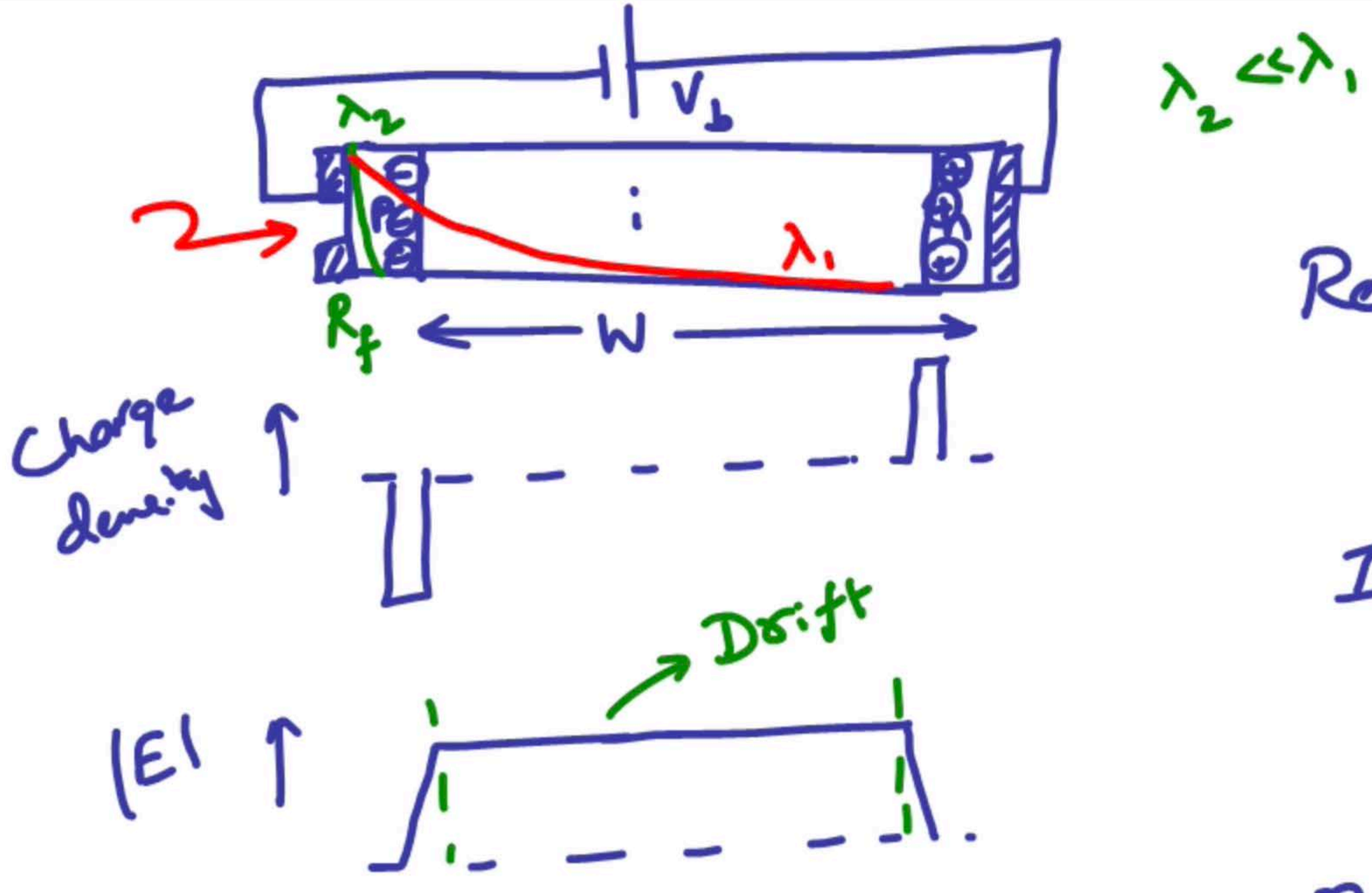
Noise in photodetectors/receivers

Photoelectron/shot noise (random arrival of photons/electron generation)

