Thesis Title

Performance analysis of WDM technique in optical fiber link

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We hereby declare that we have completed this thesis on the topic entitled **"Performance analysis of WDM technique in optical fiber link"** and submitted it to the department of Electronics and Communications Engineering, East West University, as a partial fulfillment of the requirement for the degree of B.Sc in Electronics and Telecommunications Engineering.

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A special thanks to our parents whose encouragement and prayer were always with us.

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Abstract

Wavelength division multiplexing technique is used in fiber optic transmission to incorporate multiple light wavelengths in sending data over the same medium. During the 1980s, fiber optic data communications modems used low-cost LEDs to put near-infrared pulses onto low-cost fibers. Continuous-wave (CW) operation of a laser means that the laser is continuously pumped and continuously emits light. The emission can occur in a single resonator mode (single-frequency operation) or on multiple modes. WDM systems used 1550nm wavelengths for multi-channel systems. In 1550nm region – the fiber attenuation is lowest. In this thesis, we have used 8 channels WDM system and analyzed the average of each channel bit error rate. We've designed the system in two times-one is with amplifier and another is without amplifier. We analyzed and compared the temperature dependence, power consumption, BER of 8-QAM modulation schemes at 1550 nm wavelength for CW based optical link. It's found that the bit error rate of the system (with amplifier) is kept fixed at 10 Gb/s and fiber length is increasing 10 km. And the bit error rate of the system (Without amplifier) is kept fixed at 10 Gb/s and also fiber length is kept fixed at 10 km. We also analyzed the bit error rate for 0.25m to 2m in automobile. In future it will help us to use optical fiber in automobile. The working temperature range extends up to 125^0C for 1550 nm and we also analyzed bit error rate in room temperature. As increasing temperature reduces a major portion of q-factor. Optical access networks will be a challenge in the future when end-user demand outgrows current network limit. Wavelength division multiplexing (WDM) has been managed an ideal solution to extend the limit of optical networks without definitely changing the fiber infrastructure. In this thesis we investigate key issues and review enabling technologies for upgrading current-generation optical access networks with WDM techniqu

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Chapter-1

Introduction

1.1 Optical Fiber:

Optical fiber refers to the medium and also the technology related to transmit a message as light pulses on a glass or plastic strand or fiber. A variable variety of those glass fibers - from some up to a pair hundred will containing in an optic fiber cable. These strands are bundled together in a protective sheath or cover and the whole assembly (the optical fibers and other parts inside the sheath) is often referred to as fiber optic cable or just fiber known as protective cover. A layer called a buffer tube protects the protective cover, and a jacket layer acts because the final protecting layer for the individual strand.[1]

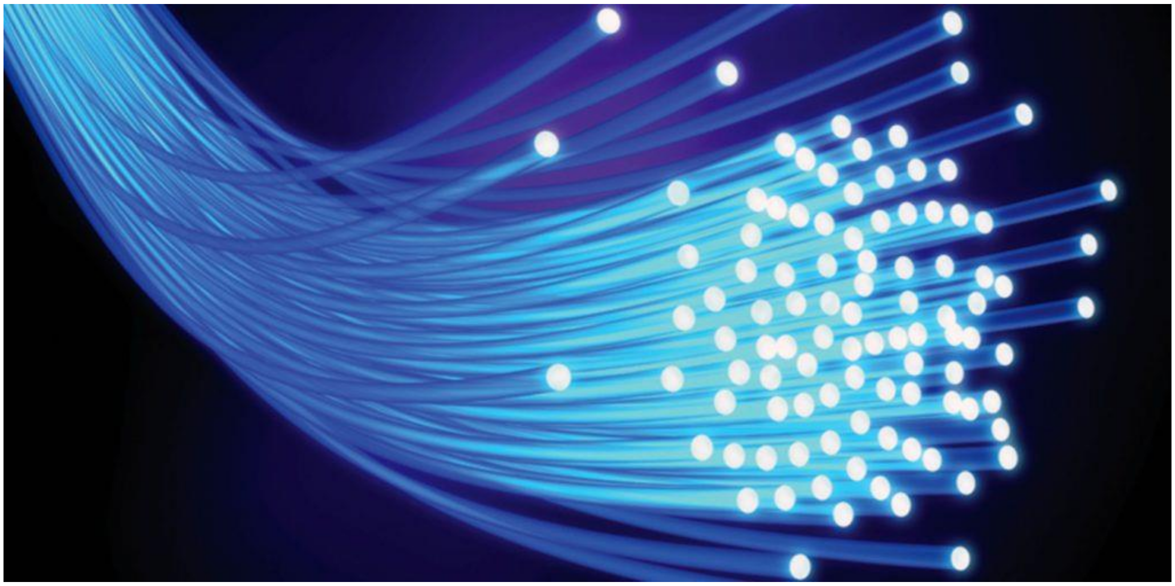


Fig 1.1: Fiber optics.[2]

1.1.1 Types of Fiber:

The fiber is divided into three parts based on the refractive filtration of fiber content,

1. State Index Fiber:
2. Grade Index Fiber
3. Monomod fiber

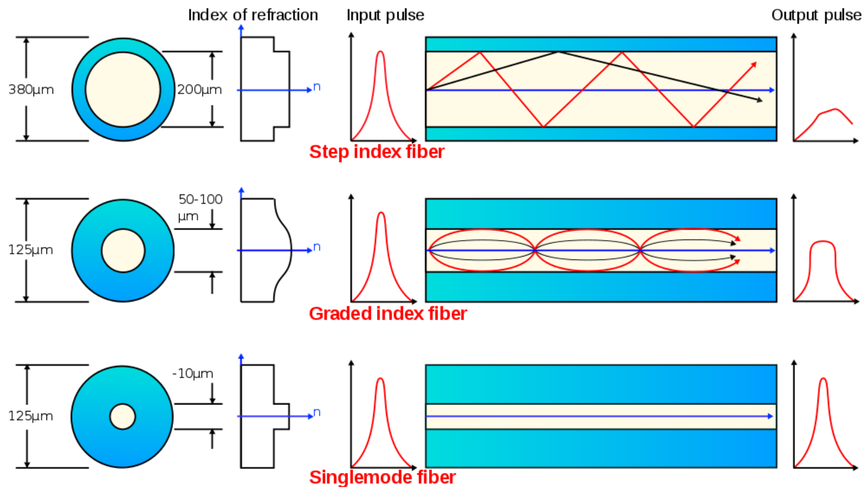


Fig 1.2: Types of fiber optic cable.[3]

1.1.2 Basic of Optical Operation:

An optical fiber may be a cylindrical material conductor (no conducting waveguide) that transmits light-weight on its axis, by the method of total internal reflection. The fiber consists of a core enclosed bya protective covering layer, each of that are manufactured from material materials.[4]

1.1.3 Index of Refraction:

The index of refraction (or refractive index) could be a manner of measure the speed of sunshine in a very material. Lightweight travels quickest in a very vacuum, like in space. The speed of light in a very vacuum is regarding 3,000 kilometers (186,000 miles) per second. The ratio of a medium is calculated by dividing the speed of sunshine in a very vacuum by the speed of sunshine therein medium. The ratio of a vacuum is thus one, by definition. A typical single mode fiber used for telecommunications contains a protection manufactured from pure silicon dioxide, with associate degree index of 1.444 at 1500 nm, associate degreed a core of doped silicon dioxide with an index around 1.4475.The larger index of refraction, the slower lightweight travels therein medium.[5]

1.1.4 Total Internal Reflection:

Total internal reflection is that the development that happens once a propagated wave strikes a medium boundary at associate degree angle larger than a specific incidence angle with relevancy the conventional to the surface. If the ratio is lower on the opposite aspect of the boundary and also the incident angle is larger than the incidence angle, the wave cannot taste and is entirely mirrored. The incidence angle is that the angle of incidence higher than that the overall internal reflection happens. This can be significantly common as associate degree physical phenomenon, wherever lightweight waves are concerned, however it happens with many sorts of waves, like magnetic force waves generally or sound waves.[6][7]

1.1.5 Multi-Mode Fiber:

Fiber with giant core diameter (greater than ten micrometers) could also be analyzed by geometrical optics. Such fiber is termed multi-mode fiber, from the magnetic attraction analysis (see below). During a step-index multi-mode fiber, rays of light are guided on the fiber core by total internal reflection. Rays that meet the core-cladding boundary at a high angle (measured relative to a line traditional to the boundary), bigger than the incidence angle for this boundary, are fully mirrored. The incidence angle (minimum angle for total internal reflection) is decided by the distinction in index of refraction between the core and protective cover materials.[8]

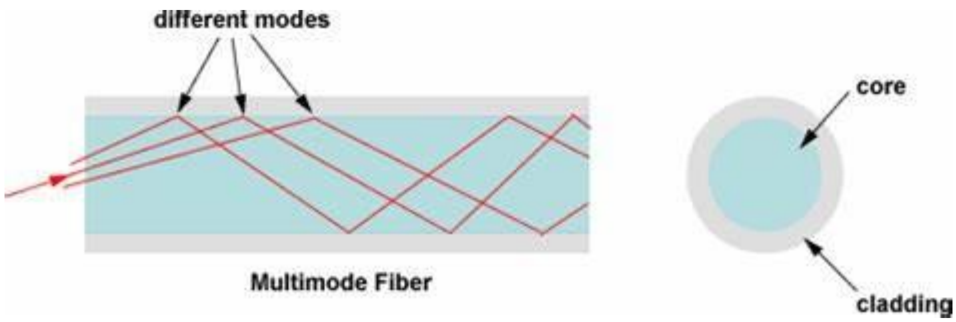


Fig 1.3: Multi-mode fiber.[9]

1.1.6 Single-Mode Fiber:

Fiber with a core diameter but concerning ten times the wavelength of the propagating lightweight cannot be shapely mistreatment geometric optics. Instead, it should be analyzed as associate magnetic attraction structure, by resolution of Maxwell's equations as reduced to the radiation equation. The magnetic attraction analysis can also be needed to grasp behaviors like speckle that occur once coherent lightweight propagates in multi-mode fiber. As associate optical wave guide, the fiber supports one or additional confined crosswise modes by that lightweight will propagate on the fiber. Fiber supporting just one mode is termed single-mode or mono-mode fiber. The wave guide analysis shows that the sunshine energy within the fiber is not fully confined within the core. Instead, particularly in single-mode fibers, a major fraction of the energy within the certain mode travels within the protective covering as a temporary wave the foremost common form of single-mode fiber contains a core diameter of 8–10 micrometers and is meant to be used within the close to infrared.[10][11]

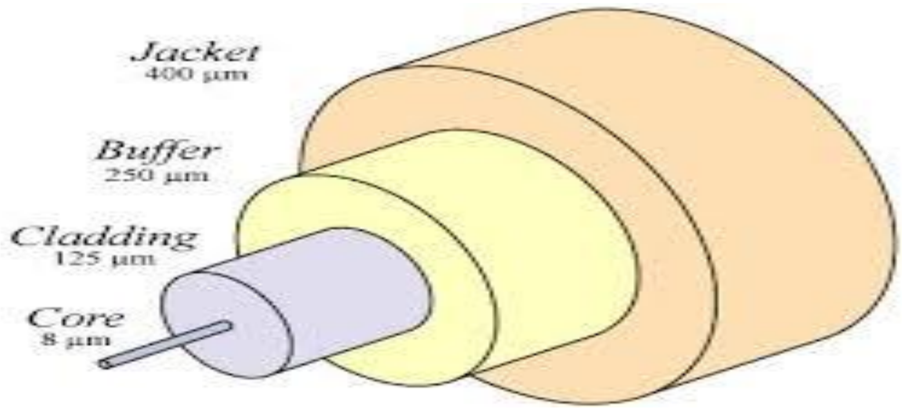


Fig 1.4: Single-mode fiber.[10]

1.1.7 Special Purpose Fiber:

Some special-purpose glass fiber is built with a non-cylindrical core and facing layer, sometimes with an elliptical or rectangular crosswise.[4]

1.2 Optical Fiber Cable:

An optical fiber cable, conjointly called a fiber optic cable, is associate degree assembly just like associate degree transmission line, however containing one or a lot of optical fibers that are accustomed carry light weight. The optical fiber components are usually one by one coated with plastic layers and contained during a protecting tube appropriate for the surroundings wherever the cables are deployed.[12]

1.2.1 Optical Fiber Cable Types:

- **OFC:** Optical fiber, conductive
- **OFN:** Optical fiber, nonconductive
- **OFCG:** Optical fiber, conductive, general use
- **OFNG:** Optical fiber, nonconductive, general use
- **OFCP:** Optical fiber, conductive, plenum
- **OFNP:** Optical fiber, nonconductive, plenum
- **OFCR:** Optical fiber, conductive, riser
- **OFNR:** Optical fiber, nonconductive, riser
- **OPGW:** Optical fiber composite overhead ground wire
- **ADSS:** All-Dielectric Self-Supporting
- **OSP:** Fiber optic cable, outside plant

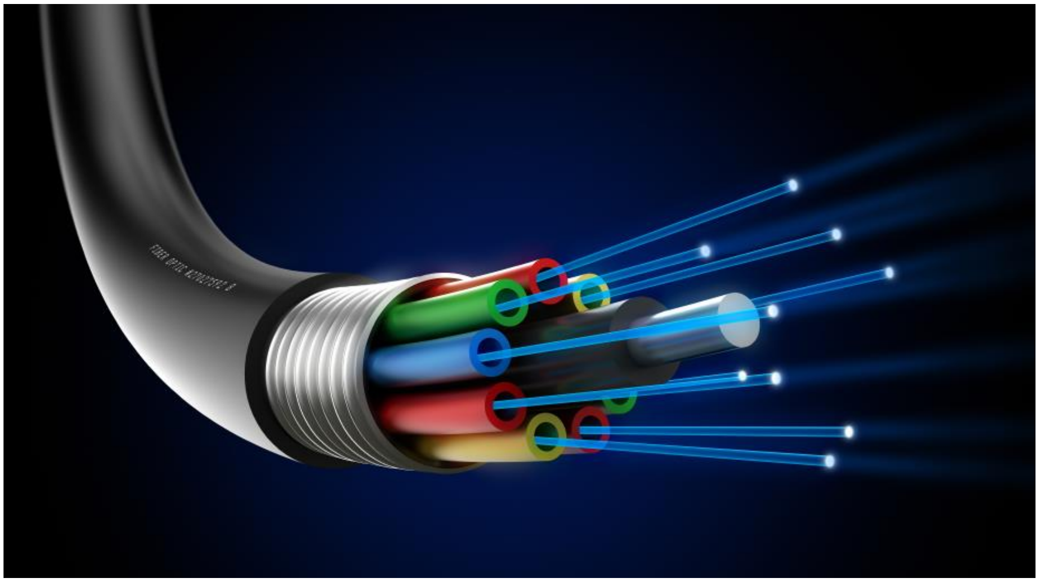


Fig 1.5: Optical fiber cable.[13]

1.2.2 Jacket Material:

The jacket material is application specific. The fabric determines the mechanical strength, chemical and ultraviolet illumination radiation resistance, and so on. Some common jacket materials are LSZH, polyvinyl resin, polythene, polymer, butylene terephthalate, and polymeric amide.[12]

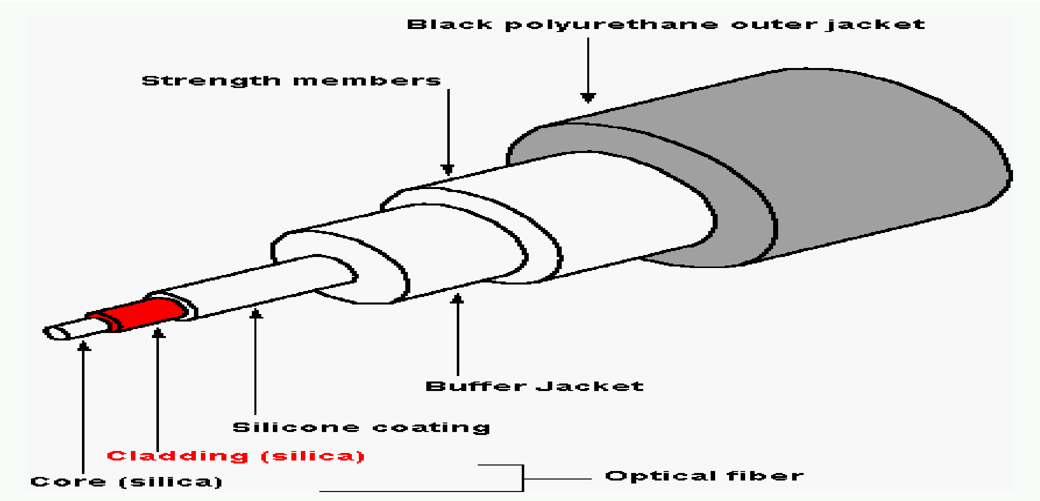


Fig 1.6: Structure of the optical fiber cable.[14]

1.2.3 Fiber Material:

There are two main sorts of material used for optical fibers: glass and plastic. They provide wide completely different characteristics and notice uses in terribly different applications. Generally, plastic fiber is employed for terribly short vary and shopper applications, optical fiber is employed for short/medium vary (multi-mode) and long vary (single-mode) telecommunications.[12]

Fig 1.7: Optical fiber materials.[15]

1.2.4 Cladding:

Cladding in optical fibers is one or a lot of layers of materials of lower index of refraction, in intimate contact with a core material of upper index of refraction. The facing causes lightweight to be confined to the core of the fiber by total internal reflection at the boundary between the two.[16]

1.2.5 Core:

The core of a standard fiber may be a cylinder of glass or plastic that runs on the fiber's length. The core is surrounded by a medium with a lower index of refraction, sometimes a facing of a unique glass, or plastic. Light move within the core reflects from the core-cladding boundary thanks to total internal reflection, as long because the angle between the sunshine and also the boundary is a smaller amount than the angle of incidence. The core is characterized by its diameter or cross-sectional space.

The three most common core sizes are 9 µm diameter (single-mode),50 µm diameter (multi-mode), 62.5 µm diameter (multi-mode).[17]

1.2.6 Signal Propagation:

Optical fiber transmit message within the kind of lightweight particles or photons that pulse through a fiber optic cable. The glass fiber core and therefore the protective cover every have a unique ratio that bends incoming lightweight at a specific angle. Once lightweight signals are sent through the fiber optic cable, they replicate off the core and protective cover in an exceedingly series of zig-zag bounces, adhering to a method referred to as total internal reflection. The light signals don't travel at the speed of light due to the denser glass layers, instead traveling concerning 30th slower than the speed of light. To renew, or boost, the signal throughout its journey, fiber optics transmission typically needs repeaters at distant intervals to regenerate the optical signal by changing it to associate degree electrical signal, process that electrical signal and re-transmitting the optical signal.[18]

1.3 Component Using in Optical Link:

A fiber-optic link (or fiber channel) is a part of an optical fiber communications system which provides a data connection between two points (point-to-point connection). It essentially consists of a data transmitter, a transmission fiber (in some cases with built-in fiber amplifiers), and a receiver. Even for very long transmission distances, extremely high data rates of many Gbit/s or even several Tbit/s can be achieved.

The used components, which are mostly based on fiber optics, are explained in the following, beginning with a simple single-channel system. More sophisticated approaches are discussed thereafter.[19]

1.3.1 Transmitter:

A transmitter is associate device employed in telecommunications to provide radio waves so as to transmit or send knowledge with the help of associate antenna. The transmitter is in a position to get a frequency that's then applied to the antenna, which in turn, radiates this as radio waves.

1.3.2 Receivers:

Receiver is essentially a photo detector that converts light-weight into electricity exploitation the photoelectric result. The image detector is additionally a semiconductor-based photodiode.

1.3.3 Fiber Optic Sensors:

A fiber optic detector could be a detector that uses glass fiber either because the detector, or as a method of relaying signals from an overseas detector to the electronics that method the signals. Fibers have several uses in remote sensing. reckoning on the applying, fiber could also be used due to its tiny size, or as a result of no electric power is required at the remote location, or as a result of several detectors may be multiplexed on the length of a fiber by mistreatment light-weight wavelength shift for every sensor, or by sensing the time delay as light-weight passes on the fiber through every detector. Time delay may be determined employing a device like an optical time-domain meter and wavelength shift may be calculated mistreatment an instrument implementing optical frequency domain reflectometry.[20]

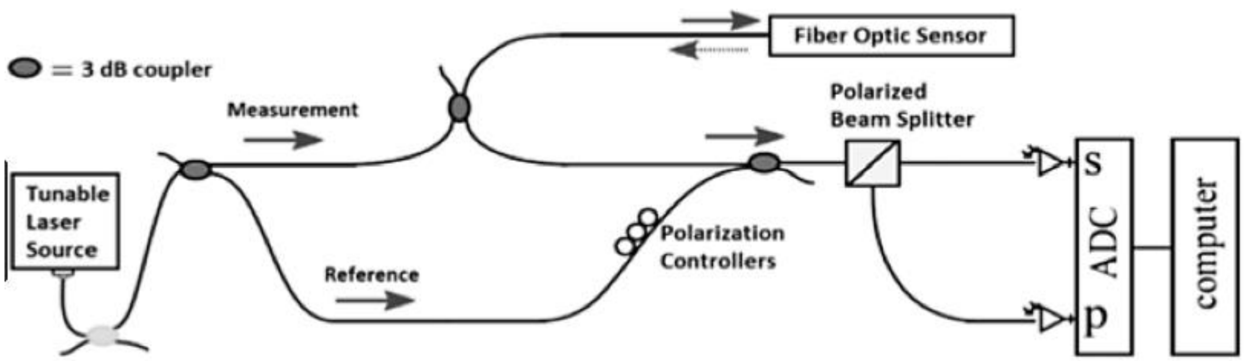


Fig 1.8: Block diagram of fiber optic sensor A Classification of optic fiber sensor (Based on sensor location).[21]

1.3.4 Light Source Used in Optical Communication:

Light source plays a major half in a very fiber optic communication system. The choice of AN optical supply is decided by the actual application for prime speed, fiber optic communication systems, that operate at speed above 1 Gbit/s, the choice of sunshine supply is even additional important. The supply ought to meet many basic necessities. Physical dimensions to suit the fiber pure mathematics.[22][23]

- Slender radiation diagram (beam width)
- Ability to be directly modulated by variable driving current
- Quick latent period
- Adequate output power to couple into the fiber
- Slender spectral dimension
- Driving circuit problems and Stability, Efficiency, Reliable, and Price.

