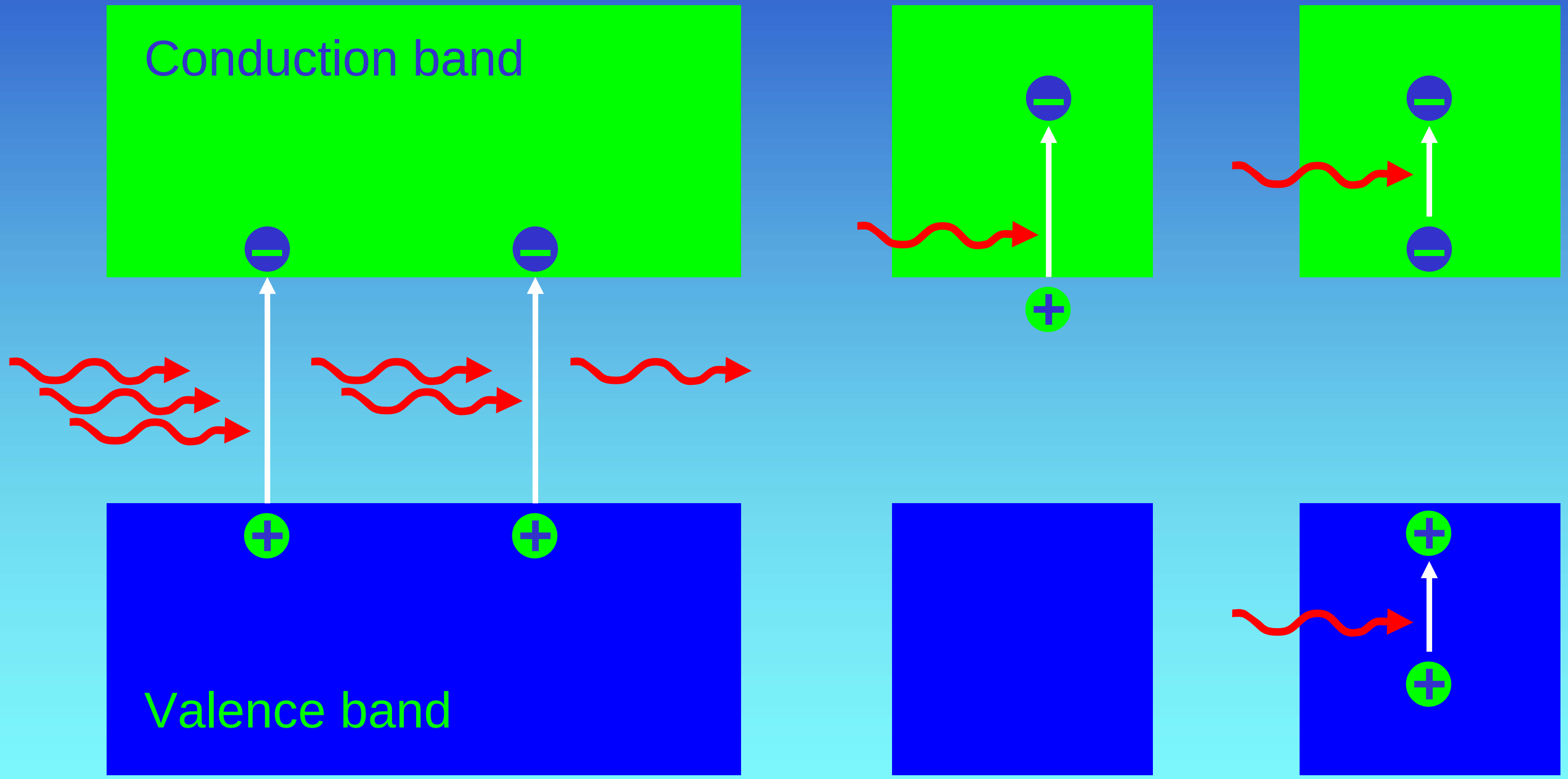
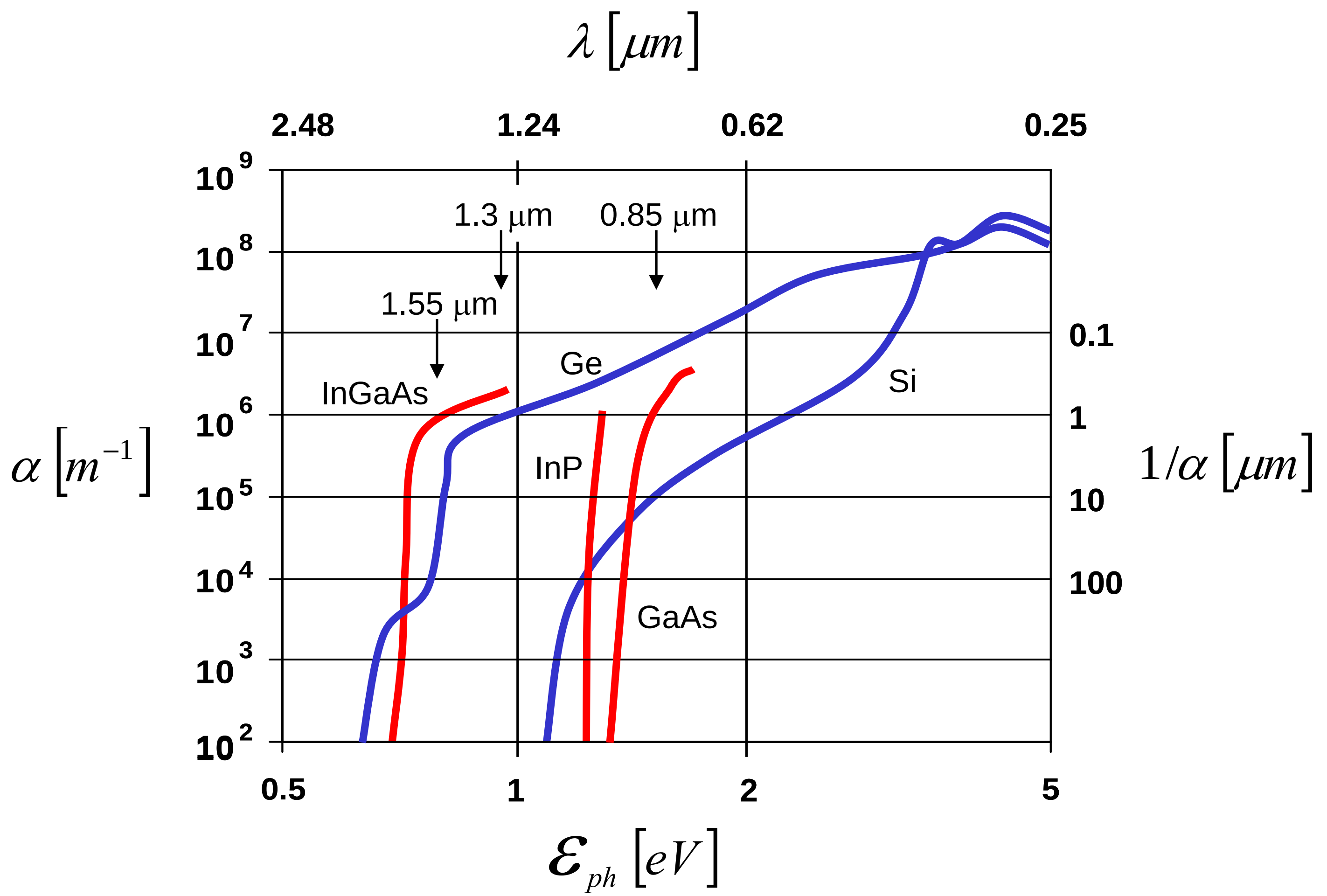
Detectors

