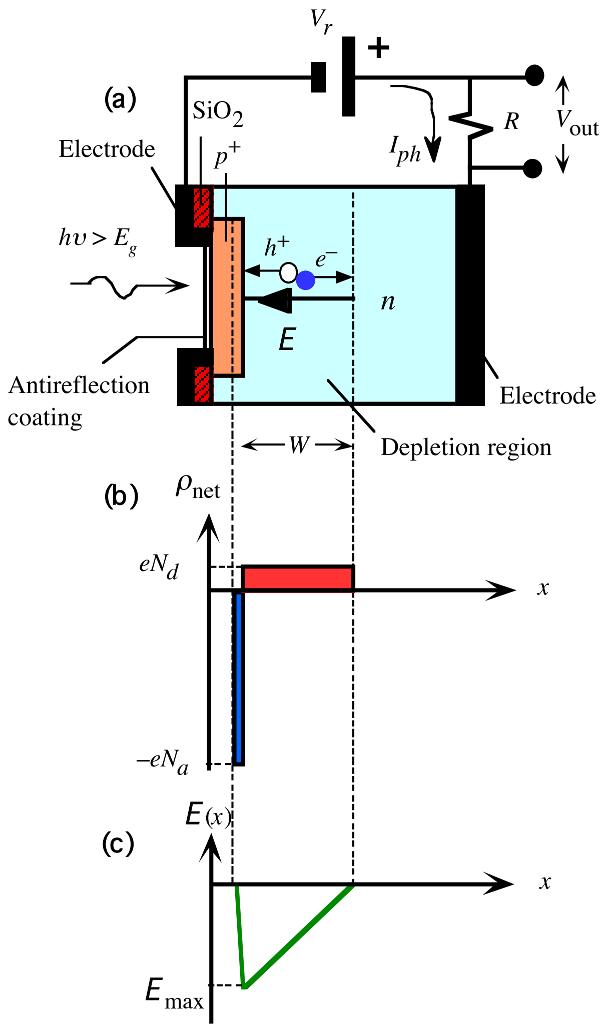
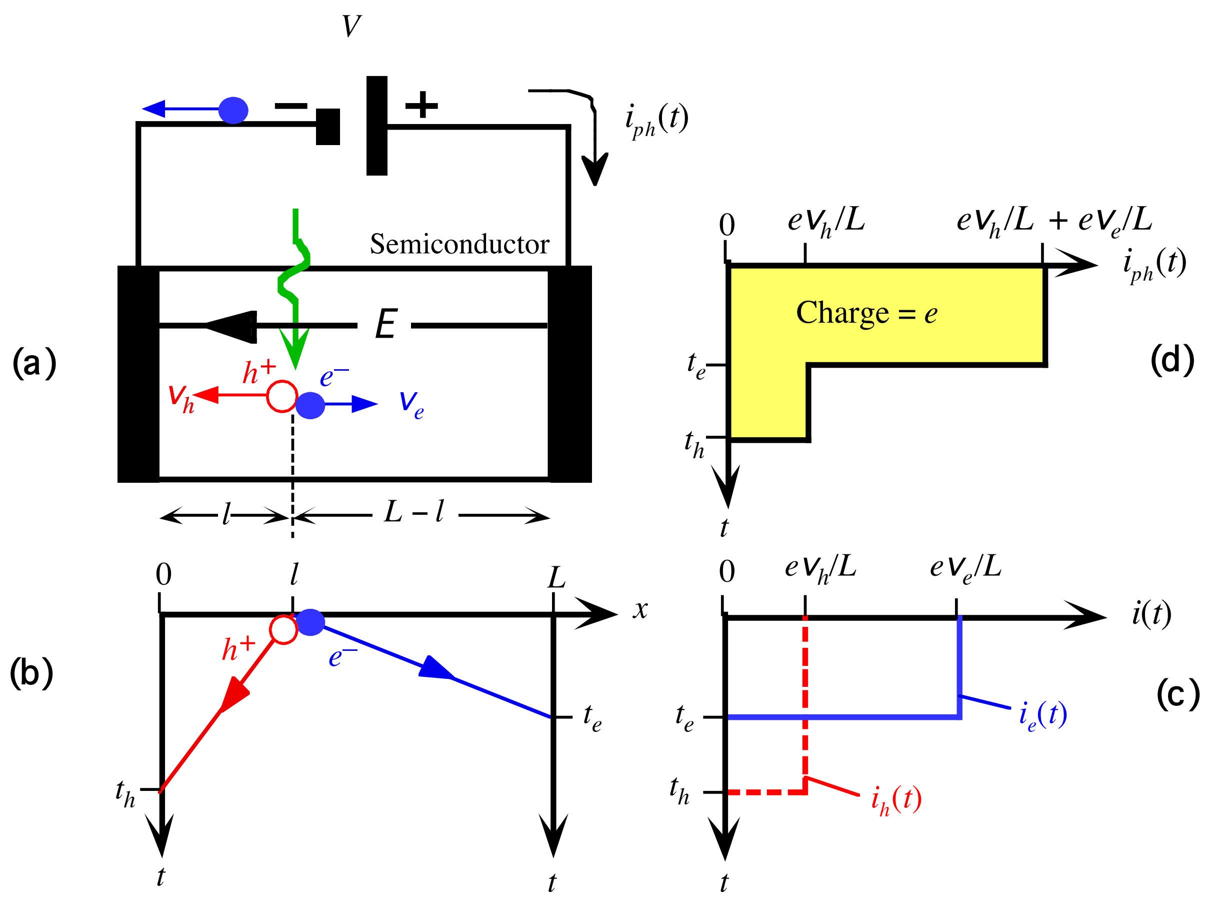
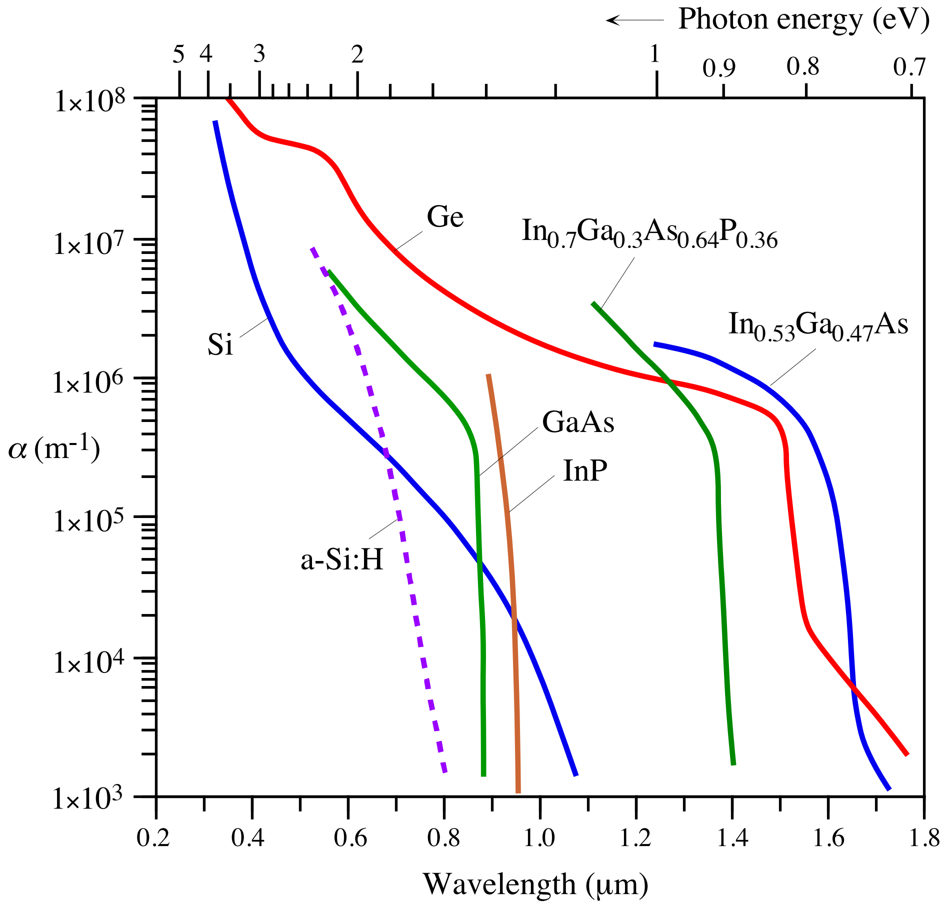


(a) A schematic diagram of a reverse biased *pn* junction photodiode. (b) Net space charge across the diode in the depletion region. N_d and N_a are the donor and acceptor concentrations in the *p* and *n* sides. (c). The field in the depletion region.

