# Design Considerations of Laser Source in a Ring Network Based on Fiber Distributed Data Interface (FDDI)

**Sercote N. Abdullah** [(1)]     **Hussein A. Jawad** [(2)]  and   **Hussam  A. Mohammed** [(1)]

(1)  *Electronic and Communication Engineering Department, College of Engineering,
University of Baghdad., Jadiriah, Baghdad, IRAQ*

(2)  *Institute of Laser and Plasma for Postgraduate Studies, University of Baghdad.
P.0. Box 47314 Jadiriah, Baghdad, IRAQ*

**Abstract:** This work presents the use of laser diode in the fiber distributed data interface FDDI networks. FDDI uses optical fiber as a transmission media. This solves the problems resulted from the EMI, and noise. In addition it increases the security of transmission. A network with a ring topology consists of three computers was designed and implemented. The timed token protocol was used to achieve and control the process of communication over the ring. Nonreturn to zero inversion (NRZI) modulation was carried out as a part of the physical (PHY) sublayer. The optical system consists of a laser diode with wavelength of 820 nm and 2.5 mW maximum output power as a source, optical fiber as a channel, and positive intrinsic negative (PIN) photodiode with maximum responsivity at wavelength of 820 nm as a detector. Practical tests were carried out on the laser diode showed that the output characteristics and spectral characteristics of the laser diode depend largely on the drive current. The maximum separation distance between successive stations in the ring was 5.4 km. From the performance tests, it was concluded that the maximum throughput and maximum access delay are directly proportional to length of the transmitted information.   A trade off between the transmitted information length and the maximum access delay is needed.

## Introduction

It has been widely accepted that the 21st century will be an information age, and people will enter the information society. Computers and optical fiber communication systems, those use lasers as a source, are the most important technological pillar of the information society. Laser communications present the most exciting, and probably the most challenging, aspects of modern systems. Laser communications found applications in computers, which fall into two major categories, peripheral interconnection and a Local Area Network (LAN) setup. In both areas, one of the critical fiber parameters includes high bandwidth, immunity to electromagnetic interference (EMI), and long distance.

The optical components of a laser communications system, as shown in the Fig. (1) are, in a simple term, a light emitter which is a laser that initiates the optical signal, a fiber, which transmits it, and a detector, which receives it and converts it into an electrical equivalent.

Laser source is a key element in any laser communication system. This component converts the electrical signal into a corresponding light signal that can be injected into the fiber [2]. The common laser sources for communication systems are the semiconductor lasers, that is the laser diode (LD) [3].

The laser diode is a solid state-device that emits a coherent, very intense beam of light over a narrow bandwidth [1,2]. This results in a higher data rate over longer distances. Its PN

junction forms an optical cavity, which is made to lase.

This work aims to use the laser diode with the optical fiber in order to increase the separation distance between successive stations in a ring networks. Also the work aims to reduce the effect of electromagnetic interference and noise on the performance of the system. The communication is implemented via the RS-232 standard interface. The low attenuation factor of the optical fiber in conjunction with the very intense output optical power from the laser diode make this possible. The fiber distributed data interface (FFDI) networking technique was utilized.

Fiber Distributed Data Interface is a standard for network technique based originally on fiber optics. It was established by American National Standards Institute (ANSI) in the mid 1980s. Today, its specifications also include standard copper media for interconnection. FDDI basically represents the technical specifications for a LAN to communicate at a standard rate of 100 Mbs but today is also widely used to interconnect LANs and Wide Area Networks (WANs) over longer cable lengths [3]. Because of its superior speed, FDDI is especially useful for sending large files such as graphics or digital video. It is a useful method of adding bandwidth without having to make a costly, long-term commitment. FDDI uses the timed token as an access method. A token is a special series of bits that travels around a token-ring network. Each network has only one token.

