Communication with Optical Fiber Link

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This Project submitted in partial fulfilment of the Requirement for the Degree of
Bachelors of Science in B.Sc. in Information and Communications Engineering

To the

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Acceptance

This research report presented to the department of Electronics and Communications Engineering, East West University submitted to partial fulfilment to the requirement for the degree of B.Sc. in Information and Communications Engineering under complete supervision of the undersigned.

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Declaration

We hereby declare that this research project report is an original piece of work carried out by us, under the guidance and supervision of Dr. Mohammed Moseeur Rahman. This report is the requirement for the successive completion of B.Sc. Information and Communications Engineering under the department of Electronics and Communications Engineering.

We state that the report along with its literature that has been demonstrated in this report, is our own work with the masterly guidance and fulfil assistance of our supervisor for the finalization of our report successfully.

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Abstract

Optical fiber communication is one of the most important communication methods in today's world. Almost all of the communication systems are either made of optical fiber system or they are built on the optical fiber systems. Even the intercontinental communication is also based on optical submarine cables. As such it is very important to know about this communication system. In this thesis we have discussed on the key aspects of the optical fiber communication system. This thesis gives an overview of fiber optic communication systems including their key technologies, also discusses their technological trend towards the next generation and also discusses on their implementations. We have tried to discuss the important hardware used in optical fiber communication in details and also about different mechanisms related with it. Moreover, different techniques of processing signals related to optical fiber communication were also discussed. We have also talked about the development of optical fiber communications in Bangladesh and the future development of optical fiber communication system itself. Lastly, we discussed about a hardware project related to this communication system to give the reader a basic understanding of optical fiber communication system.

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1 Introduction

An optical fiber is a thin, flexible, transparent and pure glass fiber that transmits light by multiple internal refection over long distances with minimum loss and the light carries the data. German physicist Manfred Börner demonstrated the first working fiber-optical data transmission system in Telefunken Research Labs in 1965. We live in an era of communication technology. So, day by day use of optical communication is growing rapidly. Optical fiber is a revolutionary transmission medium. It is able to connect the world and make people close to each other in a much more efficient way. It has enabled communication between us on earth to be established within seconds. Everyone is connected across the globe after the invention of fiber optics. This technology soon spread across the world. Fiber Optics line are run from town to town and city to city on land but when it comes to crossing the ocean a special cable is needed. Then connectivity just brings us very close together. Hopefully optical fiber will continue to be a force to change the world for many years to come. Optical fiber is additionally utilized widely for transmission of information signals by huge organizations, banks, colleges, and others private systems. These organizations need security to transfer information around the globe. The security intrinsic in optical fiber frameworks is a significant advantage. In the development of high quality and high-speed telecommunication systems, optical fiber communication plays a vital role. Optical fiber is strong, flexible and reliable inch for inch and stronger than steel and more durable than copper. Fiber offers excellent signal performance over a wide range of environmental conditions since fiber carries light instead of electricity. Optical fiber reduces maintenance cost and has a proven record of reliability in the field. Optical fiber is cost effective durable and scalable, has low attenuation and it features the superior transmission quality needed for high speed transmission of voice data and video in today’s leading applications. Optical fiber is utilized by numerous broadcast communications organizations to transmit phone signals, Internet communication, and TV signals. Specialists at Bell Labs have arrived at internet speed of more than 100 petabit × kilometer every second utilizing fiber-optic communication. After 1975, the first optical fiber communications system was improved that executed around 0.8 μm wavelength with utilizing GaAs semiconductor lasers. At the beginning system operated in bit rate of 45 Mbit/s with repeater spacing of up to 10 km [1].

As we all are aware today the bandwidth demand has increased exponentially going to many multimedia driven internet traffic. We all use smartphones, we all want data on the go, we watch movies on smartphones we watch videos on you tube, we share large sized data files within flow one pace to another place. Have we ever wondered what drives all this internet traffic and many other types of high-speed data communications? We would see that underlying all this data communication network is an optical fiber network that data is carried through optical fibers in an appropriately modulated form of light. The development of the network based on the optical fiber was actually pioneered in the 1960. The first optical fibers which were for use came in the late 1960s where the data rates were just a few kilobits per second. The first telephone cable that use optical fiber was TAT-8 which was activated in 1988 [2]._However today the data rates have reached about 100 gigabits per second which is the latest internet standard. And the data rate is continuously increasing and is expected to reach about one terabyte per second per channel. It is necessary because of the large demand in the traffic. The physical infrastructure of an optical fiber consists of large amount of fiber of thousands and thousands of kilometers in length linking all over the world, one continent to another continent, one country to another country and within country within cities everywhere we have seen optical fiber laid out.

Optical fiber carries information in the form of light. The fiber optics are utilized for transmission of information from point to point area. Fiber optics is a significant structure in the media transmission framework. Its high transfer speed capacities and low attenuation attributes make it perfect for gigabit transmission.

Since its creation in the mid-1970s, the utilization of and interest for optical fiber have developed hugely. The employments of optical fiber today are very various. Today is the era of information technology. Without optical fiber we cannot think the infrastructure of telecommunication. This infrastructure needed for worldwide broadband networks. Optical fiber has a low loss of signal strength and therefore enables long distance transmission and has very large bandwidth and therefore enables high data rate communication. Quality of the optical fiber network is characterized by many performance parameters. In order to build the network, we need support infrastructure like Routers, wavelength converters, filters, multiplexers, couplers to couple light from one channel to another channel. The most important thing is to put this infrastructure into use by actually modulating light with the data to transmit and understanding what sequence of operations are necessary at the receiver to recover the original data back. So that the data that recorded originally actually matches with the originally transmitted data. Optical fiber which is used in most long-distance communication, barely has a dimension of a human hair yet. It can carry terabytes per second of data aggregate data would be even higher in that small dimension. By utilizing WDM (wavelength division multiplexing) the transmission limit can be improved.

The optical fiber communication industry is an ever advancing one that is produce huge number of optical fibers. Still the researchers research on optical fiber communication how to improve more. In telecommunication sector optical fiber plays a vital role. A superior optical fiber communication base can possibly make a nation work more intelligently. Now Fiber optic communication framework has developed as the most significant communication system. In recent years the optical fiber industry has grown tremendously. Experts expect that this industry will keep on growing at a large rate into the following decade. Optical fiber communication is not very expensive as before. All the major communications within the countries are carried by optical fiber. The demand for optical fiber communication will continue to grow an exponential rate and it's important for us to know about this communication system.

2 Construction, Working Principle and Technical Aspects

A single optical fiber consists of three layers namely core, cladding and buffer coating. Core is the thin glass center of the fiber through which the light travels. Cladding is the outer optical material surrounding the core that reflects the light back into the core. Buffer coating is the plastic coating that protects the fiber from moisture and any kind of external damage. It also prevents light from escaping the strand and may have a color coating for identification purposes. The bundles are protected by the cable’s outer covering a jacket.

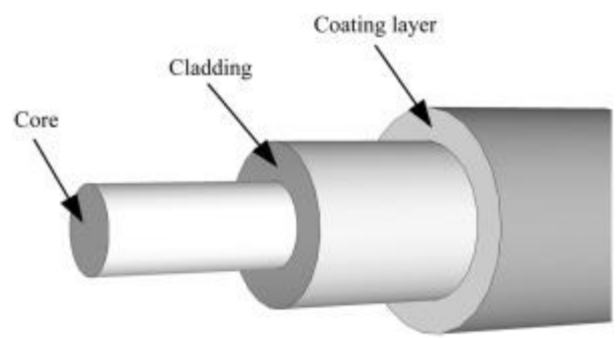


Figure: Optical Fiber

Fiber optic strands are typically bundled into a cable. These strands can be grouped as either tight or loose buffered cables. Both types of cables contain some type of strengthening member such as aramid yarn stainless steel wire strands or gel filled sleeves. They are however designed for different environments. A tight buffered cable consists of one or more bundled fiber strands covered by an outer jacket. Often the outer jacket contains multiple layers to add structure to the cable and provide water resistance. In loose buffer cables the fiber strands are contained within buffer tubes allowing the strands to move freely. While also providing additional protection for the strands.

Figure: Loose and Tight buffer cable

The addition of buffer tubes and other protective layers causes the cable diameter to be larger and the cables to be less flexible. It also means that tight buffer cables are more easily damaged than loose buffer cables. These factors make tight buffer cables more appropriate for indoor use and loose buffer cables primarily for outdoor use. Fiber cable that is used outdoor is normally filled with a waterproof gel. The buffer tubes may also contain this gel as well as a water blocking coating between the inner and outer jackets. Both inner and outer jackets are made of materials designed to resist corrosion and add greater protection to the cable. Some cables also have a metallic armored coating for strength and protect against rodents.

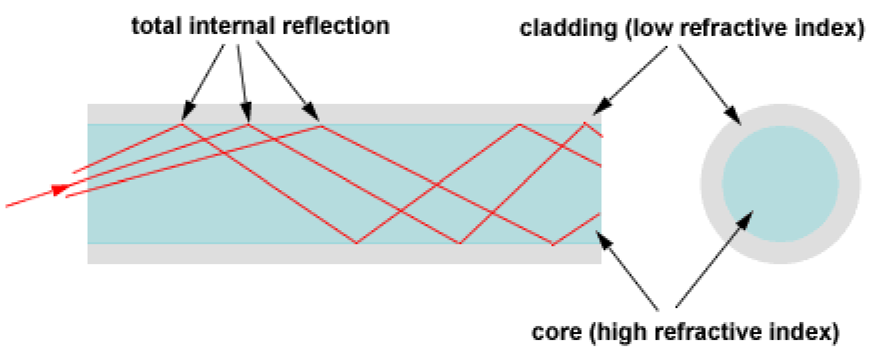


Figure: Total internal Reflection

Total Internal reflection is used in optical fiber cables to transmit the light. The simplest form of optical fiber cable is cylindrical glass with a high refractive index. If the laser strikes the interface at an angle greater than the critical angle, total internal reflection will happen and the light will reach the other end due to a series of multiple total reflections. This means light can be confined in the optical fiber over a long distance. Total internal reflection happens between the high refractive index glass and low refractive index air. Optical fibers need a protective coating. A protective coating is not possible with this configuration. The introduction of protective material will replace the position of the air and cease the total internal reflection phenomena. An easy way to overcome this issue is to introduce a low refractive index glass above the core glass known as cladding. This way total internal reflection will happen and we will be able to use a protective layer. Optical fiber constructed won't be able to carry signals for more than 100 kilometers. This is due to various losses that happen in the cable. This loss of signal strength is generally called attenuation. Absorption and scattering are the main reasons for signal attenuation.

Any information can be represented in the form of zeros and ones. First the information will be converted into an equivalent binary code as a sequence of zeros and ones. After the conversion mobile phone will transmit these zeros and ones in the form of electromagnetic waves. One is transmitted as a high frequency and zero as low frequency wave. The local cell tower picks up these electromagnetic waves. At the tower if the electromagnetic wave is of high frequency. A light pulse is generated otherwise no pulse is generated. These light pulses an easily be transmitted through optical fiber cables. The light pulses which carry the information have to travel through a complicated network of cables to reach their destination. For this purpose, the entire globe is covered with optical fiber cables. These cables are laid under the ground and below the ocean. It is mainly the government organizations that maintain these underground cables. AT & T orange and Verizon are some of the few global players who own and maintain the submarine cable network.

A detailed cross section view of an undersea cable that only a small portion of the cable is used for holding the optical fiber. The remaining area of the cable is a mechanical structure for protection and strength. A thin copper shell is used inside the cable which carries electric power along the cable. So that the amplifiers can be powered. If optical fiber cables do not reach a part of the globe that part will be isolated from the internet or mobile communications on an international level or even if connected the data speed will not be high and the structure will not be cost effective. The optical fiber cable is superior in almost every way. Fiber optic cables provide larger bandwidth and transmit data at much higher speeds. The light which travels through the optical cable is always confined within the fiber. Thus, the chance of interaction with an external does not exist. Any light signal which enters from the side has a minimal chance of travelling along the cable. These two factors ensure that data is not corrupted during transmission.

2.1 Types of Optical Fiber

There are two different types of fiber single mode and multimode single. Single mode fiber has a small core diameter designed to carry light in a single path over long distances. It has high information carrying capacity and low attenuation and is the most widely deployed optical fiber in the world. Multimode fiber has a larger core which allows light to travel down many paths simultaneously. Typically, multimode fiber is deployed in data centers local area networks and storage area networks where it is more cost effective than single mode fiber. Corning invented the first low loss fiber in 1970 and has continued to deliver significant performance improvements for the past 40 years through continuous innovation. Three key attributes that can limit the speed or information carrying capacity of the optical fiber are attenuation, dispersion and bend induced loss in the form of macro bending and micro bending performance. Attenuation refers to signal loss along the length of the fiber. In this illustration the light gets dimmer as it travels down the fiber. It can be caused by the quality of the glass itself or can be induced by bending. Dispersion is the distortion of a signal along the fiber length. This occurs because different spectral components of the optical signal in the optical fiber travel at different speeds.

Two additional characteristics of single mode fiber that are important are cutoff wavelength and mode field diameter. Cutoff wavelength is the wavelength above which a fiber will support only a single mode. Wavelengths below the cutoff support two or more modes. The cutoff wavelength is determined by the fiber's refractive index profile. The length and bend fiber as well as the cabling process and deployment conditions encountered during use. In a single mode fiber, some of the optical power is actually guided outside the core. The mode field diameter defines the size of the optical power distribution in the fiber.

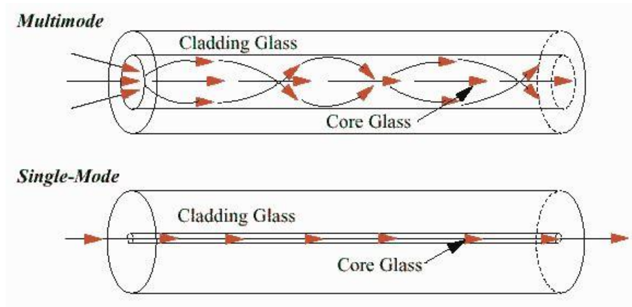


Figure: Single and multi-mode cable

Multimode fiber has two important characteristics numerical aperture and core size. Numerical aperture is the measure of the angular range of acceptance of light into a fiber. The angle over which a fiber accepts light depends on the refractive indexes of the core and cladding glass. Core diameter is a fundamental design parameter of multimode optical fiber. The larger the core the more modes of light can propagate through the fiber. Multimode fiber has a much larger core size than single mode fiber.

Sr No.	Fiber type	Cladding diameter (μm)	Core diameter (μm)	Δ	Applications
1	Single mode (8/125)	125	8	0.1% to 0.2%	1.Long distance 2.High data rate
2	Multimode (50/125)	125	50	1% to 2%	1.Short distance 2.Low data rate
3	Multimode (62.5/125)	125	62.5	1% to 2%	LAN
4	Multimode (100/140)	140	100	1% to 2%	LAN

Table of standard fibers [3]

Based on the refractive there are 2 types of fiber step index and graded index fiber discussed in later section.

2.2 Step index fiber

In the step index fiber, the refractive index of the core is uniform and there is a sharp decrease in the index of refraction at the cladding. Step index fiber is two types one is mono mode fiber and another is multi-mode fiber. The fiber has lower transmission capacity. The data transfer capacity is around 50 MHz km for multimode step index fiber though it is in excess of 100 MHz km if there should arise an occurrence of single mode step index fiber. Inside the core the light beam is propagating in zigzag manner. It is basically used in small distance communication and more affordable.