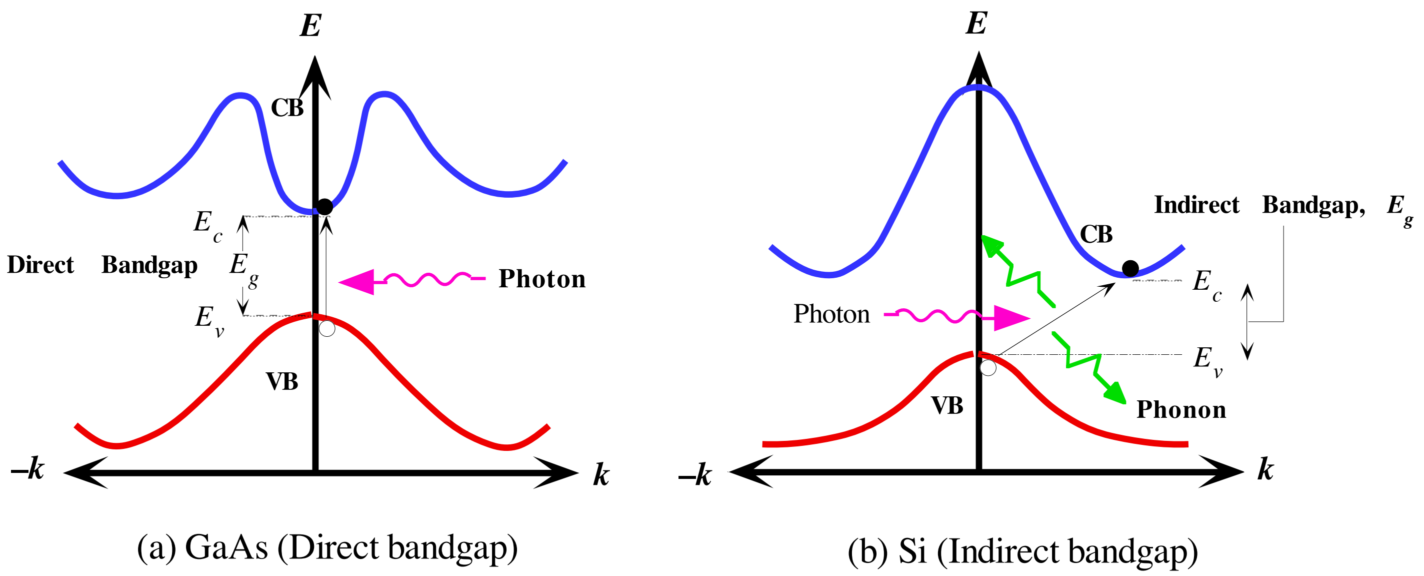


(a) An EHP is photogenerated at $x = l$. The electron and the hole drift in opposite directions with drift velocities v_h and v_e. (b) The electron arrives at time $t_e = (L - l)/v_e$ and the hole arrives at time $t_h = l/v_h$. (c) As the electron and hole drift, each generates an external photocurrent shown as $i_e(t)$ and $i_h(t)$. (d) The total photocurrent is the sum of hole and electron photocurrents each lasting a duration t_h and t_e respectively.

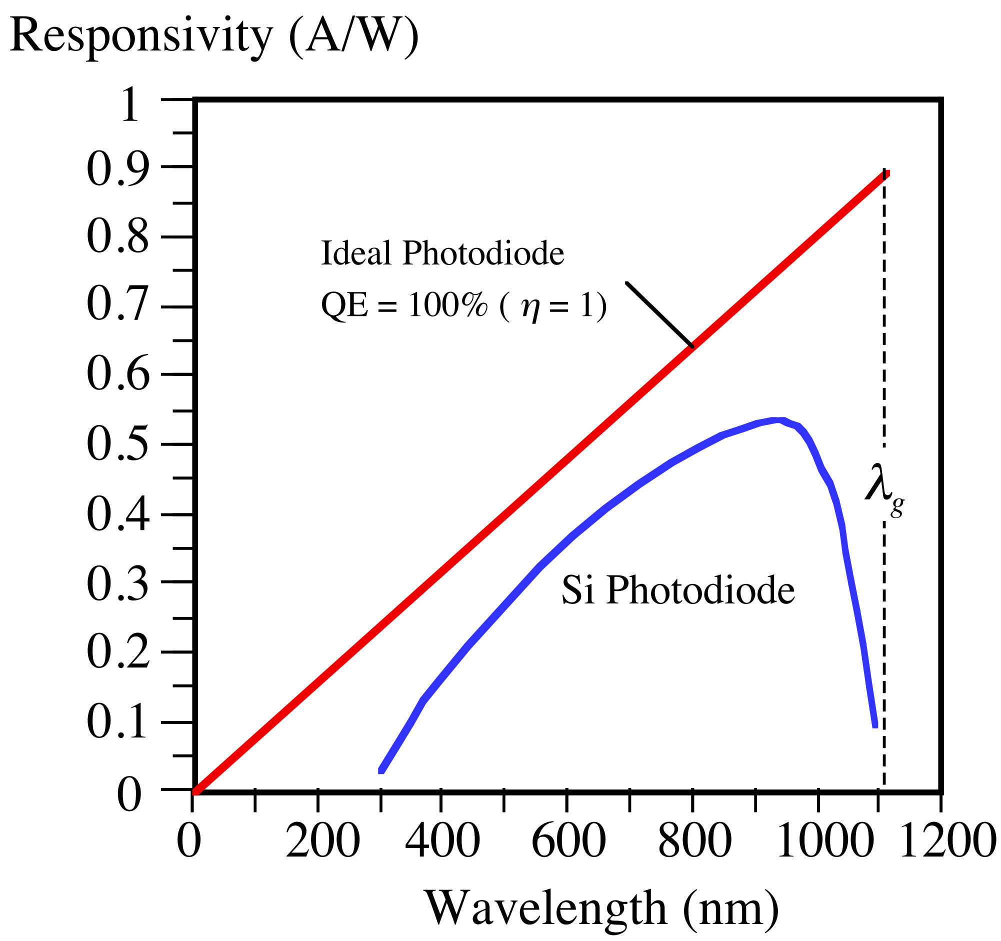


Absorption coefficient (α) vs. wavelength (λ) for various semiconductors
(Data selectively collected and combined from various sources.)