Another important characteristic of FDDI is its ability to interoperate easily with IEEE 802.3 10 Mbps Ethernet networks. It is used as a backbone to large networks, as well as an interim network for connecting LANs to high-speed computers. Some of FDDI's benefits are higher capacity and performance than older LANs, higher availability (dual ring topology), predetermined performance (adding users have minimal impact on throughput), and longer distance loops (2 to 100 km).
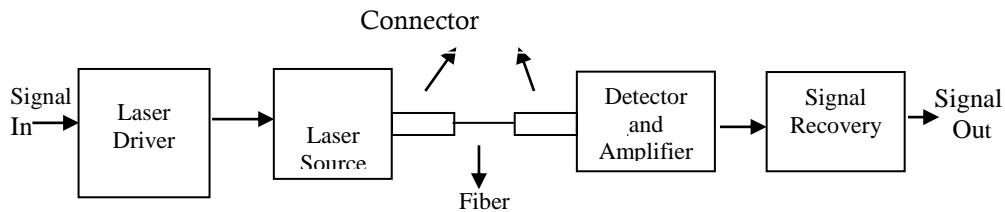


**Fig. 1:** Basic laser communication system [1,2].

### System description

The FDDI covers the first two layers of the open system interconnection (OSI) model. FDDI is not actually a single specification, but it is a collection of four separate specifications each with specific functions. Combined, these specifications have the capability to provide high-speed connectivity between upper-layer protocols such as transport control protocol internet protocol (TCP/IP) and internet packet exchange (IPX), and media such as fiber-optic cabling. Fig. (2) illustrates the four FDDI specifications and their relationship to each other and to the IEEE-defined Logical-Link Control (LLC) sublayer [4]. These specifications are Physical Medium Dependent (PMD) sublayer, Physical Protocol (PHY) sublayer, Media Access Control (MAC) sublayer, and Station Management (SMT) sublayer.

The proposed system consists of three computers that are connected in a ring topology using diode laser as a carrier. Each computer is connected to the one precedes it and to the one that follows it.

Fig. (3) shows the layout of the proposed system including the interface card used to connect the computers with each others while Fig. (4) shows a block diagram of the system. The timed token protocol is used to control the computer communication. Each station in the proposed system consists of the four layers mentioned previously. These layers are discussed as follows:
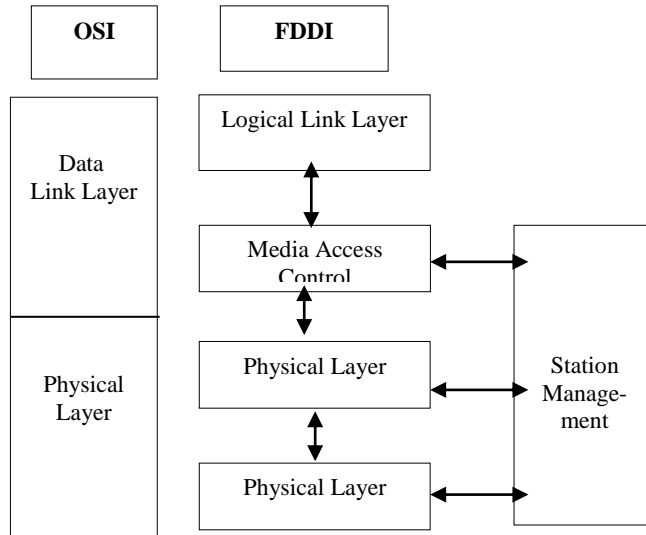
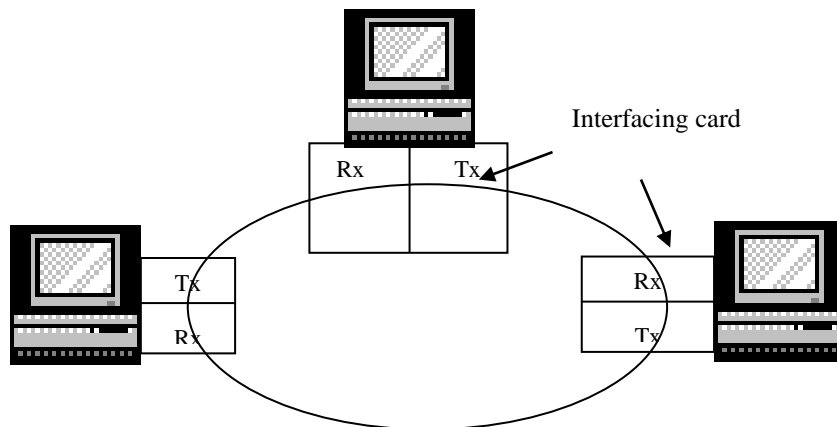**Fig. (2)** FDDI specifications map to the OSI hierarchical model.