For step index fiber, no of mode of propagation:

$$Nstep = 4.9\left(\frac{d \times NA}{\lambda}\right)^2 = \frac{V^2}{2}$$

Where, d= diameter of the fiber core

λ= wavelength

NA= Numerical Aperture

V=V-number is less than or equal to 2.405 for single mode fibers and greater than 2.405 for multimode fibers

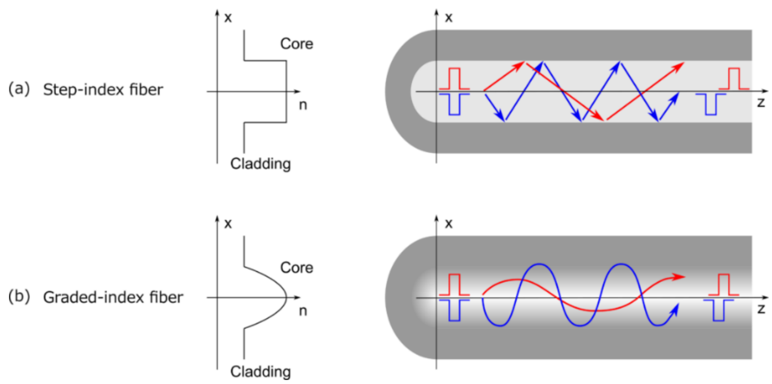


Figure: Step & Graded index fiber

2.3 Graded index fiber

Graded index fiber is a type of fiber where the refractive index of the core is maximum at the center of the core. Only multimode fibers can be graded index fiber. Index profiles is in the shape of a parabolic curve. The light rays propagate in the form of helical rays. It has lower coupling efficiency. Numerical aperture changes continuously with distance from fiber axis. Pulse spreading is less. It is widely used in local and wide area networks and long-distance communication. This fiber has higher bandwidth. The diameter of the core is about 50µm (multimode fiber). Graded index fiber has less dispersion than multimode step index fiber and index of fraction is not constant in core

This fiber is highly expensive and attenuation of light from 0.6 to 1 dB/km at 1.3 µm.

For graded index fiber, no of mode of propagation:

$$\text{Ngraded} = \frac{4.9\left(\frac{d \times NA}{\lambda}\right)^2}{2} = \frac{V^2}{4}$$

Or, Ngraded = $\frac{Nstep}{2}$

Where, d= diameter of the fiber core

λ= wavelength

NA= Numerical Aperture

V=V-number is less than or equal to 2.405 for single mode fibers and greater than 2.405 for multimode fibers.

3 Losses in optical fiber

Loss in a system can be expressed as,

Loss = Pout / Pin

Where, Pin = input power to the fiber

Pout = power available at the output of the fiber

Fiber optic loss is generally expressed in terms of decibels (dB) and can be calculated by using the following equations

Loss_{dB} = 10 log (Pout / Pin)

When the light energy is transmitted inside the optical fiber a small percentage of light energy maybe lost due to different mechanism. The losses in optical fibers is measured in decibels or dB/km for attenuation. Attenuation is defined has the sum of all loses. [4].

This Attenuation plays an important role in determining the transmittance distance in the optical fiber. The Attenuation mechanism are considered in designing the optical fiber. Three mechanisms are considered while manufacturing or designing the optical fiber.

1.Absorption

2.Scattering

3.Radiative Loss

Absorption: Absorption takes place in the optical fiber due to presence of defects in the optical fiber. These defects may be missing of atoms or missing of hydroxyl group or due to high energy cluster of atoms. Some parts of the light energy are absorbed by the defects. Absorption depends on the wavelength of the light energy.

Scattering: Scattering is also wavelength dependent. The closure the wavelength of the light to the size of particle, greater will be the scattering. A decrease in wavelength naturally leads to more scattering. Since glass is used for manufacturing optical fibers there may be some distortion or irregular structure inside the optical fiber. The irregular structures in the optical fiber may cause a change in refractive index inside the optical fiber. This will lead to scattering of the light pulse called Rayleigh Scattering.

Radiative Loss: The radiative loss occurs in optical fiber due to presence of bending in the optical fiber.

The bending is classified into two different types that is

(a) Macroscopic bending: It occurs when radius of the core is larger compare to the diameter of the optical fiber. So, when the optical fiber is turn or bend curvature is more.

(*b) Microscopic bending:* Microscopic bending occurs when there may be small disturbance or distortion inside the cable. This bending present inside the core of the material which cannot be seen by naked eye. This type of microscopic bending occurs during the manufacturing of optical fiber or during the cabling of optical fibers and when there is no uniform pressure apply on the cable.

4 Connectors in Optical Fibers

Connector offers mechanical means to connect optical cables to other fibers and active devices. The main requirement of the connector is that the end of the fiber is held accurately in place so that the maximum light transfer occurs. In general fiber optic connector referred to a male connector.

Connector are used to join optical source as well as detectors with optical fiber. Similarly, connectors are also used to join two fibers. The main criteria about the connector is that the connector should be aligned properly in order to reduce losses. The separable connectors are used to join the optical fibers. Hence the caution should be taken that two fiber optic ends should not be joined and vibration that may be taking place in one optical fiber should not be transferred to another fiber.

4.1 Requirements of connectors:

1.The connector should have low coupling loss.

2.The design of connector should be such that the repeated connection and disconnection is possible without affecting the fiber alignment.

3.It should not be affected by environmental factors

4.Ease of connection

5.It should protect fiber ends

6.It should provide the strength to the joint

7.There are basically two major types of connectors

8. Ferrule type connectors

Optical connectors are usually used in telephone exchange, cross connect cables and various systems.

4.2 Types of connector in optical fiber

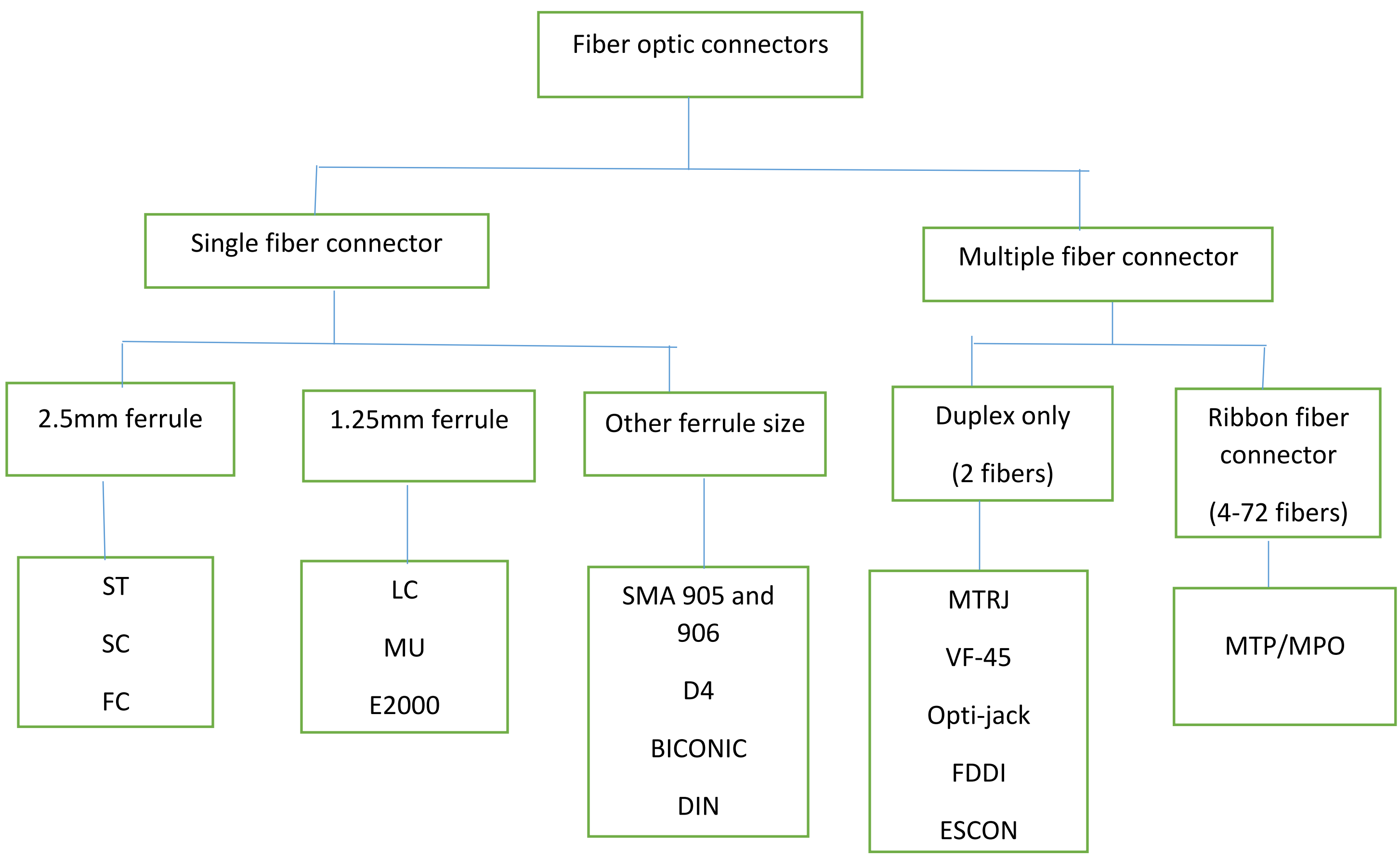


Figure: Different types of connector [5]

There are many different types of fiber connectors on the market. Some of legacy connectors can be traced back to the 1980s. Some other newer ones who are recently directly in the 1990s. Fiber connectors are typically categorized as single fiber connector and multiple fiber connector. Single fiber connectors hold only one fiber and multiple fiber connectors can hold up to 2 to 72 fibers.

Single fiber connector can be further categorized by the size of their ferrule. The most common ones are the 2.5 mm ferrule connector and the 1.25 mm ferrule connector. There is some other ferrule size available also which mostly are legacy obsolete.

A single fiber connector which has 2.5mm ferrule. The ST connector has a bayonet coupling mechanism. It has a 2.5mm ferrule. It is available in simplex water only. ST connector is an available in a single mode and multimode fiber.

The most common types of connectors on the market are SC and LC connectors. Measurements and techniques for mechanical coupling are the main differences among types of connectors.

Figure: Different types of connectors

SC connector has a push-pull coupling. It also has a 2.5mm ferrule. SC connectors are available in simplex which has one single fiber and duplex. Both simplex and duplex SC connectors are available in single mode and multimode fibers.

The other major type is FC connector. FC connectors has a screw locking mechanism and 2.5mm ferrule. FC connectors are available in simplex only. The simplex FC connectors are available in single mode and the multi-mode.

The next major type single fiber connector has 1.25mm ferrule. The most common one is LC connector. LC was developed by Lucent. It has a snap coupling mechanism. 1.25 mm ferrule LC connectors are available in both simplex which holds one fiber and duplex which holds two fibers version. Both types as single mode fiber and multimode fiber version is available [6].

The next leader type is MU connector. MU connector looks like a miniature SC connector. MU connector is also available in simplex single fiber and duplex two fiber portions. Both simplex and duplex also has a single mode and multimode fibers are available.

Another major type is called E2000.

E2000 is also called LX5 connector. It looks like a LC connector with a shutter over the end of the fiber. E2000 connectors are also available in simplex single fiber and duplex two fibers portions. Each type has single mode and multimode fiber versions available.

There are some legacy single fiber connectors available too. Most common of SMA connectors as are many connectors were developed by ethanol. SMA strands for subminiature version. It has a 3.14 mm ferrule. SMA connectors Commonly used in medical and industrial applications.

Some other connectors including D4, BICONIC and DIN are available in duplex fibers version only. They do not have simplex single fiber version. The MTRG connector is a small form factor duplex connector. It has both fibers in a single polymer ferrule. It is available in multimode version only. It has a snap coupling mechanism as a RC and after the next duplex only connector is called VF-45. It is also called 3M Volition connector. It is a slick duplex connector with no ferrule at all. It doesn’t use ferrules. Opti-jack is a duplex connector. Opti jack has 2.5 mm ferrule just like regular SC connectors. The size of the Opti jack is a RJ45 connector. FDDI and ESCON connectors are both duplex connectors with 2.5 mm ferrule. They are often used to connect the equipment from a wall outlet. Finally, there is one type of connector which goes from 4 to 72 fibers it is called MT connector. Commercially available as MPO and MTP connectors.

5 Elements of optical fiber transmission link

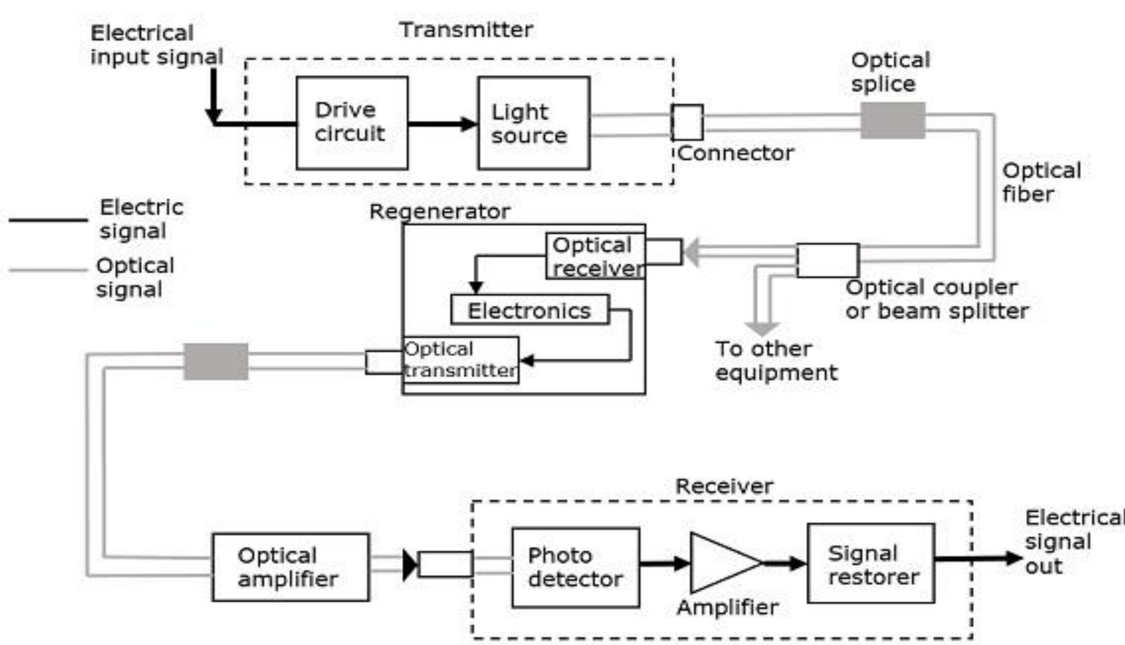


Figure: Optical fiber transmission link [7]

The three major sections of optical fiber transmission link are Transmitter, Regenerator and Receiver. There are two elements in transmitter side. One is drive circuit another is light source. Here original electrical signal is converted into light signal. And this light signal from light source is coupled into optical fiber. There are various elements presents along with the optical fiber. They are optical splices, optical coupler, beam splitter and so on.

