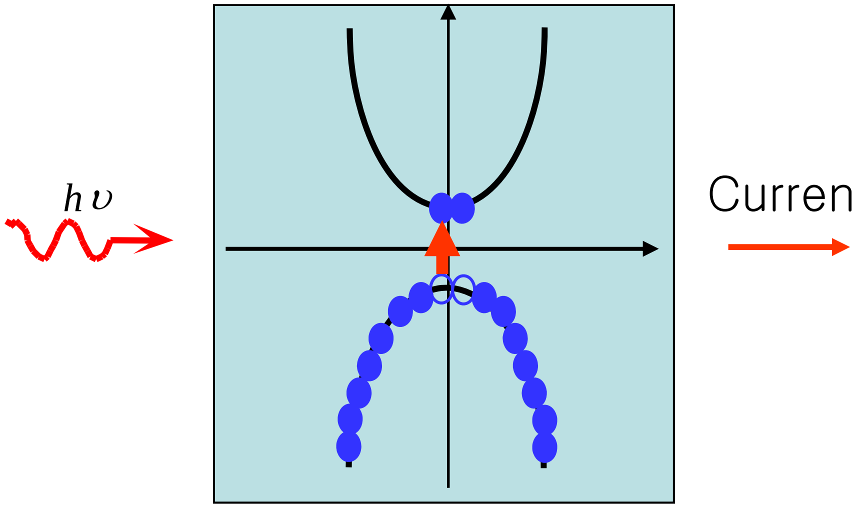
Lect. 26: Photodetectors

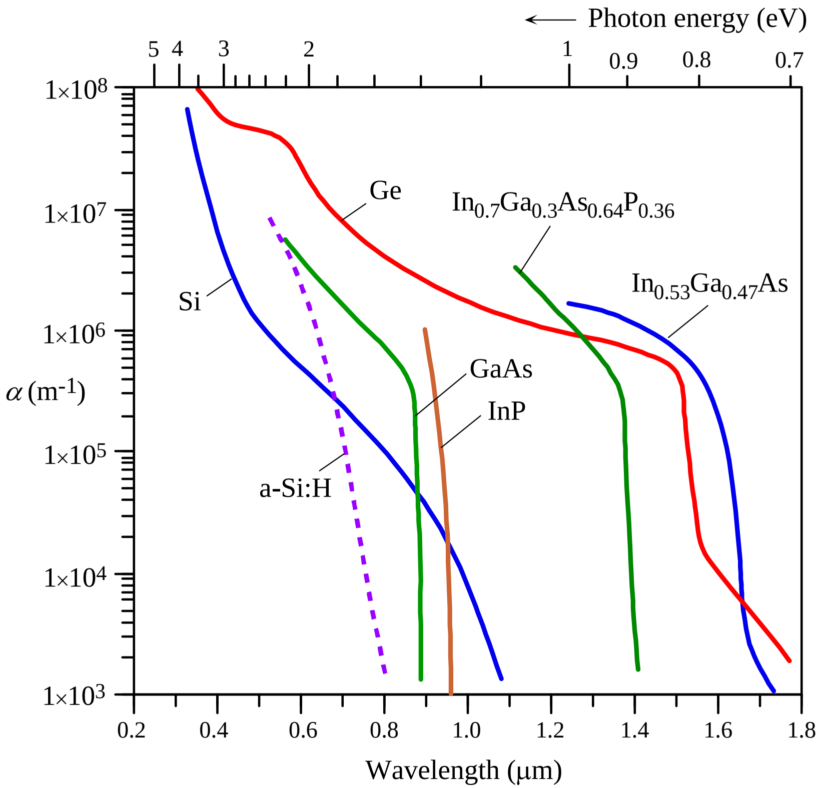
Photodetection: Absorption => Current Generation



Materials for photodetection: $E_g < h\nu$

Various methods for generating currents with photo-generated carriers: photoconductors, photodiodes, avalanche photodiodes