$$\sigma_s^2 = 2 e I_p B$$

Thermal/Johnson Noise

$$\sigma_T^2 = 4 \frac{K_B T}{R_L} \cdot B$$



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

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

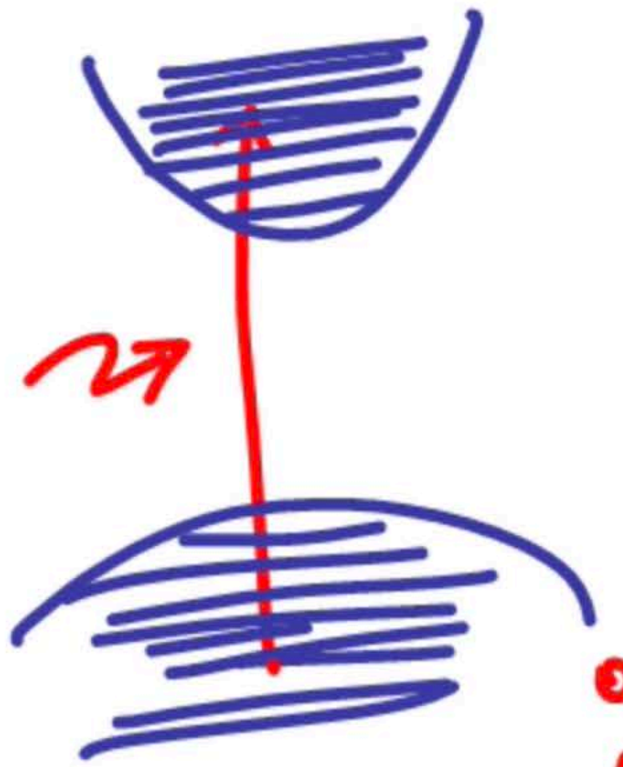
η

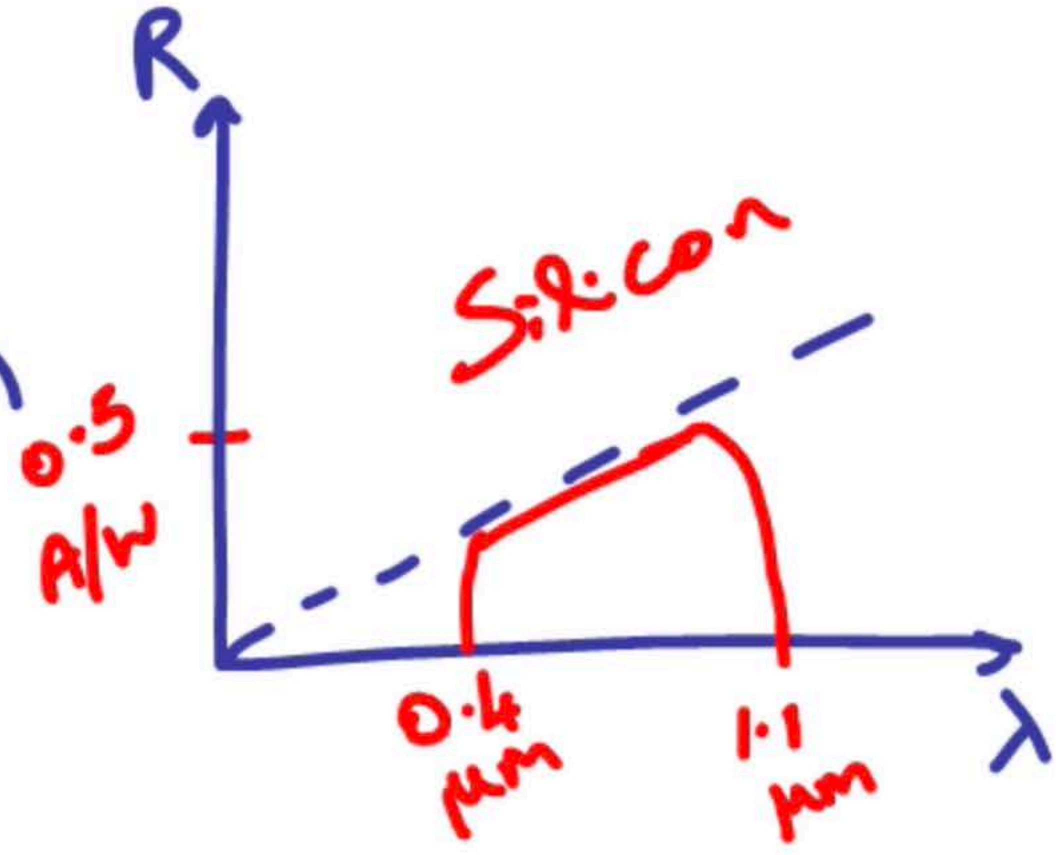
ζ: 0.9 for InGaAs

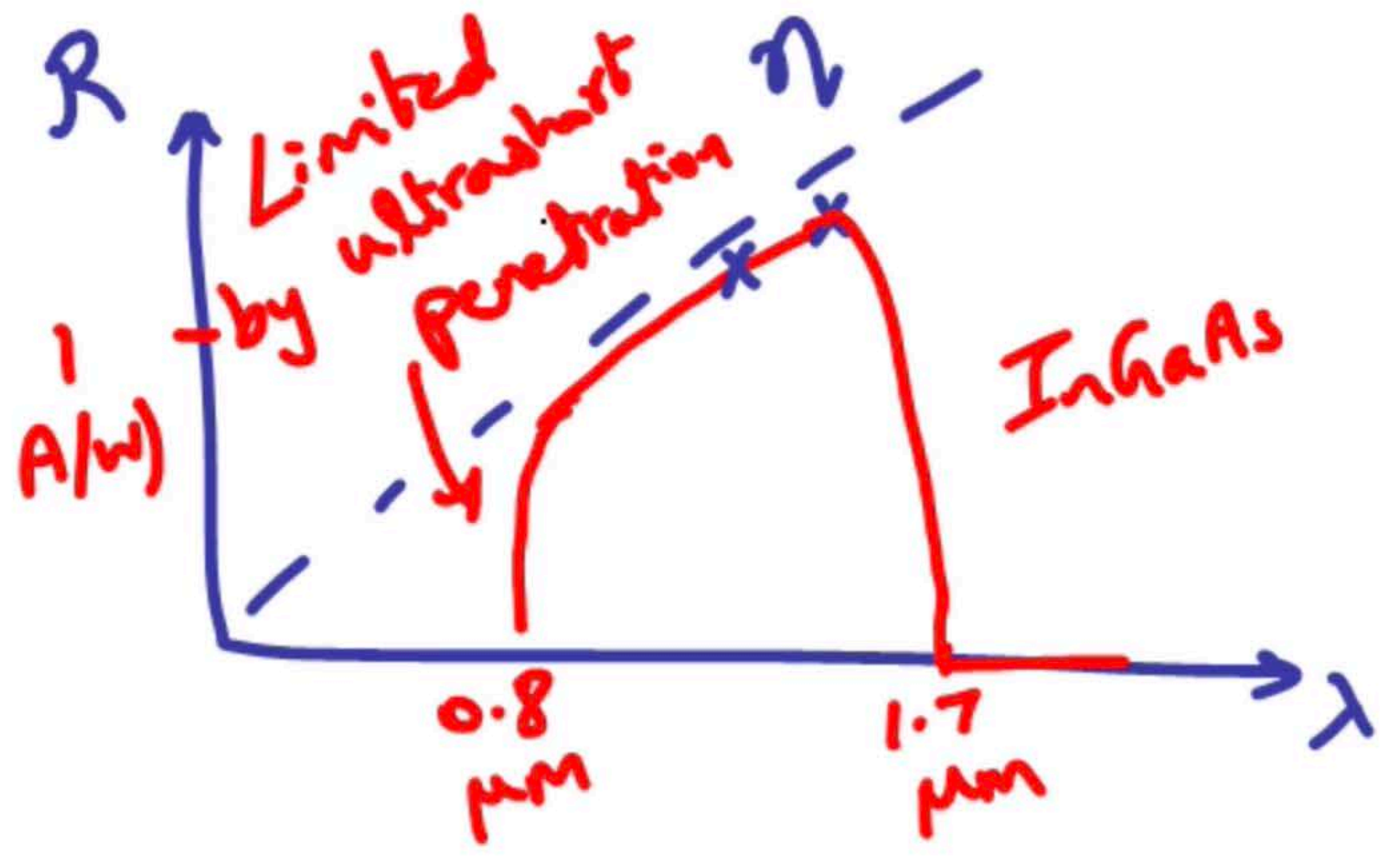