The regenerator plays a vital role in optical communication specially in electrical to optical and optical to electrical conversion. Here light from optical fiber is converted into electrical signal by means of the electronics circuits and then amplify. Again, this electrical signal is converted into optical signal and it is transmitted to fiber. But now a days we can boost the optical signal in optical domain itself.

Then the last part is Receiver. Here converts optical signal into electrical signal by means of photo detector. When light pulse falls on the photodetector which is a p-n junction device, electron-hole pair are generated and the flow of this electrons or holes leads to formation of an electrical signal.

6 Attenuation Vs Wavelength Curve

Figure below shows the relationship between attenuation and wavelength.

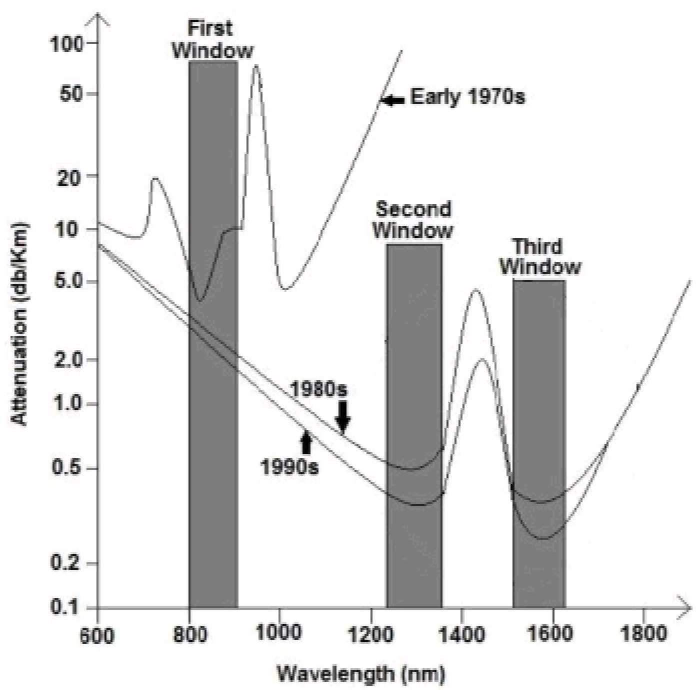


Figure: Attenuation vs Wavelength Curve [8]

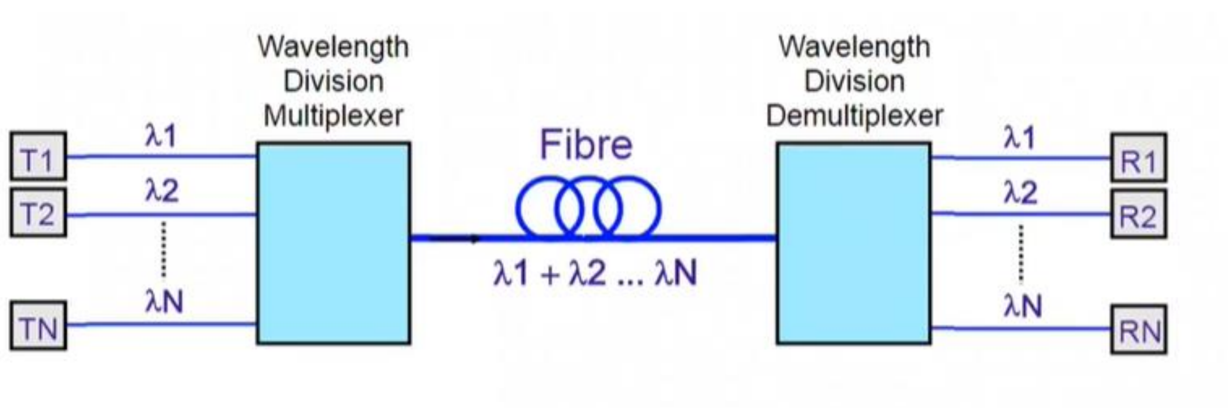
A very important property of optical fiber in optical communication is attenuation Vs wavelength curve. In optical transmission the loss depends on the wavelength. So, there is a particular wavelength where the minimum signal attenuation occurs which is known as optical window.

In early 90s people have used the wavelength range from 800nm to 900nm and be call it as first window. Then researchers have identified the presence of OH ions as the reason for attenuation in optical fiber. After sometime, in 1980s this OH ions have been removed from the optical fiber. So that the fiber became more and more pure resulting a decrease in attenuation. There are also two windows in the range from 1200nm to 1600nm which is called second window and third window. That attenuation is less when compared to first window.

7 Wavelength Division Multiplexing (WDM) Architecture

One of the main features of optical communication is to combine multiple light signals which can transmitted through a single fiber. That property or technology for combining light of different wavelengths into a single fiber is called wavelength division multiplexing (WDM). WDM is the most important and most popular method to increase the capacity of a single strands of a fiber. A good optical fiber communication system which is standardized can support up to 200 WDM channels with a spacing that goes anywhere from 50 to 100 GHz [9].

The idea was first published in 1978, and by 1980 WDM frameworks were being acknowledged in the research facility. In telecommunications companies WDM system are widely used to expand the capacity of the network. In the beginning of the WDM systems it was able to combine only two signals. But nowadays WDM system can handle 160 signals. In the past WDM systems were expensive and complicated to run. In recent WDM systems are less expensive to deploy.



There are multiple terminal T1, T2 up to TN which are assigned with different wavelength $\lambda 1$, $\lambda 2$ up to λN and are combined by multiplexer. So, this multiplexer will combine different signals with different wavelengths and transmit it to fiber. The demultiplexer at receiver side will divide this combined light signal according to their initial wavelengths and will send it to different terminals R1, R2 up to RN.

So ultimately in WDM architecture we can increase the capacity of the fiber by combining light signals of different wavelengths. So multiple signals from multiple transmitters are forwarded to multiple receivers through a fiber.

8 Point to Point Link of Optical Fiber Communication System

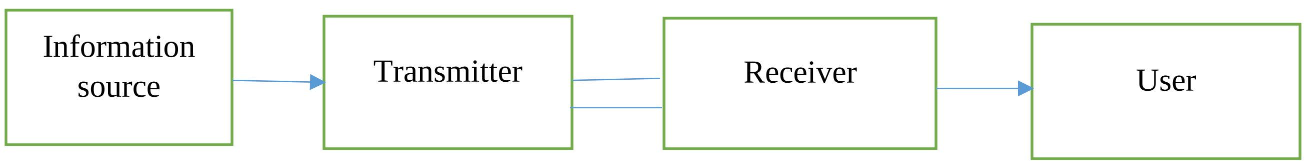


Figure: Point to Point Link of Optical Fiber Communication System

The simplest transmission link is a point to point link. It has three major components.

1. One transmitter

2. One receiver

3. One channel (two connector, fiber and splices)

Here first information source which is getting translated into electrical signal. Then transmitter is a light pulse in the optical fiber channel. Then the receiver will transform that light signal received into electrical one and the user will receive the electrical signal.

As channel is made up of optical fiber. Here channel parameters are: -

-Core size

-Numerical Aperture

-Bandwidth

-Attenuation (dB/km)

-core refractive index

In transmitter basically using source and the source will be either LED or LASER. So, based on LED or LASER transmitter parameters are: -

-Emission wavelength

-spectral line width

-Effective radiation area

-Emission pattern

So, in transmitter we need to select LED or LASER to generate light signal.

The receiver parameters are: -

-Responsivity

-Operating wavelength

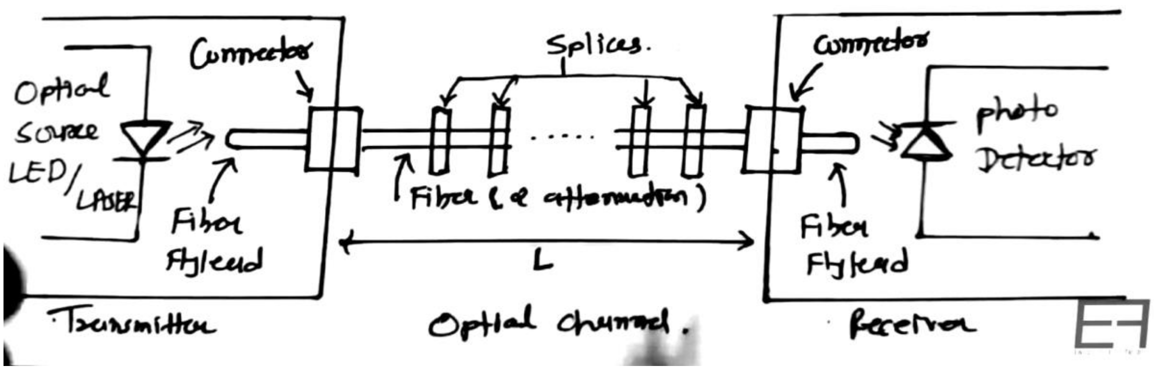
-Sensitivity

Two types of analysis done to identify system performance

1. Link power budget analysis

2. Rise time budget analysis

8.1 Point to point detail block diagram



In this diagram there are two blocks one is transmitter block the other is receiver block. And these two blocks are connected with optical channel.

Transmitter is having LED or LASER as a source that will radiate signal in terms of light from electrical signal to light signal and this light that has been captured by fly lead. This fly lead is there with the connector. At transmitter side there is one connector which is connecting the optical fiber cable to the transmitter.

In the receiving system light signal is there in this optical cable that is connected with the connector and again there is a fly lead. That fly lead gives light signal to the photo detector. This photo detector could be photo diode or it could be pin photo diode or it could be an avalanche photodiode and that will translate light signal into electrical signal.

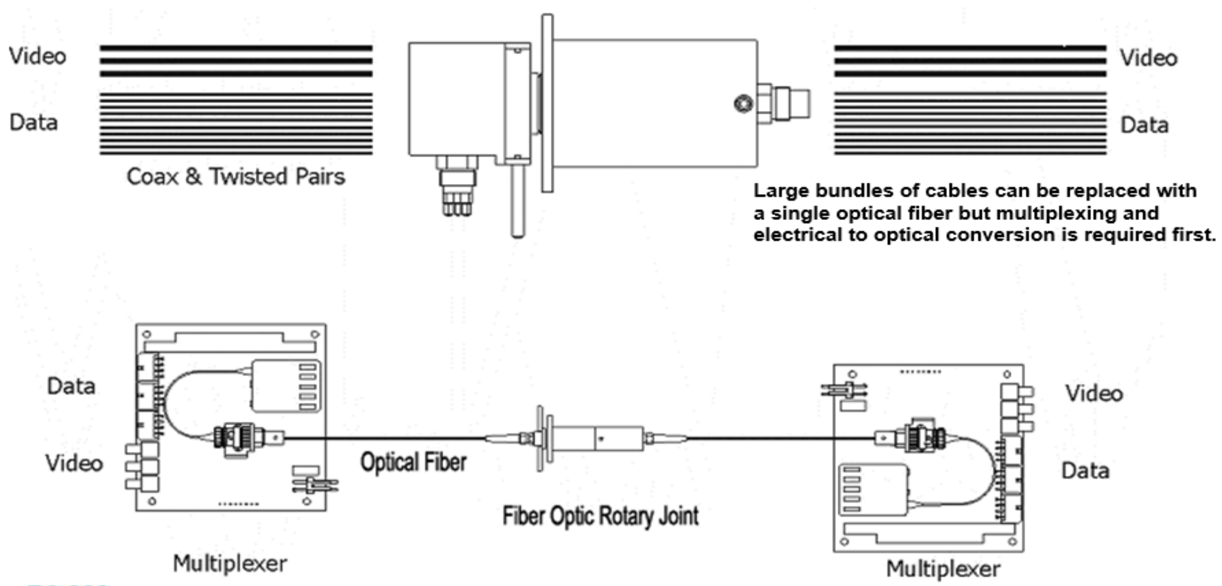
Between transmitter and receiver, the channel is optical channel. but is very difficult to have very long length of a single optical fiber as the channel length is usually in terms of kilometers. So that time connecting multiple optical fibers by using splices. Those splices are connecting multiple optical cables. Attenuation constant of the optical fiber will justify by what distance this signal can propagate along with optical fiber. So optical channel includes optical fiber and splices.

9 Multiplexing in Fiber Optics

The transmission of capacity of optical fiber are well known making it the main choice for high information and video application. So that the different kinds of multiplexing are needed to take advantage of this transmission capacity. TDM and FDM are the two commonly used multiplexing methods in this sector. As fiber is the best option for high rated transmission, low rated computerized signal can be TDM using electronic parallel to serial converter. A few low rate signals are combined into a signal high speed channel for transmission and after that reproduced or broken out at the accepting for total conclusion.

Even though the high-speed TDM gadgets are accessible for total information rates 10-40 GBS for broadcast communication application, reasonable component, fiber optic transceiver and test hardware, are as of now restricted to 2.5 GBPS.TDM can be exhausted a few stages, programable rational gadget can be utilize to combine some low-rate signal. Over operating a typical clock is required whenever the signs are abnormal. Wavelength division multiplexing is applied to transmit more than one rapid advanced information stream on a solitary optical fiber. Various wavelengths of light, for example various hues, engender in a solitary fiber without meddling as demonstrated as follows. The gadgets that do the optical consolidating and partition are alluded to as WDMs. These are latent optical gadgets that commonly utilize optical channels or gratings [10].

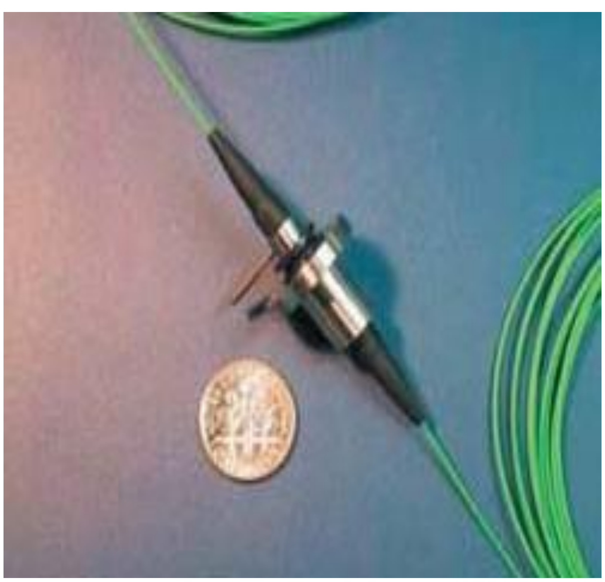
Applying a typical clock is required when the signs are offbeat. Wavelength division multiplexing is utilized to transmit more than one rapid advanced information stream on a private optical fiber. Various wavelengths of light, for example various hues, engender in a solitary fiber without meddling as demonstrated as follows. The gadgets that do the optical consolidating and partition are alluded to as WDMs. These are latent optical gadgets that commonly utilize optical channels or gratings

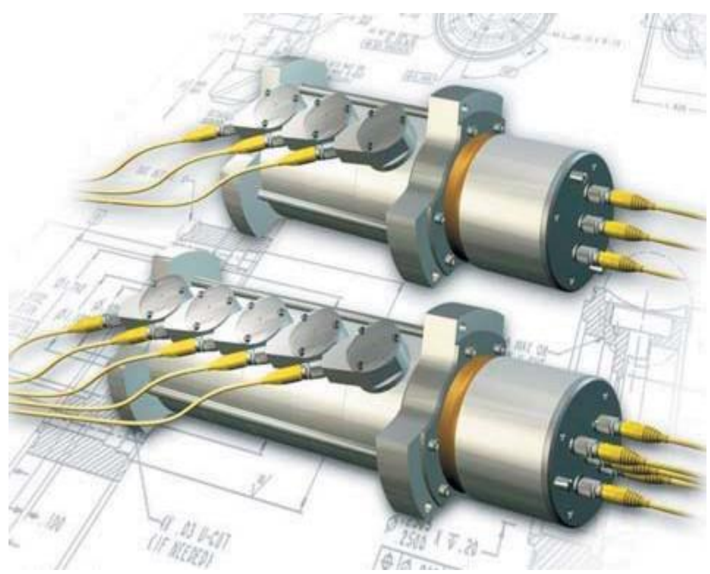


WDMs for 1310 and 1550 nm are common and regularly utilized to supply bi-directional transmission in a single fiber. These are compact (2 mm x 50 mm) cheap gadgets. Thick or DWDM utilizing accuracy channels and lasers with tight temperature control are accessible that permit 80 or more channels, i.e. wavelengths, on a single fiber with 0.4 nm dividing. Be that as it may, cost is 3 - 5 times higher.

