Introduction to Organic Electronic and Optoelectronic Materials and Devices 2nd edition Sun Solutions Manual

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Introduction to Organic Electronic and Optoelectronic Materials and Devices 2nd edition Sun Solutions Manual

Chapter 2 Introduction to Optoelectronic Device Principles

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QUESTION 1: A solar cell under illumination of 500 W/m^2 has a short circuit current of I_{sc} = 15 mA and an open circuit voltage of V_{oc} = 0.6 V. Calculate I_{sc} and V_{oc} for double the light intensity assuming a diode ideality factor of $m=1$.

SOLUTION 1: The solar cell current-voltage characteristic is given by Eq. (12). The open circuit voltage is obtained for $I=0$ and $V_{oc} >> mkT/e$ as

$$V_{oc} = \frac{mkT}{e} \ln\left(\frac{I_{ph}}{I_o}\right)$$

The short circuit current is equal to the photocurrent which is proportional to the light intensity. Double the intensity gives I_{sc2} = 30 mA and

$$V_{oc2} = V_{oc1} + \frac{mkT}{e} \ln\left(\frac{I_{sc2}}{I_{sc1}}\right) = 0.6V + 0.0259V \times \ln(2) = 0.618V \ .$$

QUESTION 2: The LED emission wavelength λ is sensitive to the temperature T which is mainly related to the band gap shift $E_g(T)$. Consider an LED with an emission wavelength of 870 nm at 20 ^{o}C that red-shifts by 2.8 nm for 10 ^{o}C temperature increase. What is the band gap E_g and its temperature sensitivity $\Delta E_g/\Delta T$?

SOLUTION 2: The band gap – wavelength relation is given in Eq. (1). At 20

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^{o}C, the wavelength of 870 nm gives a band gap of $E_g = 1241/870 = 1.426$ eV. The thermal shift of the band gap is calculated as

$$\frac{\Delta E_g}{\Delta T} = \frac{1241}{10}\left(\frac{1}{870} - \frac{1}{867.2}\right) = -0.46\times10^{-3}\,\frac{eV}{K}.$$

QUESTION 3: Consider a Mach-Zehnder modulator as in Figure 23 with a Pockels coefficient $r = 3.4\ 10^{-12}$ m/V and a branch thickness $d = 5$ μm. For a maximum half-wave voltage of $V_\pi = 10$ V, what should be the minimum branch length L for modulator operation at 1.55 μm wavelength ($n_r = 2.2$) ?

SOLUTION 3: The half-wave voltage is given by Eq. (35), which leads to

$$L = \frac{d}{V_\pi}\frac{\lambda}{rn_r^3} = \frac{5\times10^{-6}m}{10V}\,\frac{1.55\times10^{-6}m}{3.4\times10^{-12}m/V\times2.2^3} = 2.14cm.$$

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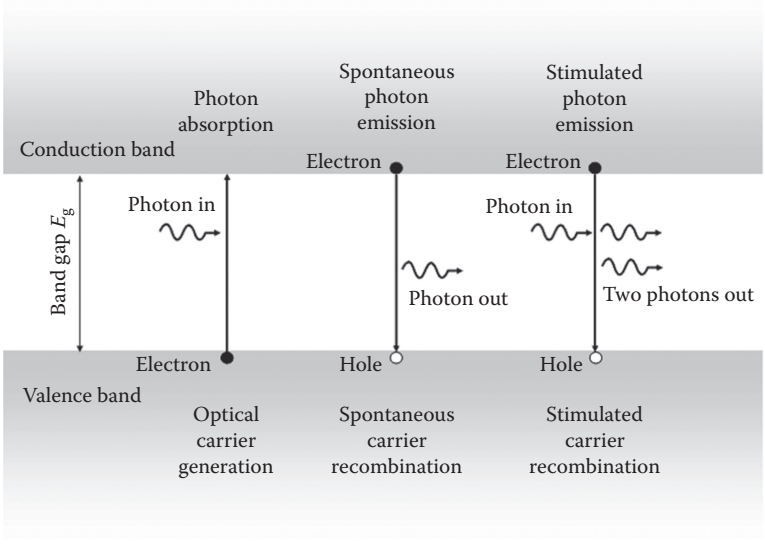


Figure 2.1 Illustration of key processes in optoelectronic devices.

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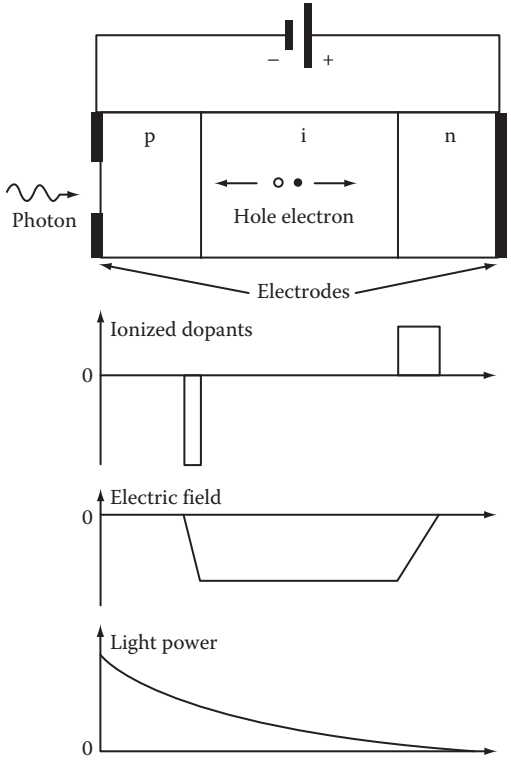


Figure 2.2 Schematic structure and internal physics of pin photodiodes.

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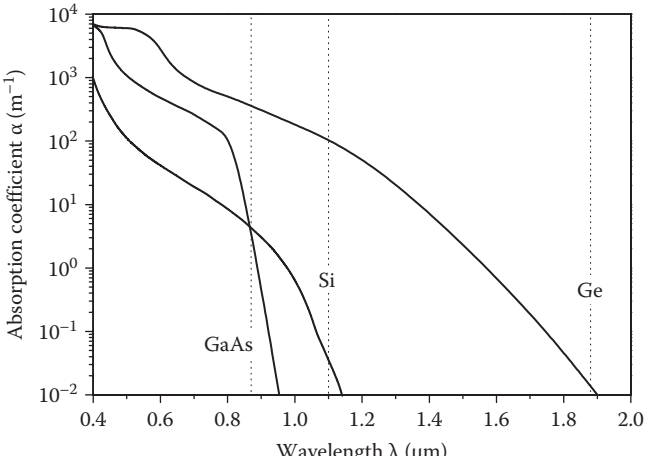


Figure 2.3 Optical absorption constants of GaAs, Si, and Ge as function of light wavelength. The dotted lines indicate the band gap wavelength.

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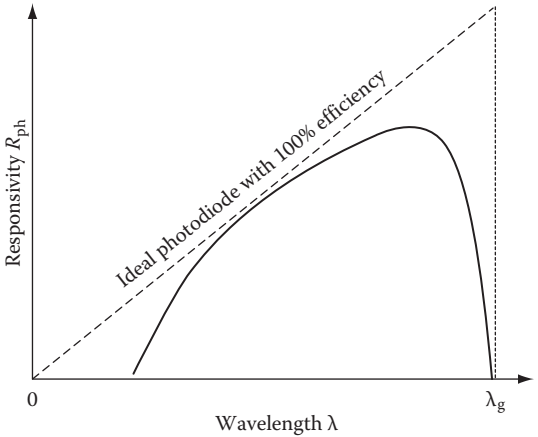


Figure 2.4 Schematic responsivity spectrum of photodiodes.

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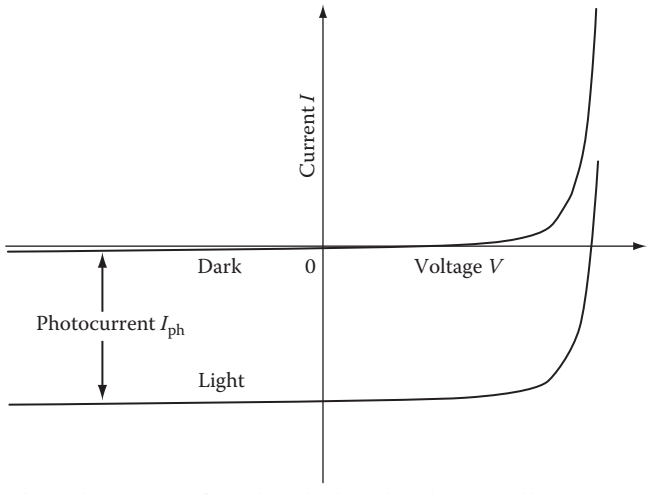


Figure 2.5 Current–voltage characteristic for a photodiode with and without illumination.

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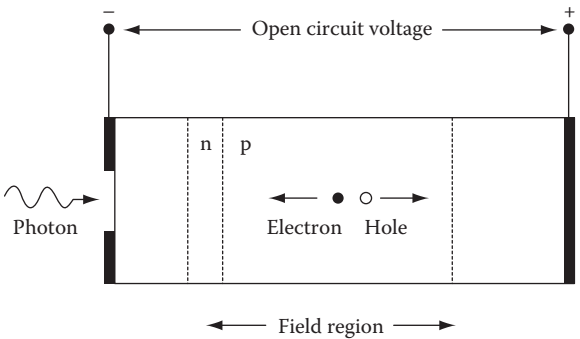


Figure 2.6 Solar cell.

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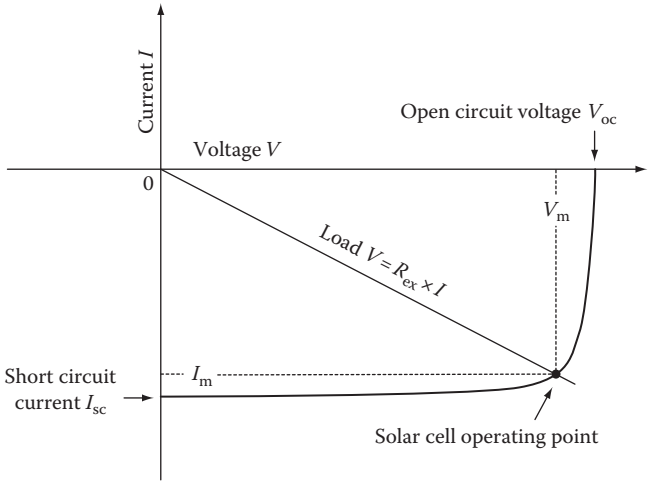


Figure 2.7 Solar cell current–voltage characteristic and parameters.

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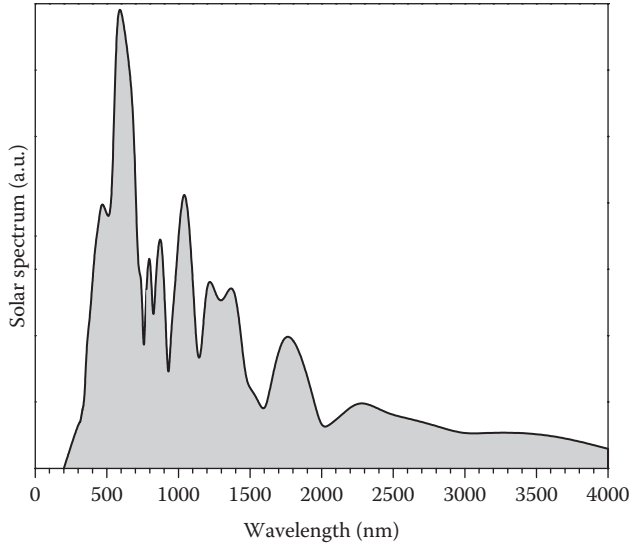


Figure 2.8 Solar spectrum.

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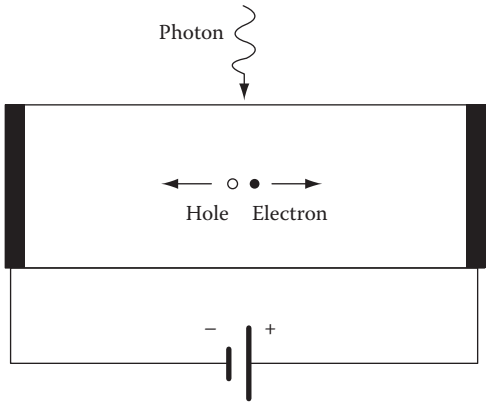


Figure 2.9 Photoconductor.

