DISSERTATION REPORT

ON

“0.8-Tb/s Transmission in DWDM system Employing Dispersion Compensating fiber and Erbium Doped Fiber Amplifier”

Submitted in partial fulfillment of the requirements for the award of degree

Master of Technology

In

Electronics and Communication Engineering

Submitted by

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LOVELY
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Department of Electronics & Communication Engineering

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TOPIC APPROVAL PERFORMA

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Qualification : ________________________ **Research Experience :** ________________________

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SPECIALIZATION AREA : Wireless Communication **Supervisor Signature:** ____________________

PROPOSED TOPIC : investigation of Wavelength division multiplexing on n Channels in Optical Networks and Systems

Qualitative Assessment of Proposed Topic by PAC		
Sr.No.	**Parameter**	**Rating (out of 10)**
1	Project Novelty: Potential of the project to create new knowledge	7.50
2	Project Feasibility: Project can be timely carried out in-house with low-cost and available resources in the University by the students.	7.50
3	Project Academic Inputs: Project topic is relevant and makes extensive use of academic inputs in UG program and serves as a culminating effort for core study area of the degree program.	6.50
4	Project Supervision: Project supervisor's is technically competent to guide students, resolve any issues, and impart necessary skills.	7.00
5	Social Applicability: Project work intends to solve a practical problem.	8.00
6	Future Scope: Project has potential to become basis of future research work, publication or patent.	7.50

PAC Committee Members		
PAC Member 1 Name: Rajeev Kumar Patial	UID: 12301	Recommended (Y/N): Yes
PAC Member 2 Name: Lavish Kansal	UID: 15911	Recommended (Y/N): Yes
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Final Topic Approved by PAC: **Already a lot of work has been done on this topic. So, please change it.**

Overall Remarks: Approved (with major changes)

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ABSTRACT

Over the last decade, fiber optic cables have been installed by carriers as the backbone of their interoffice networks, becoming the mainstay of the telecommunications infrastructure. Using time division multiplexing (TDM) technology, carriers now routinely transmit information at 2.4 GB/s on a single fiber, with some deploying equipment that quadruples that rate to 10 GB/s. The revolution in high bandwidth applications and the explosive growth of the Internet, however, have created capacity demands that exceed traditional TDM limits. It is clear that as we approach the 21st century the remarkable revolution in information services has permeated our society. Communication, which in the past was confined to narrowband voice signals, now demands a high quality visual, audio, and data context. Every aspect of human interplay—from business, to entertainment, to government, to academia—increasingly depends on rapid and reliable communication networks. Indeed, the advent of the Internet alone is introducing millions of individuals to a new world of information and technology. The telecommunications industry, however, is struggling to keep pace with these changes. Early predictions that current fiber capacities would be adequate for our needs into the next century have proven wrong. The bad news, however, is that the once seemingly inexhaustible capacity promised by ever increasing SONET rates is reaching its limit. In fact, bandwidth demand is already approaching the maximum capacity available in some networks. Primarily because of technical limitations and the physical properties of embedded fiber, today there is a practical ceiling of 2.4 GB/s on most fiber networks, although there are instances where STM–64/OC–192 is being deployed. Surprisingly, however, the TDM equipment installed today utilizes less than 1% of the intrinsic capacity of the fiber.

As a result, the once seemingly inexhaustible bandwidth promised by the deployment of optical fiber in the 1980s is being exhausted. To meet growing demands for bandwidth, a technology called Dense Wavelength Division Multiplexing (DWDM) has been developed that multiplies the capacity of a single fiber. DWDM systems being deployed today can increase a single fiber’s capacity sixteen fold, to a throughput of 40 GB/s. This cutting edge technology—when combined with network management systems and add-drop multiplexers— enables carriers to adopt optically-based transmission networks that will meet the next generation of bandwidth demand at a significantly lower cost than installing new fiber.

ACKNOWLEDGEMENT

I would like to express my gratitude to my thesis guide Prof. Munish Singh for his guidance, advice and constant support throughout my thesis work. I would like to thank him for being my advisor here at Lovely Professional University, Jalandhar. I would also like to thank all faculty members and staff of the Department of Electronics and Communication Engineering, Lovely Professional University, Jalandhar for their generous help in various ways for the completion of this thesis. I would like to thank all my friends and especially my classmates for all the thoughtful and mind stimulating discussions we had, which prompted us to think beyond the obvious. I am especially indebted to my parents for their love, sacrifice, and support. They are my first teachers after I came to this world and have set great examples for me about how to live, study, and work.

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DECLARATION

I, Sahil Kakalia student of M.Tech E.C.E under Department of Electronics and Communications of Lovely Professional University, Punjab, hereby declare that all the information furnished in this Dissertation I report is based on my own intensive research and is genuine.

This report does not, to the best of my knowledge, contain part of my work which has been submitted for the award of my degree either of this university or any other university without proper citation.

Date:

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Signature and name of Student

Sahil Kakalia

It is certified that the above statement is correct to the best of my knowledge and belief.

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CERTIFICATE

This is to certify that Sahil Kakalia, bearing Registration no. 11407116 has completed Dissertation II titled, **“0.8-Tb/s Transmission in DWDM system Employing Dispersion Compensating fiber and Erbium Doped Fiber Amplifier”** under my guidance and supervision. To the best of my knowledge, the present work is the result of his original investigation and study. No part of the thesis has ever been submitted for any other degree at any University.

The thesis is fit for submission and the partial fulfillment of the conditions for the award of *the award of the Degree of* **MASTER OF TECHNOLOGY IN Electronic and Communication Engineering.**

Signature and Name of the Research Supervisor

Designation

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Date:

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Chapter1

Introduction

1.1 Introduction

Optical fiber cables are being installed by users as the backbone of the network in the office, thereby making the optical fiber cables as the mainstay of the infrastructure constituting telecommunication. By using Time Division Multiplexing (TDM), data rate of around 2.4 GB/s is achieved on a single fiber. This data rate is increased to 10 GB/s by employing certain equipment, there by quadrupling the data. There has been a great demand in the increase in data rate due to increase of use of large bandwidth applications and internet, thereby putting a lot of pressure on TDM to stretch its limits. It has become quite clear that as we are approaching 21^{st} century, our society will be inhabited by the need of information services. In the past, communication only meant voice calls. But now the entire definition of communication has changed. Communication now corresponds to not only a demand of high quality voice but also video calling, text messaging, transfer of data files, videos and a lot more. Every human activity now depends on reliable and rapid communication networks.

The internet alone is attracting a lot of individuals to the world of information and technology. And it has become for the communication industry to cope up with the pace with which the things are changing. And the predictions, that the optical fiber would be able to meet the bandwidth requirements have been proven wrong.

Due to this, the once inexhaustible bandwidth promised by optical fibers laid in 1980’s is nearly exhausted. Facing the need of high data capacity, the service providers have three possible solutions to cater the problem. These solutions are as under:

- By installation of new fiber.
- To invest more in already available TDM technology to get a higher data rate.
- Develop and deploy a new technique called as Dense Wavelength Division Multiplexing (DWDM).

Installing a new fiber will be a high cost solution, since it requires a high cost material and labour for installation. And even if we invest in already available TDM technology it would still not be able to meet the bandwidth requirement in near future, again leading to the same problem. So, in order to meet the current bandwidth requirements by using the already laid infrastructure, a technique called as Dense Wavelength Division Multiplexing (DWDM) has been developed. It multiplies the capacity of the already laid single fiber. The DWDM systems employed today are capable of increasing the capacity of the single fiber by sixteen folds, to give a 40 GB/s throughput. This technology when combined with optical equipments such as add-drop mux, amplifiers etc. will enable the service providers to adopt optical based networks to meet the requirements of bandwidth of the next generation at a low cost rather than installing new fiber.

1.2 Dense Wavelength Division Multiplexing

DWDM is a technology that allows multiple wavelengths to be transmitted simultaneously over a single fiber, thereby allowing carriers to increase the data rate by using already laid single fiber. Each information stream is transmitted on a unique wavelength. All the wavelengths are combined by using a mux. Wavelength Division Multiplexing (WDM) has been a well-known technology but it was restricted to provide only two widely spaced wavelengths. Recently this technology has emerged that allow multiple data streams on different wavelengths to be transmitted simultaneously and to be packed densely. These signals are transmitted in the 192 to 200 terahertz (THz) range.