In the past few a long time, CWDM innovation has ended up commercially accessible which gives 8 or more channels with a broader 20 nm wavelength dispersing that, coupled with a modern laser diode innovation (VCSEL), hinders the require for broad laser screening and exact temperature control coming about in more prominent taken a toll viability. Tall unwavering quality commercial handsets and WDMs of this sort are available. Coarse WDM offers 8 - 10 channels at 20 nm optical dividing in a single fiber. An include/drop CWDM module is appeared (right) that licenses a particular wavelength to be extricated or embedded from a fiber.

Moog Components Bunch moreover produces related gadgets from basic single-pass fiber optic revolving joints below left to multichannel plans just like the below right for both multimode and single-mode optical fiber. These are frequently utilized to supplant numerous circuits in electrical slip rings with a tall transmission capacity.





Now Below we will be going to briefly Discuss about the types of Multiplexing, Such as TDM, WDM and DWDM.

9.1 Optical Time-Division Multiplexing (OTDM)

Optical Time-Division Multiplexing is a very powerful optical multiplexing technique that deliveries very high capacity of data in optical fiber. Without any multiplexing optical fiber bandwidth becomes an issue because the effective usage of its maximum bandwidth is dependent on the capability of the electronics in the terminal. The commercially available electronic components are limited to around 10Gb/s data rate, thus execute a bottleneck to obtaining higher speed communication. But OTDM is a very attractive for overcoming this electronic speed bottleneck. The basic principle of this technology is to multiplex a number of low bit rate optical channels in time domain. OTDM system can be viewed as three big blocks—transmitter block, line system, and receiver block. Transmitter block is consisting of Laser sources, modulators, channel alignment systems, and multiplexer. The line system contains optical amplifiers and transmission fibers. The receiver block is made of synchronization extraction circuit and demultiplexer. Channel allocation by TDM is dependent on the electrical data rate and pulse width [11].

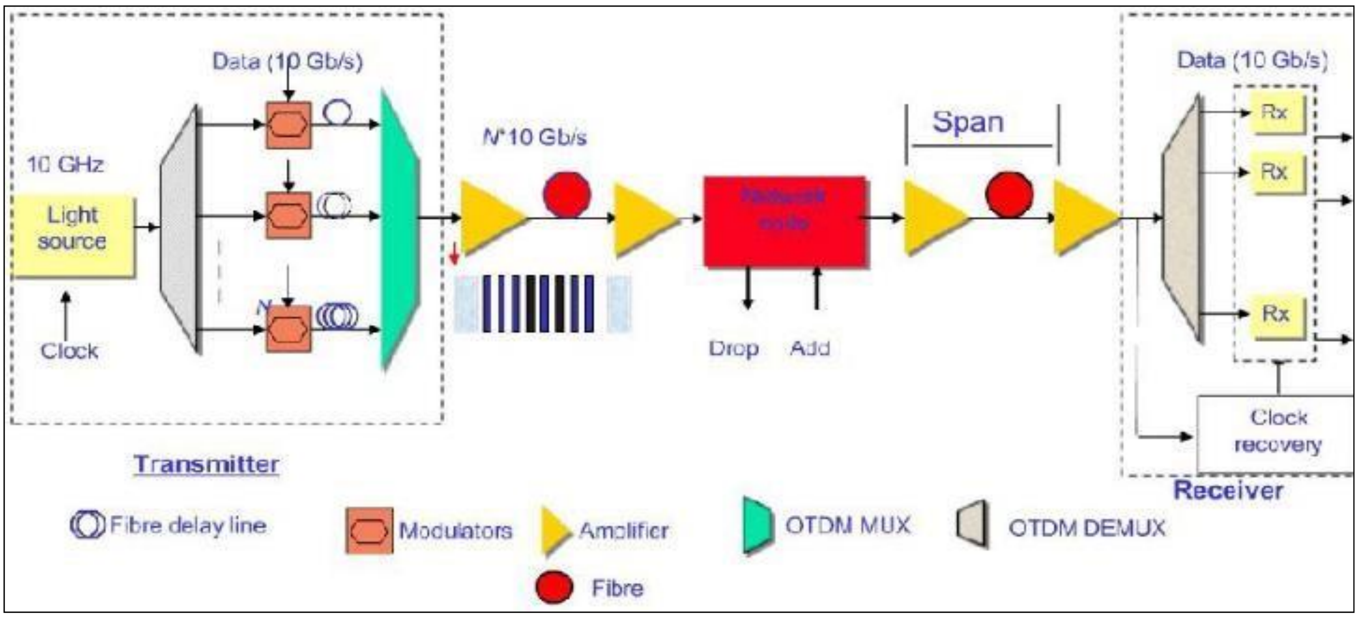
The use of transform-limited pulse and dispersion technique can reduce the dispersion effect on OTDM. Transform-limited pulse has the property to minimizes the optical spectral width for a given pulse width which can ensures the pulse broadening. Adding negative slope dispersion fiber can actually reduce the pulse broadening effect for long distance. This is dependent on the choice of dispersion and length of the dispersion which depends on the fiber fabrication technology. Polarization mode dispersion is also a main concern for distance increases over 100km.

Accurate control on the channel is also critical as transmission speed increases. Because more channels are multiplexed in a fix clock period. Mis control can affect the performance of the OTDM system. The electro-optic technique is great for transmission speed at less than 40Gb/s. It is more difficult to achieve for speed over 40Gb/s due to limitation on electrical drive power. Optical switching is based on third order nonlinear effect of the optical fiber. Although optical switch is very expensive to made. But, successful demultiplexing can only be accomplished with accurate timing extraction. The timing from the extraction circuit can directly affect the BER performance of the OTDM system.

Metrology:

The basic principle of OTDM is as follows:

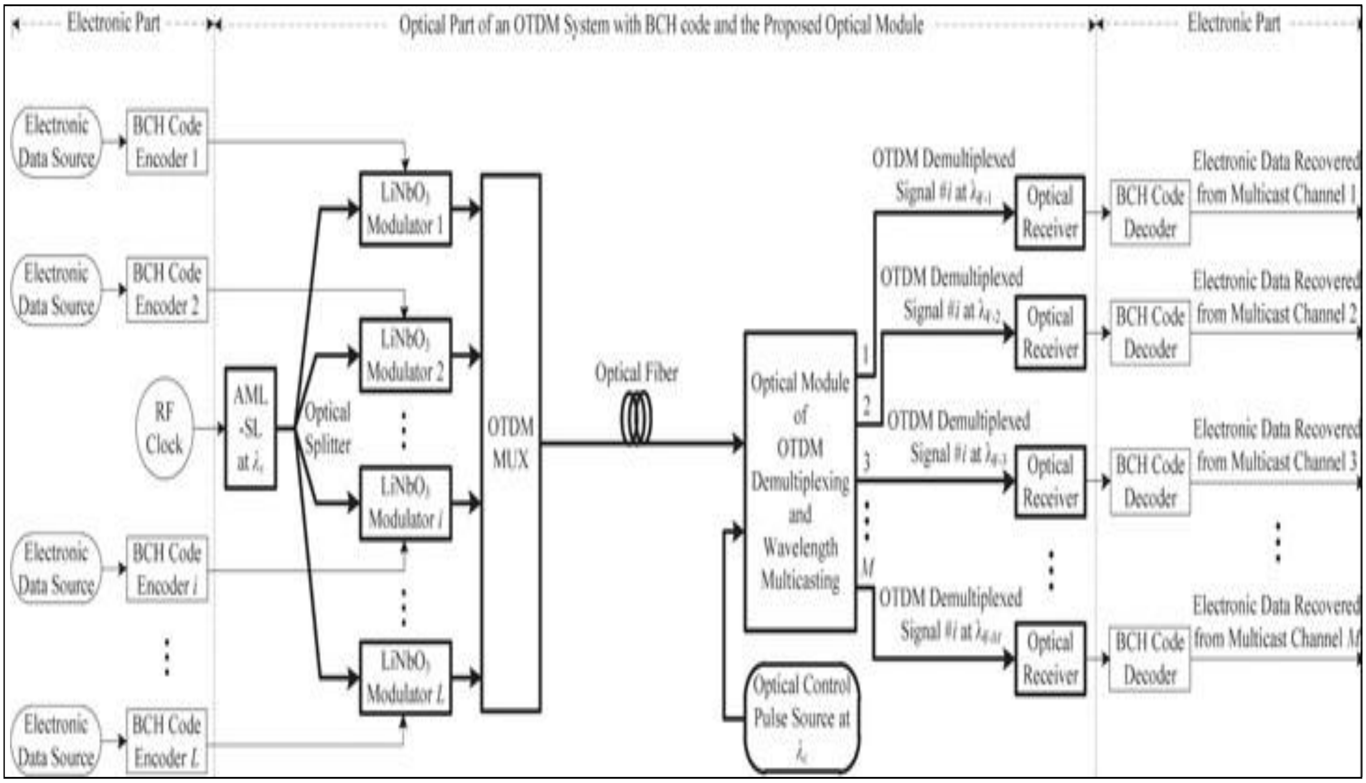
Optical time division multiplexing is undoubtedly more powerful optical multiplexing technique that it can combine multiple low bit rate channel into single high bit rate channel. Each channel can be multiplexed by a multiplexer for given period of time. In OTDM, only one wavelength of light is used instead of different wavelength of light in WDM.



A Simple OTDM consists of the following three stages

1. Transmitter
2. Inline system Receiver

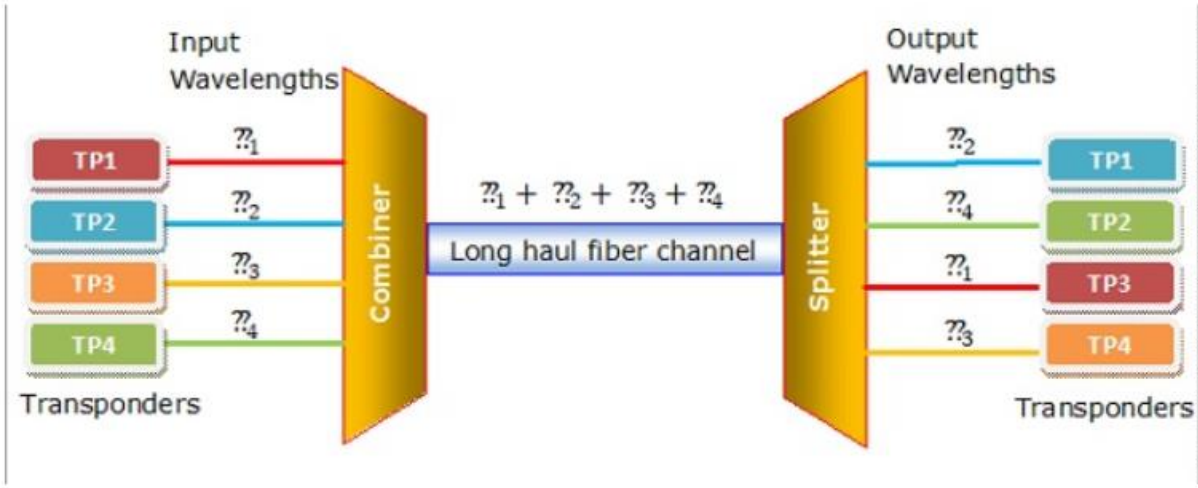
The transmitter made of the optical source, modulator, channel arrangement, and multiplexer. The optical flag can be tweaked utilizing Return to Zero (RZ), Non-Return to Zero (NRZ), various lengths of fiber can be utilized for the channel arrangement or delay flag, the multiplexer is utilized to combine the different optical information stream. The line framework comprises of optical enhancer, add-drop multiplexer, and transmission fiber. Semiconductor Optical Speaker (SOA) and Erbium dropped fiber Enhancer (EDFA) are utilized for the optical speaker to open up the optical flag in between into the organize whereas the collector comprises a demultiplexer and synchronous clock. The synchronous clock is utilized to extricate the surrounding beat or clock flag. The demultiplexer is at that point utilized to partitioned out the multiplexed optical flag. The figure appears the plan of optical time-division multiplexing.



9.2 Wavelength-Division Multiplexing (WDM)

Wavelength division multiplexing is a kind of frequency division multiplexing where optical signals with different wavelengths are combined and transmitted together. It is mostly used for optical fiber communications to transmit data in several channels with slightly different wavelengths., The transmission capacities of fiber-optic links can be increased strongly, so that most efficient use is made not only of the fibers themselves but also of the active components such as fiber amplifiers. But wavelength division multiplexing is also used for multiple fiber-optic sensors within a single fiber.

The following diagram conceptually represents multiplexing WDM. It has four optical signals with four different wavelengths. The four senders generates data streams of a particular wavelength. The optical combiner multiplexes the signals and transmits data over one long fiber channel. At the end the demultiplexes the signal into the initial four data streams.



Categories Of WDM: -

Based on the wavelength, WDM can be divided into two categories:

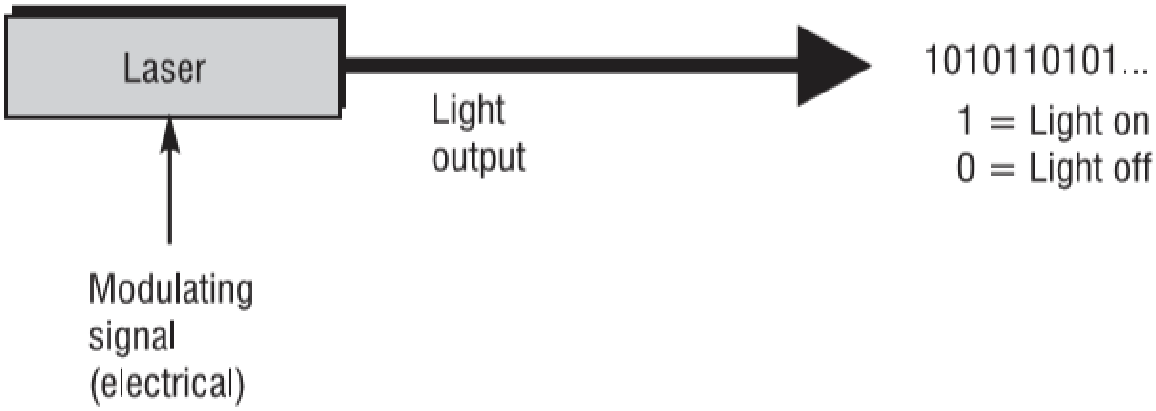
- **Course WDM(CWDM):** CWDM operates with 8 channels where the spacing between the channels is 20 nm apart. It consumes less energy than DWDM and less expensive. However, the capacity of the link and distance supported, is lesser.

