Semiconductor Photodetectors

- Semiconductor band structure

- Optical absorption across the bandgap

- p-n Junction

If $h\nu > E_G$, an electron and hole (pair) is created after photon absorption.

In a suitable structure, the electron and the hole can contribute to an electric current through the device.
• Depletion approximation: Assumes carriers diffuse across junction and create regions that are totally devoid of free carriers

\[ \rho \]

\[ -ln \]

\[ \varepsilon \]

\[ z \]

• Reverse bias

Under reverse bias, no current flows because the barrier to diffusion increases. Under forward bias, barrier to diffusion is reduced.

\[ \rho \]

depletion widths wider

Photodiode

Reverse bias condition: electron and hole created in the depletion region follow the electric field and separate.

These carriers are pulled apart by the field.
The electric field exists *only* inside the depletion region. So the light absorption must also occur there to create current.

**Construction**

- Photodiodes can be used at longer wavelength than photomultiplier – $E_G < \Phi$
- Typically fast response time < 10 nsec
- Compact, inexpensive

![Diagram of a p-i-n photodiode](image)

**p-i-n photodiode**

- Thin electrode passes light
- Thin, heavily doped n$^+$ layer
- Depletion region
- Lightly doped p-region
- Backside electrode

![Diagram of constant ε-field in the i-layer](image)

**constant ε-field in the i-layer**
Solar cells


silicon p-n junction diode:

\[
I = I_0 \left[ \exp \left( \frac{qV}{kT} \right) - 1 \right]
\]

Solar radiation -
AM 1.5 - on a clear day, the typical maximum solar irradiance is \( \sim 1 \text{kW/m}^2 \) or 100 mW/cm\(^2\), which translates to \( \sim 4.4 \times 10^{17} \) photons/cm\(^2\)-sec.

In principle, when absorbed, this photon flux could produce a ‘generation current’ of

\[
I_g = qNA
\]

where \( N \) is the number of photons absorbed per second, and \( A \) is the area that is exposed to light. For the entire solar spectrum, this corresponds to about 70mA/cm\(^2\). The band gap for crystalline silicon is 1.1 eV, so only the part of the spectrum shown above that is shaded in black can be absorbed. Thus, for silicon, the maximum generation current is about 44 mA/cm\(^2\).