0.7 for Si

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

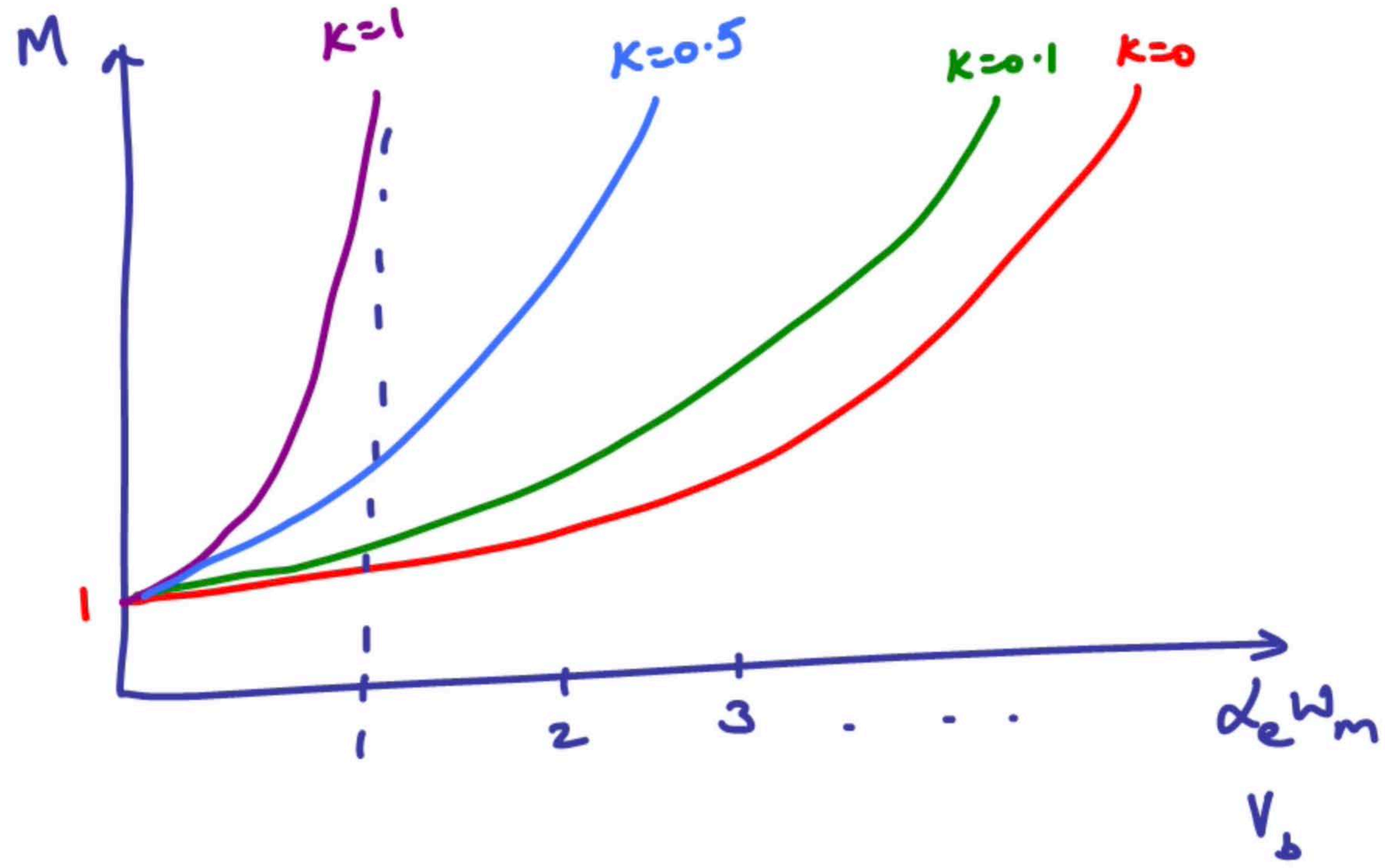
$$\boxed{\mathcal{R} = \frac{\eta\lambda(\mu m)}{1.24}}$$

