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Research Article

Design and Construction an Optical System of Data Transfer in Air using Laser Technology

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Abstract

In this research, two computers are used to transfer data in free space optical communication system using transmitter and receiver circuits and the distance separation between these computers is 50 m. The transmitter part of the optical communication system contains a drive circuit and semiconductor laser as a light source, while a receiver part of the optical communication system contains a phototransistor and an amplified circuit. In this research, we have designed and constructed an optical system of information transfer between two computers in practice based on the theoretical design circuits A green laser with wavelength of 532 nm and measured output power 26 mW is used. The COM port (RS-232) is used to send and receive data with "advanced serial port" program version 5.5 with a bit rate of 9600Kbps. The results of the optical communication system are achieved as sent a sequence of binary digit 0/1 from one computer to another computer using the measured transmitted power of the laser at a specific distance between computers.

Keywords: *Transfer Data, free-space communication, Wireless Optical Communication, Optical , Transceiver, laser in optical communication.*

1. Introduction

In recent years, there has been a migration of computing power from the desktop to portable, mobile formats. Devices such as digital still and video cameras, portable digital assistants and laptop computers offer users the ability to process and capture vast quantities of data. Although convenient, the interchange of data between such devices remains a challenge due to their small size, portability and low cost.

High performance links are necessary to allow data exchange from these portable devices to established computing infrastructure such as backbone networks, data storage devices and user interface peripherals. Also, the ability to form *ad hoc* networks between portable devices remains an attractive application. The communication links required can be categorized as short-range data interchange links and longer-range wireless networking applications.

One of the earliest wireless optical communication devices using electronic detectors was the *photophone* . Figure (1) presents a drawing made by the inventors outlining their system. The system is designed to transmit an operator's voice over a distance by modulating reflected light from the sun on a foil diaphragm. The receiver consisted of a selenium crystal which converted the optical signal into an electrical current (A. Bell *et al*, 1880).

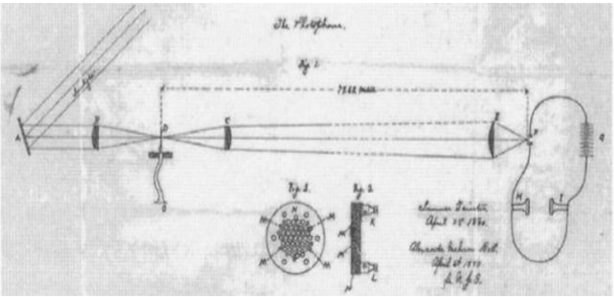

Fig. 1 Drawing of the photophone (A. Bell *et al*, 1880).

In the present day wireless optical links can transmit 4 Mbps over short distances using optoelectronic devices (S. Hranilovic, 2005; J. Kahn *et al*, 1997). However, much high rates approaching 1 Gbps have been investigated in some experimental links. Wireless optical links transmit information by employing an optoelectronic light modulator, typically a light-emitting diode (LED). The task of up- and down-conversion from baseband frequencies to transmission frequencies is accomplished without the use of high-frequency RF circuit design techniques, but is accomplished with inexpensive LEDs and photodiodes. Optical radiation in the infrared or visible range is easily contained by opaque boundaries. As a result, interference between adjacent devices can be minimized easily and economically. Although this contributes to the security of wireless optical links and reduces interference it also impacts rather stringently on the mobility of such devices. For example, it is not

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possible for a wireless optical equipped personal digital assistant to communicate if it is stored in a briefcase. Wireless optical links are also suited to portable devices since small surface mount light emitting and light detecting components are available in high volumes at relatively low cost.

2-Applications of free Space Optical Communication

Typically scenarios for use are (J. Xue *et al*, 2010):

- LAN-to-LAN connections on campuses at Fast Ethernet or Gigabit Ethernet speeds.
- LAN-to-LAN connections in a city. *Example, Metropolitan area network*.
- To cross a public road or other barriers which the sender and receiver do not own.
- Speedy service delivery of high-bandwidth access to optical fiber networks.
- Converged Voice-Data-Connection.
- Temporary network installation (for events or other purposes).
- Reestablish high-speed connection quickly (disaster recovery).
- As an alternative or upgrade add-on to existing wireless technologies.
- As a safety add-on for important fiber connections (redundancy).
- For communications between spacecraft, including elements of a satellite constellation.
- For inter- and intra-chip communication.