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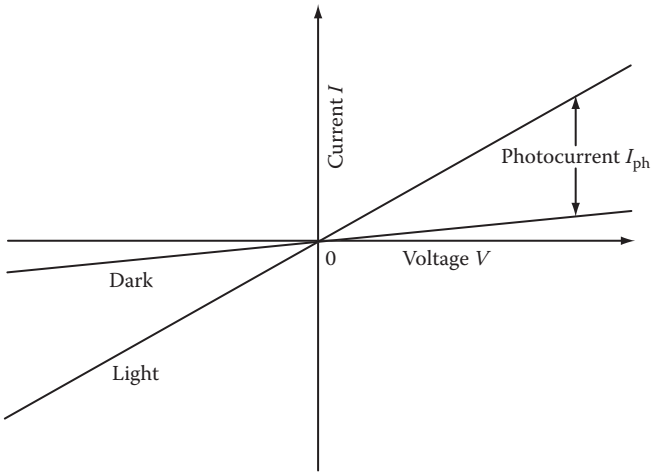


Figure 2.10 Current–voltage characteristic for a photoconductor with and without illumination.

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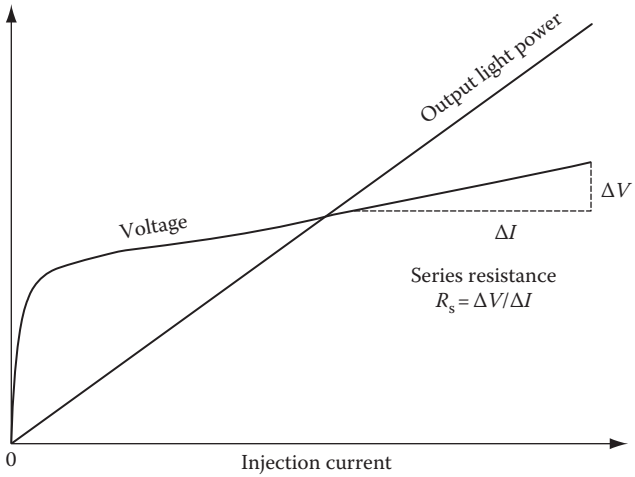


Figure 2.11 Typical LED characteristics: light versus current (*LI*) and voltage versus current (*IV*).

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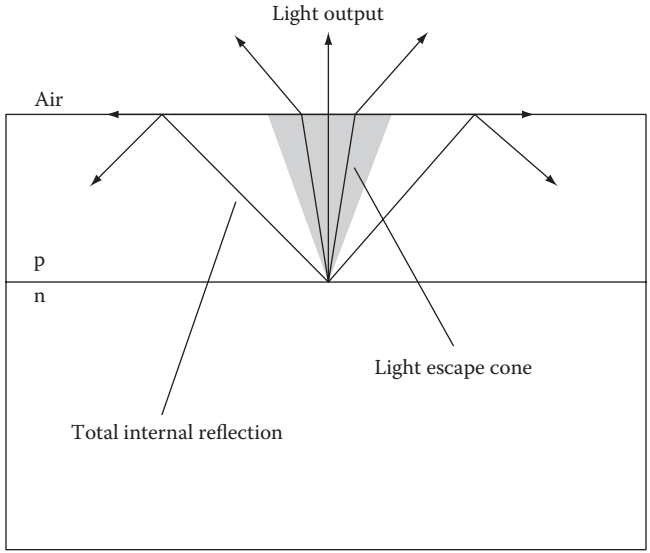


Figure 2.12 Illustration of light propagation in a simple LED structure.

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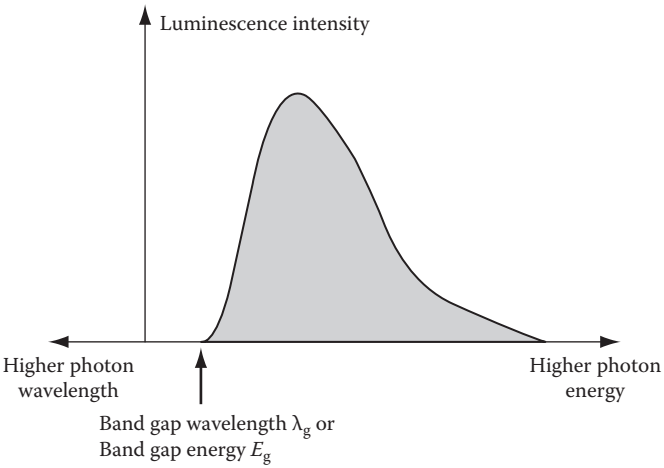


Figure 2.13 Schematic LED emission spectrum.

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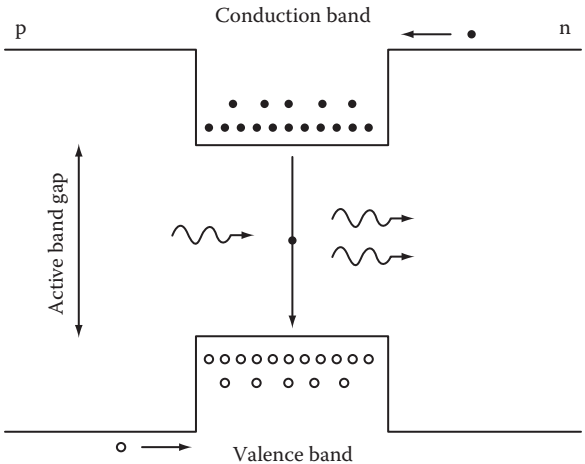


Figure 2.14 Energy band diagram of a pin heterojunction illustrating stimulated photon emission at forward bias.

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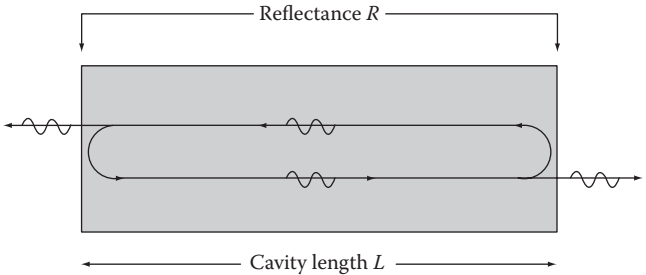


Figure 2.15 Optical feedback in a Fabry–Perot laser.

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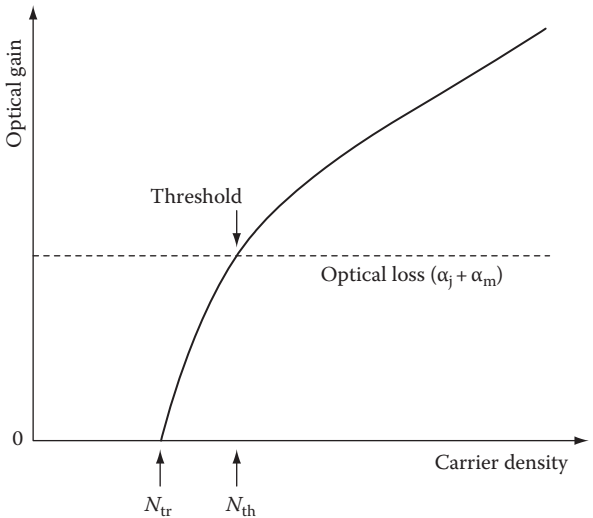


Figure 2.16 Gain versus carrier density $g(N)$ with transparency density N_{tr} and threshold density N_{th}.

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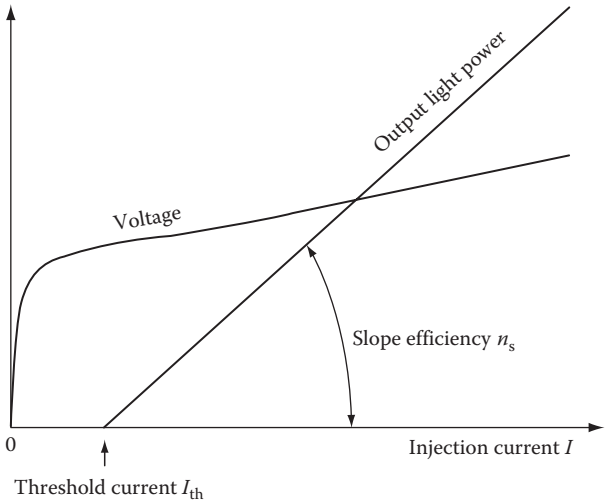


Figure 2.17 Laser characteristics: light power versus current (LI) and voltage versus current (IV).

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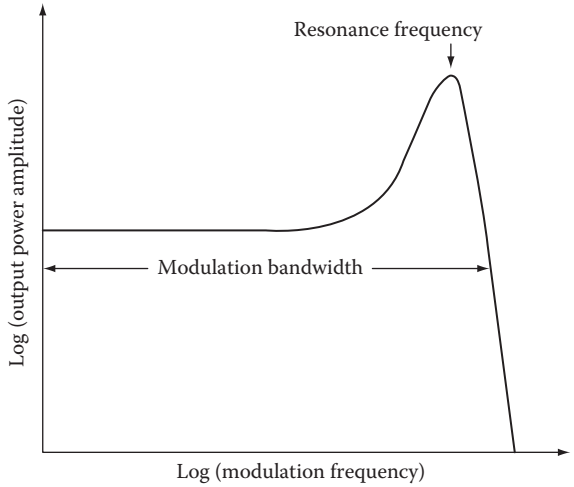


Figure 2.18 Analog modulation characteristic of a laser.

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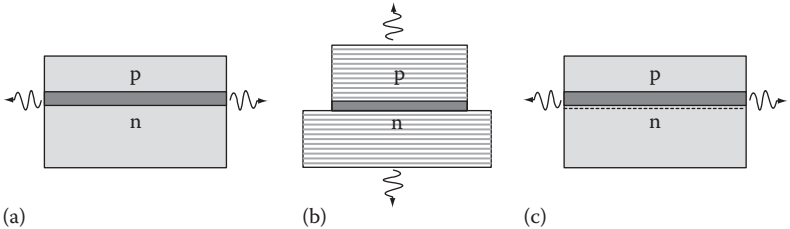


Figure 2.19 Optical resonator designs for semiconductor lasers: (a) Fabry–Perot laser, (b) VCSEL, and (c) DFB laser.

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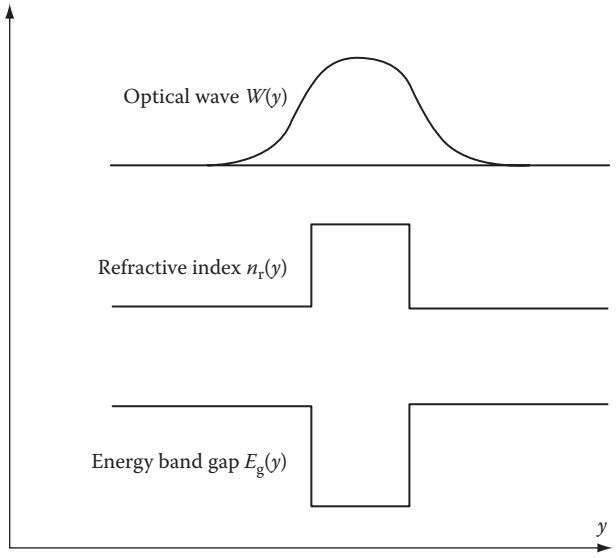


Figure 2.20 Vertical profile of band gap, refractive index, and optical wave within a planar symmetric heterostructure.

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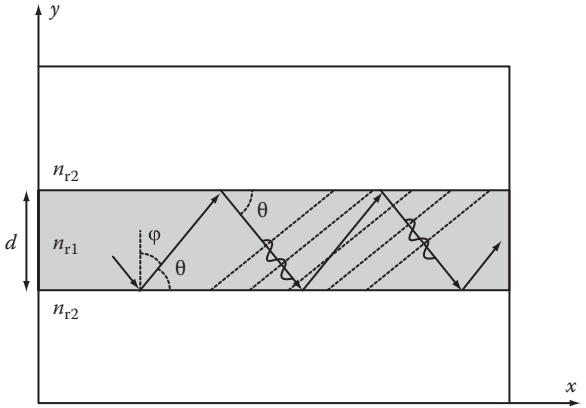


Figure 2.21 Light propagation in a planar waveguide. The dashed lines indicate constructive interference of reflected waves.

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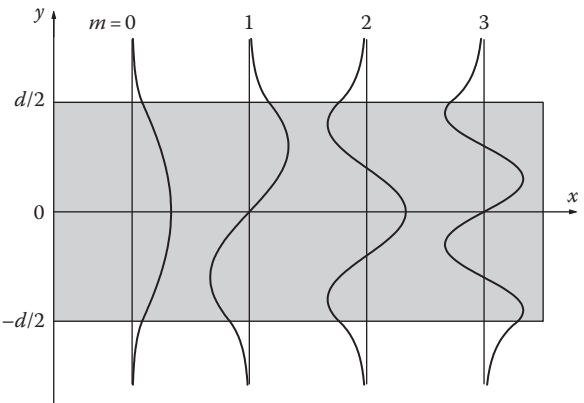


Figure 2.22 Transverse optical field profiles $W_m(y)$ for waveguide mode number m.