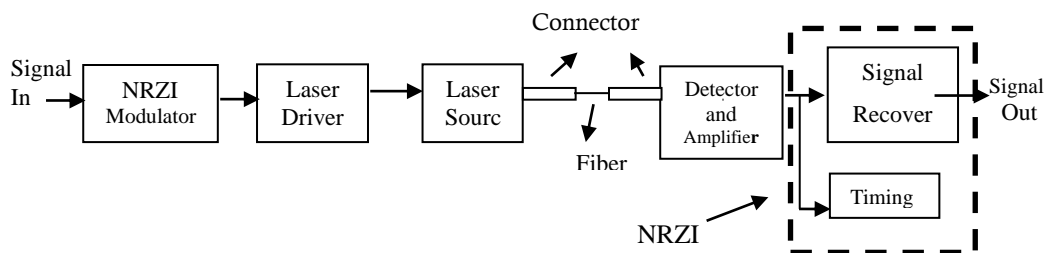**Fig. (3)** A layout of the proposed system



**Fig. (4)** A block diagram of the proposed system

### 1. Physical (PHY) Sublayer

PHY encodes and decodes symbols that are the smallest pieces of information between the MAC and the PMD using the 4B/5B-encoding scheme. In this scheme, each group of 4 data bits encoded in a 5 bits code group called a symbol. This encoding allows 80% efficiency since it takes 5 bits to convey 4 bits of information. Symbols are defined for the hexadecimal numbers 0 through F and also for a number of communication-specific functions. Table (1) shows the symbols used and their

4B/5B encoding. The 5 bit symbols are selected so as to guarantee a line transition at least every 3-bit time on the average, which is utilized in the process of clock recovery at the transmitter side.

The encoder circuit diagram of the NRZI encoder is shown in Fig. (5), while the NRZI decoder consists mainly of two sections shown in Fig. (6). These are the clock recovery, which extract the clock information from the NRZI signal, and the data recovery, which extracts the data from the NRZI stream.

**Table 1:** FDDI 4B/5B data symbols and control symbols.

| Hexa decimal | 4 bit data | 5 bit data | Hexa decimal | 4 bit data | 5 bit data | Control symbol | 5 bit symbol |
|---|---|---|---|---|---|---|---|
| 0 | 0000 | 11110 | 8 | 1000 | 01110 | IDLE | 11111 |
| 1 | 0001 | 01001 | 9 | 10001 | 01111 | J | 11000 |
| 2 | 0010 | 10100 | A | 1010 | 10010 | K | 10001 |
| 3 | 0011 | 10101 | B | 1011 | 10111 | T | 01101 |
| 4 | 0100 | 01010 | C | 1100 | 11010 | R | 00111 |
| 5 | 0101 | 01011 | D | 1101 | 11011 | S | 11001 |
| 6 | 0110 | 01110 | E | 1110 | 11100 | QUIET | 00000 |
| 7 | 0111 | 01111 | F | 1111 | 11101 | HALT | 00100 |
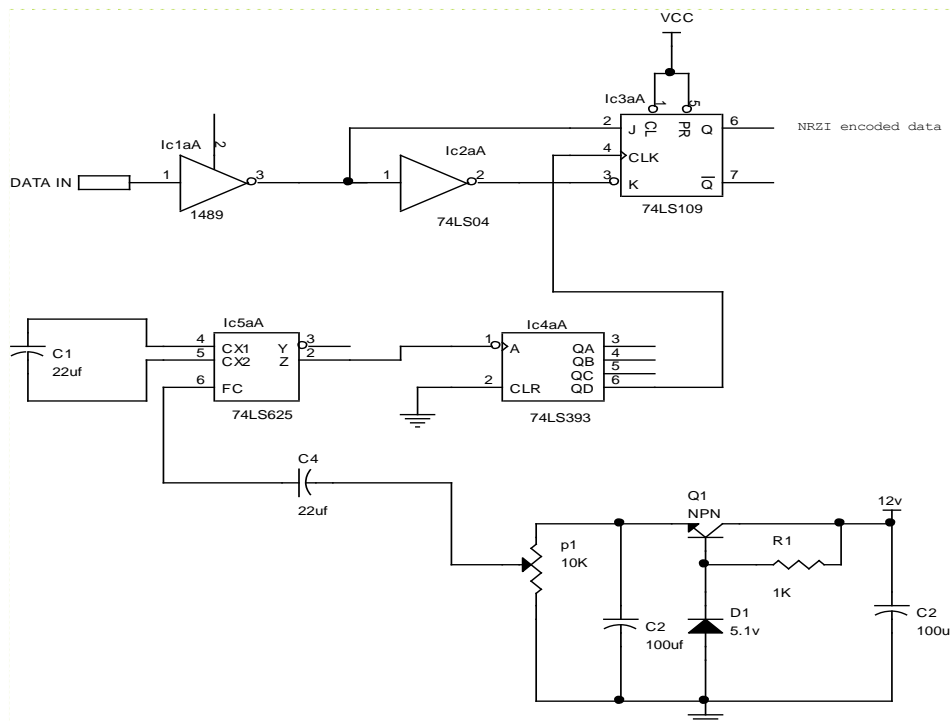