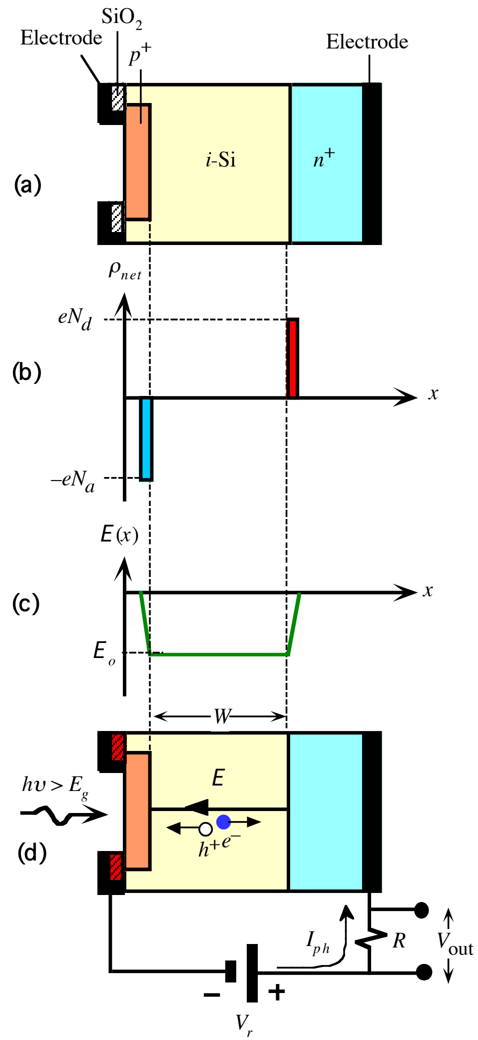
Figure 5.3



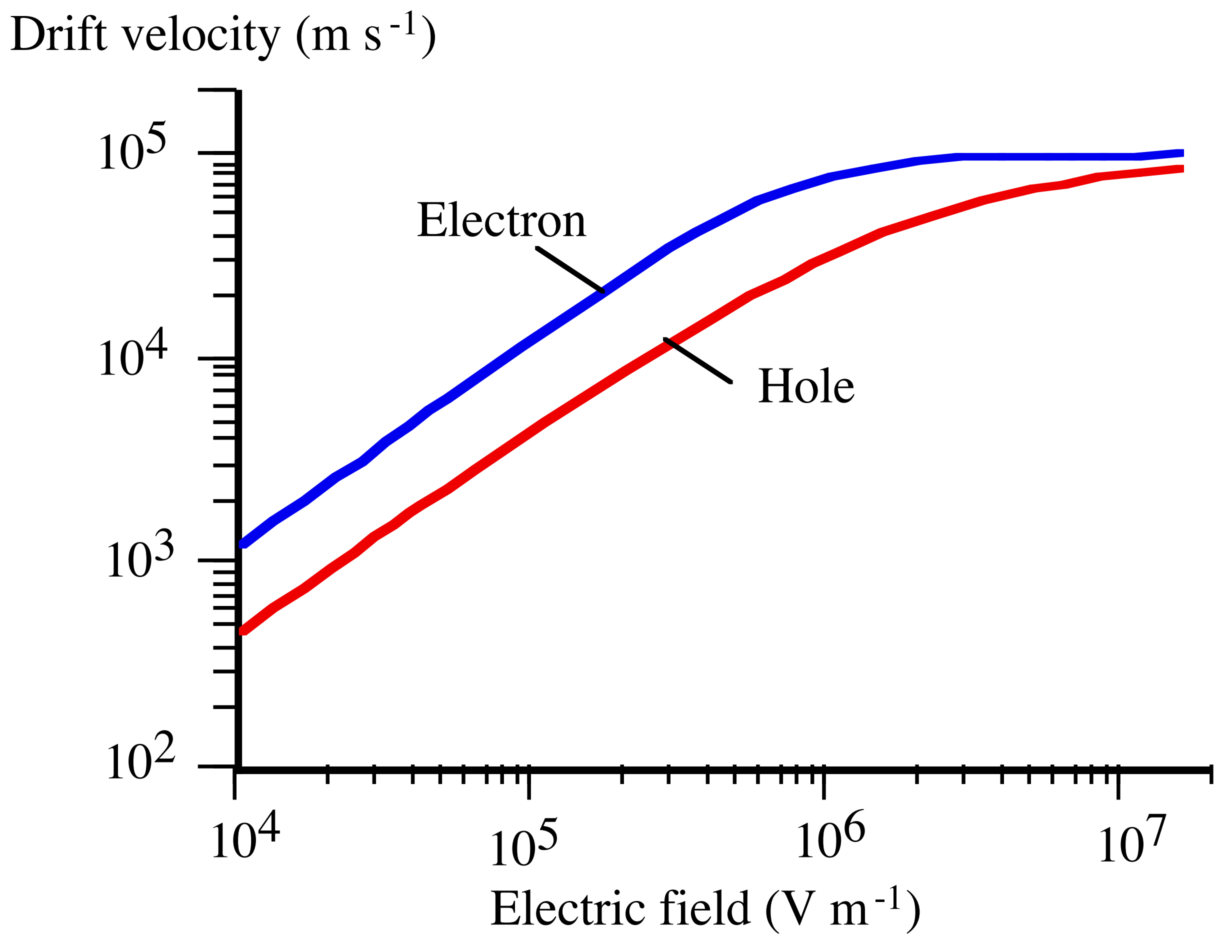
(a) Photon absorption in a direct bandgap semiconductor. (b) Photon absorption in an indirect bandgap semiconductor (VB, valence band; CB, conduction band)



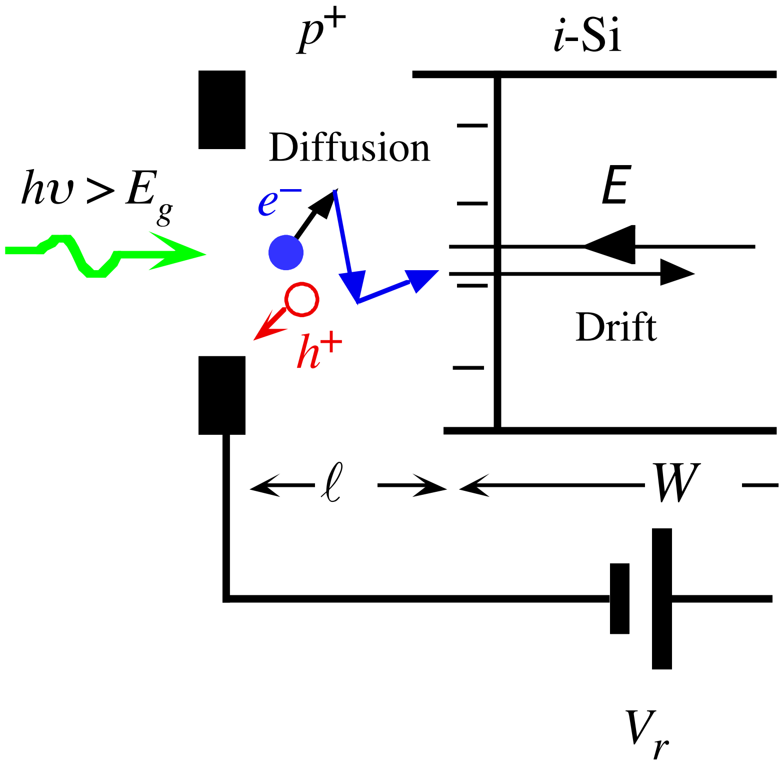
Responsivity (R) vs. wavelength (λ) for an ideal photodiode with QE = 100% ($\eta = 1$) and for a typica commercial Si photodiode.



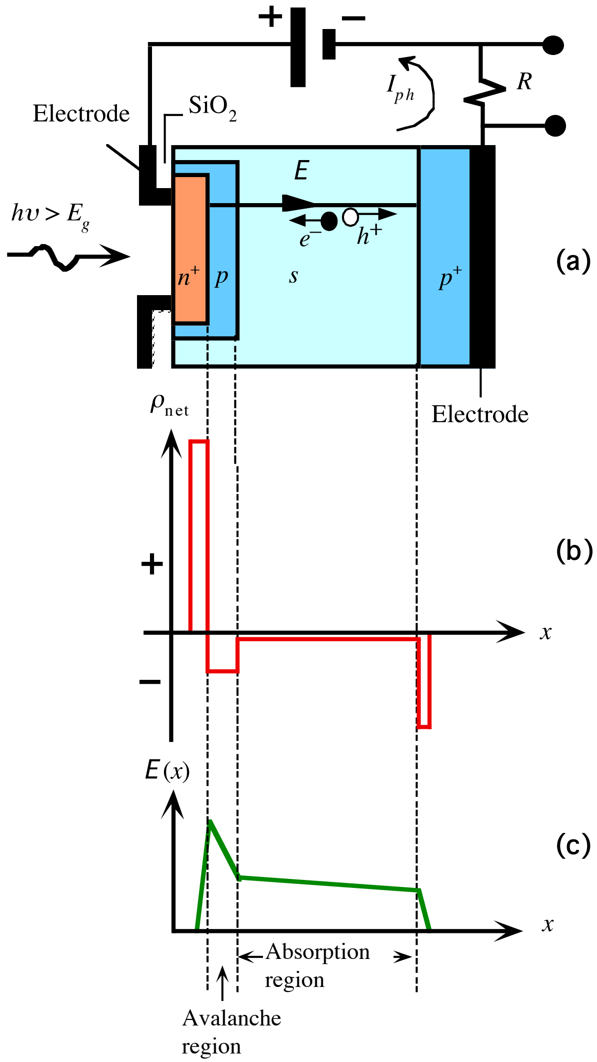
The schematic structure of an idealized *pin* photodiode (b) The net space charge density across the photodiode. (c) The built-in field across the diode. (d) The *pin* photodiode in photodetection is reverse biased.