1.3 Architecture of DWDM

DWDM is a technique which works on principle of combining multiple light waves on to a single fiber. It is done by using a WDM mux. It combines the different wavelengths on to a single fiber and transmits it over the channel. The Channel comprises of various amplifiers and repeaters to regenerate the distorted signal. At the receiver side, WDM demux is placed which performs the reverse operation of separating the light waves and send it to the desired user.

The architecture of DWDM network [14] is shown in figure 1.1. In this figure, DWDM mux multiplexes several wavelengths on a single fiber. These optical signals are then sent over the channel. The optical signal suffers from various types of attenuations and interferences on the channel. In order to reduce it, several amplifiers such as EDFA is used at different distances.

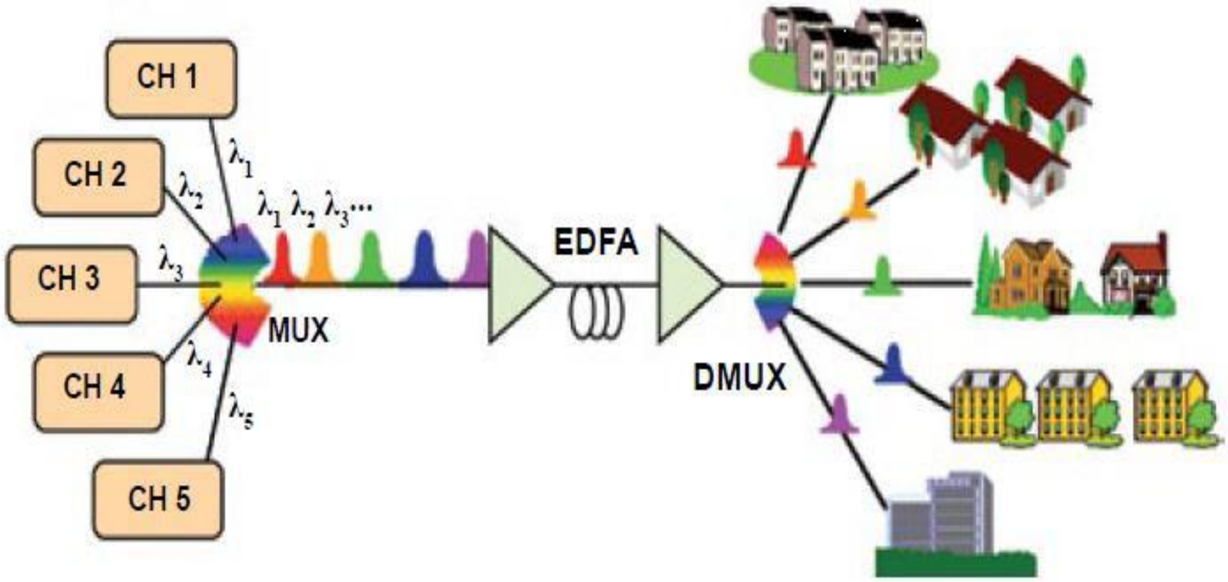


Fig. 1.1 Architecture of DWDM

A back reflection is minimized by using an optical isolator with each optical source. This multiplexed signal is then sent via optical fiber cable. At the receiver, a WDM de-multiplexer made up of an array of FBGs, each tuned to a specific wavelength, splits and separates the wavelengths and the data is extracted.

1.4 Components of DWDM system

1. Transmitter and receiver:

At the transmitter side, a transmit transponder is used. It performs the task of changing electrical signals into ITU grid- specific optical wavelengths. A laser performs the task of generating optical signals. At the receiver's side, a 3r generator followed by a filter and an error detector will convert optical signals to electrical signals.

2. Transmission Media:

There is minimum attenuation at 1550 nm and optical amplifiers are also available in 1550 nm region. So most of DWDM systems operate in 1530 nm to 1565 nm. In this range, high dispersion is being faced by single mode fibers [3]. Due to this the distance between the repeater stations is highly affected. This problem can be solved by using Dispersion compensating fiber. It has small and non-zero dispersion and can reduce to a great extent the non-linearity effects.

3. WDM MUX and DEMUX

A transponder is used at the transmitting side which basically consists of two components: WDM transmitter and a WDM multiplexer. A WDM transmitter which is basically a laser produces the desired optical signals tuned at different wavelengths. These optical signals at different wavelengths are then joined together or multiplexed using a WDM mux and sent over a single mode fiber as a single unit.

At the receiver side, a WDM de-mux separates the optical signals of different wavelengths. Several techniques such as Fiber Bragg gratings or diffraction gratings are used to separate different wavelengths depending on the spacing between them. FBG is used to diffract the light entering it by inducing period variations in the refractive index. The periodic variations are spaced at half of the wavelength and multiples of the desired signals. Each variation produces a 360- degree phase shift in the reflected light. It allows only specific wavelength to pass thereby causing a constructive interference.

4. Optical amplifier:

Three types of amplifiers are used namely post amplifier, inline amplifier and pre amplifier. A pre amplifier acts as a booster for the optical signal at the transmitter side, a post amplifier at the receiver's side and an in line amplifiers is placed at different distances usually 50-60 km from source in order to recover signals before it is degraded to a large extent. The most popular amplifier is the EDFA. It boosts the signal level in 1530 nm to 1570 nm window. The most important fact about EDFA’s is that they allow signals to be regenerated back without converting them into electrical signals. This amplifier is pumped externally by a laser source of 1480 nm or 980 nm. It produces a high amplification of order of 30 db.

1.5 Outline of the report

Chapter 1: It contains the introduction and will give information about the need of the DWDM.

Chapter 2: It contains all the terminologies related to DWDM system.

Chapter 3: It contains the review of the papers studied to get the basic understanding of DWDM.

Chapter 4: It contains the scope of the thesis done.

Chapter 5: It contains the objectives that are served in this thesis.

Chapter 6: It contains the information about the research methodology and the software used.

Chapter 7: It contains all the desired results that are obtained during the thesis work.

Chapter 8: It contains the conclusion and future work that can be done on this thesis.

Chapter 2

Terminology

WAVELENGTH DIVISION MULTIPLEXING (WDM)

A technology that multiplexes (combines) onto a single fiber optical transmission from two or more sources each operating at different optical wavelengths. Transmission from combined sources is separated at a remote location according to the individual wavelengths by de-multiplexing onto multiple fibers. WDM is often used to refer to filtering products that perform multiplexing or de-multiplexing.

MUX: A WDM filtering product that performs a process of multiplexing or combining of two or more optical sources of different wavelengths onto a single fiber.

DEMUX: A filtering product that performs the process of de-multiplexing or separating optical transmission comprised of multiplexed wavelengths onto individual fibers assigned to each wavelength. **Note:** Most filters used in WDM filtering products are bi-directional in their filtering operation. Therefore, a MUX product can in fact function as a DEMUX, and vice versa. However, TE Connectivity designs WDM products, which employ concatenated, discrete thin film filters, to help balance the link losses across all channel wavelengths by inverting the filter concatenation order between the MUX and DEMUX products.

Wavelength: In its electromagnetic wave form, the wavelength of light is the distance spanned by one complete cycle of the electric field magnitude. The wavelength λm of monochromatic light travelling in a dielectric medium (e.g., optical fiber) is expressed:

$\lambda_m = \lambda / n = v / f$
λ = optical wavelength,
n = refractive index of the dielectric medium,
v = phase velocity, given by c / n
c = the speed of light: 2.99792458×10^8 m/s,
f = optical frequency.

Channel: In WDM systems, a channel is a single, unique transmission at a designated wavelength that may occur along with other channels having different wavelengths. A transmission channel can also refer to the end-to-end physical path.

Single fiber: When referring to a fiber optic communication system, a single fiber system places all optical transmissions onto a single fiber span.

Dual fiber: A fiber optic communications system comprised of two, single fibers. The second fiber may serve as a backup fiber as in a redundant system, or it may provide an optical path in the opposite direction.

Ring topology: A type of network topology consisting of a closed loop. Fiber ring networks are comprised of a series of fiber spans that terminate at network nodes spread throughout the loop. Each node in the ring will connect to two, and only two, adjacent nodes. Ring networks are often dual fiber systems. Contrast ring topology with an unclosed, end-to-end or point-to-point fiber span.