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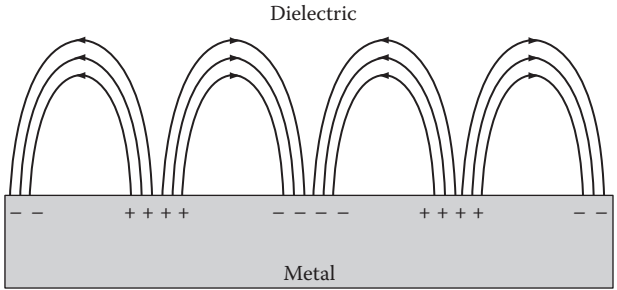


Figure 2.23 Surface plasmons: interaction of electrons and optical waves at a metal/dielectric interface.

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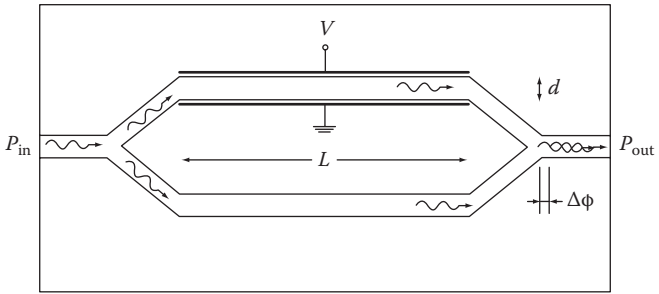


Figure 2.24 Mach–Zehnder modulator.

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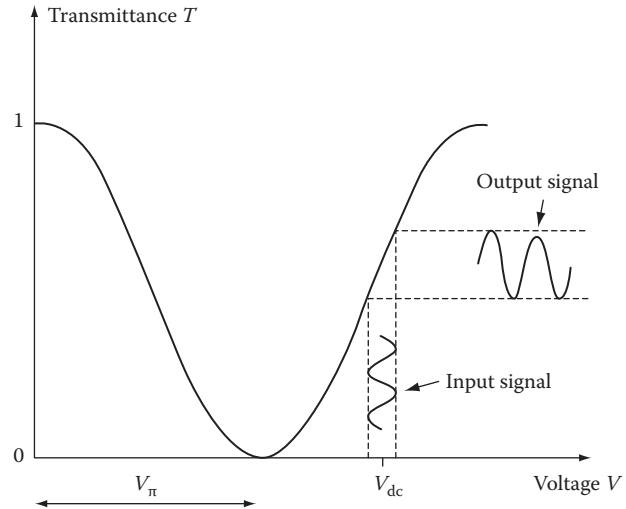


Figure 2.25 Modulator transmittance function $T(V)$.

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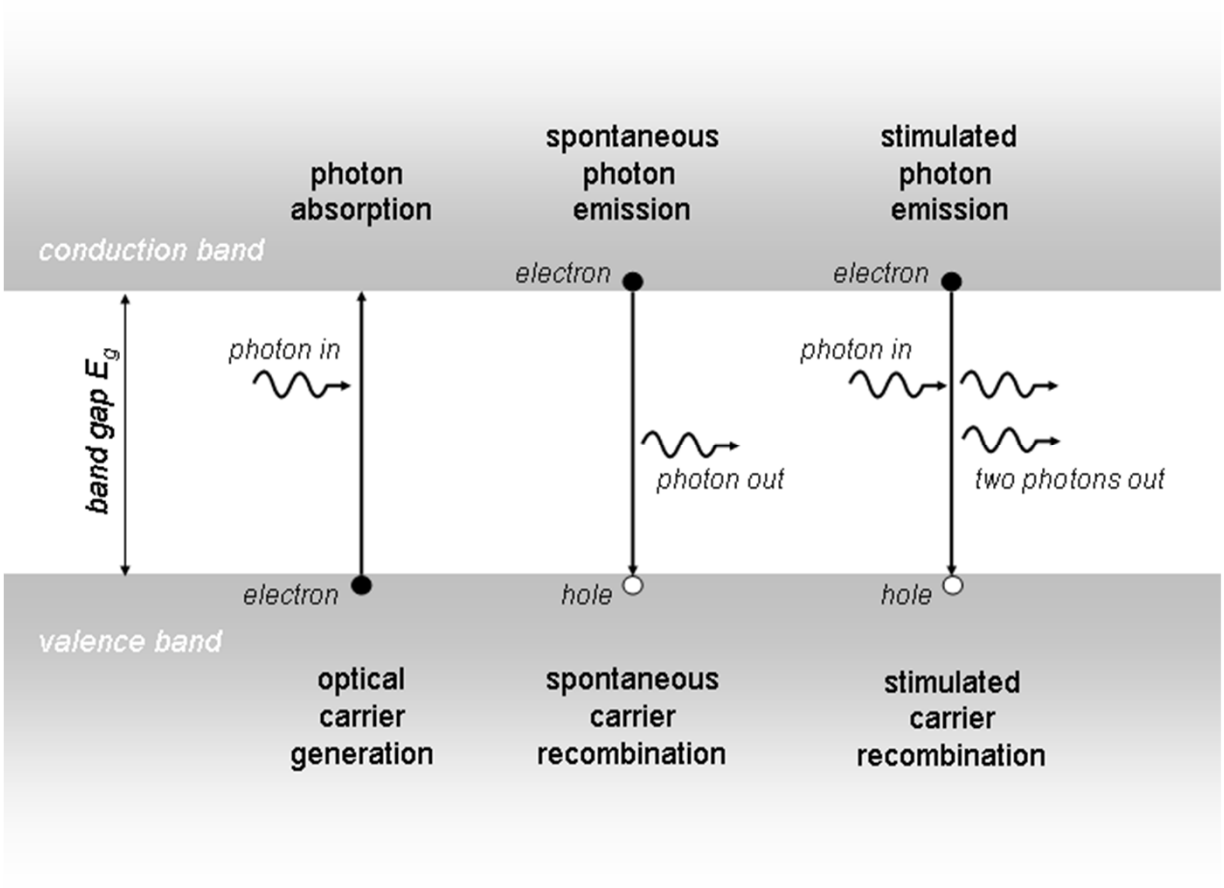


Figure 2.1 Illustration of key processes in optoelectronic devices.

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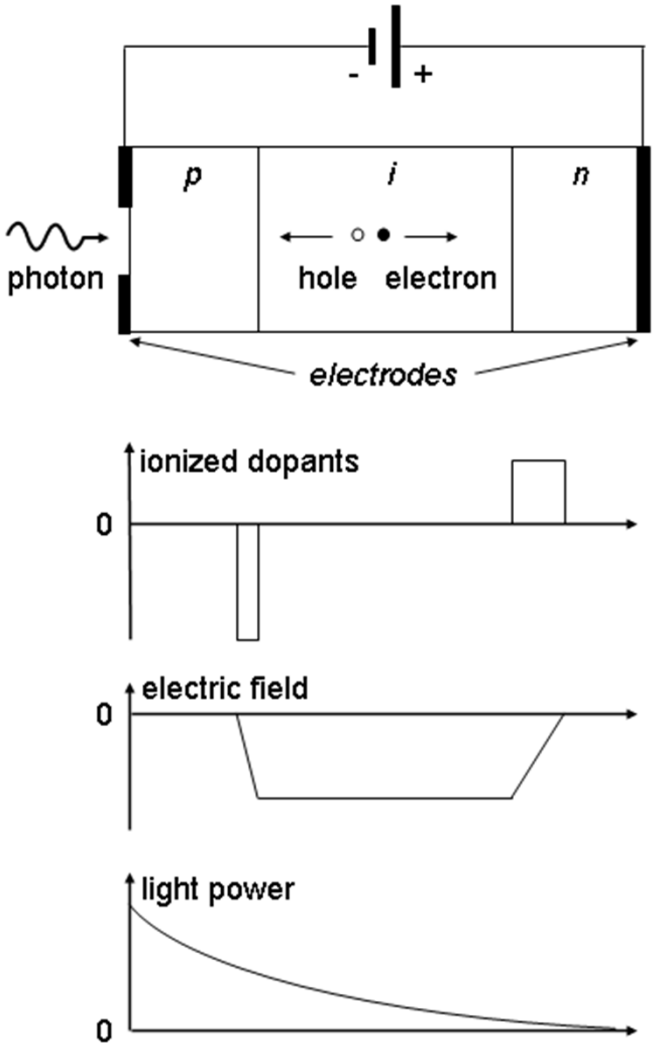


Figure 2.2 Schematic structure and internal physics of *pin* photodiodes.

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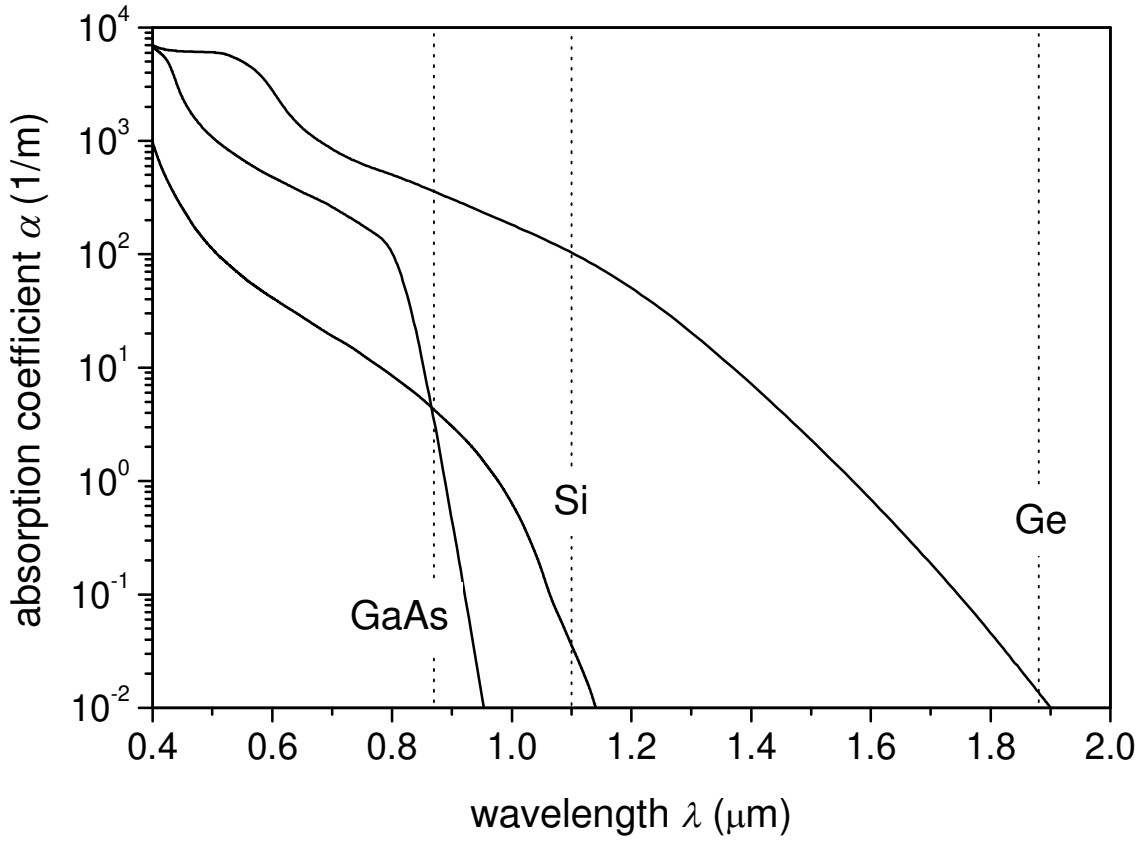


Figure 2.3 Optical absorption constants of GaAs, Si, and Ge as function of light wavelength. The dotted lines indicate the band gap wavelength.