Lect. 26: Photodetectors

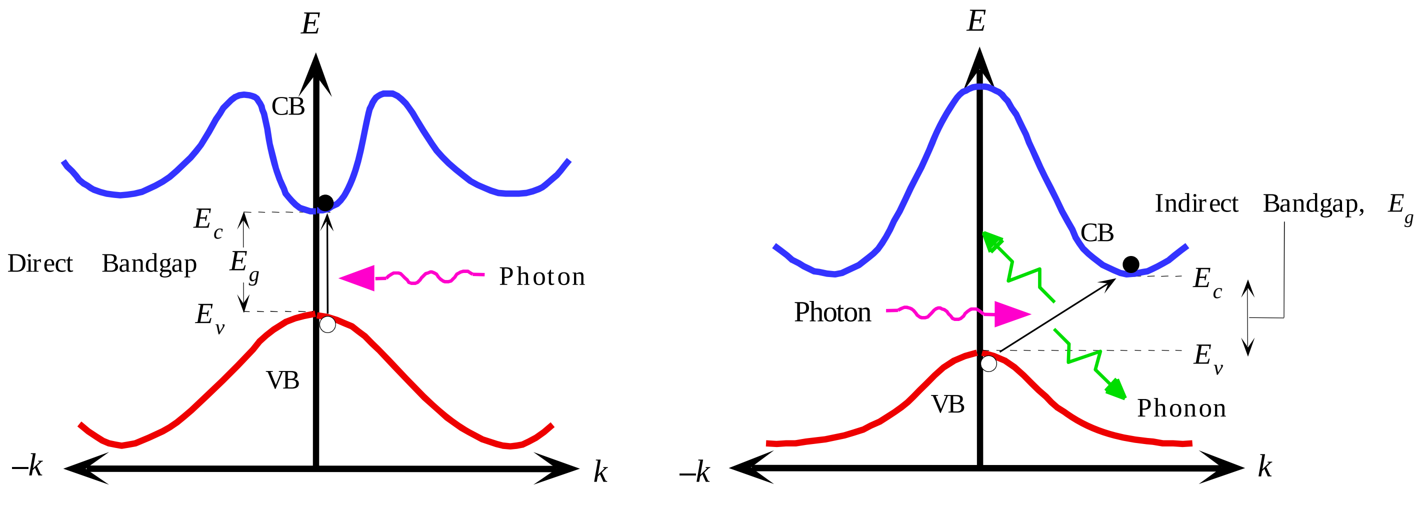


Sharp decrease in absorption for photon energy < E_g

$P_{out}/P_{in} = \exp(gL)$

$g < 0$ ➔ $\alpha = -g$

- Photodetection for indirect bandgap materials



(a) GaAs (Direct bandgap) (b) Si (Indirect bandgap)