3- Free space laser communication system parameter

System parameters of laser communication in free space includes:

3.1 -The Optical Transmitter

The major component of optical transmitters is an optical source. Optical communication systems often use semiconductor optical sources such as light-emitting diodes (LEDs) and semiconductor lasers (LDs) because of several inherent advantages offered by them. Some of these advantages are compact size, high efficiency, good reliability, right wavelength range (P. Govind, 2002).

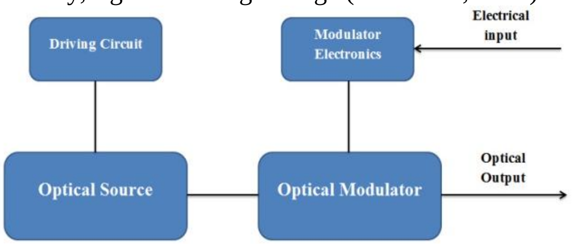

Fig. 2 Basic transmitter block diagram (S. Hranilovic, 2005).

The role of optical transmitters is to convert an electrical signal into an optical form and to launch the resulting optical signal into the free space as a communication channel. The transmitter is composed of two parts: laser diode and a laser diode driver, as shown in figure (2) (S. Hranilovic, 2005).

3.1.1- Optical Sources

Optical sources such as tungsten filament and arc lamps are suitable, but there are two types of devices, which are widely used in optical communication systems such as Light Emitting Diode (LED) and Laser Diode (LD) (S. Hranilovic, 2005; J. Senior, 1992).

Light source is often considered to be the active component in an optical communication link. Its fundamental function is to convert the electrical signal into a corresponding light signal.

Optical signals begin at the source with laser or LEDs transmitting light at the exact wavelength at which it is most efficiently to transmit. The source must be switched on and off rapidly and accurately enough to properly transmits the signals. Lasers are more powerful and operate at faster speeds than LEDs, and they can also transmit light farther in space with fewer errors.

LEDs, on the other hand, are less expensive, more reliable, and easier to use than lasers. Lasers are primarily used in long-distance, high speed transmission systems, but LEDs are fast enough and powerful enough for short-distance communications.

Lasers provide stimulated emission rather than the simplex spontaneous emission of LEDs. The main difference between a LED and a laser diode is that the laser has an optical cavity required for lasing. This cavity is formed by cleaving the opposite end of the chip to form highly parallel, reflective, mirror like finishes. A comparison of the advantages of LED and LD is shown in table (1) (J. Senior, 1992).

Table 1 Comparison of Light Sources.

LED	LD
Low efficiency	High efficiency
Slow response time	Fast response time
Lower data transmission rate	Higher data transmission rate
Broad output spectrum	Narrow output spectrum
Incoherent beam	Coherent output beam
Low launch power	High launch power
Higher distortion level at the output	Less distortion
Suitable for shorter transmission distances.	Suitable for longer transmission Distances
Higher dispersion	Lower dispersion
Less temperature dependent	More temperature dependent
Simple construction	Construction is complicated
Longer life time	Smaller Life time
Lower modulation bandwidth	Higher modulation bandwidth

3.2- The Optical Receiver

The main task of optical receiver is to convert light signal back to electrical signal and amplify the weak electrical signal.

The main component of optical receiver is the optical detector which converts the optical signal to electrical signal by the photoelectric effect (P. Govind, 2002).

The optical receiver has two main components: a photodetector and an amplifier circuit. Figure (3) shows the basic components of an optical receiver (S. Hranilovic, 2005).

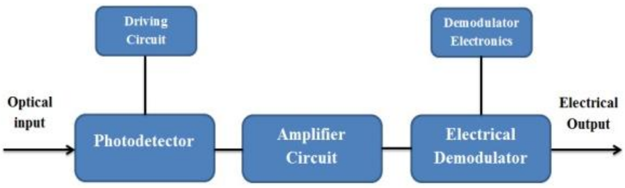

Fig. 3 Basic receiver block diagram (S. Hranilovic, 2005).

