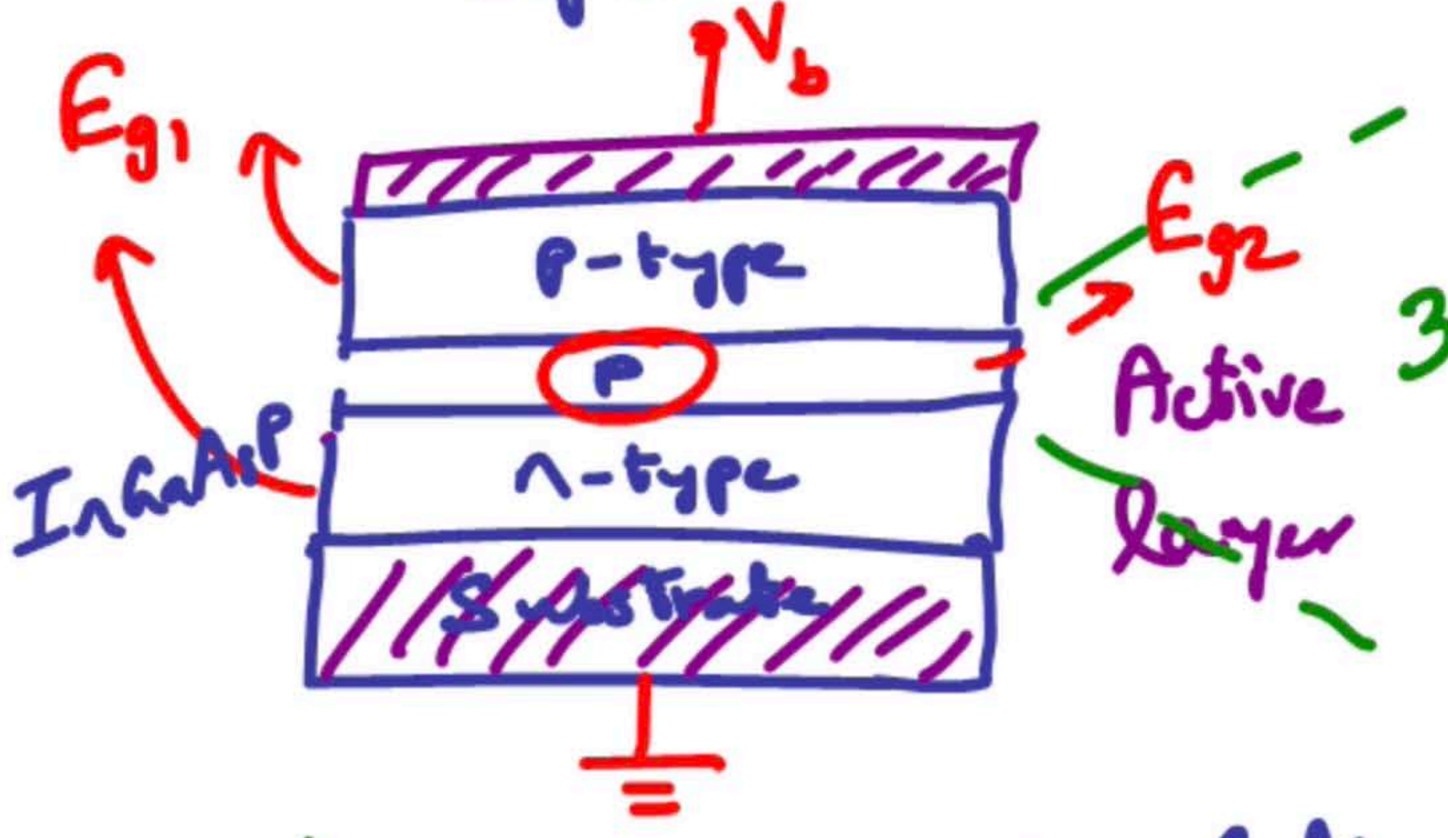
$$R = \left(\frac{n-1}{n+1}\right)^2 \Rightarrow T = 1 - \left(\frac{n-1}{n+1}\right)^2 = \frac{4n}{(n+1)^2}$$