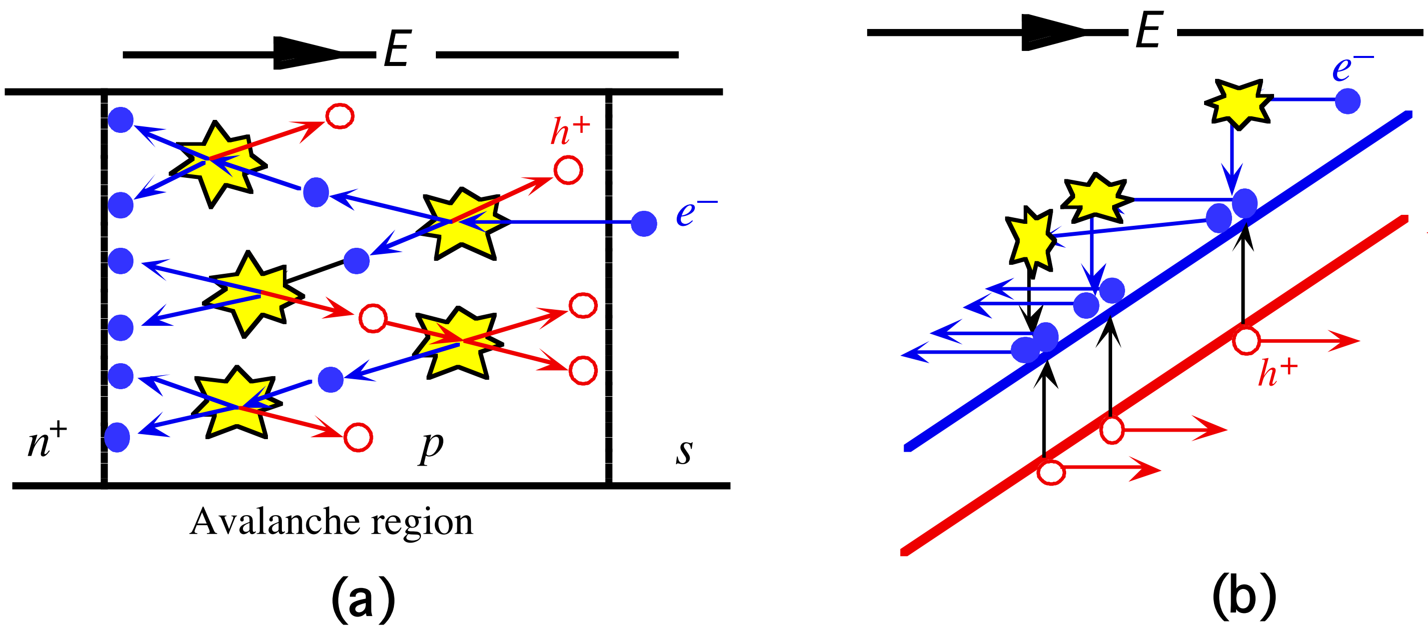
Drift velocity vs. electric field for holes and electrons in Si.



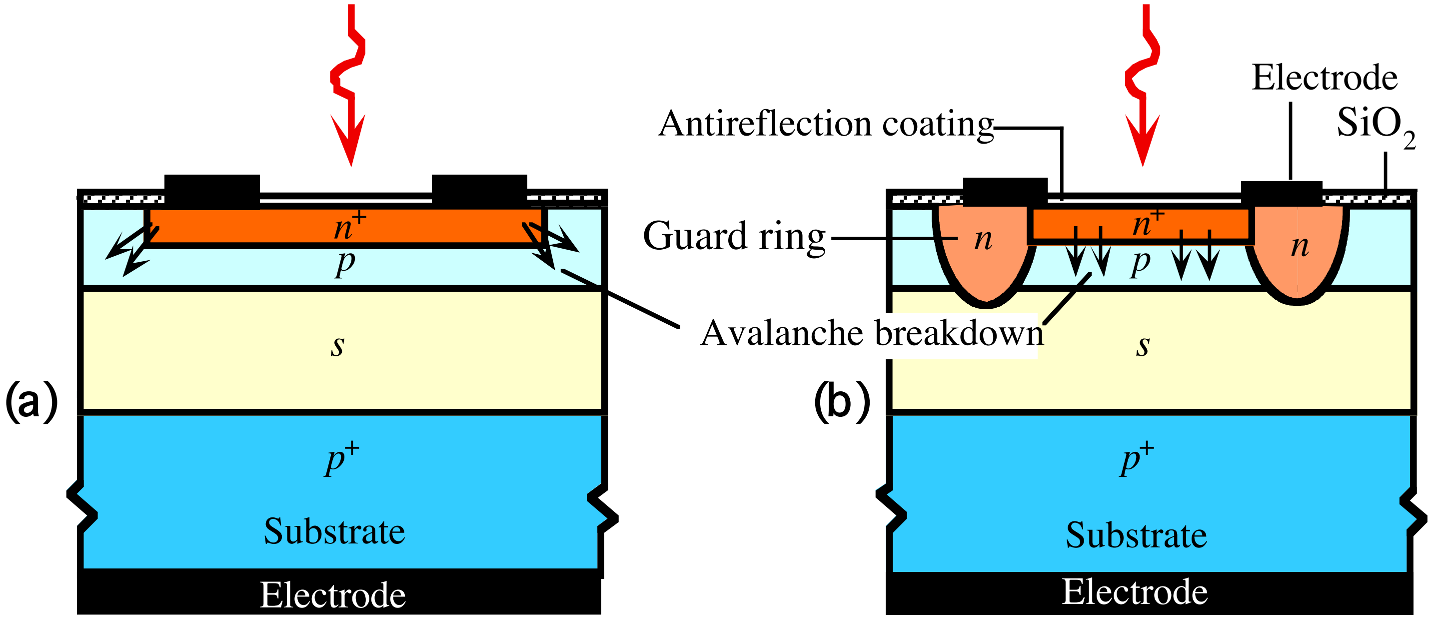
A reverse biased pin photodiode is illuminated with a short wavelength photon that is absorbed very near the surface. The photogenerated electron has to diffuse to the depletion region where it is swept into the *i*-layer and drifted across.



