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Md. Mashrur Islam
Dept. of Electrical & Electronic Engineering, RUET, Bangladesh, anisulme11@gmail.com

Shahriar Ahmed
Dept. of Electrical & Electronic Engineering, AUST, Bangladesh, anisulme11@gmail.com

Anisul Islam
Dept. of Mechanical Engineering, RUET, Bangladesh, anisulme11@gmail.com

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Performance Analysis of 2.5 Gbps PIN and APD Photodiodes to Use in Free Space Optical Communication Link

Md. Mashrur Islam[1], *Sadman Saffaf Ahmed* [2] *and Anisul Islam*[3,*]

[1]Dept. of Electrical & Communication Engineering, RUET, Bangladesh

[2]Dept. of Electronics & Communication Engineering, RUET, Bangladesh

[3]Dept. of Mechanical Engineering, RUET, Bangladesh

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Abstract: Ever since ancient times, people had a principle need to communicate with one another. This need created interests in device based communication system for sending messages from one distant place to another. Optical communication methods were of special interest among the many systems. In this paper, investigation has been done on two different photodiodes PIN and APD for use as a receiver in free space fiber optical link. We have considered 2.5 Gbps PIN and APD photo diodes for our experiment. From the simulation, we found that APD with single mode fiber gives the better performance over PIN. However, the value of Q-factor is maximum when APD has been used as the receiving photodiode at 1550nm wavelength and minimum when PIN diode has been used as receiving photodiode at 1550nm wavelength. We used OptiSystem and MATLAB software for our investigation.

Keywords: PIN; APD; BER; Q-factor.

1 Introduction

Exchange of information between any two devices across a communication channel involves using some type of electrical or optical signal which carries the information. Parameters considered while analyzing the optical link are desired transmission distance, data rate or channel bandwidth and BER. Free Space Optics (FSO) is a technology that is used for telecommunication and can be used to transmit optical signals over the air. Free Space Optical communication can be considered as wireless transmission system [1-9]. FSO is capable of handling data at very high data rates of order of hundreds of Gbps. In Free Space Optical communication system licensing is not required as in case of radio communication and could be realized as a very low cost as compared to other telecommunication systems such as wireless communication. Also the narrow beams used for the purpose of transmission of information signals in FSO system are very difficult to intercept, and are resistant to interference or jamming [9-13]. Free Space Optical Communication can also be viewed as optical wireless communication. In Free Space Optical communication system different transmission medium can be used such as Light Emitting Diodes (LED) and Lasers. FSO can be used to establish a link between transmitter and receiver at very high data rate of the order of about tens of Gbps [1]. FSO depends on Line of Sight communication and there should not be any obstacle between transmitter and receiver in FSO [6]. FSO is very advantageous over other methods of data transmission system in many aspects for example t does not require any licensed frequency band for communication. It is very easy and relatively cheaper to install and price required for maintenance of FSO link is considerably quiet low as compared to other data transmission systems. Data transfer rate are very high in Free Space Optical transmission system. Because of the high security of information that can be transferred using FSO transmission system, it can also find its applications in military services. There are many parameters which decide the overall performance of a Free Space Optical transmission system. These performance parameters can be grouped as either internal parameters or external parameters [3-7]. Internal parameters consists of types of Laser used,

*Corresponding author E-mail: anisulme11@gmail.com

the central wavelength used in transmission of data, amount of divergence of beam etc. Appropriate values of inner parameters are to be substituted in order to get desirable results from the data transmission system. The performance of a FSO has to encounter many challenges. The first and the most important is the loss incurred due to Free Space Path loss [5-12]. Second challenge is the dependence of performance on the current weather condition at different place and at different time of afternoon and night. The above mentioned challenges hinder the performance of the FSO transmission system and cause scattering [6], turbulence [5], and scintillation [10].
Communication can be wireless [14-16] or wired. Fiber optic communication brings some advantages. In this study, we have selected the optimum photo detector between PIN and APD photodiodes.

2 Types of Photo-Diodes

There are generally two types of photo diodes in stu. The details description is illustrated bellow:

2.1 PIN Photo-Diode

In order to allow operation at longer wavelength where the Light penetrates more deeply into the semiconductor material a wider depletion region is necessary. To achieve this the n type material is doped so lightly that it can be considered intrinsic, and to make low resistance contact a highly doped n type (n+) layer is added. This creates a PIN structure, as may be seen in Fig.2 where all absorption takes place in the depletion region.

