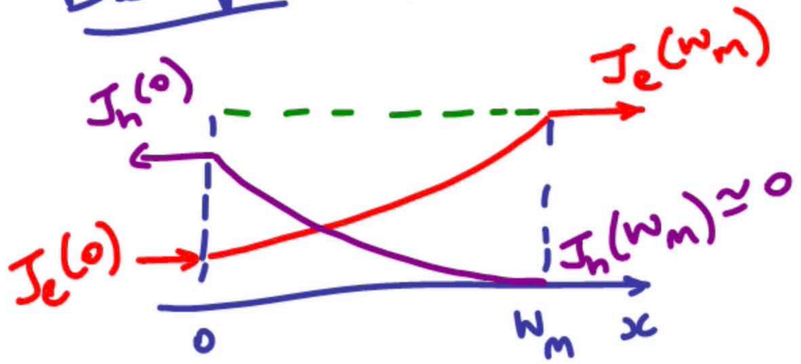
Example: APD



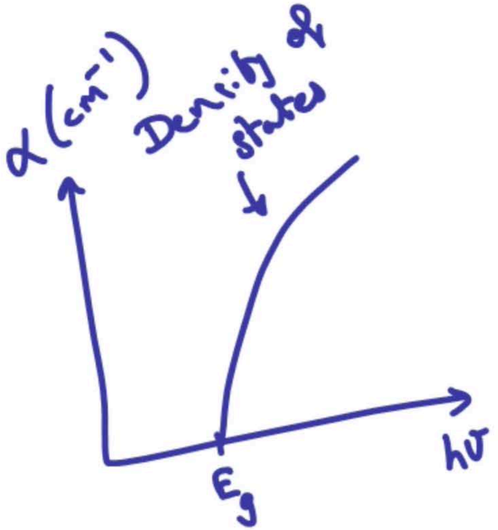
$$M = \frac{J_e(W_m)}{J_e(0)}$$

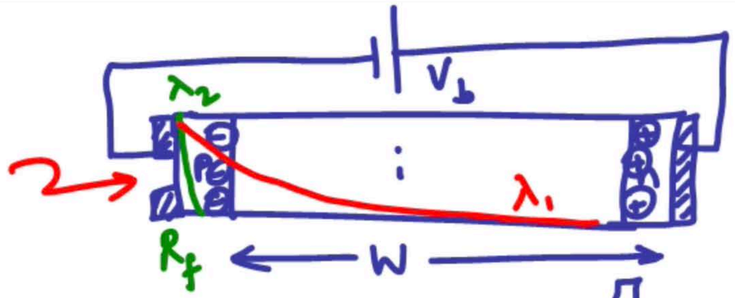
$$\frac{dJ_e}{dx} = \alpha_e J_e(x) + \alpha_h J_h(x)$$

Charge neutrality $\quad \frac{dJ_e}{dx} = -\frac{dJ_h}{dx}$

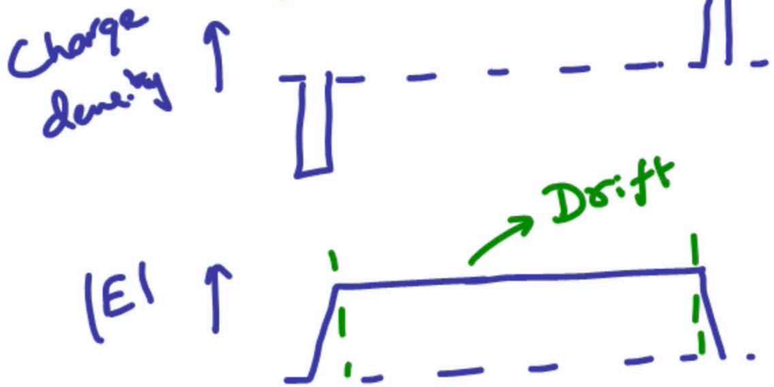
$$J_e(x) + J_h(x) = \text{const.} = J_e(W_m)$$

$$M = \frac{\alpha_e - \alpha_h}{\alpha_e \exp\left[-(\alpha_e - \alpha_h) W_m\right] - \alpha_h}$$





