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# Study of the Characteristics Performance of Pin Photo Detector in Optical Fiber Communication System

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## Abstract

Many investigation have been made for message receiving device interprets the information contained. The main purpose of this work to increase the receiving sensitivity or high speed response of the photo detector in optical fiber communication system. If depletion region of the semiconductor diodes or photo detector is large the information receiving capacity will be large.

When an incident photon has energy greater than or equal to the band energy gap of semiconductor material the photon can give up its energy and exit an electron from valence band to conduction band. They are photon generated charge carriers. The photo detector is normally designed so that these carriers are normally generated in the depletion regions. The high electric field present in depletion region.

To achieve high quantum efficiency the depletion region must be thick enough to permit a large fraction of incident light signal to be observed.

The performance of different photo detector is characterized responsitivity and this is related to quantum efficiency.

$R = \frac{Ip}{P0} = \frac{\eta}{h\nu}$

Where $I_p$ = Primary photo current
$P_0$ = Optical power incident on photo detector
hv= Photon energy
q = Charge of the particles

**Keyword:** Photo detector, Depletion region, Band energy,Semiconductor, Quantum efficiency, Responsitivity,Charge carriers

**Introduction**

The Pin diode consists of an intrinsic semiconductor sandwiched between two heavily doped p-type and n-type semiconductors. Sufficient reverse voltage is applied so as to keep intrinsic region free from carriers, so its resistance is high, most of diode voltage appears across it. And the electrical forces are strong within it. The incident photons give up their energy and excite an electron from valance to conduction band. Thus a free electron hole pair is generated, there are called as photo carriers. These carriers are collected across the reverse biased junction resulting in rise in current in external circuit called photocurrent. In the absence of light.

PIN photodiode behave electrically just like an ordinary rectifier diode. If forward biased, they conduct large amount of current. PIN detectors can be operated in two modes: photovoltaic and photoconductive. In photovoltaic mode, no bias is applied to the detector. In this case detectors works very slow, and output is approximately logarithmic to the input light level. Real world fiber optic receivers never use the photovoltaic mode. In photoconductive mode, the detector is reverse biased. The output in this case is a current that is very linear with the input light power. The intrinsic region some what improves the sensitivity of the device. It does not provide internal gain. The combination of different semiconductors operating at different wavelengths allows the selection of material capable of responding to the desire operating wavelength.

A p-i-n photo detector has become most important and popular in optical fiber communication. Photo detector (PD) is mainly used in optical fiber communication as receiver. It is also used for the high-speed communication, optical storage systems CD-ROM, as well as red and blue laser DVDs. Among of P-N, PIN, avalanche (APD) or metal-semiconductor-metal (MSM), photo detector model, we analysis the performance of P-I-N waveguide photo detector model structure. There are several reasons for choosing P-I-N waveguide photo detector model. Waveguide photo detector model is used for increasing fiber to detector coupling efficiency. Speed of response is high for p-i-n PD than p-n Pd.

For p-n Pd, in the depletion region carrier pairs separate and drift under the influence of electric field, whereas outside this region the hole diffuses towards the depletion region in order to be collected . The diffusion process is very slow compared to the drift and thus limits the response of the photodiode. But in case of p-i-n photodiode, diffusion and drift process both are very fast compared to the p-n PD and for this reasons speed of response of PD is fast.

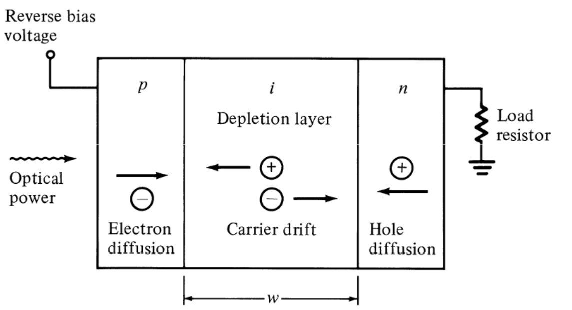
APD has the random nature of the gain mechanism which gives an additional noise contribution. But in p-i-n PD, there is a little noise effect due to low gain mechanism. It is important that both bandwidth and quantum efficiency be high for high performance photodetector. The thin absorption layer is good for high bandwidth but then quantum efficiency is reduced. The InGaAs-absorption layer in the model is suitable for long-haul fiber-optic communication systems at the important 1.3- and 1.55- μm wavelengths. The thin absorption layer thickness is used to decrease the transit time of carriers.

The carriers are nonuniformly distributed in the two-dimensional (2-D) plane, i.e., along the length and thickness of the PD. It may be mentioned here that modeling of the frequency response is very critical in such structures. Because of the thin absorption layer, it is important to include the interface trapping effect in the modeling of a heterojunction PD. Two dimensional model is used to determine frequency response. Frequency response is determined from the transfer function of equivalent circuit model of InGaAs based photodetector. 3 db bandwidth obtained from normalized frequency response curve is found to be large for optical fiber communication. Photocurrent density with respect to the position from side in where light is incident, frequency and incident optical power. Photocurrent density decreases with increasing penetration depth and increases with increasing incident optical power.