2.2 Avalanche Photo-Diode

The second major type of optical communications detector is the avalanche photodiode (APD). This has a more sophisticated structure than the PIN photodiode in order to create an extremely high electric field region as may be seen in Fig.3. Therefore, as well as the depletion region where most of the photons are absorbed and the primary carrier pairs generated there is high field region in which holes and electrons can acquire sufficient energy to excite new electron-hole pairs. This process is known as impact ionization and is the phenomenon that leads to avalanche breakdown in ordinary reverse biased diodes. It often requires high reverse bias voltages (50 to 400 V).
APD can give carrier multiplication factors as great as 10^4. Most of the III-V semiconductors have nearly equal value of electron and hole ionization rate and as a result the APDs made with these materials become very noisy. For silicon, the Si-APDs are comparatively less noisy.

3 System Set up and Parameters

FSO transmission system design has been proposed for performance evaluation and for simulation purpose OptiSystem 7.0 tool has been used. The diagram for FSO link used in the simulations is shown in Fig. 3.
In the optical transmitter block, first we have the Pseudo Random Bit Generator (PRBS) which is used to generate sequence of zeroes and ones randomly. Then next in the transmitter section we have Gaussian pulse generator. The output of PRBS is fed as input to Gaussian pulse generator.

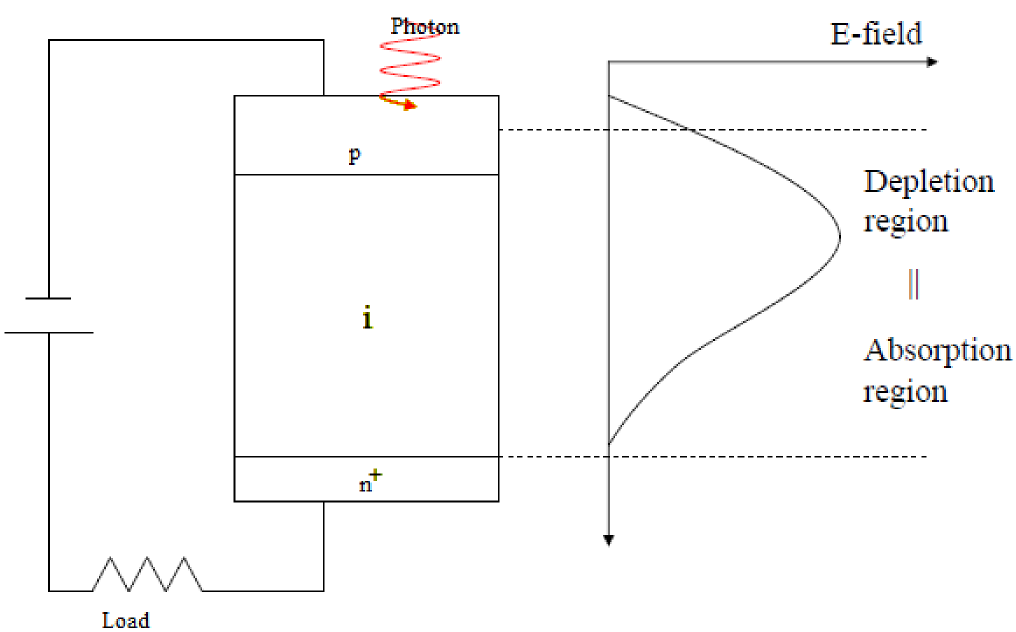

Fig. 1: PIN photodiode showing combined absorption and depletion.

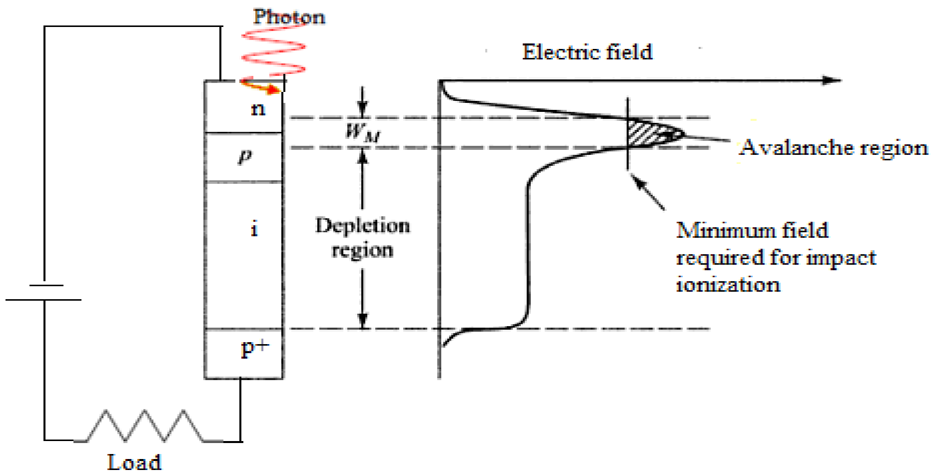

Fig.2: Avalanche photodiode showing high electric field region.