- **DENSE WDM(DWDM):** In DWDM, the number of multiplexed channels much larger than CWDM. It is 40 at 100GHz spacing or 80 with 50GHz spacing. So, they can transmit the huge quantity of data through a single fiber link. DWDM is generally applied in core networks of telecommunications and cable networks. It is also used in cloud data centers for their services.

10 Direct vs External Modulation in Optical Transmission:

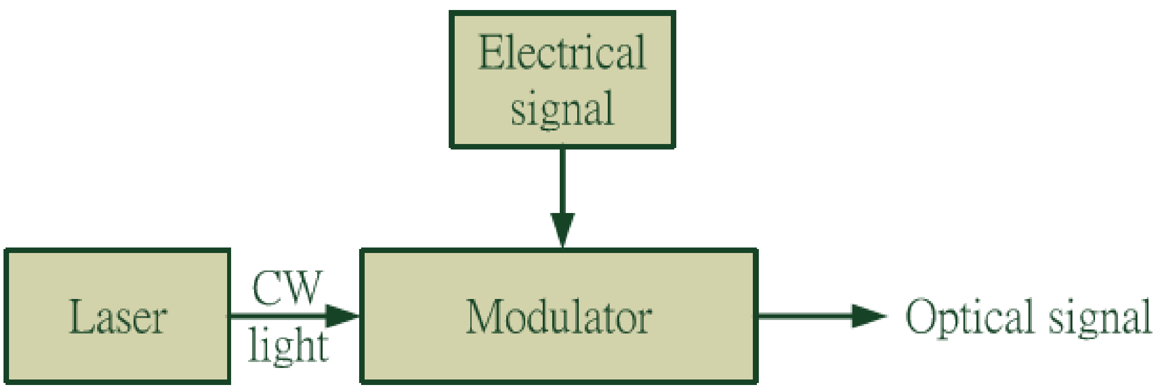
There are two distinct methodologies for optical adjustment in the fiberoptic connection, direct tweak and outside balance. Every has its own focal points and drawbacks.

The clearest technique for balance is to straightforwardly balance the laser source. Because of the prerequisites of transfer speed and proficiency, just semiconductor lasers are of pragmatic enthusiasm for direct regulation. In direct adjustment the yield intensity of the gadget fluctuates straightforwardly with the information drive current. The two LEDs and lasers can be legitimately adjusted utilizing simple and computerized signals. The advantage of direct regulation is that it is straightforward and modest. The burden is that it is more slow than roundabout adjustment with cutoff points of not exactly around 3 GHz.



In contrast to coordinate balance, outside adjustment has better for wide data transmission optical fiber interchanges, by utilizing high linearity

LiNbO3 outside modulator can be used to tweak signal. Anyway, the potential detriments are including framework multifaceted nature and significant expense. which shows a rapid transmitter where the laser is one-sided at a steady flow to produce CW yield, and an outside optical modulator is put beside the laser; the CW yield light goes through the outer modulator material whose optical properties can be altered by an applied outer electric field.

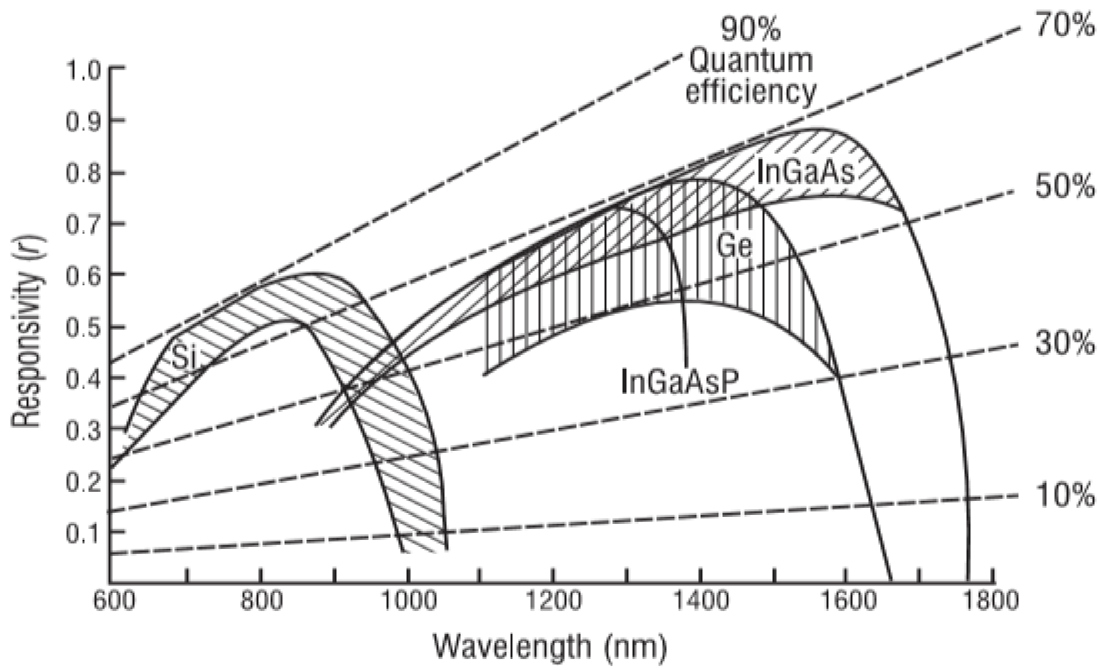


There are three sorts of outside modulators: electro-assimilation modulators dependent on the gallium arsenide or indium phosphide semiconductors, electro optic modulators dependent on energized polymers, and electro optic modulators-based electro optic precious stones, for example, lithium niobite LiNbO3, and different materials.

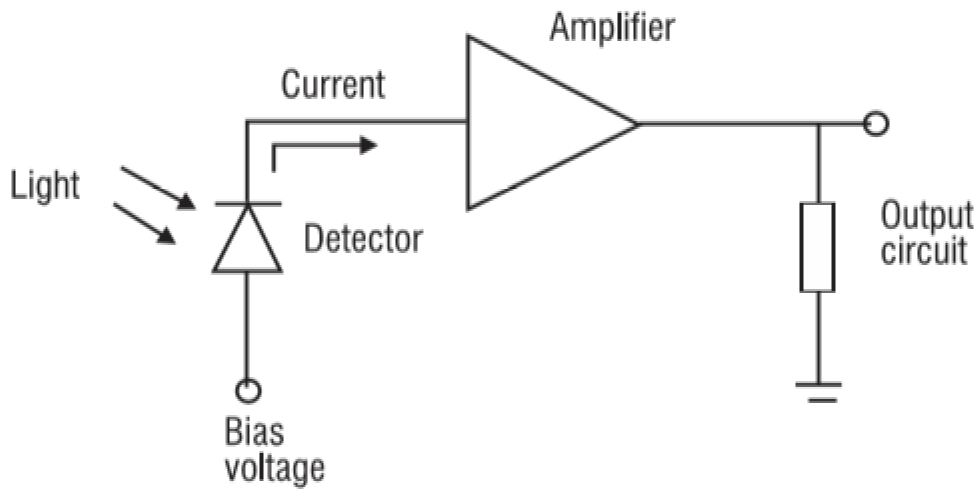
Electro-optic precious stone LiNbO3, electro-optic polymers or III-V semiconductor can be utilized to give data transmissions more noteworthy than 10 GHz for the outer regulation. A portion of these gadgets have balance frequencies more than 40 GHz.

11 Fiber Optic Detector

The motivation behind a fiber optic detector is to change over light projecting from the optical fiber back into an electrical sign. The decision of choosing a fiber optic detector relies upon a few variables including frequency, responsivity, and speed or rise time. The following shows the different types of detectors and their responsivity.



The procedure by which light is changed over into an electrical signal is something contrary to the procedure that delivers the light. Light striking the detector creates a little electrical flow that is being amplified by an outside circuit. Consumed photons energize electrons from the valence band move to the conduction band which results the production of an hole and mobile electron. Affected by a predisposition voltage these bearers travel through the material and prompt a current in the outer circuit. For every electron-gap pair made, the outcome is an electron streaming in the circuit [12].



Typical Photodetector Characteristics

Photodetector	Wavelength (nm)	Responsivity (A/W)	Dark Current (nA)	Rise Time (ns)
Silicon PN	550–850	0.4–0.7	1–5	5–10
Silicon PIN	850–950	0.6–0.8	10	0.070
InGaAs PIN	1310–1550	0.85	0.5–1.0	0.005–5
InGaAs APD	1310–1550	0.80	30	0.100
Germanium	1000–1500	0.70	1000	12

12 Fiber Optic Couplers

A fiber optic coupler is a gadget used to interface a solitary fiber to numerous other separate fibers. Here we are going to discuss about 2 types of coupler which are: -

1.Star Coupler: The star couplers consist of multiple input and output ports. Input power is given out evenly to the output fibers. For larger networks star couplers are preferred as it gives lower loss. There are 2 kinds of star coupler directional (light from input is sent to output) and non-directional (light from input is sent to all ports input and output alike).

2.T Couplers: Multiple terminals on a network can be connected to the network by cascade connection through these couplers. They are readily available.

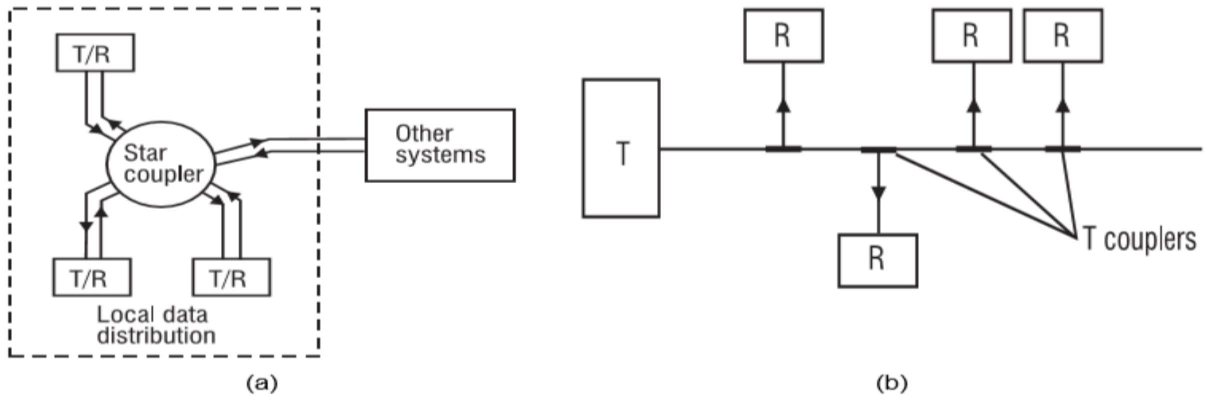


Figure: Star Coupler and T Couplers

13 Semiconductor Photodiodes and its work:

Photodiodes is an essential element of any optical fiber systems. Basically, fiber optic performance is depending on protectors. Semiconductor photodiodes is commonly used in optical fiber system that provides good performance. The detector is usually electrically reversed biased. From the figure the first part, when no light is absorbed the reverse bias there is no flow of carriers in depletion region which stops current from passing through the diode. When the light falls on the detector with proper energy which can create electron-hole pair and causes carrier to drift quickly away from the junction by built in electric field which causes current flow and it is proportional to the light hitting detection [13].

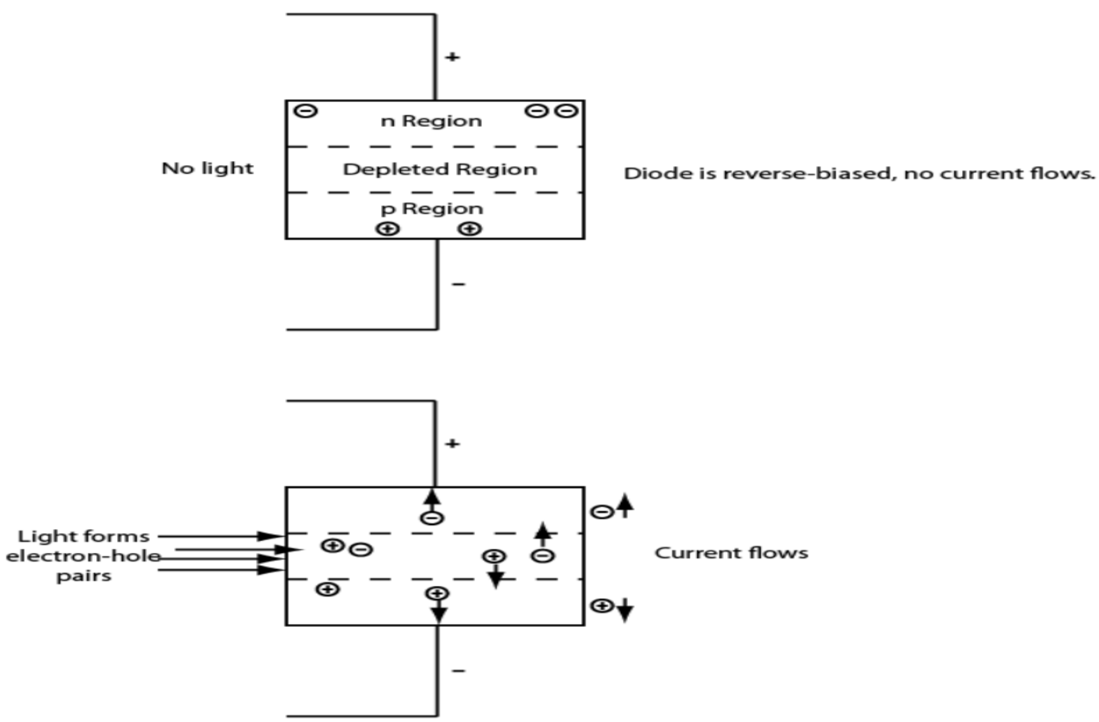


Figure: Depletion region of the semiconductor photodiode

14 Optical Fiber and Bangladesh

14.1 The Present Status of Optical Fiber Communication in Bangladesh

The first establishment of optical fiber links in Bangladesh began in 1986, along with the installation of new digital switches. In 1989, BR under a modernization project of it signaling system installed the optical fiber network at 300 stations with financial assistance from the Norwegian government. As the capacity of the fiber optic remained mostly unused in 1997, Grameenphone, majority owned by Norwegian company Telenor, signed an agreement with the then railway division to use, maintain and run the business operation of the fiber optic cable, after winning an international bid.

Grameenphone's exclusivity in using the Bangladesh Railway's fiber optic network is set to come to an end after 20 years as the government looks to make the most of the resources available to realize its Digital Bangladesh vision. The government has now taken an initiative to withdraw the exclusivity agreement between Grameenphone and BR as the cable is a public resource and should be open to all such that they can digitize the country. A joint committee comprising representatives from Grameenphone and BR has started working on reviewing the terms of agreement between the entities. “The revision of the deal will open up more than 2,100 kilometers of optical fiber cable of BR to all interested parties,” said an official of Bangladesh Telecommunication Regulatory Commission. “BR will be able to supervise and lease or sub-lease the cable to any other entity. The other entities, including internet service providers, will also get to use the cable to take their services to the rural areas.”