Consider a reverse biased Pin photodiode.

**Characteristics of PIN Photo detector**

Reverse-biased pin photodiode




**Schematic representation of a reversed biased pin photodiode**

Fig-1

There are a number of Pin diode characteristics that set this diode apart from other forms of diode. These key Pin diode characteristics include the following:

The wide depletion layer provided by the intrinsic layer ensures that Pin diodes have a high reverse breakdown characteristic. Again the intrinsic layer increases the depletion region width. As the capacitance of a capacitor reduces with increasing separation, this means that a Pin diode will have a lower capacitance as the depletion region will be wider than a conventional diode. This Pin diode characteristic can have significant advantages in a number of RF applications - for example when a Pin diode is used as an RF switch. Carrier storage gives a most useful Pin diode characteristic. For small signals at high frequencies the stored carriers within the intrinsic layer are not completely swept by the Rf signal or recombination.

At these frequencies there is no rectification or distortion and the Pin diode characteristic is that of a linear resistor which introduces no distortion or rectification. The Pin diode resistance is governed by the Dc bias applied. In this way it is possible to use the device as an effective RF switch or variable resistor for an attenuator producing far less distortion than ordinary Pin junction diodes. The sensitive area of a photodiode is the depletion region. Light striking the crystal lattice can release holes and electrons which are drawn away out of the depletion region by the reverse bias on the diode. By having a larger depletion region - as in the case of a Pin diode - the volume for light reception is increased. This makes Pin diodes ideal for use as photodetectors.

**Quantum Efficiency**

It is the ratio of primary electron-hole pairs created by incident photon to the photon incident on the diode material.

R=

$$\eta = \frac{\text{number of electron hole pair generated}}{\text{no of incident photons}}$$

$$\eta = \frac{I_p/q}{P_0/h\nu} \text{-------------------------------(1)}$$

Where $I_p$ = arrange photo current generated by steady –state average optical power

$P_0$=optical power incident on the photo detector.

To achieve high quantum efficiency the depletion layer must be thick enough , large fraction of incident light to be observed.

The performance of photo detector is often characterized by the responsitivity R .This related to the quantum efficiency by

$$R = \frac{I_p}{P_0} = \frac{\eta q}{h\nu} \text{----------------------------(2)}$$

$$I_p = P_0 R \text{ ----------------------------(3)}$$

This parameter is quite useful.

The proportionality factor R, between the electric current and the optical power , is defined as the responsivity R of the device. R= $i_p$/P has units of A/W and is given by

The responsivity relates the electric current flowing in the device to the incident optical power. If every photon were to generate a single photoelectron, a photon flux Φ ( photons per second) would produce an electron flux , corresponding to a short – circuit electric current

$i_p = e\Phi\eta$ An optical power

P=hvΦ(watts) at frequency v would then give rise to an electric current $i_p$ =ep/hv. Since fraction of photons producing detected photoelectrons is ɳ rather than unity, the electric current is

$I_p$= ɳe Φ= ɳe P/hv= R p.--------------------------------(4)

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R=ɳe/hʋ =ɳ $\lambda_0$/ 1.24--------------------------------(5)

R increases with $\lambda_0$ because photoelectric detectors are responsive to the photon flux rather than to the optical power. As $\lambda_0$ increases, a given optical power is carried by more photons, which in turn , produce more electrons. The region over which R increases with $\lambda_0$ is limited however , since the wavelength dependence of ɳ comes into play for both long and short wavelengths. It is important to distinguish the (detector responsivity defined here (A/W) from the light- emitting – diode responsivity(W/A)

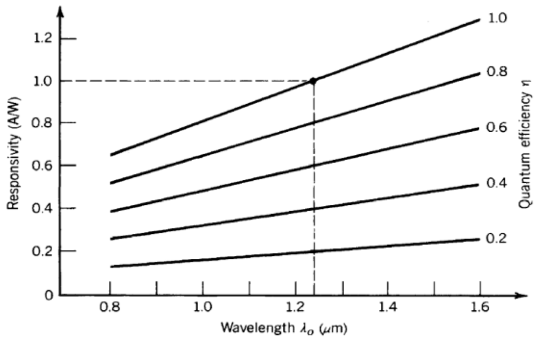


**FIG 3**

Responsivity R (A/W) versus wavelength $\lambda_0$ with the quantum efficiency ɳ as a parameter . R=1 A/W at $\lambda_0$ =1.24 μm when ɳ=1.

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## Conclusion

The photo current is directly proportion to the optical power $P_0$ incident upon the photo detector.So that the responsitivity , R is constant at a wavelength or a given value of hv. The quantum efficiency is not constant at all wavelength. It varies according to the photon energy. The responsitivity is a function of wavelength and of a photodiode material. So InGaAs Pin photo detector having large depletion layer. So it has large information receiving capacity.

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