Gaussian pulse generator is used to generate Gaussian signals. Then the third block is directly modulated laser. This laser can be used to decide different parameters such as for instance line width, chirp, side mode, suppression and relative intensity noise. After this the signal is transmitted in the free space. This free space is also named as channel. It's distance between transmitter telescope and receiver telescope. There are many parameters which affect the performance of FSO link in the channel namely link distance, attenuation, geometric losses, transmitter loss, receiver loss, beam divergence, additional losses etc. In the receiver side we can either use APD or PIN photodiode to receive signal. This receiver is capable of regenerating the electrical signal. The optical receiver consists of a photodiode followed by a LPF, and at last a 3R generator is used. The output of 3R generator is fed as input to BER analyzer. This BER analyzer is used to calculate value of Q Factor of system, and also calculates the Bit Error Rate (BER) of the system. It can also be used to determine eye diagrams of the received signal.

3.1 Parameters for Photo-Detector Analysis

3.1.1 Conversion Efficiency

Conversion efficiency is the ratio of electrons generated to incident photons. It is defined as ability of the photo-detector to convert received optical power into the electrical power. It is transparent with the variation in the transmission data rate and decreases with the decrease in the incident optical power on it. When incident optical power is below the required sensitivity of detector conversion efficiency is almost equal to zero.

3.1.2 Bit Error Rate

In telecommunication transmission, the bit error rate (BER) is the percentage of bits that have errors relative to the total number of bits received in a transmission, usually expressed as ten to a negative power. For example, a transmission might have a BER of 10^{-6}, meaning that, out of 1,000,000 bits transmitted, one bit was in error.

3.1.3 Fibers

Multimode fibers are with a core diameter of around 50μm or greater, which is large enough to allow the propagation of many modes within the fiber core. Single mode fiber allows the propagation of only one transverse electromagnetic mode (typically HE11), and hence the core diameter must be of 2 to 10μm.

4 Results and Discussions

In this proposed system, the evaluation has been done of performance of FSO communication system on the basis of type of photodiode used at the receiver side namely PIN and APD photodiode. The minimum BER we found with respect to Power in dBm is plotted in MATLAB. We plot it for both PIN and APD diodes. The resultant graph can

ensure better photodiode. We have considered here 2.5 Gbps PIN and APD photo diodes during finding our results from OptiSystem.

Figure 1 shows a comparison of PIN and APD diode where the green line with red stars signifies APD and blue line with purple stars represents PIN diode. From Fig. 4, we can see that the APD diode maintains better BER in lower power compared to PIN photo diode. This signifies that APD is optimum. However, now we will analyze the eye diagram for PIN and APD photo diode.

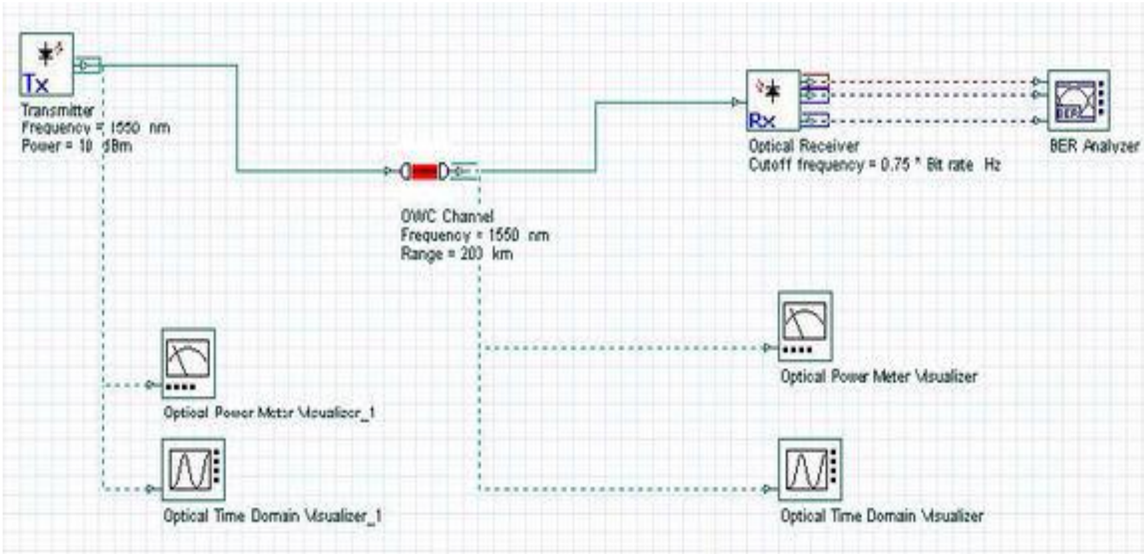

Fig.3: Block Diagram of FSO link design.