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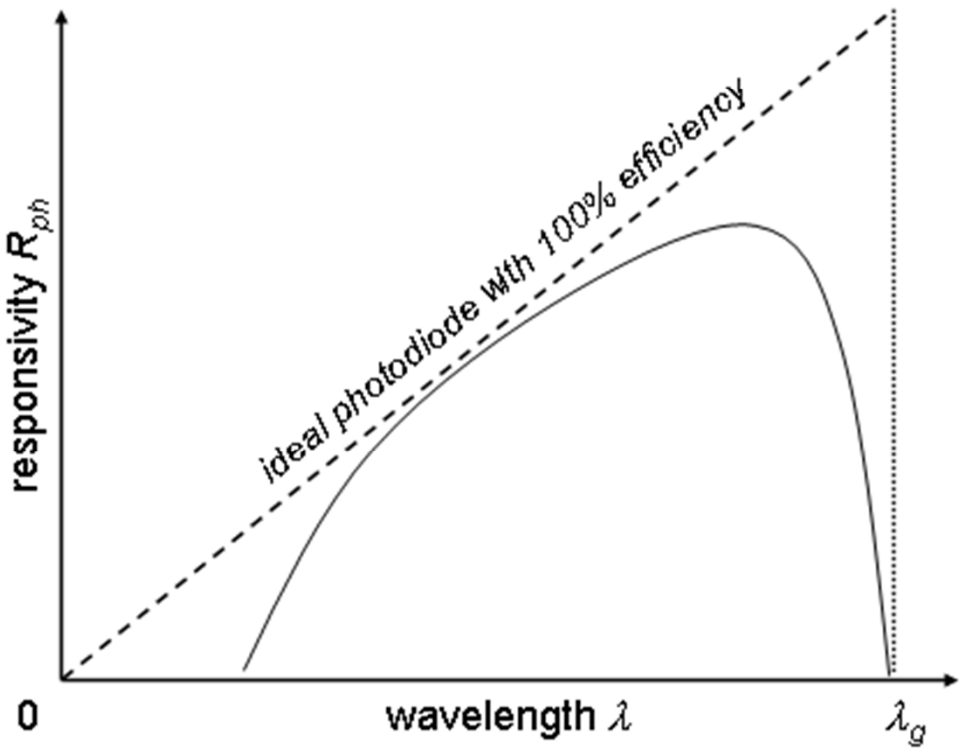


Figure 2.4 Schematic responsivity spectrum of photodiodes.

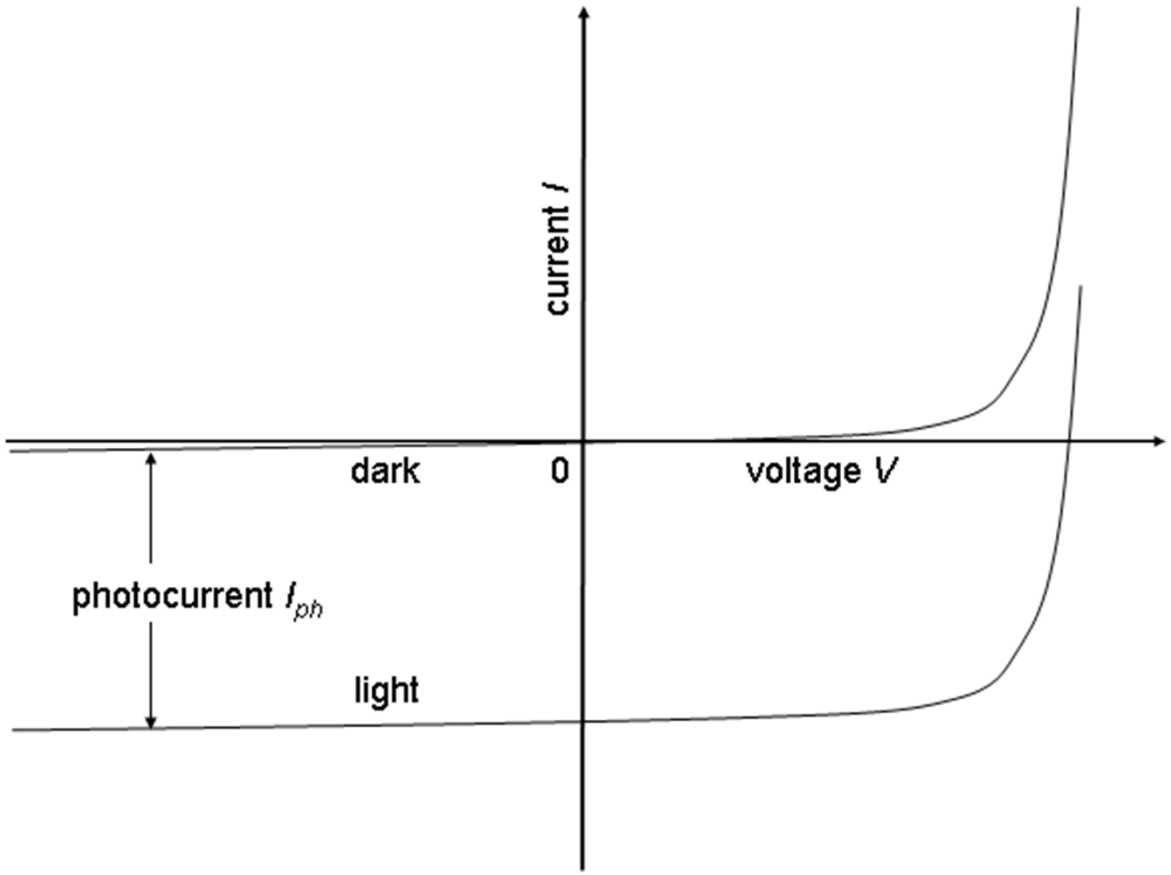


Figure 2.5 Current-voltage characteristic for a photodiode with and without illumination.

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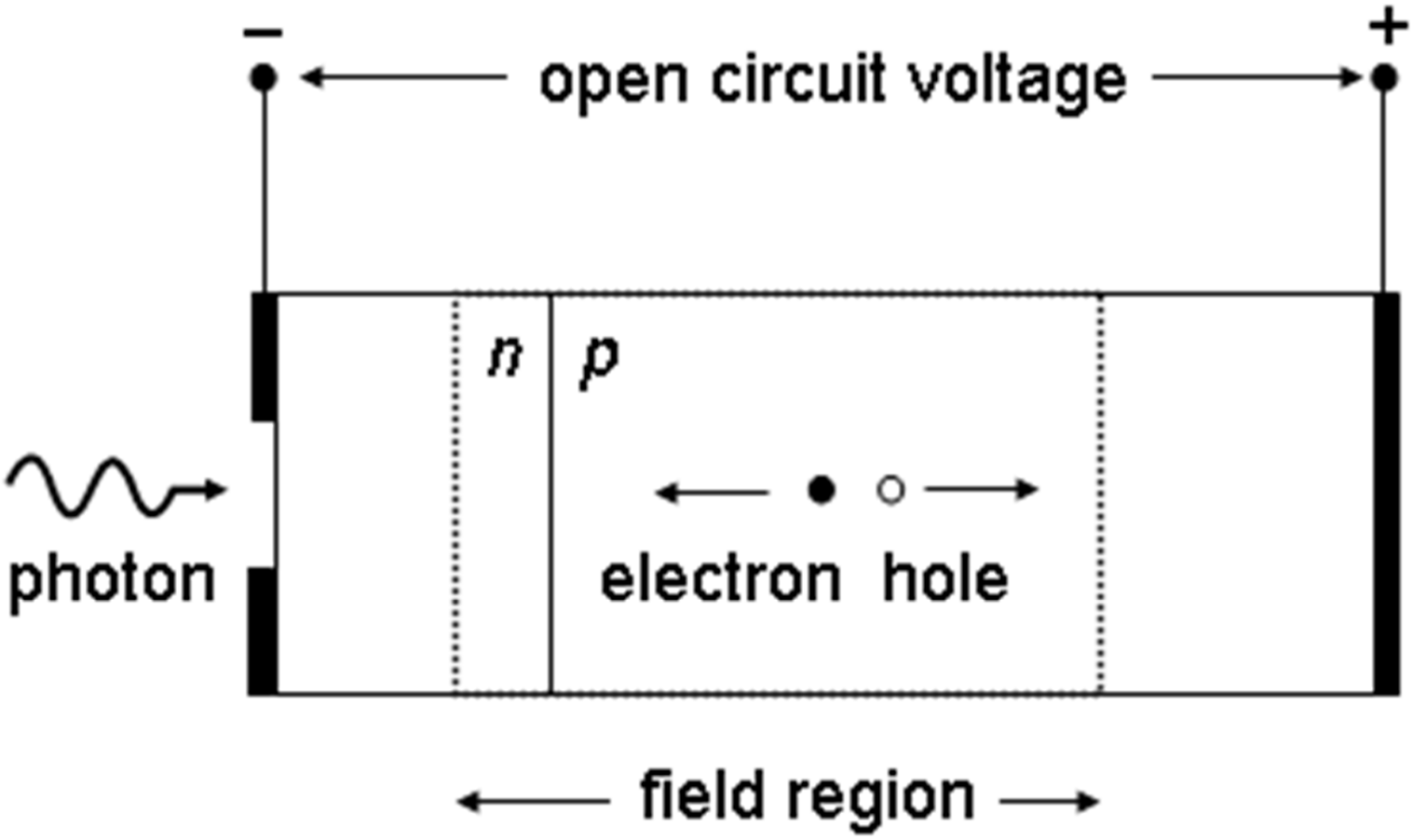


Figure 2.6 Solar cell.

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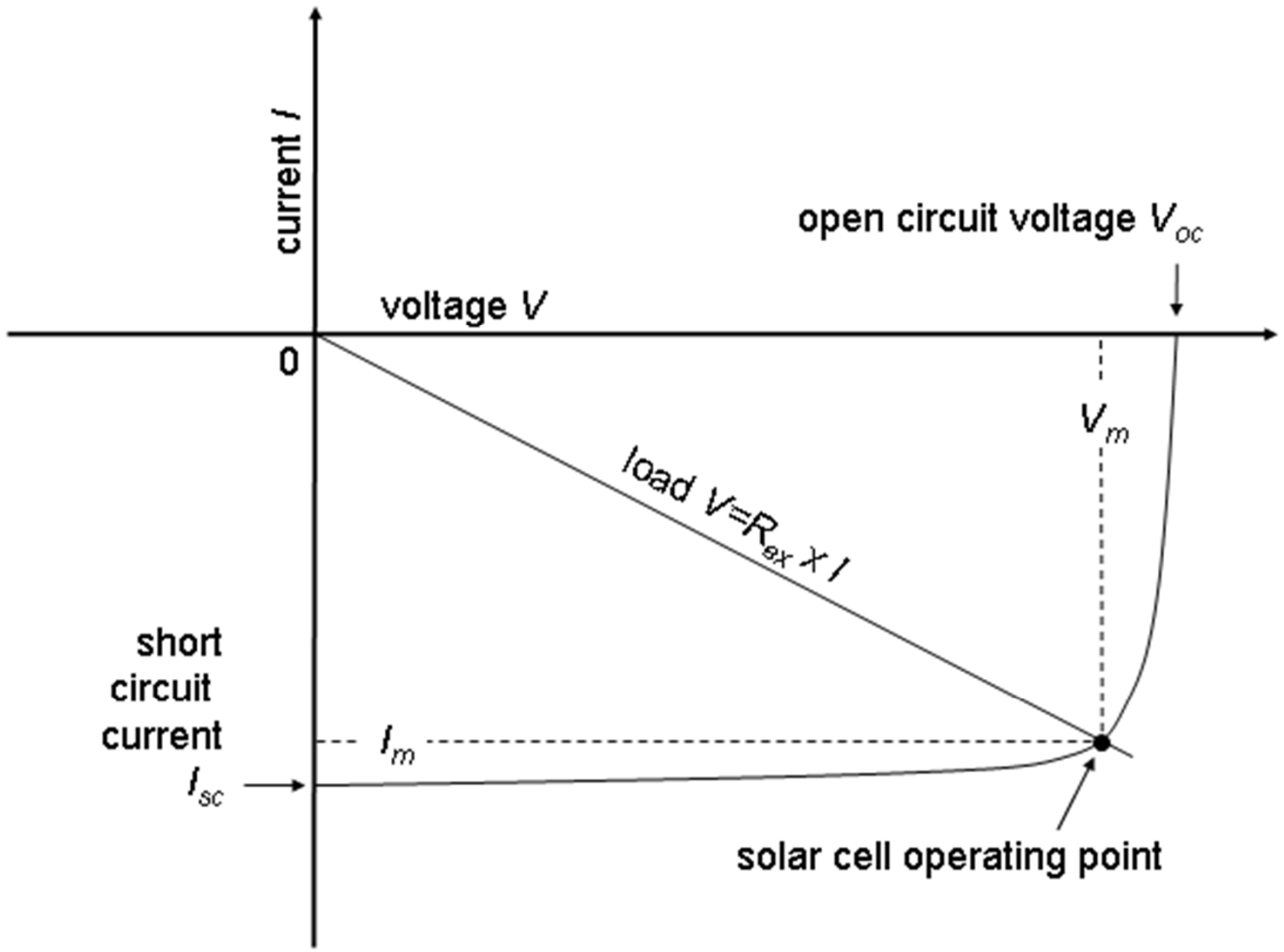


Figure 2.7 Solar cell current-voltage characteristic and parameters.