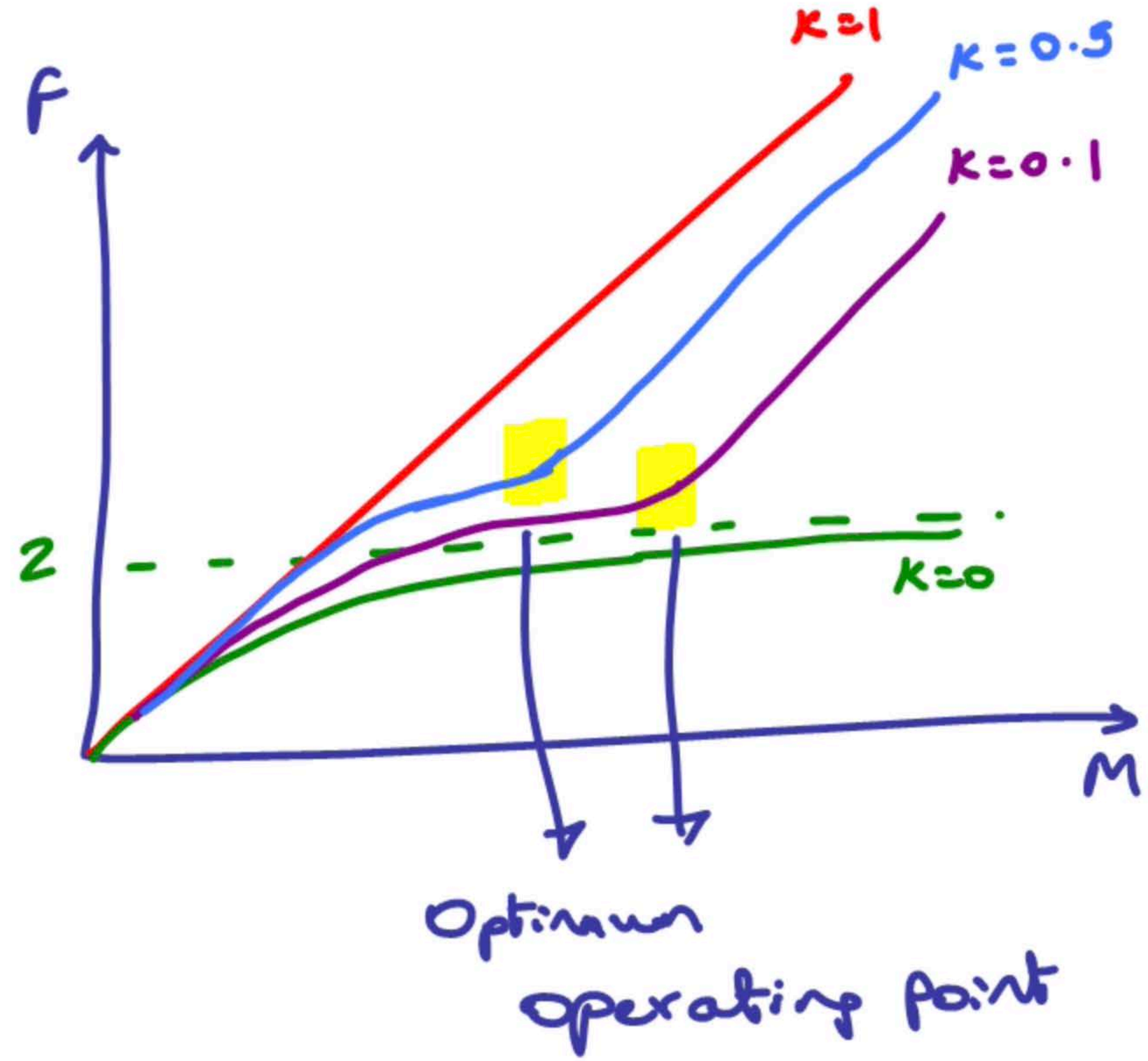






Excess noise factor $F = kM + (1-k)\left(2 - \frac{1}{M}\right)$





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

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

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

$$\sigma_T^2 = 4\frac{K_B T}{R_L} \cdot B$$

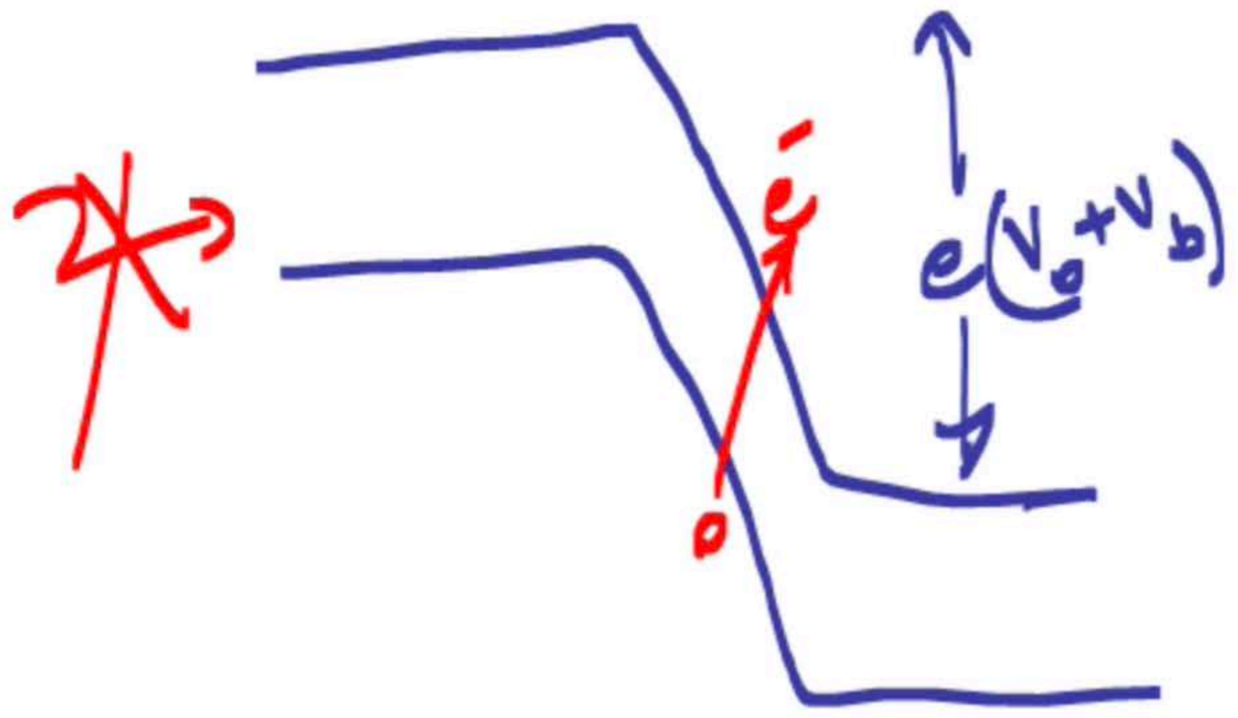
24 / 24

New Pa

Shot noise, $\sigma_s^2 = 2q(I_p + I_d)B$ (PIN)