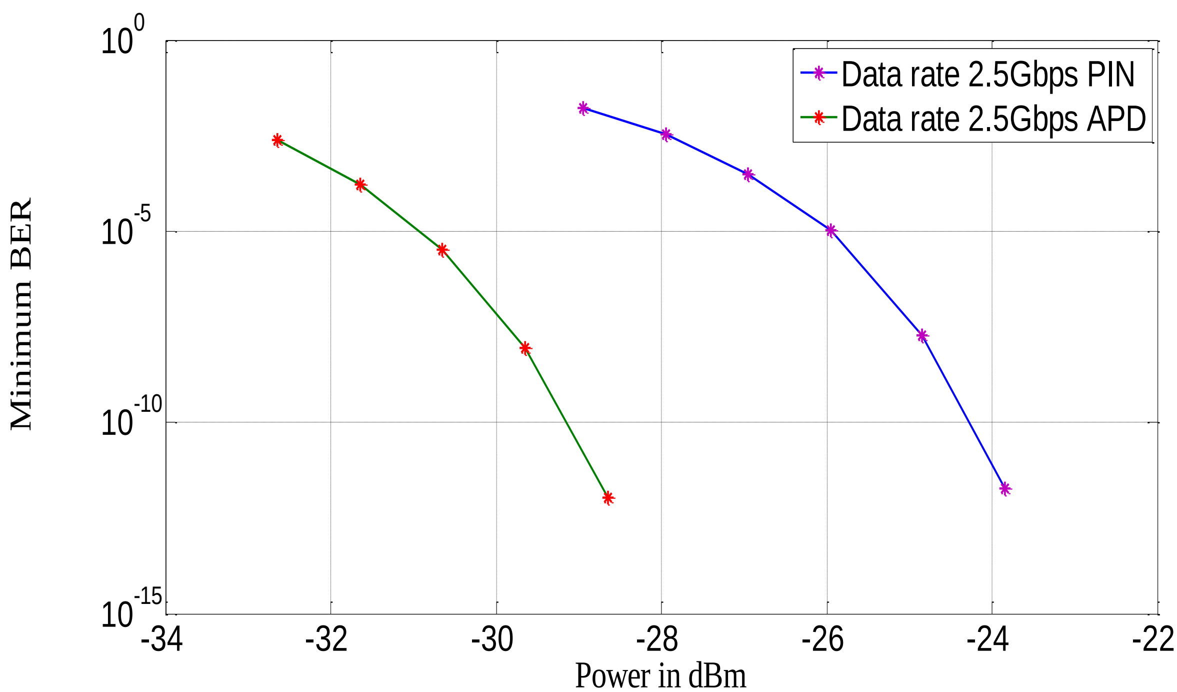

Fig.4: power in dBm vs. Minimum BER for 2.5 Gbps PIN and APD photodiodes.

Fig. 5 shows eye diagram of a system having wavelength 1550 nm. From eye diagram it's clear that the Q element in this design is 64.037. The Q element in this system is highest among another system discussed in this paper. Fig. 6 shows eye diagram of something having wavelength 1550 nm. From eye diagram it's clear that the Q element in this design is 34.4519. The Q factor has been decreased from 64.037 to 34.4519. This decline in Q factor is because of the utilization of PIN photodiode.