Fraction of light escaping $\Big\} = 1 - \cos\theta_c = 1 - \sqrt{1 - \left(\frac{1}{n}\right)^2} \simeq \frac{1}{2n^2}$

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

Light Emitting Diodes

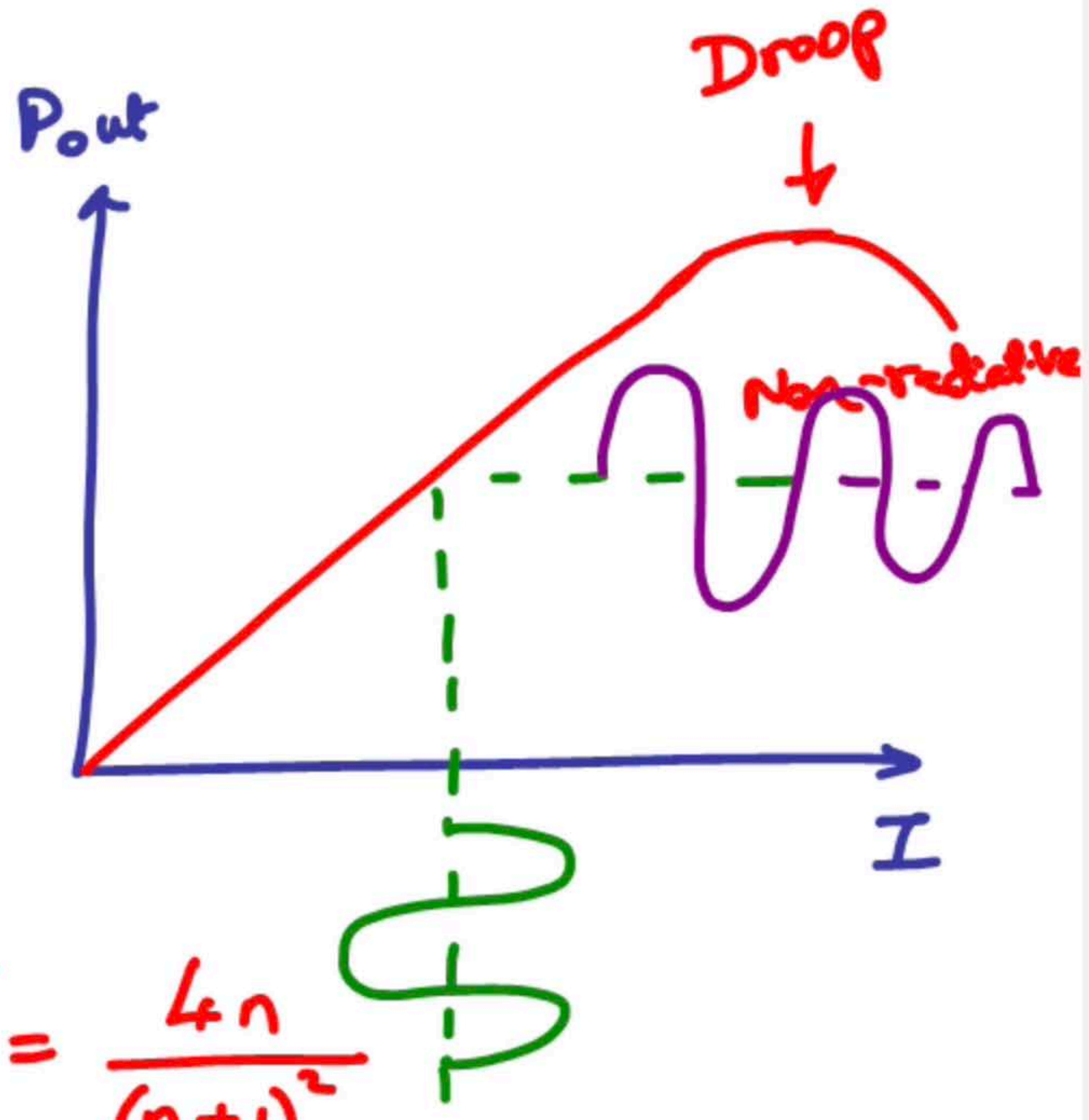
Edge-emitting LED



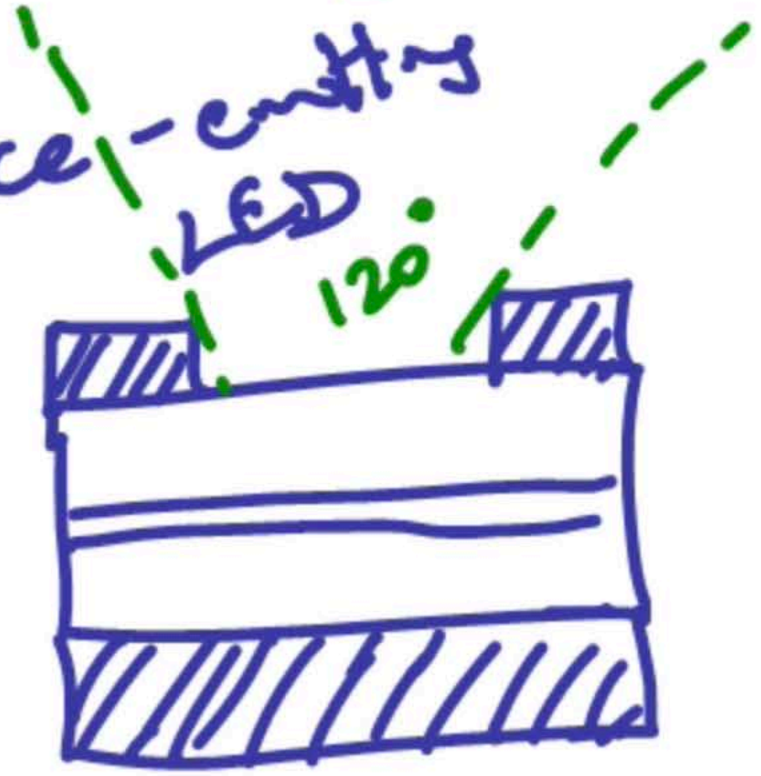
Output Power.

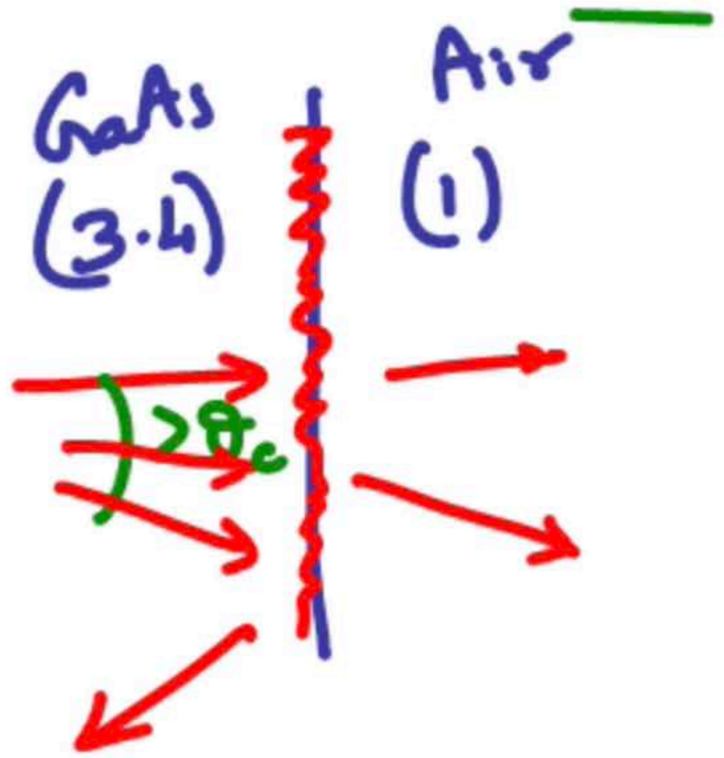
$$P_{out} = \frac{I}{e} h\nu \, \eta_{int} \, \eta_{out}$$

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



Surface-emitting LED





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

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

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

Modulation Characteristics

$N \rightarrow$ electron density

$$\frac{dN}{dt} = \frac{I}{e.V} - \frac{N}{\tau_c} \quad \text{where} \quad \frac{1}{\tau_c} = \frac{1}{\tau_r} + \frac{1}{\tau_{nr}}$$