Add/Drop: The add/drop terminology may refer to a single wavelength filter, or to a multi-channel WDM product. In the case of the filter, it is just another way to describe the bi-directional nature of the filter, in which a particular channel wavelength may be either added, as in multiplexed, or dropped as in de-multiplexed. There also is a particular WDM product configuration that provides the ability to drop off (or de-multiplex) any number of channels at a location and, with the same product, add back those or other channels at that location along a fiber span. Hence, the add/drop product will have for the same circuit two common ports for incoming and outgoing transmission, sometimes referred to as the East and West ports. If the add/ drop product is configured for a redundant, dual fiber system, then it is called a redundant add/drop WDM. Usually, add/ drop WDMs add and drop the same channels. When referring to the number of channels associated with that product, only the unique channels are counted. Therefore, if an add/drop WDM can drop off, say, 8 channels and then add back the same channels, it will have 16 channel ports but is referred to as an 8 channel add/drop product. This is also the case for a redundant add/drop product, i.e., a redundant 8 channel will have 32 channel ports.

Pass band: WDM filters are characterized by many parameters. Pass band is a specification that gives the range of wavelengths about the nominal, central wavelength of the filter that adhere to the specified insertion loss. In practice, it is the tolerance of the filter for laser drift away from the center wavelength. For example, a typical pass band for CWDM filters is ± 6.5 nm about the center wavelength. So a 1551 nm laser could operate within a range of 1544.5 nm to 1557.5 nm without encountering extra channel loss.

Insertion loss: The wavelength-dependent optical power loss introduced by inserting a WDM filter, expressed in dB. It is normally specified as the maximum insertion loss occurring across the filter pass band. The insertion loss of a WDM product is given as the maximum insertion loss occurring at the channel port with the highest loss. In WDM networks, insertion loss is one of several contributors to the total loss of the communication link. Thin film filters exhibit fairly wide manufacturing variance in their insertion loss values and are screened prior to use in WDM products.

Ripple: Ripple is defined as the maximum peak-to-peak variation in dB of insertion loss across a filter pass band. WDM product ripple is specified as the largest allowed ripple occurring in any channel.

Network topologies: WDM products bring higher efficiency to fiber networks through multiple channel usage of fiber. Networks are identified by their fiber layout or topology. Network topologies such as Mesh, Ring, Point-to-Point, and Point-to-Multipoint will sometimes use WDM products particularly designed for the network. So, it is important to understand the intended network use when selecting WDM products. Entire networks are often comprised of several kinds of sub-network topologies.

Node: In network topology, a node is a termination of a single branch or multiple branches of the network. (A branch is just a fiber span.) In HFC/CATV terminology, a node, or optical node, is a powered media converter that converts CATV services carried over optical fiber cable from the head end to an RF-modulated signal delivered over coax cable for customer access. The use of WDM on the fiber side allows the node to be segmented or divided into additional serving areas thus expanding the customer base and available bandwidth.

Upstream/downstream (forward/return): This refers to the direction of a communication signal. The downstream direction is defined as communication originating at a service provider and sent to the service user. Upstream is in the opposite direction. In HFC/CATV terminology, the term forward is used to identify the downstream direction and return identifies the upstream.

Passive Optical Network, or PON: Describes a network in which there are no active (powered) elements. Such networks may utilize passive optical splitters, passive WDM filters, and other passive optical components. In common practice, a PON is a kind of access network directly serving customers.

Chapter 3

Review of literature

The following papers are studied to reach a basic understanding of the DWDM system and to know the current work being done on the system. By studying below papers we have attained a sufficient knowledge to carry on the research work. These papers are as discussed below:

\S.No.	Author	Year	Topic	Approach	Results	Future Work
1.	Ioannis Papagiannakis et al.	2008	Investigation of 10-Gb/s RSOA-Based Upstream Transmission in WDM-PONs Utilizing Optical Filtering and Electronic Equalization	RSOA is employed to get a enhanced 10 GB/s data rate.	It is demonstrated that 10 Gb/s data rate is achieved by using offset filtering and DFE/FFE equalization at receiver end.	This work reflects the use of RSOA's for use in future PON modulated at 10 GB/s.
2.	M.Omella, V. Polo, J. Lazaro, B. Schrenk and J. Prat	2008	10 Gb/s RSOA Transmission by Direct Duobinary Modulation	Passive equalization and duobinary encoding by using RSOA.	10 Gb/s data rate is achieved by using passive equalization and duobinary encoding by using RSOA.	RSOA will be emerging as a candidate to combine remodulation capability, broadband amplification and integration.
3.	Charbonnier et al.	2008	Experimental demonstration of 10 Gbit/s upstream transmission by remote modulation of	Remote modulation of RSOA using adaptively modulated optical OFDM for WDM PON.	10 GB/s data rate is achieved over 20 km SMF fiber over 30 nm optical BW.	It can be further optimized with the help of FEC and negotiation between transmitter and receiver.

			1 GHz RSOA using Adaptively Modulated Optical OFDM for WDM-PON single fiber architecture			
4.	Papagiannakis et al.	2009	Full-Duplex Bidirectional Transmission at 10 Gbps in WDM PONs with RSOA-based ONU using Offset Optical Filtering and Electronic Equalization	10 GB/s data rate is achieved using RSOA in the ONU assisted by DFE and optimum filtering at OLT.	10 Gb/s data rate is achieved at 25 km length single fiber and even more.	
5.	Frank J. Effenberger et al.	2010	Standardization Trends and Prospective Views on the Next Generation of Broadband Optical Access Systems	10 Gb/s PON is laid out. Various solutions to long reach PONS are reviewed.	General requirements, that are important to discuss which technology/system should be standardized, must be getting clearer in the next few years through the full-scale deployment of the first generation PONs, i.e. GE-PON and G-PON, as well	The next wave of standardization will be in Q2/15. It will involve two major aspects. First, the existing GPON series of recommendations will continue to undergo maintenance for at least the next few years. Second, the XG-PON series of

					as the completion of the second generation 10G-class PON standards.	recommendations will be consented. The first versions of this series will be completed in the late 2009 to mid 2010 period. After this, the next wave of standardization, perhaps concerning some form of WDM-based or WDM-TDM-based PON, will begin.
6.	A. Agata, and Y. Horiuchi	2010	RSOA-based 10G WDM PON using FEC and MLSE Equalizers	Achieving the 10Gbit/s transmission in RSOA-based WDM PON systems is one of the important challenges because of its strict modulation bandwidth. This paper describes various state-of-the-art techniques to overcome this issue.	In this paper, we reviewed various state-of-the-art techniques to achieve 10Gbit/s operations in RSOA-based WDM PON systems. We showed that there have been many techniques to achieve 10Gbit/s operation by using directly modulated	For future broadband access networks capable of providing 10Gbit/s or more to each subscriber, WDM PON has been extensively investigated. However, it is difficult to achieve such high bit rate systems due to the slow dynamics of the colorless light

					RSOA, of which the modulation bandwidth is only ~2GHz, such as the use of the spectrally efficient modulation format, electric equalizers at the receiver side, and forward error correction (FEC) codes. Among these techniques, we demonstrated that the use of optimally designed MLSE and FEC would be a cost effective solution, and that 10Gbit/s signal transmission over 10km SMF should be feasible by using 8-state MLSE and RS(255,243) even when the modulation bandwidth of the RSOA is	sources used at the optical network units (ONUs), such as reflective semiconductor optical amplifiers (RSOAs).