Absorption in indirect bandgap semiconductor is possible

➔ Indirect semiconductors (Si) are used for solar cells and image censors

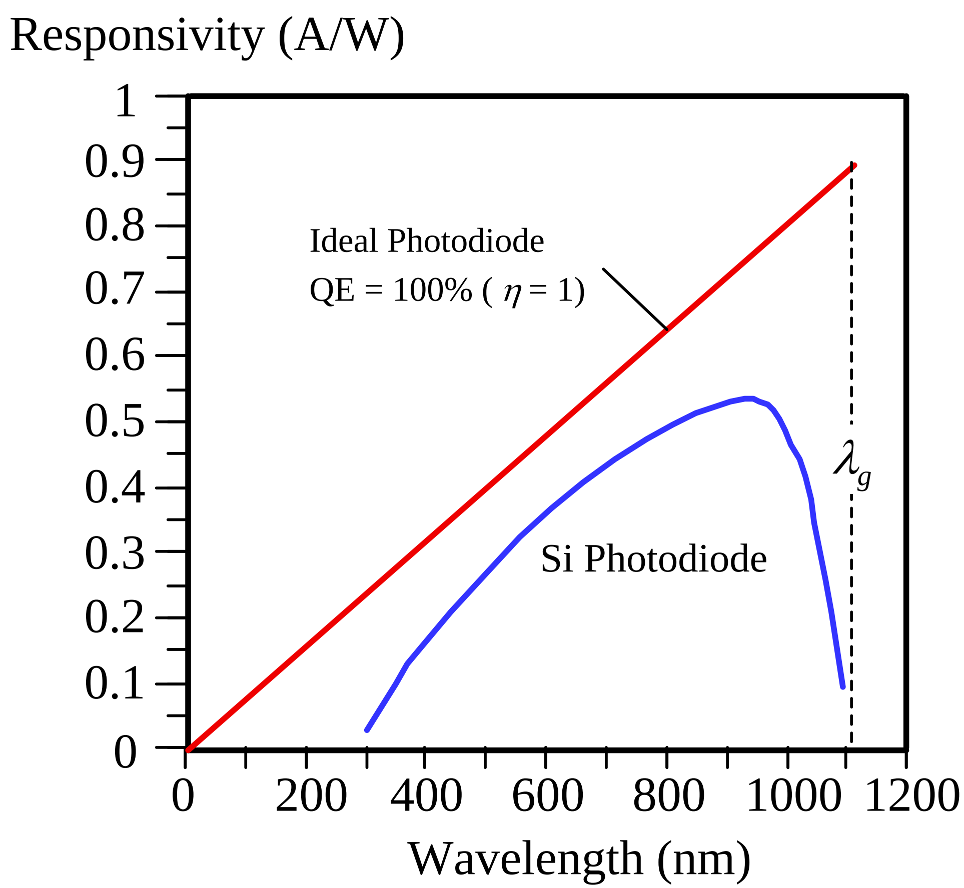
Photodetection efficiency

$$R\ \text{(Responsivity)} = \frac{I}{P}$$

$$\eta\ \text{(Quantum Efficiency)} = \frac{I/q}{P/h\nu}$$

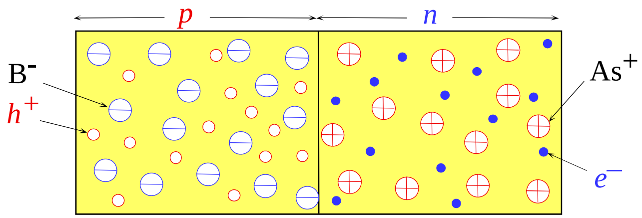
$$R = \eta \cdot \frac{q}{h\nu} \qquad h\nu[\text{eV}] = \frac{1.24}{\lambda[\mu\text{m}]}$$

$$R = \eta \cdot q[C] \cdot \frac{\lambda}{1.24[eV]} = \eta \cdot \frac{\lambda}{1.24}[1/V]$$



Lect. 26: Photodetectors

Photodiodes



PN junction in reverse bias

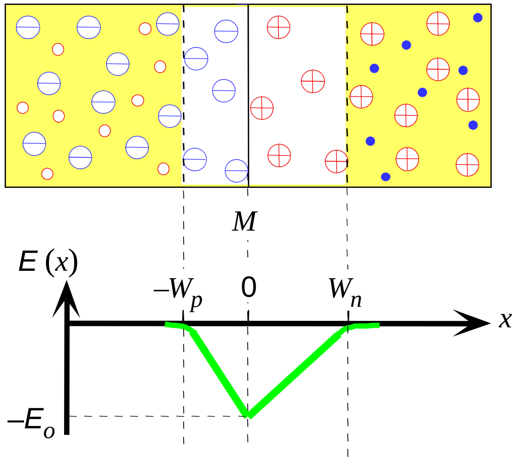


Photo-generated carriers are removed by built-in field in depletion region (space charge region)