3.2.1 Photodetectors

A photo detector operates by converting light signals that hit the junction to a voltage or current. The junction uses an illumination window with an anti-reflect coating to absorb the light photons. The result of the absorption of photons is the creation of electron-hole pairs in the depletion region. Examples of photo detectors are photodiodes, phototransistors which are used in optical communication system (S. Hranilovic, 2005).

Phototransistor is similar to the photodiode except an additional n-type region is added to the photodiode configuration. The phototransistor includes a photodiode with an internal gain. A phototransistor can be represented as a bipolar transistor that is enclosed in a transparent case so that photons can reach the base-collector junction. The electrons that are generated by photons in the base-collector junction are injected into the base, and the current is then amplified. Since phototransistor detection is on the order of the photodiode they cannot detect light any better than a photodiode. The drawback of a phototransistor is the slower response time in comparison to a photodiode. Figure (4) shows the relationship between a photodiode and phototransistor (S. Hranilovic, 2005).

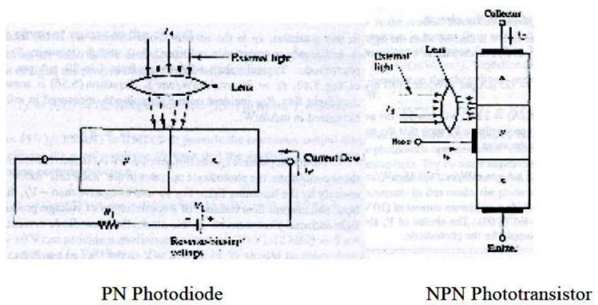

Fig. 4 The relationship between a photodiode and phototransistor (S. Hranilovic, 2005).

3.2.2 Amplifier Circuit

The output of the detector is a very weak signal, so the photodiode circuitry is followed by one or more amplification stages. This is to amplify the signal to yield an electrical signal representing the original input (J. AL-Shamary, 2003).

The most commonly used amplifier is trans impedance feedback amplifier, it has a wide bandwidth, no equalizer circuit is needed, and greater dynamic range (same gain at all frequencies) (J. Senior, 1992).

Equalization compensates for distortion of the signal due to the combined transmitter, medium and receiver characteristics. The equalizer is often a frequency shaping filter which has a frequency response that is the inverse of the overall system frequency response. In wideband systems this will normally boost the high frequency components to correct the overall amplitude of the frequency response. To acquire the desired spectral shape for digital systems in order to minimize inter symbol interference, it is important that the phase frequency response of the system is linear. Thus the equalizer may also apply selective phase shifts to particular frequency components. Figure (5) shows a trans-impedance amplifier circuit (J. Senior, 1992).

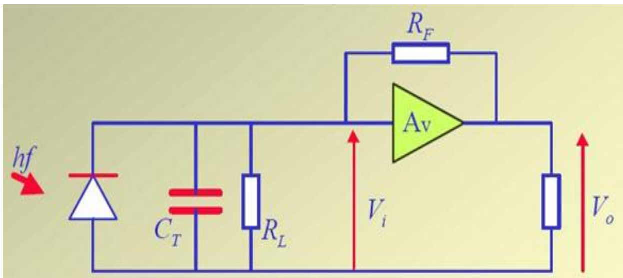

Fig. 5 A trans-impedance amplifier circuit (J. Senior, 1992).

4. Serial Port

Serial Cables can be longer than Parallel cables. The serial port transmits a '1' as -3 to -25 volts and a '0' as +3 to +25 volts where as a parallel port transmits a '0' as 0v and a'1' as 5v. Therefore the serial port can have a maximum swing of 50V compared to the parallel port which has a maximum swing of 5 Volts. Therefore cable loss is not going to be as much of a problem for serial cables as they are for parallel.

We don't need as many wires as parallel transmission. If the device needs to be mounted a far distance away from the computer then 3 core cable is going to be a lot cheaper that running 9 or 25 core cable. However, must be take into account the cost of the interfacing at each end.