					only 2.2GHz.	
7.	Jun-ichi Kani	2008	Enabling Technologies for Future Scalable and Flexible WDM-PON and WDM/TDM-PON Systems.	This paper reviews recent state-of the-art research on the enabling technologies needed to realize future WDM-PON and WDM/TDM-PON systems, and discusses future directions toward practical PON systems.	This paper reviewed the state-of-the-art technologies needed to realize flexible and scalable WDM-based PON systems after defining three architectures from the functional viewpoint. The three architectures are WDM-PON, static WDM/TDM-PON, and dynamic WDM/TDM-PON.	Further research and development activities on PON technologies as well as L2 SW technologies are encouraged, and the direction of practical systems will become clearer in the next few years.
8.	Qi Guo, An V. Tran, and Chang-Joon Chae,	2011	10-Gb/s WDM-PON Based on Low-Bandwidth RSOA Using Partial Response Equalization	An extended reach 10-Gb/s wavelength division multiplexing passive optical network (WDM-PON) system based on a low-bandwidth reflective	We have investigated the relationship between the degree of distortion of the received signal and the amount of fiber dispersion. The dispersion together with the frequency chirp results	It is indicated that PRE using same structure can be applied to upstream channels with ONUs at different location from CO. The proposed scheme has the potential to

				semiconductor optical amplifier (RSOA) is demonstrated using a novel partial response equalization (PRE) scheme.	in frequency dips and determines the general shape of the signal spectrum. We have demonstrated that PRE using FLCS as the TIR is able to assist the RSOA-based transmission in WDM-PON to achieve 10 Gb/s data rate and reach up to 75 km. It has been proven that error-free transmission can be achieved from 0 km to 75 km by a common receiver with the same four level PRE.	realize an extended-reach, high-capacity WDM-PON for customers with sparse geographic distributions.
9.	Hoon Kim	2011	10-Gbps Upstream Transmission for WDM-PON Using	Transmission of 10-Gbps NRZ signals over 20-km standard	We have demonstrated 10-Gbps, 20-km transmission of	A series of BER measurements show that Rayleigh scattering may

			RSOA and Delay Interferometer	single mode fiber using an RSOA in a loopback configured WDM-PON systemis demonstrated. Significant performance improvement is achieved using a delay interferometer , which acts as an optical equalizer of the band-limited RSOA.	directly modulated TO-can-packaged RSOA signals using a delay interferometer in a loopback configuration. We also demonstrate >40-nm wavelength operation of the proposed scheme and 5-dB margin of outside plant loss.	be a major source of system impairment.
10.	Dirk Breuer, Frank Geilhardt, Ralf Hülsermann, Mario Kind, Christoph Lange, Thomas Monath, and Erik Weis.	2011	Opportunities for Next-Generation Optical Access.	It is expected that in the near future an end user will require much more guaranteed bandwidth than is available today .There is a common understanding that fiber to the home (FTTH) will overcome the bandwidth limitations of today's	Next-generation optical access technologies and architectures are evaluated based on operators' requirements. The study presented in this article compares different FTTH access network architectures. Additionally, the impact of	From today's point of view, and requires further research and in-depth investigations which will be conducted to a certain extent in current FP 7 projects like OASE.

				copper-based and hybrid fiber access solutions (e.g., fiber to the cabinet [FTTCab]).	new business models on network architectures is discussed.	
11.	Elaine Wong	2012	Next-Generation Broadband Access Networks and Technologies	This paper reviews the future directions of next generation passive optical networks. A discussion on standardized 10 Gb/s passive optical network (PON) systems is first presented. Next, new technologies that facilitate multiple access beyond 10 Gb/s time division multiple access (TDMA)-PONs will be reviewed. The	A review of the emerging trends in next generation passive optical networks and technologies have been presented. In meeting increasing capacity demands, standardized 10 Gb/s PON systems, namely XG-PON and 10 GE-PON, were discussed. The main reasons behind the push for these TDM/TDMA PON systems are to extend the longevity of existing ODNs and to allow co-existence with the	In order to successfully deploy these technologies, the implementation complexity must be minimized to a level that is comparable to existing commercialized systems and with a cost that is sufficiently low to meet the cost constraints of the access market.

				wavelength division multiplexed (WDM) PON will be discussed and in combination with TDMA, the hybrid WDM.	current generation PONs such that the operational impact on existing users will be minimized. The basic architecture of the WDM PON and its various colorless schemes to alleviate inventory problems, were also presented.	
12.	Zaineb Al-Qazwini, and Hoon Kim	2012	Symmetric 10-Gb/s WDM-PON Using Directly Modulated Lasers for Downlink and RSOAs for Uplink	We demonstrate a cost-effective, 10-Gb/s full-duplex wavelength-division-multiplexed passive optical network over 20 km single-feeder fiber using a single light source per optical network unit (ONU).We exploit a directly modulated	The use of an optical delay interferometer enables the upstream transmission of the 10-Gb/s NRZ signal with a TO-can-packaged RSOA having a 1.3 GHz bandwidth. Even though the downstream and upstream signals are allocated in separate frequency	Distortion can be mitigated by using an RSOA having a higher saturation power. Despite the crosstalk between the downstream and upstream signals, we were able to achieve uncorrected BERs less than 10^{-4} for both downlink and uplink when the downstream subcarrier

				laser (DML) and a reflective semiconductor optical amplifier (RSOA) for downlink and uplink, respectively.	bands, we have observed nonlinear crosstalk from the downstream signal into the upstream baseband signal. This is caused by the nonlinear frequency mixing in the RSOA operating in the saturation condition. The second-order distortion components 1) from the downstream signal and 2) between the downstream and upstream signals fall on the baseband region and interfere with the upstream signal.	frequency was 22 GHz.
13	Gaurav Soni, Rupinder jeet kaur	2014	Performance Analysis of WDM Link Using Dispersion Compensating	Dispersion is compensated using the dispersion compensating	The system shows better performanve at 1550 nm as compared to	

			Fiber at Different Wavelengths.	fiber	1330 and 980 nm.	
14.	K.Uthayasuriyan and K.Sheela Sobana Rani	2015	Design of Point to Point Metro DWDM Network and Its Performance Evaluation	The wavelength effective for DWDM system will be from 1525nm to 1565nm in C Band and from 1570nm to 1610nm in L Band. In this paper we use single mode fiber for length of 110 km at 1550nm to decrease dispersion in signal.	The DWDM system analysis is performed using optisystem with flow rate of 10 Gb/s per channel and carried out simulation, EDFA amplifier is used to achieve signal with improved Q-Factor and BER.	The work will be extended to 80 channel DWDM system and the performance will be evaluated.
15	Ravi Shanker, Dr. Pankaj Srivastav, Dr. Mahua Bhattacharya	2016	Performance analysis of 16-Channel 80-Gbps optical fiber communication system	A single chirped fiber bragg grating is used for compensate the dispersion in single channel and 16 cascaded chirped FBG for 16 channel.	This work analyzed 16 channel dense WDM using cascaded fiber Bragg grating. As data rate and optical fiber length increases pulse getting start broadening this is due to dispersion.	

					So we are using loop control unit to amplify the signal at 80km. To compensate the effect of dispersion, we are amplifying the signal so that signal amplitude increase and quality factor also increases and BER decreases.	

Chapter 4

Scope of Study

In the recent years, the growth in the internet activities like E-mail, audio-video conferencing, multimedia services, has increased greatly. This has led to an increase in demand for higher data rates for high speed internet services. It is estimated that in near future, an end user will require more bandwidth than it is available today [1]. In order to meet these increasing data rate, the increase in bandwidth is the only solution. The bandwidth can be increased in by installing more number of cables, increasing system bit rate to multiplex more signals or multiplex different wavelengths (DWDM).

In order to meet this growing demand of bandwidth, a technique which combines various wavelengths together called as Dense Wavelength Division Multiplexing (DWDM) is developed. It is used to increase fiber's capacity. DWDM systems these days can increase the system's capacity up to 40 GB/s [2].

This technique when combined with network management systems such as add- drop mux will meet the next generation bandwidth requirement which is significantly lower than installing new fiber. DWDM uses an optical signal which carries multiple wavelengths carrying user data on each wavelength. DWDM system can handle more number of users per wavelength. But dispersion compensation plays a key role in DWDM at bit rate greater than 10 Gbps. It can be compensated by using dispersion compensating fiber [3].EDFA's are used in addition to DCF's to amplify and regenerate the optical signal. If EDFA is placed before SMF, it is called pre compensation and if it is used after SMF, it is called post compensation. Both these techniques can be combined to produce and deliver a good quality of optical signal at the transmitter.

So, in order to meet the current bandwidth requirements by using the already laid infrastructure, a technique called as Dense Wavelength Division Multiplexing (DWDM) has been developed. It multiplies the capacity of the already laid single fiber. The DWDM systems employed today are capable of increasing the capacity of the single fiber by sixteen folds, to give a 40 GB/s throughput. This technology when combined with optical equipments such as add-drop mux, amplifiers etc. will enable the service providers to adopt optical based networks to meet the requirements of bandwidth of the next generation at a low cost rather than installing new fiber.