**Fig. (5)** Circuit diagram of the nonreturn to zero inversion modulation.
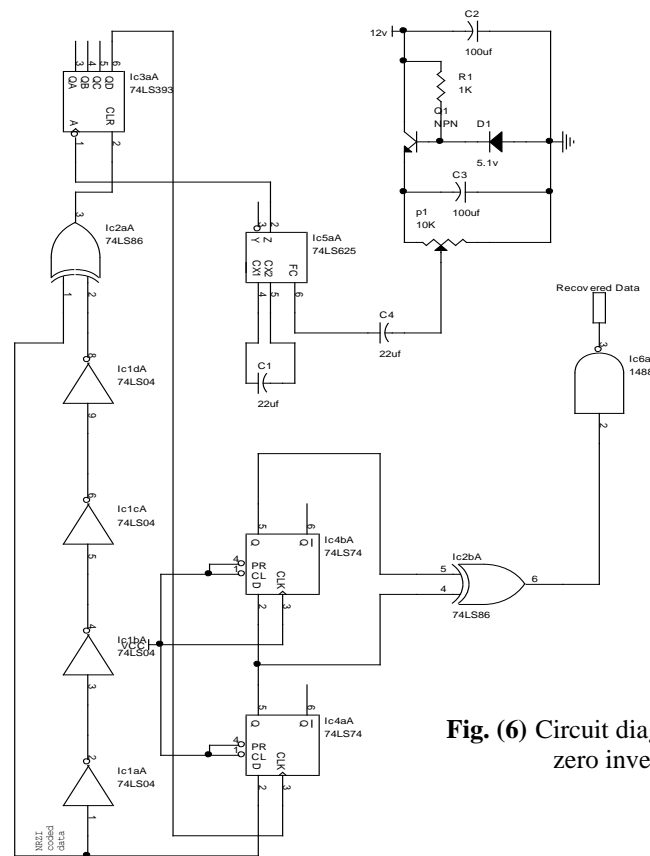
**Fig. (6)** Circuit diagram of the nonreturn to zero inversion decoder.

## 2. Physical Medium Dependent (PMD)

This defines the characteristics of the transmission medium, including the fiber-optic link, power levels, bit error rates, optical components, and connectors. The specifications of each of the parts of the PDM sublayer are:

I- The optical transmitter uses a laser diode of type CQL70A as an optical source. The laser diode emits radiation at 820 nm, which is modulated using direct intensity modulation (DIM).

II- The optical receiver of HFBR-2404 type which uses a PIN diode as an optical detector with a peak response at 820 nm.

III- The optical fiber cables used are 50/125 $\mu$m multimode fiber with attenuation factor of 3 dB/km and 400 MHz.km bandwidth at 850nm wavelength.

IV- The connectors used are SMA types with attenuation factor of 3 dB.