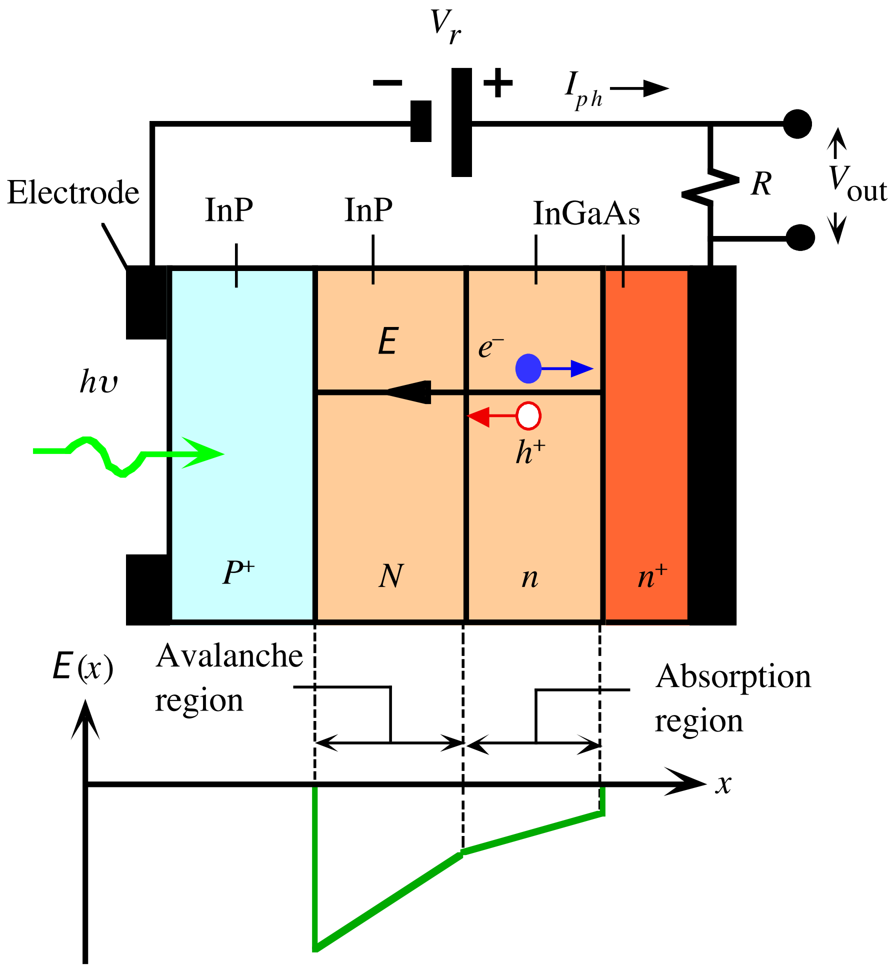
(a) A schematic illustration of the structure of an avalanche photodiode (APD) biased for avalanche gain. (b) The net space charge density across the photodiode. (c) The field across the diode and the identification of absorption and multiplication regions.



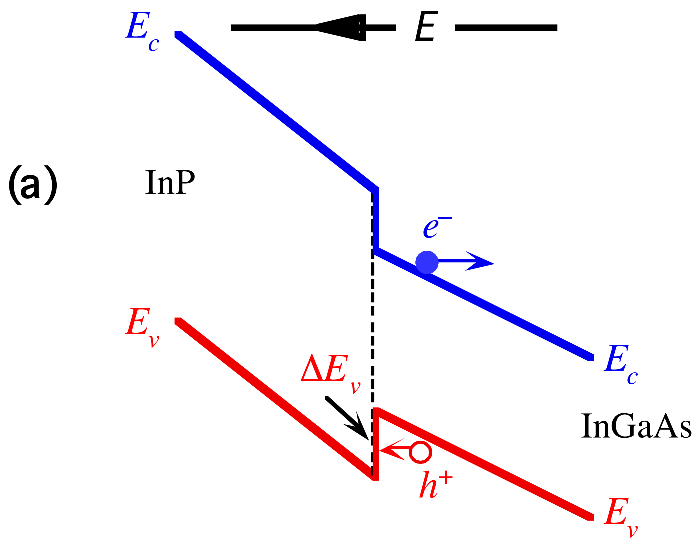
(a) A pictorial view of impact ionization processes releasing EHPs and the resulting avalanche multiplication. (b) Impact of an energetic conduction electron with crystal vibrations transfers the electron's kinetic energy to a valence electron and thereby excites it to the conduction band.



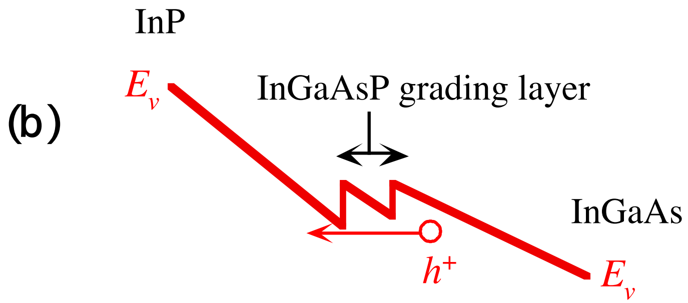
(a) A Si APD structure without a guard ring. (b) A schematic illustration of the structure of a more practical Si APD



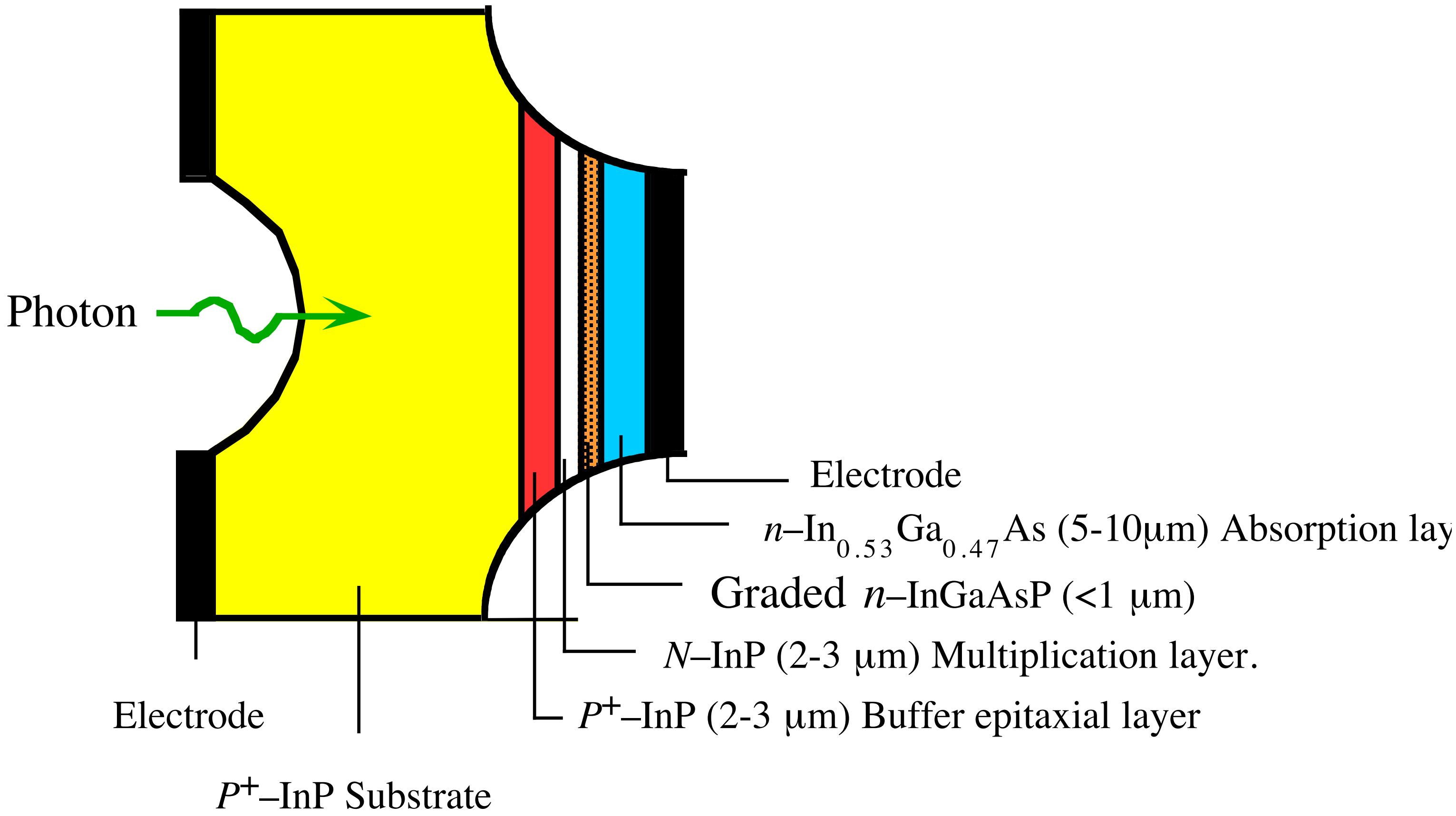
Simplified schematic diagram of a separate absorption and multiplication (SAM) APD using a heterostructure based on InGaAs-InP. *P* and *N* refer to *p* and *n* -type wider-bandgap semiconductor.



