Desirable Characteristics of Optical Sources

- Emission within low loss window of the fiber
- Narrow spectral width
- Capability to couple adequate power to fiber
- Ease of coupling to fiber
- Ease and linearity of modulation
- High modulation speed
- High reliability
- Ruggedness for field use
Various Optical Sources

- Gas Sources (Lasers)
  - High power
  - Narrow spectral width
  - Highly directional

- Semiconductor Sources (Light Emitting Diode (LED), Injection Laser Diode (ILD))
  - Low power
  - Large spectral width
  - Non-directional radiation
Photon Wavelength
Direct band
\[ \frac{\text{GaAs}}{} \]

\[ \text{Momentum} \]

Indirect band
\[ \frac{\text{Si, Ge}}{} \]
Optical Sources

Direct Band gap Material

\[ E = E_2 - E_1 = h \nu = \frac{hc}{\lambda} \]

\[ \lambda (\mu m) = \frac{1.24}{E (eV)} \]

For GaAs \( E = 1.4 \) eV

\[ \iff \lambda = 0.8 \mu m \]

For Ga\(_x\) Al\(_{1-x}\) As \( E (eV) = 1.424 + 1.266x + 0.266x^2 \quad 0 < x < 0.37 \)

For In\(_{1-x}\) Ga\(_x\) As \(_y\) P\(_{1-y}\) \( E (eV) = 1.35 - 0.72y + 0.12y^2 \quad y = 2.2x, \ 0 < x < 0.47 \)

\[ \iff \lambda = 0.92 - 1.65 \mu m \]

Prof. R.K. Shevgaonkar, IIT Bombay
\[ S_C(E_2) = \text{Distribution of energy states in conduction band} \]

\[ S_C(E_2) = \frac{4\pi (2m_e)^{3/2}}{h^2} \left( E_2 - E_c \right)^{1/2} \]

\[ S_V(E_1) = \text{Distribution of energy states in valence band} \]

\[ S_V(E_1) = \frac{4\pi (2m_h)^{3/2}}{h^2} \left( E_v - E_1 \right)^{1/2} \]

\[ F(E) = \frac{1}{1 + e^{(E-E_F)/kT}} \]
Forward bias condition

Narrowed depletion region

External battery

Prof. R.K. Shevgaonkar, IIT Bombay
\textbf{n-type material}

\begin{align*}
F(E_2) &= \frac{E_{Fn}}{1 + e^{(E_2 - E_{Fn})/kT}} \\
&\approx \frac{1}{e^{(E_2 - E_{Fn})/kT}} \\
&\approx e^{-(E_2 - E_{Fn})/kT}
\end{align*}

Prob of electron in conduction band

\[ n(E_2) \approx e^{-(E_2 - E_{Fn})/kT} \]
p-type material

\[ F(E_1) = \frac{1}{1 + e^{(E_1 - E_{FP})/kT}} \]

Prob of absence of electron in the valence band is

\[ 1 - F(E_1) = 1 - \frac{1}{1 + e^{(E_1 - E_{FP})/kT}} \]

\[ E_c = 1 - \left\{ 1 + e^{(E_1 - E_{FP})/kT} \right\}^{-1} \]

\[ E_{FP} \approx \chi - \chi + e^{(E_1 - E_{FP})/kT} \]

\[ E_V \quad \text{Prob. of hole} \approx e^{(E_1 - E_{FP})/kT} \]
Prob. of photon generation

\[ \alpha = \frac{n(E_2) \times p(E_1)}{e^{\frac{(E_2-E_{Fn})}{kT}} \times e^{\frac{(E_1-E_{Fp})}{kT}}} \]

\[ = \frac{e^{\frac{(E_2-E_1)}{kT}} \times e^{\frac{(E_{Fn}-E_{Fp})}{kT}}}{A - \text{const}} \]