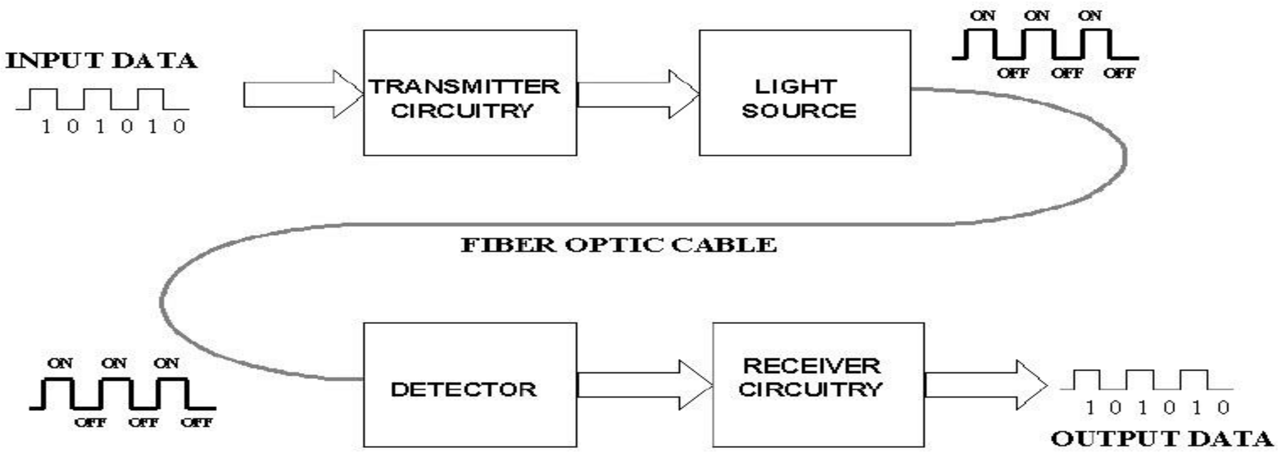


Fig 1.9: Block diagram of optical communication.[23]

1.4 LED:

Light-emanating diode could be a P-N semiconductor device during which the recombination of electrons and openings yields a photon. At the purpose once the diode is electrically one-sided the forward approach, it emanates entailed limit vary lightweight. At the point when a voltage is connected to the leads of the LED, the electrons recombine with the openings within the contraption and discharge vitality as photons. This impact is named as electroencephalogram. It’s the modification of electrical vitality into lightweight. The shade of the light is chosen by the vitality band hole of the fabric. The use of LED is helpful because it expands less power and creates less heat. LEDs last longer than bright lights. LEDs may turn out to be the up and coming back era of lighting and used anywhere like in sign lights, computer segments, healthful gadgets, watches, instrument boards, switches, fiber-optic correspondence, emptor hardware, relative apparatuses, and so on.[22][24]

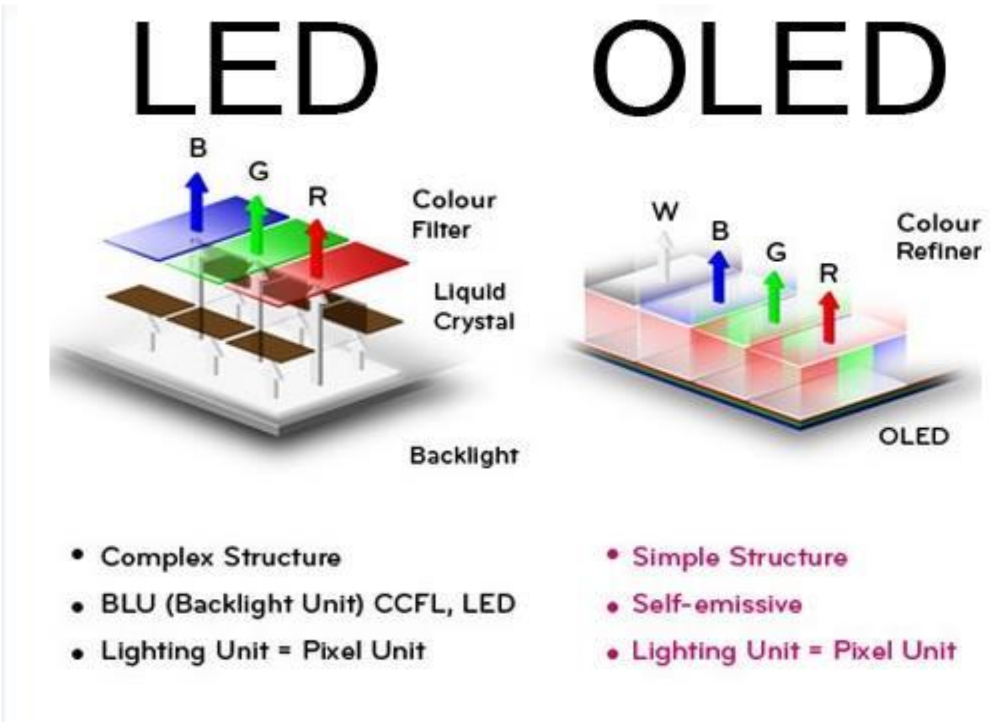


Fig 1.10: LED vs OLED.[24]

1.5 Laser Diode:

The conditions of the sources incorporate power, speed, supernatural line dimension, clamor, toughness, cost, temperature, etc. Two components are employed as light-weight sources: light-weight discharging diodes (LED's) and optical maser diodes. The sunshine manufacturing diodes are utilized for brief separations and low data rate applications due to their low information transmission and power capacities. Two such LEDs structures incorporate Surface and Edge Emitting Systems. The surface discharging diodes are simple in arrangement and are dependable, but due to it's a lot of extensive line dimension and regulation return confinement edge diverging diode are for the foremost part utilized. Edge discharging diodes have high power and smaller line dimension capacities. For longer separations and high data rate transmission, optical maser diodes are favored due to its powerful, fast and smaller phantom line dimension qualities. [22][26]

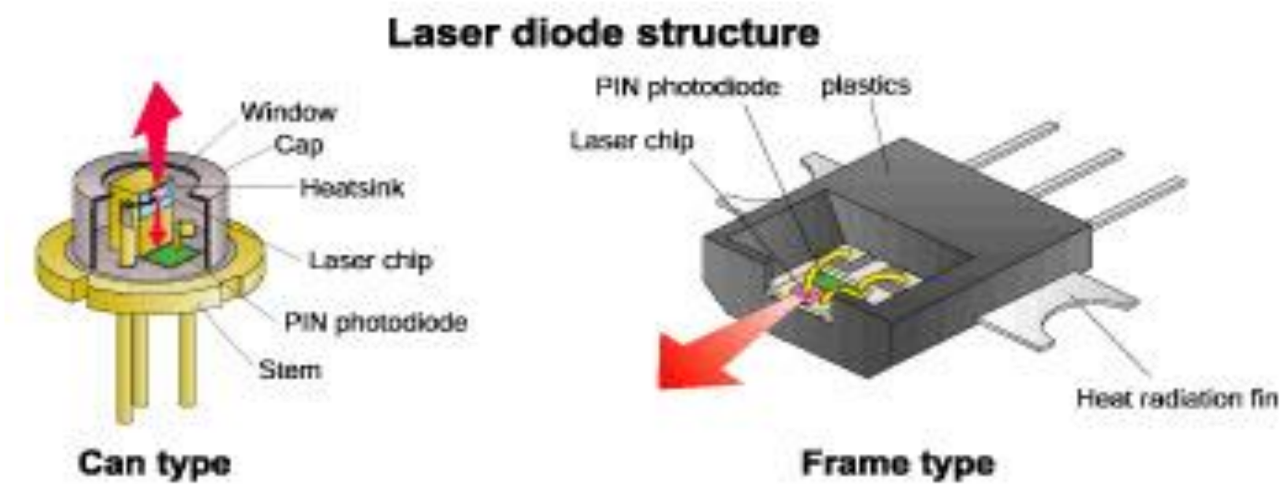


Fig 1.11: Structure of Laser diode.[25]

1.5.1 Edge Emitting Laser:

Semiconductor laser is sorted into two classes:

1. Edge-emitting lasers, wherever the optical maser light-weight is propagating parallel to the wafer surface of the semiconductor chip and is mirrored or coupled out at a cleaved edge.
2. Surface-emitting lasers, wherever the sunshine propagates in the direction perpendicular to the semiconductor wafer surface.

Edge-transmitting lasers are the primary and still generally used kind of semiconductor lasers. Their resonator length is often between a pair of hundred micrometers and a pair of millimeters. This is often adequate for achieving a high develop.

Semiconductor lasers will be assembled into 2 classes: Edge-producing lasers, wherever the optical device light is proliferating parallel to the wafer surface of the semiconductor chip and is mirrored or coupled out at a cut edge. Surface-radiating lasers, wherever the light engenders toward the trail opposite to the semiconductor wafer surface.[27]

(a) Surface diverging

(b) Edge-producing

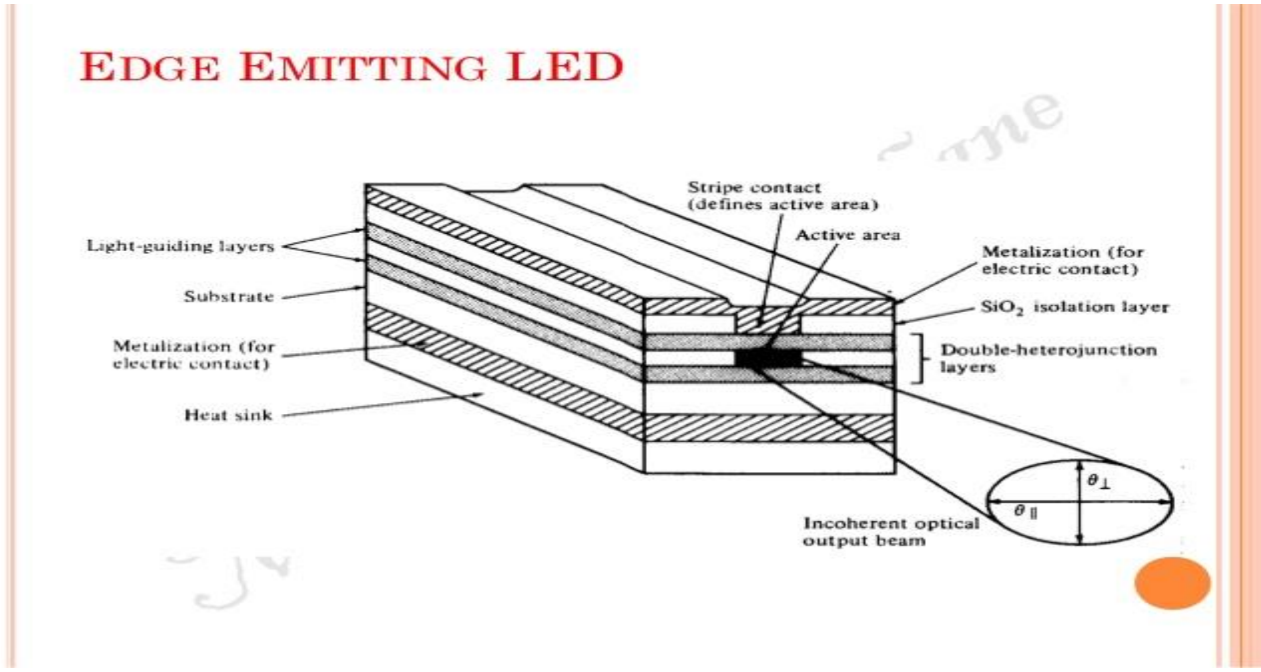


Fig 1.12: EDGE emitting LED.[28]

1.5.2 Vertical Cavity Surface Emitting Laser:

The vertical-hole surface-transmitting laser, or VCSEL, is a sort of semiconductor laser diode with laser shaft emanation opposite from the top surface, in spite of regular edge-producing semiconductor lasers (additionally in-plane lasers) which discharge from surfaces framed by separating the individual chip out of a wafer. VCSEL applications incorporate fiber optic interchanges, exactness detecting, PC mice and laser printers.[29][30]

1.5.3 Structure of VCSEL:

The optical device resonator contains of two confiscated bragg reflector (DBR) mirrors parallel to the wafer surface with a dynamic district comprising of a minimum of one quantum wells for the optical device light era within the middle. The coplanar DBR-mirrors comprise of layers with exchanging high and low refractive files. Every layer has a thickness of a fourth of the optical device wavelength within the material; yielding power reflectivity's over 99. High reflectivity mirrors are needed in VCSELs to regulate the short polar length of the pickup area.

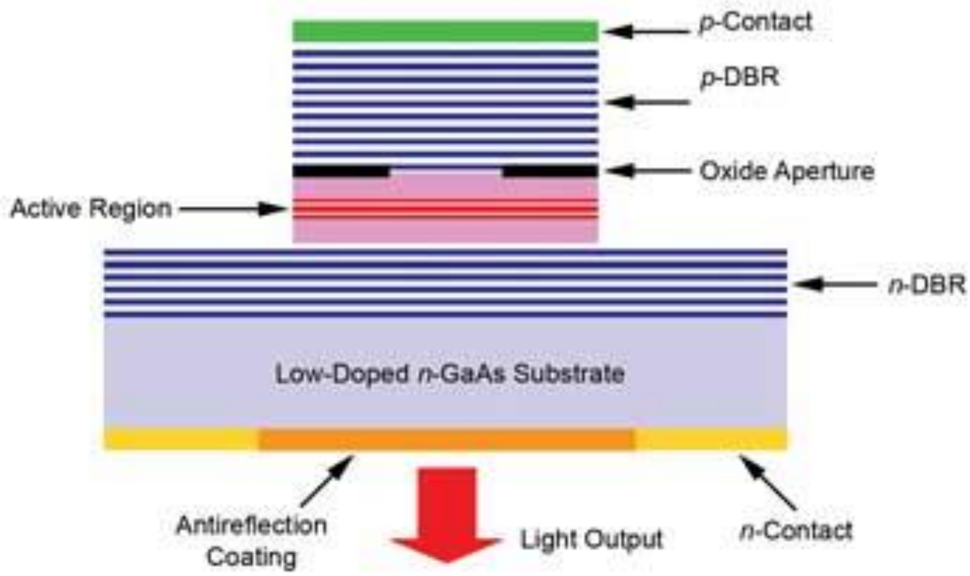


Fig 1.13: A realistic VCSEL device structure. This is a bottom-emitting multiple-quantum-well VCSEL.[31]

- In like manner VCSELs the higher and lower mirrors are doped as p-sort and n-sort materials, shaping a diode intersection. In additional complex structures, the p-sort and n-sort districts may be put in between the mirrors, requiring a additional incredible semiconductor procedure to succeed in to the dynamic area, nevertheless dispensing with power misfortune within the DBR structure. In center examination of VCSELs utilizing new material frameworks, the dynamic space may be tense by an outdoor light with a shorter wavelength, usually another optical device. This allows a VCSEL to be exhibited while not the additional issue of accomplishing nice electrical execution; but such gadgets don't seem to be right down to earth for typically applications. VCSELs for wavelengths from 650 nm to 1300 nm are unremarkably in sight of gallium arsenide (GaAs) wafers with DBRs framed from GaAs and aluminum gallium arsenide (AlxGa(1-x)As). The GaAs– AlGaAs framework is favored for developing VCSELs on the grounds that the cross sections steady of the fabric doesn't disagree firmly because the arrangement is modified, permitting numerous "grid coordinated" epitaxial layers to be developed on a GaAs substrate. In any case, the refractive list of AlGaAs varies usually unquestionably because the Al portion is enlarged, limiting the amounts of layers needed to border a skilled bragg mirror contrasted with alternative hopeful material frameworks. Moreover, at high aluminum fixations, an oxide can be shaped from AlGaAs, and this oxide can be utilized to confine the current in a VCSEL, empowering low limit streams.[31]

1.5.4 CW Laser:

A continuous waveform (CW) is an electromagnetic wave of constant amplitude and frequency, almost always a sine wave that for mathematical analysis is considered to be of infinite duration. Continuous wave is also called to an early method of radio transmission, in which a sinusoidal wave is switched on and off as called Morse code. Being carried in the varying duration of the on and off periods of the signal is information.

The ideal radio wave for radio telegraphic communication would be a sine wave with zero damping, a continuous wave. Theoretically there has no bandwidth in an unbroken continuous sine wave, energy is concentrated at a single frequency and doesn't interfere with transmissions on other frequencies. Continuous waves could not be produced with an electric spark, but were achieved with the vacuum tube electronic oscillator.

Continuous wave vacuum tube transmitters around 1920 were replaced Damped wave, and damped wave transmissions were finally outlawed in 1934.[33]

Fig 1.14: CW Laser Diode.[71]

1.6 Simulation Software:

Our CW based optical data transmission system is designed and simulated in “OPTISYSTEM” software.
OptiSystem is an optical communication system simulation package for the design, testing, and

optimization of virtually any type of optical link in the physical layer of a broad spectrum of optical networks, from analog video broadcasting systems to intercontinental backbones. A system level simulator based on the realistic modeling of fiber-optic communication systems, OptiSystem possesses a powerful simulation environment and a truly hierarchical definition of components and systems. Its capabilities can be easily expanded with the addition of user components and seamless interfaces to a range of widely used tools.OptiSystem is compatible with Optiwave's OptiAmplifier and OptiBPM design tools. OptiSystem serves a wide range of applications, from CATV/WDM network design.
The optisystem software package has three major sections that are Transmission section, Channel section and Receiver section.[34]

1.6.1 Transmission Section:

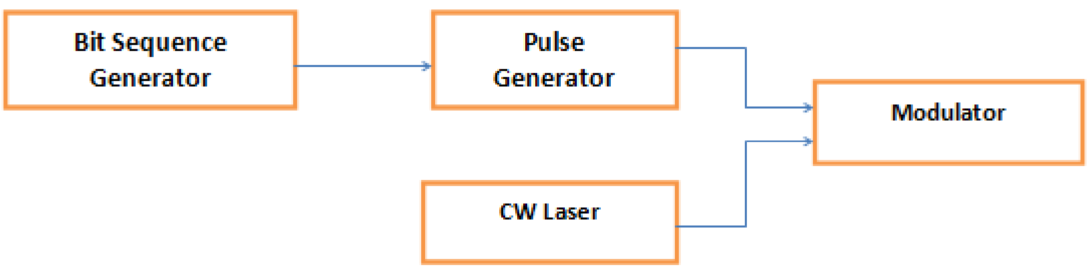


Fig 1.15: Transmission section

1.6.2 Bit Sequence Generator:

The output of the PRBSG is termed a pseudorandom bit sequence. There are many sorts of PRBSG such as MLS, QRB, HAB, TPB and QRT. MLS is one in every of the foremost necessary categories of PRBSG and employed in planning the PRBS generator because of its simplicity in construction. It's excellent pseudo randomness properties and fulfills all randomness criteria.

(a) Balance property

(b) In every amount of random sequence of the amount of logic zeros mustn't take issue from the number of logic ones by at the most one.

(c) Run property

Let a run sit down with a string of consecutive ones. The zero runs and one run alternate with equally several zero runs and one runs of the identical length. The lengths of runs in every amount are distributed such one half the runs are of length one, one quarter the runs are of length two, one eighth the runs are of length three etc.

(d) Correlation property

If amount of the random sequence is compared term by term with any cyclic shift of itself, then the amount of agreements and disagreements shouldn't take issue by quite one.[35][36]

1.6.3 Pulse Generator:

The output of PRBSG is then sent to generator to convert the bit sequence into rectangular pulse. A generator is either an electronic circuit or a bit of electronic equipment used to generate rectangular pulses. Electrical bit "1" was related to a better optical intensity, while bit "0" was related to a lower optical intensity. 2 formats are enclosed during this modulation group: NRZ and RZ. NRZ is that the oldest and simplest modulation format and it's obtained by shift optical device supply between ON or OFF. RZ describes a line code used in telecommunication signals during which the signal drops to zero between every pulse. Generator is used to drive devices like lasers and optical elements, modulators, it's been demonstrated numerically and through an experiment that the traditional NRZ modulation format is superior compared to the RZ modulation causes a big eye nearer penalty near finish channels. As a generator, we've got used NRZ and RZ generator that has rectangular shape, 1a.u amplitude, 0.05 bit rise time, 0.05 fall time.[37][38]

1.6.4 Bias Current:

Bias generator is additionally referred to as a driver circuit that is employed to drive the VCSEL within the optical data transmission. It constitutes an electrical supply that generates current on the optical maser input. Amplitude of one is employed here to design this bias generator for this technique.

1.6.5 Optical Modulator:

An optical modulator may be a device that is employed to modulate a beam of sunshine. The beam is also carried over free area, or propagate through an optical conductor. Counting on the parameter of a lightweight beam that is manipulated, modulators is also classified into amplitude modulators, phase modulators, polarization modulators etc. Modulators contains a fabric that changes its optical properties under the influence of an electrical or flux. Normally three approaches are used

(i) Electro-optic and Magneto-optic Effects

There are several materials that change their optical properties within the presence of either an electrical or a flux. This property modification is typically a change in ratio and most frequently this change is totally different for incident lightweight of various polarizations. Any changes within the ri cause changes in section of the light passing through it. Phase modulation of this type isn't very helpful to us. However, alternative device is also wont to convert the state change into an amplitude change. Most speed modulators are designed around this principle.

(ii) Electro-Absorption Effects

An ideal easy modulator may contain a fabric that had a variable absorption of light depending on the presence of an applied field of force. However there don't seem to be too several materials like this. However, a contact in a very 3-5 semiconductor will behave this fashion and this material is used to build modulators.

(iii) Acoustic Modulators

Acoustic modulators use terribly high frequency sound move among a crystal or two-dimensional wave guide to deflect light from one path to a different. By dominant the intensity of the sound we are able to control the quantity of light deflected and therefore construct a modulator.

In our projected technique we have a tendency to use Mach-Zender modulator with extinction quantitative relation of 6dB and symmetry issue of one, wherever tiny changes in ratio induced by an electrical field cause large changes in signal amplitude at the output. In one arm the ri can increase and within the alternative arm it'll decrease. This causes the signal in one arm to be backward in section and therefore the signal in the other arm to be advanced. Once the signal is recombined at the output junction, the very small section changes can cause interference effects. These interference effects cause terribly massive variations within the amplitude of the optical signal terribly considerably in step with an applied electrical field. The standard material wont to build measuring system modulators is lithium niobate. As considerable exactitude in manufacture is required these are typically created in two-dimensional conductor technology instead of as fiber devices.[39]

1.6.6 Channel Section:

Fig 1.16: Channel Section

1.6.7 Optical Fiber:

Optical fibers may be accustomed transmit light-weight and therefore info over long distances. They are widely used for telecommunication, however additionally for web traffic, long high-speed native space networks, cable TV and progressively additionally for shorter distances among buildings. In most cases, silicon dioxide fibers are used, apart from terribly short distances, wherever plastic optical fibers may be advantageous.

Compared with systems supported electrical cables, the approach of glass fiber communications has benefits, the foremost necessary of that are:

1. The capability of fibers for knowledge transmission is huge: one silicon dioxide fiber will carry

Hundreds of thousands of phone channels, utilizing solely a tiny low a part of the theoretical capacity. Within the last thirty years, the progress regarding transmission capacities of fiber links has been considerably quicker than e.g. the progress within the speed or storage capability of computers.

2. The losses for light-weight propagating in fibers are astonishingly little; ~0.2 dB/km for contemporary single mode silicon dioxide fibers, in order that several tens of kilometers may be bridged while not amplifying the signals.

3. An outsized range of channels may be re-amplified during a single fiber-amplifier, if needed for very massive transmission distances.

4. The large transmission rate accomplishable, the price per transported bit may be extremely low.

5. Compared with electrical cables, fiber-optic cables are terribly light-weight.

Two varieties of glass fiber are utilized in optical communication system, just in case of medium or long-distance transmission, the fiber is sometimes one mode fiber except for short distances communication multimode fiber is employed. Once light-weight enters one finish of the fiber, it opened up during transmission through the fiber and dispersion happens. Due to dispersion a brief pulse becomes longer and ultimately joins with the heartbeat behind, creating recovery of a reliable bit stream not possible. There are several types of dispersion, every of that works during a totally different means, but the foremost necessary 3 are mentioned below:

(i) Material Dispersion

Because of the actual fact that the index of refraction of the glass we tend to are mistreatment varies with the wavelength. Some wavelengths thus have higher cluster velocities and then travel quicker than others. Since each pulse consists of a spread of wavelengths it'll opened up to some degree throughout its travel. All optical signals encompass a spread of wavelengths. This vary could be solely a fraction of a micro millimeter wide however there's invariably a spread concerned.

(ii) Conductor Dispersion

The design of the fiber contains a terribly important impact on the cluster rate. It is often as a result of the electric and magnetic fields that represent the heartbeat of sunshine extend outside of the core into the protection. The quantity that the fields overlap between core and protection depends powerfully on the wavelength. The longer the wavelength the more the no particulate radiation extends into the protection.

(iii) Modal Dispersion

In mistreatment multimode fiber, the light is in a position to require many alternative ways because it travels among the fiber. The space traveled by light-weight in every mode is totally different from the space cosmopolitan in alternative modes. Once a pulse is distributed, components of that pulse take many alternative modes.