Dense Wavelength division multiplexing allows the multiple channels to transmit the data at high speed at the same instant. For large distance communication, Single mode fiber is preferred over Multimode fiber. Quality factor decreases as data rate and optical fiber length increases. In this proposed work Optisystem 7.0 simulator is used to analyze dispersion effect on 80 channel dense WDM system at 10 Gbps data rate. Dispersion compensation technique is used to compensate the dispersion for 80 channel DWDM. EDFA’s are used before and after the fiber to compensate for dispersion. Signal is amplified at each multiple of 50 km optical fiber length using Loop control unit. The performance of optical system has been given using BER and eye analyzer.

Chapter 5

Objectives of Study

DWDM uses an optical signal which carries multiple wavelengths carrying user data on each wavelength. DWDM system can handle more number of users per wavelength. But dispersion compensation plays a key role in DWDM at bit rate greater than 10 Gbps. It can be compensated by using dispersion compensating fiber [3].EDFA's are used in addition to DCF's to amplify and regenerate the optical signal. If EDFA is placed before SMF, it is called pre compensation and if it is used after SMF, it is called post compensation. Both these techniques can be combined to produce and deliver a good quality of optical signal at the transmitter. Further we compared the system parameters such as BER, quality factor, eye height etc. between NRZ and RZ modulation formats and analyse the system behavior. Finally conclusion and perspective are drawn. The following are the key objectives tried to serve in the thesis file:

1. The main aim of this thesis is to design a 80 channel DWDM system each having 10 Gbps data rate multiplexed with frequency spacing 100 GHz and upstream transmission employing Erbium Doped Fiber Amplifier (EDFA).

2. Realization of 0.8 Tbps data rate by using DCF as a dispersion compensating module and using EDFA as an amplifier in the channel.

3. Performance Analysis of 80 channel DWDM system with RZ and NRZ modulation format.

4. Performance Analysis of 80 Channel DWDM system using two different wavelengths 980 nm and 1555 nm.

Chapter 6

Materials and research methodology

6.1 Design Technique

Optical fiber communication systems can be designed by using a number of soft wares. A large number of simulators are available. We have used Optisystem software to design a 80 channel DWDM system with 10 GB/s data rate for each channel. This has been made possible by using dispersion compensating fiber as a module for catering the interference on the channel. EDFA's are also used to amplify and regenerate the signal on the optical path. All the parameters are tested and optimized to achieve the desired results.

6.2 Design Material (Optisystem software)

Optisystem is a tool that allows the users to design an optical communication system and to test it by using various parameters such as BER, eye height. It has a library that includes transmitters, receivers and DSP components for every type of optical system.

6.3 Research methodology

Following steps are used to design DWDM system in the optisystem software:

1. From the library, we get the WDM transmitter which generates the optical signal to be transmitted. In the parameters section we can set the various values of frequency spacing, frequency used etc.

2. Then the WDM mux is also used from the library and connected to the transmitter to combine all the wavelengths on to a single fiber and ready for transmission over channel.

3. The library also consists of various types of fibers and amplifiers. The channel can be designed using all the components in the library.

4. The receiver is designed by using WDM demux and optical receiver detects the signal and it reflects various features such as BER, eye height, Q factor etc. All these parameters are used to compare the optical systems.

Due to demand for data rate greater than 10 GB/s, dispersion on the channel must be minimised and managed. To cater this a number of dispersion compensation techniques are implemented to improve the performance of the system. These techniques can be divided into two types:

- Using Dispersion compensating fiber
- Using Fiber Bragg Grating

A. Using Dispersion compensating fiber:

The positive dispersion of single mode fiber is compensated by negative dispersion of DCF. There are three dispersion techniques that can be identified.

- Pre compensation method: In this technique DCF is placed before the SMF.
- Post compensation method: In this technique DCF is placed after the SMF.
- Mixed compensation method: In this technique DCCF is placed before and after the SMF.

B. Using Fiber Bragg Grating:

A fiber Bragg grating can be defined as the perturbations which can be periodic or aperiodic refractive index of an optical wave guide. It can reflect a predefined range of wave length and let others pass through it.

Chapter 7
Results and Discussion

7.1 DWDM design

We are developing a 80 channel DWDM system each having 10 Gbps data rate multiplexed with frequency spacing 100 GHz with upstream transmission employing Erbium Doped Fiber Amplifier (EDFA) using Optisystem software.

7.2 Simulation setup

A. Performance analysis of 80 channel DWDM system.

Figure 7.1 shows the simulation setup of an 80 channel DWDM setup. In this set up, at the transmitter side we have used WDM transmitter and WDM mux. The Bit rate used is 10 Gb/s. The channel consists of Optical fiber, loop control, dispersion compensating fibers and EDFA's. The optical channel has two optical fibers of 25 km length, so a total fiber of 50 km is used. Various EDFA's are used to improve the quality of the signal. In addition, Dispersion compensating fiber is also used to tackle the dispersion on the channel. The receiver side consists of WDM de-mux, optical receivers and BER analyzers for the analysis of WDM link. This entire set up is implemented and analyzed using “Optisystem 7.0”.

A. Transmitter

A transmitter is that component of a DWDM system which generates the different wavelengths for different channels and multiplexes them or combines them on to a single fiber. The WDM transmitter here generates 80 different wavelengths for 80 different channels with frequency spacing 100 GHz. The optical signal is transmitted at a frequency of 1555 nm with power 5dbm with NRZ type of modulation. These 80 different wavelengths are multiplexed using WDM mux. The various parameters used at the transmitter side are as shown below and are taken from simulation on optisystem software.

Parameters	Value
Frequency	1555 nm
Frequency spacing	100 GHz
Power	5dBm
Extinction ratio	30dB
Modulation	NRZ

Table (i): Simulation parameters of WDM transmitter.

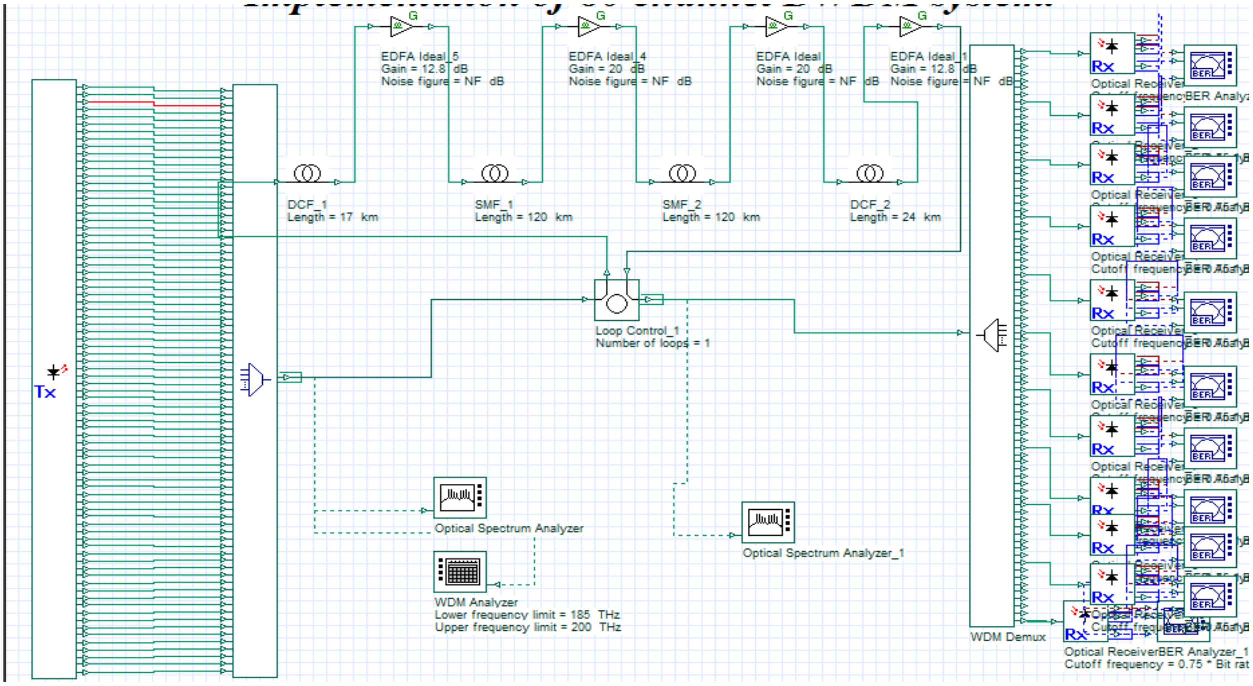


Fig. 7.1. Structure of an 80 channel DWDM system.