The laser transmitter consists of two sections, the prebiasing section and the driving section, which are shown in Fig. (7). The complete circuit diagram of the optical receiver is shown in Fig. (8).

## 3. Medium Access Control (MAC) Sublayer

MAC sublayer controls nodal access to the medium. Its functions include address recognition, removal of frame from ring (this is done by the MAC at the originating station), transmitting frames, repeating frames addressed to other stations, and removing and inserting tokens. Each station is allowed to transmit one waiting frame once it captures the token frame at once. Then, it releases a new token into the ring as it finishes the transmission of the frame status of the frame. The frame length is 1000 byte. Fig. (9) indicates the frame formats for the proposed protocol.

## 4. Station Management (SMT) Sublayer

The Station Management (SMT) Sublayer is used to communicate between stations to maintain and monitor the ring by collecting statistics detecting, isolating and solving faults. The SMT protocol handles the management of the FDDI's ring, which includes adjacent neighbor indication, fault detection and reconfiguration, insertion and deletion from the ring, traffic statistics monitoring and results and discussion.
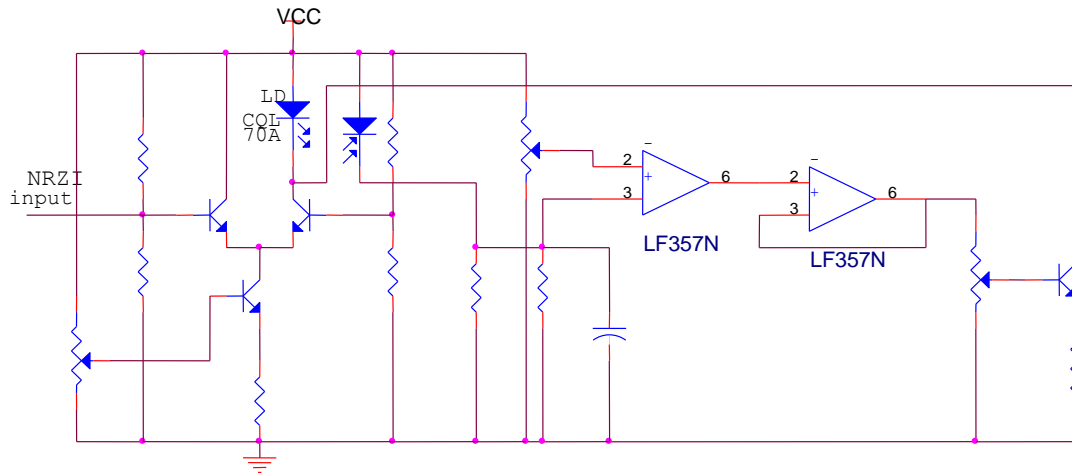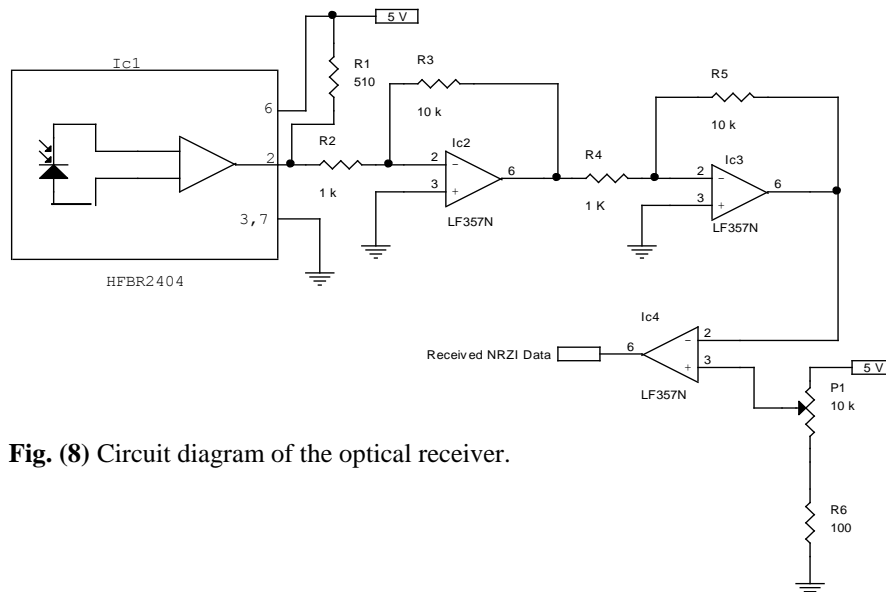
**Fig. (7)** Circuit diagram of the laser transmitter