Therefore, some parts of the heartbeat can arrive before others. The distinction between the arrival times of sunshine taking the quickest mode versus the slowest clearly gets larger as the distance gets larger. The good news here is that these 2 varieties of dispersion have opposite signs, so that they tend to counteract each other thus dispersion are decreased. So, single mode fiber has lower dispersion than multi-mode fiber.[4][40]

1.6.8 Optical Amplifier:

An optical electronic equipment may be a device that amplifies an optical signal directly, while not the requirement to first convert it to an electrical signal. AN optical electronic equipment is also thought of as an optical device while not an optical cavity, or one during which feedback from the cavity is suppressed.[41]

1.6.9 Semiconductor Optical Amplifier (SOA):

A semiconductor optical electronic equipment is an optical electronic equipment supported a semiconductor gain medium. it is basically sort of optical maser diode wherever the top mirrors are replaced with antireflection coatings, a tipped conductor will be wont to more cut back the top reflectivity. The signal light is typically sent through a semiconductor single-mode conductor with transversal dimensions of e.g. 1–2 μm and a length of the order of zero.5–2 mm. The conductor mode has significant overlap with the active (amplifying) region that is pumped-up with an electrical current. The injection current creates a particular carrier density within the conductivity band, with optical transitions from the conductivity band to the valence band. The gain most happens for photon energies slightly on top of the band gap energy.

In principle, one can even use a semiconductor optical electronic equipment wherever the top reflectivity's are not reduced. One must operate such a Fabry–Pérot amplifier (FP amplifier) slightly below the optical maser threshold; in this regime, the output power depends powerfully on the input power, one obtains a high effective signal gain. However, the obtainable optical information measure is then very small, and therefore the prevalence of sturdy reflections is also prejudicial to the system within which such a device is employed. For these reasons, in most cases one uses traveling-wave amplifiers, where the end reflectivity are suppressed as way as attainable. The amplification is per se polarization-sensitive, however electronic equipment styles are developed which give nearly polarization-independent characteristics. For instance, one may use two identical amplifiers nonparallel, wherever the second is turned against the primary one by 90°C. There are configurations with two parallel amplifiers for the two polarization directions, with polarizing beam splitters before and when these amplifiers. Another chance is to use a double tolerate one electronic equipment, wherever there's a chemist rotator between the devices and therefore the reflective mirror.

SOAs will be employed in medium systems within the sort of fiber-pigtailed elements (with either normal single-mode fibers or polarization-maintaining fibers), operational at signal wavelengths near 1.3 μm or 1.5 μm, and giving a gain of up to ≈ 30 sound unit, restricted basically by amplified spontaneous emission (ASE). The strong gain saturation in SOAs will be a controversy for a few applications, however it can even be exploited for nonlinear signal process in medium systems, for example the channel translation during a wavelength division multiplexes system.[41][42]

1.6.10 Erbium Doped Fiber Amplifier (EDFA):

Erbium-doped fiber electronic equipment (EDFA) is an optical repeater device that's won't to boost the intensity of optical signals being carried through a fiber optic communications system. The erbium-doped fiber electronic equipment (EDFA) is that the most deployed fiber electronic equipment as its amplification window coincides with the third transmission window of silica-based optical fiber. Two bands have developed within the third transmission window – the standard, or C-band, from approximately 1525 nm – 1565 nm, and therefore the Long, or L-band, from some 1570 nm to 1610 nm. Each of those bands will be amplified by EDFAs, however it's traditional to use two completely different amplifiers, every optimized for one among the bands. EDFAs have two usually used pumping bands – 980 nm and 1480 nm. The 980 nm band includes a higher absorption cross-sectional and is generally used wherever low-noise performance is needed. The optical phenomenon is comparatively narrow and then wavelength stabilized optical device sources are sometimes required. The 1480 nm band includes a lower, however broader, absorption cross-sectional and is mostly used for higher power amplifiers. A combination of 980 nm and 1480 nm pumping is mostly utilized in amplifiers.[41]

1.6.11 Advantages of EDFA:

- High power transfer potency from pump to signal power
- borderline polarization sensitivity
- Low insertion loss
- High output power > 1mW (10 to twenty-five dBm)
- terribly high sensitivity
- Low distortion and borderline inter-channel noise
- comparatively low in value and better potency.[43]

1.6.12 Receiver Section:

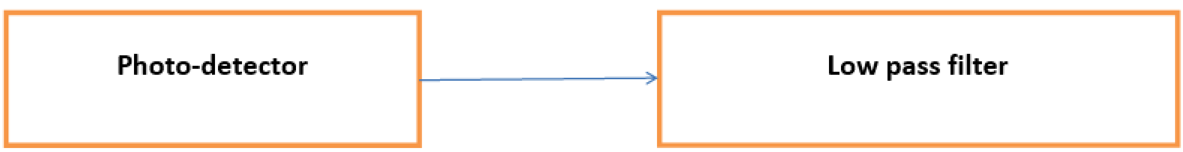


Fig 1.17: Receiver Section

1.6.13 Photo Detector:

Photo detectors, additionally referred to as photo sensors, are sensors of light or different electromagnetic wave. A photograph detector features a p–n junction that converts light photons into current. The absorbed photons build electron hole pairs within the depletion region. Photodiodes and image transistors are some samples of image detectors. Star cells convert a number of the light energy absorbed into power.

Photo detectors also classified by their mechanism for detection:

- Photoemission or photoelectrical effect:
  Photons cause electrons to transition from the physical phenomenon band of a cloth to free electrons in a very vacuum or gas.

- Thermal:
  Photons cause electrons to transition to mid-gap states then decay back to lower bands, causation phonon generation and so heat.
- Polarization:
  Photons induce changes in polarization states of appropriate materials, which can cause modification in index of refraction or different polarization effects.
- Photochemical:
  Photons induce an activity in a very material.
- Weak interaction effects:
  photons induce secondary effects like in photon drag detectors or force per unit area changes in Golay cells.

Photo detectors also utilized in completely different configurations. Single sensors might sight overall light-weight levels. A 1-D array of photo detectors, as in a very photometer or a Line scanner, is also wont to live the distribution of light on a line. A 2-D array of photo detectors is also used as a picture device to create pictures from the pattern of sunshine before it. A photo detector or array is usually lined by associate.

There are varieties of performance metrics, by that photo detectors are characterized and compared

Spectral response:
The response of a photo detector as operate of photon frequency.

Quantum efficiency:
The amounts of carriers (electrons or holes) generated per photon.

Responsivity:
The output current divided by total light-weight power falling upon the photo detector.

Noise equivalent power:
The quantity of light power required to get a sign comparable in size to the noise of the device.

Detectivity:
The root of the detector space divided by the noise equivalent power.

Gain:
The output current of a photo detector divided by this directly created by the photon incident on the detectors, the inherent current gain.

Dark current:
This flowing through a photo detector even within the absence of sunshine.

Response time:
The time required for a photo detector to travel from tenth to 90th of ultimate output.

Noise spectrum:
The intrinsic noise voltage or current as operate of frequency. This could be described within the style of a noise spectral density.

Nonlinearity:
The RF-output is restricted by the nonlinearity of the photo detector.[44]

1.6.14 PIN Photodiode:

There are variety of performance metrics, additionally referred to as figures of benefit, by that photo detectors are characterized and compared.

A PIN diode may be a diode with a good, not doped intrinsic semiconductor region between a semiconductor device associate degreed a semiconductor unit region. The p-type and n-type regions are usually heavily doped as a result of they're used for resistance unit contacts.

The wide intrinsic region is in distinction to a standard p–n diode. The wide intrinsic region makes the PIN diode associate degree inferior rectifier (one typical operate of a diode), however it makes it appropriate for attenuators, quick switches, photo detectors, and high voltage power physics applications.

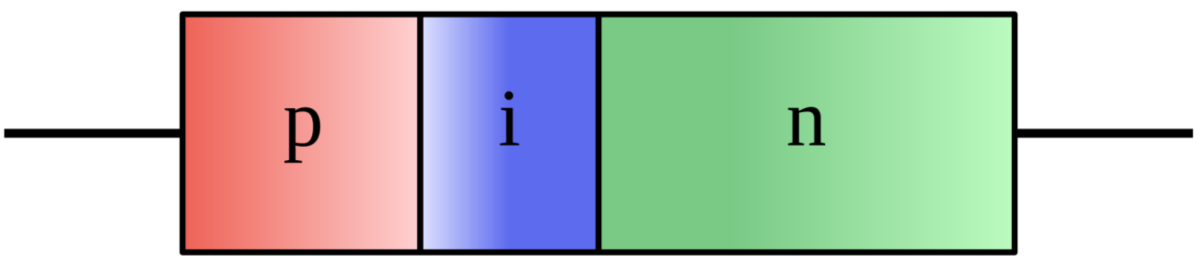


Fig 1.18: PIN Photodiode.[45]

PIN photo detectors performance is quit high because the short noise affects it gently. However just in case of APD, once the dark current is high the short noise dominates the system and also the performance is greatly affected. PIN signal to noise quantitative relation is more than the APD. The PIN performs higher because the thermal noise effects decrease. Whereas, in the APD, as short noise dominates over thermal noise its performance becomes worse.[46]

1.6.15 Avalanche Photodiode (APD):

An avalanche photodiode (APD) could be a sensitive semiconductor device that exploits the physical phenomenon result to convert light to electricity. APDs is thought of as photo detectors that give an intrinsic initial stage of gain through avalanche multiplication. Since APD gain varies powerfully with the applied reverse bias and temperature, it's necessary to manage the reverse voltage to stay a stable gain. Avalanche photodiodes thus are a lot of sensitive compared to different semiconductor photodiodes. APDs that operate during this high-gain regime are in Hans Geiger mode. This mode is especially helpful for single-photon detection, only if the dark count event rate and after pulsing likelihood are sufficiently low.

Typical applications for APDs are optical maser rangefinders, long-range fiber-optic telecommunication, and quantum sensing for acid-based management algorithms.

APD relevancy and quality depends on several parameters. Two of the larger factors are: quantum potency that indicates however well incident optical photons are absorbed so won't to generate primary charge carriers, and total outflow current, that is the added of the dark current and photocurrent and noise. Electronic dark-noise elements are series and parallel noise**.** APDs are inherently noisy as the multiplier factor result applies to any or all free electrons. This can be particularly an issue in longer wavelength devices wherever the band gap energy is low.[47]

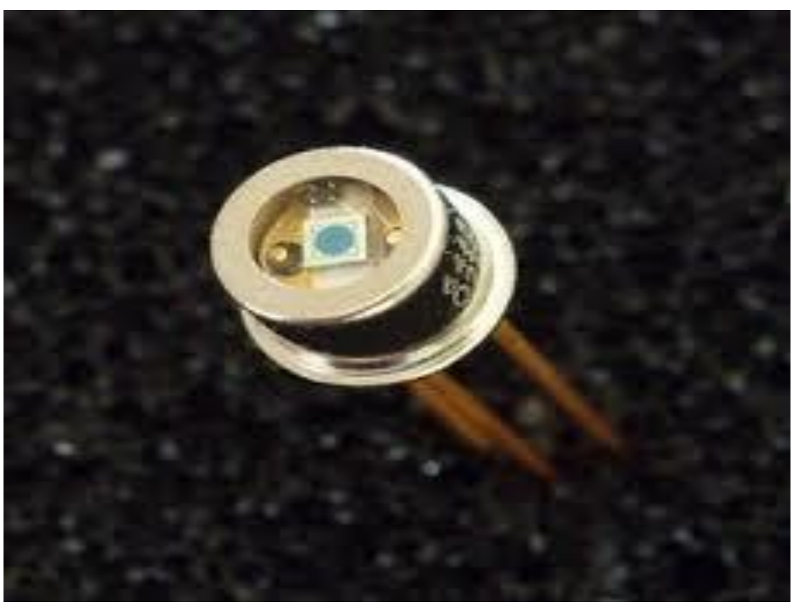


Fig 1.19: Avalanche Photodiode.[47]

1.6.16 Low Pass Filter:

A low-pass filter (LPF) could be a filter that passes signals with a frequency less than a particular cutoff frequency and attenuates signals with frequencies beyond the cutoff frequency. The precise frequency response of the filter depends on the filter style. The filter is typically referred to as a high-cut filter, or treble-cut filter in audio applications. A low-pass filter is that the complement of a high-pass filter. Low pass filter is employed at demodulator or receivers. Before causing the info through fiber, we modulate the info, thus modulated information have terribly high frequency elements. We want to extract the information to low frequency and during this case we want low pass filter that passes signals with a frequency less than a particular cutoff frequency and attenuates signals with frequencies beyond the cutoff frequency. Its sort might vary in line with its applications and type of receivers.[48]

Here are the common kinds of filter response:

1. Butterworth
2. Chebyshev
3. Inverse Chebyshev
4. Elliptical
5. Bessel

1.7 Modulation:

Modulation technique is capitally two types

1. Direct modulation:

In this modulation laser is modulated directly without the help of any modulation circuitry.

2. External modulation:

Here, modulation technique laser is modulated externally with the help of pulse generator and modulator.

1.7.1 NRZ Modulation:

In telecommunication, a non-return-to-zero (NRZ) line code may be a code within which ones are diagrammatic by one vital condition, sometimes a positive voltage, whereas zeros are diagrammatic by another vital condition, sometimes a negative voltage, with no alternative neutral or rest condition. NRZ isn't inherently a self-clocking signal, thus some further synchronization technique should be used for avoiding bit slips, samples of such techniques are a run-length-limited constraint and a parallel synchronization signal. NRZ-level itself isn't a synchronous system however rather a coding which will be employed in either a synchronous or asynchronous transmission setting, that is, with or while not a certain clock signal concerned.[38]

1.7.2 RZ Modulation:

Return-to-zero (RZ or RTZ) describes a line code employed in telecommunications signals during which the signal drops (returns) to zero between every pulse. This takes place whether or not variety of consecutive 0s or 1s occurs within the signal. The signal is self-clocking. This implies that a separate clock doesn't must be sent alongside the signal, however suffers from exploitation doubly the information measure to realize the identical data-rate as compared to non-return-to-zero format.

The "zero" between every bit may be a neutral or rest condition, like a zero amplitude in pulse modulation (PAM), zero section shift in phase-shift keying (PSK), or mid-frequency in frequency-shift keying (FSK).[49]

1.8 Wavelength Division Multiplexing (WDM):

Wavelength Division Multiplexing (WDM) is an optical fiber technology which multiplexes a number of optical carrier signals onto a single optical fiber by utilizing different wavelengths of light. The word wavelength-division multiplexing is generally used for an optical carrier, which is typically represented by its wavelength which is described by frequency. A WDM system uses a multiplexer at transmitter to join the several signals together and a de multiplexer at the receiver to split them apart. By using WDM and optical amplifiers, they can accommodate several generations of technology development in their optical infrastructure. WDM systems can manage160signals which will extend a 10Gbit/s system with a single fiber optic pair of conductors to more than 1.6 Tbit/s

WDM systems are divided into three various wavelength forms:

1. Normal WDM
2. Coarse WDM
3. Dense WDM

WDM, CWDM, DWDM depend on a similar idea of utilizing various wavelengths of light on a single fiber yet the wavelength are differ in spacing.[50]

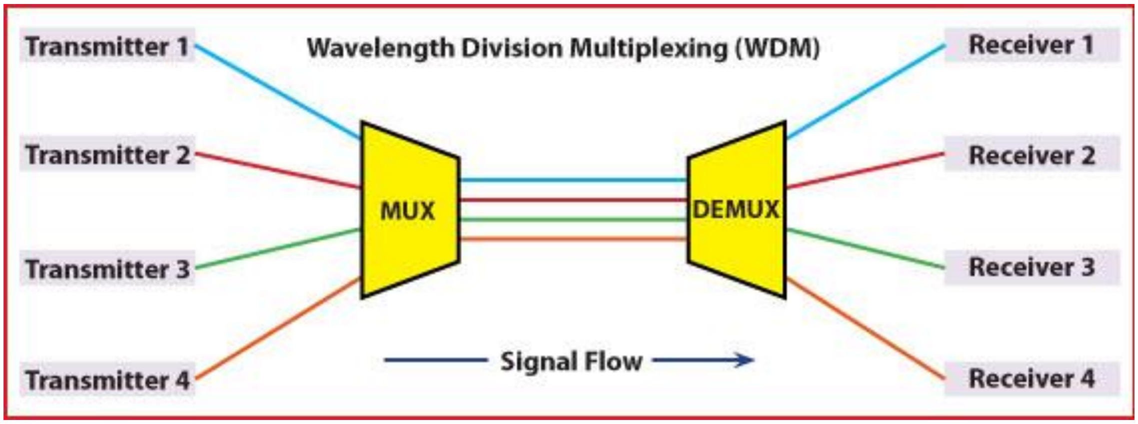


Fig 1.20: WDM system.[50]

1.9 Visualizes Used for Performance Testing:

From CW laser primarily based system we get the performance like output power worth, signal quality, Bit error rate, Optical signal to noise magnitude relation we have a tendency to used 3 visualizes that are optical meter, optical spectrum analyzer and BER analyzer.[51]

1.9.1 BER Analyzer:

The bit error rate (BER) is that the variety of bit errors per unit time. The bit error magnitude relation (also BER) is that the variety of bit errors divided by the entire variety of transferred bits throughout a studied interval. Bit error magnitude relation may be a unit less performance live, typically expressed as a proportion. Bit error rate instrument measures the performance of the system supported the signal before and after the propagation. Bit error rate instrument is employed to determine the standard issue like Quality factor, Bit error rate, Eye height, Optical signal to noise magnitude relation. It's associate degree experimental tool for the analysis of the combined effects of channel noise on the performance of a baseband pulse transmission.[52][54]

1.9.2 Quality Factor:

The quality issue or letter issue could be a dimensionless parameter that describes however under damped associate degree generator or resonator is, and characterizes a resonator's information measure relative to its center frequency. Higher letter indicates a lower rate of energy loss relative to the hold on energy of the resonator; the oscillations die out additional slowly.[53]

1.9.3 Bit Error Rate:

BER is that the variety of incorrect bit divided by the overall variety of transferred bits throughout a studied amount. Because of noise, distortion or synchronization errors knowledge stream will be altered in digital transmission. The BER provides the higher limit as a result of some degradation happens at the receiver finish. The bit error is chance that the expectation price of the BER. The BER will be thought about as associate degree approximate estimate of the bit error chance. The BER is commonly expressed as operate of the normalized carrier to noise quantitative relation in a noisy channel. For optical knowledge transmission the quality price of BER for error free system is 10-12.[54]

1.9.4 Eye Pattern:

Though eye pattern is employed to visualize however the waveforms won't to send multiple bits of information will potentially result in errors within the interpretation of these bits. Vertical eye gap indicates the amount of distinction in amplitude that's gift to point the distinction between one and zero bit. The larger the distinction the simpler it's to discriminate between one and 0. Whereas, horizontal eye gap indicates the number of interference gift within the signal. Associate degree open eye pattern corresponds to stripped signal distortion. Distortions of the signal undulation because of entomb image interference and noise seems as closure of the attention diagram.[55]

1.9.5 Optical Spectrum Analyzer:

An optical spectrum analyzer (OSA) is associate degree instrument accustomed live properties of light over a particular portion of the spectrum, usually employed in spectrometry to spot materials. A spectroscope is employed in spectrometry for manufacturing spectral lines and mensuration their wavelengths and intensities. Spectrometers may additionally operate over a good vary of non-optical wavelengths. Associate degree OSA traces displays power within the vertical scale and therefore the wavelength within the horizontal scale. The increasing field of optics connected applications has created by an unlimited type of industries and organizations that need advanced optical spectral measurements for each R&D and manufacturing. These industries embrace telecommunications, client physics, healthcare, life science/medical analysis, security, sensing, microscopy, and gas/chemical analysis, and environmental observation. The foremost common application of associate degree OSA is characterizing optical components and testing optical signals in telecommunication networks. OSA usually uses either direct spectral activity or quick fourier remodel (FFT) based mostly activity.[57]

1.9.6 Optical Power Meter:

An optical electric meter (OPM) could be a device used live the ability in an optical signal. For testing average power in fiber optic system the term usually refers to a tool. Here, alternative general purposes light power activity devices are known as radiometers, photometers, optical maser power meters (can be photodiode sensors or thermometer optical maser sensors), light-weight meters or illumination unit meters. A typical optical electric meter consists of a graduated sensing element, activity electronic equipment and show. The acceptable vary of wavelengths and power levels are choice by the sensor primarily consists of a photodiode. The measured optical power and set wavelength is displayed.[56]

1.9.7 3R Generator:

An optical communications repeater is used in a fiber-optic communications system to regenerate an optical signal. Such repeaters are used to extend the reach of optical communications links by overcoming loss due to attenuation of the optical fiber. These repeaters are also called regenerators for the same reason.

Classification of regenerators:

Optical regenerations are classified into 3 categories by the 3 R's scheme-

1. R: reamplification of the data pulse alone is carried out.
2. 2R: in addition to reamplification, pulse reshaping is carried out.
3.3R: in addition to reamplification and reshaping. Retiming of data pulse is done.

3R regenerator is a subsystem based on the Data Recovery component and a NRZ pulse generator. 3R regenerator can be used to recover the bit sequence, the reference signal and the output signal. Though, it can fail for vey noise systems where the global bit rate does not match the received bit rate.[73]

Chapter-2

2.1 OptiSystem:

OptiSystem is a comprehensive software design suite that enables users to plan, test, and simulate optical links in the transmission layer of modern optical networks.[58]

2.2 SPECIFIC BENEFITS:

- Provides global insight into system performance.
- Assesses parameter sensitivities aiding design tolerance specifications.
- Visually presents design options and scenarios to prospective customers.
- Delivers straightforward access to extensive sets of system characterization data.
- Provides automatic parameter sweep and optimization.
- Integrates with the family of OptiWave products.[58]

2.3 APPLICATIONS:

Created to address the needs of research scientists, optical telecom engineers, system integrators, students and a wide variety of other users, OptiSystem satisfies the demand of the evolving photonics market for a powerful yet easy to use optical system design tool.

OptiSystem enables users to plan, test, and simulate (in both the time and frequency domain):

- Optical network designs including OTDM, SONET/ SDH rings, CWDM, DWDM, PON, Cable, OCDMA.
- Single-mode/multi-mode transmission.
- Free space optics (FSO), Radio over fiber (ROF), OFDM (direct, coherent).
- Amplifiers and lasers (EDFA, SOA, Raman, Hybrid, GFF optimization, Fiber Lasers).
- Signal processing (Electrical, Digital, All-Optical).
- Transmitter and receiver (direct/coherent) sub system design.
- Modulation formats (RZ, NRZ, CSRZ, DB, DPSK, QPSK, DP-QPSK, PM-QPSK, QAM-16, QAM-64).