Microcontrollers have also proven to be quite popular recently. Many of these have in built SCI (Serial Communications Interfaces) which can be used to talk to the outside world. Serial Communication reduces the pin count of these MPU's. Only two pins are commonly used, Transmit Data (TXD) and Receive Data (RXD) compared with at least 8 pins if 8 bit Parallel method was used (M. Yuksel, 2010). Figure (6) shows two serial ports on the back of a PC.

The name "serial" comes from the fact that a serial port "serializes" data. That is, it takes a byte of data and transmits the 8 bits in the byte one at a time. The advantage is that a serial port needs only one wire to transmit the 8 bits (while a parallel port needs 8). The disadvantage is that it takes 8 times longer to transmit the data than it would if there were 8 wires. Serial ports lower cable costs and make cables smaller. Before each byte of data, a serial port sends a start bit, which is a single bit with a value of 0. After each byte of data, it sends a stop bit to signal that the byte is complete. It may also send a parity bit.

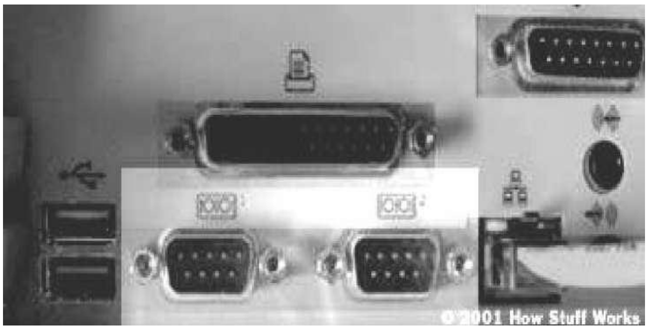

Fig. 6 Two serial ports on the back of a PC

Serial ports, also called communication (COM) ports, are bidirectional. Bidirectional communication allows each device to receive data as well as transmit it. Serial devices use different pins to receive and transmit data using the same pins would limit communication to half-duplex, meaning that information could only travel in one direction at a time. Using different pins allows for full-duplex communication, in which information can travel in both directions at once (S. Hranilovic, 2005).

5. Designed Parameters

In this work the light source is green laser with wavelength of 532 nm and measured output power is about 26 mW.

5.1 The Optical Transmitter

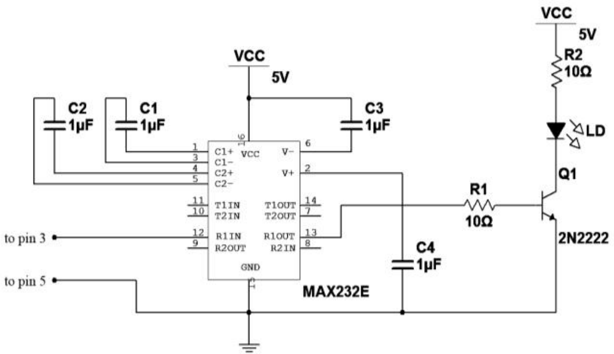

Fig. 7 Designed Transmitter Circuit.

Figure (7) shows a transmitter circuit designed for connecting two computers using the RS-232 standard serial port, while figure (8) shows the circuit setup of optical transmitter of free space laser communication. The port is a trapezoidal shaped, 9-pin connector. The trapezoidal shape of the connector keeps the user from plugging it upside down, as shown in figure (9).

The data comes from the RS-232 with voltage levels of ±12v which must be converted into the TTL level to be processed by the electronics circuit. The dual drivers/receivers (MAX232) achieved this conversion process. Data signals transmitted through pin3 of 9-pin 'D' connector of RS- 232 COM port are sent to pin12 of MAX232 and it converts these RS- 232 compatible levels of ±12V to 0/5 volt TTL levels at pin 13.

Fig. 8 The Transmitter Circuit Setup.