$$2q\,M^2F\,(I_p + I_d)\,B \quad \text{(APD)}$$

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



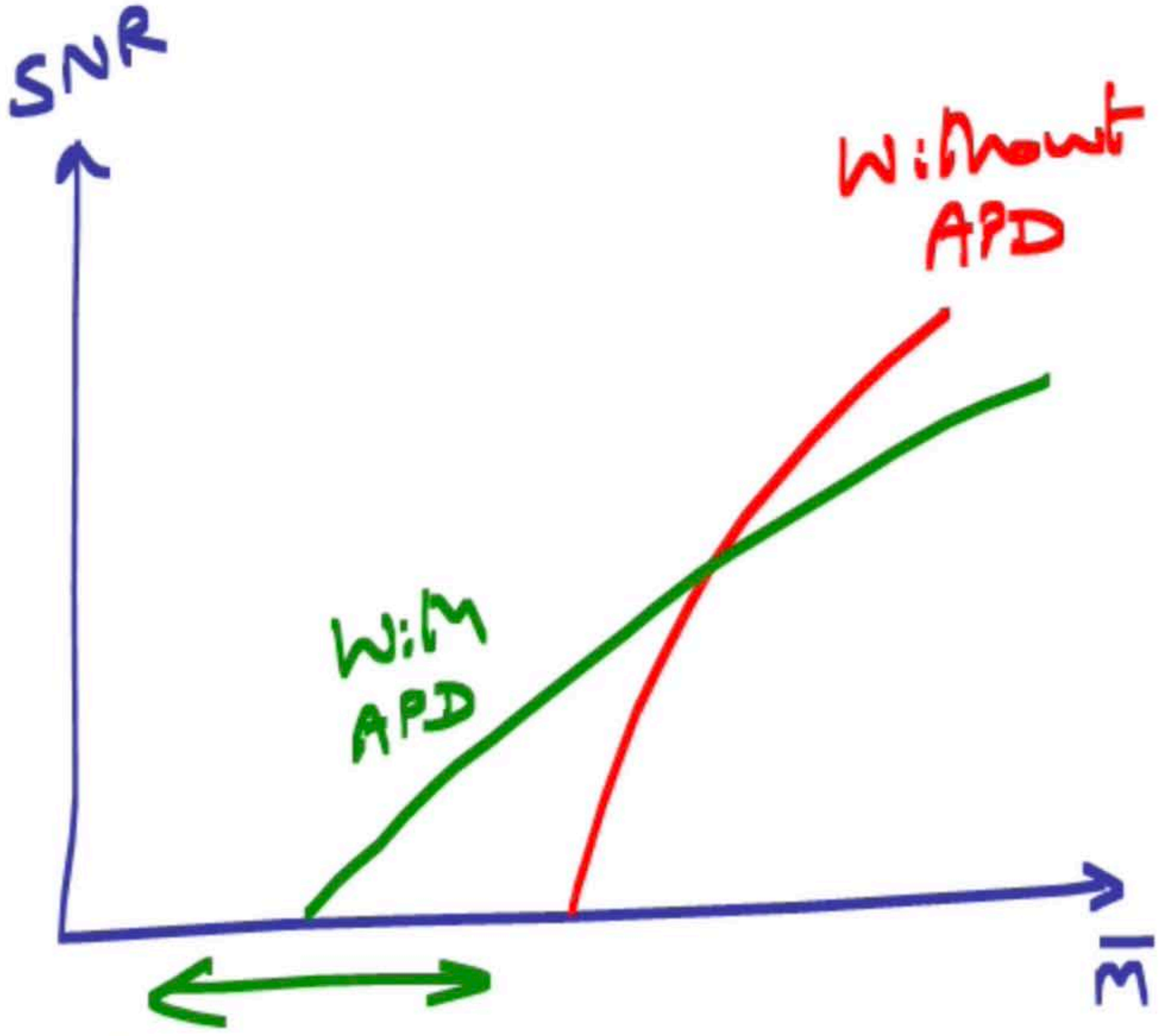
$$\sigma_T^2 = \frac{4k_B T}{R_L} B$$

Signal to Noise Ratio (SNR) $= \dfrac{I_p^2}{\sigma_s^2 + \sigma_T^2} = \dfrac{(M\eta q\phi)^2}{2q^2M^3F\eta\phi B + \sigma_T^2}$

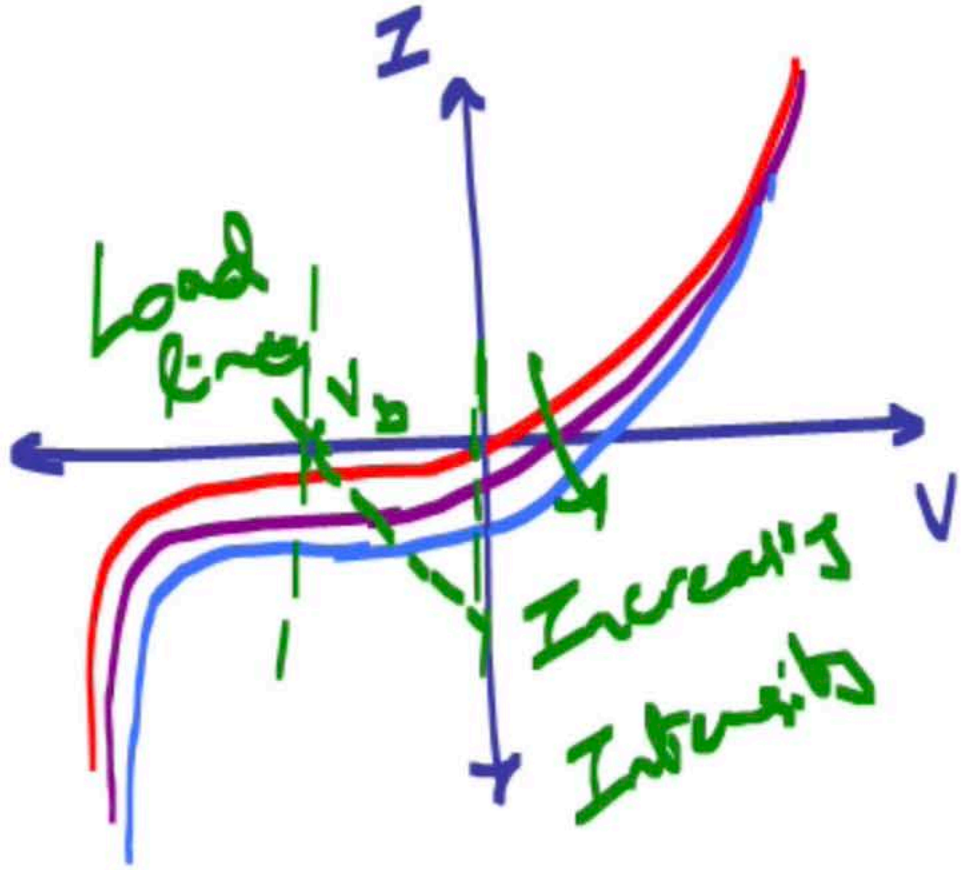
Thermal noise limit → very few photons falling on detector ($\sigma_s^2 \ll \sigma_T^2$)