B. Optical channel

The multiplexed optical signal consisting of all the 80 wavelengths is transmitted over the channel. The optical channel consists of two single mode fibers of 25 km length so the total length is 50 km. We have used Dispersion compensating fiber to counter the dispersion occurring in the system. The optical signal is amplified at various intervals of distance by using EDFA's. For this various EDFA's and DCF are used in such an arrangement that a SMF have an EDFA both in front and back. The various parameters of Optical channel used are as shown below:

Parameters	Value
Operation mode	Gain control
Gain	5dB
Power	10dBm
Noise figure	6dB

Table (ii): Simulation parameters of EDFA.

Parameters	Value
Length	25 km
Attenuation	0.2 dB/km
DCF length	10 km
Attenuation	0.5 dB/km

Table (iii): Simulation parameters of SMF and DCF.

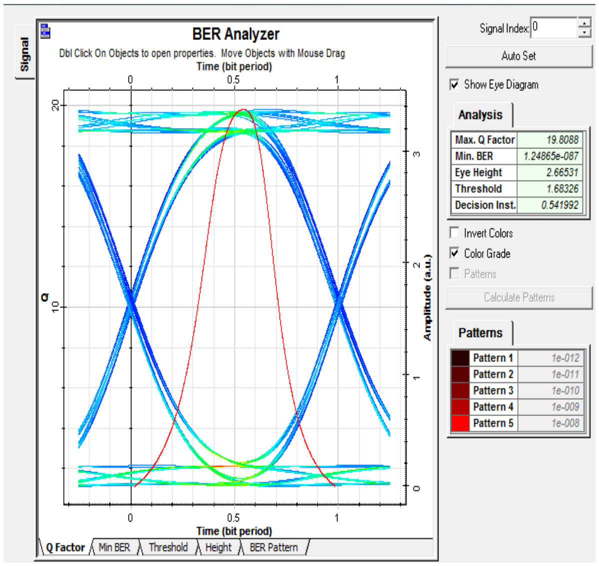
C. Receiver

The receiver consists of WDM de-mux which de-multiplexes or separates the multiplexed signal into its constituent wavelengths. In addition to de-mux, the receiver also has optical receiver and a BER analyzer. The BER analyzer is used to analyze the various parameters of WDM link such as BER, Q factor, eye height etc. Various parameters used at receiver in optisystem software are as shown below:

Parameters	Value
Bandwidth	80 GHz
Responsivity	1 A/W
Cut off frequency	0.75*bit rate

Table (iv): Simulation parameters of WDM de-mux and optical receiver

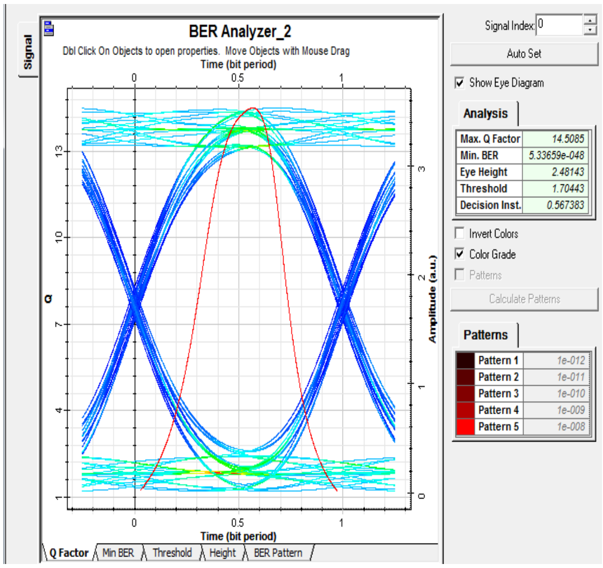
By using the dispersion compensating fiber as dispersion compensator, we have optimized and established an 80 channel DWDM link. The min. BER is found to be 1.24865e-087 and Q factor is found to be 19.8088 on channel 1 as shown in fig.7.2. The eye diagram in fig. 7.3 shows the Q factor to be 14.5085 and BER to be 5.33659e-048. The eye diagram and other parameters for channel no. 1,8,16,24,32,40,48,56,64,72,80 are analyzed and as shown from fig. 7.2 to 7.12. A summarized table is also given at the end to show the results. All these figures and tables are the result obtained from optisystem simulator.



Max. Q Factor	19.8088
Min. BER	1.24865e-087
Eye Height	2.66531
Threshold	1.68326
Decision Inst.	0.541992

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

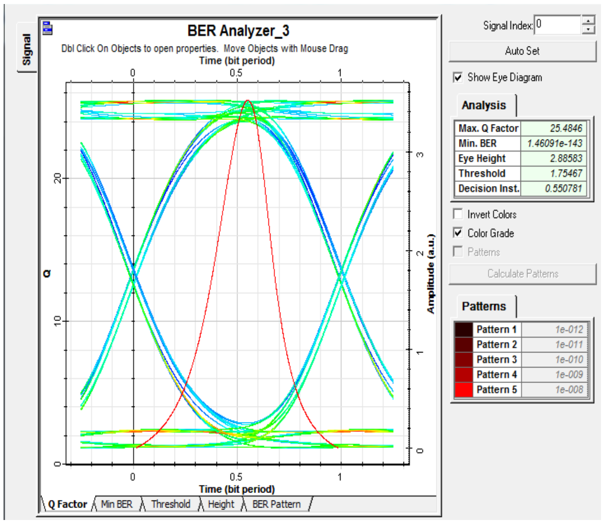
Fig. 7.2. Eye diagram analysis of first channel.



Max. Q Factor	14.5085
Min. BER	5.33659e-048
Eye Height	2.48143
Threshold	1.70443
Decision Inst.	0.567383

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.3. Eye diagram analysis of eighth channel.



Signal Index: 0

☑ Show Eye Diagram

Analysis

Max. Q Factor	25.4846
Min. BER	1.46091e-143
Eye Height	2.88583
Threshold	1.75467
Decision Inst.	0.550781

☐ Invert Colors

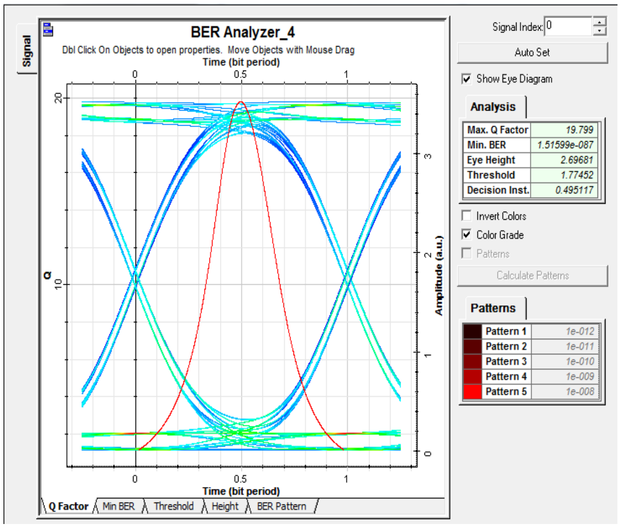
☑ Color Grade

☐ Patterns

Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.4. Eye diagram analysis of 16th.channel.



Signal Index: 0

☑ Show Eye Diagram

Analysis

Max. Q Factor	19.799
Min. BER	1.51599e-087
Eye Height	2.69681
Threshold	1.77452
Decision Inst.	0.495117

☐ Invert Colors

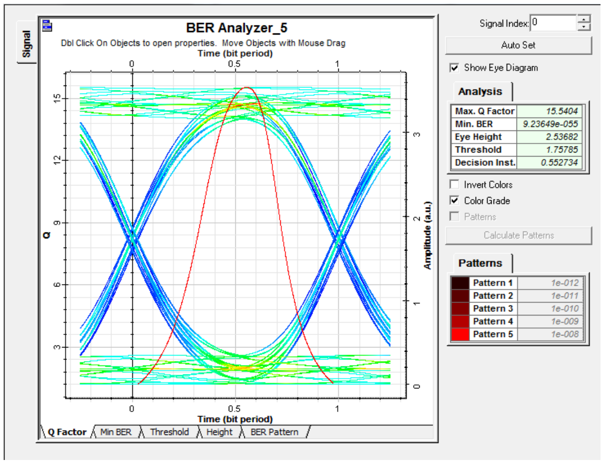
☑ Color Grade

☐ Patterns

Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.5. Eye diagram analysis of 24th channel.