- pn photodiodes
- p-i-n photodiodes
- Avalanche photodiodes
- Solar cells

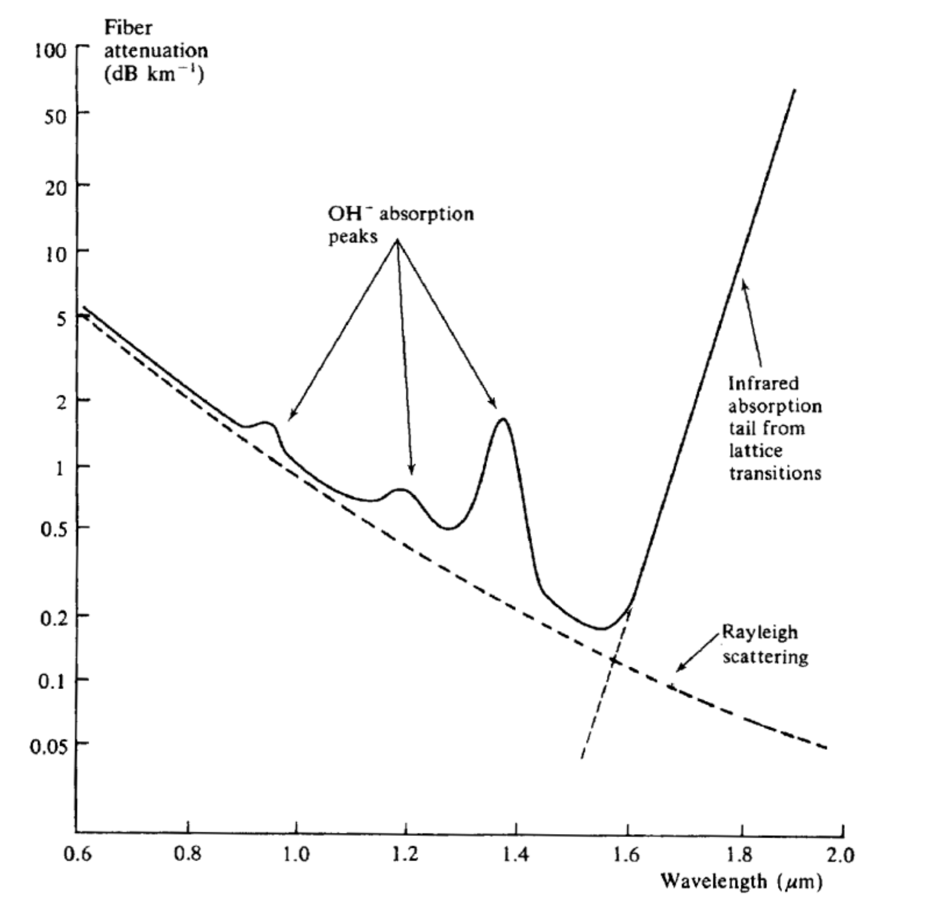
Photon absorption processes

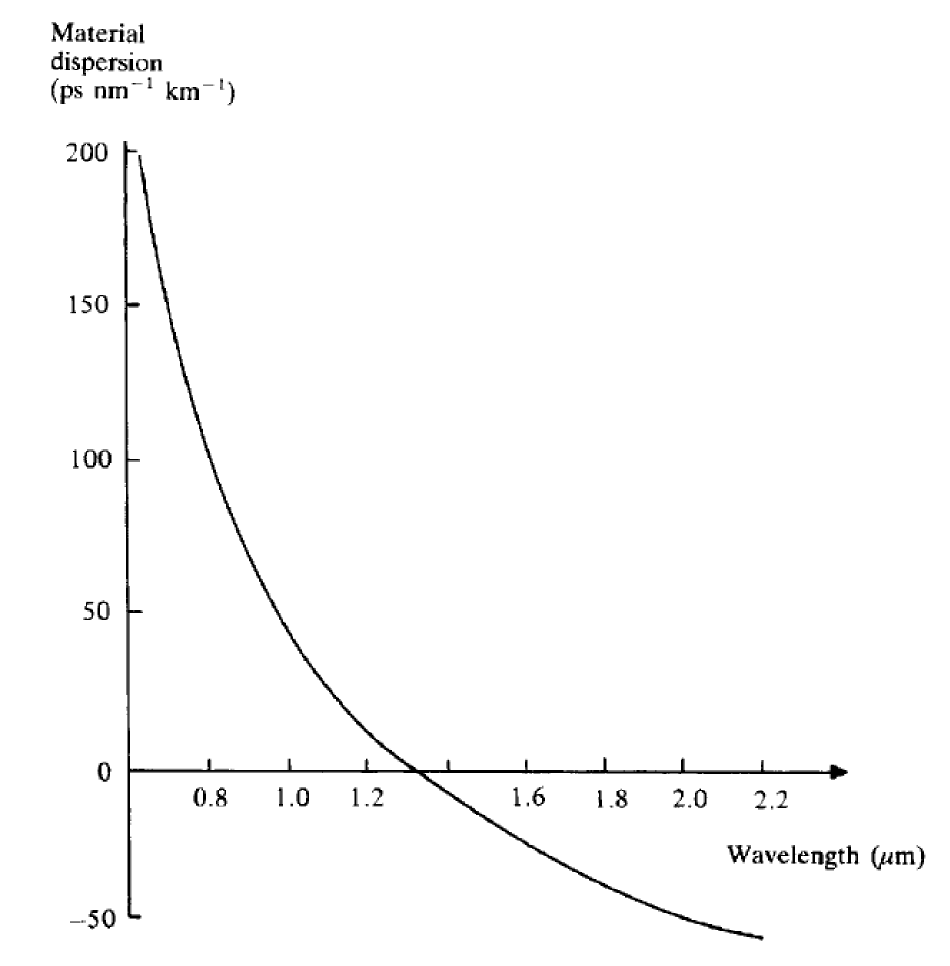


Material absorption

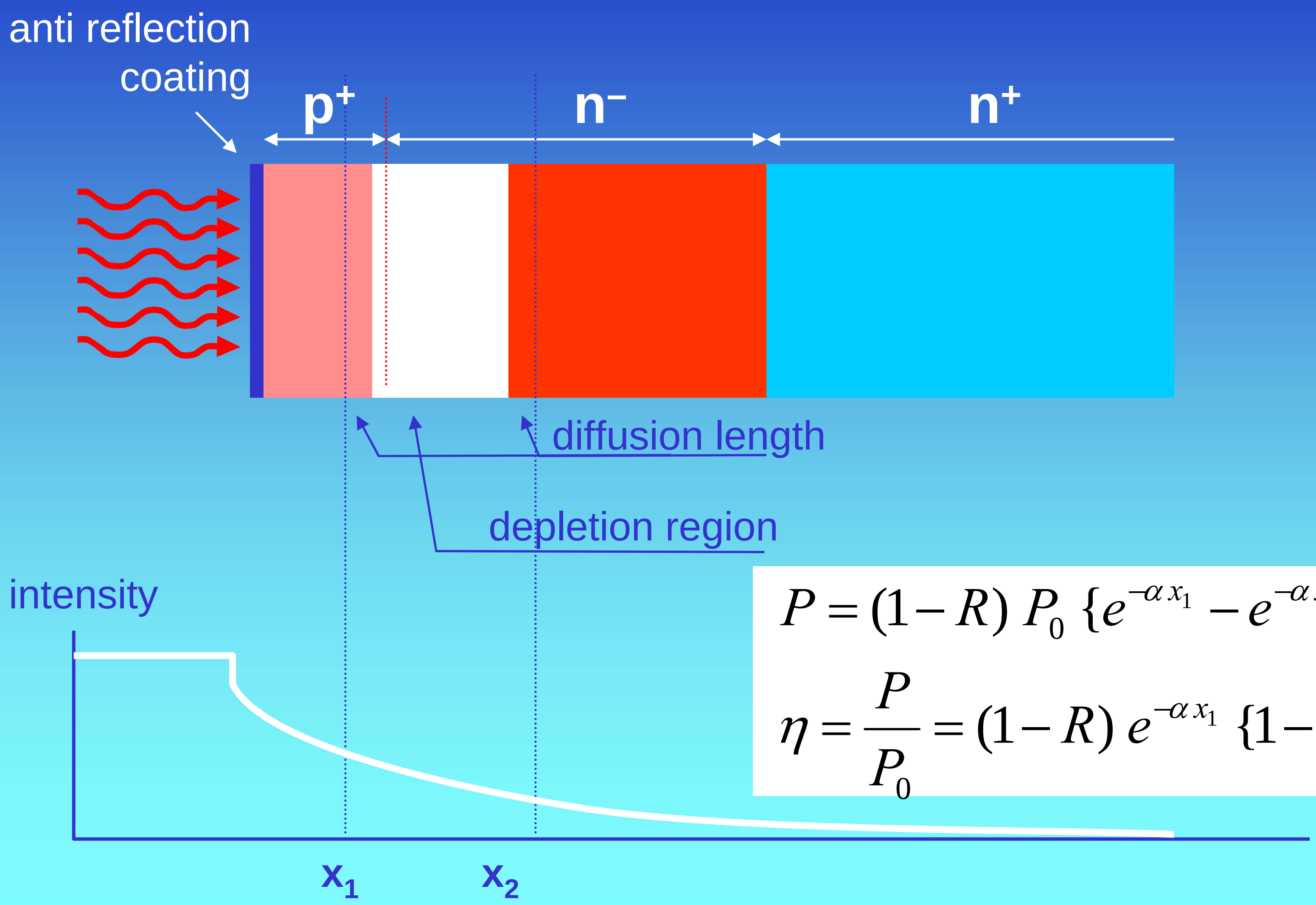


Fibre dispersion and loss





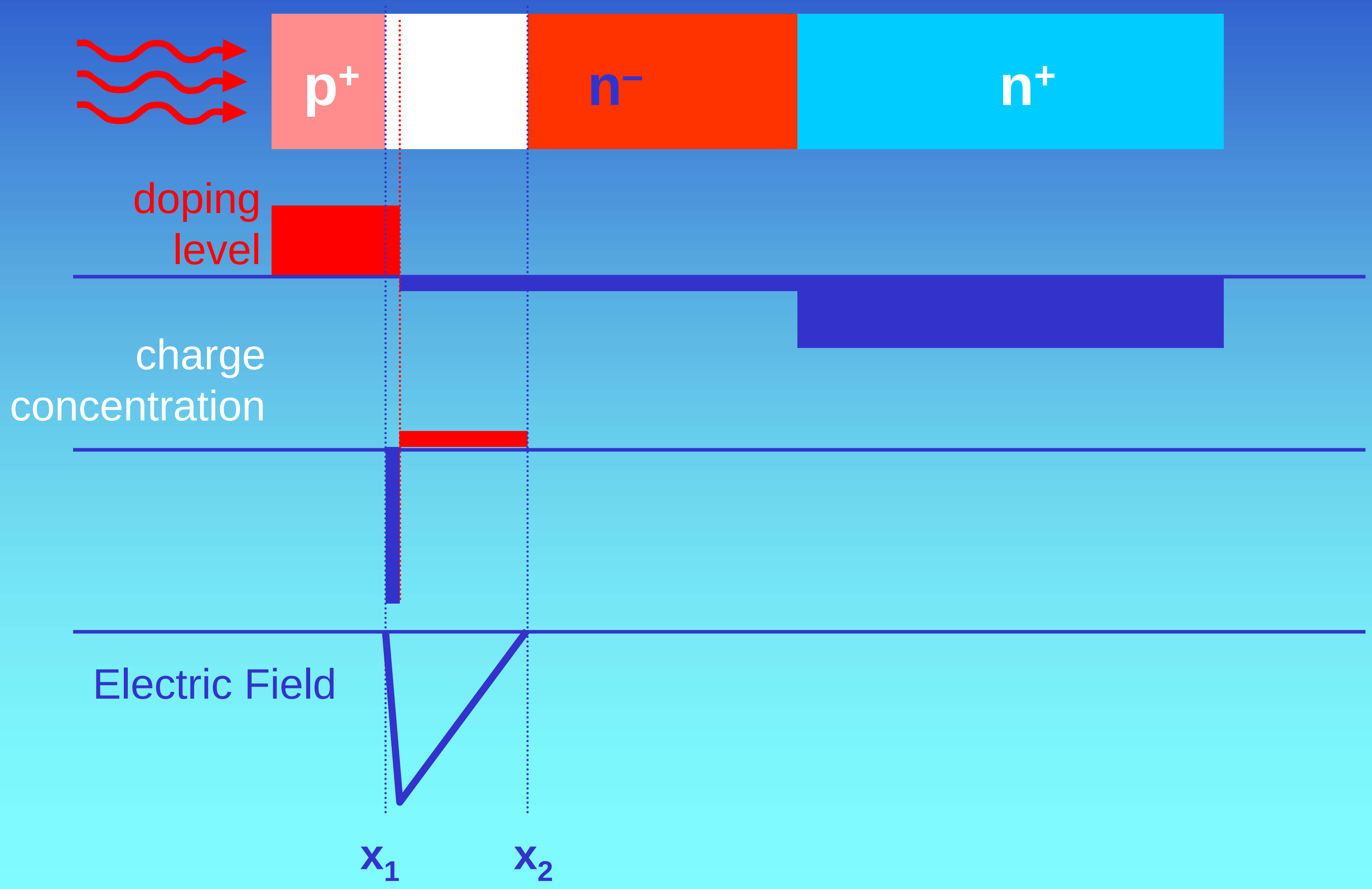
pn-photodiode



$$P = (1-R)\,P_0\,\{e^{-\alpha x_1} - e^{-\alpha x_2}\}$$

$$\eta = \frac{P}{P_0} = (1-R)\,e^{-\alpha x_1}\,\{1 - e^{-\alpha (x_2 - x_1)}\}$$

pn-photodiode



pn-photodiode

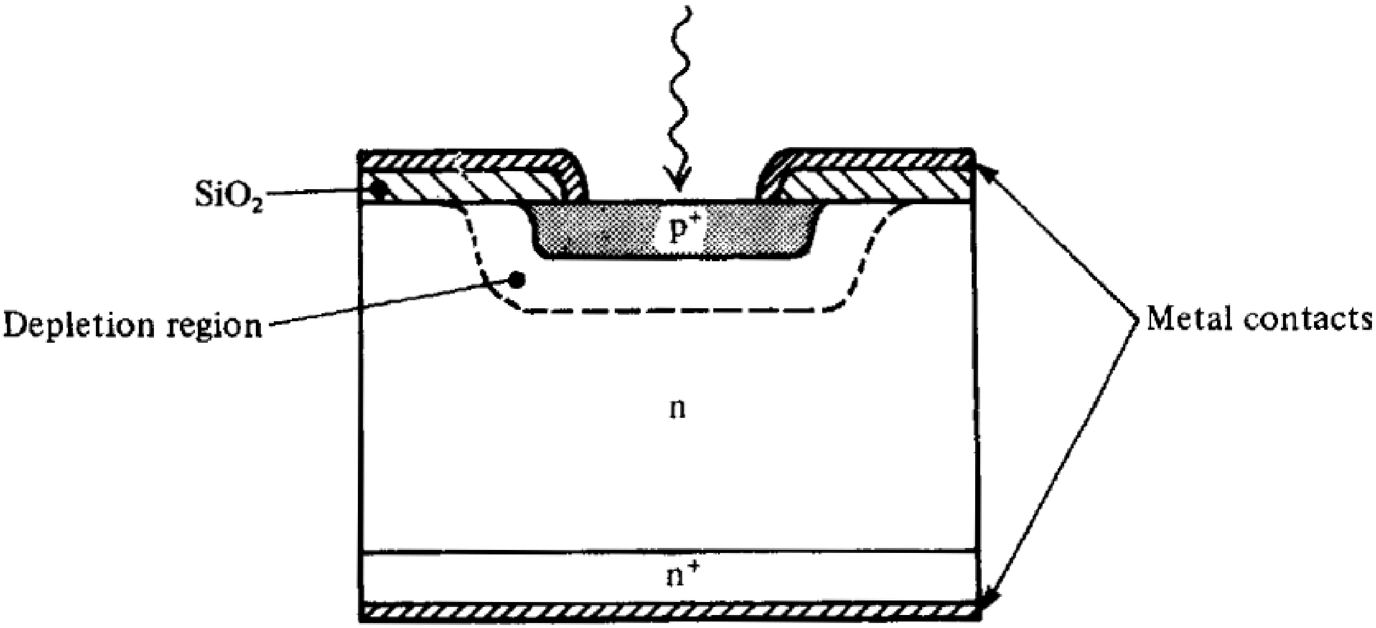


Figure 5.9 Typical silicon photodiode structure for photoconductive operation. A junction is formed between heavily doped p-type material (p^+) and fairly lightly doped n-type material so