Lect. 26: Photodetectors

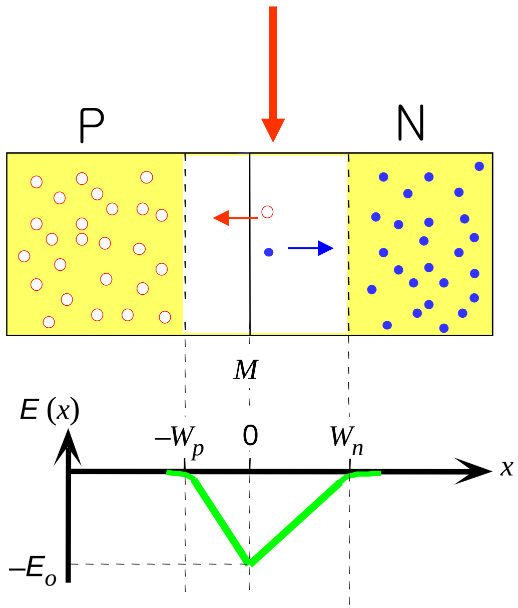
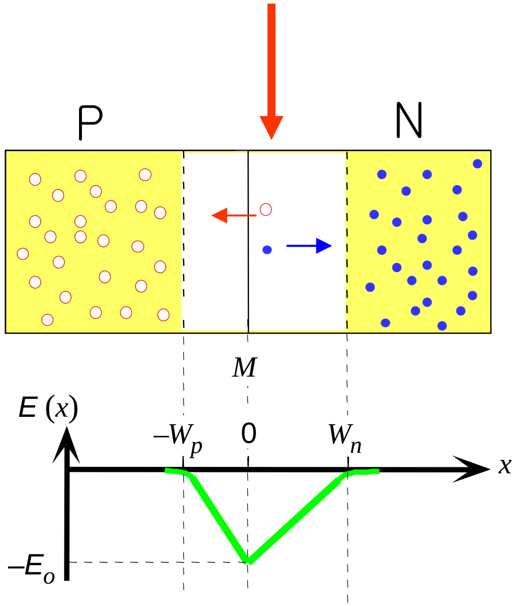


Photo-generated carriers drift into P (holes) and N (electrons) regions generating currents

$$I = \eta_{\text{int}} \frac{P}{h\nu} q$$

One photon creates a pair of electron and hole

Lect. 26: Photodetectors



Problem: depletion region is very thin (< 1 μm)

➔ η_{int} is very small

=> Use PIN structure

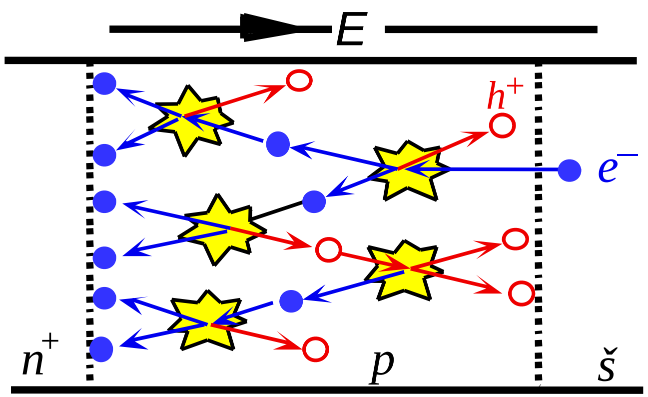
Lect. 26: Photodetectors

PD with gain?

Avalanche Photodiode (APD)
(avalanche: a large mass of snow, ice, earth, rock, or other material in swift motion down a mountainside)

Achieve gain by multiplying electrons and/or holes.

Impact Ionization: Under high E-field, electrons and holes can have sufficiently high kinetic energies breaking bonds and creating new e-h pairs.