Meanwhile, BTRC officials said that the commission in 2014 provided Nationwide Telecom Transmission Network (NTTN) license to BR, allowing the entity to do business in the sector. According to BTRC, there are currently 54,237 kilometers of fiber optic cable, where the NTTN operators have a major share of 20,670km. Summit Communication has 15,468km, Bangladesh Telecommunications Company Limited 4,935km, Power Grid Company of Bangladesh 4,402km and BR 2,105km. Among the mobile phone operators, Banglalink has 3,000km, Grameenphone 2,500km and the other operators 1,157km of fiber optic cables.

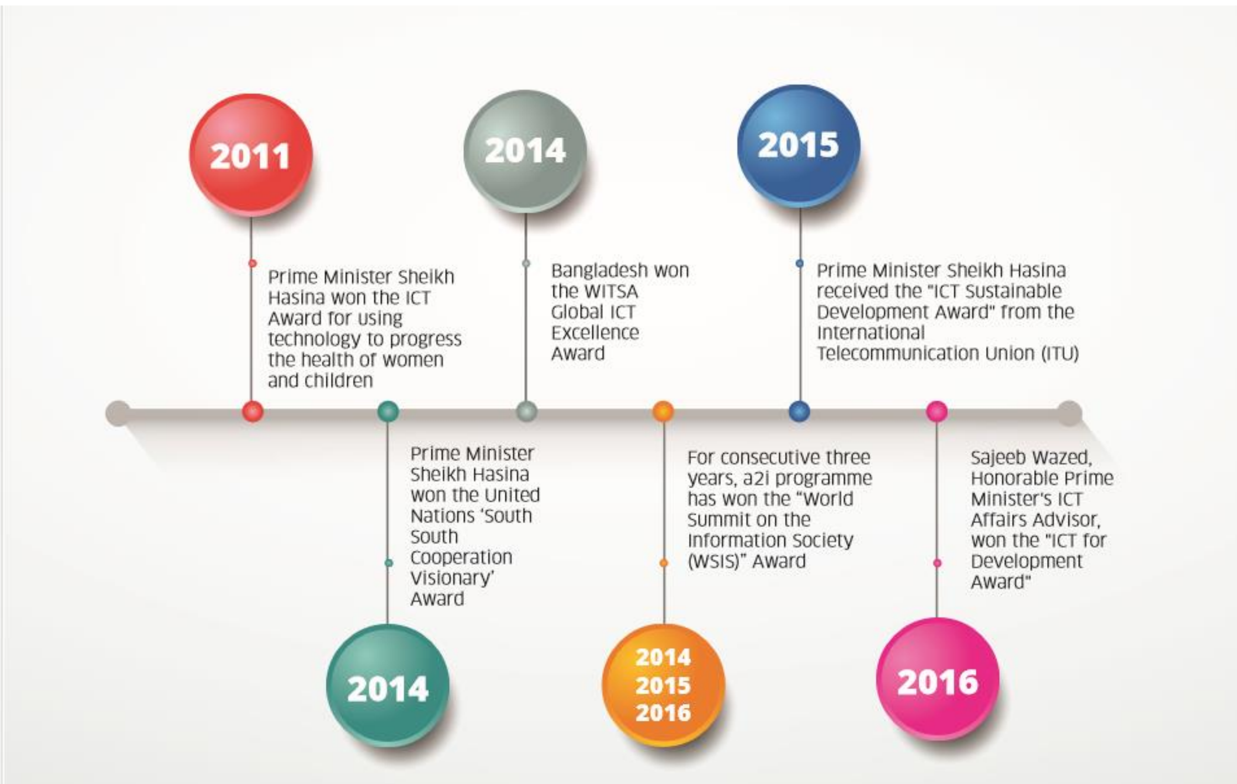
14.2 The Recent movement in optical fiber communication Bangladesh

The government sets up to 8000-kilometer fiber optic cable nationwide in step with daily star. In 2018-19 budget, highlighted the building an in-depth essential IT infrastructure for delivering fast and straightforward services to the doorsteps of the marginalized. For taking Bangladesh's property to consequent level, the govt. of Asian country has recently expressed the determined and really applicable National Telecommunications Policy 2016. below this policy, the principal aims are to make sure the phone and net for All. so as to realize these aims, the subsequent short-run, mid-term and long targets are set to be achieved by 2018, 2021 and 2025 severally.

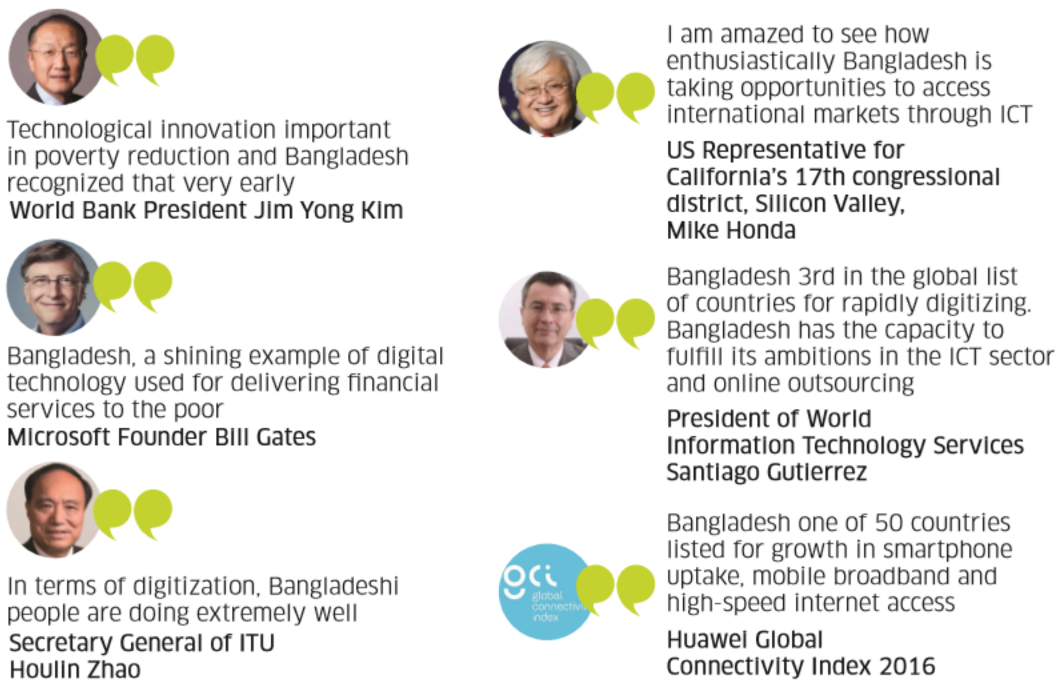
Achieve By 2018	Achieve By 2021	Achieve By 2025
90% teledensity	**100%** teledensity	Increasing internet penetration to **90%**
45% internet penetration	**65%** internet penetration	
20% people to have fixed-broadband	**40%** people to have fixed-broadband	Reaching broadband facilities to **90%**
64 districts, 490 sub-districts and 2,000 unions to have optical fibre connection	**4553** unions to have optical fibre connectivity	**50%** residences and organizations to have optical fibre connectivity

14.3 Achievement of Bangladesh

Optical communication was first established in Bangladesh 1986. Since then the revenue of this sector is rapidly increasing. Revenue has been growing from 3.8 billion to 5.08 billion US dollars in the last 5 years. Job growing rate of this sector has been increasing at a rate of 9% every year. This sector accounted 6.98% of the total economy. The government of Bangladesh is very conscious of this sector and wants to improve it to achieve digital Bangladesh and solve the unemployment rate.

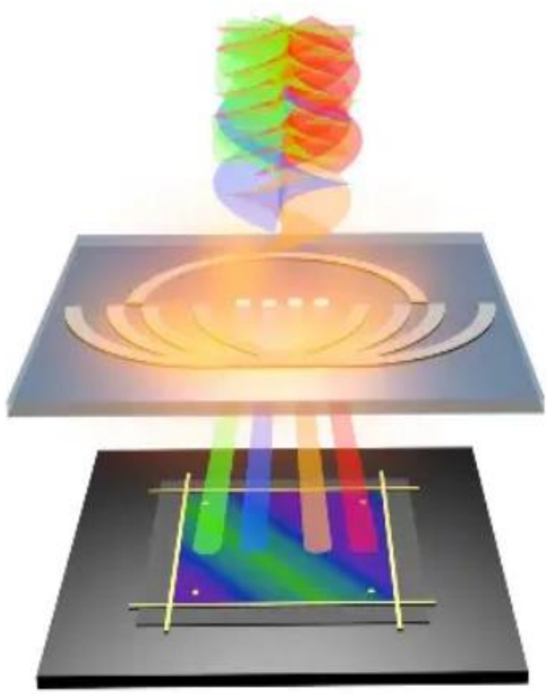


What the World Says:



15 The Future of Optical Fiber communication

The New Fiber Optic technology could allow 100 times faster internet.



The miniature OAM nano-electronic detector decodes twisted light.

Broadband fiber-optics carry information on pulses of light which leads at the speed of light through optical fibers. Though the way the light is encoded at one end and then processed at the other affects data speeds. This world-first nanophotonic device, published in Nature Communications which encodes more data and processes it much faster than straight fiber optics. Dr Haoran Ren from RMIT's School of Science, who was co-lead author of the paper, said the tiny nanophotonic device they have built for reading twisted light is the mislaid key required to unlock super-fast and ultra-broadband communications. Current-day optical communications are heading towards a capacity crunch. They fail to manage with the ever-increasing demands of 'Big Data' [14].

What we've managed to do is accurately transmit data via light at its highest capacity in a way that will allow us to immensely increase our bandwidth. Current state-of-the-art fiber-optic communications, like those used in Australia's National Broadband Network (NBN), use only a fraction of light's actual capacity by carrying data on the color spectrum.

New broadband technologies under development use the oscillation, or shape, of light waves to encode data, increasing bandwidth by also making use of the light we cannot see.

This latest technology, at the cutting edge of optical communications, carries data on light waves that have been twisted into a spiral to increase their capacity further still. This is known as light in a state of orbital angular momentum, or OAM.

In 2016 a similar cluster from RMIT's Laboratory of Artificial-Intelligence Nanophotonic printed a n analysis paper in Science journal describing however they might manage to decipher a little vary of this bitter lightweight on a nanophotonic chip. 'Technology to sight a good vary of OAM lightweight for optical communications was still not viable, until now. our little OAM nano-electronic detector is meant to separate numerous OAM lightweight states in an exceedingly continuous order and to decipher the data carried by twisted lightweight.'

To do this previously would require a machine the size of a table, which is completely unreasonable for telecommunications. By using ultrathin topological nanosheets measuring a fraction of a millimeter, the new invention does this job better and fits on the end of an optical fiber. Their OAM nano-electronic detector is like a watch that may see data carried by twisted light-weight and rewrite it to be understood by natural philosophy. This technology's high performance, low price and little size makes it a viable application for future generation of broadband optical communications. It fits the size of existing fiber technology and will be applied to extend the information measure, or probably the process speed, of that fiber by over a hundred times inside future few years. This simple measurability and therefore the huge impact it'll wear telecommunications is what's thus exciting.

16 Our Circuit

16.1 Basic Architecture

We have tried to design a communication device which will be using an optical fiber as the communication medium. The entire device can be divided into segments. First, we have a source which will generate a message or signal. In this case the message will be a binary message. Next the signal is sent to a transmitter which will convert the signal into a light pulse. The transmitter will be connected to the optical fiber cable through a connector which carry the light pulses to the receiver which will convert the light pulses to electrical signal and the electrical signal will be to an output device which will show the output.

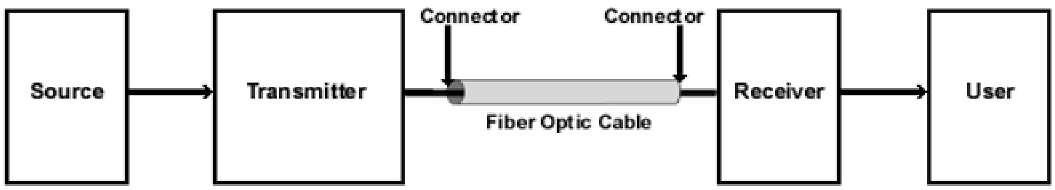


Figure 2-4: Model of "simple" fiber optic data link

16.2 Circuit Components:

1) Laser diode:

The laser diode was used as a source for light pulses in our circuit. We have chosen the PCM 00310 laser diode due to it being richly available. Whenever a voltage is applied at the ends of this laser diode, photons are generated which are led to its opening and thus resulting the laser that we see.

Figure: Laser diode (PCM 00310)

Dimension:

- Diameter: 6mm
- Length: 13mm
- Wire Length: 47mm

Specifications:

- 650nm (red) dot output
- 6mm diameter (0.235") x 13.9mm (0.55") overall length
- Dot spread at 15M distance measures 10-15mm diameter
- 5V DC maximum input
- -36 ~ 65°C operating temperature range
- Prewired with 75mm (3") wire
- 1.4g

2) LDR Sensor Module:

The Optical sensitive resistance light detection photosensitive LDR sensor module or LDR sensor module to be short has been used to detect receiving laser signal. It consists of a light dependent resistor whose resistance changes due to the presence of light. In absence of light the resistance increases while when light intensity increases the resistance decreases which also causes the voltage levels to change. A lower light intensity results in higher voltage levels and vice versa.

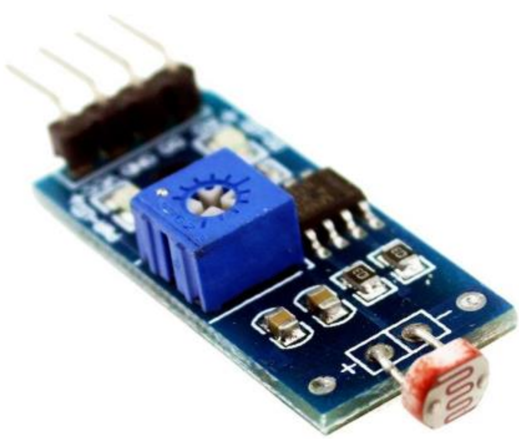


Figure: LDR Sensor Module

The module has a tunable switch with which the sensitivity can be changed, a clockwise rotation will increase sensitivity while an anticlockwise rotation will do the opposite. The module has 4 pins VCC, GND, D0 and A0. VCC and GND are needed to be connected to the positive and negative terminal of a 5V power source respectively. The D0 pin is used to provide a digital output in the form of a high or low voltage while the A0 provides an analog output. There are 2 LEDs present in the module on of which indicates that the module is powered while the other flashes when it receives a light pulse. To sum it up it is a versatile tool for light sensing and better for our circuit than a photodiode, as the photodiode has more light sensitivity and requires more complex handling [15].

3) Optical fiber:

The fiber optic cable was taken from a normal LED fiber optic lamp. Initially we tried to use a multimode optical fiber that is commonly used to make normal LAN networks. However, even the greater acceptance angle did not help us as the light from the laser was not able to pass through it. So, we had to improvise and the fiber from the LED lamp worked quite well.