that the depletion region extends well into the n-type material. The p^+ layer is made fairly thin. Metallic contacts can be made directly to the p^+ material, but to obtain an ohmic contact to the n-type material an intermediate n^+ layer must be formed.

current generation

The current generated by a beam of light with power P and photon energy $h\nu$ is:

$$i_P = \frac{q\eta P}{h\nu}$$

where η is the fraction of photons that generate e-h pairs. The new drift current is i_0+i_P, and so the diffusion current must also increase in order to bring the junction back to equilibrium. If the change in junction voltage is ΔV_J the diffusion current becomes:

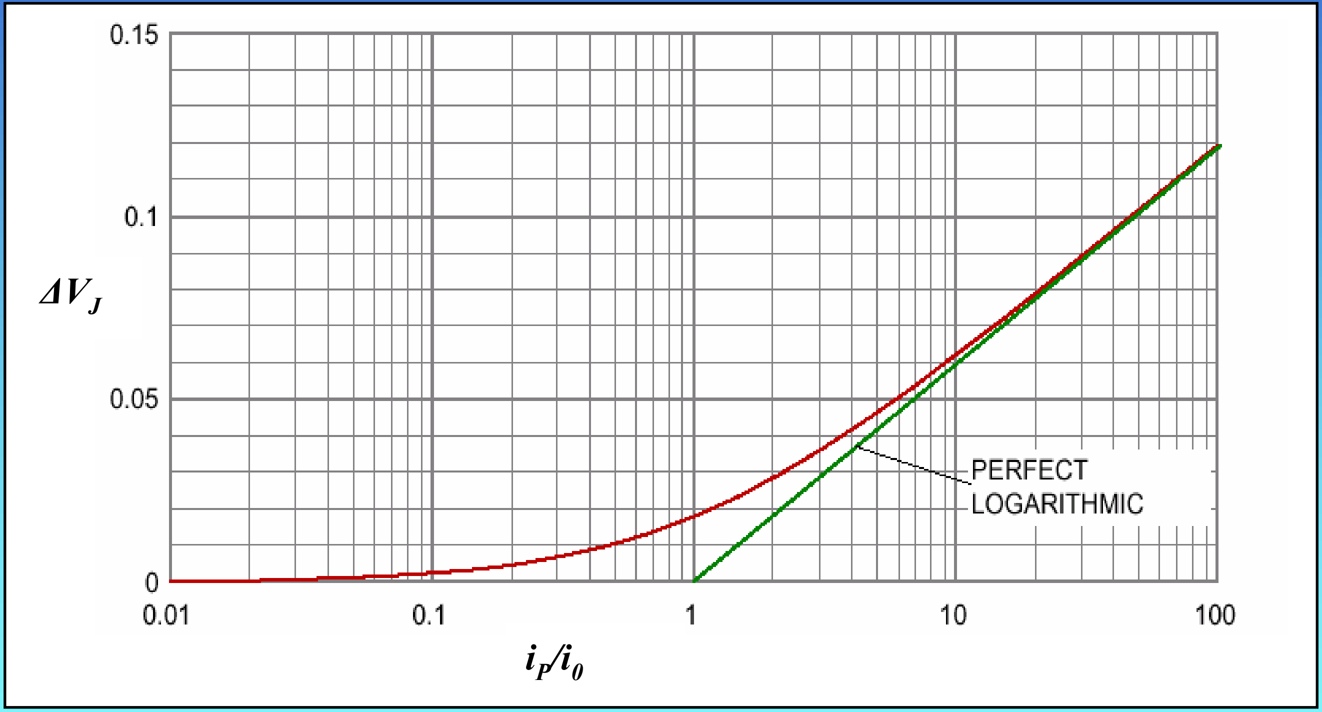
$$i_D = i_0 \exp(\frac{q\Delta V_J}{k_B T})$$

