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Performance Analysis of 48 Channels DWDM System using EDFA for Long Distance Communication

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Abstract

Dense wavelength division multiplexing (DWDM) is an advance technology. Optical fiber communication technology is used to send data in long distance. In this work to calculated the performance and analysis of Dense Wavelength Division Multiplexing. And also evaluate the quality factor and bitrate of optical pulse. Different mode of optical fiber used to send the data. Here SMF (Single mode fiber) and DCF (dispersion compensation fibers) are used. This work focuses on the 48 channel DWDM with described looping particularly explained by the BER analyzer and the Optical Analyze. Optical Add/Drop Multiplexers (OADMs) are used in wavelength-division multiplexing systems for routing fiber optic signals and multiplexing, it is used to transmit the data in long distance communication. In this method two modulation technique can be used RZ and NRZ .in this work NRZ modulation method can be used.

Keywords- BER, DWDM, DCF, EDFA

I. Introduction

In Fiber Optic Communications, wavelength-division multiplexing (WDM) is an advance technology .which multiplexes a number of optical pulses onto a single optical fiber by using different wavelengths (i.e.colours) of laser light. This technique used to send data in bidirectional communications over one strand of fiber. Fiber-optic communication is a method of transmitting information from one place to another by sending optical pulses through an optical fiber.

The light forms an electromagnetic carrier wave that is modulated to carry information. First developed in the 1970s, fiber-optics has revolutionized the telecommunications industry and has played a major role in the advent of the Information Age. Because of its advantages over electrical transmission, development of optical fibers have largely replaced copper wire communications in core networks.

Optical fiber is used by many communication sectors to transmit the signals, Internet communication, and cable television signals. Researchers at Bell Labs have reached internet speeds of over 100 pet a bit × kilometer per second using fiber-optic communication. Optisystem is an innovative of optical communication system simulation package for the design, testing and optimization of virtually any type of optical link.optisystem‘13.0 represents an optical communication system as an interconnected set of blocks.

II. Architecture

Dense wavelength division multiplexing (DWDM) technique used to optical signals Multiplexed within the 1550 nm band so as to Leverage the capabilities (and cost) of erbium doped fiber amplifiers (EDFAs), wavelengths between approximately 1525–1565nm, or 1570–1610 nm.

DWDM physical layer functions are shown in block diagram. These are depicted in Figure 1, which shows a DWDM schematic for four channels. Each optical channel occupies its own wavelength. Wavelength is expressed (usually in nanometers) different range of wavelength can be used. The effective light at a given wavelength is confined narrowly around its central wavelength.

Generating the signal—the source, a solid-state laser is provide stable light within a specific, narrow bandwidth that carries the digital data, modulated as an analog signal. Combining the signals is passed through an optical fiber different range of optical wave length can be used. There is some inherent loss associated with multiplexing and DE multiplexing. This loss is dependent upon the number of channels but can be diminished with optical amplifiers; this can be boosting all the wavelengths at once without electrical conversion.

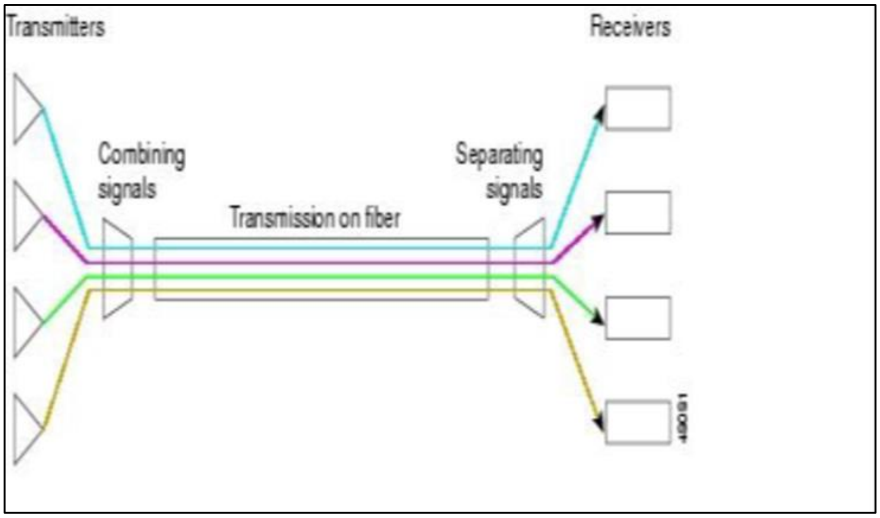

Fig. 1: block Diagram of DWDM

Transmitting the signals is affected by crosstalk and optical signal loss must be reckoned with in fiber optic transmission. These effects can be minimized by controlling variables such as separating channels wavelength tolerance, and laser power values are send Over a transmission link, the signal may need to be optically amplified. Separating the received signals—at the receiving end, the multiplexed signals are separated out. It is actually more technically difficult.

