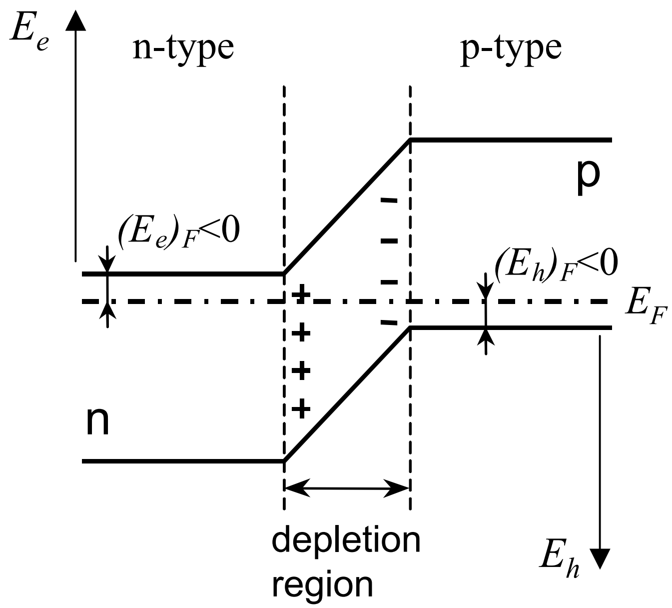
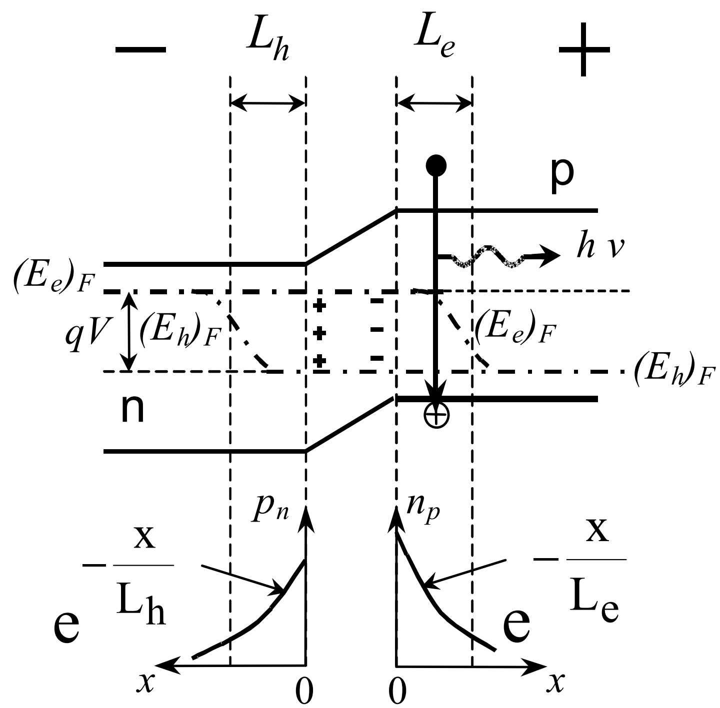
Emission in p-n homojunction
1. Weak doping





$$n_p = (n_p)_0 + \Delta n_p \approx \Delta n_p = \Delta p_p$$
$$p_n = (p_n)_0 + \Delta p_n \approx \Delta p_n = \Delta n_n$$