- System performance analysis (Eye Diagram/ Q-factor/BER, Signal power/OSNR, Polarization states, Constellation diagrams, Linear and non-linear penalties).[59]

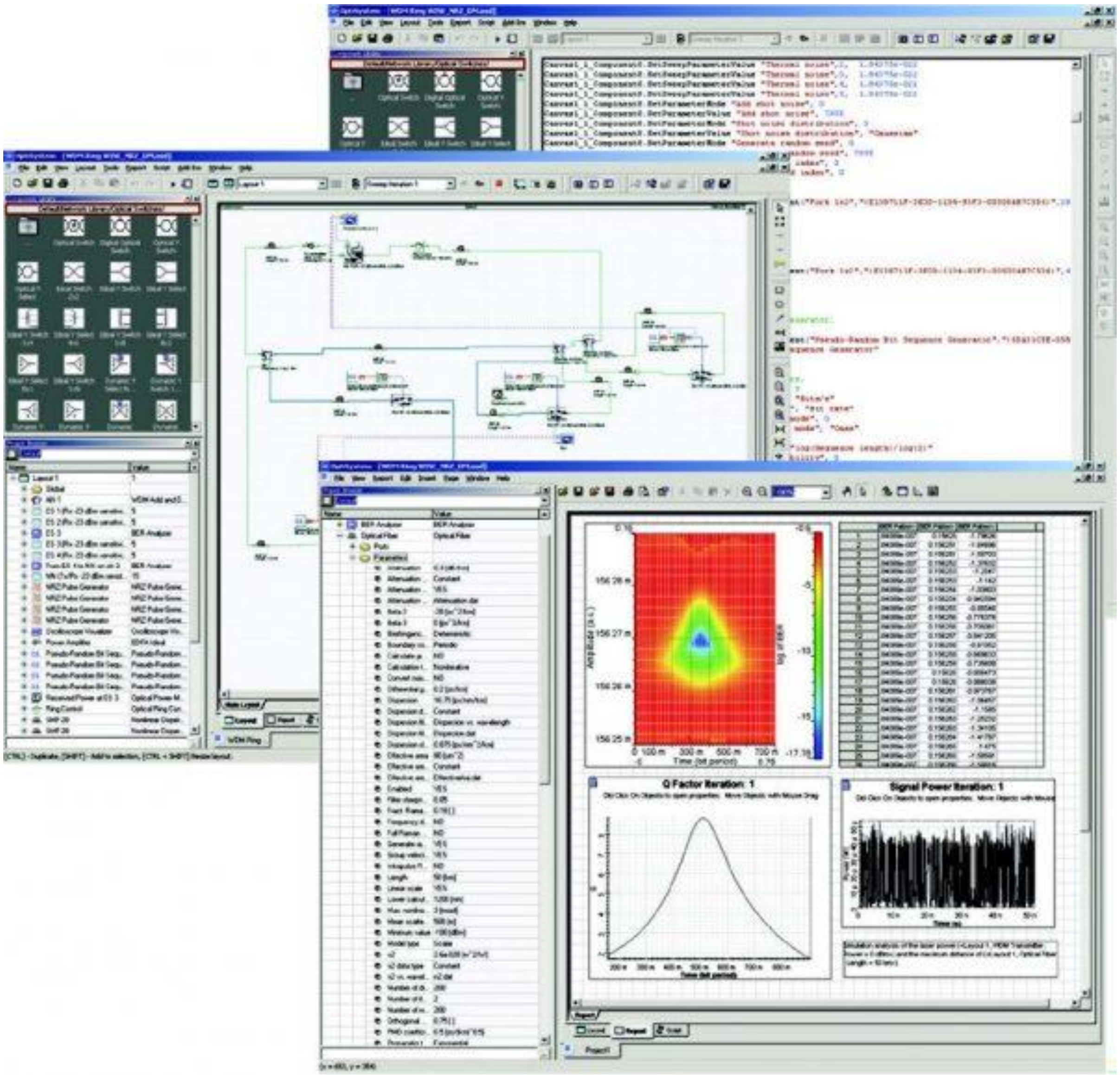


Fig 2.1: Applications of OptiSystem.[59]

2.3.1 FBG Fiber Loop Mirror Sensor Design Basics:

Fiber loop mirror configurations have been used in several different applications. One important application is sensing. Inserting a Fiber Bragg Grating (FBG) in the fiber loop mirror allows exploiting the switching feature of the loop mirror to enable enhanced sensing and accessing capabilities. A wideband LED or white source can be launched into the FBG loop mirror to create a continuous wave (CW) optical signal at the FBG center wavelength, which can be accessed from both sides of the loop by controlling the setting of a phase shifter device within the loop. The CW light wavelength changes with environmental conditions of the FBG (which include temperature, stress and strain).

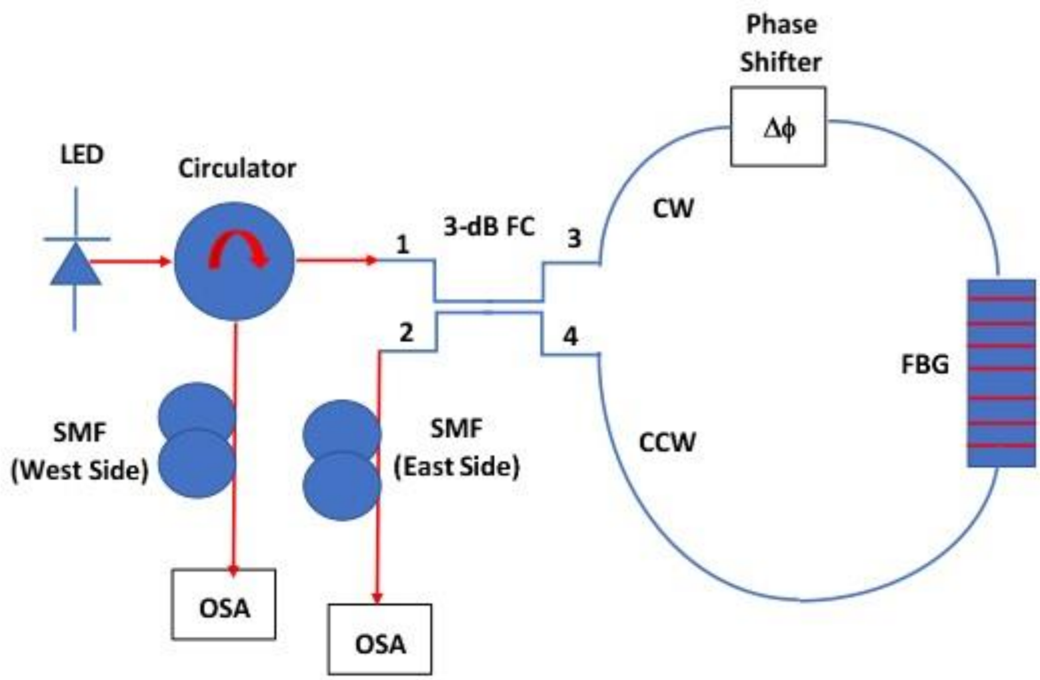


Fig 2.2: FBG Fiber Loop Mirror Sensor Design.[60]

2.3.2Signal Quality Ratios:

When designing or analyzing the performance of an analog or digital link, the following signal metrics are commonly used:
– Carrier to noise ratio (C/N)
– Noise power density (No)
– Energy per bit to noise density (EbNo)
– Energy per symbol to noise density (EsNo).

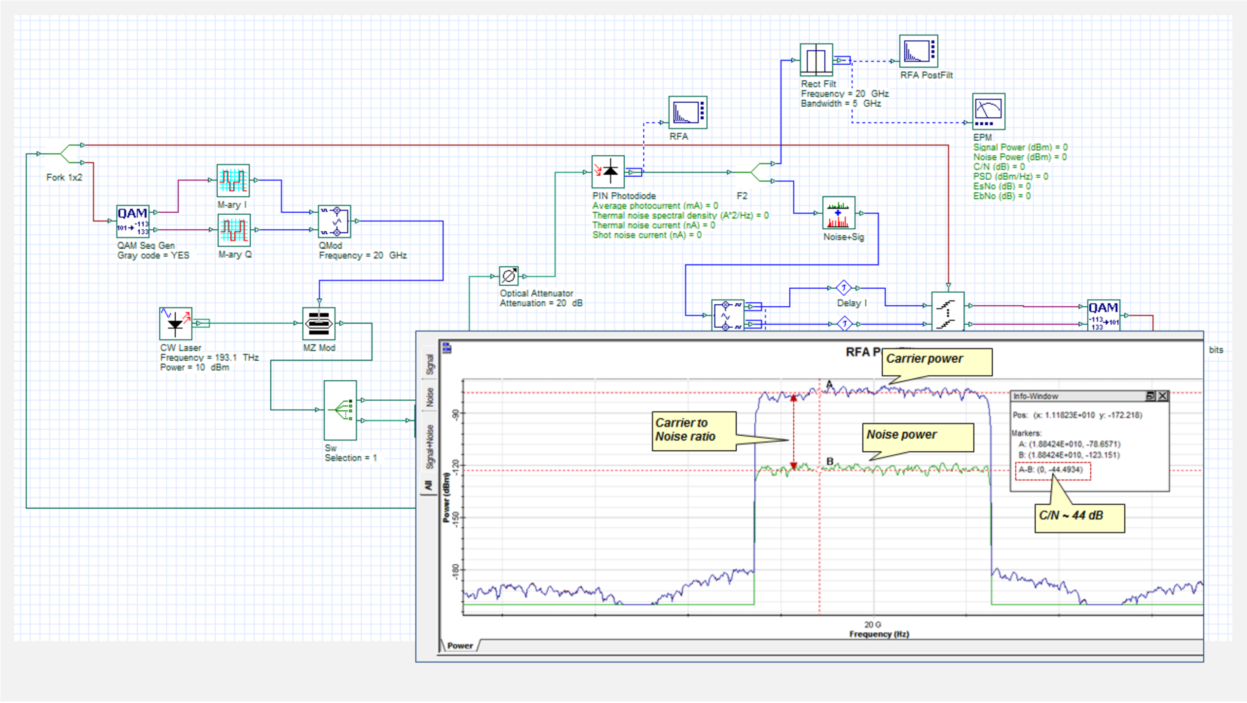


Fig 2.3: Signal Quality Ratios.[61]

2.3.3 Optical Receiver Analysis (PIN-TIA-LA):

The overall performance of a point-to-point optical communication link is normally defined based on the minimum average optical power, measured at the input to the optical receiver that is required to achieve a given BER. Known as optical receiver sensitivity, this key parameter can be used to compare different receiver configurations in order to determine the right design components for an application.

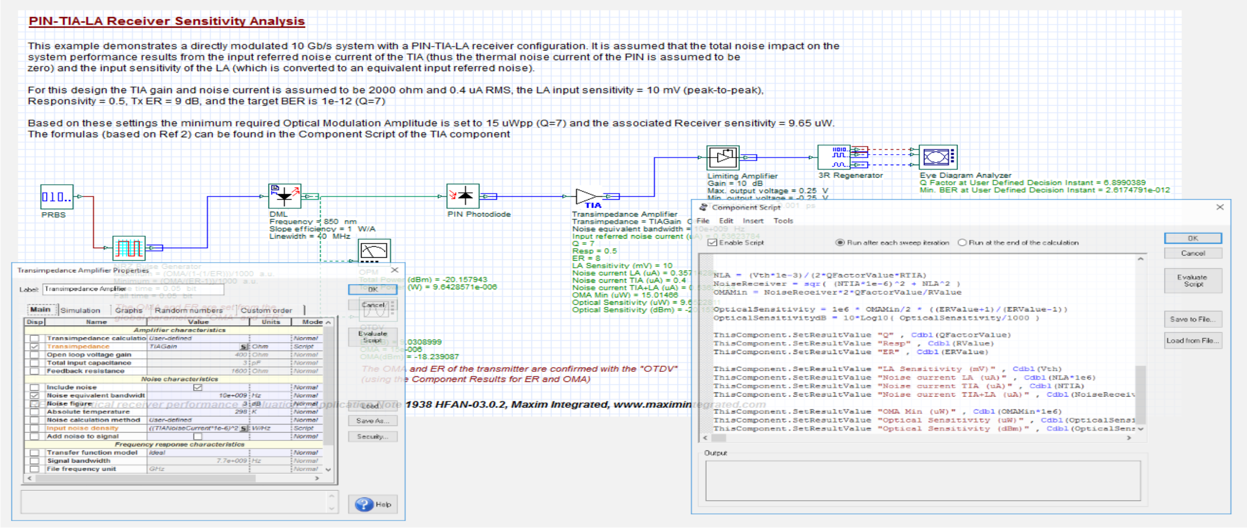


Fig 2.4: Optical Receiver Analysis.[62]

2.3.4 Matched Filter Analysis:

A matched filter is an ideal filter which acts upon a received signal so as to maximize its signal to noise ratio (SNR). Under conditions of additive white Gaussian noise, the SNR is maximized when the impulse response of the receiver filter is an exact copy of the transmitted waveform (but reversed and time delayed).

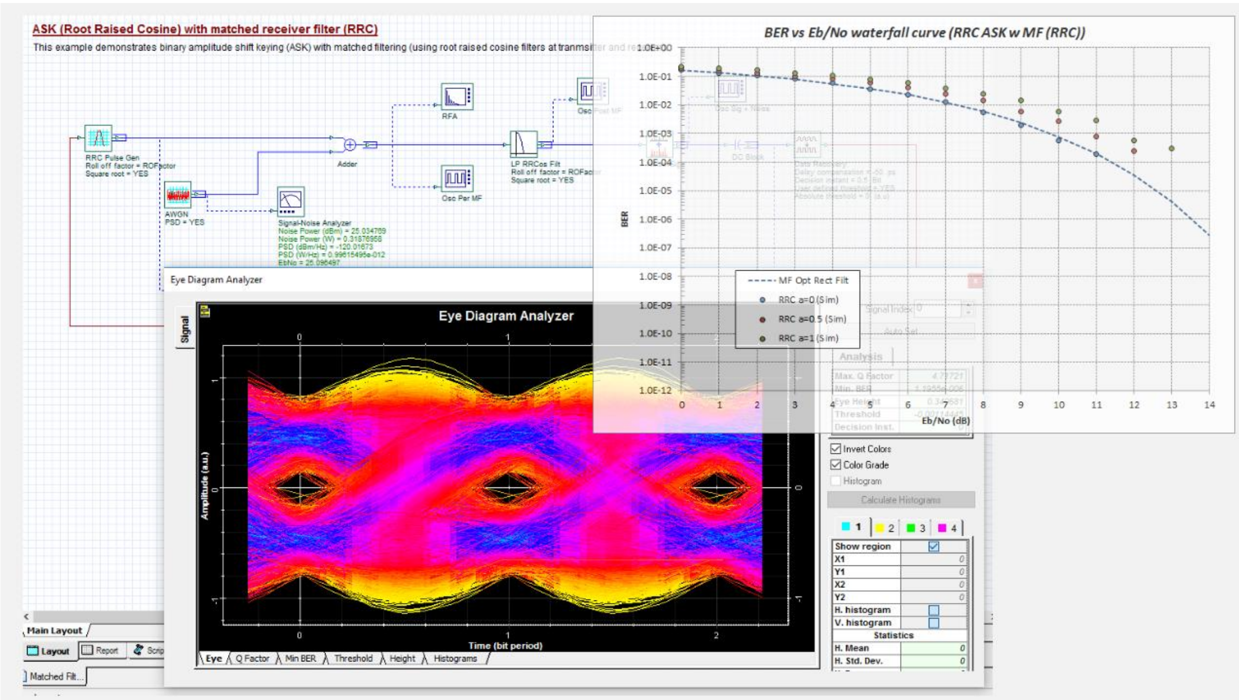


Fig 2.5: Matched Filter Analysis.[63]

2.3.5 Digital Modulation Analysis (PSK):

Digital modulation systems are used to transmit digital (quantized) information over a medium such as air or optical fiber. Transmission is achieved by mapping the information (baseband) channel onto an analog carrier channel, propagating over the medium, and then recovering the baseband channel at the receiver1. Several techniques can be used to carry the information channel and involve changing the characteristics of its analog carrier (periodic) signal.

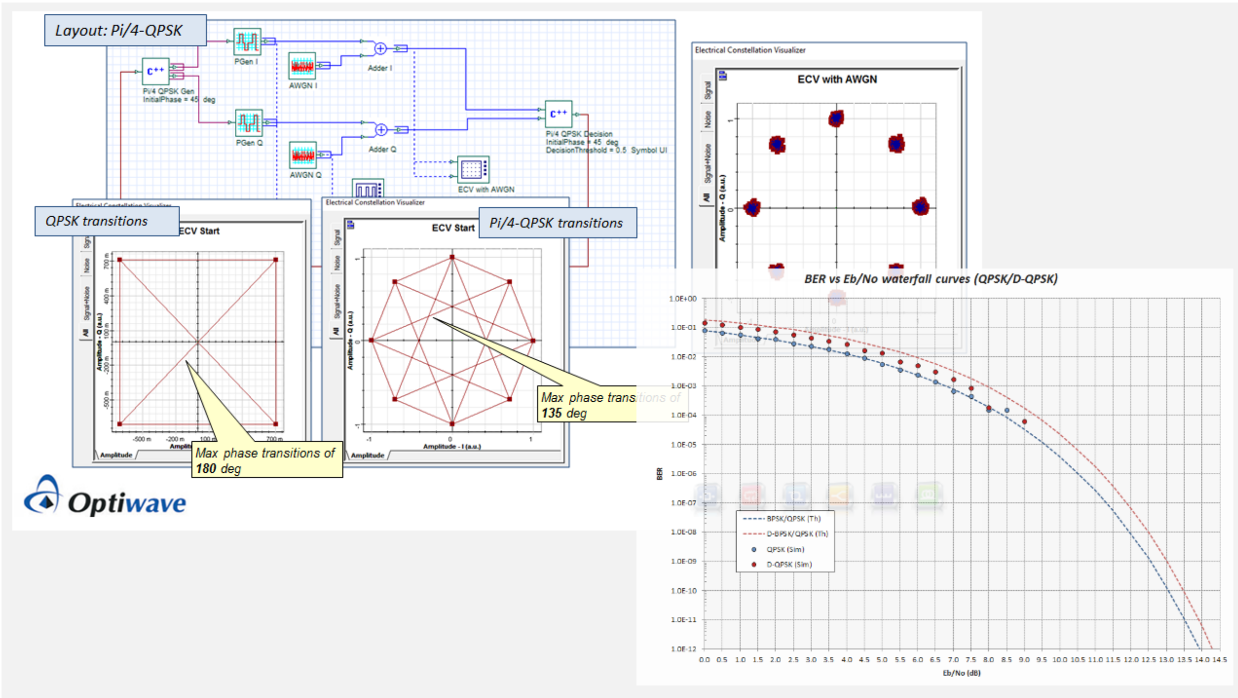


Fig 2.6: Digital Modulation Analysis (PSK).[64]

2.3.6 MATLAB Data Formats:

This application note will describe the Matlab Data Formats that are available within OptiSystem.

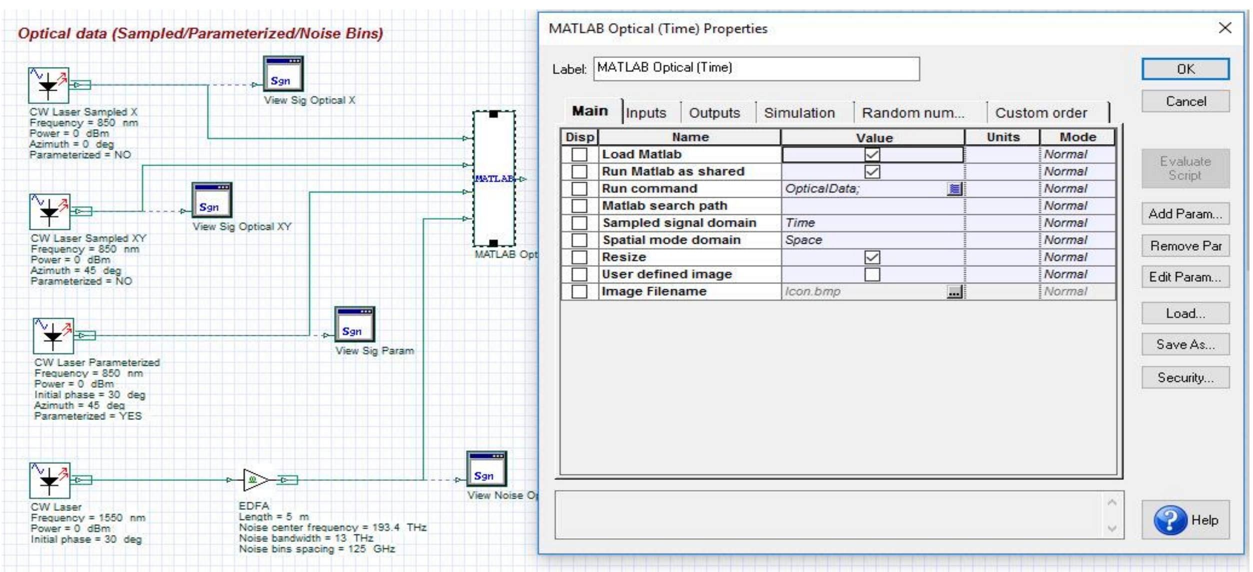


Fig 2.7: MATLAB data formats.[65]

2.3.7 Optical Coherent Receiver Sensitivity Analysis:

Optical coherent receiver technology can provide theoretical sensitivity levels to the order of 10's of photons/bit. This application note provides an overview of common coherent receiver architectures (including homodyne, heterodyne and differential detection) and compares BER waterfall sensitivity curve simulations with theoretical results.

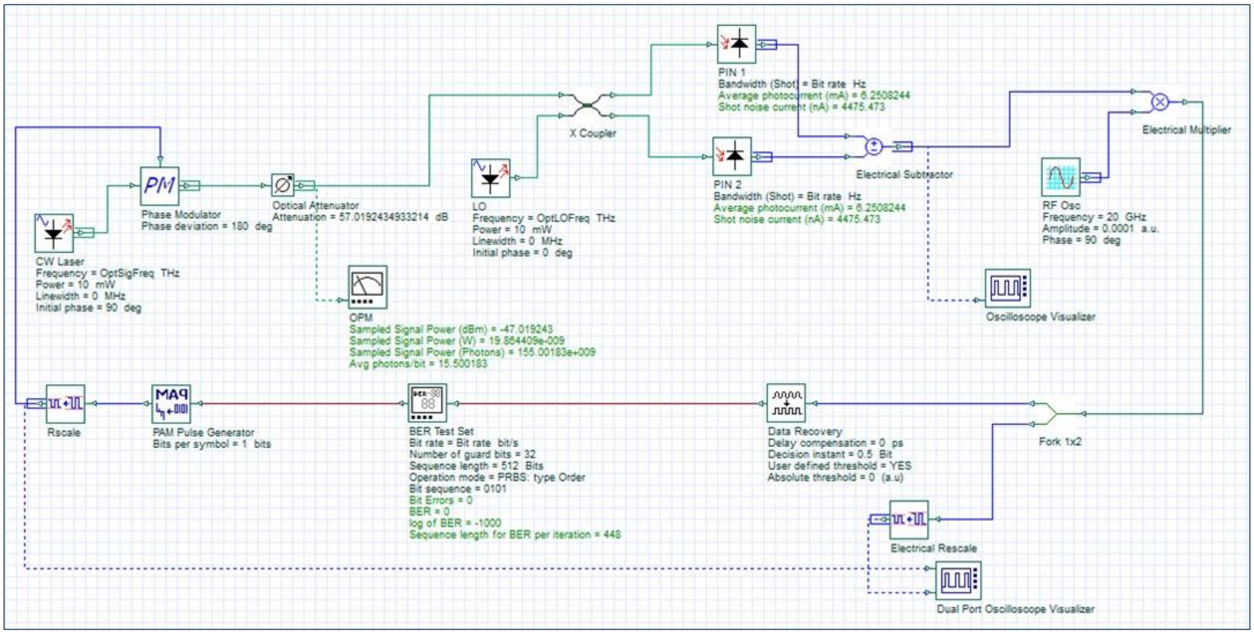


Fig 2.8: Optical Coherent Receiver Sensitivity Analysis.[66]

2.3.8 BER Analysis of BPSK with RS Encoding:

Demonstrates how to perform bit error rate (BER) testing for a binary phase-shift keyed (BPSK) optical system with Reed Solomon (RS) encoders and decoders.

The typical output of a BER analysis is a set of waterfall curves that map a system's BER results against increasing background noise levels, defined as Eb/No (the ratio of energy per bit to noise density). When Reed Solomon encoding is applied, the BER performance can be significantly improved as RS encoding can correct multiple errors per symbol block. BER coding gain results are shown for RS4, RS8 and RS16 coding schemes.