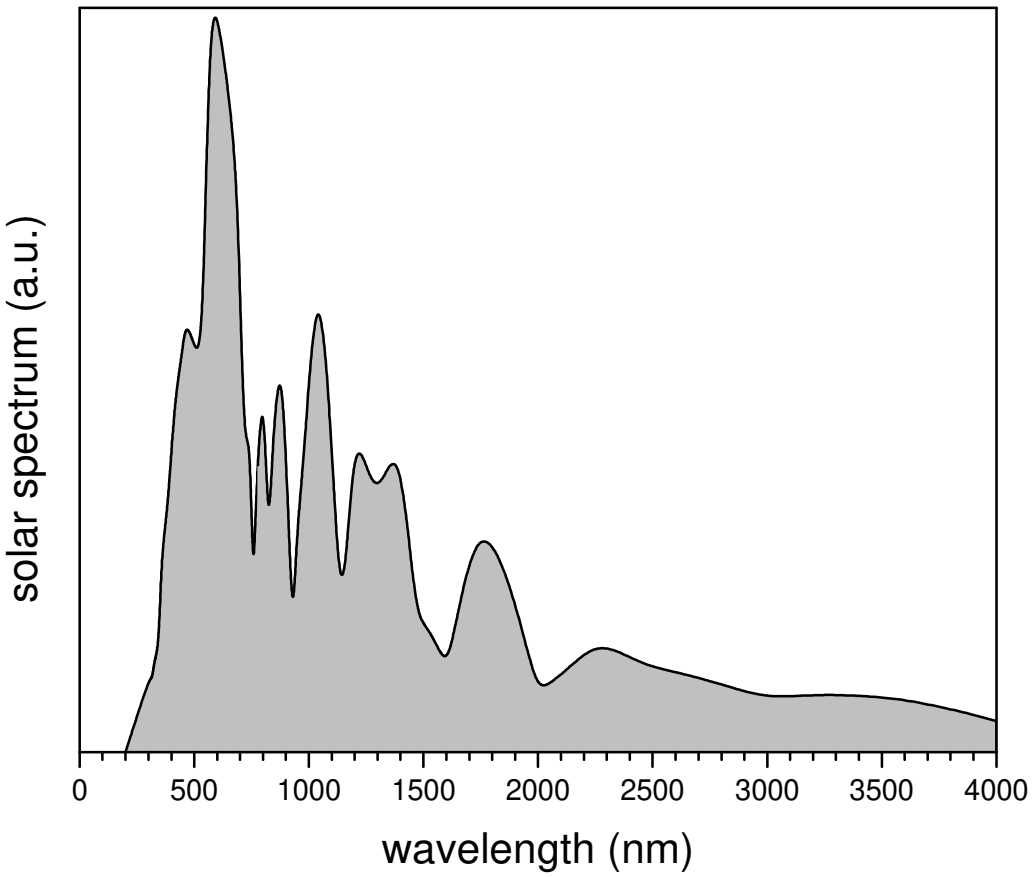


Figure 2.8 Solar spectrum.

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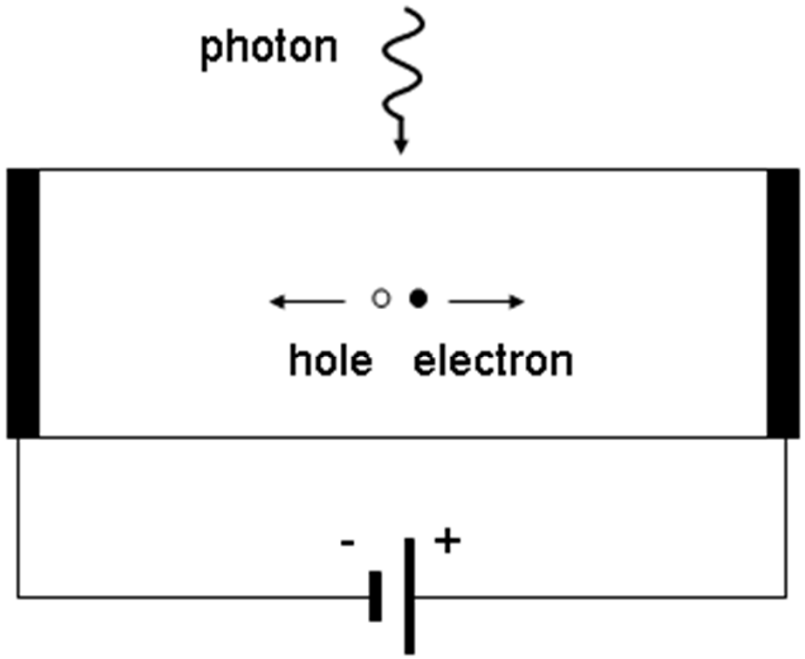


Figure 2.9 Photoconductor.

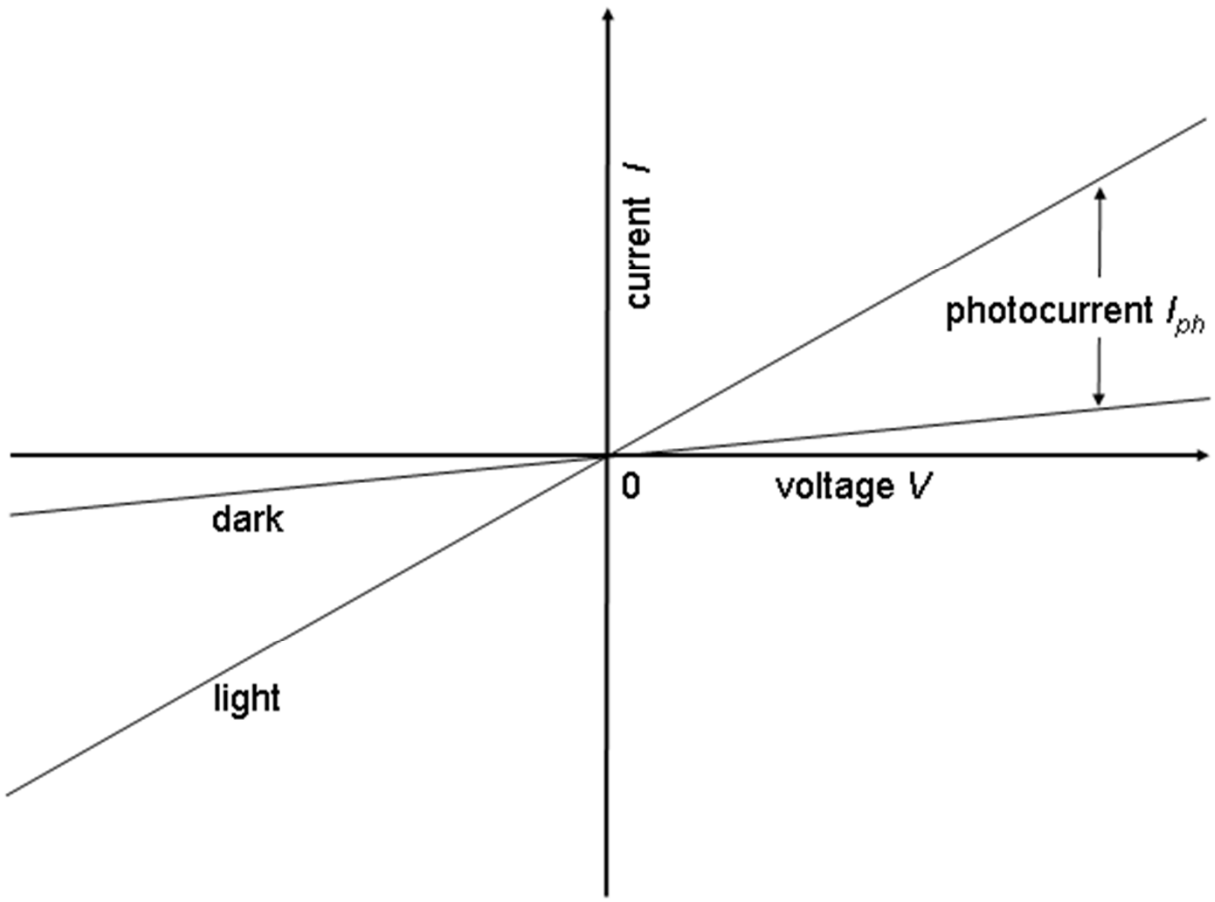


Figure 2.10 Current-voltage characteristic for a photoconductor with and without illumination.

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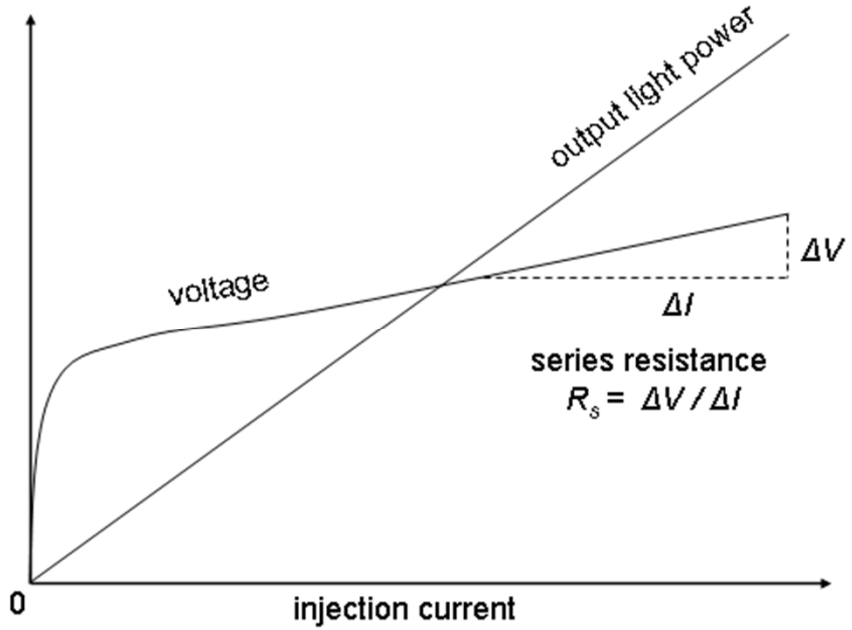


Figure 2.11 Typical LED characteristics: light vs. current (*LI*) and voltage vs. current (*IV*).

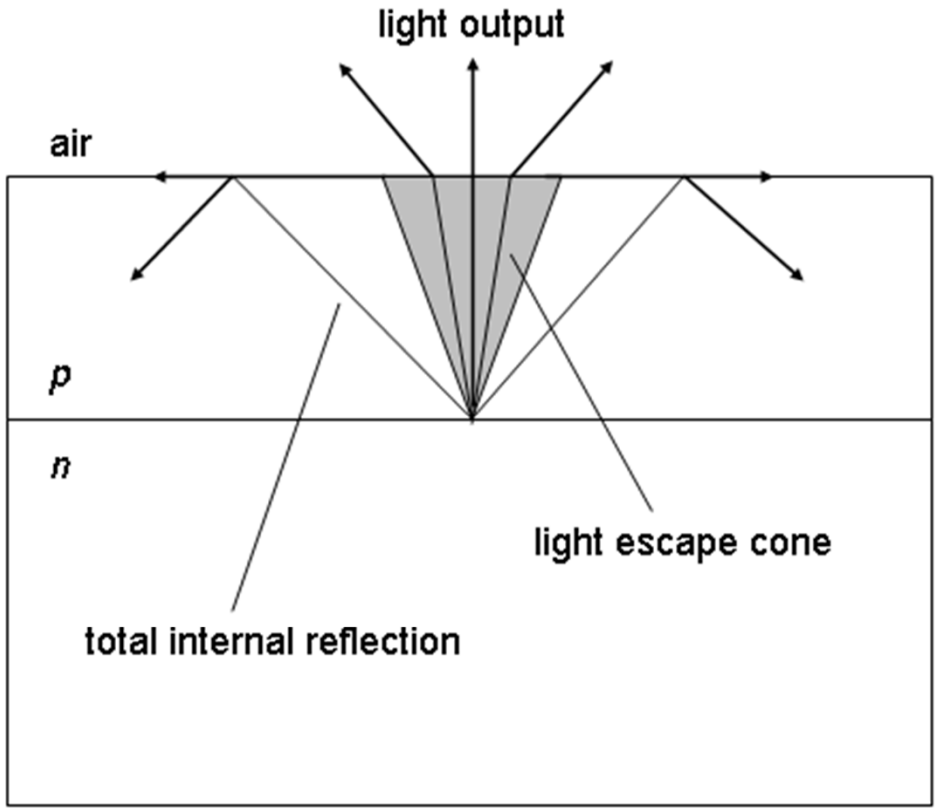


Figure 2.12 Illustration of light propagation in a simple LED structure.