**Fig. (8)** Circuit diagram of the optical receiver.

| Preamble | Starting delimiter | Frame control | Destination address | Source address | Info | Frame check sequence | Ending delimiter | Frame status |
|----------|--------------------|---------------|---------------------|----------------|------|----------------------|------------------|--------------|
| bytes 8 | 1 | 1 | 6 | 6 | 0 - 4478 | 4 | 1 | 1 |

**a**

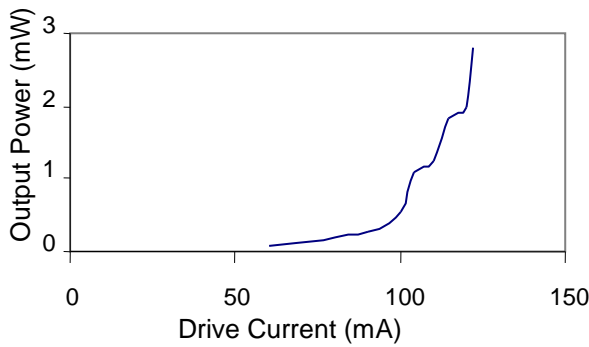| Preamble | Starting delimiter | Frame control | Ending delimiter |
|----------|--------------------|---------------|------------------|
| 16 x 1 symbols | JK | | TT |

**b**

**Fig. (9)** FDDI frame format of (a) FDDI frame，(b) Token frame．

## Results and Discussion

The output power emitted from the laser diode limits the maximum distance of the link, while the spectral width of the diode laser limits the rate of transmission since it affects the dispersion caused as the optical signal travels through the fiber. The wavelength of the emitted radiation affects both the maximum distances of the link and dispersion caused by the fiber. The drive current supplied to the laser diode and temperature variation affect these characteristics.

The output optical power as a function of the input current of the laser diode is plotted in Fig. (10). From this figure, three features can be noted. First, the curve has two distinct regions around threshold current which is 70 mA. At this current, the output power was 0.1 mW. Below threshold current the laser emits a very weak and incoherent light. The second feature is the steep gradient above threshold, which makes the device very fast. This feature is utilized in high-speed digital communication systems. The last feature is the nonlinear behavior of the device above the threshold. This nonlinearly is called kinks. These kinks result from the inhomogeneties in the active region of the device.

current is increased. Thus, the peak wavelength is shifted consequently toward longer wavelengths. This is due to increasing in the junction temperature, which reforms the energy levels of the materials forming the junction. From the budget calculations, it was found that the maximum length of the optical fiber is 4.73 km.
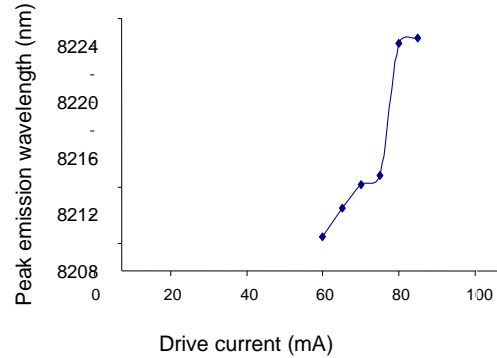


**Fig. (11)** Changes of peak emission wavelength against drive current

The performance of the network system was investigated. Delay is usually measured as the typical time taken to transmit a packet between two nodes on the network [4]. Fig. (12) shows the behavior of this delay as a function of the length of information.





**Fig. (10)** The output optical power against input current of the CQL-70A laser diode.

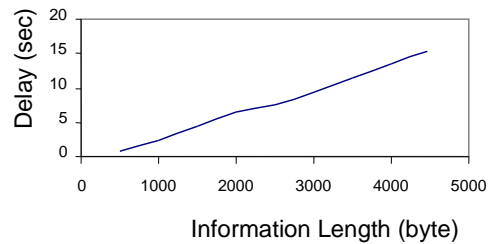**Fig. (12)** Delay measurement for bit rate of 19.2 kbps.