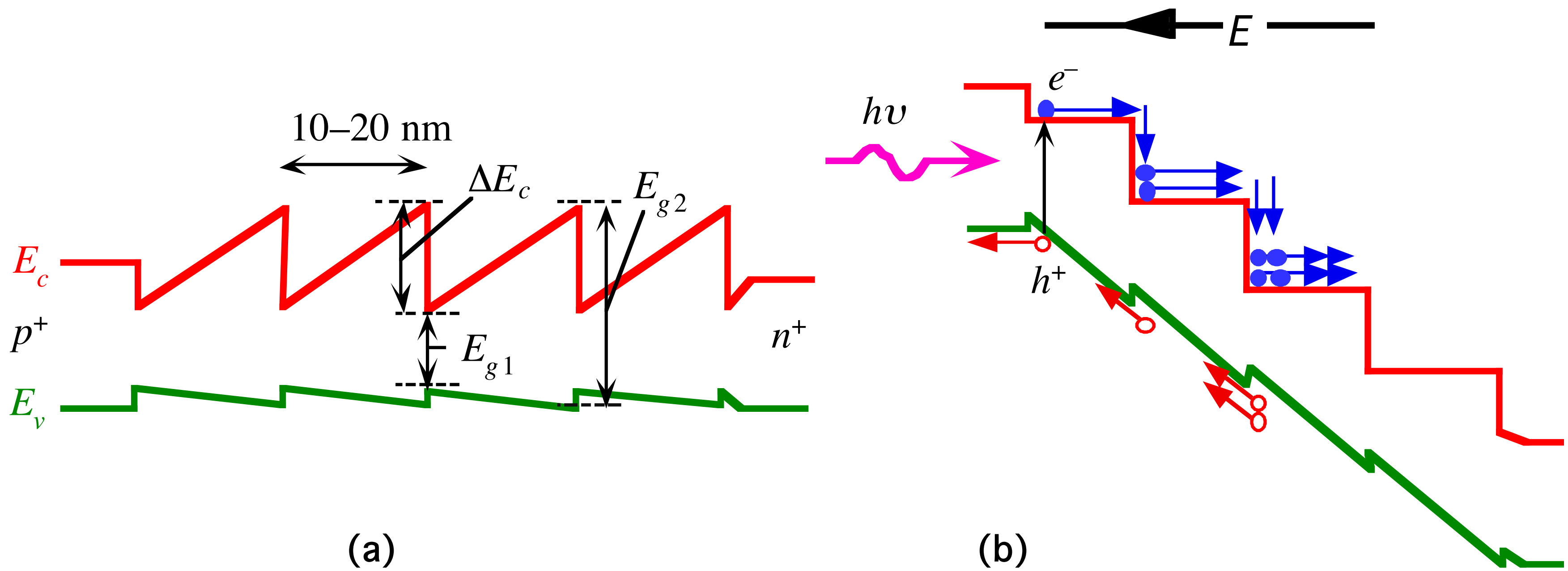
(a) Energy band diagram for a SAM heterojunction APD where there is a valence band step ΔE_v from InGaAs to InP that slows hole entry into the InP layer.



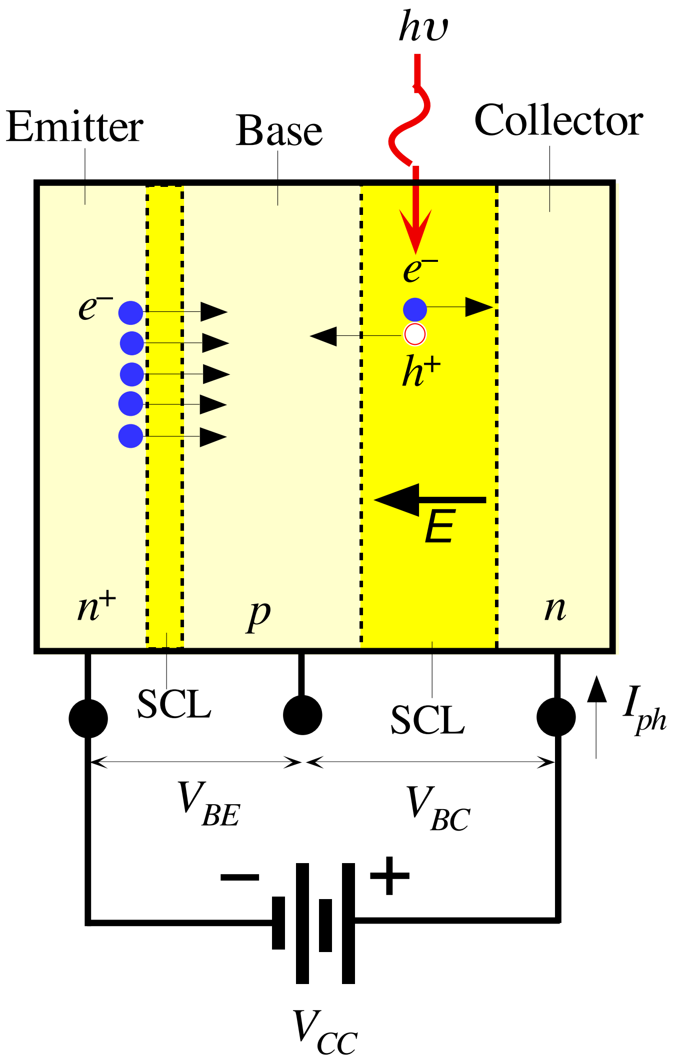
(b) An interposing grading layer (InGaAsP) with an intermediate bandgap breaks ΔE_v and makes it easier for the hole to pass to the InP layer



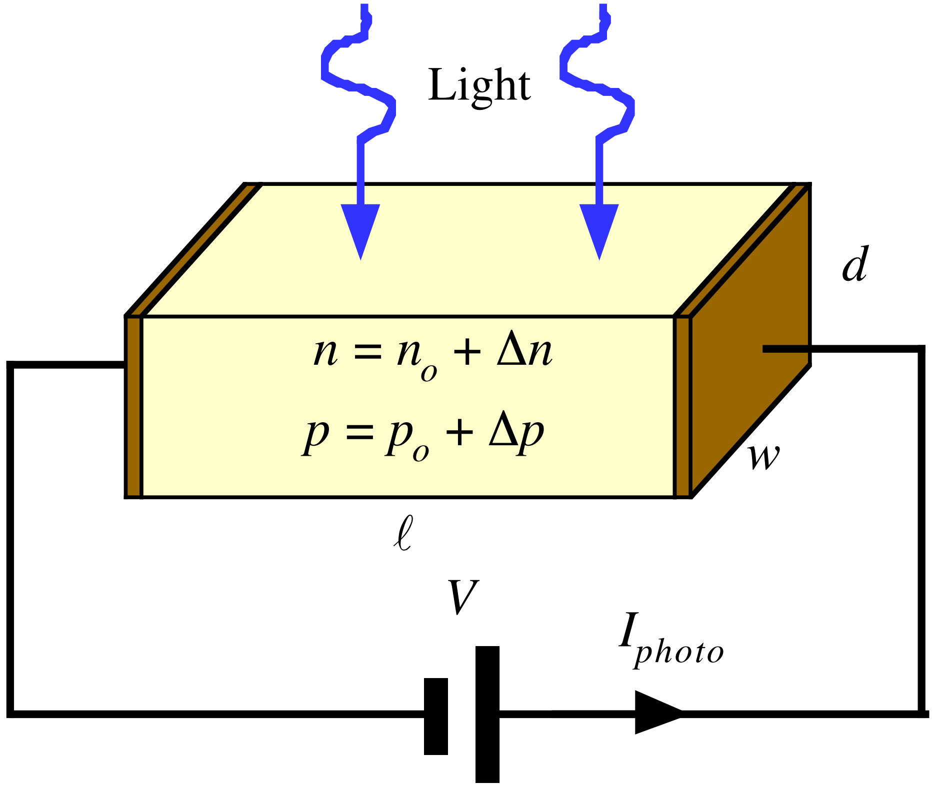
Simplified schematic diagram of a more practical mesa-etched SAGM layered APD.