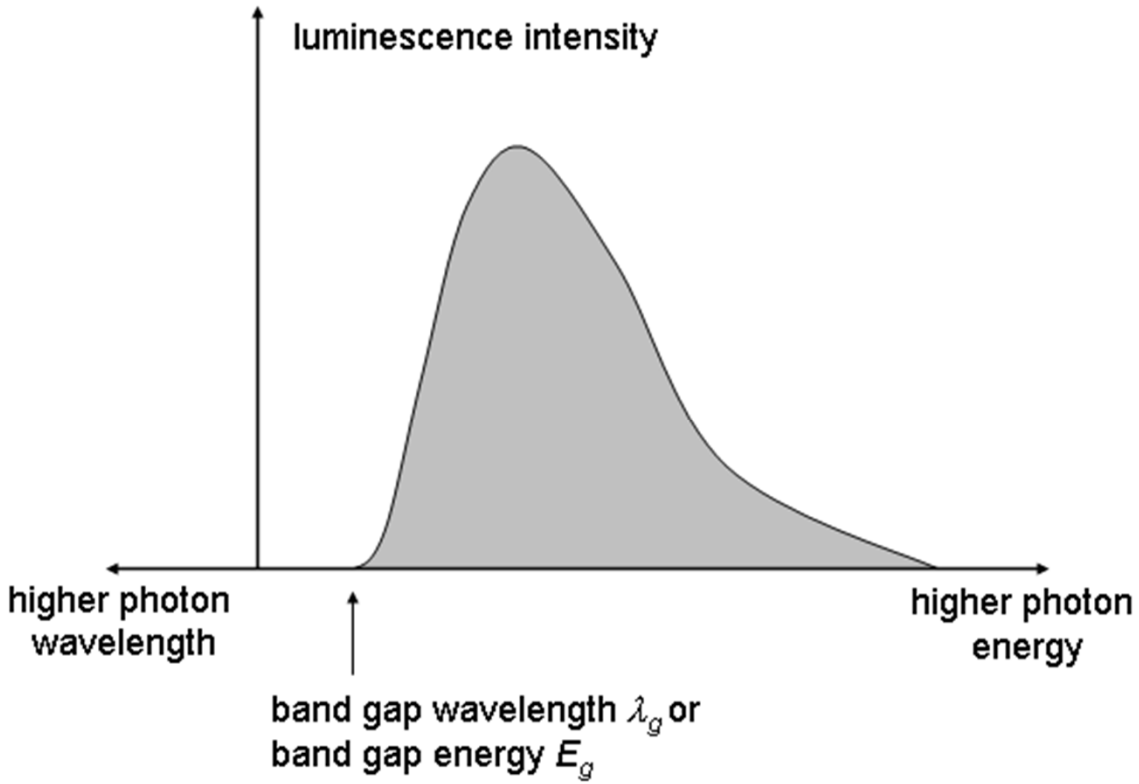


Figure 2.13 Schematic LED emission spectrum.

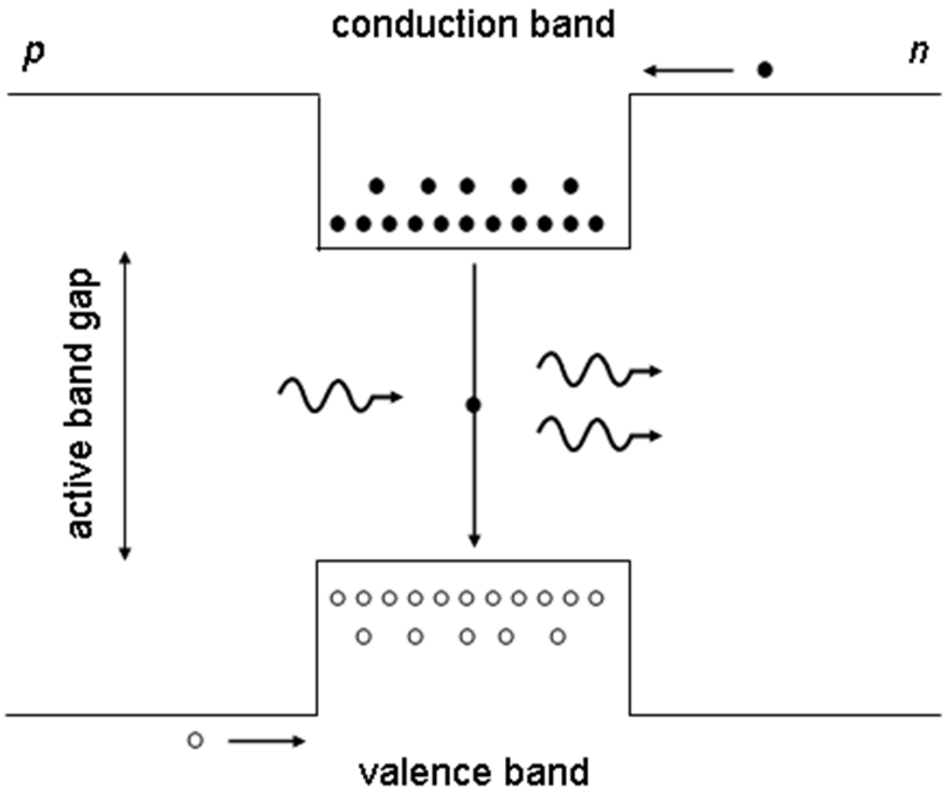


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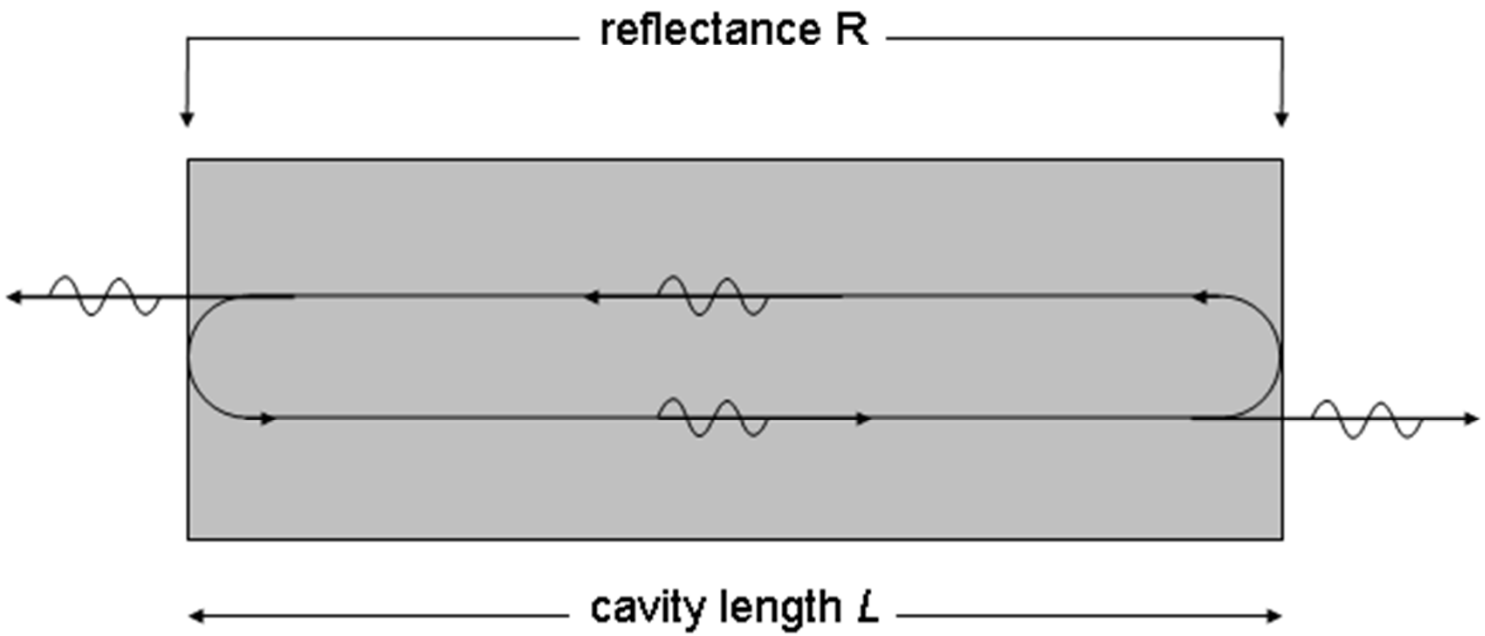


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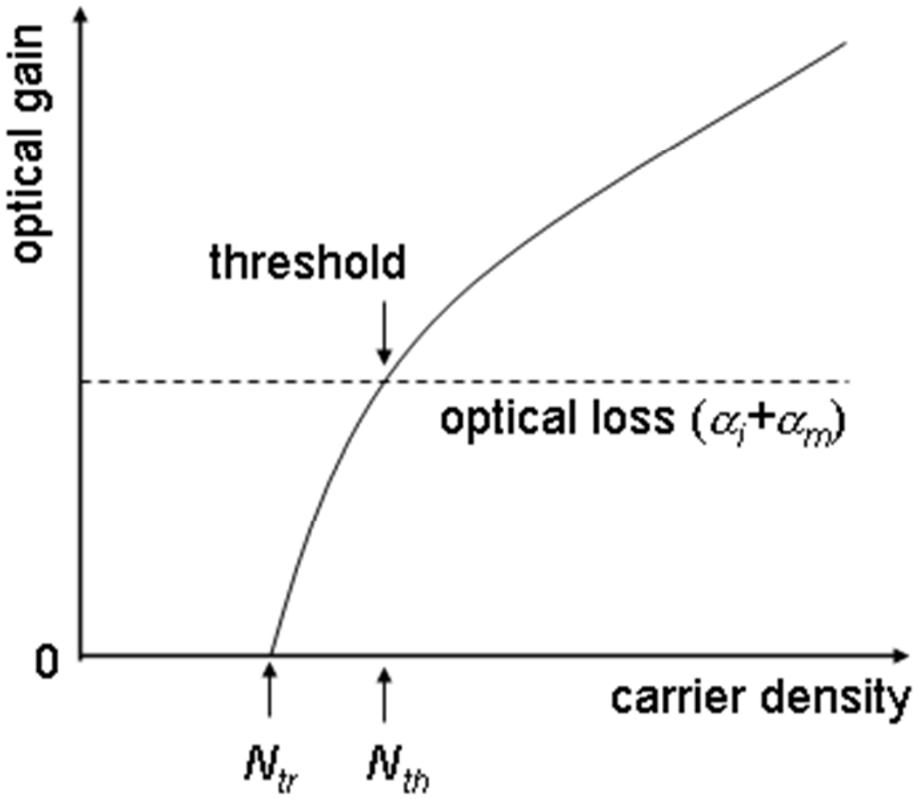


Figure 2.16 Gain versus carrier density *g(N)* with transparency density *Ntr* and threshold density *Nth.*

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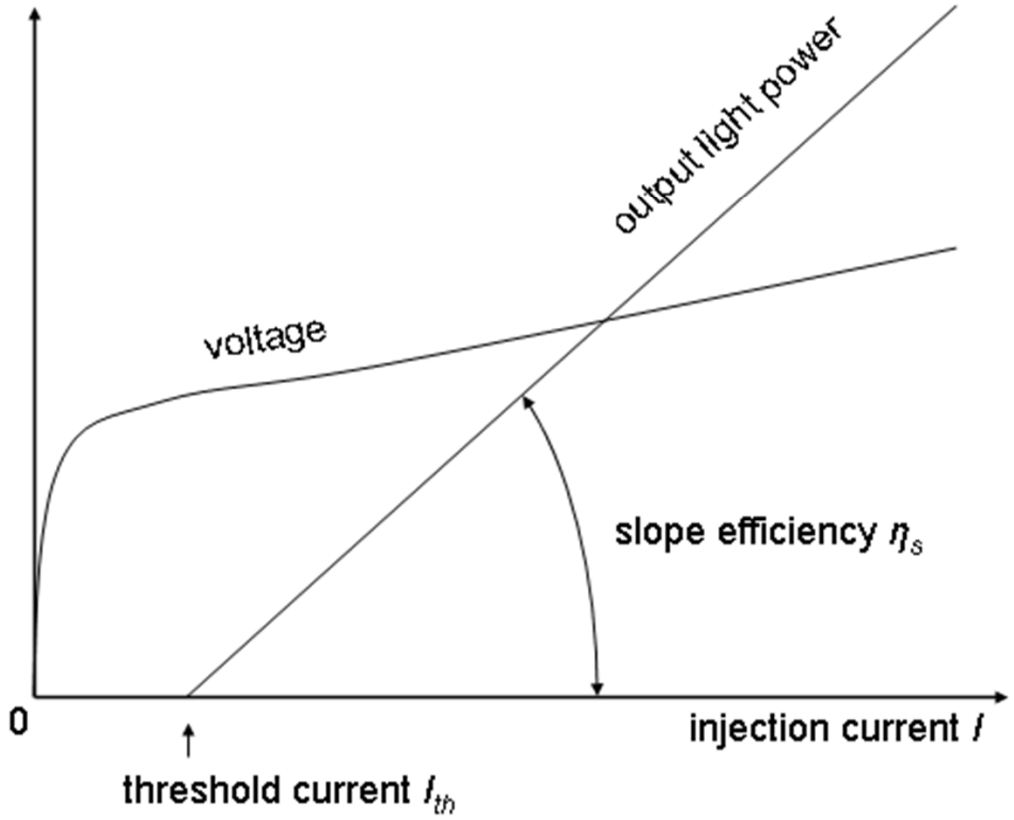


Figure 2.17 Laser characteristics: light power vs. current (*LI*) and voltage vs. current (*IV*).