In addition to these functions, a DWDM system must also be equipped with client-side interfaces to receive the input signal. This function is performed by transmitter. On the DWDM side are interfaces to the optical fiber that links DWDM systems. A DWDM terminal multiplexer. It contains a wavelength-converting transponder for each data signal, an optical multiplexer and where necessary an optical amplifier (EDFA). Each wavelength-converting transponder receives an optical data signal from the transmitting layer, such as Synchronous optical networking [SONET /SDH] or another type of data signal, converts this signal into the electrical signal and re-transmits the signal at a specific wavelength using a 1,550 nm band laser.

These data signals are then combined together into a multi-wavelength optical signal using an optical multiplexer, for transmission over a single fiber (e.g., SMF-28 fiber). The terminal multiplexer may or may not also include a local transmit EDFA for power amplification of the multi-wavelength optical signal. In the mid-1990s DWDM systems contained 4 or 8 wavelength-converting transponders; by 2000. So commercial systems capable of carrying 128 signals were available.

An intermediate line repeater is placed approximately every 80–100 km to compensate for the loss of optical power as the signal travels along the fiber. The 'multi-wavelength optical signal' is amplified by an EDFA, which usually consists of several amplifier stages.

A. Optical Amplifier

An optical amplifier is a device that amplifies an optical signal directly, without the need to first convert it to an electrical signal. An optical amplifier may be thought of as a laser without an optical cavity, or one in which feedback from the cavity is suppressed. Optical amplifiers are important in optical communication and laser physics. There are several different physical mechanisms that can be used to amplify a light signal, which correspond to the major types of optical amplifiers. In doped fiber amplifiers and bulk lasers, stimulated emission in the amplifier's gain medium causes amplification of incoming light. In semiconductor optical amplifiers (SOAs), electron-hole recombination occurs. In Raman amplifiers, Raman scattering of incoming light with phonons in the lattice of the gain medium produces photons coherent with the incoming photons. Parametric amplifiers use parametric amplification.(Senior, John 2008).

B. Erbium-Doped fiber Optic Amplifier

The erbium-doped fiber amplifier (EDFA) is the most deployed fire amplifier as its amplification window coincides with the third transmission window of silica-based optical fiber. Two bands have developed in the third transmission window – the Conventional, or C-band, from approximately 1525 nm – 1565 nm, and the Long, or L-band, from approximately 1570 nm to 1610 nm. Both of these bands can be amplified by EDFAs, but it is normal to use two different amplifiers, each optimized for one of the bands (N. K. Dutta 2006)The principal difference between C- and L-band amplifiers is that a longer length of doped fiber is used in L-band amplifiers. The longer length of fiber allows a lower inversion level to be used, thereby giving at longer wavelengths (due to the band-structure of Erbium in silica) while still providing a useful amount of gain. (Farah Diana et al 2009) EDFAs have two commonly used pumping bands – 980 nm and 1480 nm. The 980 nm band has a higher absorption cross-section and is generally used where low-noise performance is required. The absorption band is relatively narrow and so wavelength stabilized laser sources are typically needed. The 1480 nm band has a lower, but broader, absorption cross-section and is generally used for higher power amplifiers. A combination of 980 nm and 1480 nm pumping is generally utilized in amplifiers.

C. Single-Mode Fiber

Fiber with a core diameter less than about ten times the wavelength of the propagating light cannot be modeled using geometric optics. Instead, it must be analyzed as an electromagnetic structure, by solution of Maxwell's equations as reduced to the electromagnetic wave equation. The electromagnetic analysis may also be required to understand behaviors such as speckle that occur when coherent light propagates in multi-mode fiber. As an optical waveguide, the fiber supports one or more confined transverse modes by which light can propagate along the fiber. Fiber supporting only one mode is called single-mode or mono-mode fiber. The behavior of larger-core multi-mode fiber can also be modeled using the wave equation, which shows that such fiber supports more than one mode of propagation (hence the name).

The results of such modeling of multi-mode fiber approximately agree with the predictions of geometric optics, if the fiber core is large enough to support more than a few modes. The waveguide analysis shows that the light energy in the fiber is not completely confined in the core. Instead, especially in single-mode fibers, a significant fraction of the energy in the bound mode travels in the cladding as an evanescent wave. The most common type of single-mode fiber has a core diameter of 8–10 micrometers and is designed for use in the near infrared.