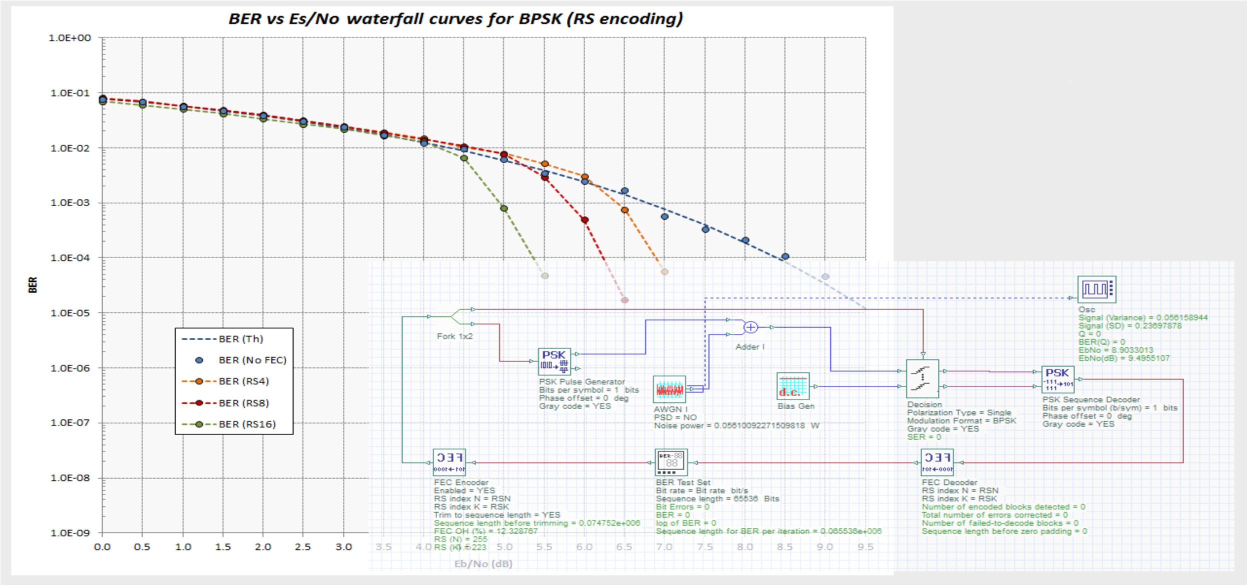


Fig 2.9: BER Analysis of BPSK with RS Encoding.[67]

2.3.9 LIDAR Systems Design:

OptiSystem is an excellent tool for designing prototype designs of communications and sensor systems. The following application note demonstrates how OptiSystem can be used to design and simulate realistic models for light detection and ranging systems (LIDAR). Four range measurement techniques are modelled: Laser pulse time of flight, Phase-shift measurement, Frequency Modulation Continuous Wave (FMCW) with direct detection, and FMCW with coherent detection.

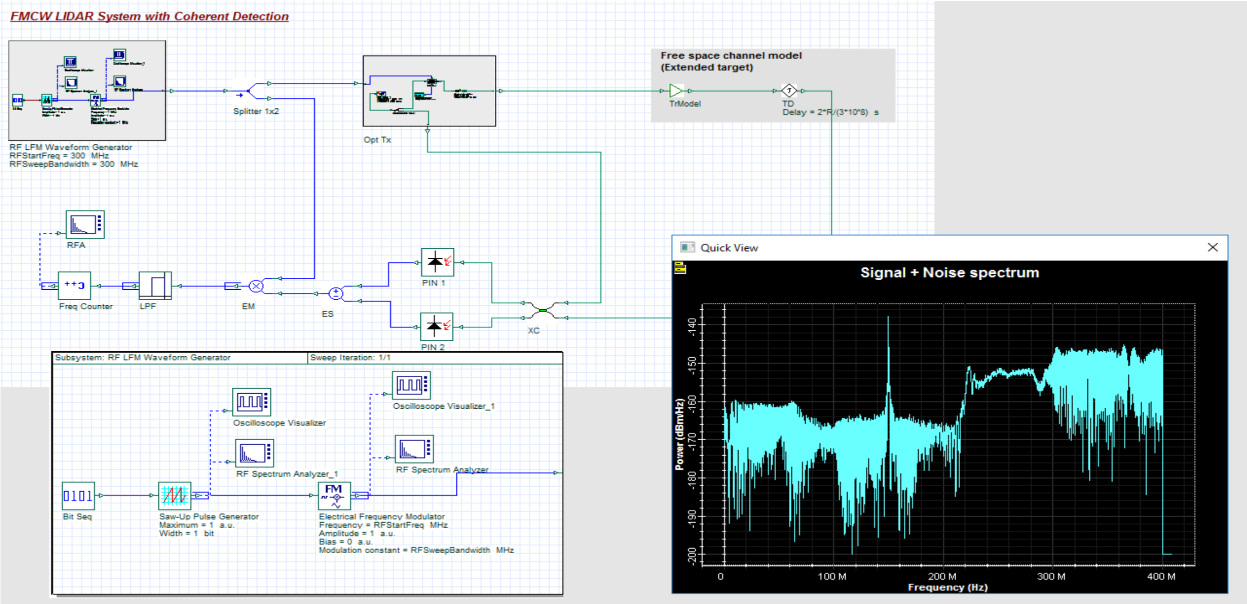


Fig 2.10: LIDAR Systems Design.[68]

2.3.10 SER & BER Analysis of QAM-PSK-PAM Systems:

This application note demonstrates how to perform symbol error rate (SER) or bit error rate (BER) testing for higher order modulation systems. The typical output of a SER/BER analysis is a set of waterfall curves that map a system's SER or BER results against increasing background noise levels, defined as Eb/No (the ratio of energy per bit to noise density) or Es/No (the ratio of energy per symbol to noise density). Three OptiSystem projects have been built to allow for the automatic creation of SER/BER waterfall curves for either pulse amplitude modulation (PAM), phase shift keying (PSK) or quadrature amplitude modulation (QAM) systems of varying order M (symbols per bit). The simulation curves are also mapped against the theoretical results to show how well the simulation results match to theory.

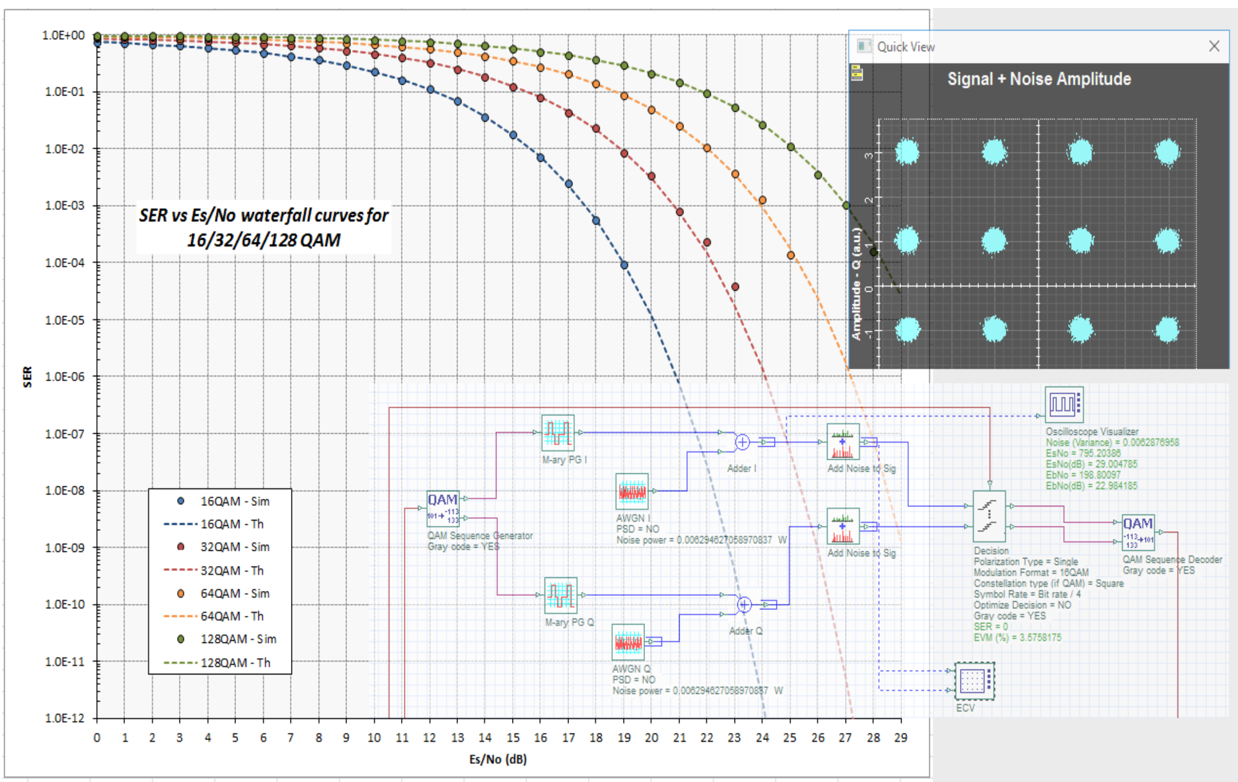


Fig 2.11: SER & BER Analysis of QAM-PSK-PAM Systems.[69]

2.4 KEY FUNCTIONALITY:

2.4.1 Component Library:

The OptiSystem Component Library includes hundreds of components that enable you to enter parameters that can be measured from real devices. It integrates with test and measurement equipment from different vendors. Users can incorporate new components based on subsystems and user-defined libraries, or utilize co-simulation with a third party tool such as MATLAB or SPICE.[70]

2.4.2 Integration with Optiwave Software Tools:

OptiSystem allows you to employ specific Optiwave software tools for integrated and fiber optics at the component and circuit level: OptiSPICE, OptiBPM, OptiGrating, and OptiFiber.[70]

2.4.3 Mixed signal representation:

OptiSystem handles mixed signal formats for optical and electrical signals in the Component Library. OptiSystem calculates the signals using the appropriate algorithms related to the required simulation accuracy and efficiency.[70]

2.4.4 Quality and performance algorithms:

In order to predict the system performance, OptiSystem calculates parameters such as BER and Q-Factor using numerical analysis or semi-analytical techniques for systems limited by inter-symbol interference and noise.[70]

2.4.5 Advanced visualization tools:

Advanced visualization tools produce OSA Spectra, signal chirp, eye diagrams, polarization state, constellation diagrams and much more. Also included are WDM analysis tools listing signal power, gain, noise figure, and OSNR per channel.[70]

2.4.6 Data monitors:

You can select component ports to save the data and attach monitors after the simulation ends. This allows you to process data after the simulation without recalculating. You can attach an arbitrary number of visualizers to the monitor at the same port.[70]

2.4.7 Hierarchical simulation with subsystems:

To make a simulation tool flexible and efficient, it is essential to provide models at different abstraction levels, including the system, subsystem, and component levels. OptiSystem features a truly hierarchical definition of components and systems, allowing the simulation to be as detailed as the desired accuracy dictates.[70]

2.4.8 Powerful Script language:

You can enter arithmetical expressions for parameters and create global parameters that can be shared between components and subsystems using standard VB Script language. The script language can also manipulate and control OptiSystem, including calculations, layout creation and post-processing.[70]

2.4.9 State-of-the-art calculation data-flow:

The Calculation Scheduler controls the simulation by determining the order of execution of component modules according to the selected data flow model. The main data flow model that addresses the simulation of the transmission layer is the Component Iteration Data Flow (CIDF). The CIDF domain uses run-time scheduling, supporting conditions, data-dependent iteration, and true recursion. OptiSystem Optical Communication System and Amplifier Design Software.[70]

2.4.10 Report page:

A fully customizable report page allows you to display any set of parameters and results available in the design. The produced reports are organized into resizable and moveable spreadsheets, text, 2D and 3D graphs. It also includes HTML export and templates with pre-formatted report layouts.[70]

2.4.11 Bill of materials:

OptiSystem provides a cost analysis table of the system being designed, arranged by system, layout or component. Cost data can be exported to other applications or spreadsheets.[70]

2.4.12 Multiple layouts:

You can create many designs using the same project file, which allows you to create and modify your designs quickly and efficiently. Each OptiSystem project file can contain many design versions. Design versions are calculated and modified independently, but calculation results can be combined across different versions, allowing for comparison of the designs.[70]

2.5 FEATURES:

OptiSystem provides the most comprehensive optical communication and photonics design suite for optical design engineers. Its key features include:

2.5.1 Transmitter library:

OptiSystem's Transmitters library contains an extensive selection of optical sources (Fabry-Perot, DFB, VCSEL), electrical and optical signal pulse generators, optical modulators (EA, MZ), electrical modulators and coders (QAM, PAM, FSK, OFDM) and multi-mode signal generators (Laguerre-Gaussian, Hermite-Gaussian).

Designers can choose between advanced physical-based or measurement-based (empirical) models for modeling the static and dynamic behavior of semiconductor lasers. Our physical-based models include 1D and 2D multi-mode laser rate equations, providing designers with the ability to switch between bulk laser rate models and the transmission line matrix method (TLMM).

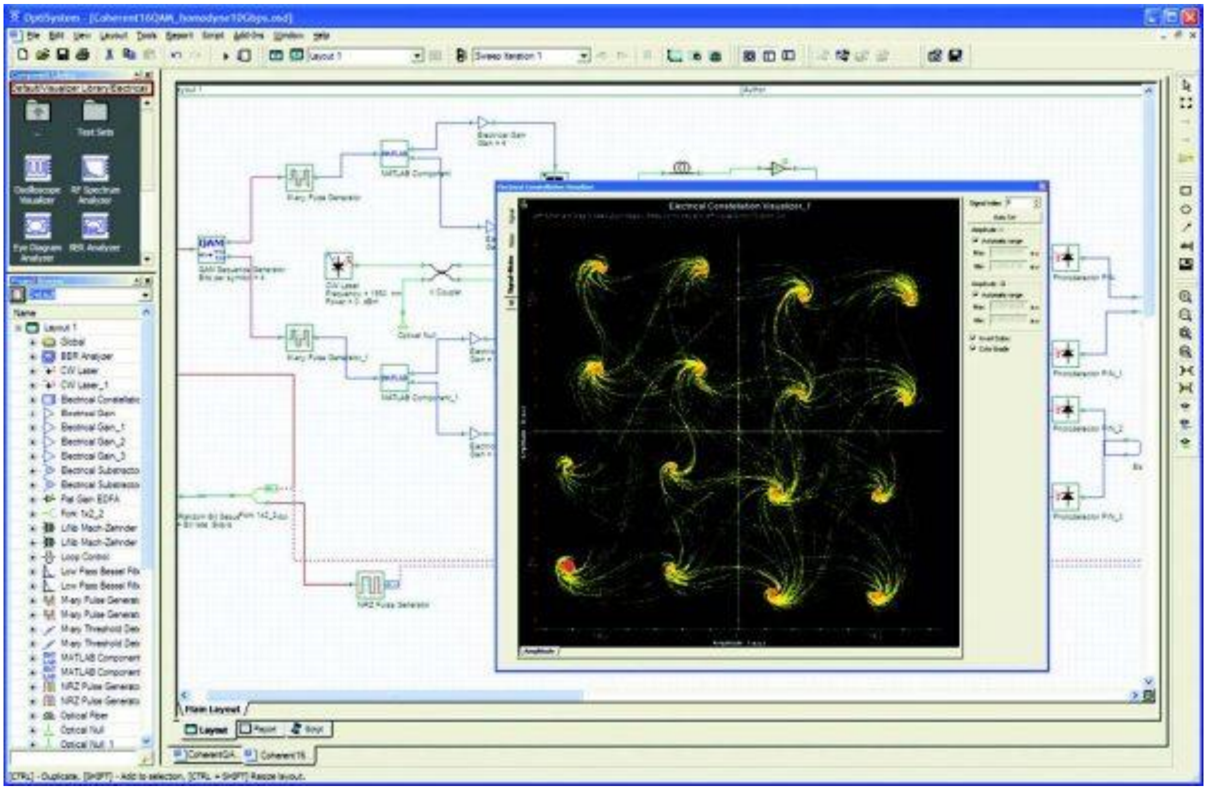


Fig 2.12: Transmitter library.[70]

2.5.2 Receiver library:

The Receivers library contains all the building blocks needed to accurately model optical communication receiver sub-systems. Components include regenerators (clock/data recovery, 3R), electronic equalizers, threshold detectors, decision circuits for PSK/QAM modulation, PIN and APD photo-detectors, demodulators (OFDM, frequency, phase amplitude), decoders (PAM, QAM, PSK, etc.), and digital signal processing (DSP) tool sets for single and dual polarization coherent PSK and QAM systems.

2.5.3 Optical fibers:

Advanced, highly parameterized, optical fiber models can be used to characterize single mode and multi-mode signal propagation; including linear (dispersion), stochastic (PMD), and non-linear impairments (FWM, self-phase modulation, and cross-phase modulation). Using OptiSystem's Bidirectional optical fiber component, it is possible to model and measure Rayleigh, Brillouin and Raman scattering effects.[70]

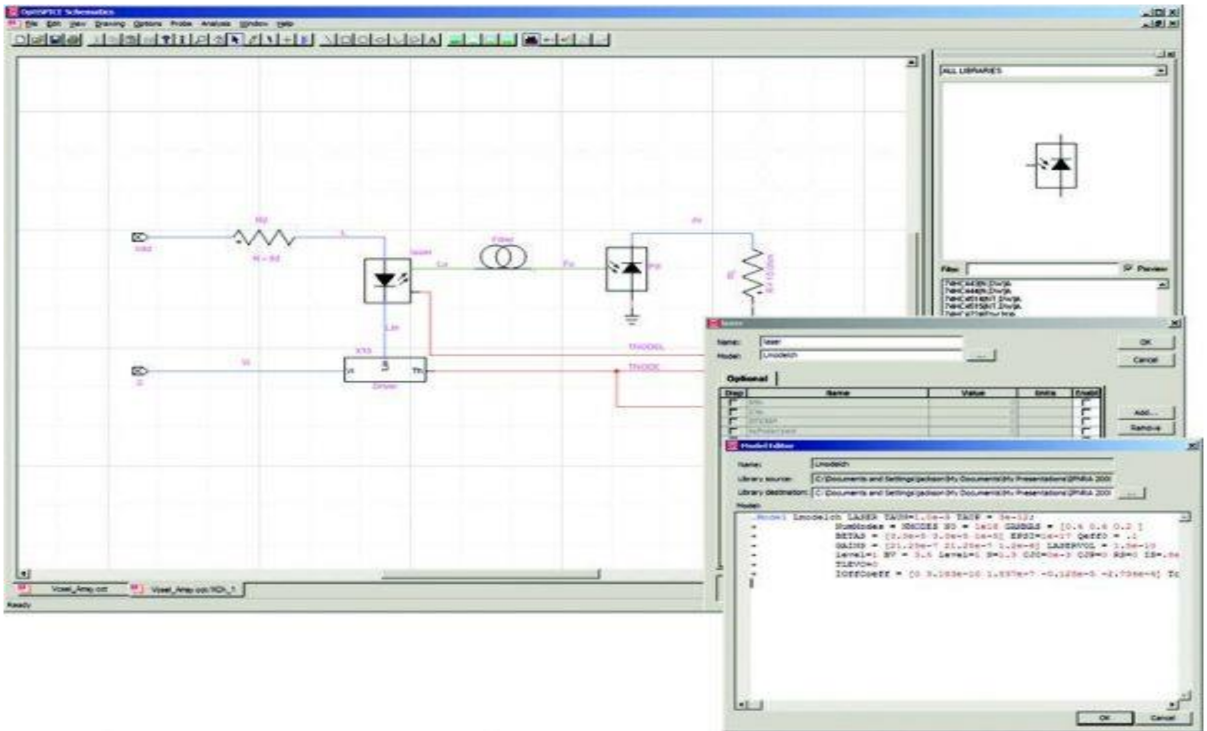


Fig 2.13: Optical fiber operations.[70]

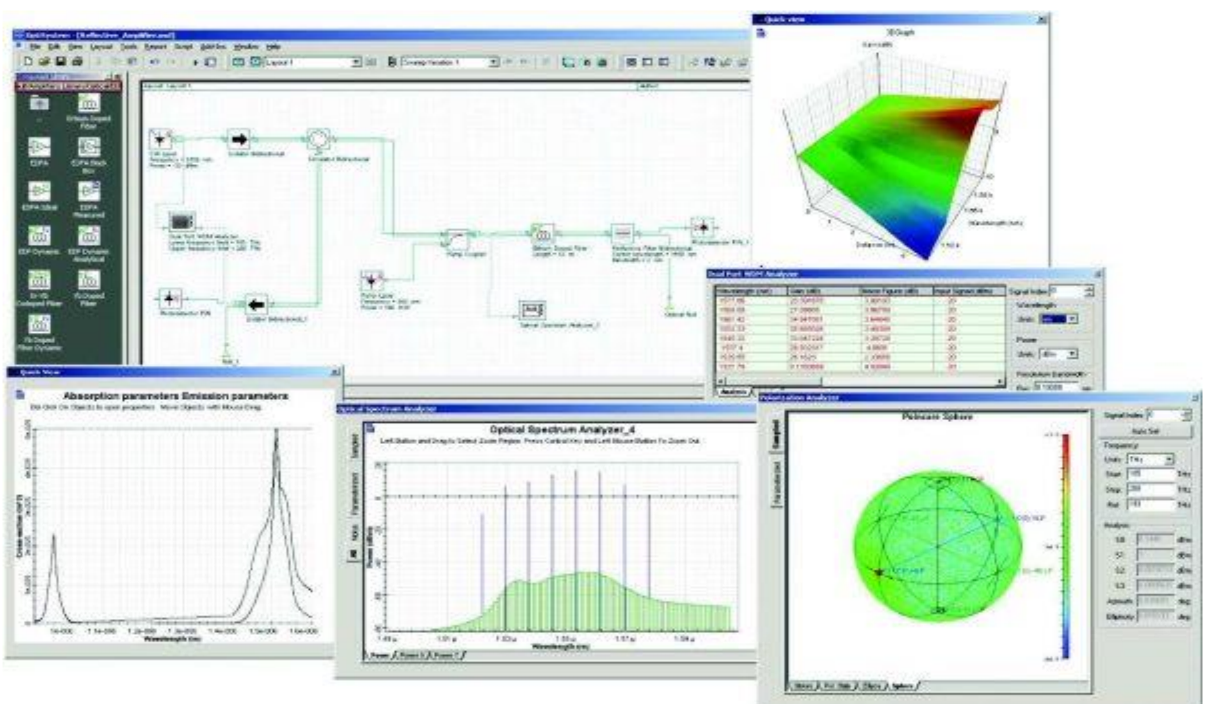


Fig 2.14: Optical fiber operations.[70]

2.5.4 Amplifiers:

A comprehensive suite of steady state and dynamic optical amplifier models is provided, including advanced doped fiber models (Er, Er multi-mode, Er-Yb, Yb, Yb multi-mode, Tm, Pr) for detailed physical fiber amplifier design; EDFA and EDFA black box (gain spectrum, noise figure measurements) for WDM network systems design; dynamic and average power Raman models; and 1D/2D semiconductor optical amplifier models (lumped rate equation, travelling wave, TLMM). Electrical domain amplifiers are also provided for receiver design (transimpedance, automatic gain control and limiting amplifier applications).[70]

2.5.5 Network design tools:

Network design tools include ideal and non-ideal models for optical switches, multiplexers, de-multiplexers, array waveguides (AWGs), fiber connectors, and PMD emulators.[70]

2.5.6 Filters:

A variety of electrical and optical filters are provided for sub-system and system design simulation including standard filter functions (Bessel, Gaussian, RC, Raised Cosine, etc.), digital IIR/FIR filters, periodic filters, reflective/FBG filters, measured filters, S-parameters filter, and acousto-optic.[70]

2.5.7 Passives:

An extensive selection of optical and electrical passive components can be used to build a variety of component and sub-system designs. Optical devices include attenuators, couplers, splitters and combiners, polarization controllers, reflectors, taps, isolators, and circulators. Electrical devices include 180 and 90 degree hybrid couplers, DC blockers, power splitters and combiners, and RF transmission lines.