Signal Index: 0

☑ Show Eye Diagram

Analysis

Max. Q Factor	15.5404
Min. BER	9.23649e-055
Eye Height	2.53682
Threshold	1.75785
Decision Inst.	0.552734

☐ Invert Colors

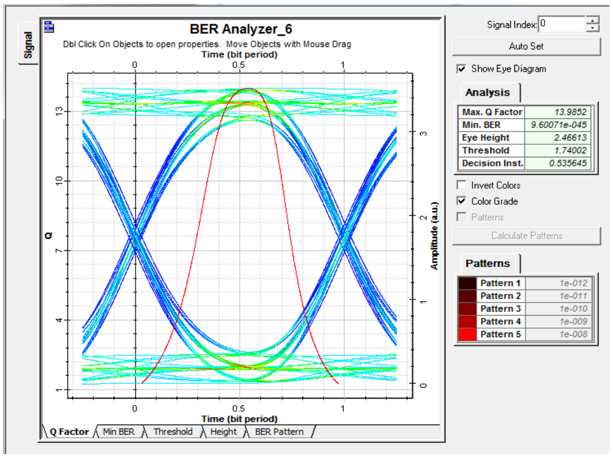
☑ Color Grade

☐ Patterns

Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.6. Eye diagram analysis of 32nd channel.



Signal Index: 0

☑ Show Eye Diagram

Analysis

Max. Q Factor	13.9852
Min. BER	9.60071e-045
Eye Height	2.46613
Threshold	1.74002
Decision Inst.	0.535645

☐ Invert Colors

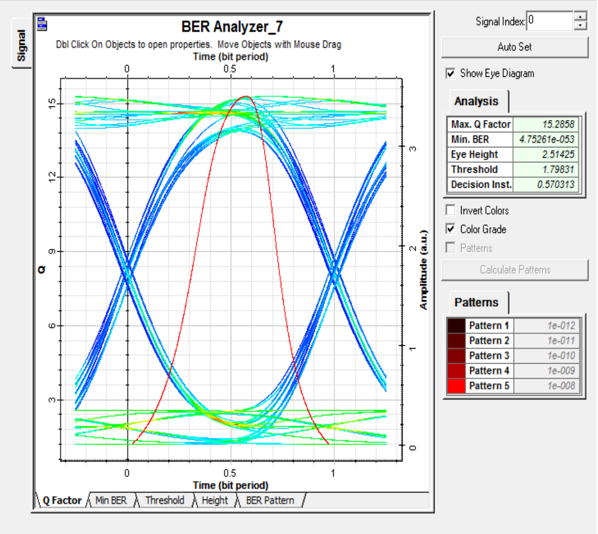
☑ Color Grade

☐ Patterns

Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.7. Eye diagram analysis of 40th channel.



Signal Index: 0

☑ Show Eye Diagram

Analysis

Max. Q Factor	15.2858
Min. BER	4.75261e-053
Eye Height	2.51425
Threshold	1.79831
Decision Inst.	0.570313

☐ Invert Colors

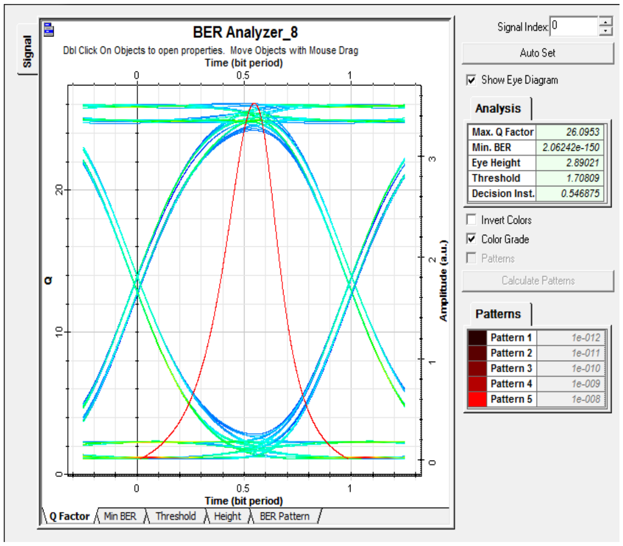
☑ Color Grade

☐ Patterns

Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.8. Eye diagram analysis of 48th channel.



Signal Index: 0

☑ Show Eye Diagram

Analysis

Max. Q Factor	26.0953
Min. BER	2.06242e-150
Eye Height	2.89021
Threshold	1.70809
Decision Inst.	0.546875

☐ Invert Colors

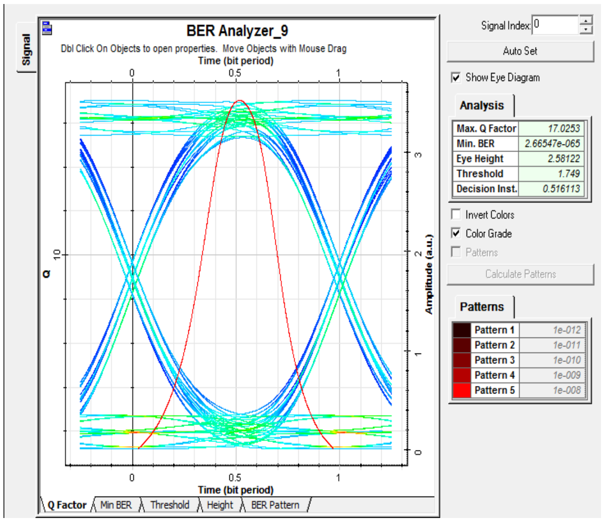
☑ Color Grade

☐ Patterns

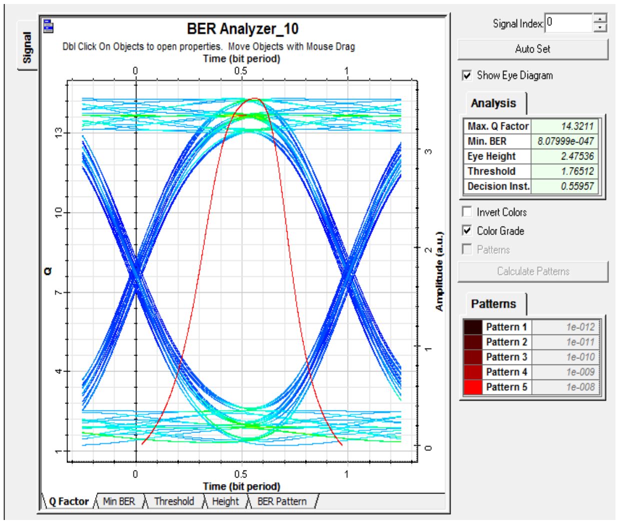
Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.9. Eye diagram analysis of 56th channel.

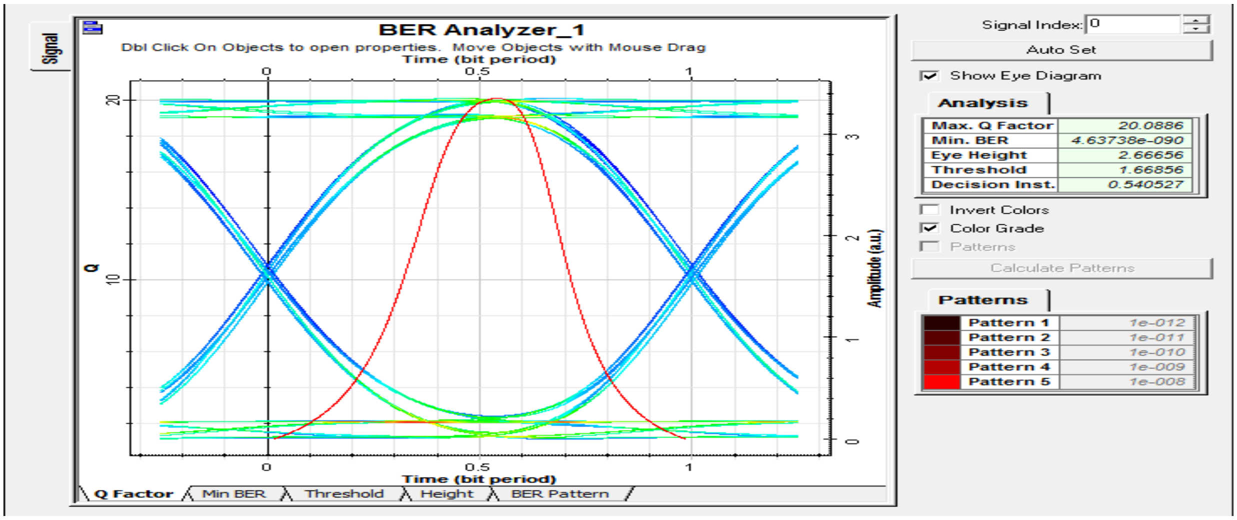


Signal Index: 0
☑ Show Eye Diagram
Max. Q Factor 17.0253
Min. BER 2.66547e-065
Eye Height 2.58122
Threshold 1.749
Decision Inst. 0.516113
☐ Invert Colors
☑ Color Grade
☐ Patterns
Pattern 1 1e-012
Pattern 2 1e-011
Pattern 3 1e-010
Pattern 4 1e-009
Pattern 5 1e-008