Figure: Fiber Optic Cable

4) Connecting wires:

Normal dual pin, breadboard friendly male to male jumper wires(model:C&C-00061) and female to male jumper wires(mode:C&C-00071) were used to provide connection between different circuit components.

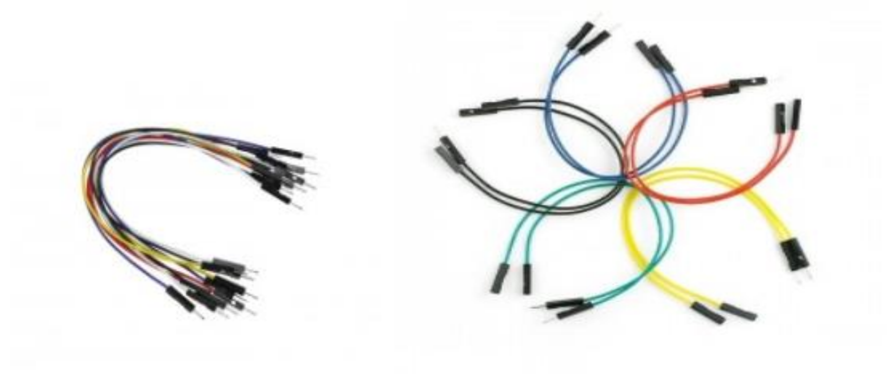


Figure: Jumper Wires (Male to Male and Female to Male)

5) Breadboard

Breadboard (Model: MIS-00002) was used to act as the foundation on which the circuit components are connected. The bread board contained 830 points and was of the dimension 6.5"x2.1".

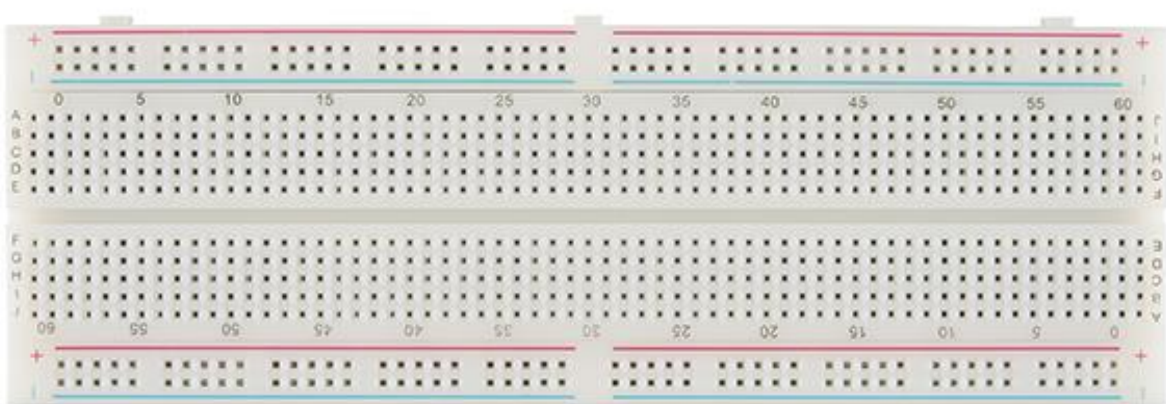


Figure: Breadboard

6) Arduino Uno:

We required 2 Arduino Uno to build our transmitter and receiver. They were used to process the input and output signals, also drive the laser diode and show the output in a computer. The Arduino Uno is a microcontroller board based on the ATmega328 chip. The chip is connected to a crystal resonator that controls this chip's operational speed which is at 16Mhz. There is another microcontroller connected to the USB port which allows programs to be uploaded to the Arduino Uno and also sends message to PC. This microcontroller is also important for debugging.

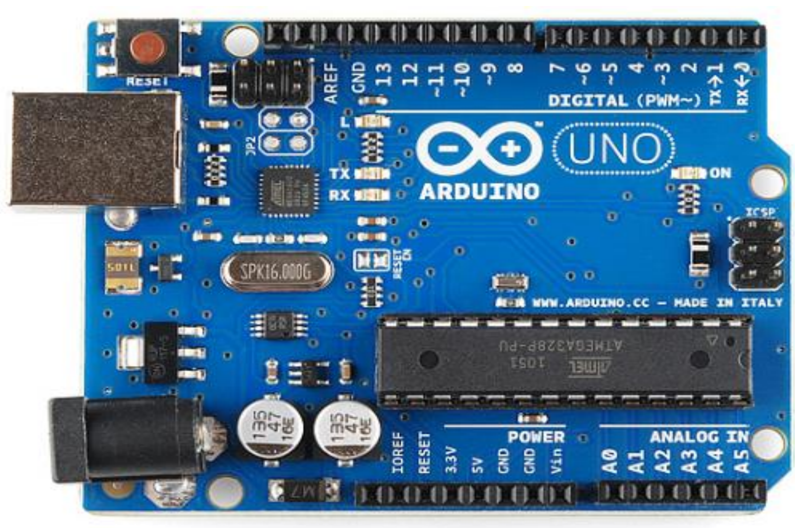


Figure: Arduino Uno

The Arduino Uno has 14 pins from D0 – D13 of which the pins D0 and D1 are also called RX and TX pins used for serial transmission. The digital input/output pins(D2-D13) spits out 5V for binary 1 and 0V for binary 0 in normal cases (this can be reversed by a program). 6 of these 14 pins (those with ~) are called PWM pins which can output PWM waives. There are 6 analog input pins (A0 – A5) which can read analog inputs. There are also power pins which are used to provide power to and from the microcontroller a circuit board. The reset button can be also used to reset the Arduino. There is also a power jack which can be used to supply a DC voltage of 7-12 V. The USB connector allows the board to be supplied a 5V DC voltage while the Vin power pin allows the board to be supplied (7-12V) [16].

Specifications: -

- Microcontroller: ATmega328P
- Digital I/O Pins: 14 (of which 6 provide PWM output)
- Analog Input Pins: 6 (DIP) or 8 (SMD)
- DC Current per I/O Pin: 40 mA
- Flash Memory: 32 KB
- SRAM: 2 KB

- EEPROM: 1KB

16.3 Designing the circuit

The main circuit could be divided into parts the transmitter, receiver and the communication medium. Both the source and destination is a computer where the input is typed and output is seen. The transmitter was used to transmit the data while the receiver to receive it and the communication medium to provide a pathway or medium for the information signal to be sent between them.

Transmitter: The transmitter is made up of an Arduino Uno and a laser diode which emits a laser 650nm when it receives an electrical signal. The Arduino Uno has been used as a microcontroller which controls the output of the laser diode. The positive terminal of the laser diode is connected to the digital pin 13 of the Arduino Uno with a jumper wire. In a similar way the negative terminal is connected to the ground pin (GND) of the Arduino Uno.

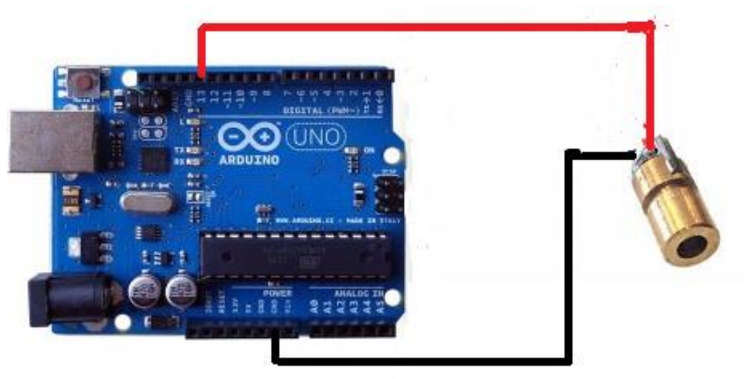


Figure: Optical Signal Transmitter Circuit Diagram

The Arduino Uno is programmed to provide an electrical signal to the laser diode according to the binary message. Here we are sending a binary information which consists of only 0's and 1's. Here we are sending a binary message 0101. A 0 is represented by a low voltage(0V) while a 1 is represented by a high voltage(5V) and this is stored in an array. A high voltage will cause the laser diode to emit a light pulse while a low will cause it to turn off. We have designed the pin 13 to be the output of Arduino as it is connected to the positive terminal of the laser diode and in the program is defined as the LASERPIN and this pin's mode is set to output using the pinMode() function. The input must be given in the code by the user defined by 'HIGH' and 'LOW'. In this project we are sending 0101 which represented in an array as [LOW, HIGH, LOW, HIGH] The

Arduino Uno will first send start bit, something that is used to interact between 2 devices and could be said to be the equivalent of ‘hello’. After this the transmitter will send the binary message which will be in the form of light pulse. When the message is sent the Arduino will send low signal to the laser diode turning it off. Then there will be a 1 second delay. We used the digitalWrite() function to define the output of the pin. A digitalWrite(LASERPIN,HIGH) will give a high output while a digitalWrite(LASERPIN,LOW) will give a low output [17]. Then the for loop will control the output according to the value stored in bits array sending successive high and low outputs at 1 second interval (this must be equal to receiver) which will in turn control the laser diode’s output. After binary message in the form of light is transmitted, the laser diode will be turned off for 3 seconds and the whole cycle is repeated. So, it can be said that the Arduino Uno has been used as a laser driver.

Transmitter_code §

```
#define LASERPIN 13
void setup() {
  // put your setup code here, to run once:
  pinMode(LASERPIN, OUTPUT);

}

void loop() {
  // 0101
  //fix array
  int bits[] = {LOW, HIGH, LOW, HIGH};

  //start bit
digitalWrite(LASERPIN, HIGH);
 delay(1000);
  digitalWrite(LASERPIN, LOW);

// sending output according to array
  for (int i = 0; i < 4; i++) {
    digitalWrite(LASERPIN, bits[i]);
    delay(1000); // 1 second interval between signal output



  }


//turns off the laser
 digitalWrite(LASERPIN, LOW);

  delay(3000); // waits for 3 seconds



}
```

Figure: Code of the Transmitter

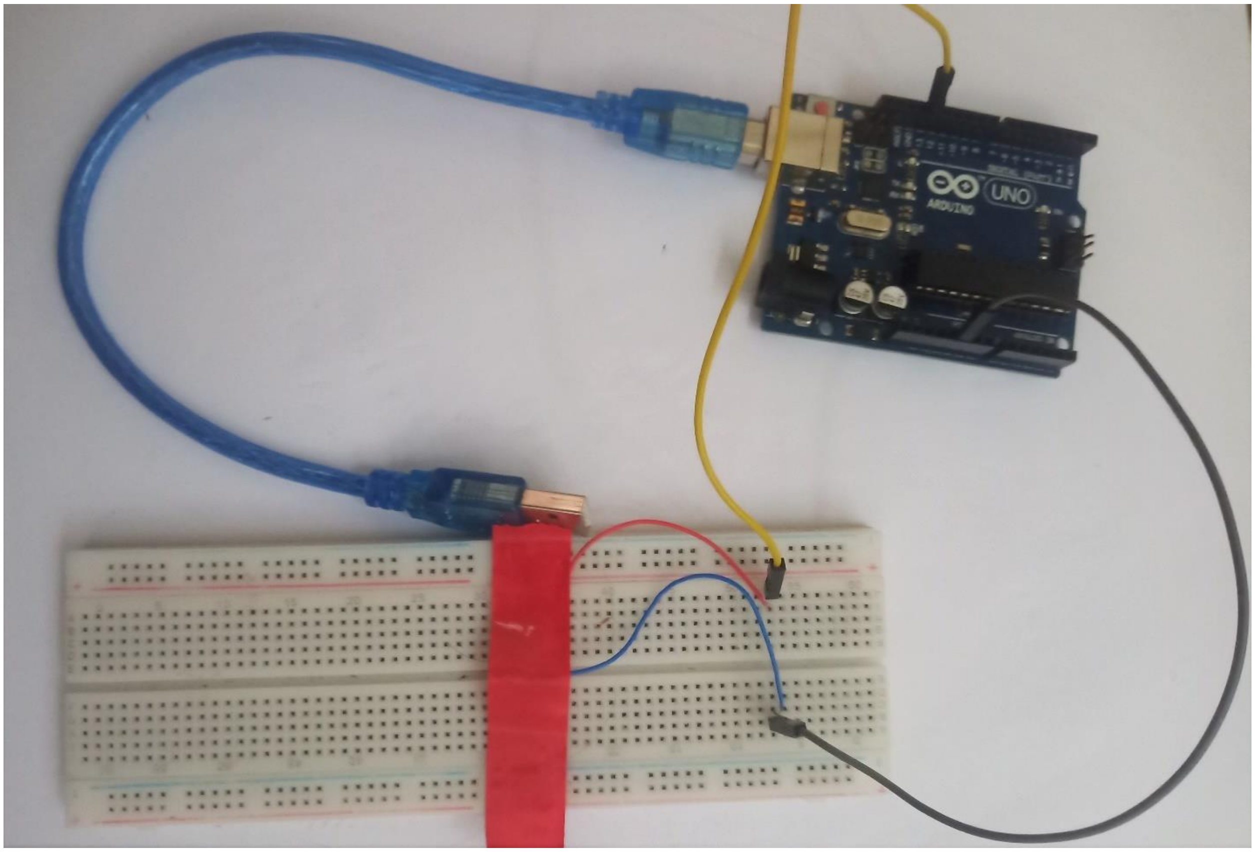


Figure: The Transmitter

Receiver: The receiver is made of another Arduino Uno and an LDR module. The A0 pin of the Arduino Uno is connected to the A0 pin of the LDR module by a male to female jumper wire. Similarly, the VCC and GND of the module is connected to the 5V and the GND pins of the Arduino Uno board respectively.