Models are also provided to allow designers to use measured data to characterize device transfer functions, including small signal scattering (S) matrices and the Jones matrix.[70]

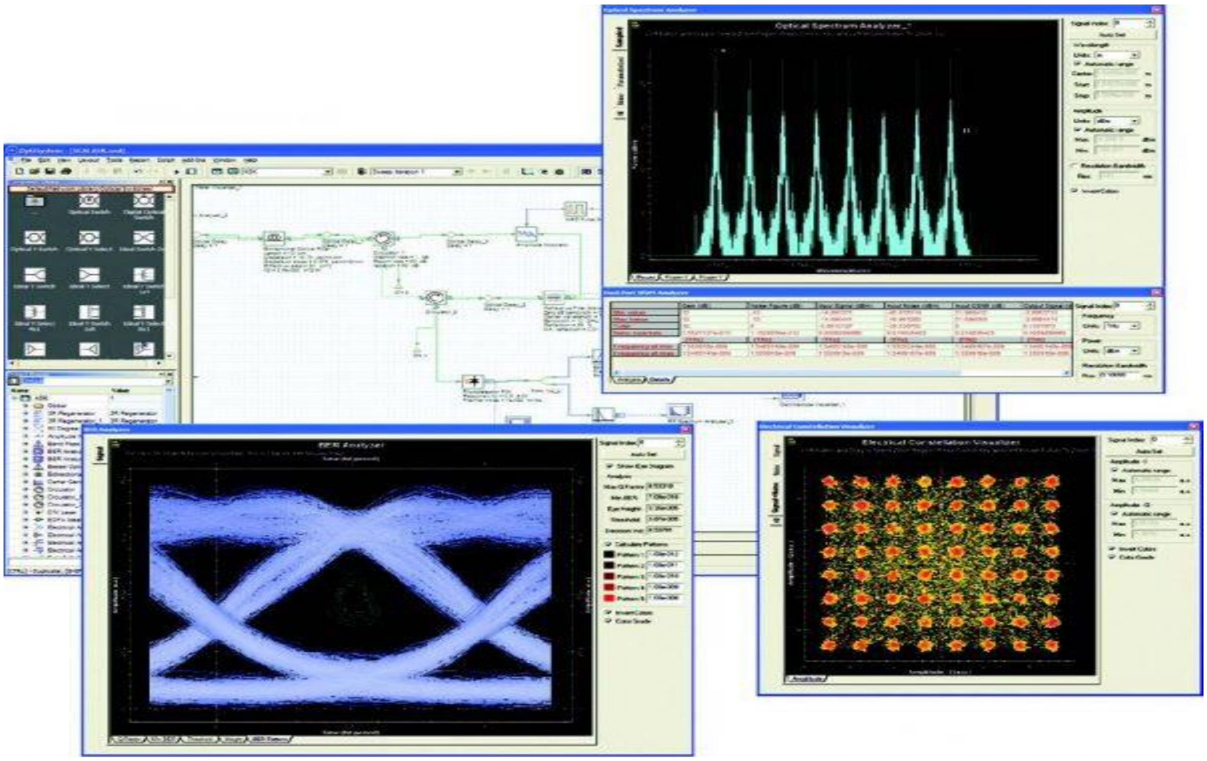


Fig 2.15: Optical fiber operations.[70]

2.5.8 Signal processing:

Signal processing tools are provided for manipulating optical, electrical and binary signals. Functions and operations include bias generators, gain, signal addition and subtraction, normalizers, electrical differentiators and integrators, down-samplers, serial-parallel and parallel-serial converters, electrical flip flops, and electrical/binary logic operators.[70]

2.5.9 Spatial and free space optics design tools:

OptiSystem has specialized components that can model free space optical channels (antenna characteristics, atmospheric propagation) and the spatial analysis of multi-mode signal coupling between devices (multi-mode generators, spatial connectors, thin lenses, spatial visualizers).[70]

2.5.10 Visualization tools:

Visualization and post-simulation analysis tools include BER test sets and analyzers, eye diagram analyzers, spectrum analyzers, oscilloscopes, optical time domain viewers, power meters, polarization analyzers, spatial visualizers, encircled flux, DMD analyzer, photonic all parameter analyzer, filter analyzer, and S-parameter extractor.[70]

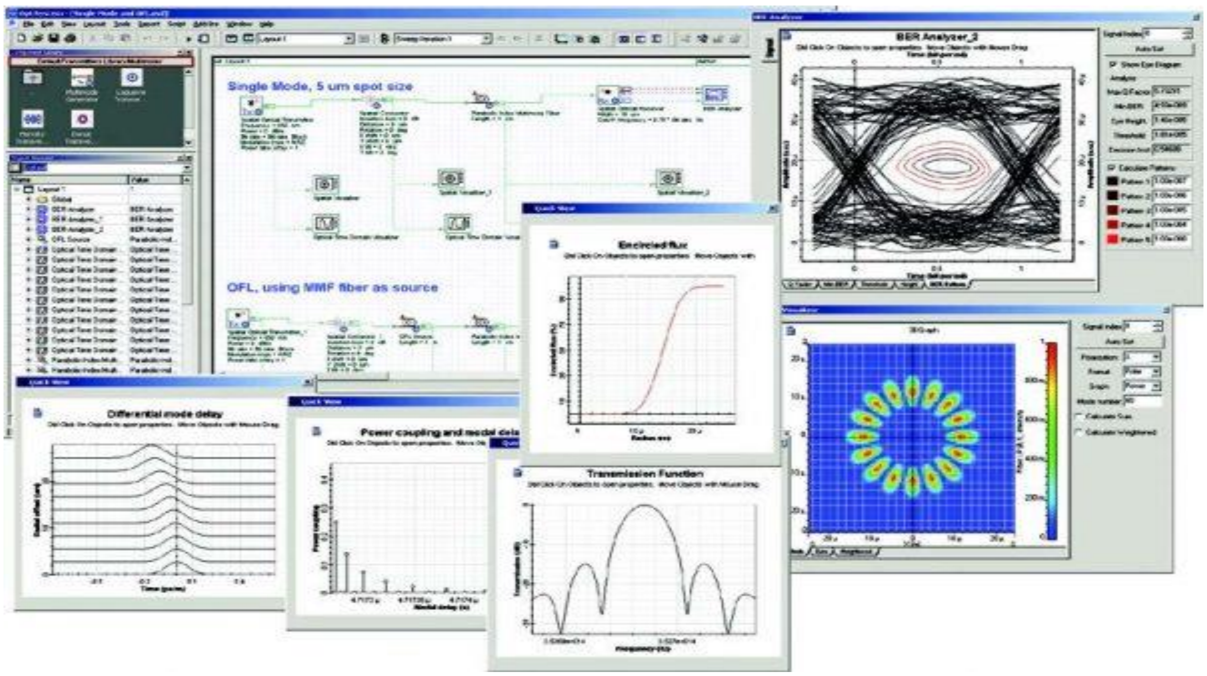


Fig 2.16: Optical fiber Operations (visual tools).[70]

Chapter-3

Simulation & Result

To optimization 8 channel WDM system we considered simulation with amplifier and without amplifier.

3.1 Simulation with Amplifier:

Simulation model of CW Laser based optical data transmission system is given below:

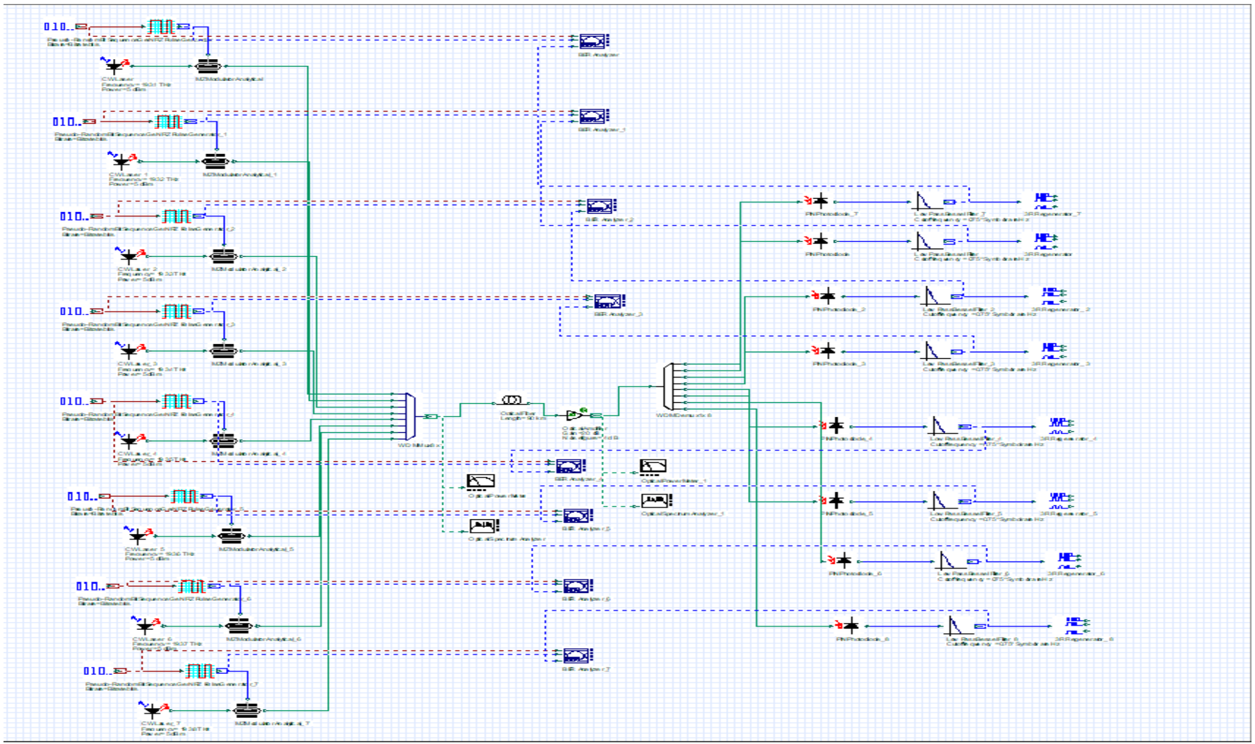


Fig 3.1: Simulation layout for an 8 channel WDM system with Amplifier

In this mode, we have used CW laser where data can be transmitted through this system by optical fiber. An optical amplifier namely EDFA is used here to maintain signal strength up to the receiver section. In receiver section PIN photo detector is used to detect the signal and then the signal passed through low pass filter to discard the higher frequencies. CW laser, Optical fiber, optical photo detector all of this component of our system model is designed by setting different parameters in their internal design section.

3.1.1 Performance analysis for 8 channel WDM system at different fiber length:

We have discussed that from our CW Laser based optical link we found BER analyzer performance, now this performance is analyzed with the help of BER value, power, Q factor curves which are depicted in fig 3.2 and fig 3.3, table 3.1.

In this case the bit error rate of the system is kept fixed at 10 Gb/s and fiber length is increasing 10km as we got Q factor 0.

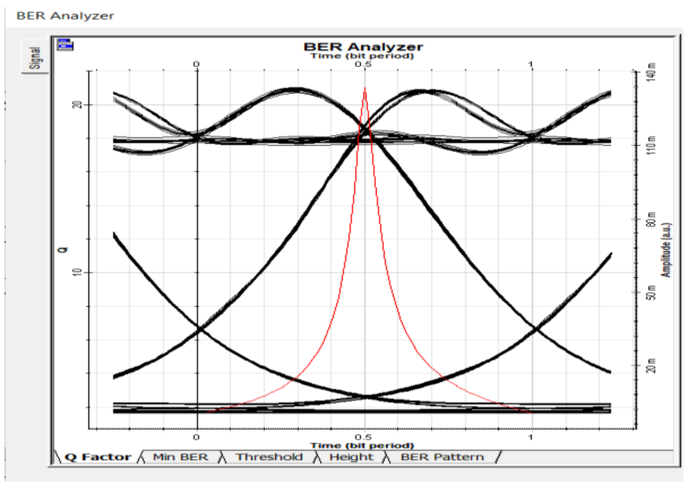


Fig 3.2: Min Bit Error Rate at 50km

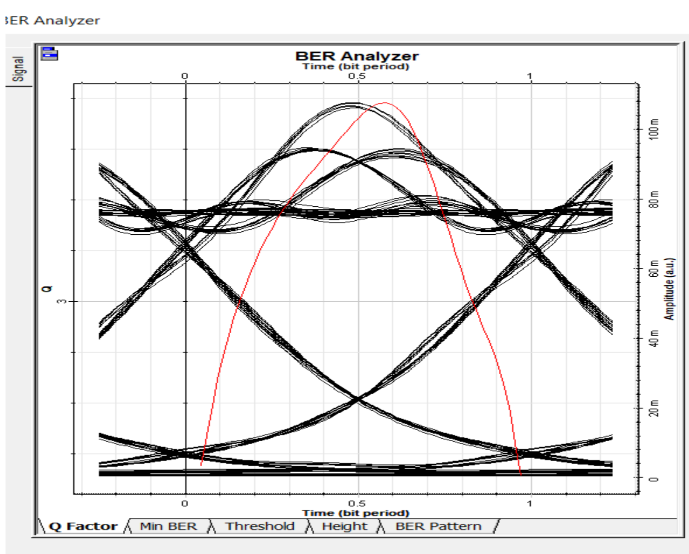


Fig 3.3: Max Bit Error Rate at 80km

Table 3.1 BER performance at 8 channels:

Distance(km)	Bit Error Rate
20	3.14526e-117
30	5.85312e-055
40	2.70895e-054
50	2.02267e-098
60	2.63648e-095
70	6.32686e-006
80	7.6265e-005

After analysis, it is seen that at 50km distance bit error rate will low and at 80km it got its highest pick value as the eye diagram shown. After 100km there is lots of noise and after 200km there is no q factor. Table 3.1 depicts BER performance at varying fiber length. We have found decreasing BER performance with the increase of fiber length. Q factor has decreased with the increased length.

3.1.2 Optical Spectrum Performance analysis for 8 channels WDM system:

We have discussed earlier that from optical link where used amplifier. We found wavelength & amplitude performance, now this wavelength & amplitude performance is analyzed with the help byOptical Spectrum analyzer of wavelength start, Centre, stop values, amplitude max & min values shown in fig 3.4 & fig 3.5.

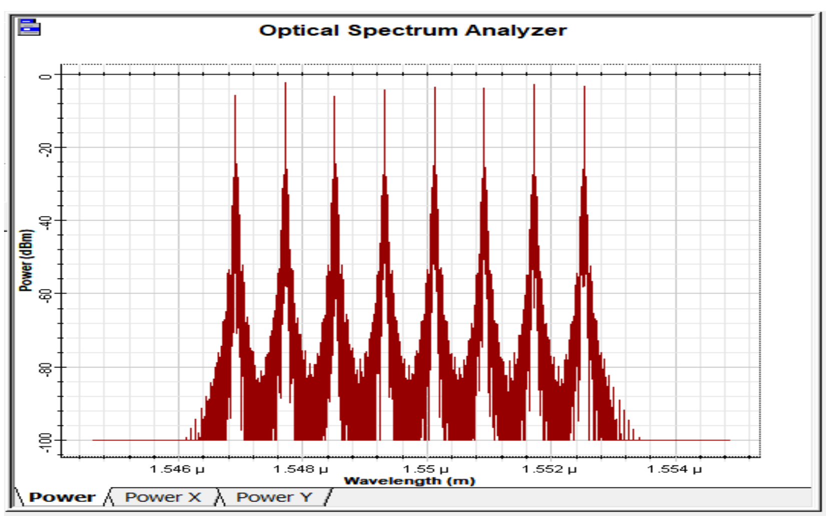


Fig 3.4: Optical Spectrum Analyzer before

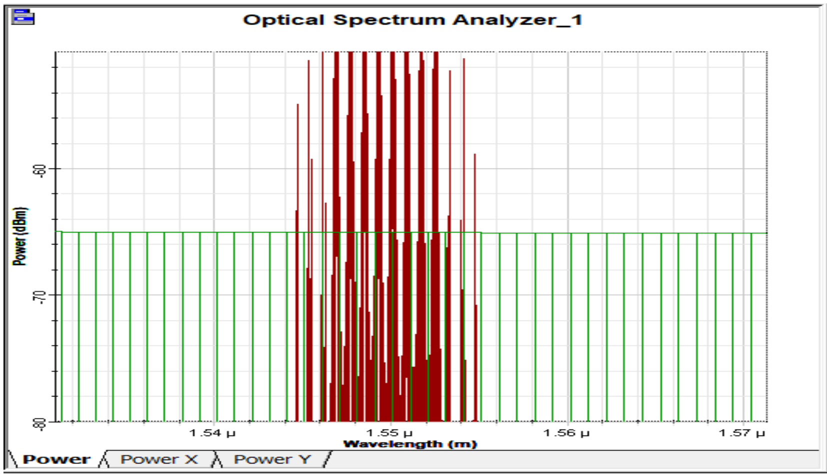


Fig 3.5: Optical Spectrum Analyzer after

It is seen that the value of wavelength and amplitude has reduced after using amplifier.

3.1.3 Performance analysis for 8 channels bit error rate average:

In our CW Laser based optical data transmission model we have succeeded to transmit 10Gb/s data and by kept this findings fixed we also have analyzed the maximum distance where we can send error free data at 10Gb/s. Fig 3.6, fig 3.7 represents the optical fiber length analysis with the help of BER, Q factor and eye diagram respectively. Table 3.2 is represent the Q factor analysis values at different length.

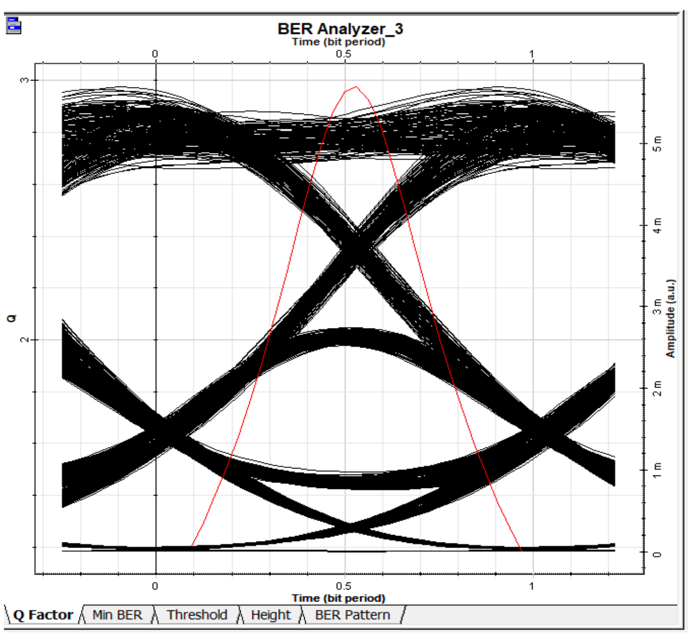


Fig 3.6: Bit Error Rate for channel 8

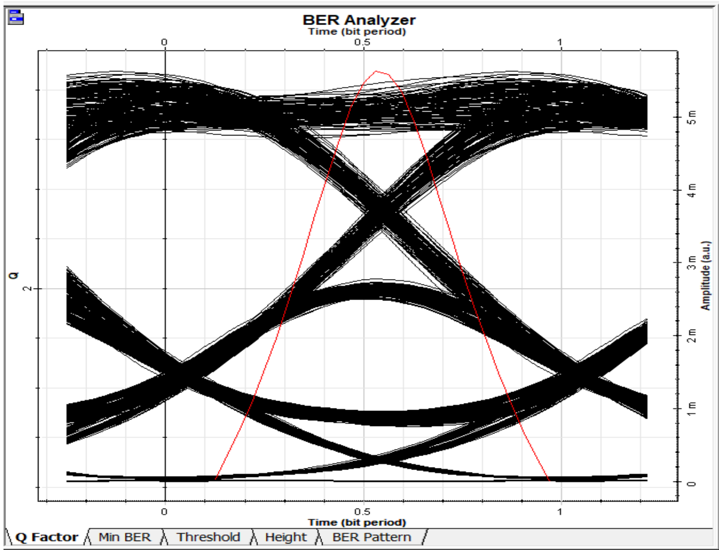


Fig 3.7: Bit Error Rate for channel 1

Fig 3.6, 3.7 represents average between input and output bit error rate for each channel.

Table 3.2: BER performance at different fiber length

Channel	Bit Error Rate
1	0.00172632
2	0.00151211
3	0.00154406
4	0.00124436
5	0.00152575
6	0.0014491
7	0.00145899
8	0.00127715

.

3.1.4 Performance analysis at different temperatures:

In this simulation from optical link we found temperature performance up to 120ºC, now this temperature performance is analyzed with the help of BER value, power, Q factor curves which are depicted in fig 3.8, fig 3.9, fig 3.10. In this case the bit error rate of the system is kept fixed at 10 Gb/s and also fiber length is kept fixed at 10 km.