$\lambda_2 \ll \lambda_1$



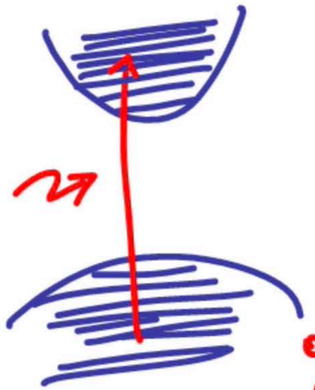
Responsivity, $\mathcal{R} = \frac{I_p}{P_{in}}$ (A/W)

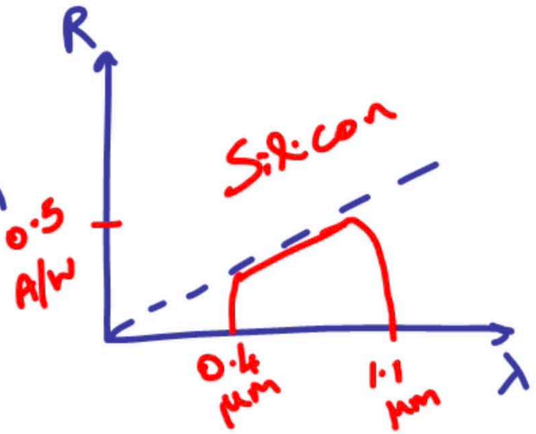
$$I_p = \frac{P_{in}}{h\nu}(1-R_f)\,\eta\, e\,(1-e^{-\alpha W})$$

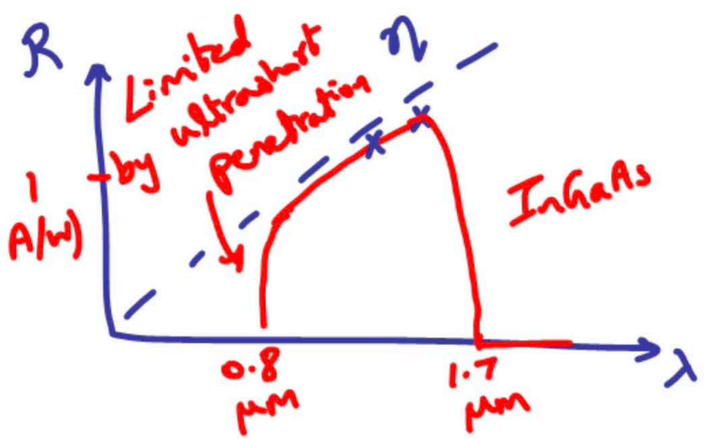
η: 0.9 for InGaAs, 0.7 for Si

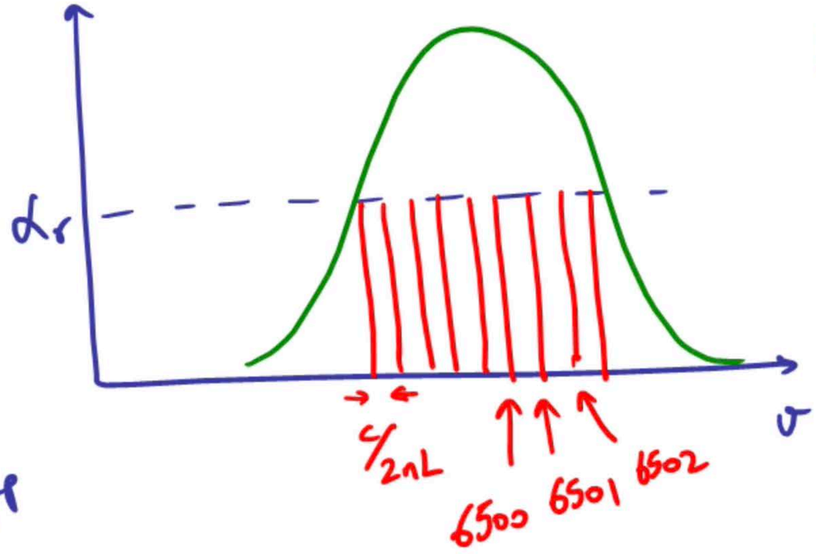
$$\mathcal{R} = \frac{\eta e}{h\nu} \text{ A/W}$$