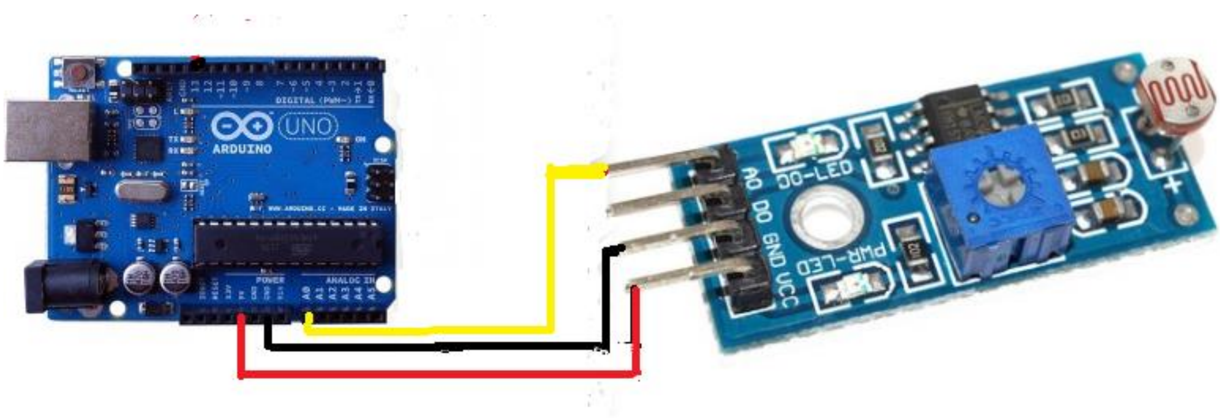


Figure: Receiver Circuit Diagram

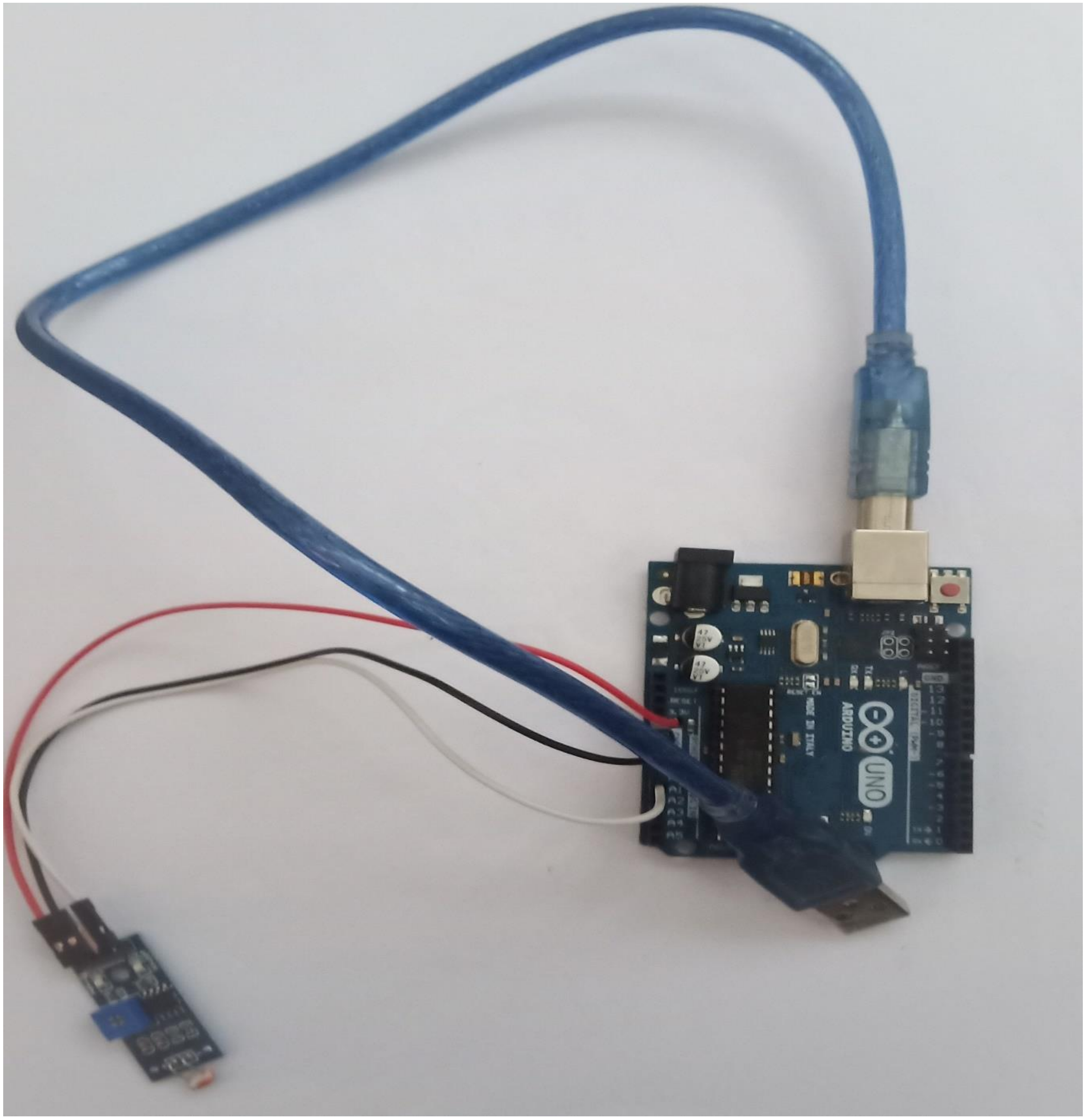


Figure: The Receiver

Receiver_code

```
#define SOLARPIN A0
#define THRESHOLD 550
void setup() {
  pinMode(SOLARPIN, INPUT); //setting the A0 pin as an input
  Serial.begin(9600); // Sets the data rate in 9600 bits per second (baud) for serial data transmission


}
void loop() {
  // reads the input at pin A0
int reading = analogRead(SOLARPIN);
int bits[4];
// listening for start bit
if (reading <  THRESHOLD)
{
  for (int i =0;i<4;i++){
  if(analogRead(SOLARPIN) < THRESHOLD){

  bits[i] = 0;

    }
  else {
    bits[i] = 1;

  }
  delay(1000); //  1 second interval between readings
  }

  }

// showing the binary message output in serial monitor
for (int i =0;i<4;i++)
{

Serial.print("array[");
Serial.print(i);
Serial.print( "]" );
Serial.println(bits[i]);

}
Serial.println("");
delay(3000); // waits for 3 seconds
}
```

Figure: Code of the Receiver

We have defined the pin A0 as 'SOLARPIN'. The Arduino Uno will receive the analog signal through this pin. 'THRESHOLD' is defined as the value which will determine a high and low voltage. In this project it was taken to be 550 which we got from using another program called calibration on the LDR modules. It was found that when there is no laser on the LDR, the Arduino read a value of around 1024. Sudden falls to 743 and 800 was also seen. When laser fell on the LDR this value fell to around 450. So, we took the deciding value to be 550. Then the Serial.begin() function is used to set the data rate(9600bps) for transmission. It is essential to see our output in the serial monitor of Arduino IDE. First, we used the analogRead() function to read the signal fed into the A0 pin. Now if the signal has a value less than 'THRESHOLD', it means that laser is being received by the receiver. This is the start bit and upon receiving this the receiver will be turned on and start to receive the bits. For a value less than 550 the program will declare the received bit 1 and for a value greater than 550 the received bit is held as 0. There is a one second delay between the reading of this bits and this should be same as the transmitter and must be selected with careful consideration as this also depends on the circuit design. We received a one-bit error or 25% error due to setting it to other values. After the binary message is received it is shown in the serial monitor by the Serial.print() function. After that the receiver will wait for 3 seconds and the whole cycle will be repeated [18].

calibration

```
#define SOLARPIN A0



int reading = 0;

void setup() {
  pinMode(SOLARPIN, INPUT);
  Serial.begin(9600);

  //ambientReading = digitalRead(SOLARPIN);
}
void loop() {
int reading = analogRead(SOLARPIN);
Serial.print(reading);
Serial.println("");
delay(1000);
}
```

Figure: Code for Calibration

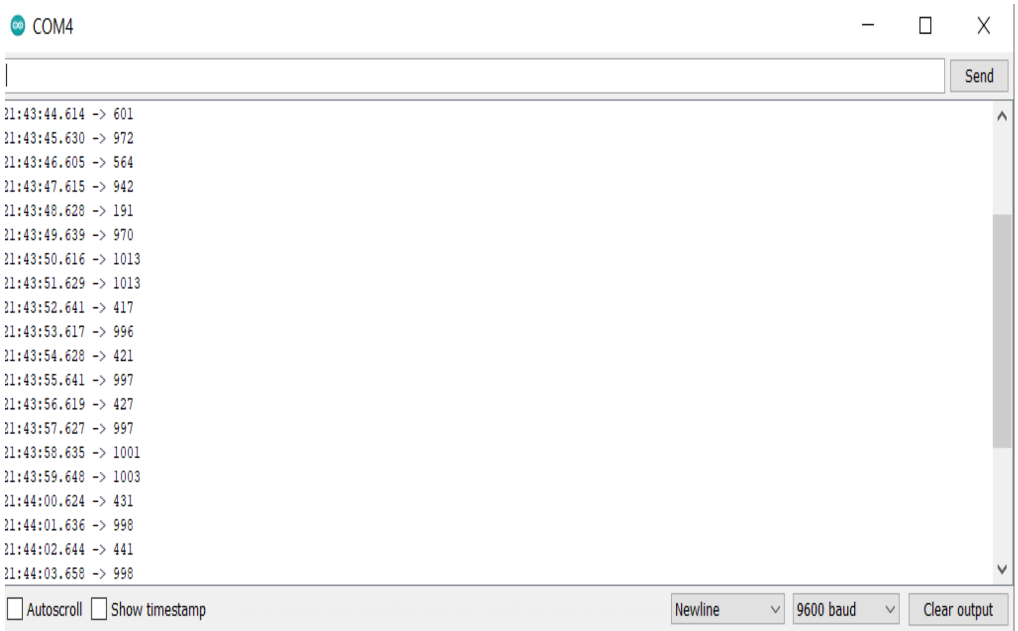


Figure: Output of Calibratio

16.4 Operational Process

The transmitter is connected to a source in this case a computer where we input the desired binary message in the code in this case 0101. The transmitter will control the laser diode according to this information making the diode emit laser when it receives a high input and turn it off when it receives low input. Later this laser light travels through an optical fiber through total internal reflections and arrives at the receiver. At the receiver these light pulses are converted to electrical signals by the LDR and then fed to the Arduino which in turn is converted to binary 0's and 1's. The destination is also a computer where we through the serial monitor can see the binary message output. In this project we sent 4-bit binary message, however, the code can be a little modified to transfer messages of higher bits. From the output it can be seen that 0101 meaning that there was 100 percent accuracy and no error. To sum it up, our objective of understand and analyzing the concepts regarding optical fiber communication through the use of this hardware circuits were achieved which broadened our views on optical fiber communication and basic application of electrical circuits.

Figure: Output of Receiver

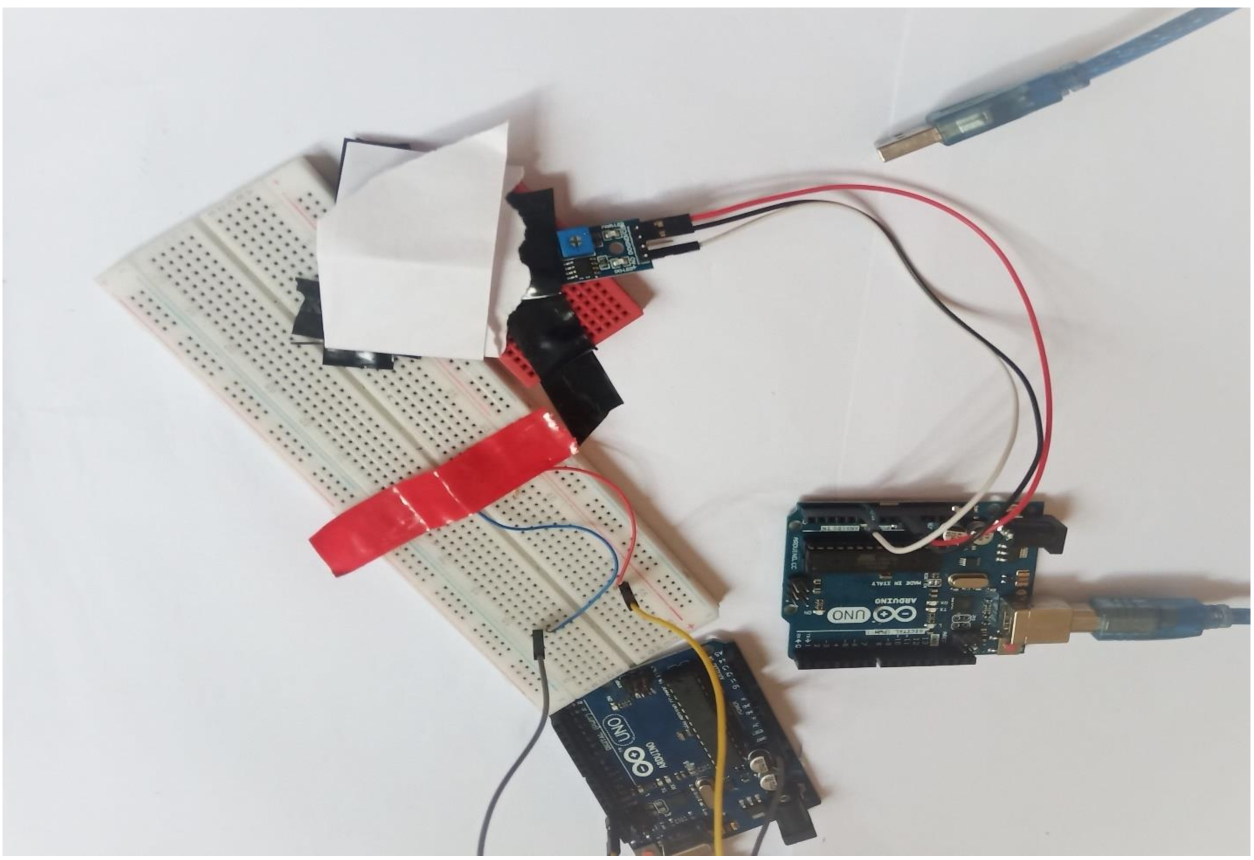


Figure: Entire System (excluding the PC)

16.5 Limitations and Further Improvements: -

- One-way communication: Using this device we can have only one-way communication that is only the source can send a binary message while the receiver receives it however the sender cannot receive a message while the receiver cannot send one. This can be changed by transforming the circuit to support 2-way communication which can be done by using additional more powerful ICs.

- Messages in other forms cannot be sent: Our device can only send and receive binary or text messages. In order to send video or audio messages circuit must be modified.

- Distortions will appear in case of long-distance communication: Since we are optical fiber with large core and no shielding as the communication medium, distortions will be significant if we try to communicate long distance, which will cause the BER to increase and ISI to occur. To cope up with that we need to use single mode optical fibers which are expensive.

- Wireless Communication: We can also allow wireless communication by allowing the use of Bluetooth or WIFI modules and a microcontroller at the transmitter and receiver.

16.6 Applications

The concept of this project can be implemented for long distance communications. We can connect different buildings or facilities to be connected with this device. This can ensure more secured connections as the signal is not transferred to a third party. One can also use it to control electrical circuits which are far from the operator. For example, it can be used to operate traffic lights. We can modify the code a bit which will only send a high or low signal which will turn on or off the lights respectively. Further improvements can also cause it to be implemented in wireless communication or even the autonomous car systems (though a huge improvement is needed for that but the concept is same). So, it can be said that there are a lot of options for the implementation of our project one just need to have a creative and innovative mind.

17 Conclusion

The current world cannot be run without optical fiber communication. Although there are various other communication mediums or methods like using microwaves as used in mobile phone networks, satellite communication etc, they are not enough to provide the huge demands of speed, volume and latency which can be fulfilled only with the help of the optical fiber. In fact, in almost every communication network for example the mobile networks, optical fibers are used to build communication link in the back. In other words, other networks are being built on the optical fiber networks with the optical fiber network being the foundation. The world is generating huge amounts of data, right now data is more important than wealth or status and with data one can rule the world. With the advent of 5G nearing, the world will need more fiber network. As such optical fiber communication should be studied well to cope up with the technological advancement. This thesis paper and the hardware project alone are not enough to provide a deep understanding of optical fiber communication but should provide with an intermediate understanding on optical fiber communication and their implementation. We have tried our best to inform the reader about optical fiber communication in both technical and general aspects. And we do feel that our project was enough to fulfill our objectives though we wanted to do more like create a system where audio message can be shared but the recent pandemic has obstructed our progress making us face with the lack of circuit components and analyzing tools like oscilloscope but then again we gave our best effort and set up a working communication system using optical fiber link.

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