Consequently

$$i_0 + i_P = i_0 \exp(\frac{q\Delta V_J}{k_B T}) \qquad \Delta V_J = \frac{k_B T}{q}\ln\left(\frac{i_p}{i_0}+1\right)$$

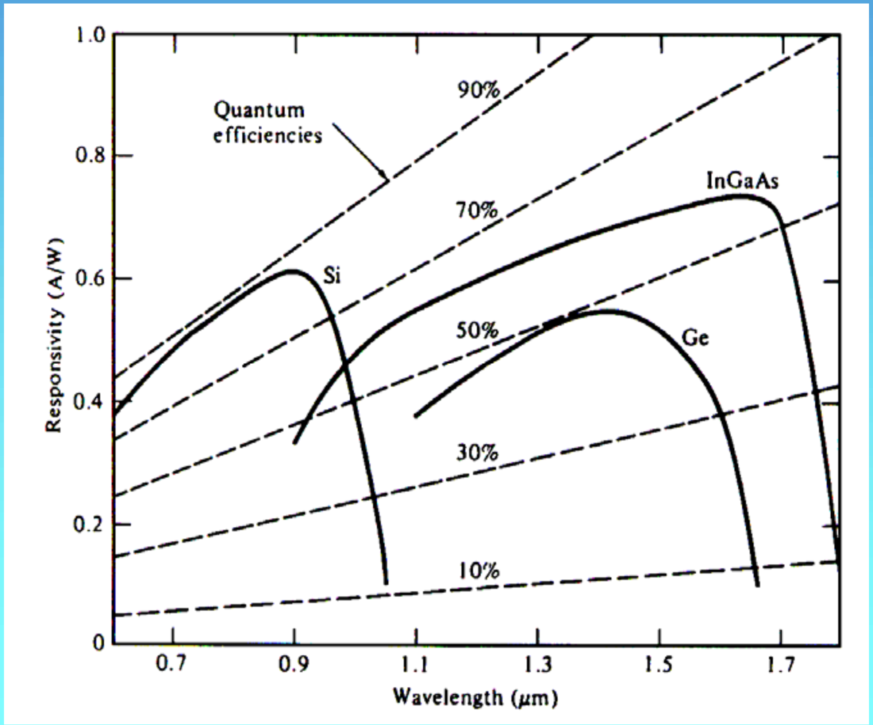
Thus the open circuit voltage increases logarithmically with power at high power.