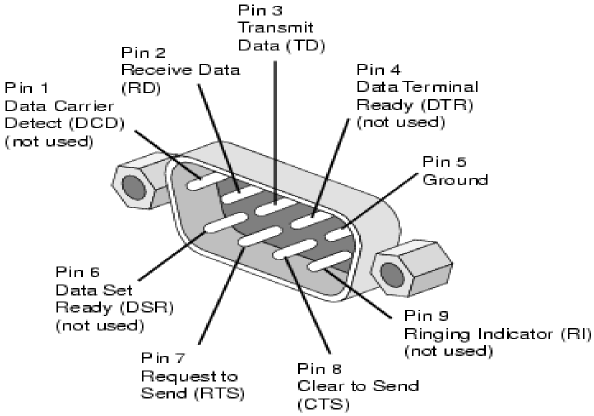

Fig. 9 Nine pin connector.

The output of MAX232 drives the NPN transistor through a bias resistor of 10 ohm, to switch on/off "semiconductor laser". Here actually when the output of MAX232 is 5V at that time the NPN transistor will be conduct and the LD will glow. And when the output of MAX232 is 0V at that time the NPN transistor will not conduct it is in cut-off region. So, at that time the LD will not glow.

It must be noted that one reason for the popularity of Intensity Modulation is its suitability for operation with LED's and LD's. LD's can produce higher optical power which is very necessary in FSO communication hence Intensity Modulation can be used with an LD (S. Hranilovic, 2005).

5.2 The Optical Receiver

Figure (10) shows the design circuit of receiver, while figure (11) shows the circuit setup. The laser signals are detected by a phototransistor. A phototransistor is reverse biased and breaks down when laser light falls on its NPN junction .The detected TTL level (0/5V) signals are coupled to pin 11 of MAX232 IC .These TTL levels are converted to ±12V levels internally and output at pin 14.

The optical signals received by the phototransistor are in fact converted to electrical pulses. The Receiver component serves two functions. First, it must sense or detect the light impacted from the transmitter then convert the light into an electrical signal.

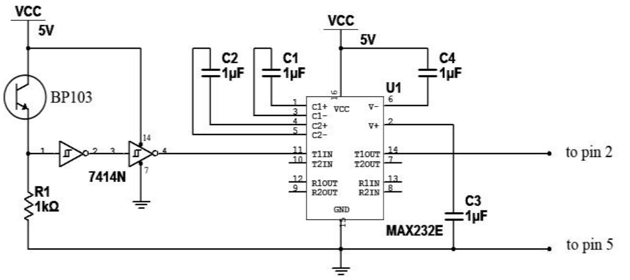

Fig. 10 The Receiver Circuit.

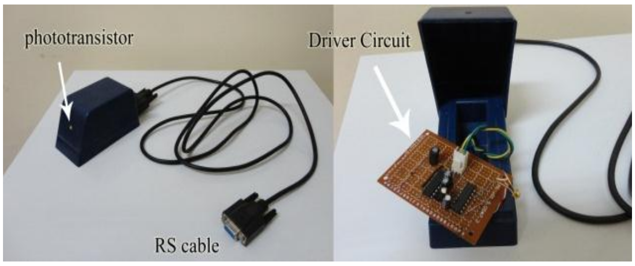

Fig. 11 The Receiver Circuit Setup.

Secondly, it must demodulate this light to determine the identity of the binary data that it represents. In total, it must detect light and then measure the relevant Information bearing light wave parameters. A Receiver is generally designed with a Transmitter.

Both are modules within the same package. The very heart of the Receiver is the means for sensing the light impacted from the transmitter. Light is detected and then converted to an electrical signal. The demodulation decision process is carried out on the resulting electrical signal. The light detection is carried out by a phototransistor. This senses light and converts it into an electrical current.

6. Measurements and Experimental Results

6.1 ICs Testing

In this section, the ICs (MAX232 and 7414N) were tested;

- **MAX232 testing**

Figure (12) show the pin configurations, it includes a charge pump, which generates ±12V from a single 5v supply. This IC also includes two receivers and two transmitters in the same package. Where pin 8 and 13 receives data from the RS232 cable in ±12V level and the output is from pin 9 and 12 as a 0v to 5v level, pin 10 and 11 receives a 0v to 5v data level and converted into ±12V level out from pin 7 and 14 respectively, pin 16 is connected to the Vcc with value of 5V and pin 15 to the ground (GND). The result of the IC tested by applying a ±12V from a function generator with square wave signal and frequency of 1 KHz to receivers and the output of IC was connected to an oscilloscope to observe the output of it was converted to 0v to 5v level as shown in figure (13 a and b). The 0v to 5v level output of IC was used to test the transmitters and the output was connected to an oscilloscope to observe the output which becomes ±12V as shown in figure (14 a and b).