$$\boxed{\mathcal{R} = \frac{\eta\,\lambda(\mu m)}{1.24}}$$

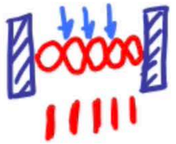






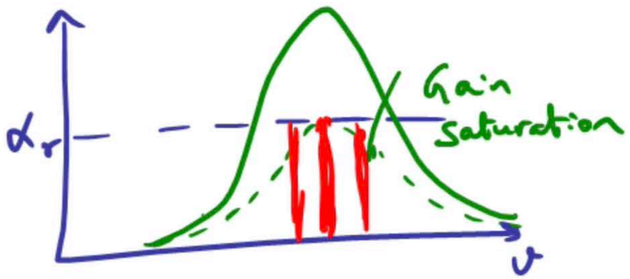


Spatial Hole Burning

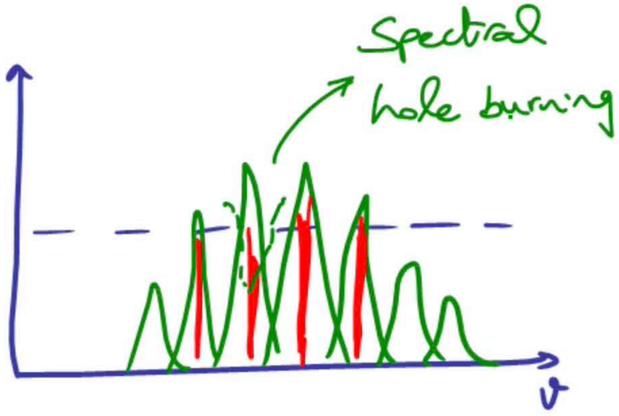


Homogeneous

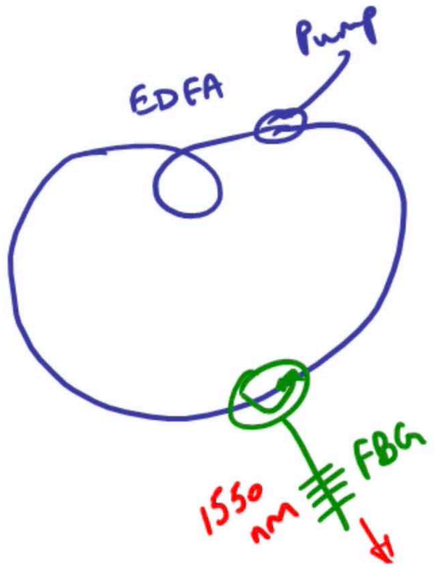
Ex: Semiconductor

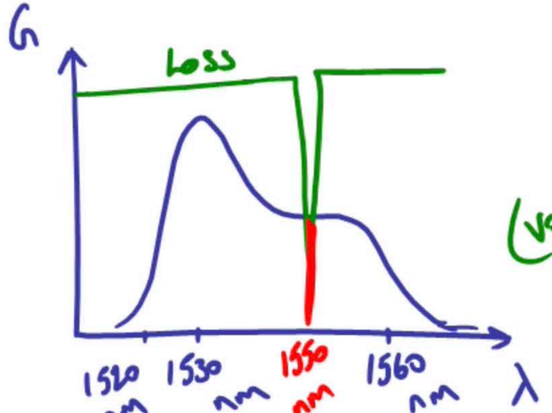


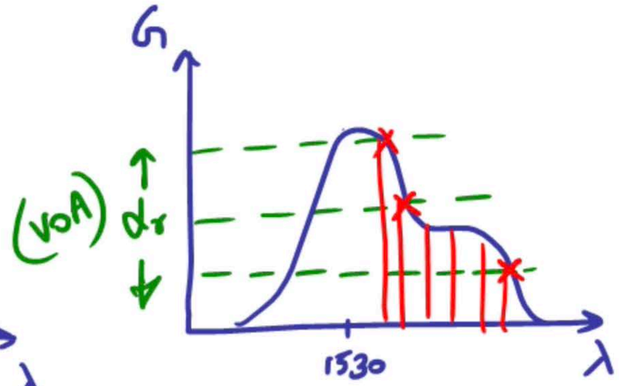
Inhomogeneous



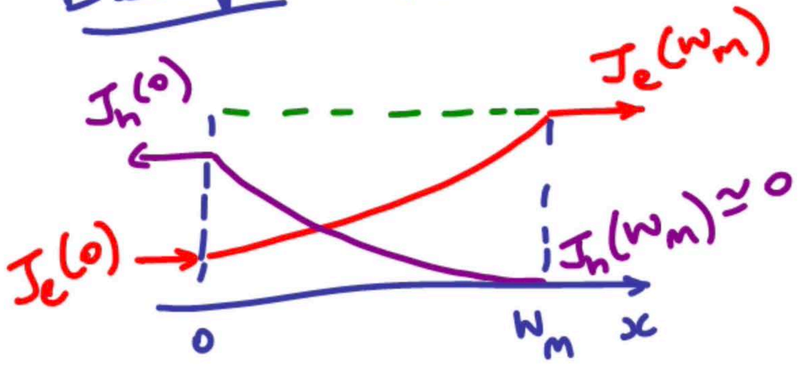
Ex: Nd: glass







Example: APD



Gain, $M = \dfrac{J_e(W_m)}{J_e(0)}$

$$\frac{dJ_e}{dx} = \alpha_e J_e(x) + \alpha_h J_h(x)$$

Charge neutrality $\quad \dfrac{dJ_e}{dx} = -\dfrac{dJ_h}{dx}$

$J_e(x) + J_h(x) = \text{const.}$

$= J_e(W_m)$

Ionization ratio, $K = \dfrac{\alpha_h}{\alpha_e}$

$$M = \frac{\alpha_e - \alpha_h}{\alpha_e \exp\left[-(\alpha_e - \alpha_h) W_m\right] - \alpha_h}$$