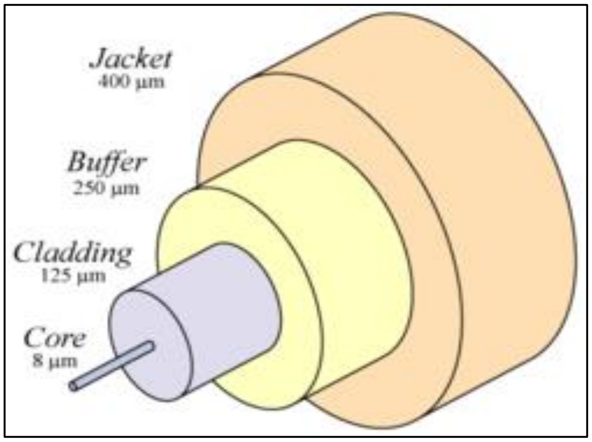

Fig. 2: single mode fiber

D. Scattering Loss

Four kinds of scattering losses in optical fiber are: Rayleigh, Mie, Brillion and Raman scattering. Rayleigh is the most important scattering loss due to small localized changes in the refractive index of the core and the cladding material. These changes are due to two problems of manufacturing process: the Fluctuations in the mix‘of the ingredients are impossible to completely eliminate and the slight change in the density as the silica cools and solidifies. The Rayleigh scattering loss in dB/km can be approximated by the expression:

$$L = 1.7(\frac{0.85}{\lambda})4 \quad (1)$$

Where, λ - is the wavelength in µm.

The scattering loss is inversely proportional to fourth power of wavelength. Therefore, the use of shortwave length in fiber optic communication is severely restricted by Rayleigh scattering.

E. Dispersion Compensation Fiber

Dispersion Compensation in Fiber-optic Communication Links. Dispersion compensation is an important issue for fiber-optic links, i.e., in the context of optical fiber communications. Here, strong dispersive broadening of modulated signals can occur in cases with high data rate.

A large number of the optical fiber cables installed today make use of non-shifted single-mode fibers, i.e., fibers with zero dispersion wavelength at 1310 nm and a dispersion of about 17 ps/ nm/ km at 1550 nm. Nowadays, wavelengths around 1550 nm are the preferred transmission window. This is because the fiber loss has its minimum close to this wavelength and because the erbium-doped fiber amplifier operates in this wavelength region. For bit rates up to 2.5 Gbit/s problems related with the dispersion can be solved by use of narrowband transmitters, bitrate is increased to 10 Gbit/s the dispersion limits the transmission distance to around 50 km. This raises the need for some sort of dispersion compensation. Use of dispersion compensating fibers was originally proposed by Lin et al. in 1980.

F. Attenuation

Signal attenuation is defined as the ratio of optical input power (Pi) to the optical output power (Po). Optical input power is the power injected into the fiber from an optical source. Optical output power is the power received at the fiber end or optical detector. The following equation defines signal attenuation as a unit of length.

$$\text{Attenuation} = \frac{10}{L}\log_{10}(P_i / P_0) \quad (2)$$

Where,
Pi – Optical Input Power

P0 - Optical Output Power

III. SIMULATION PARAMETERS

In the given layout, simulated a 32-channel DWDM network with RZ modulation formats at 40 GB/s. The transmitter section consists of a 32-channel WDM transmitter with starting Frequency of 1450nm and the frequency spacing is 100 GHz. Here used a transmission loop as an optical link with a length of 90 km of SMF, 30 km of DCF and two EDFA's are used. The receiver is a 32-channel WDM de-multiplexer, with PIN photo detectors and BER testers.

The schematic Layout for DWDM simulation Using OPTISYSTEM'13.0.The 32-channel multiplexer has been used along with DCF with the general Optical fiber. Optical amplifier gain increased up to 20 db. Than frequency spacing of the wavelength is 100GHz. WDM transmitter is use to transmit the signal in to ideal mux .Than passing through the control loop after it was separated. Than it was de mux By WDM. After de mux the wavelength than go to the photodiode .optical receiver are used to receive the signal from the WDM de mux.

Output displayed by the BER analyzer. The BER cure displayed on the graph. The waves distributed uniformly than output is high and quality factor value increases. If quality factor value increases than signal transmission rate is high.

parameters	*Value*
Reference frequency	*1450 nm*
Frequency spacing	*100GHz*
Optical fiber length	*90km*
DCF length	*30km*
EDFA gain	*20 db*
Optical receiver cutoff frequency	*0.75x Bit rate Hz*

IV. SIMULATION / CALCULATION

Simulated a 32-channel DWDM network with RZ modulation formats at 40 GB/s. The transmitter section consists of a 32-channel WDM transmitter with starting Frequency of 1450nm and the frequency spacing is 100 GHz. here used a transmission loop as an optical link with a length of 90 km of SMF; 30 km of DCF and two EDFA's are used. The receiver is a 32-channel WDM de-multiplexer, with PIN photo detectors and BER testers. The 32-channel multiplexer has been used along with DCF with the general Optical fiber. Optical amplifier gain increased up to 20 db. Than frequency spacing of the wavelength is 100GHz. WDM transmitter is use to transmit the signal in to ideal mux .Than passing through the control loop after it was separated. Signals are passed through optical fiber. Here two types of optical fiber used. One is single mode fiber another one is dispersion compensation fiber. Than it was Demux By WDM. After de mux the wavelength than go to the photodiode .optical receiver are used to receive the signal from the WDM de mux .output displayed by the BER analyzer.