From the point of view of optical system design it is important to know the peak wavelength and spectral width over the range of likely operating conditions. The output spectrum of the semiconductor laser is a function of output power, temperature, and modulation conditions. From Fig. (11), it is noted that the output spectrum of the laser diode is shifted toward longer wavelengths as the driving

## Conclusions

It can be concluded that the drive current supplied to the laser diode specifies the power of the emitted radiation, operating wavelength, and the spectral width of the emitted radiation. The separation distance between successive stations in the ring increases largely as compared to that obtained with the twisted pair cable. The

maximum distance obtained in this work was 4.73 km without the need to use repeater in between. It is preferred to transmit the information as large as possible to increase efficiency of the system. There must be a trade off between the required efficiency and the maximum access delay to obtain good performance characteristics. The use of 4B/5B encoding with nonreturn to zero inversion (NRZ) modulation ensures that a signal transition every 3 bits. This transition is important for the clock recovery at the receiver.

## References

1- H.B. Killen., "Fiber Optic Communications", Prentice-Hall, Singapore (1991)
2- G. Keiser, "Optical Fiber Communication", 3 rd ed., McGraw Hill, Singapore (2000).
3- W.E. Burr, *The FFDI Optical Data Link*, IEEE Communication Magazine 24, 18 (1985).
4- F. E. Ross, *FDDI a Tutorial*, IEEE Communication Magazine 24, 10 (1985).

تصميم وتنفيذ شبكة حلقية باستعمال موائمة ليف بيانات موزعة (FDDI)

سركوت نامق عبد الله [1]       حسين علي جواد [2]       و       حسام عبد الدائم [1]

(1) قسم هندسة الالكترونيك والاتصالات /كلية الهندسة /جامعة بغداد

(2) معهد الليزر والبلازما للدراسات العليا /جامعة بغداد

**الخ**       **أستخدم الليزر الثنائي في تقنيات شبكات المسافات الطويلة والسرع العالية وهي تقانة موائمة توزيعات بيانية بأستخدام الألياف البصرية (FDDI). يستعمل الليف البصري في هذه التقانة كوسط إرسال وهذا يحل المشكلة الناتجة عن التداخل الكهرومغناطيسي (EMI) والضوضاء بالإضافة الى أنه يزيد من أمنية الأرسال. تم تصميم وبناء شبكة حلقية مؤلفة من ثلاث محطات، كل محطة في الحلقة المقترحة تتألف من أربع طبقات هي طبقة البرتوكول الفيزيائية الفرعية (PHY) وطبقة تبعية الوسط الفيزيائي الفرعية (PDM) وطبقة السيطرة على الوصول الى الوسط الفرعية (MAC) وطبقة إدارة المحطة (SMT). نفذت محاكاة لطبقة السيطرة على الوصول الى الوسط الفرعية وطبقة إدارة المحطة. أستخدم بروتوكول الرمز المؤقت لتحقيق عملية الأتصال والسيطرة ثم تنفيذ دائرة تضمين اللارجوع للصفر المعكوسة (NRZI) كجزء من متطلبات الطبقة الفيزيائية الفرعية. تم تصميم وبناء الطبقة PDM الفرعية التي تشتمل على النظام البصري. يستعمل في هذا النظام الليزر الثنائي A 70 QL C بطول موجي 820 نانومتر وقدرة خرج عظمى 2.5 ملي واط كمصدر ضوئي أما الليف البصري فهو من النوع متعدد الأنماط وكان الكاشف البصري من نوع الدايود الضوئي PIN ذو استجابة عظمى عند الطول الموجي 820 نانومتر. بلغت المسافة العظمى بين المحطات 4.5 كم. أن النظام المقترح يعمل بشكل صحيح ومن خلال فحوصات الأنجاز أستنتج ان أقصى مدخل throughput وأقصى زمن لتأخير الوصول access delay يتناسبان طردياً مع طول المعلومات المرسلة. كما تبين أن هنالك حاجة لعمل موازنة بين طول المعلومات المرسلة وأقصى زمن لتأخير الوصول .**