Suppose $I(t) = I_b + I_m \exp(j\omega_m t)$

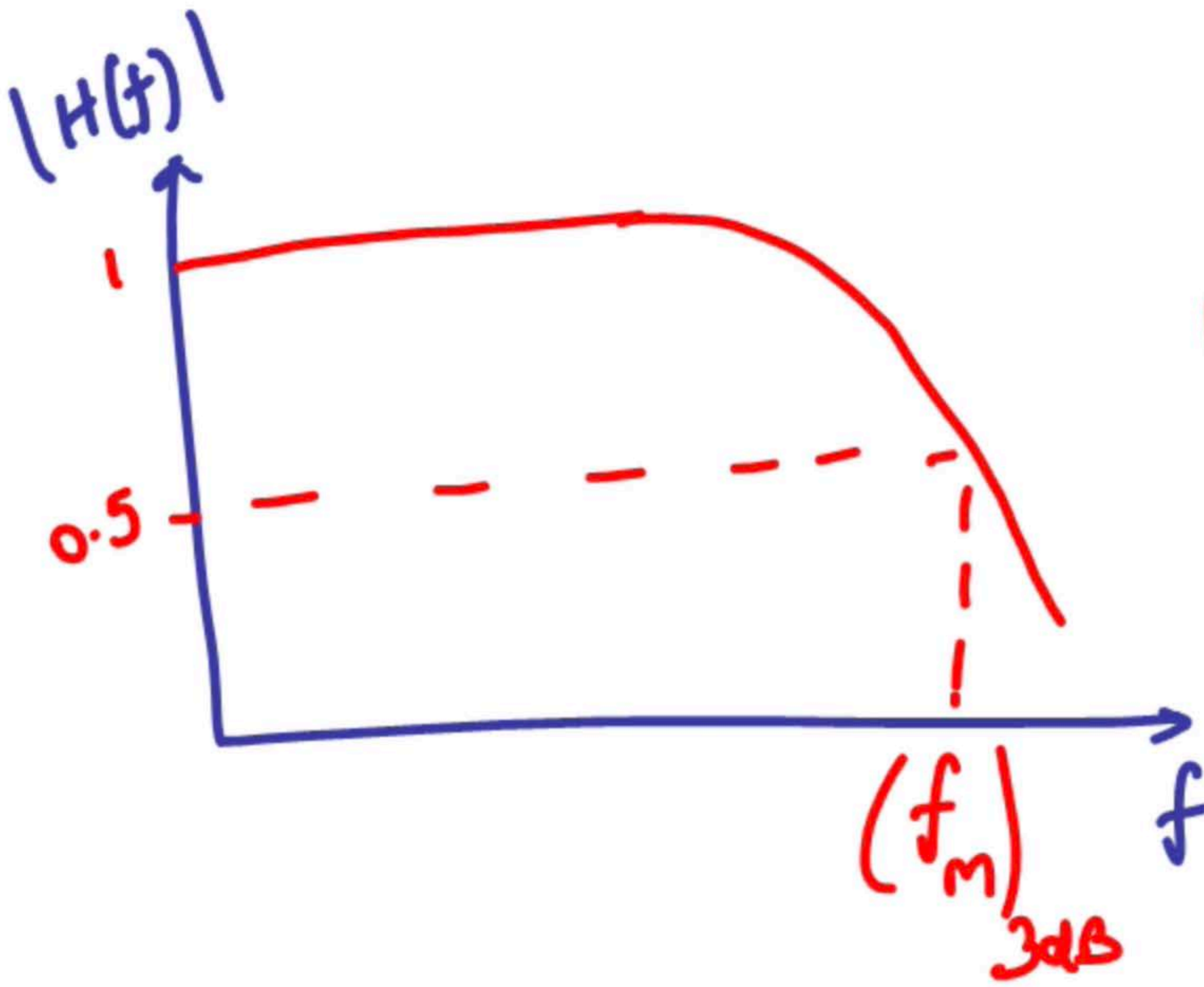
$$N(t) = N_b + N_m \exp(j\omega_m t)$$

$$N_m(\omega_m) = \frac{\tau_c . I_m/eV}{1 + j\omega_m \tau_c} = \frac{N_m(0)}{1 + j\omega_m \tau_c}$$