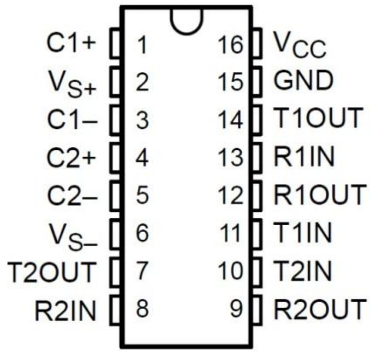

Fig. 12 Pin configuration of MAX232

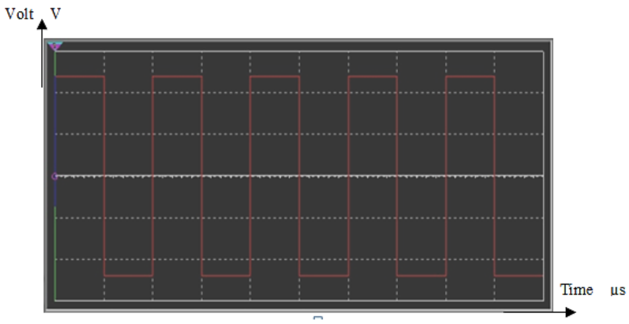

Fig. 13 a Test results of MAX232 of transmitters. Input signal is 12v at pins 8 and 13. Input signal at 5V/Div, 500µs/Div

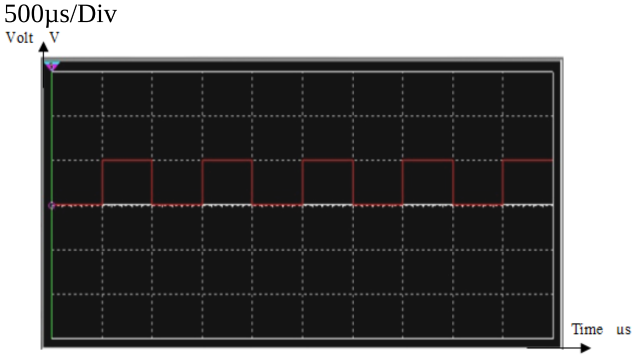

Fig. 13 b Test results of MAX232 of transmitters. Output Signal is 5v at pins 9 and 12. Output signal at 5V/Div, 500µs/Div

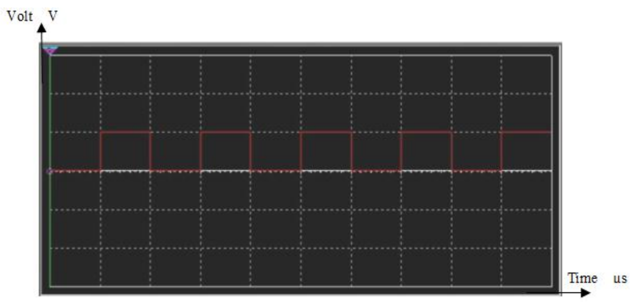

Fig. 14 a Test results of MAX232 of receivers. Input signal is 5v at pins 10 and 11. Input signal at 5V/Div, 500µs/Div

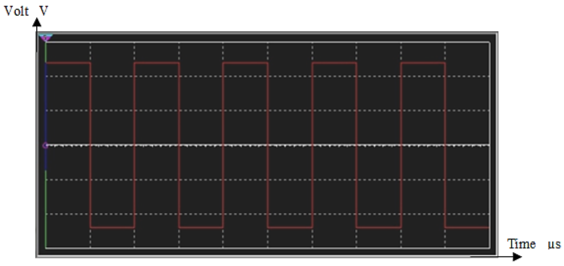

Fig. 14 b Test results of MAX232 of receivers. Output signal is 12v at pins 7 and 14. Output signal at 5V/Div, 500µs/Div

- **7414N testing**

A Schmitt-trigger inverter IC which was used to invert the signal at the receiver side.