The BER cure displayed on the graph. The waves distributed uniformly than output is high and quality factor value increases. if quality factor value increases than signal transmission rate is high. In previous system quality factor is 2.345 but now after change the distance of optical fiber length than quality factor is improved by 11.4327. If increasing the quality factor data transmitted to the long distance.

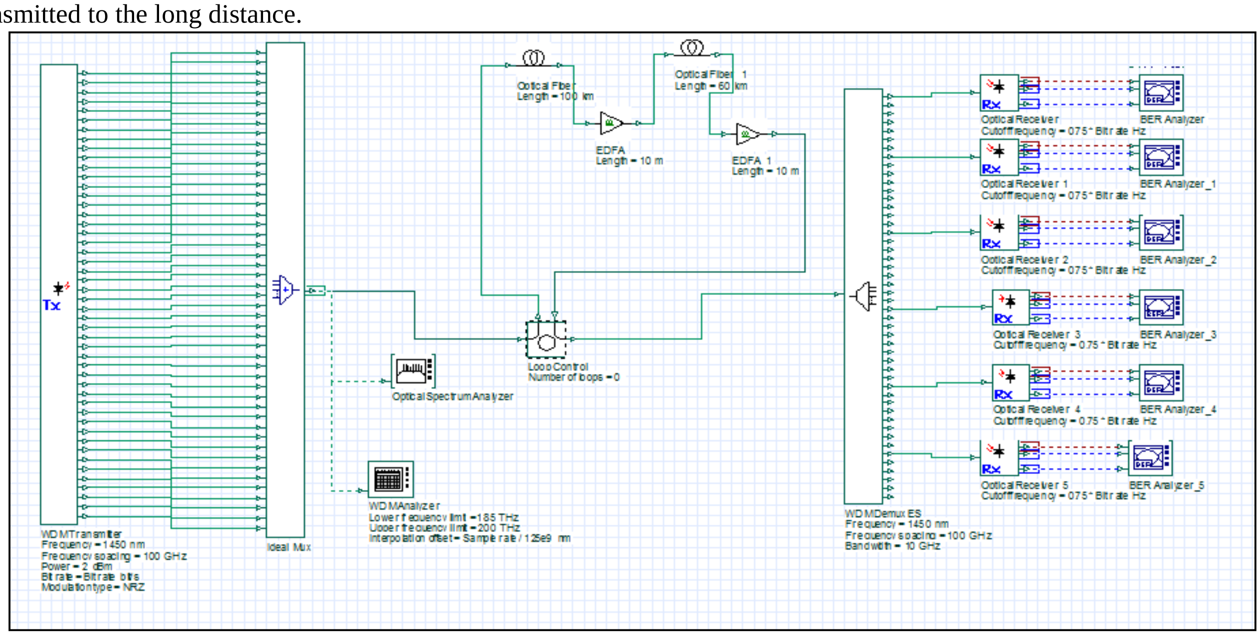

Fig. 2: Schematic layout of DWDM

V. RESULTS

A. *Optical Spectrum Analyzer*

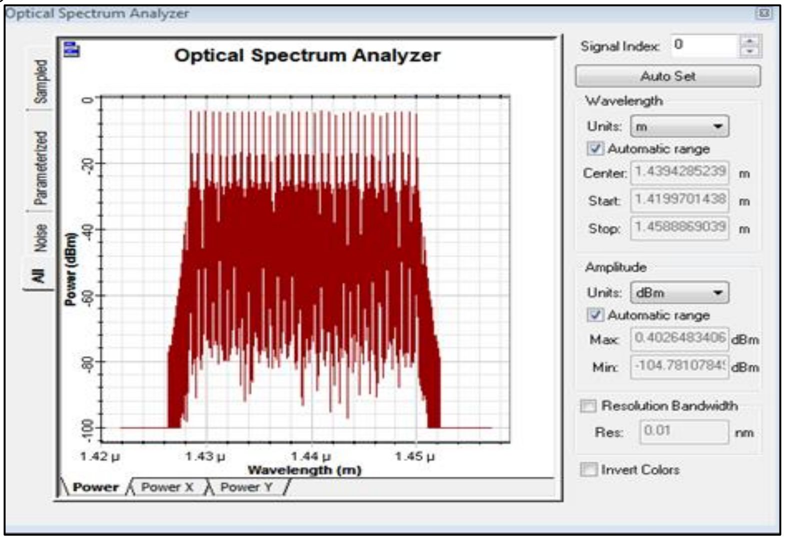

Fig. 3: simulation output of spectrum analyzer

An optical spectrum analyzer uses reflective and/or refractive techniques to separate out the wavelengths of light. An electro-optical detector is used to measure the intensity of the light, which is then normally displayed on a screen in a similar manner to a radio- or audio-frequency spectrum analyzer.