Diffusion length of electrons and holes in n and p-type regions

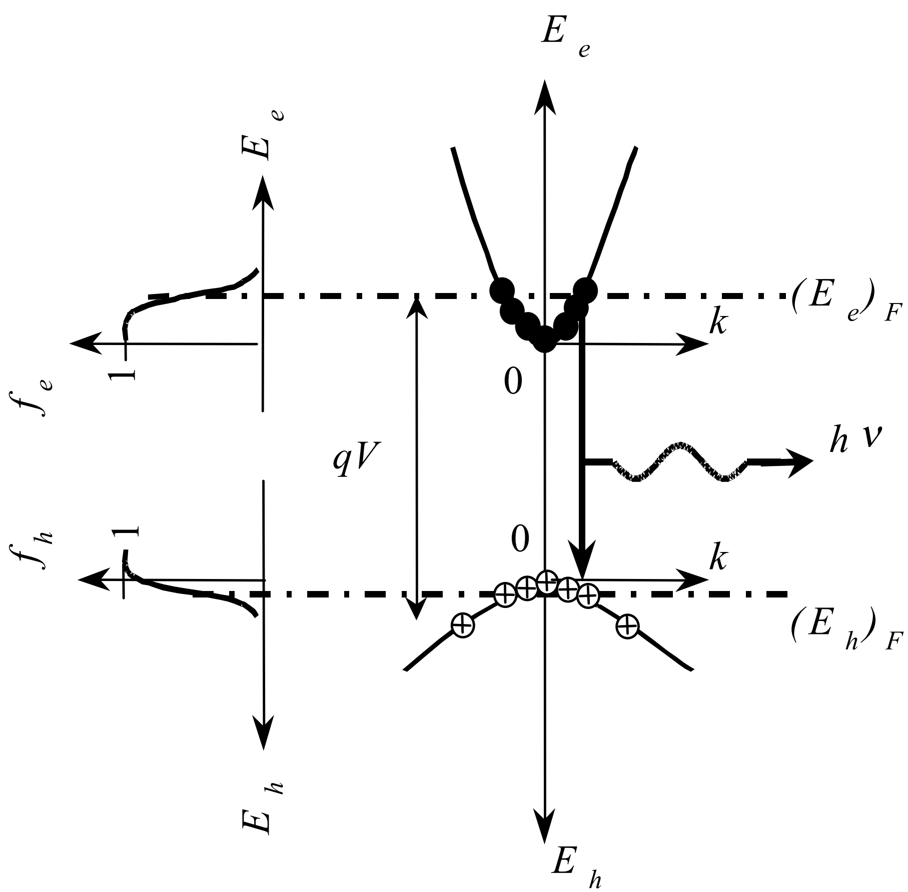
$$L_e = \sqrt{(D_e)_p (\tau_e)_p}$$
$$L_h = \sqrt{(D_h)_n (\tau_h)_n}$$

$(D_e)_p$, $(D_h)_n$ are diffusion coefficients of electrons in p-type region and holes in n-type region

$(\tau_e)_p$, $(\tau_h)_n$ are lifetimes of electrons and holes in p-type and n-type regions accordingly