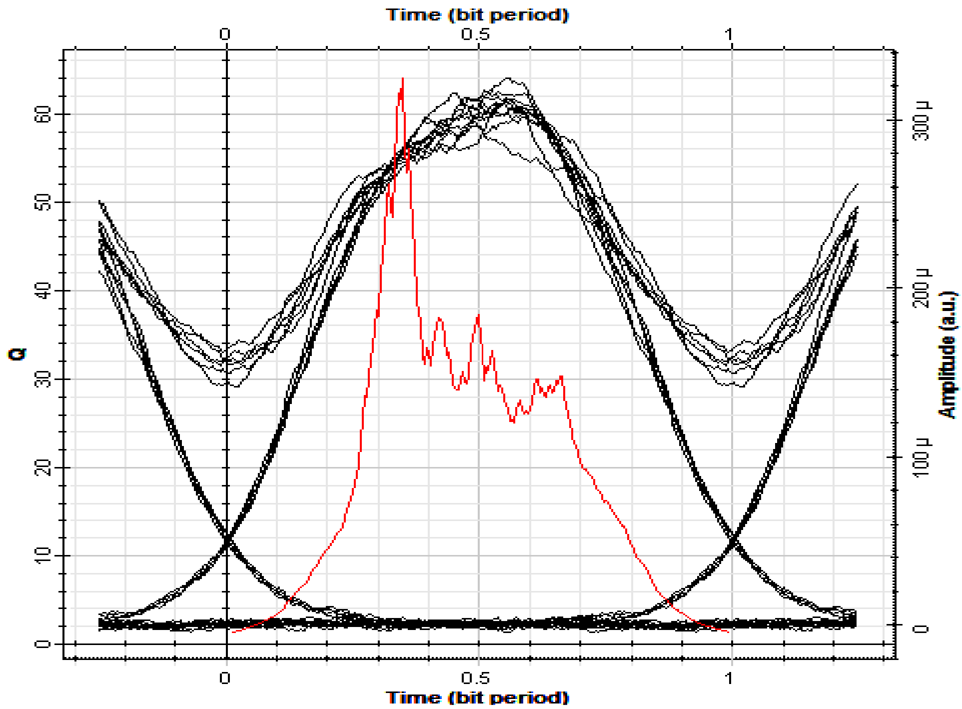

Fig. 5: Eye Diagram (APD photodiode used system at 1550 nm wavelength).

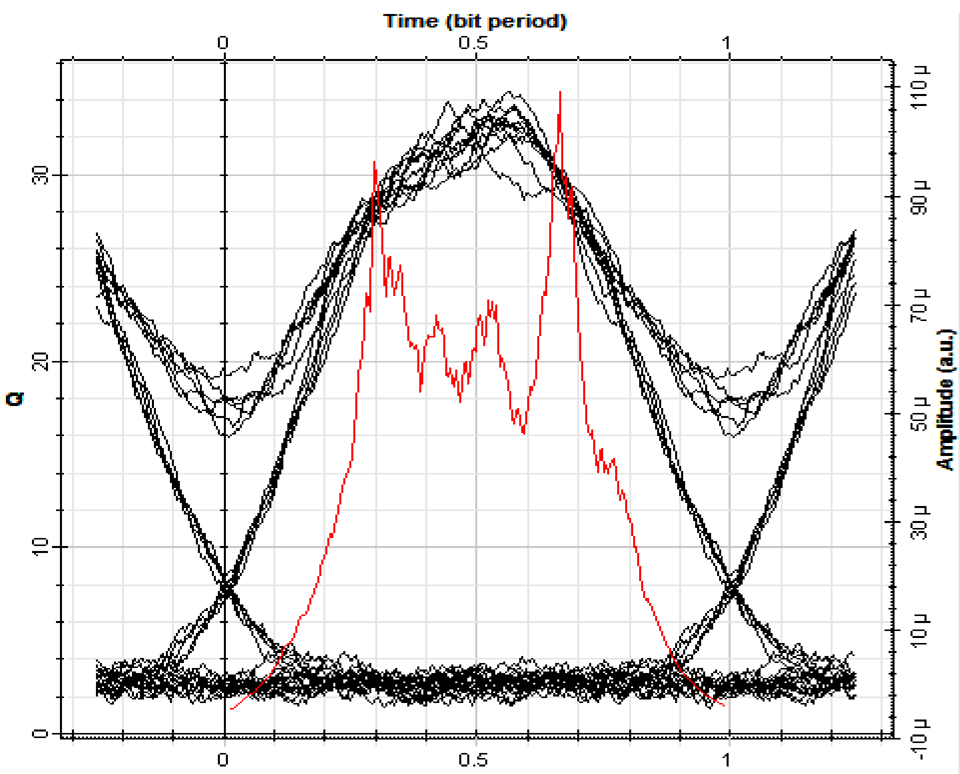

Fig. 6: Eye Diagram (PIN photodiode used system at 1550 nm wavelength).

5 Conclusions

To sum up, APD can show less BER then PIN at similar power (dBm). It can also conclude that there is considerable decline in Q factor which lies within (64.037 – 34.4519) for 1550 nm. In the event of photodiodes APD gives better Q factor then PIN photodiodes. So we can say that APD photodiode gives a better performance as a receiver in FSO transmission system as compared to PIN photodiode.

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