From October 2004 *High Frequency Electronics*

Basic Operation of Optical Detectors

Optical detectors are the components that convert the lightwave energy of fiber optic communications into electrical signals for recovery of data

This short tutorial is a first introduction to optical detectors, which recover the signal from a fiber optic link. For RF/ microwave engineers, it may useful to think of this of optical detectors as the first bit of circuitry in a THz-frequency optical receiver.

An optical front-end has a number of similarities to microwave circuitry. Both use low noise preamplifiers, filters and other signal processing, plus demodulators to recover data from the analog signal. The optical detector, however, is the component without an equivalent microwave counterpart, although it's function is analogous to an antenna, extracting signals from the fiber as an antenna captures a radiated signal.

PIN Detector Diodes

Figure 1 is a simple diagram of a photodetector. The conversion of light into electric current takes place in the I-region of a PIN diode structure. The detectors are typically integrated circuits that also include a fiber optic interface, coplanar waveguide interconnections to support high frequency signals extracted from the lightwave input.

III-V semiconductor material is used, such a InGaAs/InP or InGaAs/InAlAs, with predictable photoelectric properties. The doping, thickness, and other properties are controlled to obtain the optical response, sensitivity, noise and other desired performance properties. Like integrated transistors, thinner, smaller area I-layers result in higher speed (frequency response) of the detector. The series resistance of the device is also critical for high-speed response. InGaAs/InAlAs detectors can operate to beyond 50 GHz.

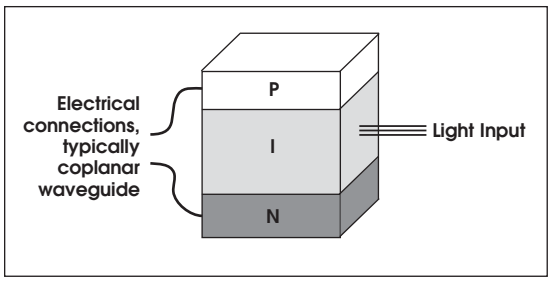

Figure 1 · PIN diode structure of a simple photodetector.

APD Detectors

Avalanche photodetectors (APDs) are used in long-haul fiber optic systems, since they have superior sensitivity, as much as 10 dB better than PIN diodes. Basically, an APD is a P-N junction photodiode operated with high reverse bias. The materials is typically InP/InGaAs. With the high applied potential, impact ionization from the lightwave generates electron-hole pairs that subsequently cause an avalanche across the potential barrier. This current gain gives the APD its greater sensitivity. APDs are commonly used up to 2.5 Gbps and sometimes to 10 Gbps if the extra cost can be justified.

Other Technologies

For instrumentation and system optical power measuring applications, optical detectors using germanium (Ge) devices are used, taking advantage of a linear optical power to current response.

Silicon photodiodes (APDs) are used in lower frequency systems (up to 1.5 or 2 GHz) where they can meet low cost and modest frequency response requirements. Si devices are used in pairs in wavelength sensors. The ratio of longer and shorter wavelength sensors is proportional to the input wavelength.

Hopefully, this short tutorial provides a useful introduction to an important part of optical communication systems.