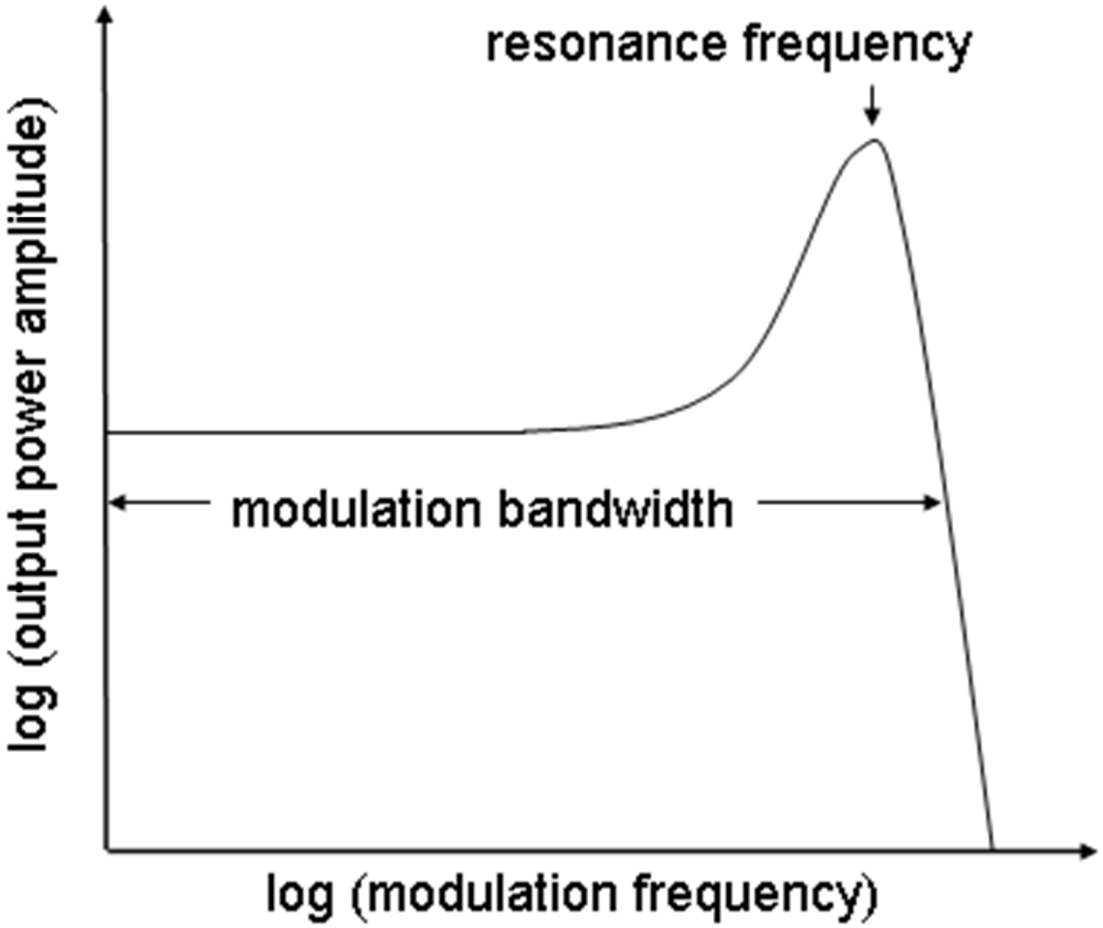


Figure 2.18 Analog modulation characteristic of a laser.

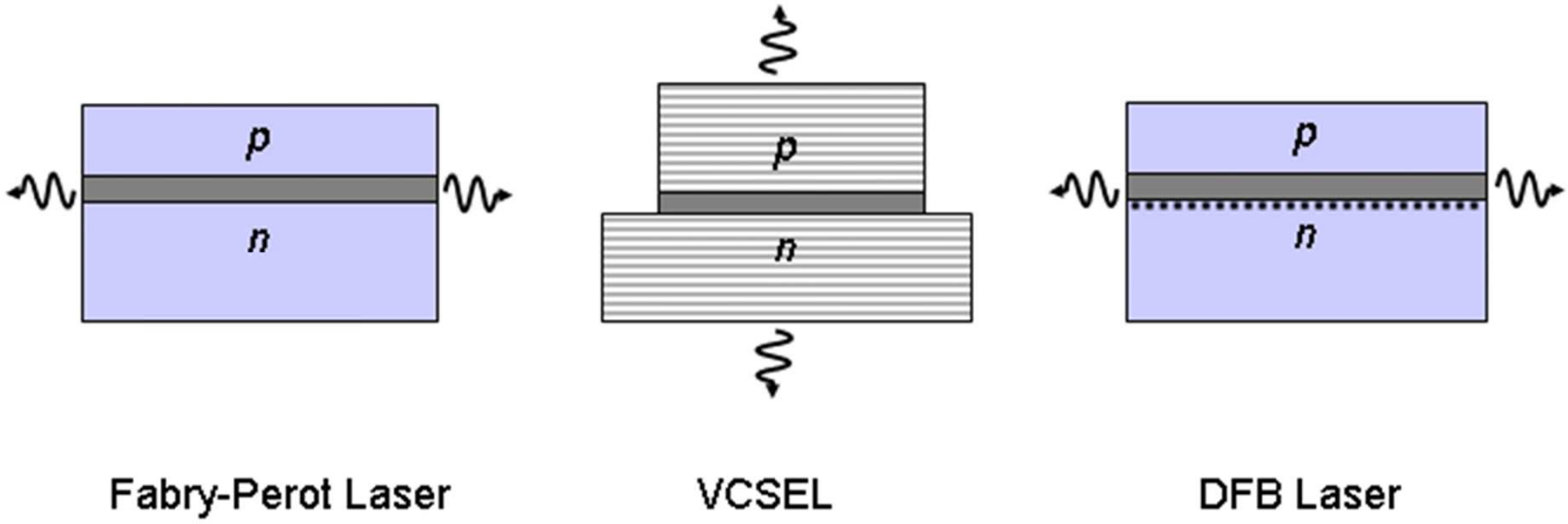


Figure 2.19 Optical resonator designs for semiconductor lasers.

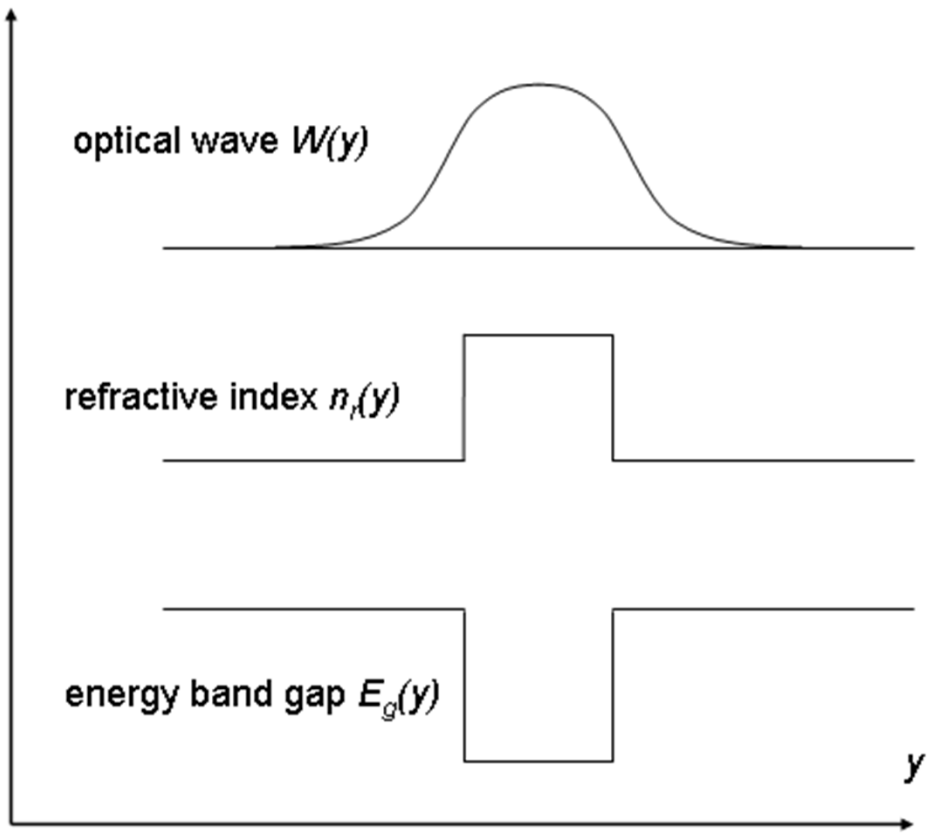


Figure 2.20 Vertical profile of band gap, refractive index, and optical wave within a planar symmetric heterostructure.

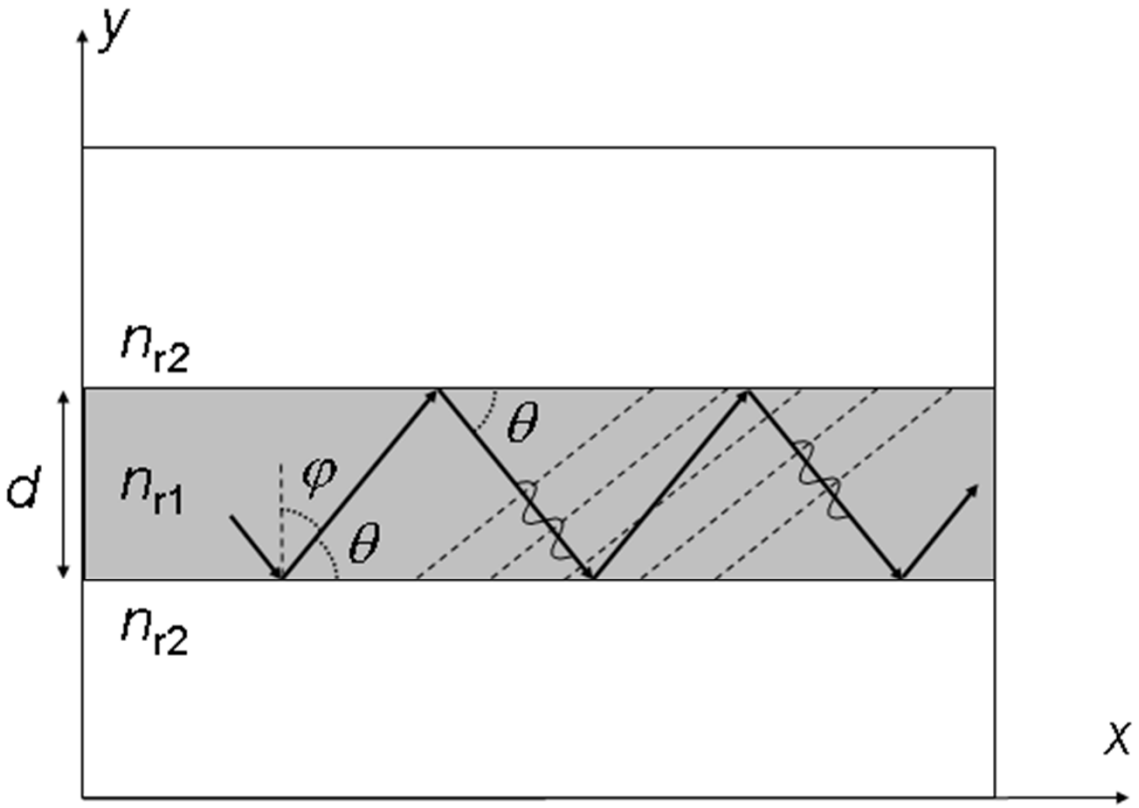


Figure 2.21 Light propagation in a planar waveguide. The dashed lines indicate constructive interference of reflected waves.