Emission in p-n homojunction

1. Heavy doping. Amplification of light.



Amplification (population inversion) condition

$$f_e(E_e) + f_h(E_h) > 1$$

$$f_e(E_e) > 1 - f_h(E_h)$$

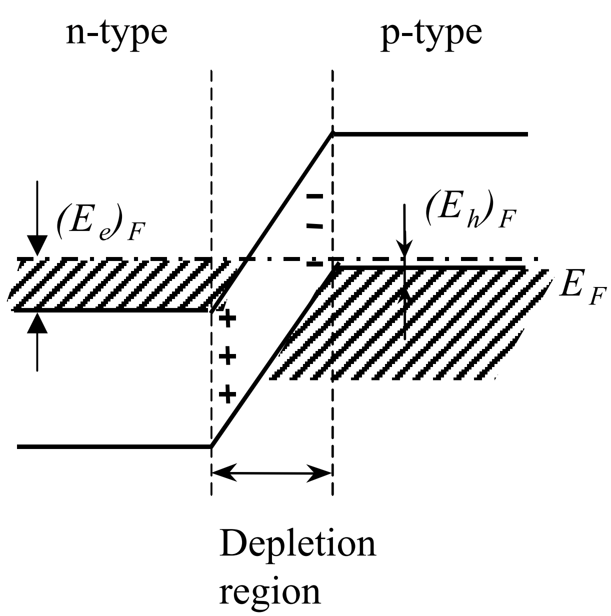
$$f_e^{CB}(E_e) > f_e^{VB}(E_h)$$

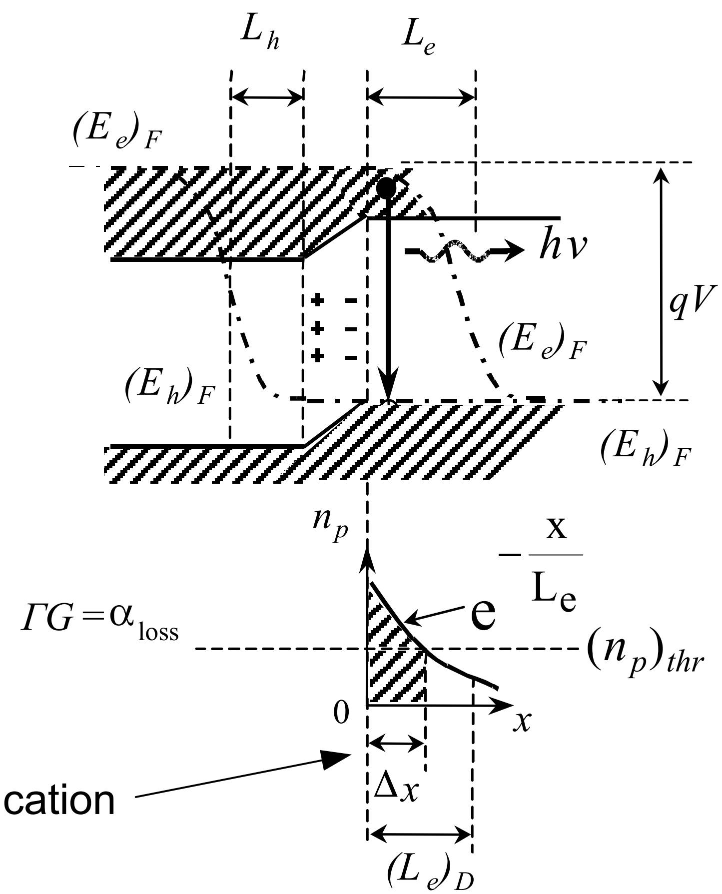
can be rewritten as

$$exp\left[\frac{(qV - h\nu)}{k_B T}\right] > 1$$

Emission in p-n homojunction

2. Heavy doping. Amplification of light.

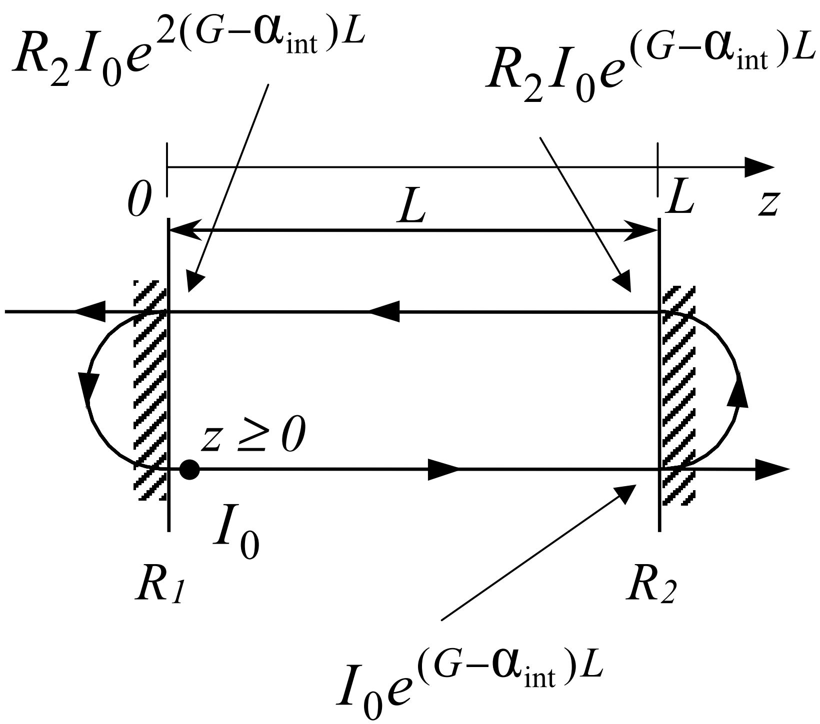




Δx is the region of the light amplification

$\Delta x \leq L_e$

Threshold condition for lasing



1. $I_o e^{(G-\alpha_{int})L} R_2 e^{(G-\alpha_{int})L} R_1 \geq I_o$

$$G = \alpha_{int} + \frac{1}{2L}\ln\frac{1}{R_1 R_2} = \alpha_{int} + \alpha_m = \alpha_{loss}$$

α_{int} – internal loss (mainly due to free carrier absorption)

α_m– mirror loss (reflection is less than 100%)