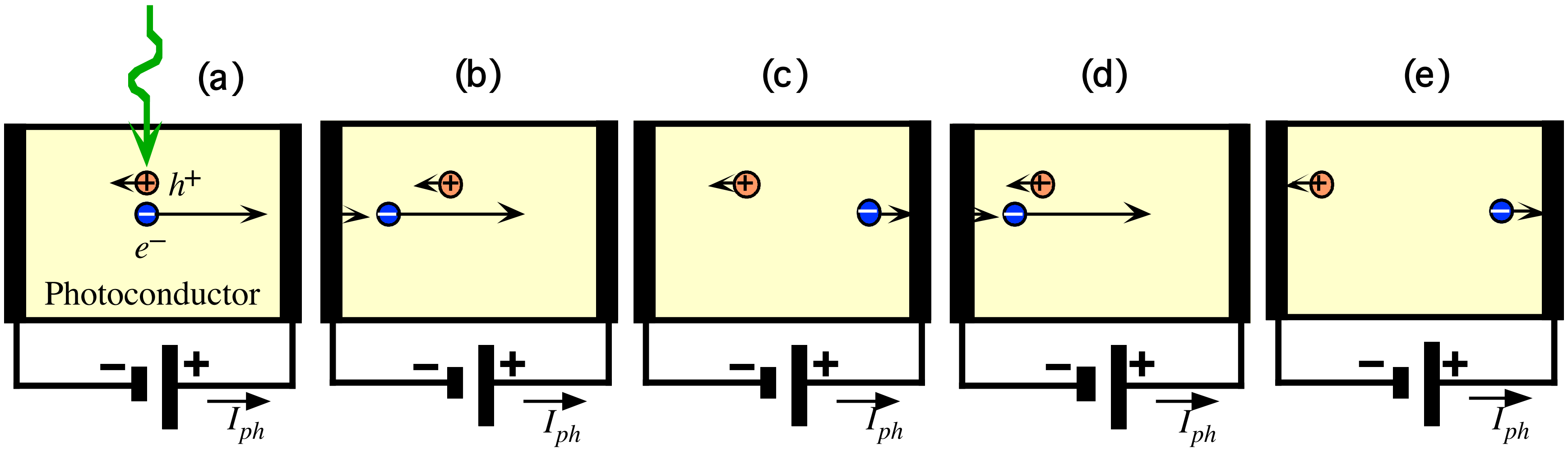
Energy band diagram of a staircase superlattice APD (a) No bias. (b) With an applied bias.



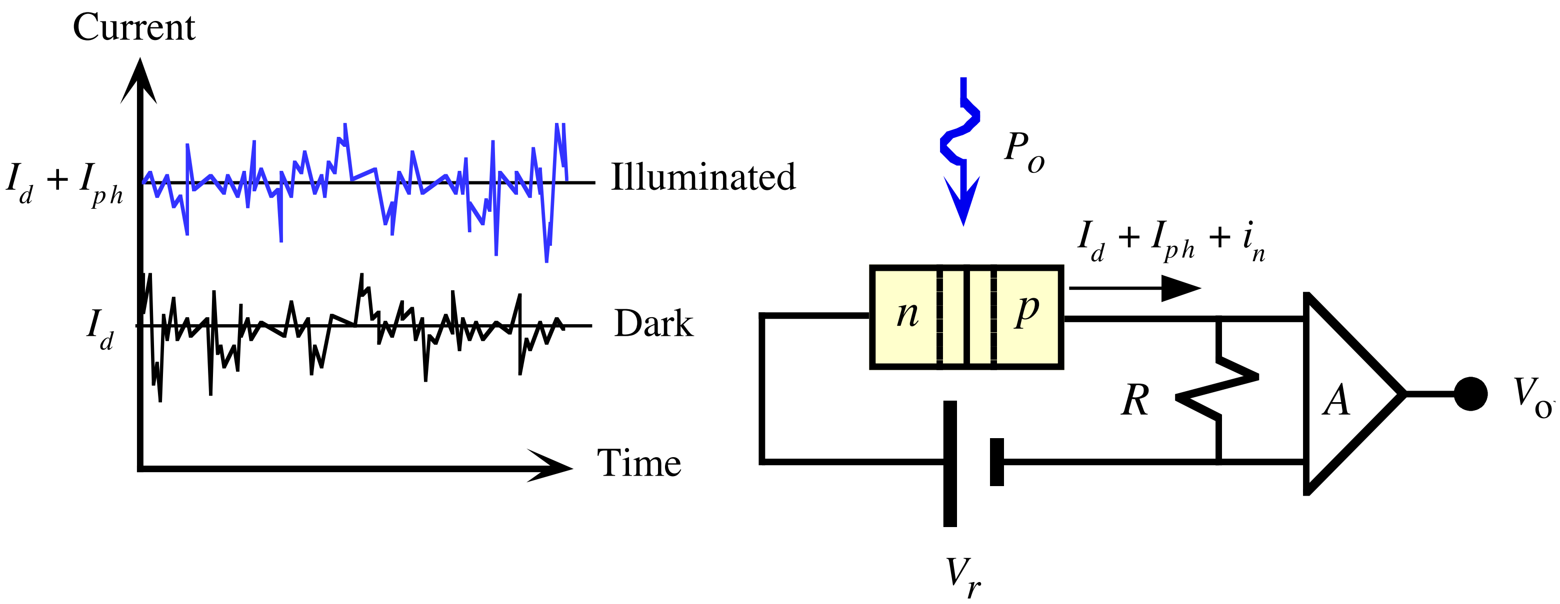
The principle of operation of the photodiode. SCL is the space charge layer or the depletion region. The primary photocurrent acts as a base current and gives rise to a large photocurrent in the emitter-collector circuit.



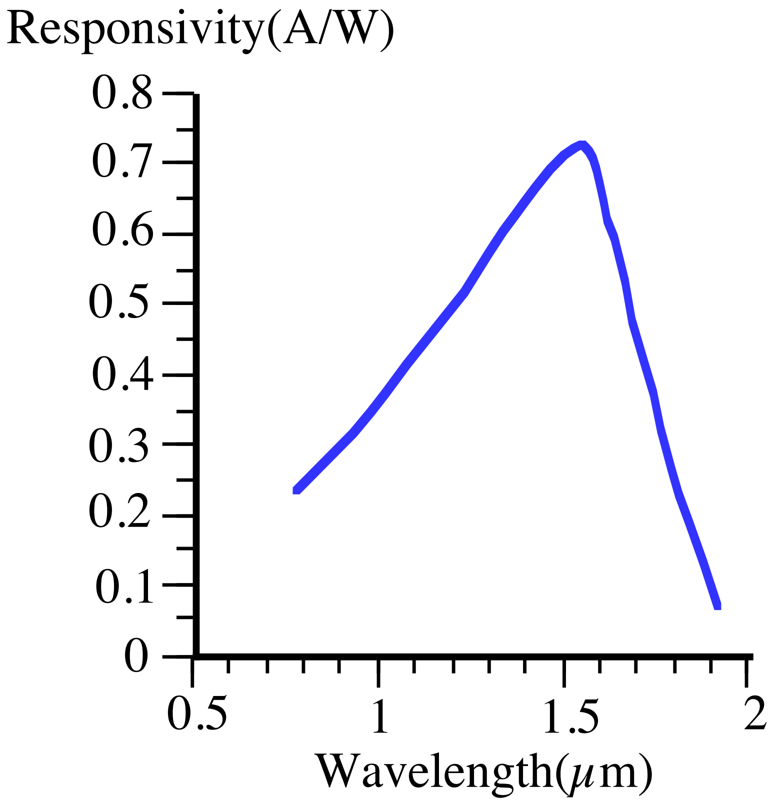
A semiconductor slab of length ℓ, width w and depth d is illuminated with light of wavelength λ.