The input to an optical spectrum analyzer may be simply via an aperture in the instrument's case, an optical fiber or an optical connector to which a fiber-optic cable can be attached. Different techniques exist for separating out the wavelengths. One method is to use a mono chromator, for example a Czerny–Turner design, with an optical detector placed at the output slit. As the grating in the mono chromator moves, bands of different frequencies (colors) are 'seen' by the detector, and the resulting signal can then be plotted on a display.

(Joe Deery 2007) More precise measurements (down to MHz in the optical spectrum) can be made with a scanning Fabry–Pérot interferometer along with analog or digital control electronics, which sweep the resonant frequency of an optically resonant cavity using a voltage ramp to piezoelectric motor that varies the distance between two highly reflective mirrors.

A sensitive photodiode embedded in the cavity provides an intensity signal, which is plotted against the ramp voltage to produce a visual representation of the optical power spectrum. Fig 3 shown output of optical spectrum analyzer. The spectrum range is 1.42µm to 1.45µm. spectrum analyzer is used to improve the strengthening of the signals and which is gives different spectrum levels. Spectrum level Differ with respect to the different wavelength. The sharp peak can be produced by the spectrum device.

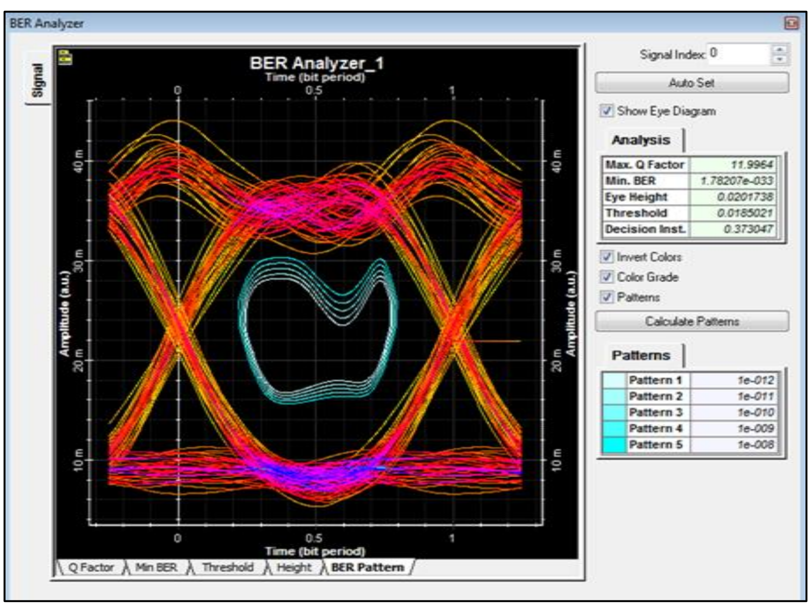

Fig. 4: Eye Diagram and Output of BER Analyzer

Above the fig 4 is explains the eye diagram of BER analyzer.in this diagram find the signal strength. Optical pulses passing through an optical fiber than some losses occurs on the inside the fiber. So in this BER analyzer used to improve the strength of the signal and good transmission of optical pulses.

Here quality factor of the device improved Maximum quality factor of this eye diagram is 11.667. This factor range is good. The shape of the waves is uniformly varied so it gives the better transmission.

