tors are cooled to lower temperatures (such as 77 K and 4.2 K). The lower temperatures reduce thermal effects which cause thermal ionization and deplete the energy levels, and increase the gain and detection efficiency. Near 0.5 μm, a CdS photoconductor has high sensitivity, whereas at 10 μm a HgCdTe photoconductor is preferred.[6] In the wavelength range from 100 to 400 μm, a GaAs extrinsic photoconductor is a better choice because of its high detectivity.[7] This photoconductor has high dynamic range and can give comparable performance for high-level (strong light intensity) detection. For low-level detection at microwave frequencies, however, a photodiode will provide considerably more speed and higher signal-to-noise ratio. Thus photoconductors have limited use in high-frequency optical demodulators, such as in optical mixing. They have been, however, extensively used for infrared detection especially beyond a few microns of wavelength.

13.3 PHOTODIODES

13.3.1 General Consideration

A photodiode has a depleted semiconductor region with a high electric field that serves to separate photogenerated electron-hole pairs. For high-speed operation, the depletion region must be kept thin to reduce the transit time. On the other hand, to increase the quantum efficiency (the number of electron-hole pairs generated per incident photon), the depletion layer must be sufficiently thick to allow a large fraction of the incident light to be absorbed. Thus, there is a trade-off between the speed of response and quantum efficiency.

For the visible and near-infrared wavelength range, photodiodes are usually reverse-biased with moderate biasing voltages, because this reduces the carrier transit time and lowers the diode capacitance. The reverse voltage is, however, not large enough to cause avalanche multiplication or breakdown. This biasing condition is in contrast to avalanche photodiodes, where an internal current gain is obtained as a result of the impact ionization under avalanche breakdown conditions. All photodiodes, with the exception of the avalanche photodiode which is not included in this section, thus have a maximum gain of one (Table 1). The photodiode family includes the *p-i-n* photodiode, *p-n* photodiode, heterojunction photodiode, and metal-semiconductor (Schottky barrier) photodiode.

We shall now briefly consider the general characteristics of a photodiode: its quantum efficiency, response speed, and device noise.

Quantum Efficiency. As mentioned previously, quantum efficiency is the number of electron-hole pairs generated per incident photon (Eq. 2). A related figure of merit is the responsivity, which is the ratio of the photocurrent to the optical power (Eq. 3). Therefore, for a given quantum efficiency, the responsivity increases linearly with wavelength. For an ideal photodiode ($\eta = 1$), $\mathscr{R} = \lambda/1.24$ (A/W) where λ is expressed in microns.

Since the optical absorption coefficient α is a strong function of the wavelength, for a given semiconductor the wavelength range in which appreciable photocurrent