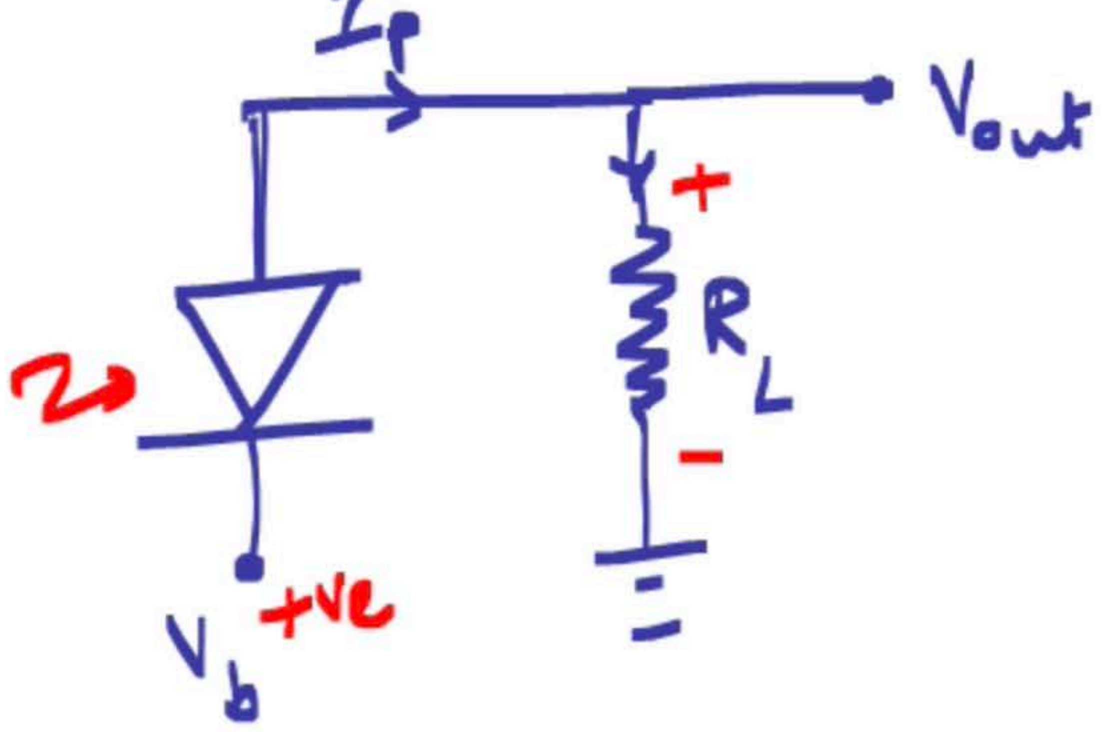
# of photoelectrons, $\bar{m} = \dfrac{\eta \phi}{2B}$

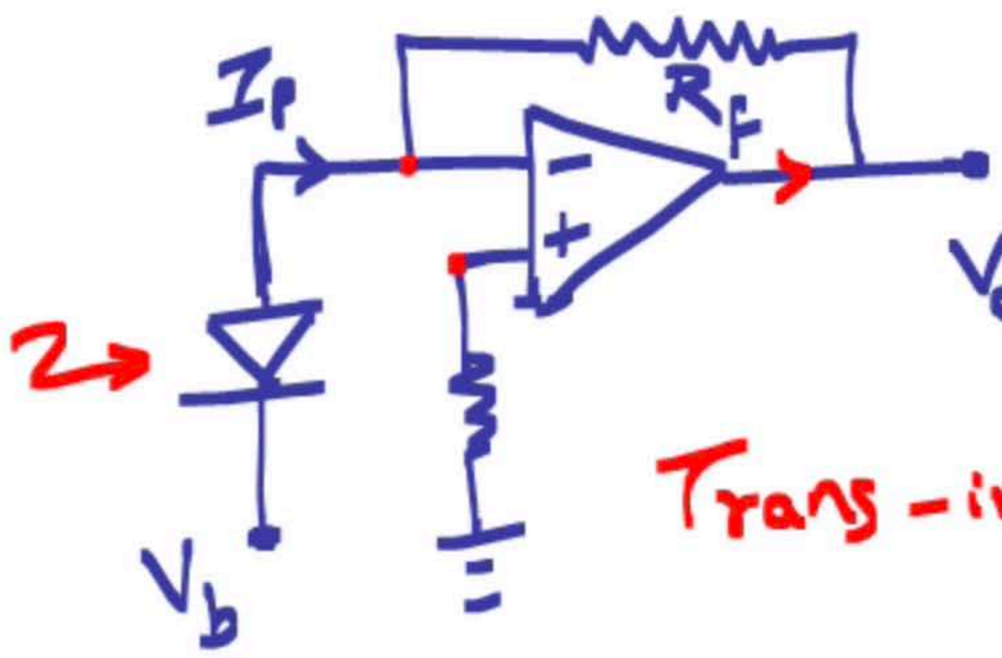
$$\boxed{SNR = \frac{M^2 \bar{m}^2}{M^3 F \bar{m} + \sigma_{ar}^2}}$$



How to extract the photocurrent efficiently?







$V_{out} = -R_f I_p$

Trans-impedance Amplifier (TIA)