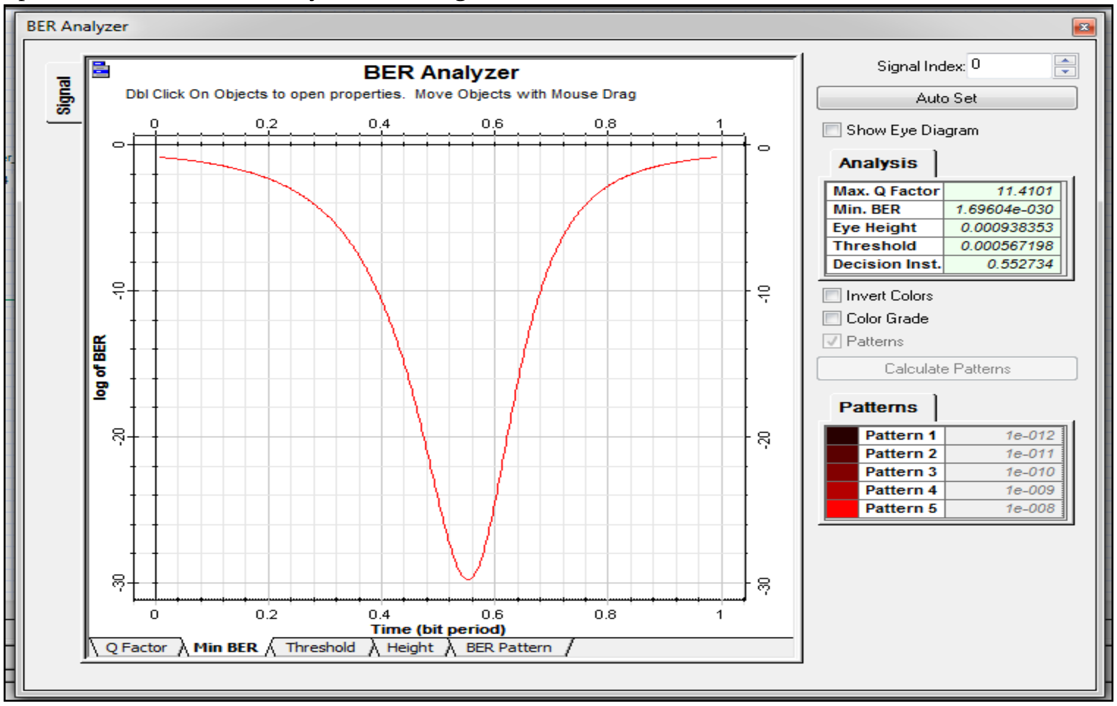

Fig. 5: output diagram of min BER

Above the fig 5 is output diagram of min Bit Error Rate. BER is important thing of the data transmission. Very less bit error rate it is not sufficient for data transmission. Value of BER changes with respect to the different modulation methods here two methods can be used NRZ and RZ. Here min bit error rate is 1.69604e – 030 is better compare to RZ modulation method.

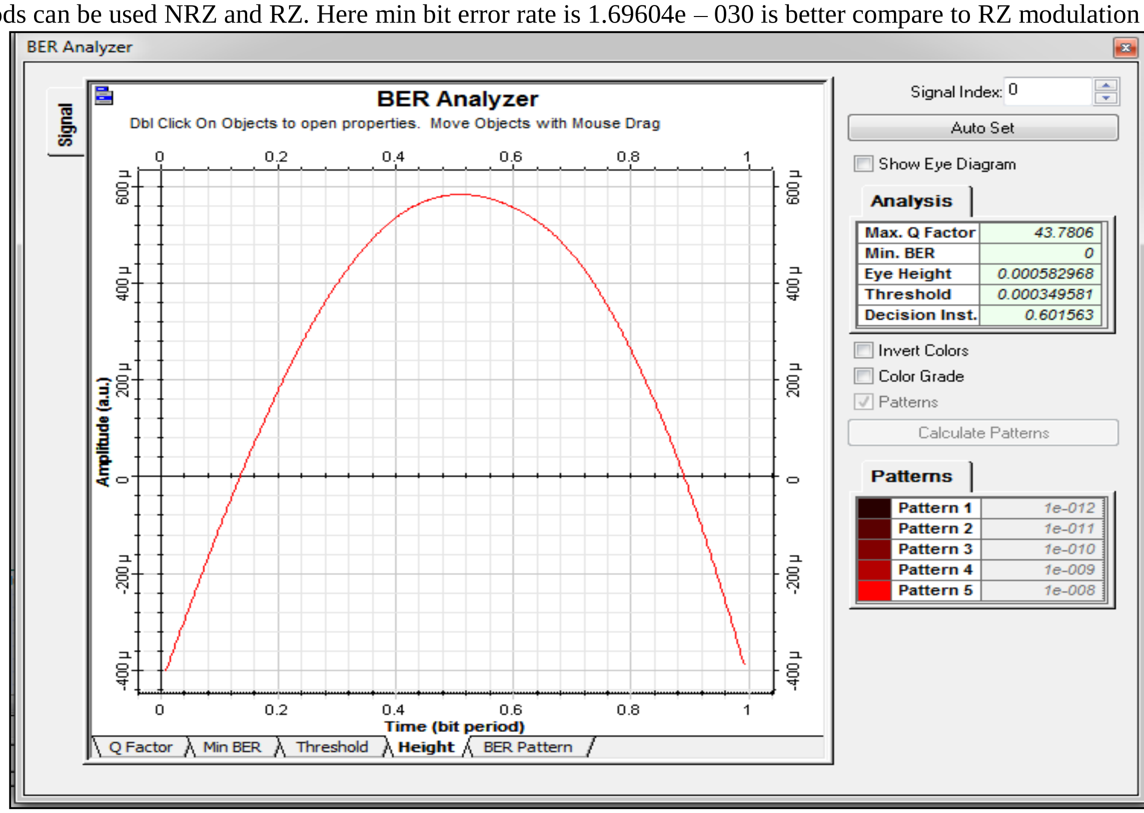

Fig. 6: output diagram of BER analyzer

Above the diagram shown output of the BER analyzer.in this diagram explains the quality factor of the BER analyzer. Here maximum quality factor is 43.666.so in this factor value is very high compare to the other modulation techniques. In NRZ modulation technique quality factor is very low compare to the RZ modulation technique. So NRZ have more energy compare to the RZ method.