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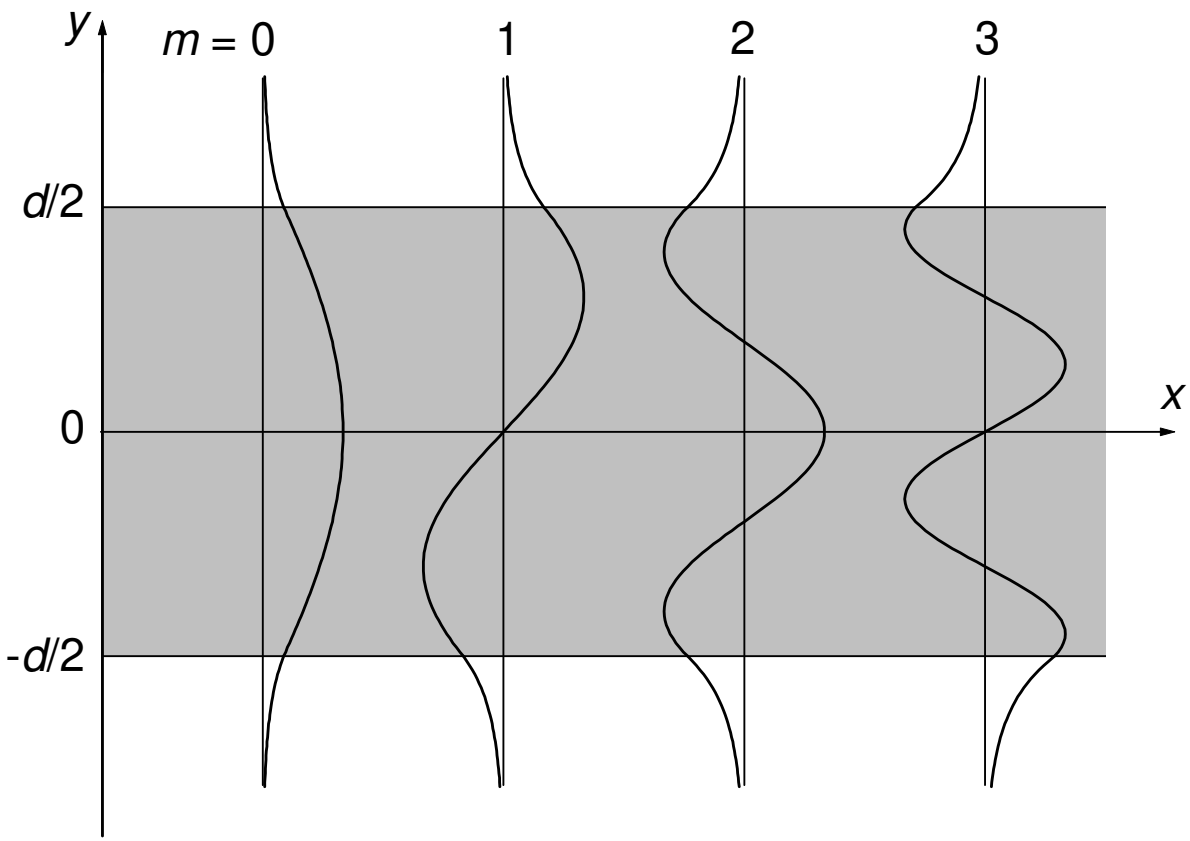


Figure 2.22 Transverse optical field profiles *Wm(y)* for waveguide mode number *m*.

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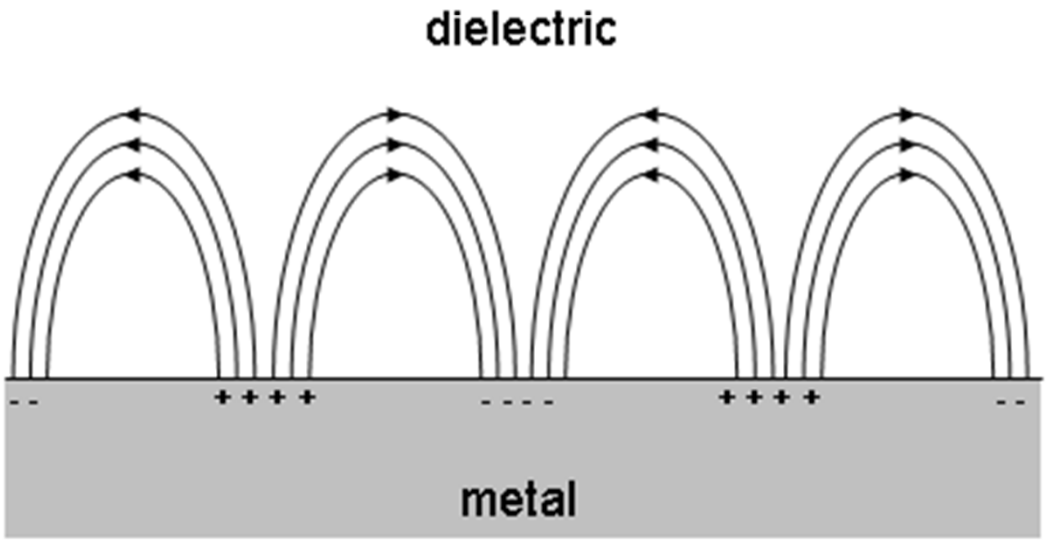


Figure 2.23 Surface plasmons: interaction of electrons and optical waves at a metal / dielectric interface.

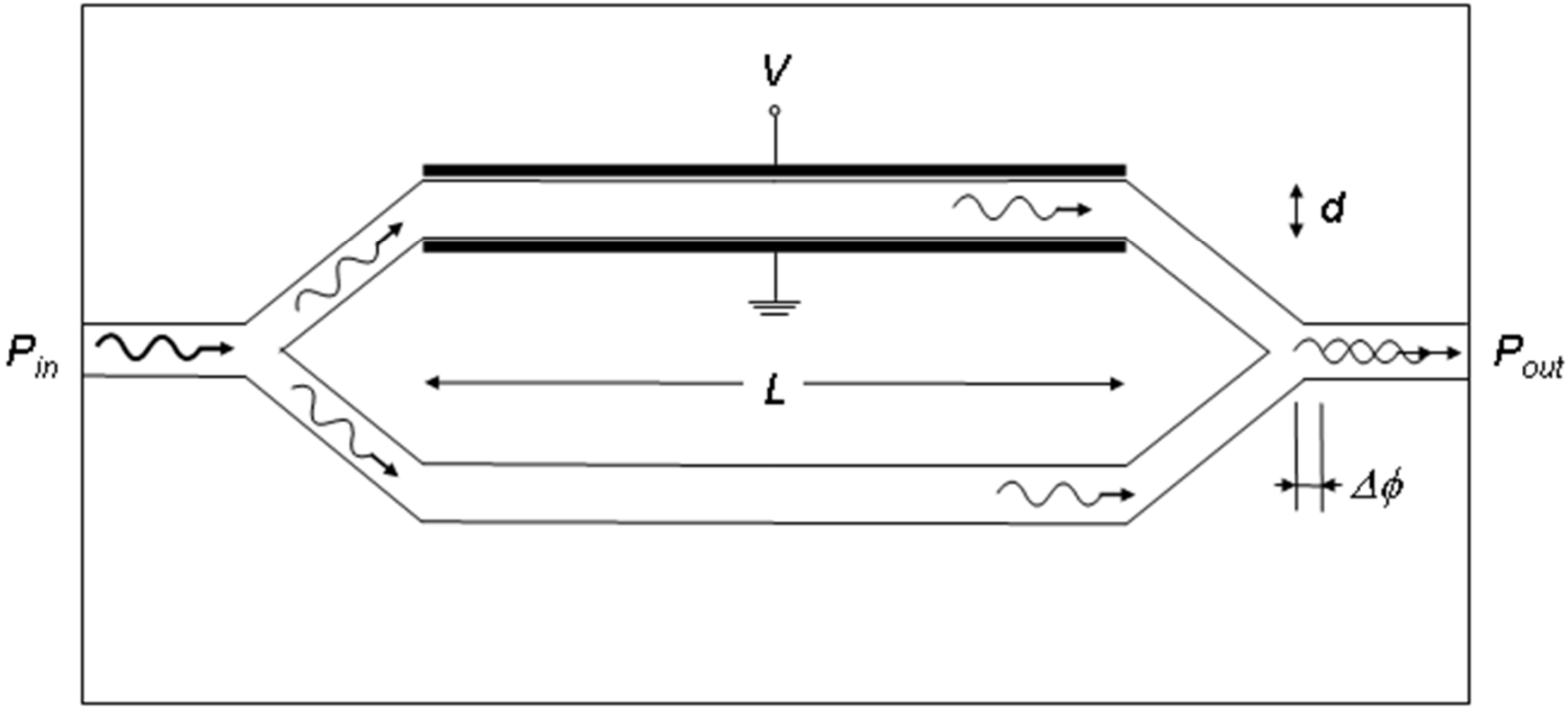


Figure 2.24 Mach-Zehnder Modulator.

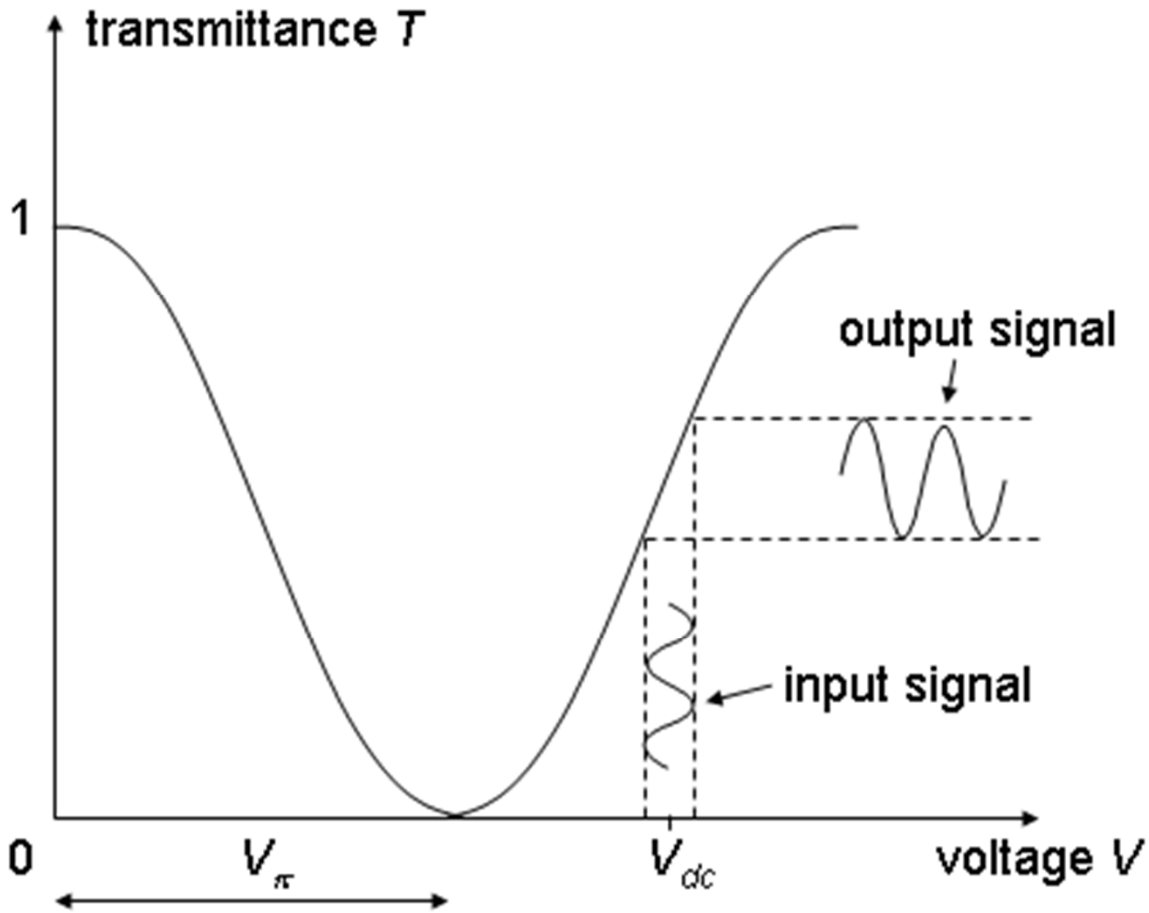


Figure 2.25 Modulator transmittance function *T(V).*