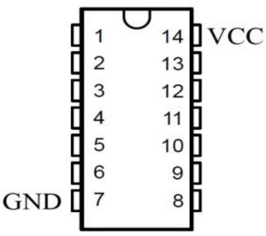

Fig. 15 Pin configuration of 7414N

The pin configuration of this IC is shown in figure (15) were pin 14 was connected to the Vcc and pin 7 to the ground (GND). The IC was tested by applying a ±5v at pin 1 from a function generator with square wave signal and frequency of 1 KHz to and the output at pin 2 was connected to an oscilloscope to observe the output as shown in figure (16 a and b).

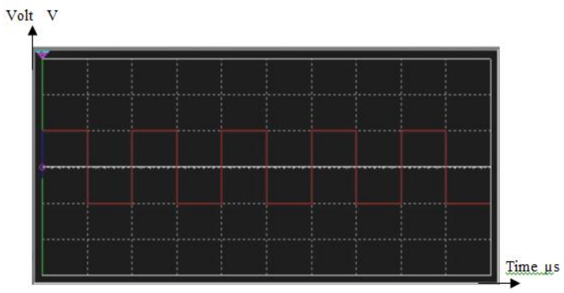

Fig. 16 a Test results of 7414N. Input signal is 10v at pin 1. Input signal at 5V/Div, 500µs/Div

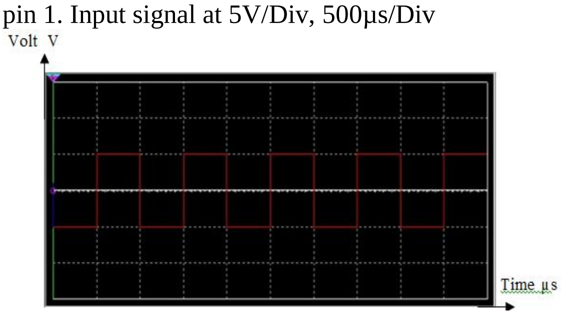

Fig. 16 b Test results of 7414N. Output signal is 10v at pin 2. Output signal at 5V/Div, 500µs/Div

6.2 The power various current curve for the laser diode operation

Table 2, shows the results of the measured values of the power transmitter (mW) and the current (A).

Table 2 Measured values of the power and the current for Laser

Current(A)	Power Transmitted (mW)
0	0
0.03	0.04
0.05	0.056
0.09	0.07
0.15	0.08
0.2	1.1
0.285	6
0.417	12.5
0.455	15.6
0.5	18.9
0.556	22
0.625	26

Figure (17) shows the P-I curve for the measured values of the power transmitter (mW) and the current (A), for the laser diode.