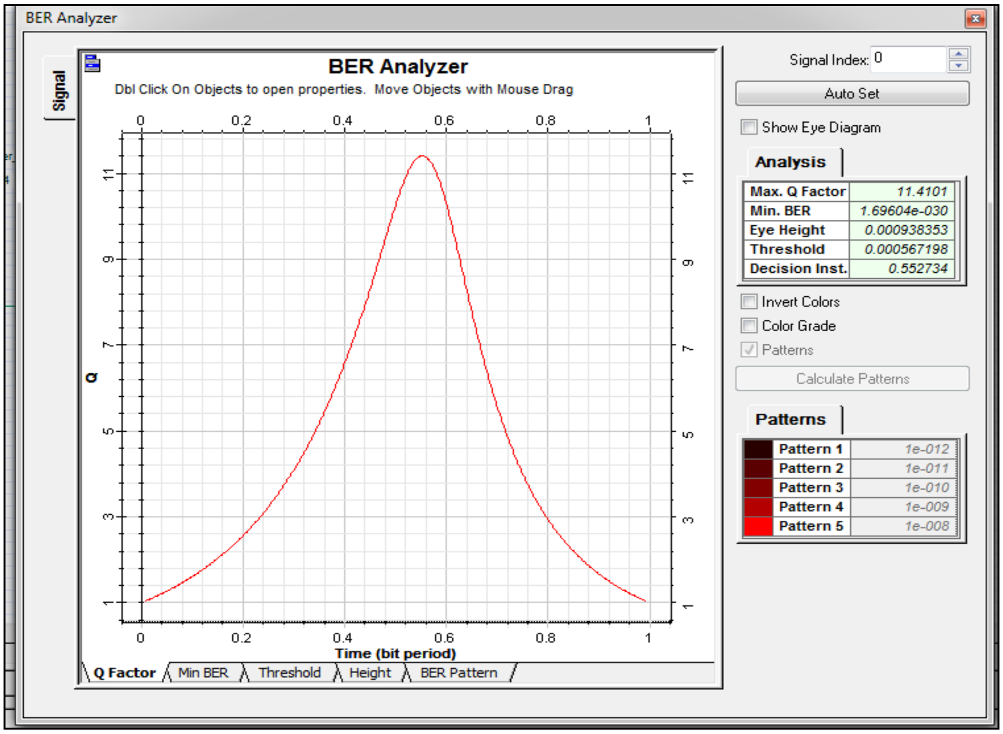

Fig. 7: output diagram of quality factor

Above the diagram is quality factor of the BER analyzer.in this curve is gradually increases than decreases . Maximum quality factor of the in this BER analyzer is 11.442 compare to the previous diagram quality factor is very less.it is good for better transmission of optical pulses.