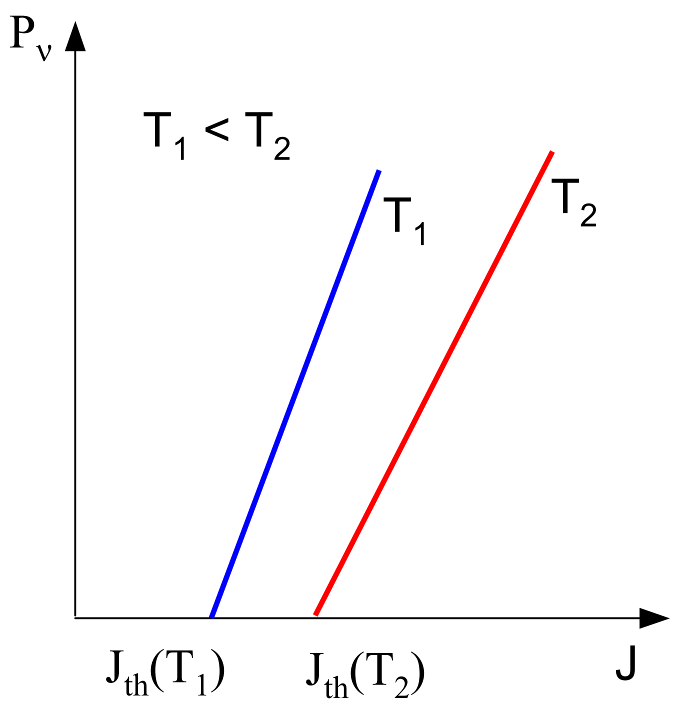
In the waveguide: $\Gamma G = g = \alpha_{loss}$, g is modal gain, Γ is optical confinement

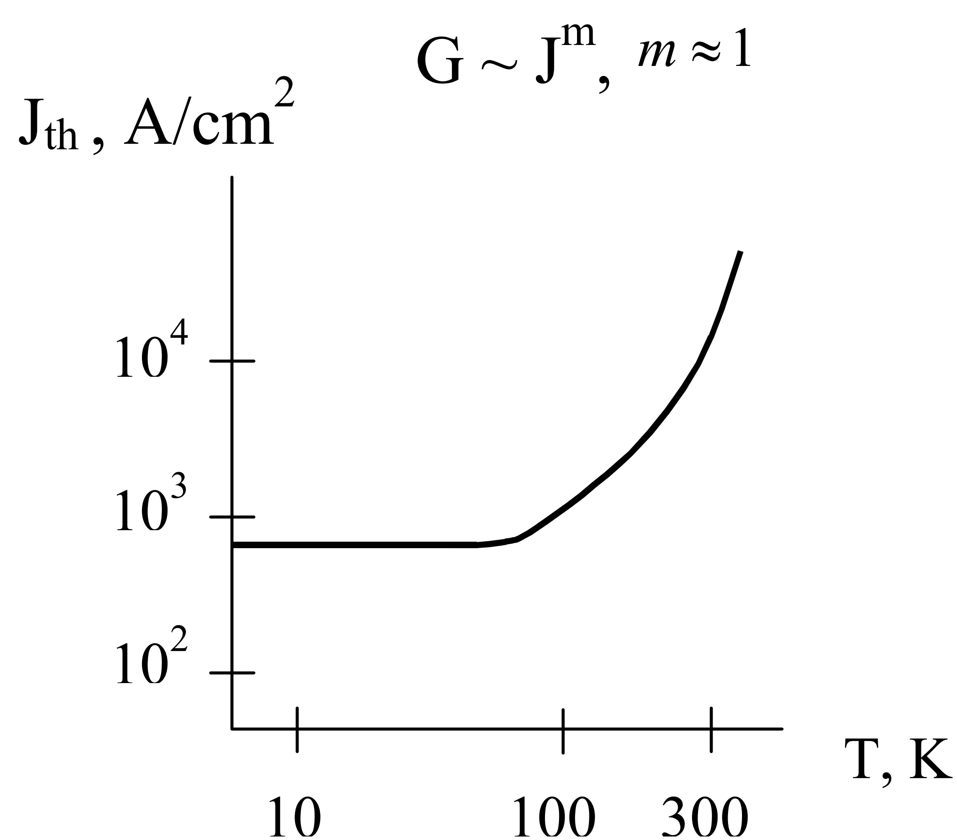
$\Gamma \approx \Delta x/d$, Δx – region of amplification, d – waveguide thickness ($d \approx \lambda/n$)

2. $\frac{2L}{\lambda/n} = m, \quad m = 1,2\ldots \quad m >> 1 \quad \nu_{m+1} - \nu_m = \Delta\nu = \frac{c}{2Ln}$

Emission in p-n homojunction

Why does j_{th} increase with increasing T?
The main reason is change of distribution function with T.