InGaAs $\quad K \sim 0.5$

Si: $\quad K \sim 0.1$

$$M = \frac{1-k}{\exp\left[-(1-k)\alpha_e W_m\right] - k}$$

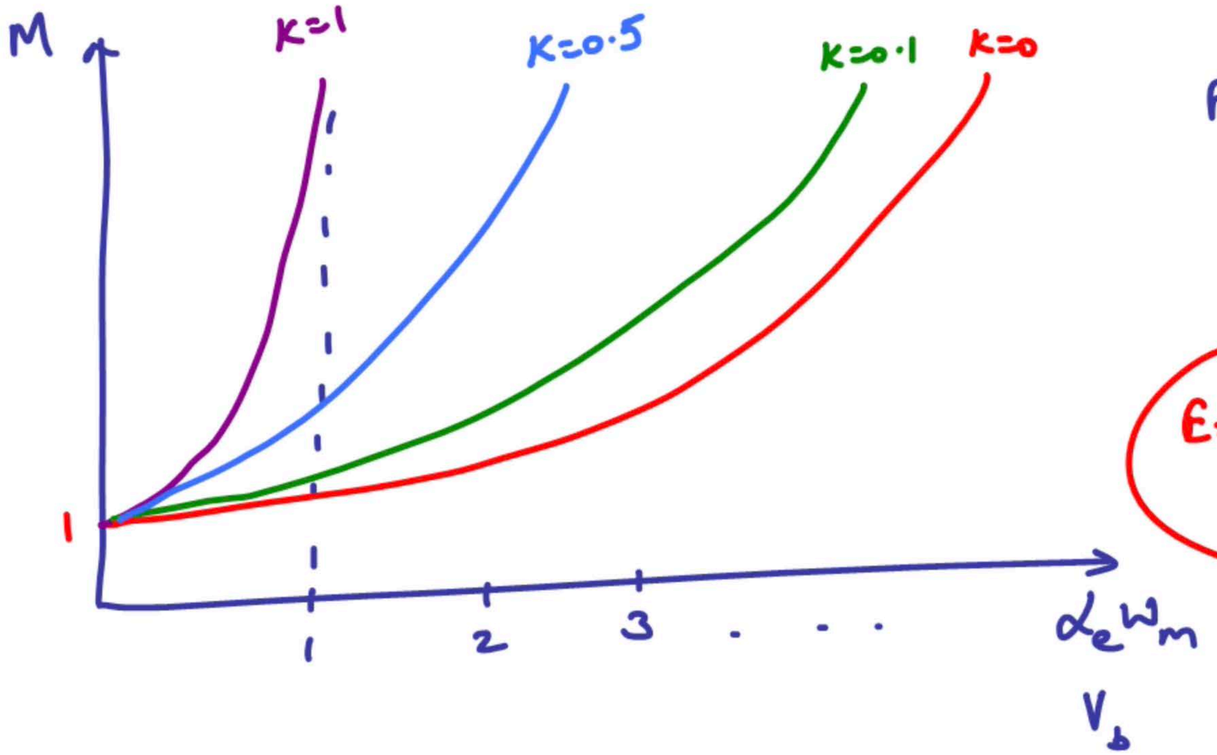
For $k=0$

$$M = \frac{1}{\exp(\alpha_e W_m)}$$

$$\Rightarrow M = \exp(\alpha_e W_m)$$

For $k=1$

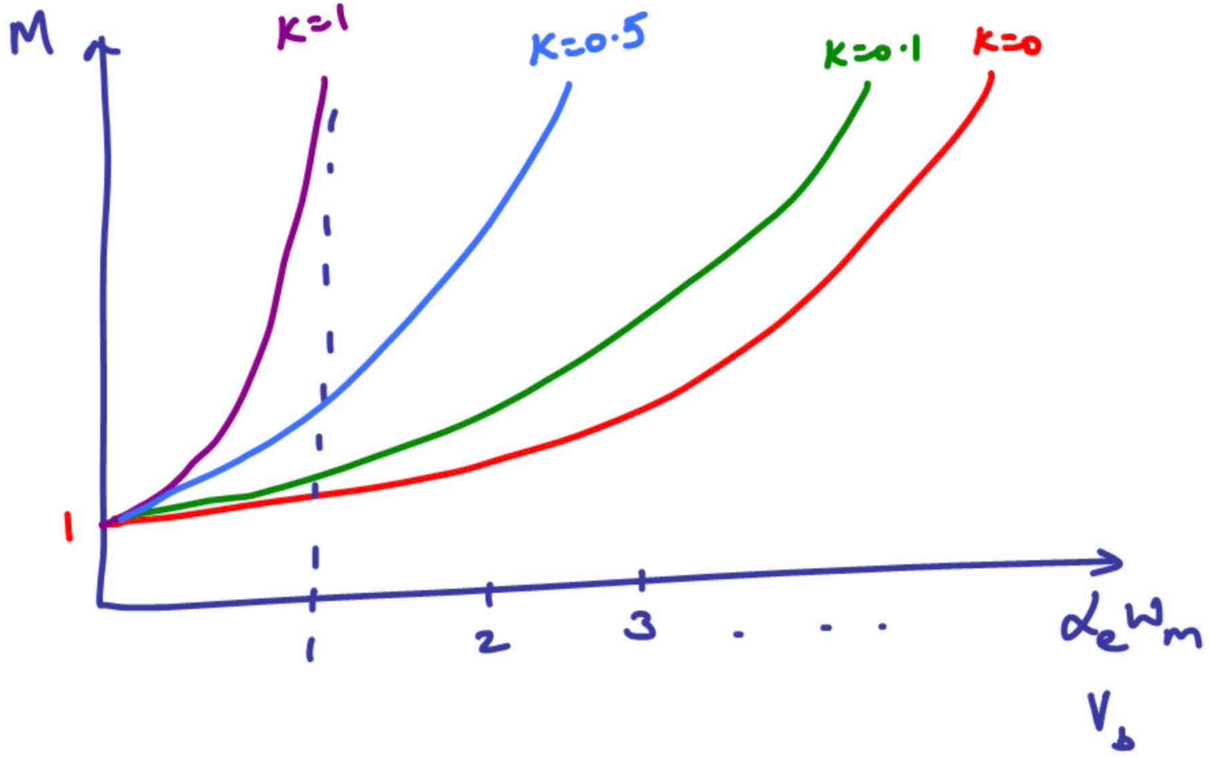
$$M = \frac{1}{1-\alpha_e W_m}$$

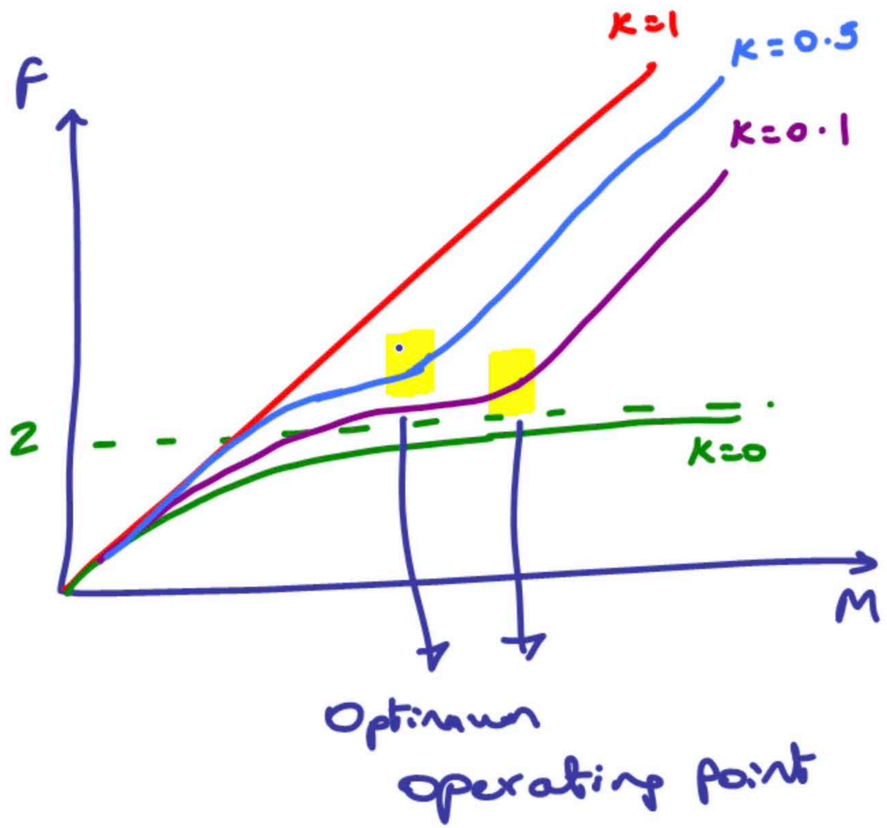


Excess Noise factor (F)

Excess noise factor

$$F = kM + (1-k)\left(2 - \frac{1}{M}\right)$$





For InGaAs ($k=0.5$), $M_{opt} \simeq 10-20$ $V_b = 10-50\ V$ $W_m = 0.1\ \mu m$

Si: ($k=0.1$), $M_{opt} \simeq 100-300$ $V_b = 100-500\ V$ $W_m = 0.5\ \mu m$

Multiplication time, $\tau_m \simeq \frac{M k W_m}{V_{dr}} \Rightarrow \tau_m = 5$ ps (InGaAs)

50 ps (Si)

Noise in photodetectors/receivers

- Photoelectron/shot noise (random arrival of photons/electron generation) $\sigma_s^2 = 2e I_p B$
- Thermal/Johnson Noise $\sigma_T^2 = 4 \frac{K_B T}{R_L} \cdot B$

Excess noise factor

$$F = kM + (1-k)\left(2 - \frac{1}{M}\right)$$