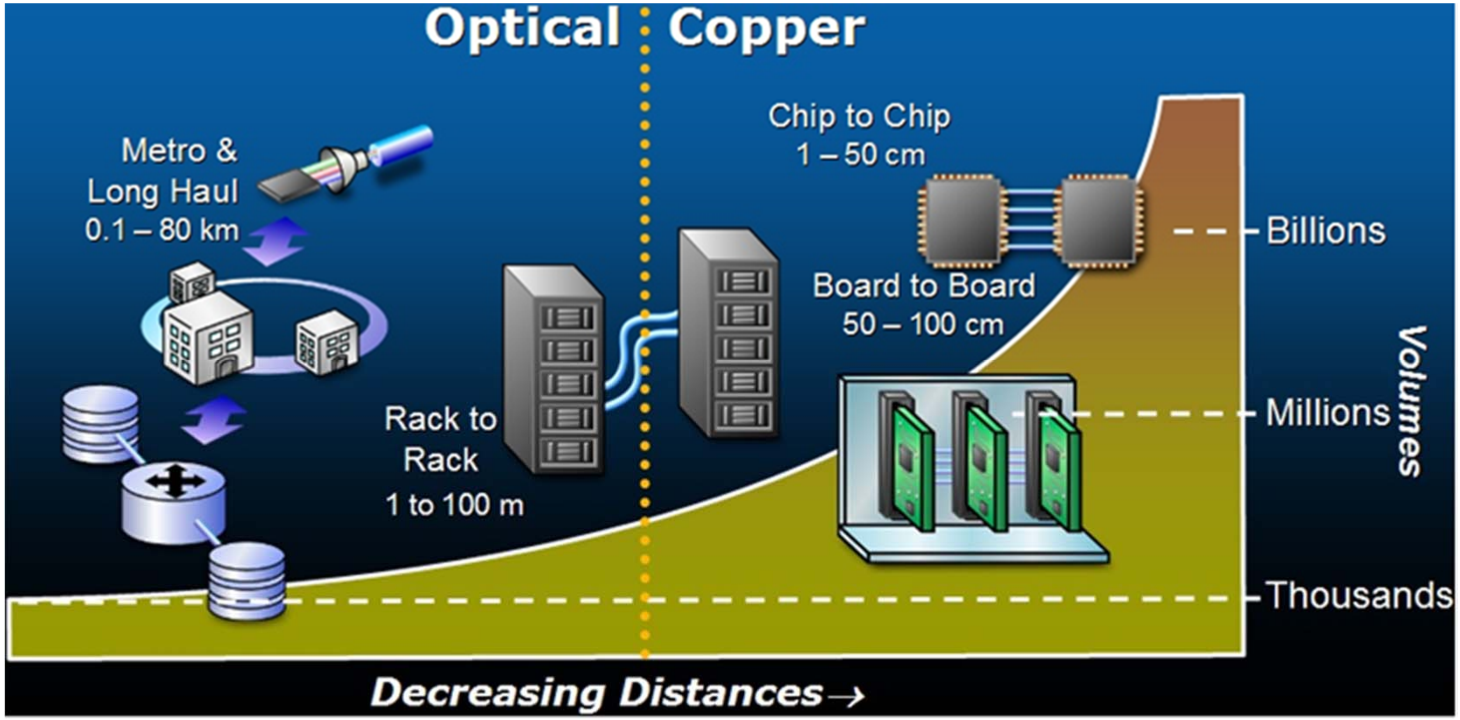


Avalanche region

It is preferred only one type of carrier (either electron or hole) causes impact Ionization