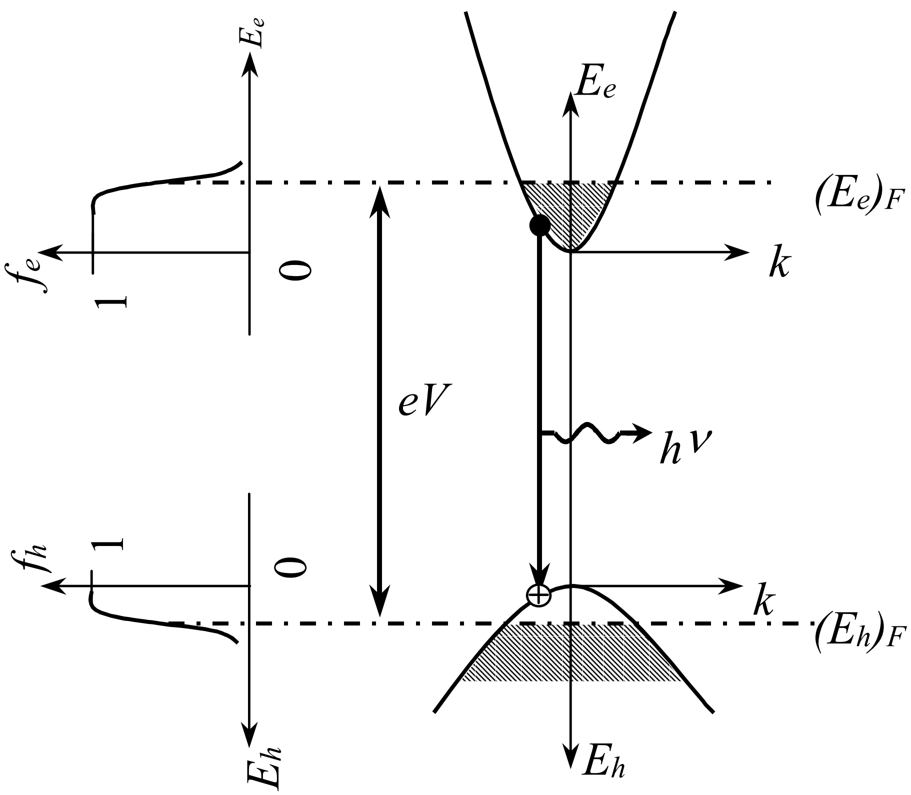


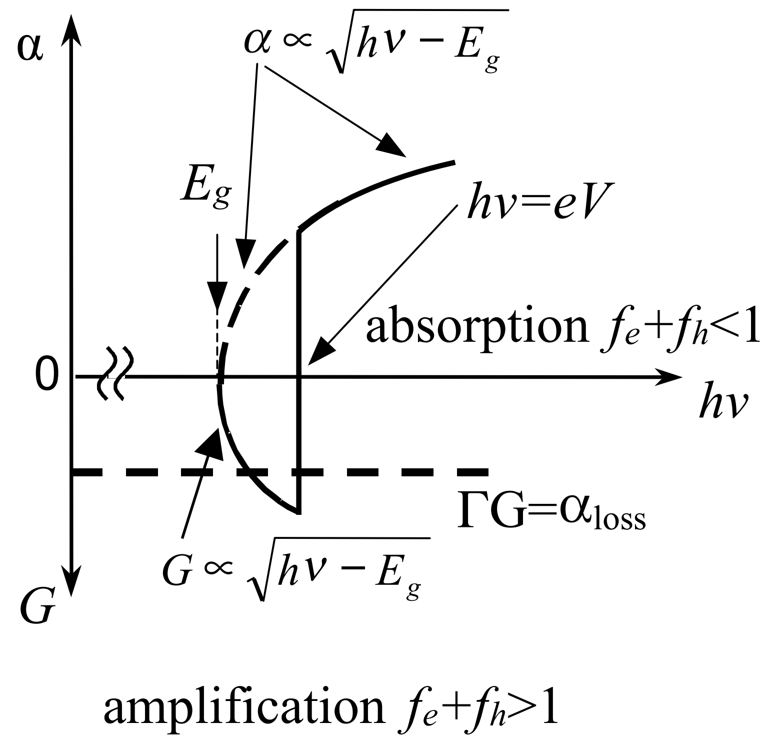


Emission in p-n homojunction

Temperature dependence of the threshold current or gain

Low Temperatures, T ~ 0K



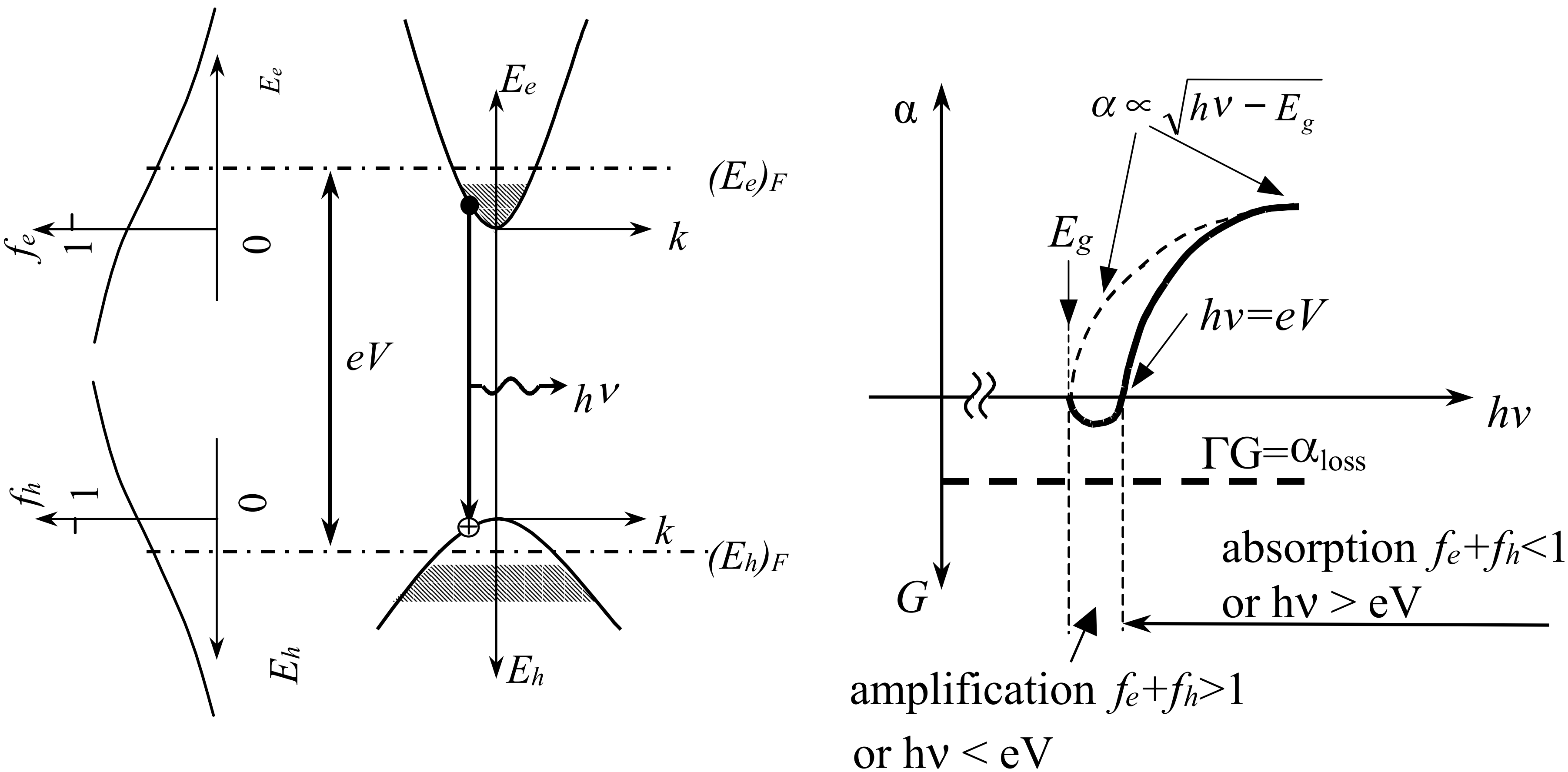


Gain can overcome losses and generation is possible

Emission in p-n homojunction

Temperature dependence of the threshold current or gain

Room Temperatures



Gain can not overcome losses and generation is not possible