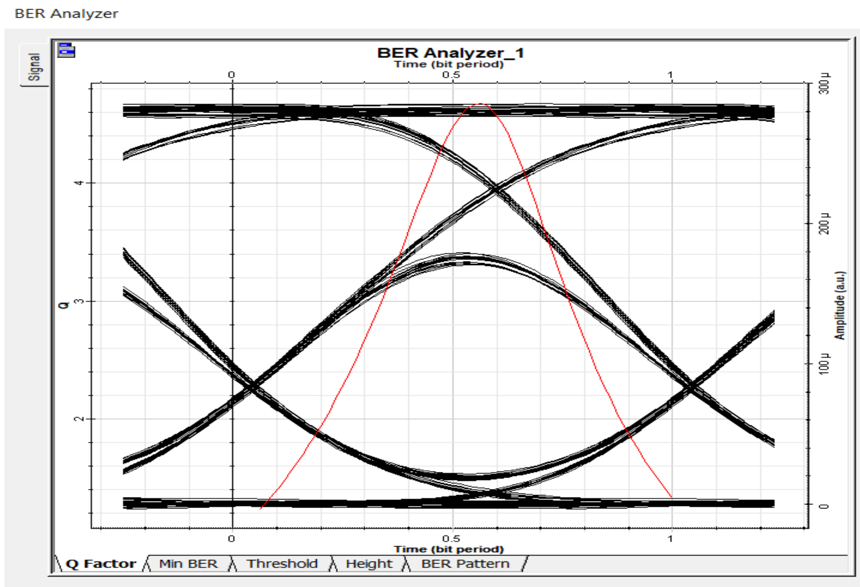


Fig 3.8: Bit Error Rate at Temperature 120ºC

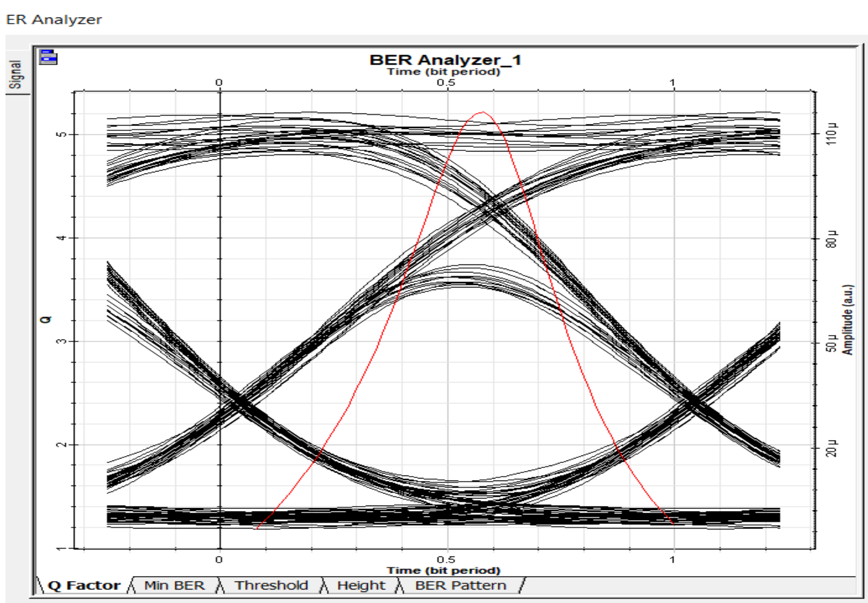


Fig 3.9: Bit Error Rate at Temperature 125ºC

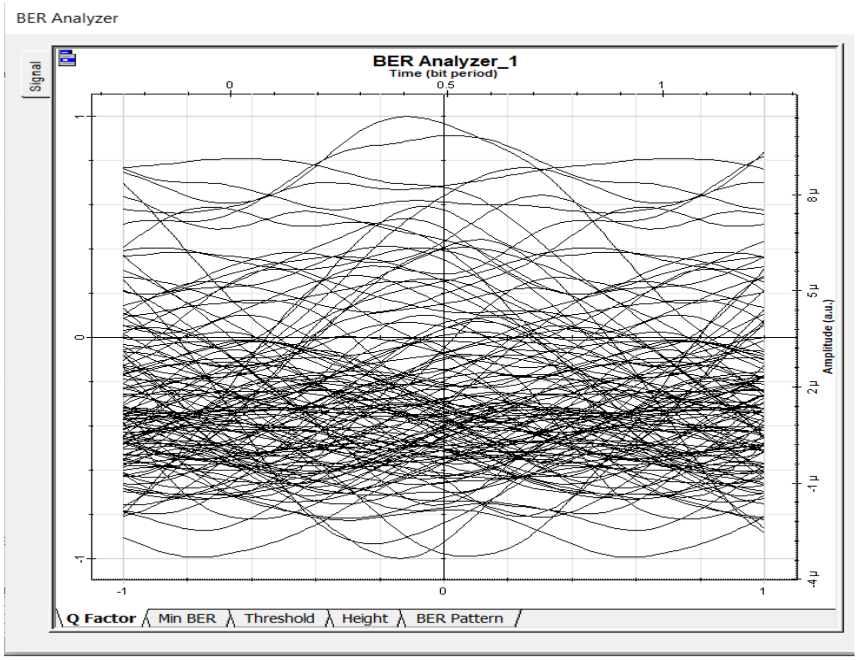


Fig 3.10: Bit Error Rate at Temperature 128º C

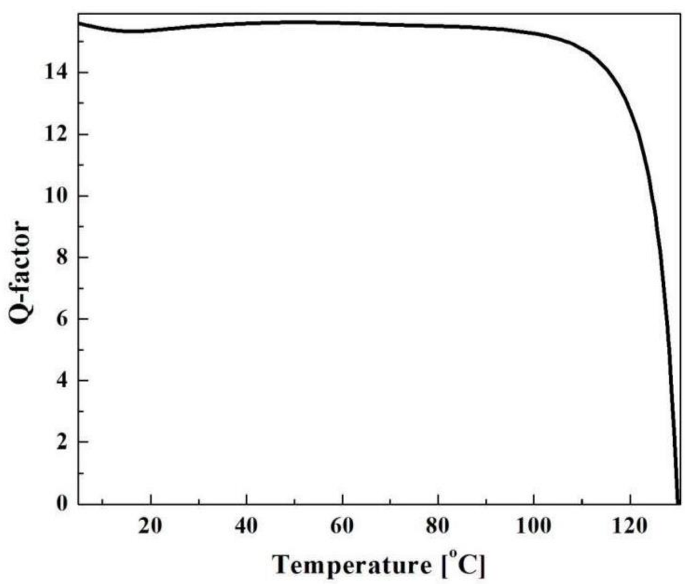


Fig 3.11: Temperature dependence of Q-factor at 1550 nm

In fig 3.8, 3.9, 3.10 the system performance at different temperatures are shown with the help of eye diagrams and it can be seen that the openness of eye decreases with the increase of temperature. When the temperature passed 125ºC the system stops performing because no particular eye openness can be identified in this temperature and there are multiple copies of eyes which indicate that the system noise level has increased.

Table 3.3: BER performance at different temperatures

Temperature ⁰C	Bit Error Rate
0	1.96487e-007
10	6.4831e-008
60	1.29012e-007
80	1.58692e-006
100	2.46036e-008
120	1.21641e-006
125	6.96829e-008
128	1

In the system performance has analyzes in terms of Q factor with different temperatures. It can be seen that Q factor performance decays very small amount with the increase of temperature but 128⁰C it decays to 1, which means that our system is performing up to 75⁰C.

3.1.5 Performance analysis at different distance:

For most mass market cars, 40-65 degrees Celsius is where the engine really starts to come into its own. At around 90–95 degrees Celsius the radiator fan begins to operate to provide further cooling.

In fiber optics systems in automobiles these systems exhibited a power budget of around 14dB and an operating temperature up to 85⁰C or 95⁰C. Therefore, the current fiber systems are limited to the passenger compartment. Roof top implementations require a maximum temperature of 105⁰C and the engine compartment takes it up to 125⁰C.[72]

3.1.5.1 Performance analysis at temperature 40˚C:

In optical link, we found distance performance. This distance performance is analyzed with the help of BER value, power, Q factor curves which are depicted in fig 3.11, 3.12, 3.13& in table 3.4.

In this case the bit error rate of the system is kept fixed temperature at 40⁰C.

BER Analyzer

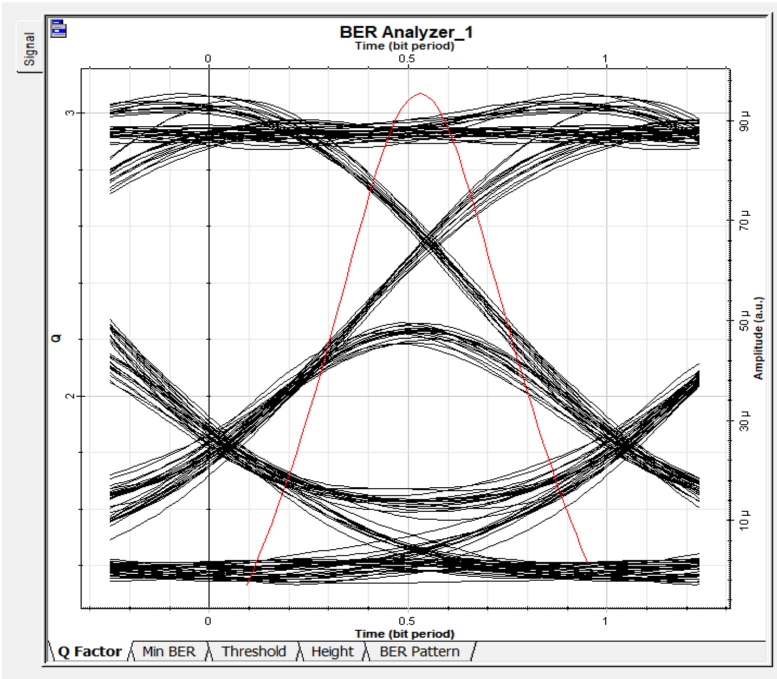


Fig 3.12: Bit Error Rate at distance at 80km

BER Analyzer

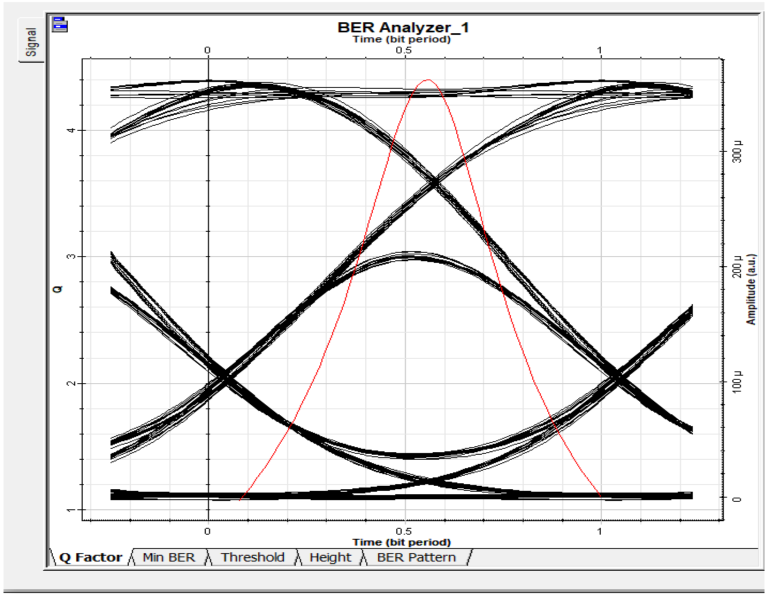


Fig 3.13: Bit Error Ratio at distance 100km

Fig 3.12, 3.13 represents eye diagram for different fiber length distance. It has been seen that eye openness decreases with the increase of fiber length.

Table 3.4: BER performance at different distance

Distance(km)	Bit Error Rate
10	2.21093e-007
20	1.29244e-007
50	4.3547e-006
80	0.000985555
100	0.00321615

Table 3.4 depicts BER performance q factor at varying fiber length distance. We have found increasing BER performance with the increase of fiber length.

Q factor decreases with the increasing fiber length distance.

3.1.5.2 Performance analysis at temperature 95^0 C:

This distance performance is analyzed with the help of BER value, power, Q factor curves which are depicted in fig 3.14, 3.15, 3.16& in table 3.4.

In this case the bit error rate of the system is kept fixed temperature at 95^0C.

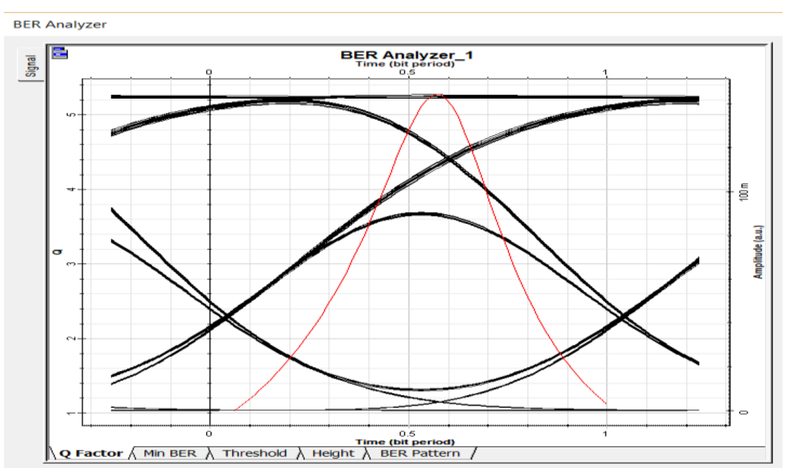


Fig 3.14: Bit Error Rate at distance 0.5m

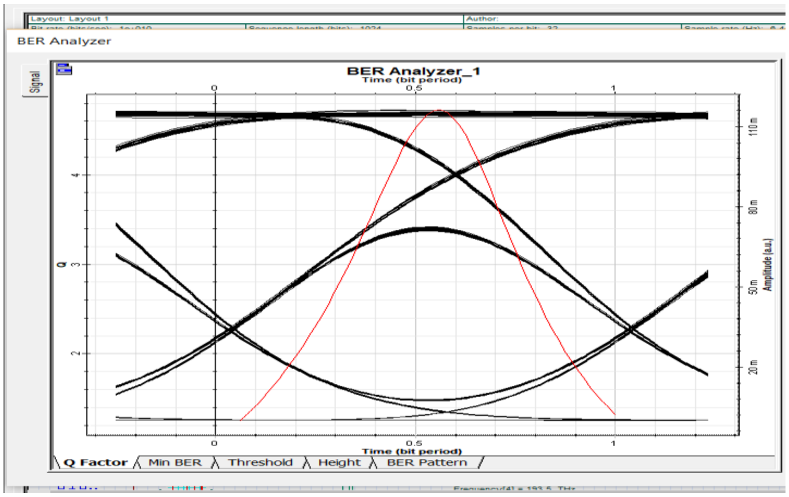


Fig 3.15: Bit Error Rate at distance 1m

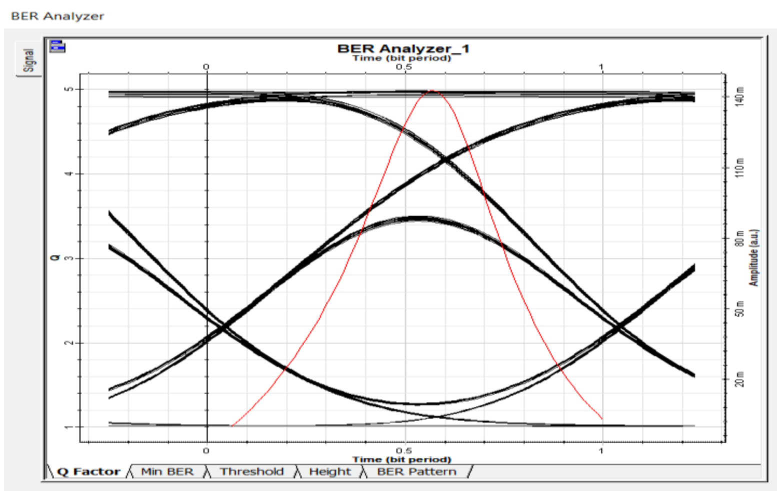


Fig 3.16: Bit Error Rate at distance 2m

Fig 3.14, 3.15, 3.16 represent that eye openness decreases with the increase of fiber length.

Table 3.5: BER performance at different distance

Distance(m)	Bit Error Rate
0.25	4.39963e-008
0.50	4.94851e-008
1	2.76096e-007
1.5	9.37975e-007
2	2.28264e-007

Table 3.5 showed that BER performance at varying fiber length distance. We have found at 2m distance bit error rate is lowest and suitable for other operations.

Here, Q factor decreases with the increasing fiber length distance.

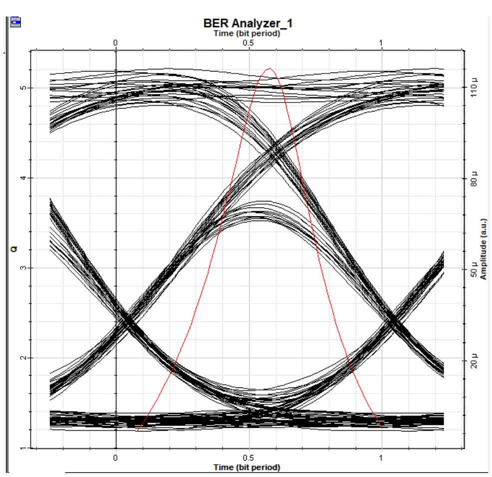
3.1.5.3 Performance analysis at different temperature:

We have discussed earlier that from our 1550 nm CW based optical link we found temperature performance up to 125^{0}C, now this temperature performance is analyzed with the help of BER value, power, and Q factor curves which are depicted in table (fig numb). In this case the bit error rate of the system is kept fixed at 10 GB/s and also fiber length is kept fixed at 10 km.

Table 3.6: Q Factor analysis at different temperature

Temperature ^{0}C	Q factor
0	5.01121
10	5.21257
60	5.08853
80	4.61345
100	5.36563
120	4.67297
125	5.21437
128	0

This system performance has analyzed in terms of Q factor with different temperatures. It can be seen that Q factor performance decays very small amount with the increase of temperature but after 80^{0}C it increases and again it decreases but after 128^{0}C decays to 0, which means that our system is performing up to 125^{0}C.



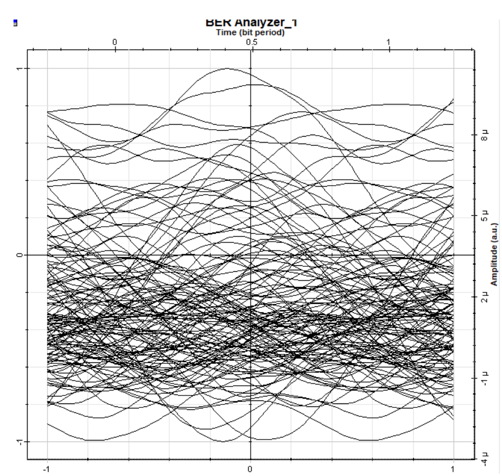


Fig 3.17: Q factor at 100^0C   Fig 3.18: Q Factor at 128^0C

In fig (3.17) and (3.18) the system performance at different temperatures are shown with the help of eye diagrams and it can be seen that the openness of eye decreases with the increase of temperature. When the temperature goes passed 125^0C the system stops performing because no particular eye openness can be identified in this temperature and there are multiple copies of eyes which indicate that the system noise level has increased.

3.2: Simulation without Amplifier:

Simulation model of CW Laser based optical data transmission system is given below:

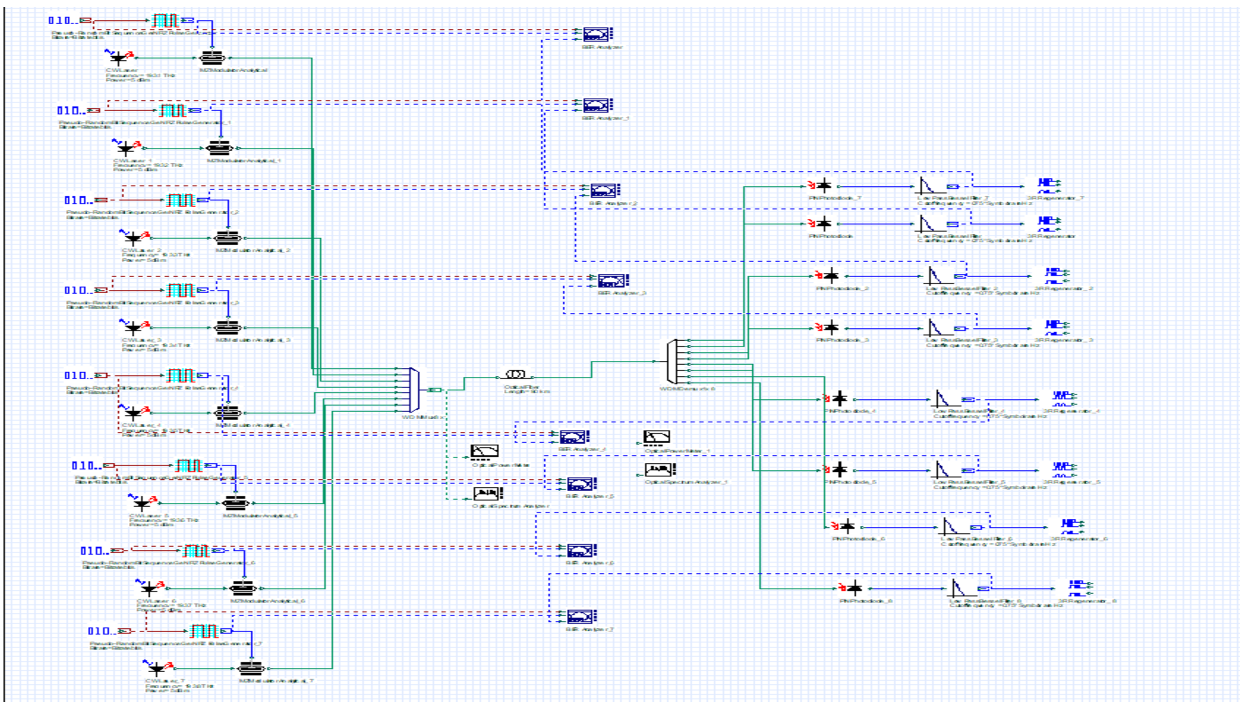


Fig 3.19: Simulation layout for an 8 channel WDM system without Amplifier

In this mode, we have used CW laser where data can be transmitted through this system by optical fiber. An optical amplifier namely EDFA is not used here to maintain signal strength up to the receiver section. In receiver section PIN photo detector is used to detect the signal and then the signal passed through low pass filter to discard the higher frequencies. CW laser, Optical fiber, optical photo detector, all of this component of our system model is designed by setting different parameters in their internal design section.

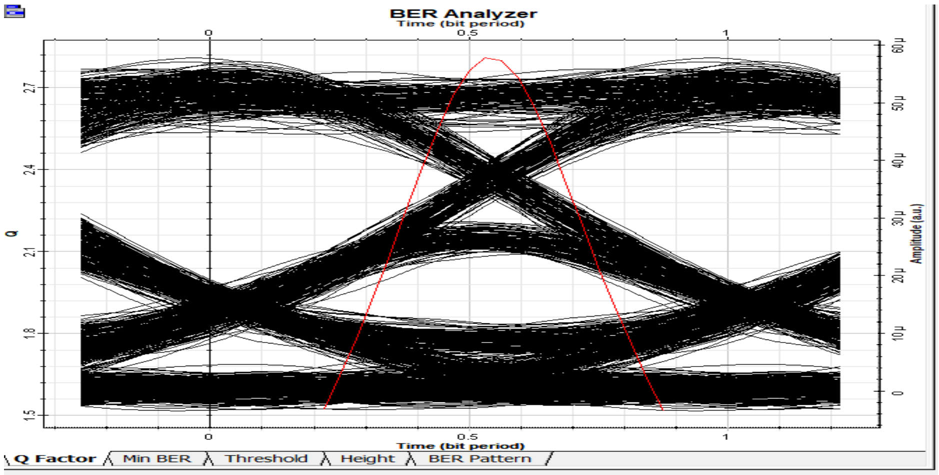


Fig 3.20: Bit Error Rate for channel 1

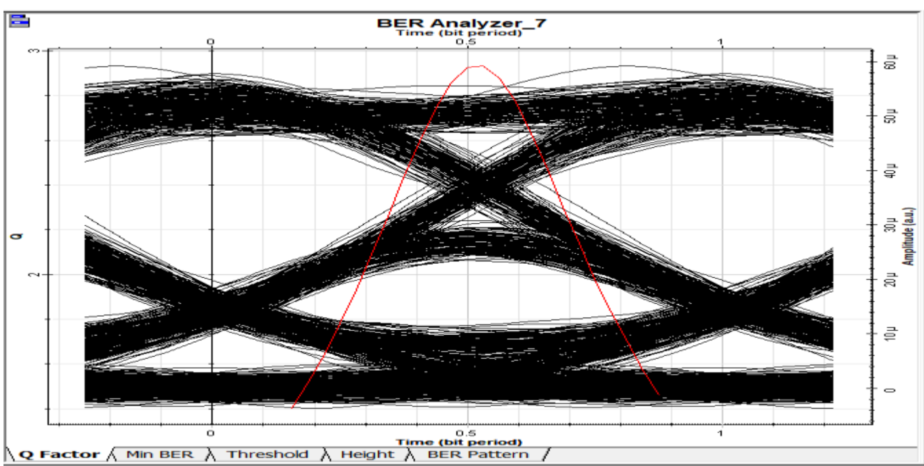


Fig 3.21: Bit Error Rate for channel 8

Fig 3.20, 3.21 represents average bit error rate between input and output for each channel.

3.2.1 Performance analysis at different temperatures:

In this simulation from optical link we found temperature performance up to 125ºC, now this temperature performance is analyzed with the help of BER value, power, Q factor curves which are depicted in fig 3.22, fig 3.23, fig 3.24. In this case the bit error rate of the system is kept fixed at 10 Gb/s and also fiber length is kept fixed at 10 km.