Open circuit voltage

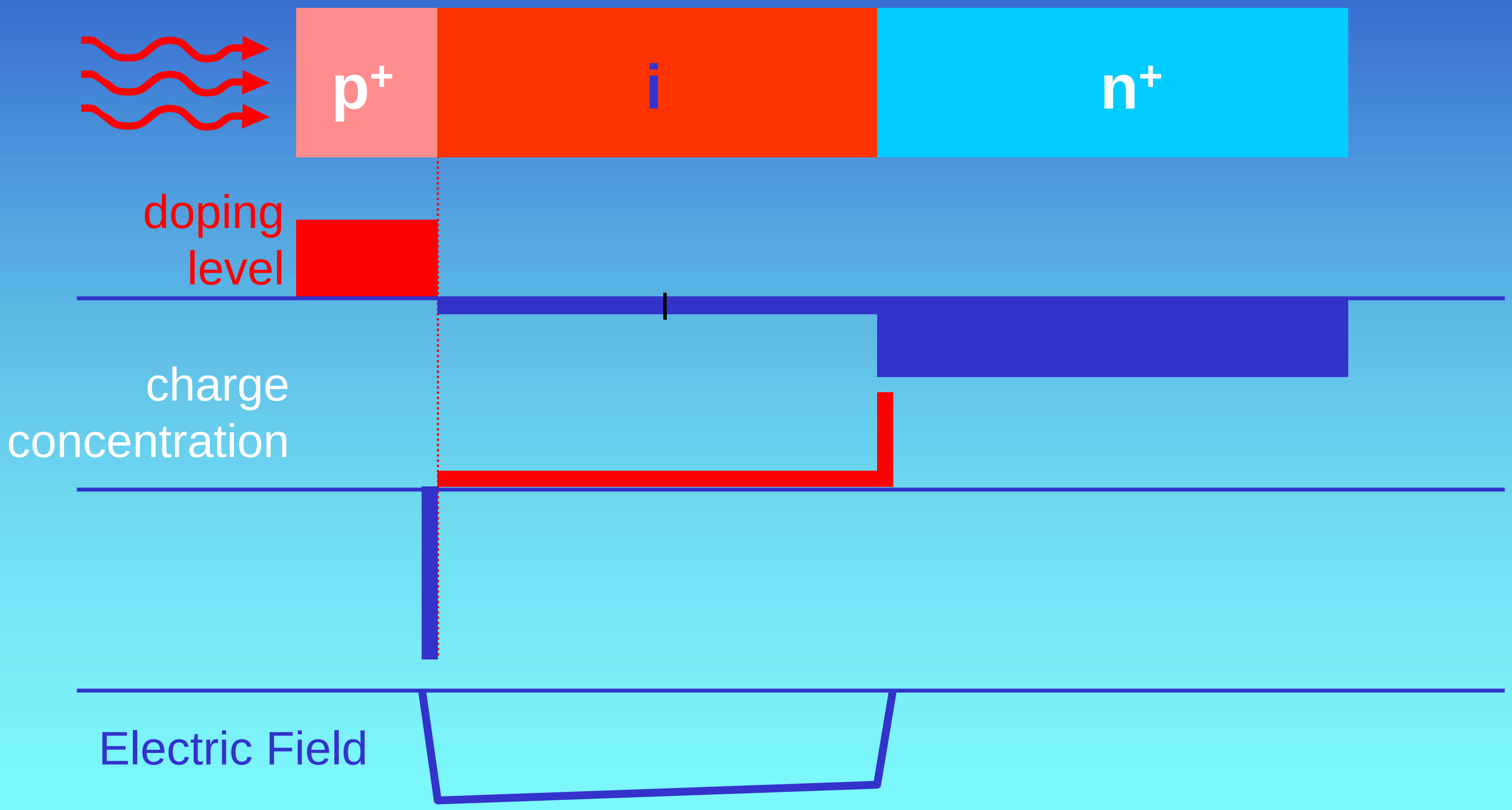


pn-responsivity

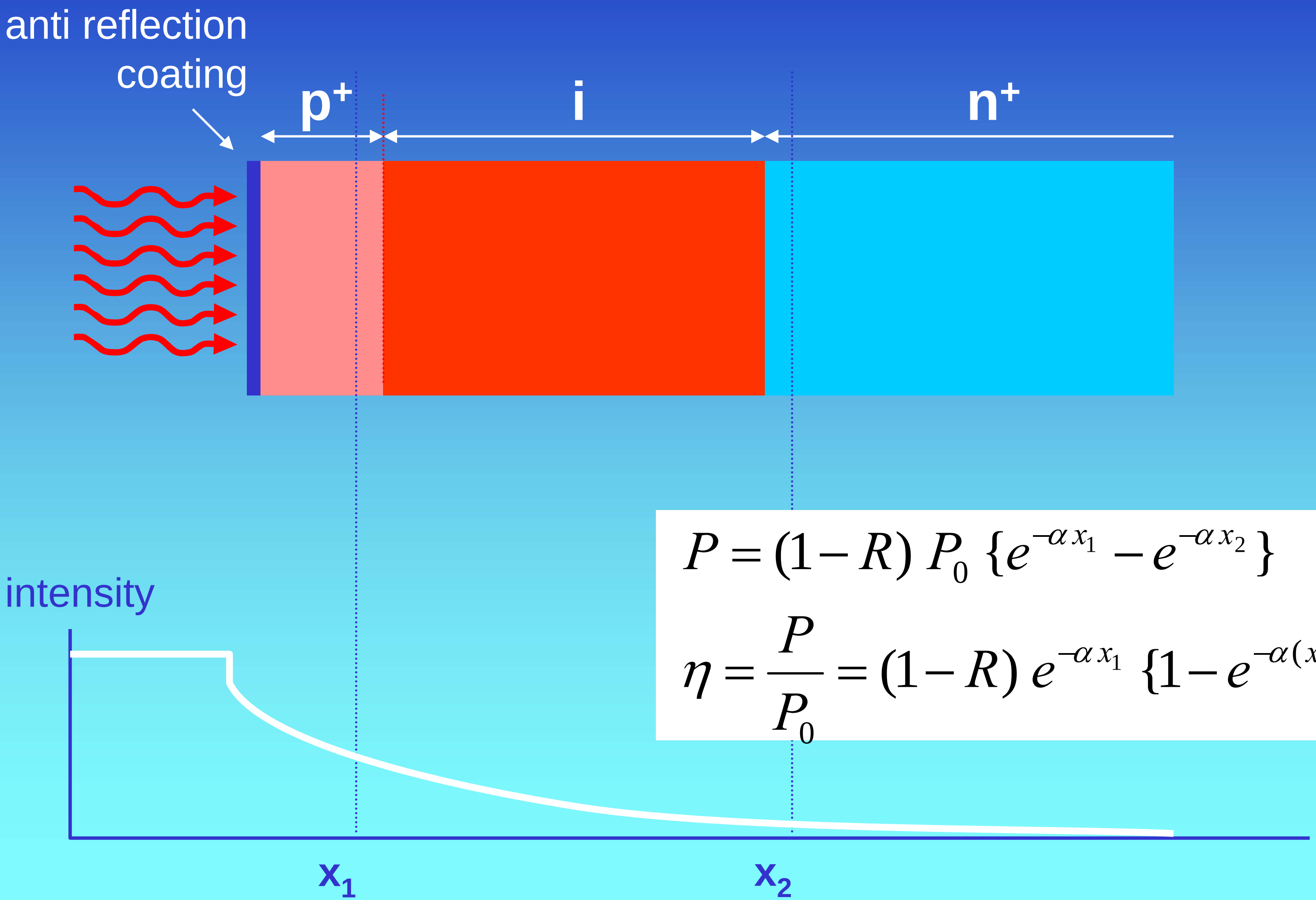
$$R = \frac{i_p}{P} = \frac{q\eta}{h\nu} = \frac{\eta\lambda}{1.24} \quad \text{amps watt}^{-1}$$



p-i-n photodiode



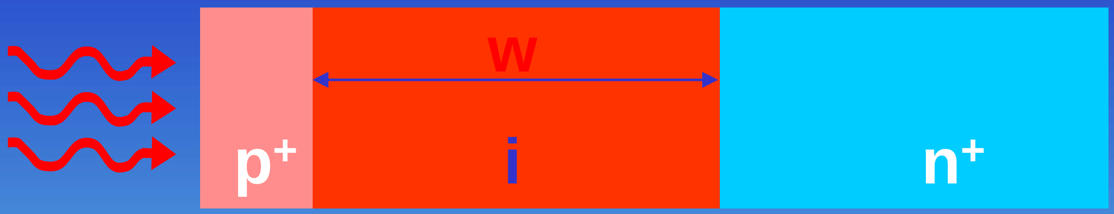
p-i-n photodiode

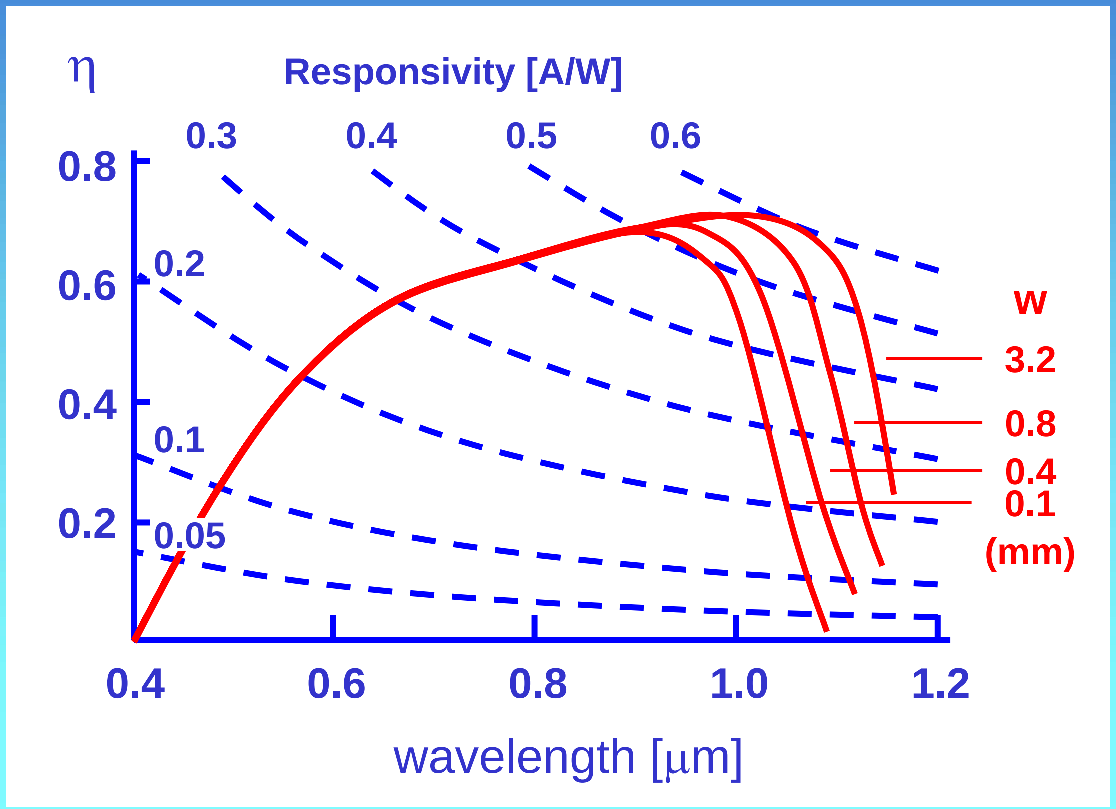


$$P = (1-R)\, P_0 \,\{e^{-\alpha x_1} - e^{-\alpha x_2}\}$$

$$\eta = \frac{P}{P_0} = (1-R)\, e^{-\alpha x_1}\, \{1 - e^{-\alpha (x_2 - x_1)}\}$$

p-i-n responsivity





Responsivity:

$$R = \frac{I}{P} \; [A/W]$$

$$\eta = \frac{n_e}{n_{ph}} = \frac{I/e}{P/\mathcal{E}_{ph}}$$

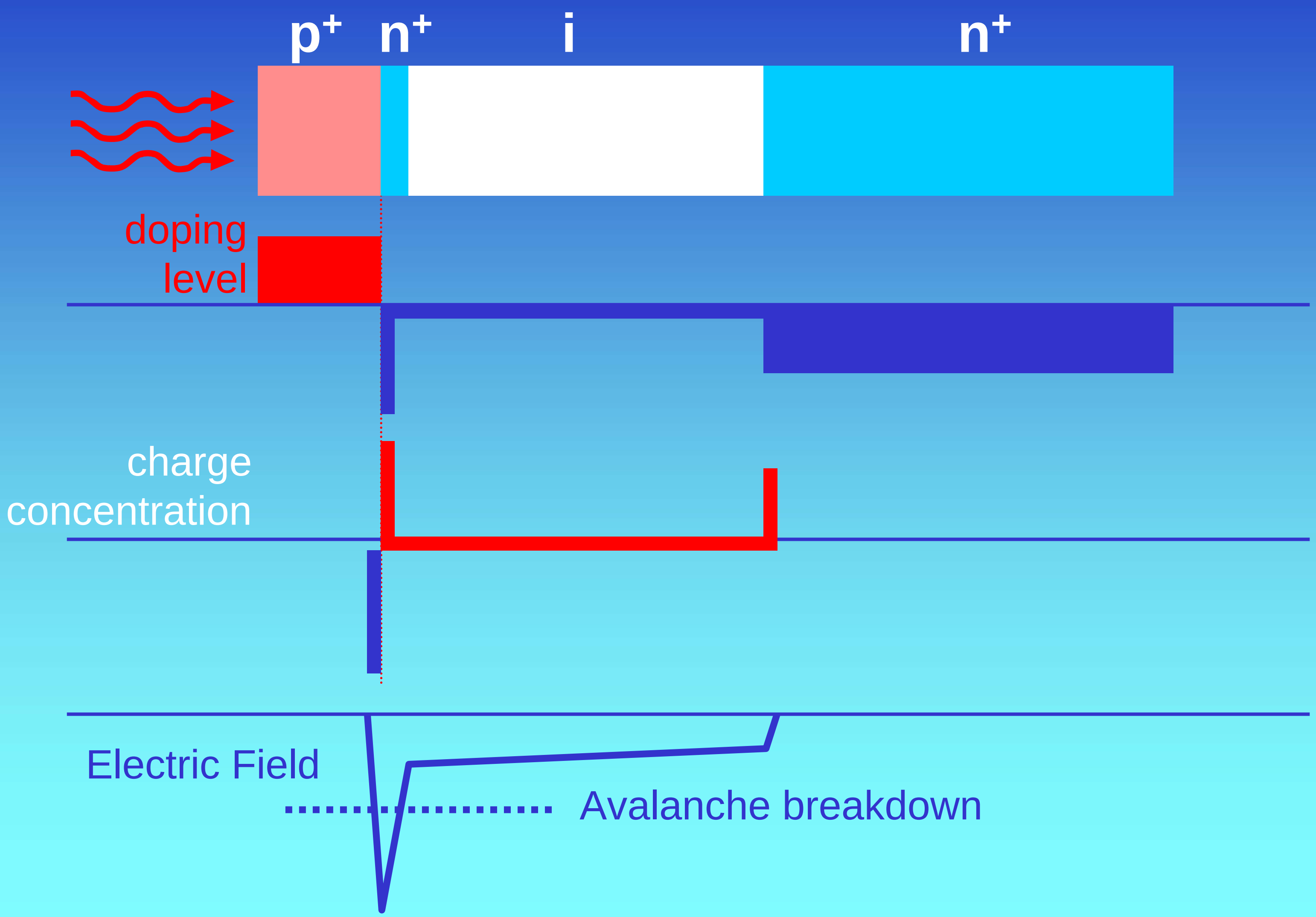
$$\eta = R\frac{\mathcal{E}_{ph}}{e} = R\frac{1.24}{\lambda}$$

$$\mathcal{E}_{ph} = \frac{hc}{e\lambda} = \frac{1.24}{\lambda[\mu m]}$$

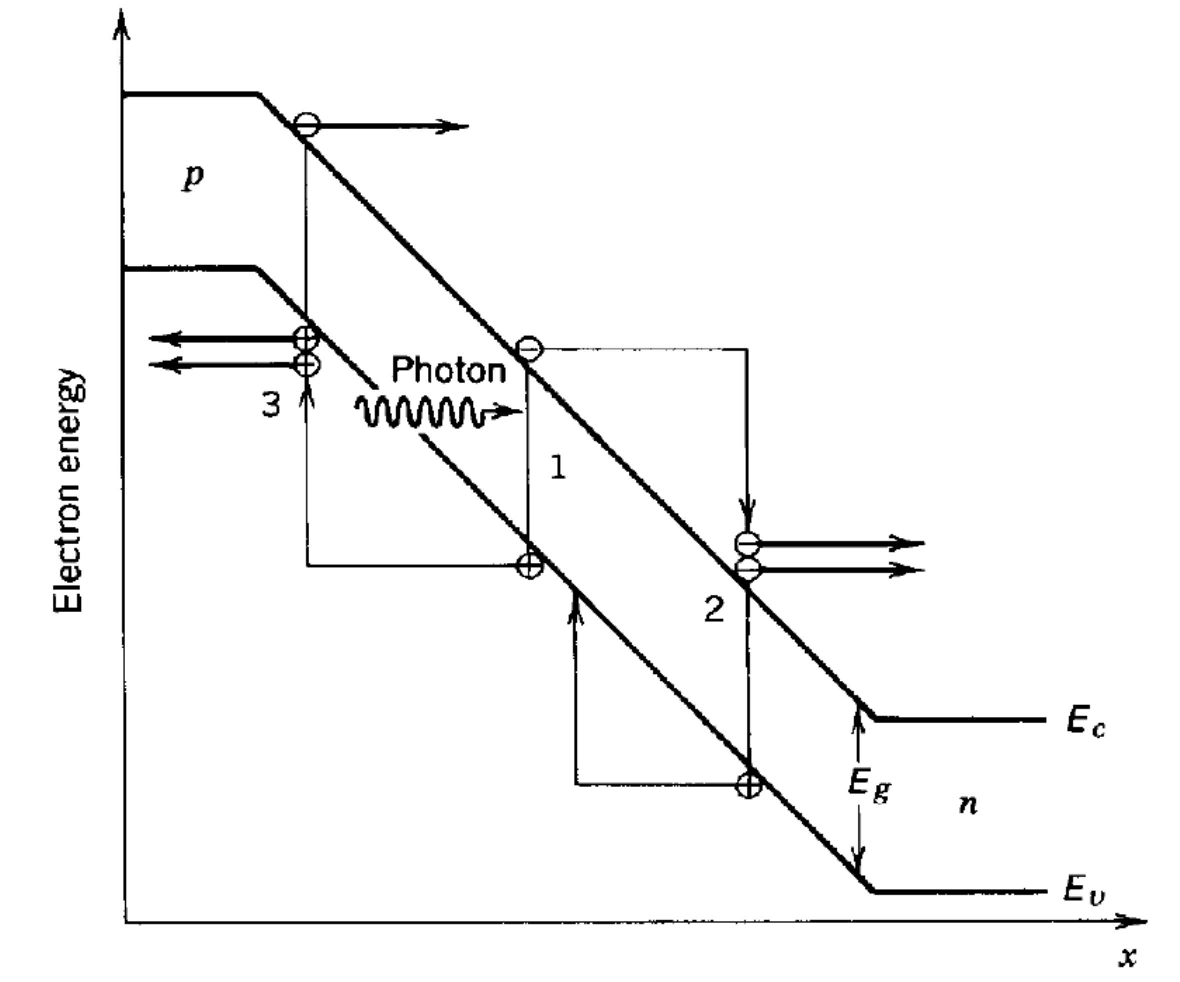
Useful Web Resource

- http://ece-www.colorado.edu/~bart/book/movie/movie2.htm

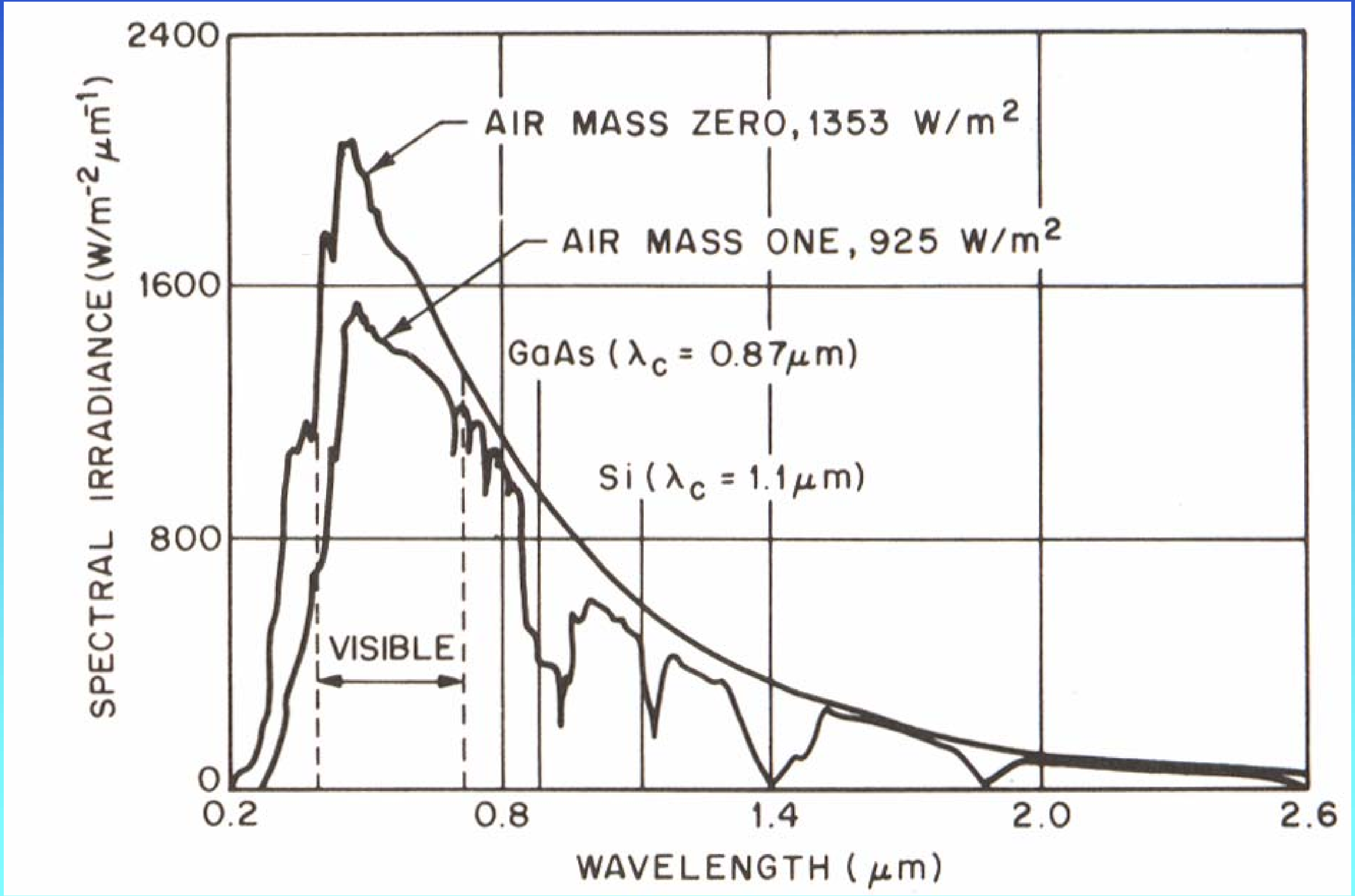
Avalanche-photodiode (APD)