Steady state density

Modulation transfer function, $H(f) = \dfrac{N_m(\omega_m)}{N_m(0)}$

$$= \frac{1}{1 + j\omega_m \tau_c}$$



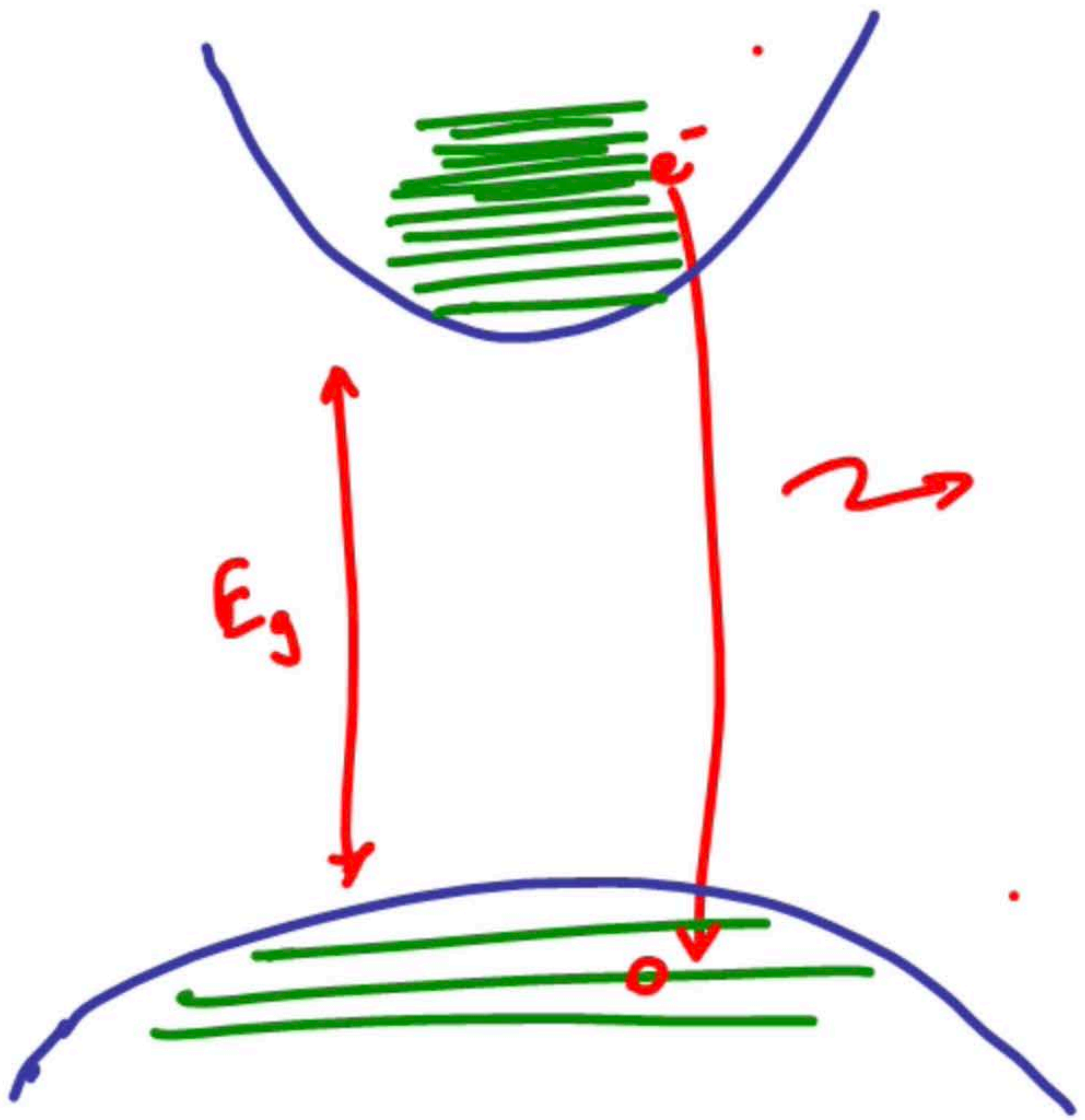
Modulation Bandwidth

$$\boxed{f_{3dB} = \frac{\sqrt{3}}{2\pi \tau_c}}$$

$\tau_r \sim 1\,ns$

