PAGE NO.
DATE 11/10/16

Optical Detectors

Optical detectors are used to convert recieved optical signal into electrical signal, which is then amplified before further processing.

Improvement of detectors performance allows ~~of fewer repeaters~~ installation of fewer repeaters & lowers both capital investments & maintenance costs

Performance and compatibility requirements for detectors:

- → High sensitivity at operating wavelengths.
- → High fidelity (detector must be linear)
- → Large electrical response to received optical signal (should produce max electrical signal for given optical i/p)
- → Short response time to obtain a suitable b.w.
- → Min. noise introduced by detector
- → Stability of performance characterstics
- → Small size
- → Low bias voltage
- → High reliability
- → Low cost.

PAGE NO.
DATE

The basic principle of photodiodes :

The photodetectors are made of semiconductor materials. Photons incident on a semicond are absorbed by e- in VB. As a result, these e- acquire higher energy & are excited to CB, leaving behind a hole in VB. When an external voltage is applied to semicond, these e- - hole pairs give rise to electrical current called photocurrent.

Energy of photon must be equal / greater than band gap energy.

$$\boxed{h\nu_c = \frac{hc}{\lambda} \geq eE_g}$$

$\lambda_c \rightarrow$ cut off wavelength.
The largest value of λ for which the above relation holds.

The fraction of energy of optical signal that is absorbed & gives rise to photocurrent is called efficiency (η).

Efficiency

PAGE NO.
DATE

The power absorbed by semi-cond of thickness L:

(μm)

$$\boxed{P_{abs} = (1 - e^{-\alpha L}) P_{in}}$$

$P_{in} \rightarrow$ incident optical power

$\alpha \rightarrow$ absorption coef of material

↓

depends upon wavelength

$$\boxed{\eta = \frac{P_{abs}}{P_{in}} = 1 - e^{-\alpha L}}$$

Photodetectors have very wide operating wavelength.

↳ Responsivity :

If a diode produces an avg current I_p (A) when incident optical power is P_{in} (W), then responsivity

$$R = \frac{I_p}{P_{in}} \quad A/W.$$

Since incident optical power P_{in} corresponds to incidence of $P_{in}/h\nu$ photon/sec on avg & a fraction η of these incident

Scanned by CamScanner

photons are absorbed & generate an e^- in ext circuit.

$$\boxed{R = \frac{e\eta}{h\nu} \quad A/W}$$

In terms of λ

$$\boxed{R = \frac{e\eta\lambda}{hc}}$$

$$\boxed{R = \frac{\eta\lambda}{1.24} \quad A/W}$$

$\lambda \rightarrow \mu m$

* p-n photodiode

A semiconductor p-n junction with reverse bias voltage forms a photodiode.

The depletion region in a p-n junction creates a built in electric field. Both depletion region and built-in electric field can be enhanced by applied reverse bias Voltage

DATE

In this e^- that are generated by absorption of photons within or close to depletion region will be swept into n-type n-type before they recombin with holes in p-type. This process is called drift & give rise to a current in ext circuit.

e^--hole pairs that are generated far away from depletion region travel primarily under effect of diffusion & may recombine without giving rise to current in ext circuit. This reduces the efficiency η of photodetector. Since diffusion is a much slower process than drift, the diffusion current that is generated by these e^--hole pair will not respond quickly to changes in intensity of incident optical signal, thus reducing the freq response of photodiode

PAGE NO.
DATE

* p-i-n photo diodes

To improve efficiency of photodetector, a very lightly doped intrinsic semiconductor is introduced b/w p- & n- type. Such a diode is called pin photodiode, where i in pin is for intrinsic.

In these, the depletion region extends completely across this intrinsic semiconductor. The width of p-type and n-type semiconductors is small compared to intrinsic region, so that much of light absorption takes place in this region. This increases the efficiency & thus responsivity of photo diode.

* Avalanche photodiodes

If generated e- is subjected to a very high electric field, it can acquire sufficient energy to knock off more e- from VB to CB. These secondary e⁻ - hole pairs can generate even further.

e^--hole pairs when they are accelerated to sufficient levels. This process is called avalanche multiplication. Such diode is called avalanche photodiode (APD).

The no. of secondary e^--hole pairs generated by avalanche multiplication process by single e^- is random, & mean value of this no. is termed the multiplicative gain & denoted by G_m

The multiplicative gain of APD can be made quite large value ~~of G_m. is also accompanied by~~ & even infinite, a condition called avalanche breakdown.