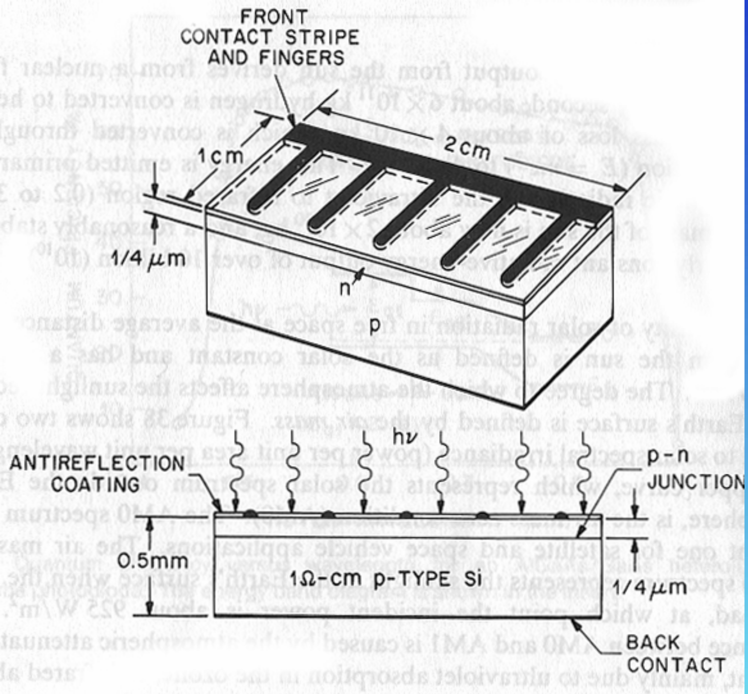
Avalanche-photodiode (APD)



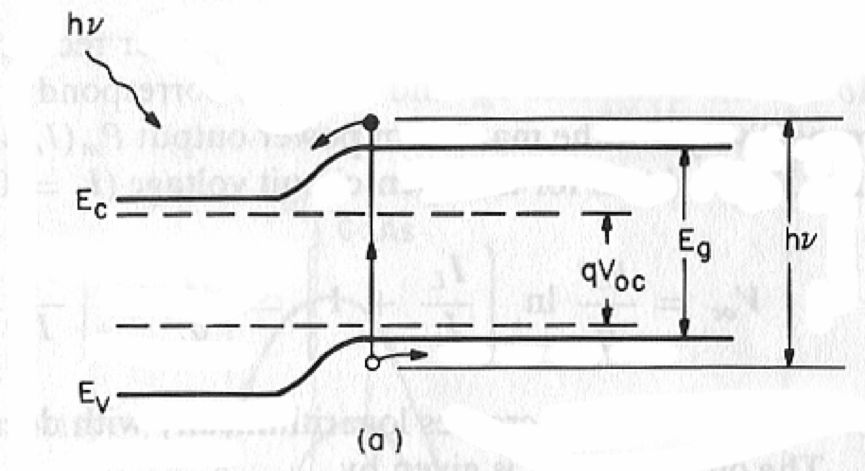
Solar Energy

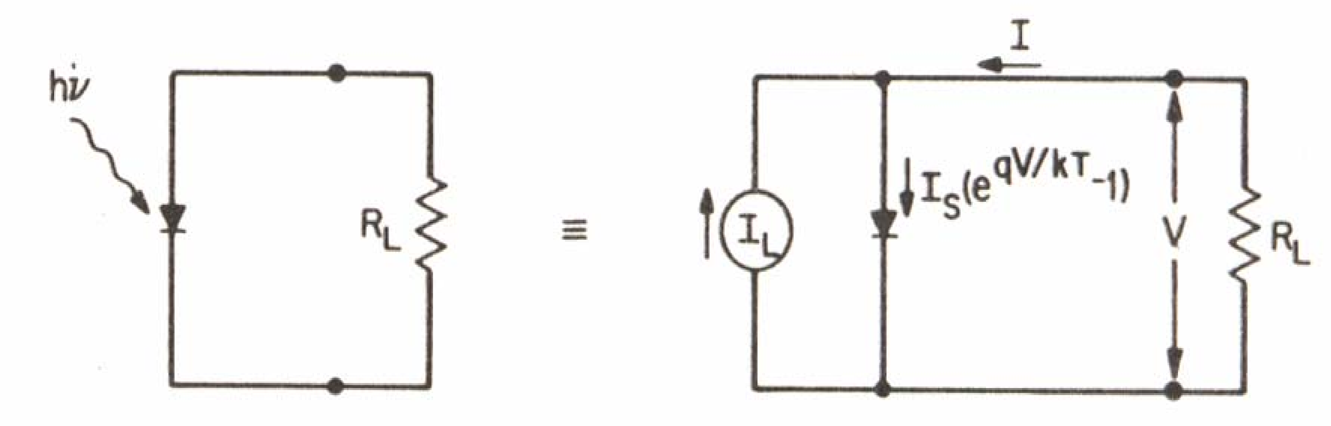


Solar cell



Schematic representation of a silicon *p–n* junction solar cell.





Photovoltaic power – solar cell

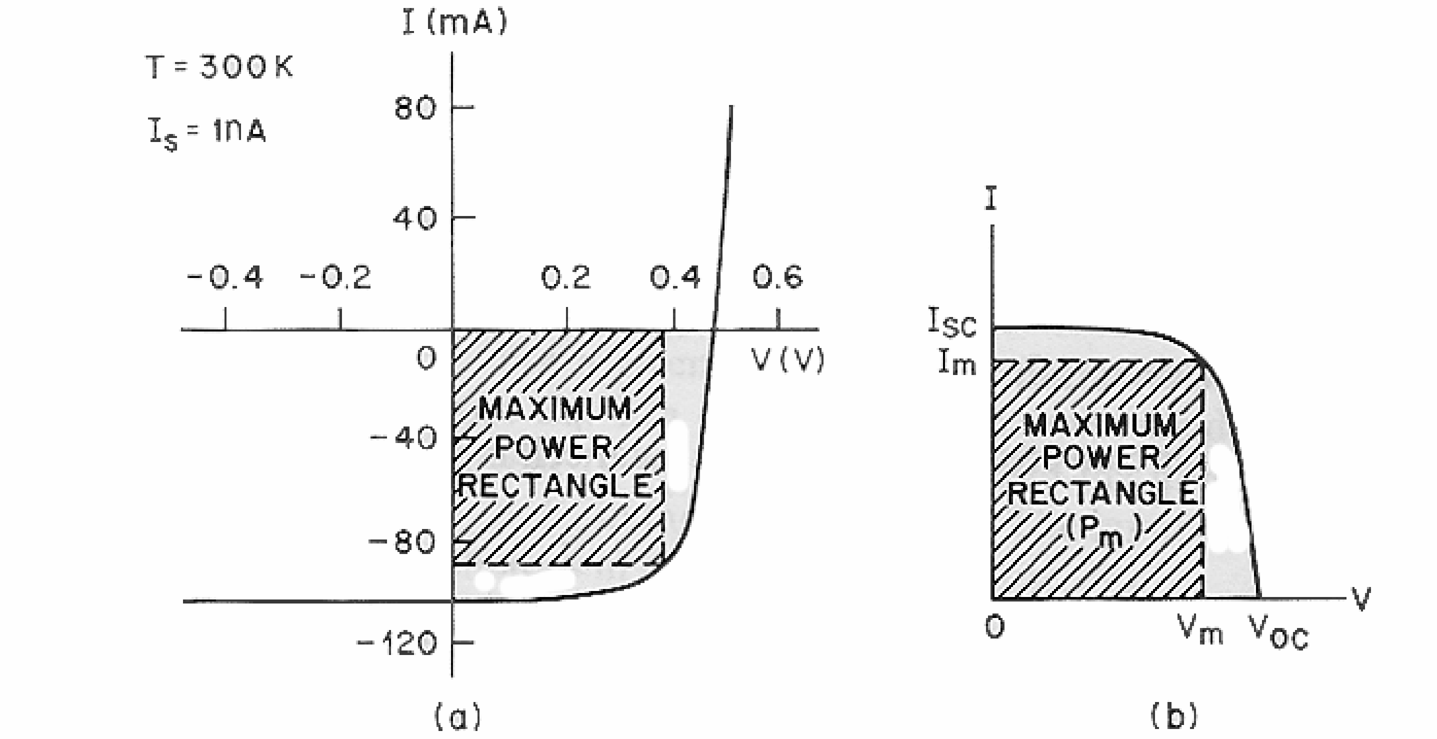
$$I = I_S(e^{\frac{qV}{k_B T}} - 1) - I_L$$

$$V_{OC} = \frac{k_B T}{q} \ln(\frac{I_L}{I_S} + 1)$$

$$P = IV = I_S V(e^{\frac{qV}{k_B T}} - 1) - I_L V$$

$$P_M \cong I_L \left[V_{OC} - \frac{k_B T}{q} \ln(1 + \frac{qV_M}{k_b T}) - \frac{k_B T}{q} \right]$$