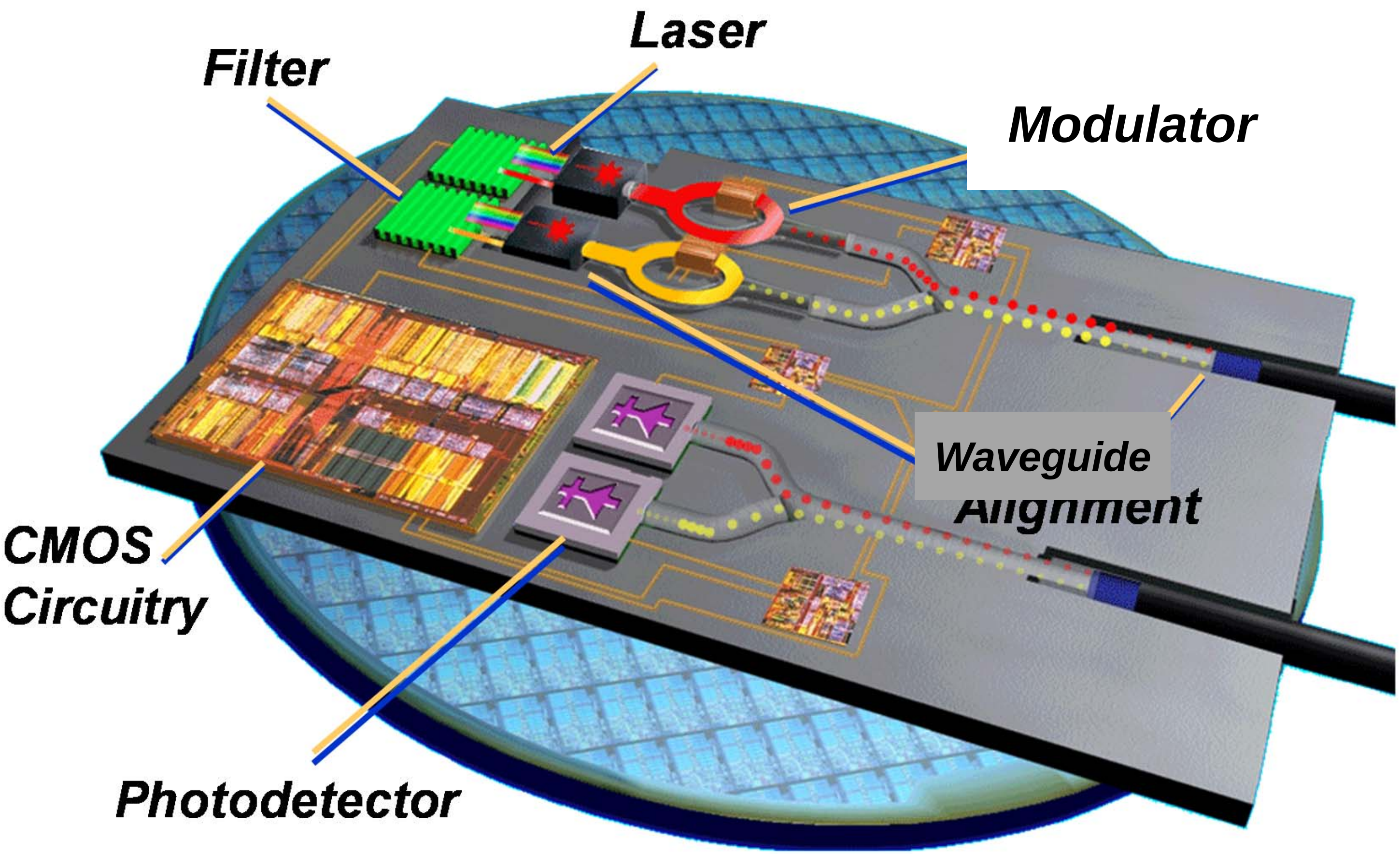
κ: ratio of ionization coefficients (= hole/electron)

Current Status of Photonics Technology



- Photonics has been very successful in **Left**
- Photonics has to go to **Right** in order to maintain its growth
- Telecom Operators ➔ Semiconductor Companies
- Data rate, Distance ➔ Data rates, Cost, Power
- There is no better platform than Si

Ultimate Solution: Si Electronic-Photonic Integration



If interested, come and see me!