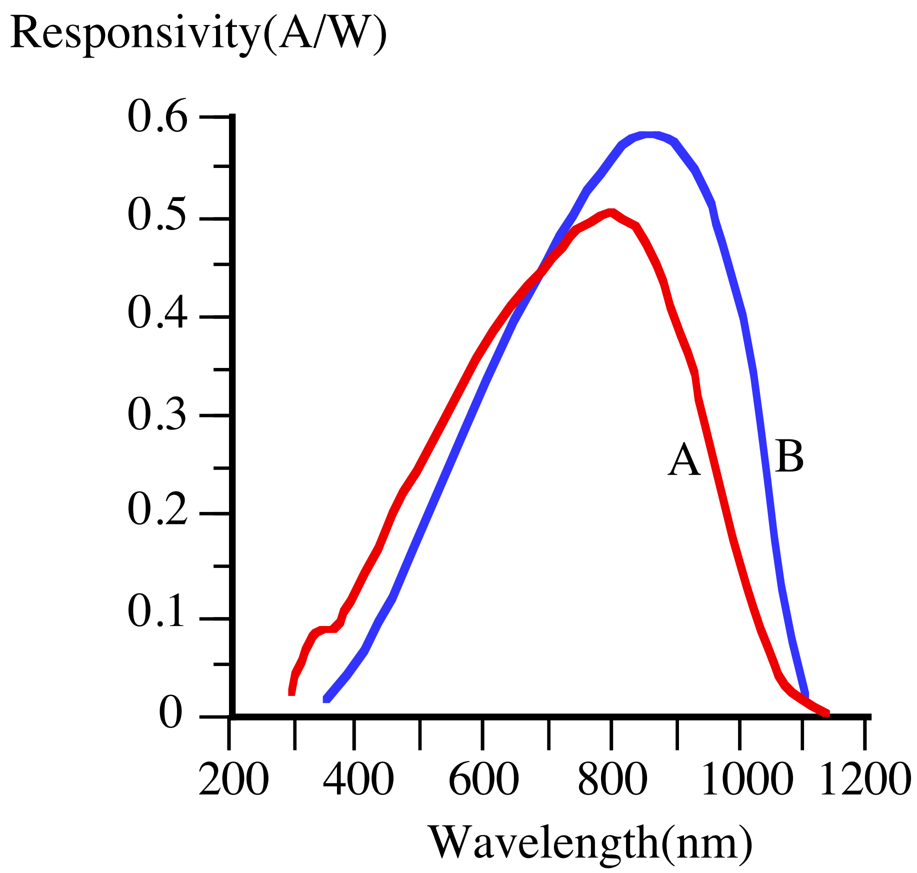
A photoconductor with ohmic contacts (contacts not limiting carrier entry) can exhibit gain. As the slow hole drifts through the photoconductors, many fast electrons enter and drift through the photoconductor because, at any instant, the photoconductor must be neutral. Electrons drift faster which means as one leaves, another must enter.



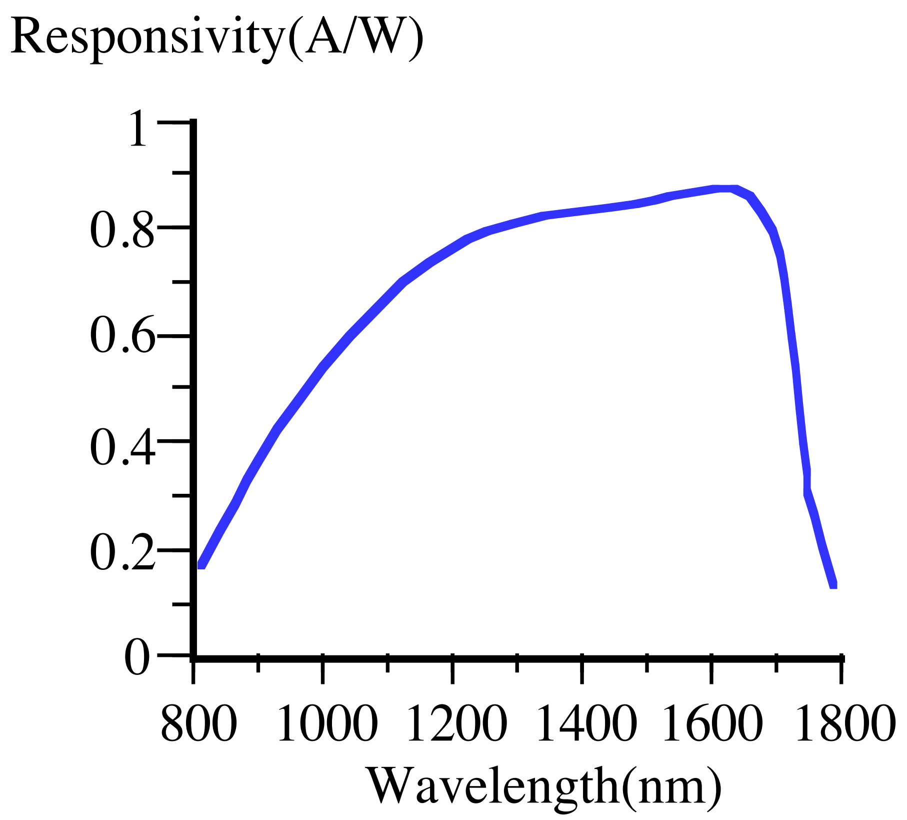
In *pn* junction and *pin* devices the main source of noise is shot noise due to the dark current and photocurrent.



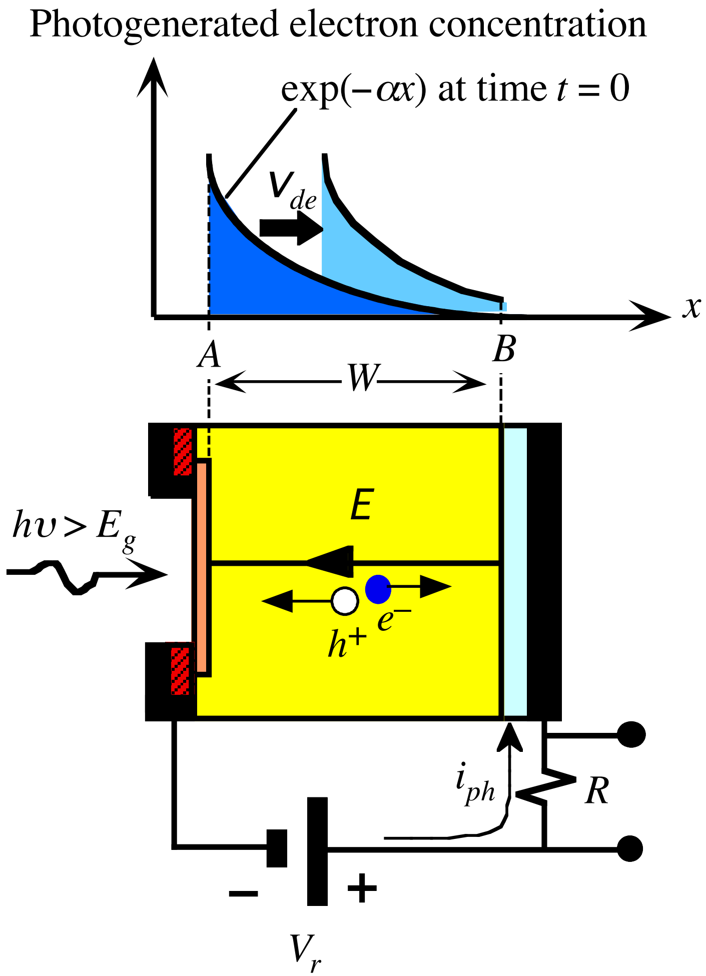
The responsivity of a commercial Ge *pn* junction photodiode



The responsivity of two commercial Si *pin* photodiodes



The responsivity of an InGaAs *pin* photodiode



An infinitesimally short light pulse is absorbed throughout the depletion layer and creates an EHP concentration that decays exponentially