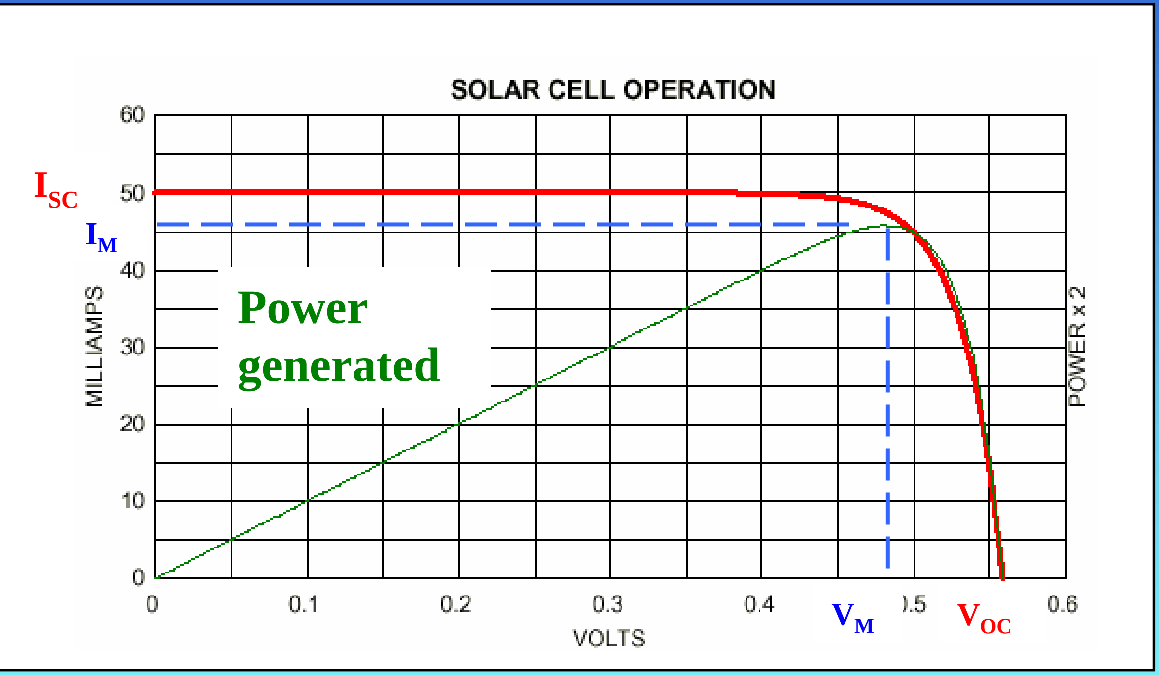
Maximum power generation



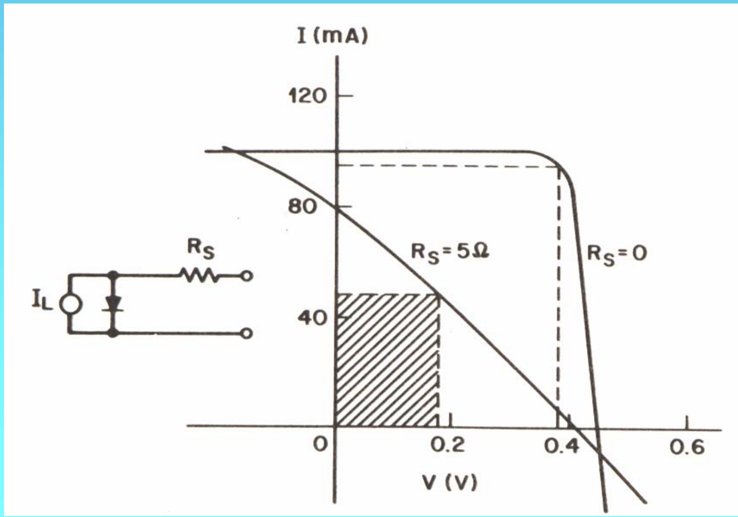
(*a*) Current–voltage characteristics of a solar cell under illumination. (*b*) Inversion of (*a*) about the voltage axis.

Maximum power generation

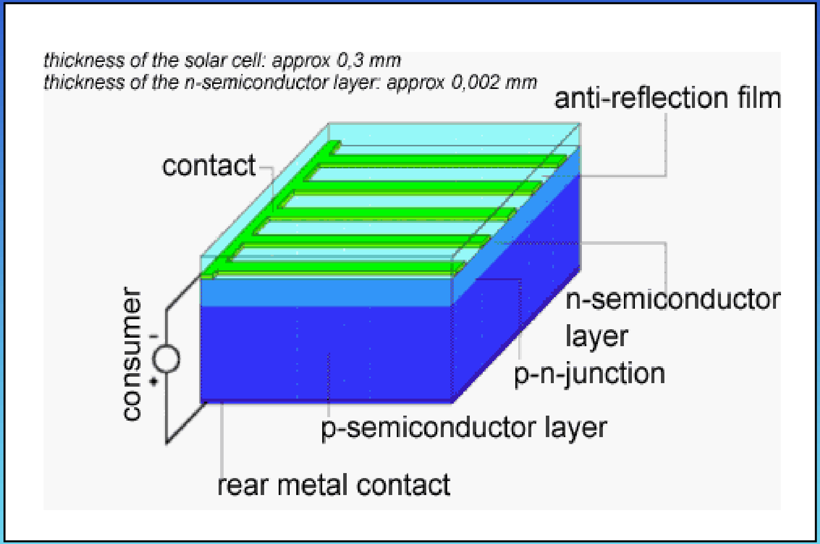
ideal

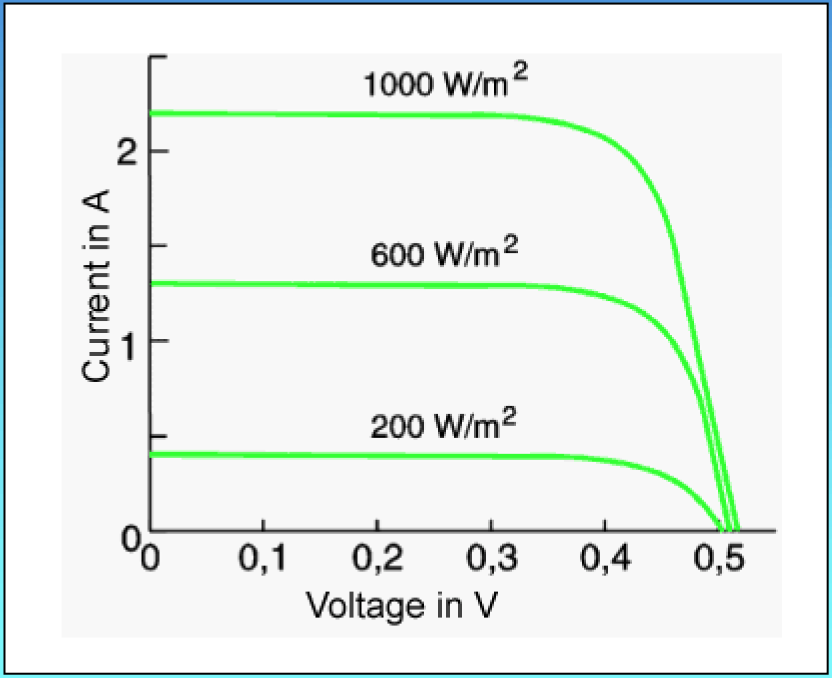


with contact resistance ...



Real Solar Cells





Efficiency of real solar cells

Material	Level of efficiency in % Lab	Level of efficiency in % Production
Monocrystalline Silicon	~ 24 (28% theoretical max)	14 to17
Polycrystalline Silicon	~ 18	13 to15
Amorphous Silicon	~ 13	5 to7