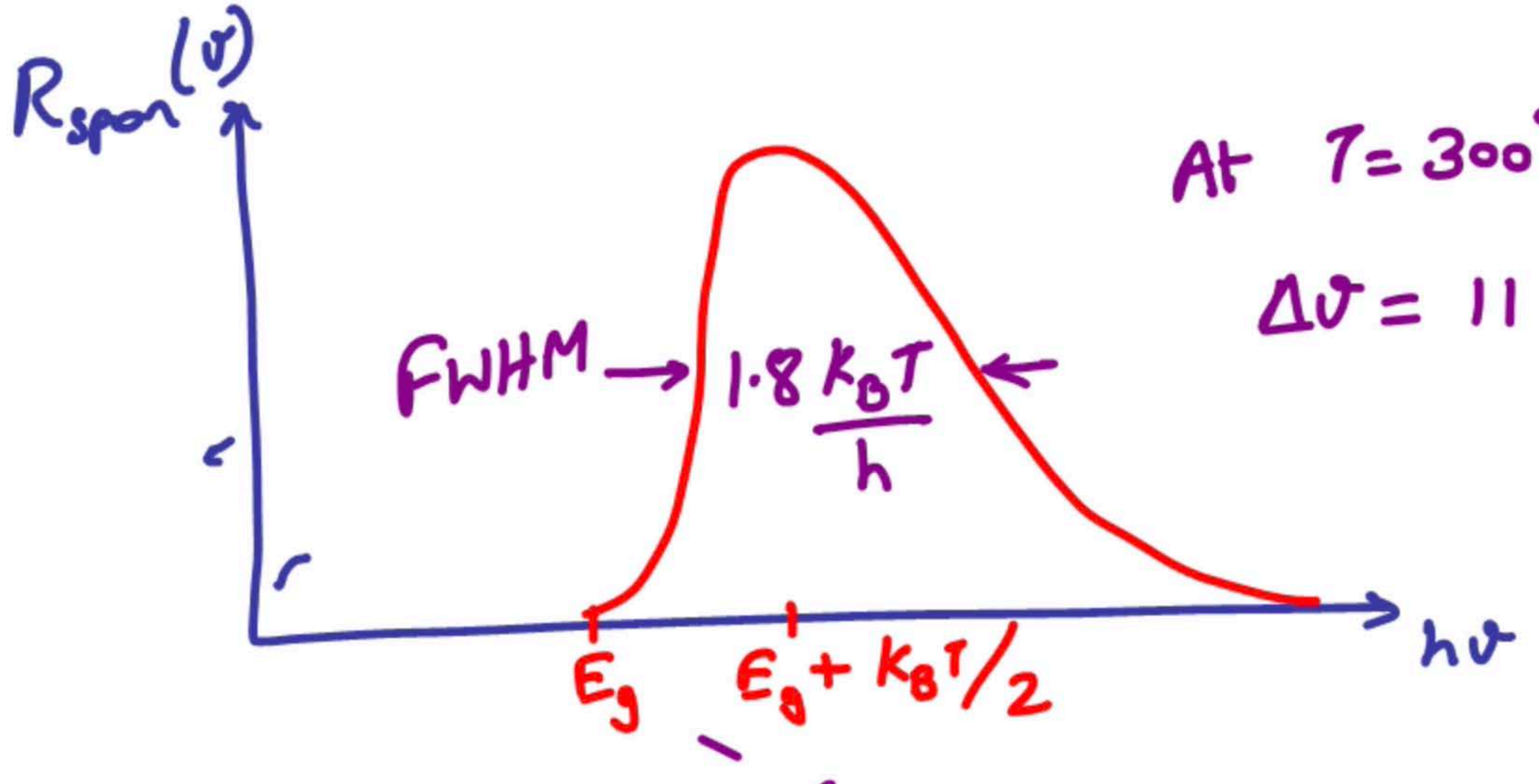
$\Rightarrow f_{3dB} \sim \underline{250\,MHz}$

Spectral Characteristics



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

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



At $T = 300^\circ K$

$\Delta\nu = 11$ THz