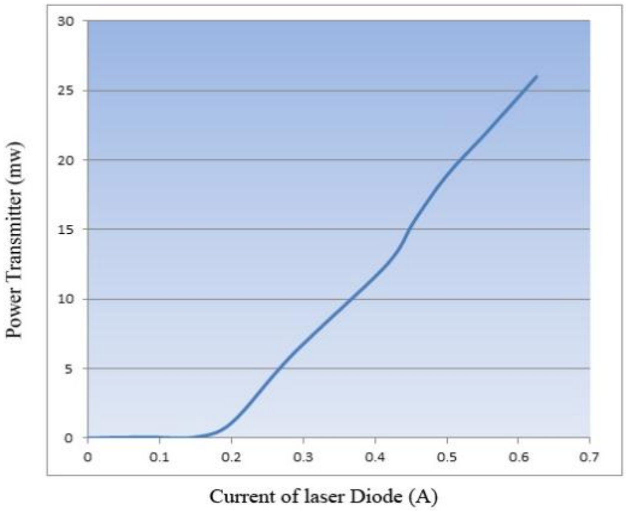

Fig. 17 The power-current curve for the laser diode

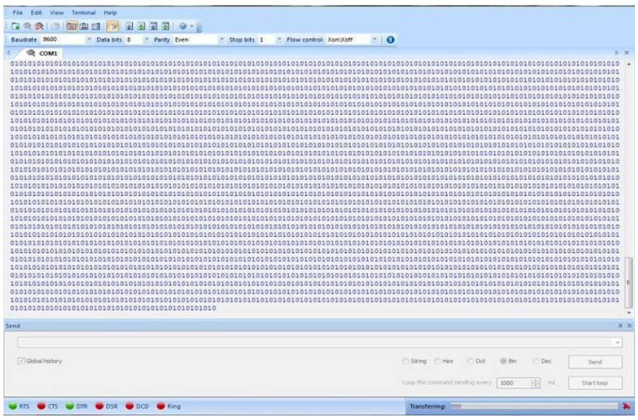

Fig. 18 Testing of the transmitter and receiver circuit. Data sent via the transmitter.

6.3 Transmitting and Receiving Test

Advanced Serial Port Terminal program (version 5.5) was used to test those two designed circuits were illustrated in figures 8 and 11, a software program allow the user to send and received binary digit 0/1 using the RS-232 port. Through any communication device, set the flow control of data to on\off and the bit rate of transmitted data to 9600kbps and a sequence of 0/1 bits continuously sent from one to another computer. The result of the transmitted part of the optical system is shown in figure (18).

The received signal after 50 m as the distance separation between transmitter and receiver is shown in figure (19).

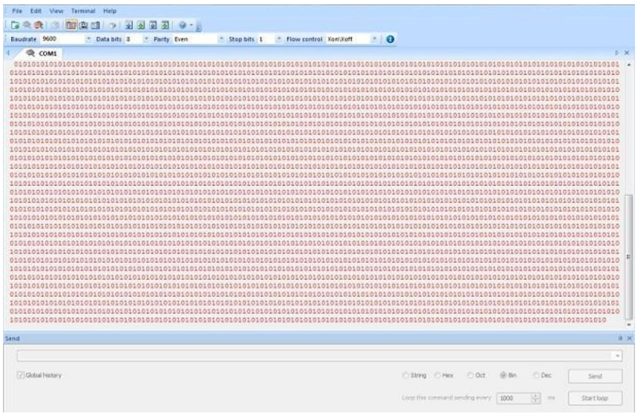

Fig. 19 Testing of the transmitter and receiver circuit. Data received via the receiver

7. Conclusions

In this work, there are many factors effect on transmit and receive data between two computer. These effected factors are summarized in the following points:

1. Due to the use of the LD as an optical source the maximum distance increased largely as compared to the distance obtained with coaxial cables.
2. The output power from the LD increases slowly with the drive current, until the threshold point, where it
3. will increase rapidly.
4. The attenuation factor is increased when the distance between the transmitter and the receiver is increased with the decreasing of the received power.
5. Best received power between two computers obtained at 50 m away from the transmitter.
6. With the increase of distance the difficulty of alignment of transmitter/receiver laser connection is increase, a stable laser stand could solve this problem.The bit rate achieved with the transmitter/receiver circuits is 9600kbps and lower, to achieved higher bit rate more sophisticated modulation circuit is required.

8. References

Bell, A. G. and Tainter, C. S. (1880), Drawing by Alexander Graham Bell and Charles Sumner Tainter, *Alexander Graham Bell Family Papers at the Library of Congress*, pp. 1834-1974**.**

Hranilovic, S. (2005), Wireless optical communication systems, Springer Science and Business Media Inc. Boston.

Kahn, J. M. and Barry, J. R. (1997), Wireless infrared communications, *proceedings of the IEEE*, vol. 85 (2), pp. 265-298.

Xue, J. and Garg, A. et al, (2010), An intra-chip free-space optical interconnect, *the 37th International Symposium on Computer Architecture*.

Govind, P. (2002), Fiber-optic communications systems, 3rd Edition, John Wiley and Sons Inc.

Senior, J. M. (1992) ,Optical fiber communications principles and practice, 2nd Edition, Prentice Hall International.

Al-Shamary, J. A. (2003), Stream ciphering of speech and transmission over optical fiber, M.Sc., Laser Institute Baghdad University, Iraq.

Yuksel, M. (2010), On prototyping multi-transceiver free-space-optical communication structures, University of Nevada, Reno.