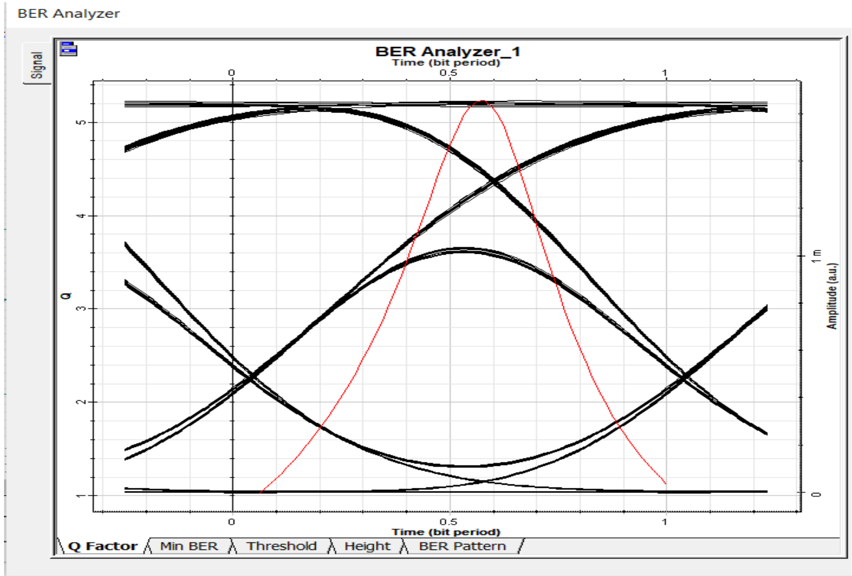


Fig 3.22: Lowest Bit Error Rate for channel 70ºC

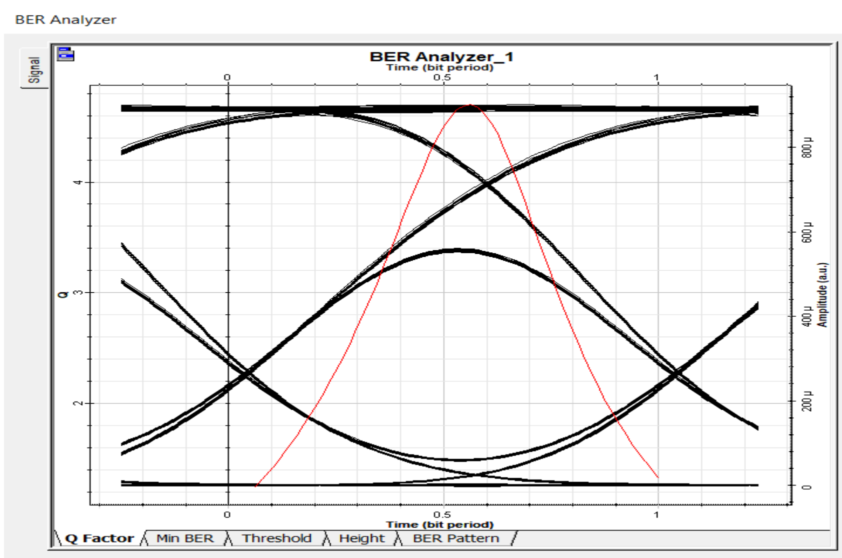


Fig 3.23: Lowest Bit Error Rate for channel 100ºC

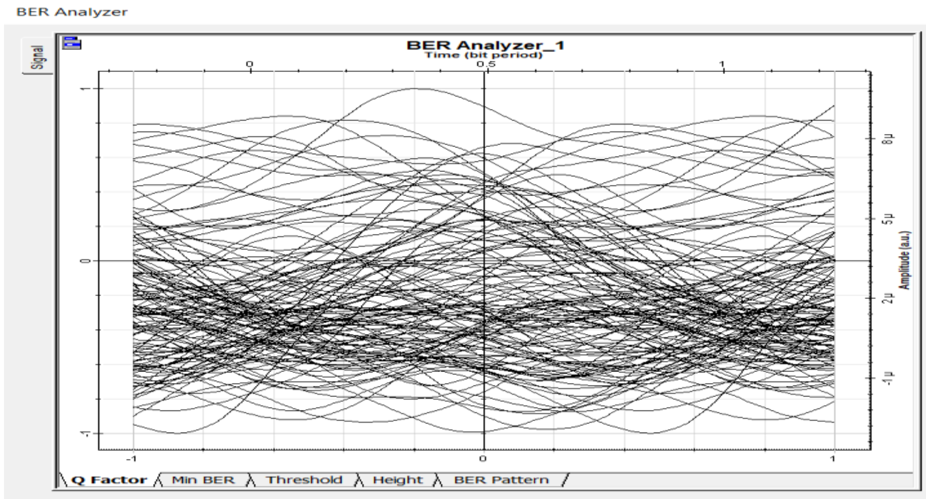


Fig 3.24: Bit Error Rate at Temperature 128⁰C

In fig 3.22, 3.23, 3.24 the system performance at different temperatures are shown with the help of eye diagrams and it can be seen that the openness of eye decreases with the increase of temperature. When the temperature passed 125⁰C the system stops performing because no particular eye openness can be identified in this temperature and there are multiple copies of eyes which indicate that the system noise level has increased.

Table 3.7: BER performance at different temperatures

Temperature ⁰C	Bit Error Rate
0	5.43628e-008
10	1.30899e-007
30	2.21322e-007
50	5.90502e-008
70	6.24078e-008
100	1.06549e-006
125	2.46021e-007
128	1

In the system performance has analyzes in terms of Q factor with different temperatures. It can be seen that Q factor performance decays very small amount with the increase of temperature but 128⁰C it decays to 1, which means that our system is performing up to 75⁰C.

3.2.2 Performance analysis at different distance:

We have discussed earlier that in fiber optics systems in automobiles these systems exhibited a power budget of around 14dB and40-65 degrees Celsius is where the engine really starts to come into its own and an operating temperature up to 85⁰C or 95⁰C.   For most mass market cars, 40-65 degrees Celsius is where the engine really starts to come into its own. At around 90–95 degrees Celsius the radiator fan begins to operate to provide further cooling.

3.2.2.1 Performance analysis at temperature 40⁰ C:

In optical link, we found distance performance. This distance performance is analyzed with the help of BER value, power, Q factor curves which are depicted in fig 3.25, 3.26 & in table 3.8.

In this case the bit error rate of the system is kept fixed temperature at 40ºC.

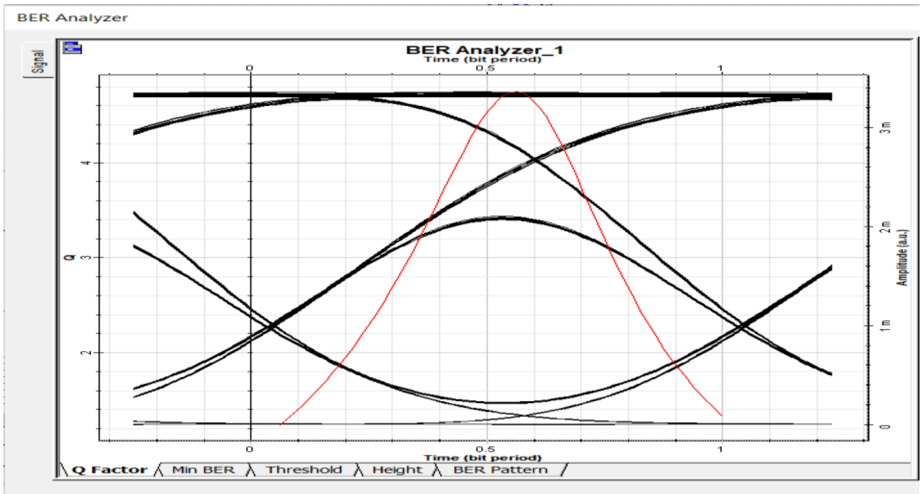


Fig 3.25: Lowest Bit Error Rate at distance 1km

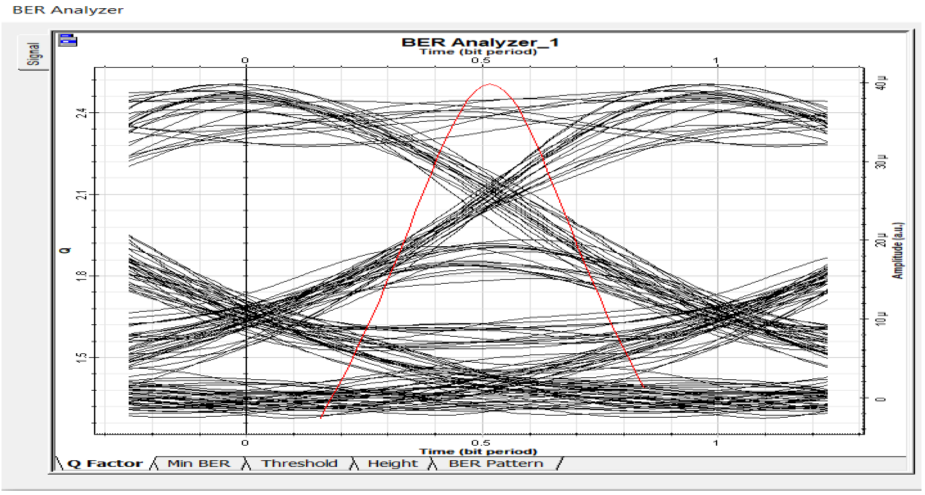


Fig 3.26: Highest Bit Error Rate at distance 100km

Fig 3.25, 3.26 represents eye diagram for different fiber length distance. It has been seen that eye openness decreases with the increase of fiber length.

Table 3.8: BER performance at different distance

Distance(km)	Bit Error Rate
0	8.37553e-007
10	2.93298e-007
20	4.75563e-007
50	4.82252e-006
80	0.000489731
100	0.00558955

Table 3.8 depicts BER performance q factor at varying fiber length distance. We have found increasing BER performance with the increase of fiber length.

Q factor decreases with the increasing fiber length distance.

3.2.2.2 Performance analysis at temperature 90^{o} C:

In optical link, we found distance performance. This distance performance is analyzed with the help of BER value, power, Q factor curves which are depicted in fig 3.27, 3.28 & in table 3.9.

In this case the bit error rate of the system is kept fixed temperature at 90^{o}C.

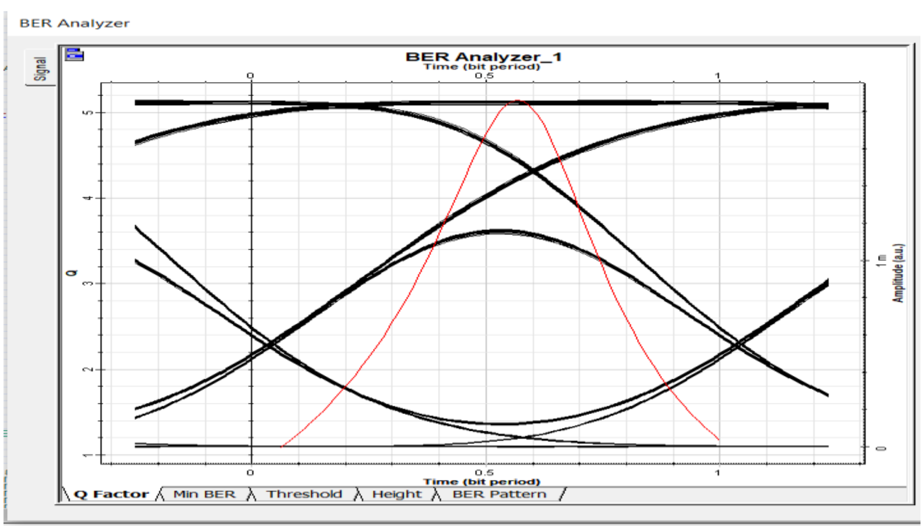


Fig 3.27: Bit Error Rate at distance 0.25m

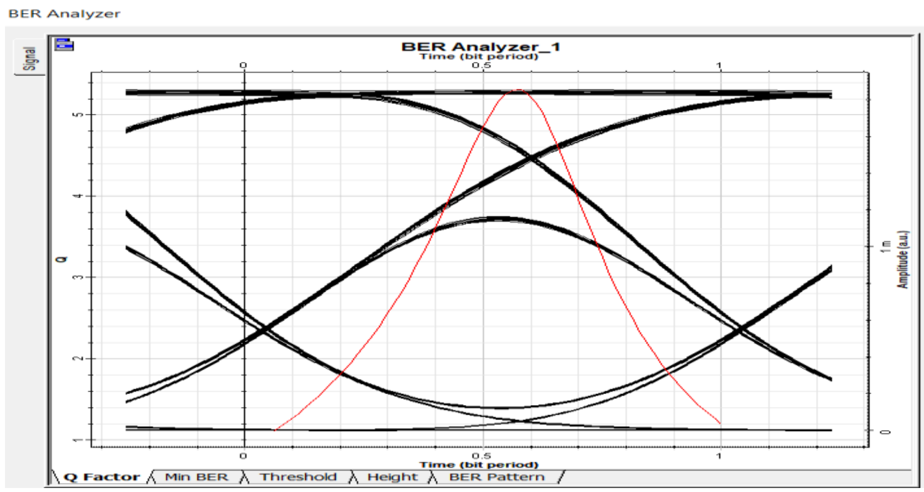


Fig 3.28: Bit Error Rate at distance 2m

Fig 3.27, 3.28 represent that eye openness decreases with the increase of fiber length.

Table 3.9: BER performance at different distance

Distance(m)	Bit Error Rate
0.25	1.07006e-007
2	4.19056e-008

Table 3.8 showed that BER performance at varying fiber length distance. We have found at bit error rate is lowest for distance 2m.

Here, Q factor increasing with the increasing fiber length distance.

3.2.2.3 Performance analysis at temperature 95^0 C:

In optical link, this distance performance is analyzed with the help of BER value, power, Q factor curves which are depicted in fig 3.29, 3.30& in table 3.10.

In this case the bit error rate of the system is kept fixed temperature and it is at 95^{0}C.

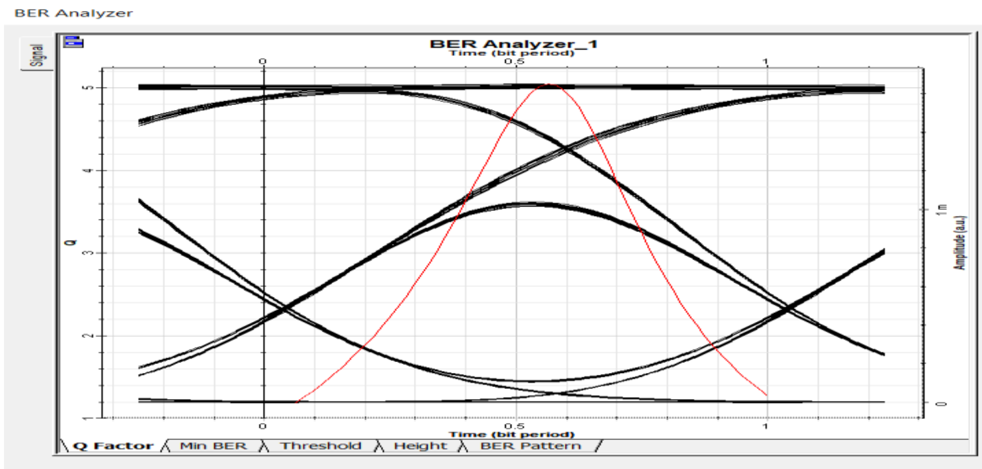


Fig 3.29: Bit Error Rate at distance 1m

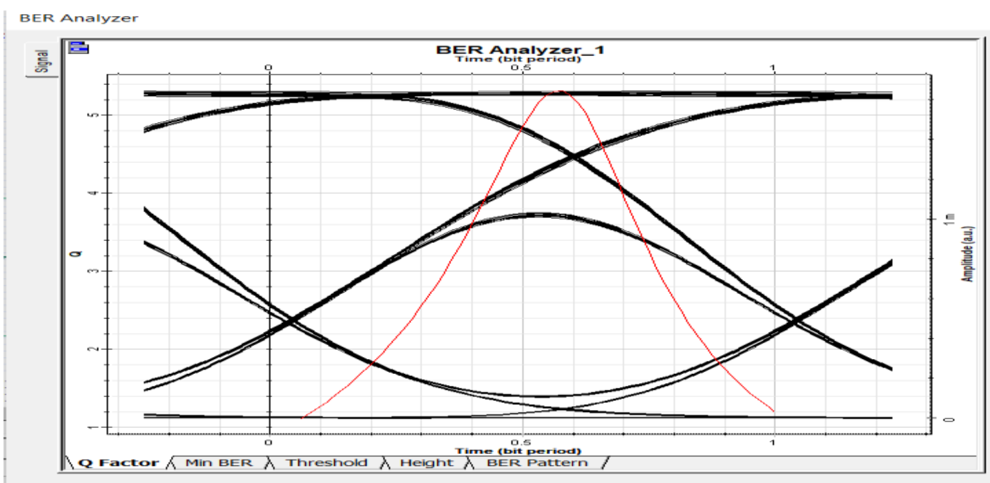


Fig 3.30: Bit Error Ratio at distance 2m

Fig 3.29, 3.30 represent that eye openness decreases with the increase of fiber length.

Table 3.10: BER performance at different distance

Distance(m)	Bit Error Rate
0.3	1.07116e-007
1	1.68415e-007
2	4.17852e-008

Table 3.10 showed that BER performance at varying fiber length distance. Q factor increased with the increasing fiber length distance. We have found at 2m distance bit error rate is lowest and suitable for other operations.

3.2.2.3 Performance analysis at different temperature:

We have discussed earlier that from our 1550 nm CW based optical link we found temperature performance up to 125^0C, now this temperature performance is analyzed with the help of BER value, power, and Q factor curves which are depicted in table (3.11) In this case the bit error rate of the system is kept fixed at 10 GB/s and also fiber length is kept fixed at 10 km.

Table 3.11: Q factor at different temperature

Temperature ^{0}C	Q factor
0	5.26375
10	5.10336
30	4.99219
50	5.25504
70	5.22797
100	4.69861
125	4.98177
128	0

This system performance has analyzed in terms of Q factor with different temperatures. It can be seen that Q factor performance decays very small amount with the increase of temperature but after 50^0C it increases again and at 128^0C it decays to 0, which means that our system is performing up to 125^0C.

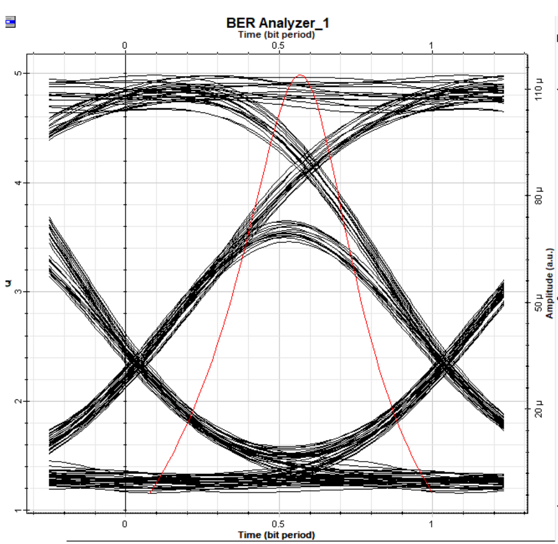


Fig 3.31: Q factor at 100^0C

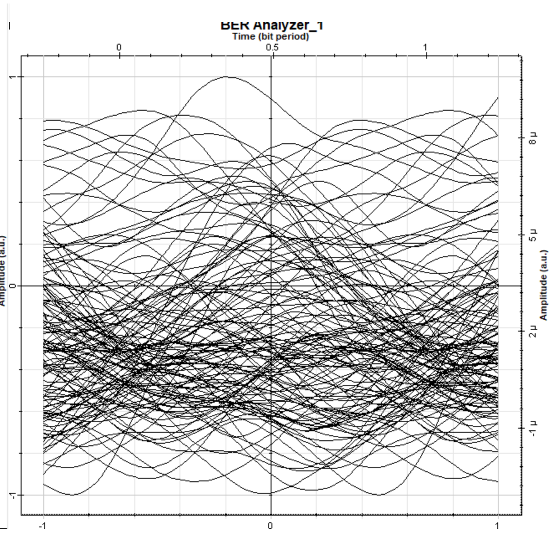


Fig 3.32: Q factor at 128^0C

In fig (3.31) and (3.32) the system performance at different temperatures are shown with the help of eye diagrams and it can be seen that the openness of eye decreases with the increase of temperature. When the temperature goes passed 125^0C the system stops performing because no particular eye openness can be identified in this temperature and there are multiple copies of eyes which indicate that the system noise level has increased.

Chapter 4

Conclusion

WDM systems are prominent with broadcast communications organizations since they enable them to grow the limit of the system without laying more fiber. By utilizing WDM and optical amplifiers, they can suit a few ages of innovation improvement in their optical foundation without upgrading the spine organize. Limit of a given connection can be extended just by overhauling the multiplexers and de multiplexers at each end.

WDM Systems are separated into three diverse wavelength designs: Normal (WDM), coarse (CWDM) and dance (DWDM). Typical WDM (once in a while called BWDM) utilizes the two ordinary wavelengths 1310 and 1550 on one fiber. Dense WDM (DWDM) utilizes the C-Band (1530 nm-1565 nm) transmission window however with denser channel separation. Channel plans shift, yet an ordinary DWDM system would utilize 40 channels at 100 GHz dispersing or 80 channels with 50 GHz dividing. Some innovations are fit for 12.5 GHz dividing (some of the time called ultra-dance WDM). The new intensity choice strengthens the ability to increase the use of L-band wavelengths (1565 nm-1625 nm), pretty much multiplying these numbers.

A DWDM terminal multiplexer, terminal multiplexer has wavelength-conversion transponders for each data signal, an optical multiplexer and where an optical amplifier (EDFA) is needed. Each wavelength-converter transformer receives an optical data signal from the client-layer, such as synchronous optical networking (SONET) or other types of data signals, this signal transforms into an electrical domain and re-synthesizes the signal through a specific wavelength, 1,550 nm band laser. These data signals are integrated into multiple wavelength optical signals using an optical multiplexer for transmission on single fiber. Terminal multiplexer may or may not include a local transmittance EDFA for power-amplification of multi-wavelength optical signals.

Although the WDM system is expensive and complicated to run. However, due to better understanding of the latest standards and the dynamism of the systems, WDM is less costly. In this thesis, we designed and simulated a CW Laser based fiber optic link for 1550 nm operating wavelength and data transmission using optisystem for WDM system. In the first chapter of this thesis, we have discussed about optisystem major parts like CW laser, VCSEL, LED, Photodiode, Optical Modulator etc. We also discussed about the simulation components in transmission section like Bit Sequence Generator, Pulse Generator, Bias Current and Optical Fiber, EDFA in optical link and Photodiode, Low Pass Filter in receiver section. Later we covered, we consider the OptiSystem software's special benefits, applications, key functionality and main features. In simulation section, we designed temperature sustainable CW by setting its internal and global design parameters. Then, we incorporated that CW in our optical data transmission system. We investigated the dependence of temperature, link distance and bit rate on Q-factor and BER in WDM modulation schemes for optical fiber link. From analysis, we found that the system supports error free (BER < 10-12) data transmission at a rate of 10 Gb/s up to 50km single mode fiber link at a maximum bit error rate and at 128°C temperature chosen q-factor was poor. Automobile sector can use optical fiber in future, for this in suitable temperature and distance bit error rate has been analyzed in this thesis. The obtained results show that the WDM modulation technique has a better performance in noisy environments. It has been seen that eye openness decreases with the increase of fiber length.

It is also found that for high temperature operation NRZ provides better signal power and WDM. In the 10-Gb/s single-channel optical networks, using NRZ modulation technique is recommended, because of its high Q-factor for optical transmission network.

Although from our discussions in this thesis on optical link solutions, we can develop some solutions for the real-world implementation of different networks that is a hybrid of optical fiber links, existing twisted-pair copper lines and even free-space optics. The interfaces between the different technologies and media in hybrid access create interesting research areas with challenges in size and power minimization. In particular, the units which must eventually merge this traffic onto the network must be flexible, small, cost-effective and field-deployable. In this way WDM maximizes the usefulness of fiber and helps optimize network investments. In WDM process full duplex transmission is possible, it is easier to reconfigure, optical components are more reliable with high bandwidth and security. It is simple to implement but light wave carrying WDM are limited to 2 point circuit and signal can't be very close. WDM networks performance is strongly influenced by nonlinearity characteristic inside the fiber. Therefore the nonlinearity effects of fiber optics pose an additional limitation in WDM systems.

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