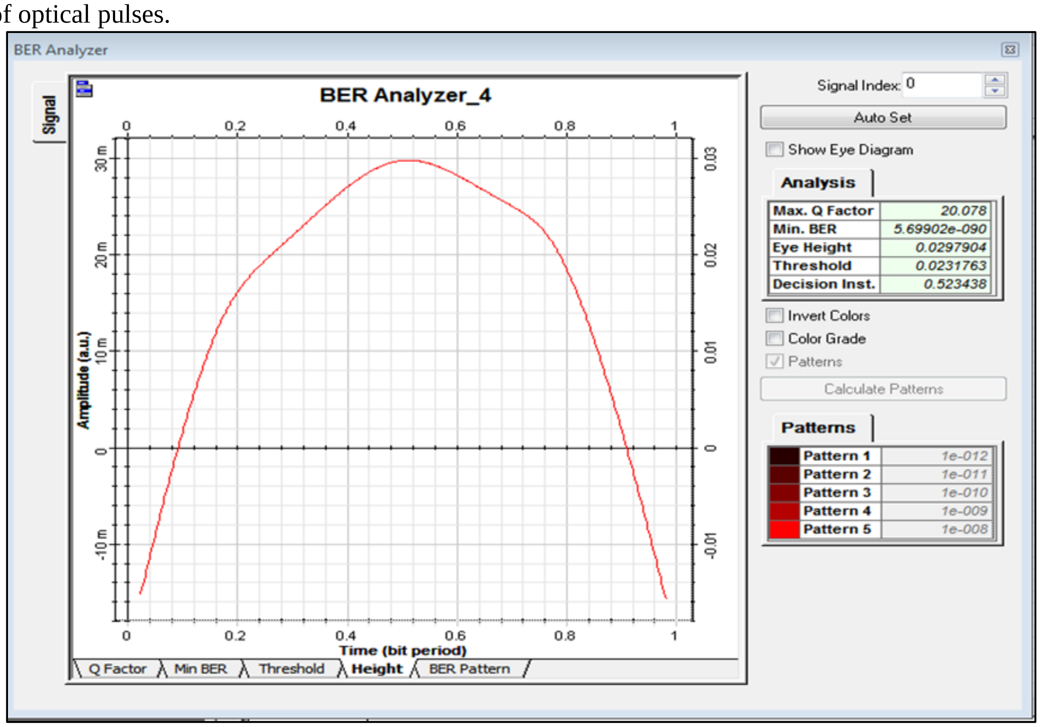

Fig. 8: amplitude of BER analyzer

Fig .5 shown the amplitude range of the BER analyzer. Height of amplification is 0.02979 threshold value is 0.023117 max quality factor is 20.070 and finally min BER is 5.6992e-090.

By using different range of wavelength than amplitude range also change amplitude is some height of the curve or waves. Amplitude is depends on the power if power value can be increased than also increases the amplitude value.

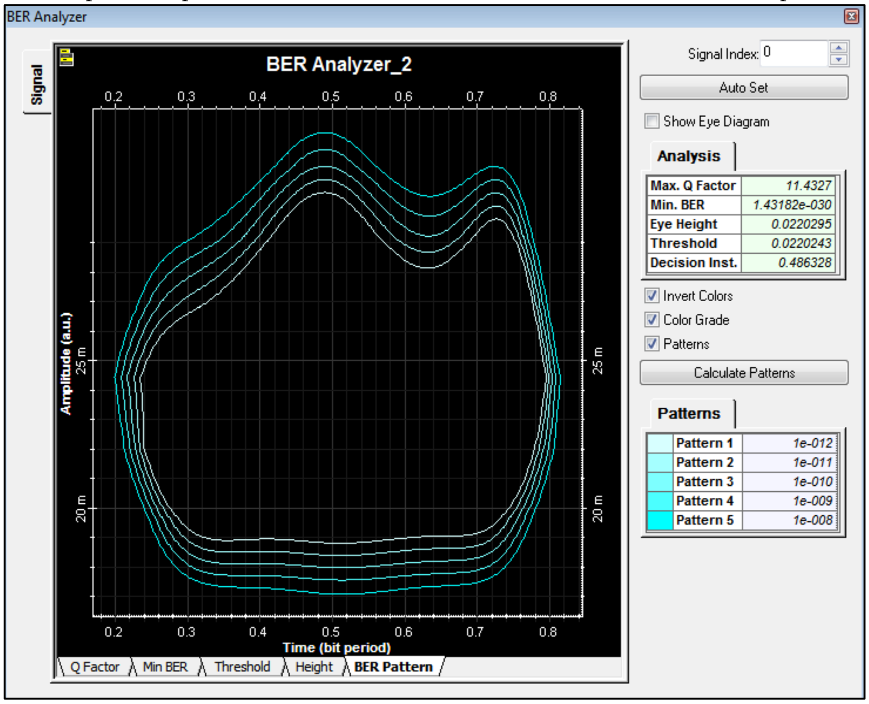

Fig. 9: Output of BER pattern

Fig. 9 shown that the BER pattern of the DWDM techniques. This waves are distributed uniformly. BER pattern is calculated by the BER analyzer. Analyzer is analyzed the BER rate and gives the BER pattern of the optical pulses.

VI. CONCLUSION

Simulated a 32-channel DWDM network with NRZ modulation formats at 40 GB/s. The transmitter section consists of a 32-channel WDM transmitter with starting Frequency of 1450nm and the frequency spacing is 100 GHz. here used a transmission loop as an optical link with a length of 90 km of SMF; 30 km of DCF and two EDFA's are used. The receiver is a 32-channel WDM de-multiplexer, with PIN photo detectors and BER testers. The 32-channel multiplexer has been used along with DCF with the general Optical fiber. Optical amplifier gain increased up to 20 db. Than frequency spacing of the wavelength is 100GHz. WDM transmitter is use to transmit the signal in to ideal mux .Than passing through the control loop after it was separated. Signals are passed through optical fiber. Here two types of optical fiber used. One is single mode fiber another one is dispersion compensation fiber. Than it was Demux by WDM. After de mux the wavelength than go to the photodiode .optical receiver are used to receive the signal from the WDM de mux .output displayed by the BER analyzer. The BER cure displayed on the graph. The waves distributed uniformly than output is high and quality factor value increases. If quality factor value increases than signal transmission rate is high. In previous system. Quality factor is 2.345 but now after change the distance of optical fiber length than quality factor is improved by 11.4327. If increasing the quality factor data transmitted to the long distance.

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