Signal Index: 0
☑ Show Eye Diagram
Max. Q Factor 14.3211
Min. BER 8.07999e-047
Eye Height 2.47536
Threshold 1.76512
Decision Inst. 0.55957
☐ Invert Colors
☑ Color Grade
☐ Patterns
Pattern 1 1e-012
Pattern 2 1e-011
Pattern 3 1e-010
Pattern 4 1e-009
Pattern 5 1e-008

Fig. 7.10. Eye diagram analysis of 64th channel. Fig. 7.11. Eye diagram analysis of 72nd channel.



Signal Index: 0
☑ Show Eye Diagram
Max. Q Factor 20.0886
Min. BER 4.63738e-090
Eye Height 2.66656
Threshold 1.66856
Decision Inst. 0.540527
☐ Invert Colors
☑ Color Grade
☐ Patterns
Pattern 1 1e-012
Pattern 2 1e-011
Pattern 3 1e-010
Pattern 4 1e-009
Pattern 5 1e-008

Fig. 7.12. Eye diagram analysis of 80th channel.

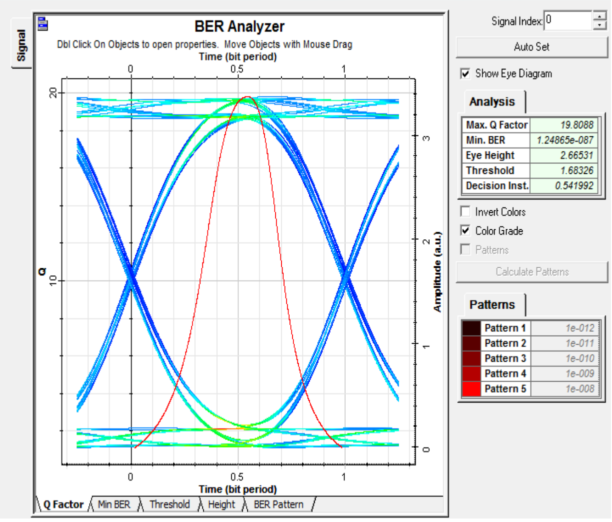
Channel no.	Max. Q factor	Min. BER
1	19.808	1.24865e-087
8	14.5085	5.33659e-048
16	25.4846	1.46091e-143
24	19.799	1.51599e-087
32	15.504	9.23649e-055
40	13.9852	9.60071e-045
48	15.2858	4.75261e-053
56	26.0953	2.06242e-150
64	17.0253	2.66547e-065
72	14.3211	8.07999e-047
80	20.0886	4.63738e-090

Table (v): Values of Q factor and BER for various channels.

B. Performance Analysis of 80 channel DWDM system with RZ and NRZ modulation format.

A. *Analysis of DWDM system using NRZ modulation format*

By using the dispersion compensating fiber as dispersion compensator, we have optimized and established an 80 channel DWDM link. The min. BER using NRZ scheme is found to be 1.24865e-087 and Q factor is found to be 19.8088 on channel 1 as shown in fig. 7.13. The eye diagram in fig. 7.14 shows the Q factor to be 14.5085 and BER to be 5.33659e-048 for eighth channel. The eye diagram and other parameters for channel no. 1,8,16,24,32,40,48,56,64,72,80 are analyzed and as shown below:



Signal Index: 0

☑ Show Eye Diagram

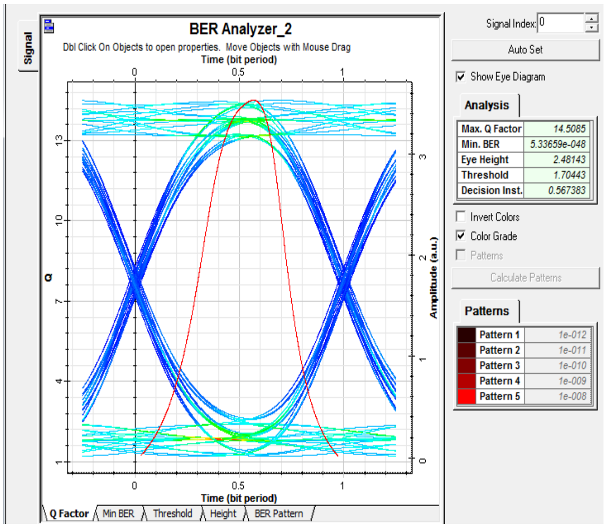
Analysis	
Max. Q Factor	19.8088
Min. BER	1.24865e-087
Eye Height	2.66531
Threshold	1.68326
Decision Inst.	0.541992

☐ Invert Colors

☑ Color Grade

☐ Patterns

Patterns	
Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008



Signal Index: 0

☑ Show Eye Diagram

Analysis	
Max. Q Factor	14.5085
Min. BER	5.33659e-048
Eye Height	2.48143
Threshold	1.70443
Decision Inst.	0.567383

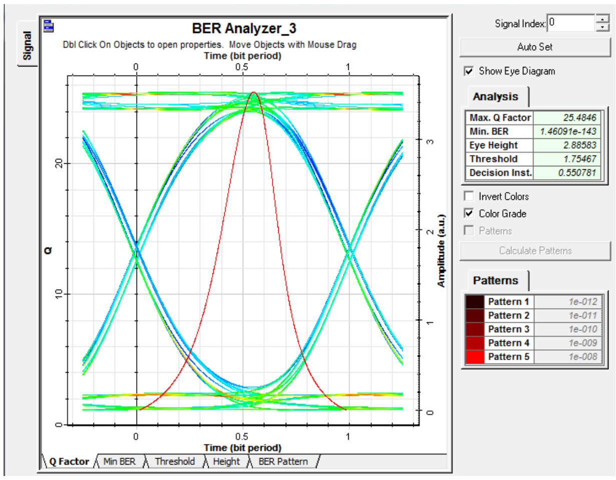
☐ Invert Colors

☑ Color Grade

☐ Patterns

Patterns	
Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.13. Eye diagram analysis of 1st channel. Fig. 7.14. Eye diagram analysis of 8th channel.



Signal Index: 0

☑ Show Eye Diagram

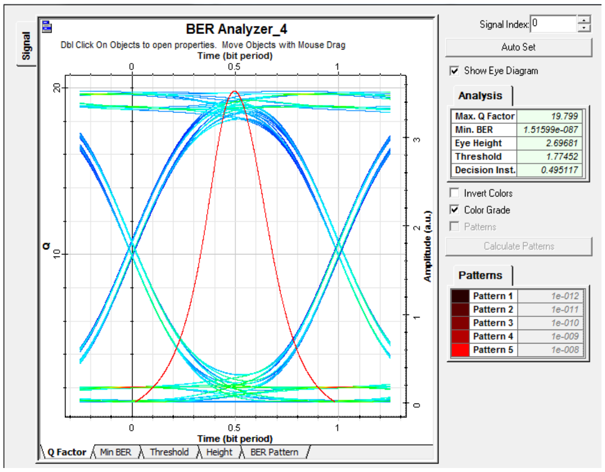
Analysis	
Max. Q Factor	25.4846
Min. BER	1.46091e-143
Eye Height	2.88583
Threshold	1.75467
Decision Inst.	0.550781

☐ Invert Colors

☑ Color Grade

☐ Patterns

Patterns	
Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008



Signal Index: 0

☑ Show Eye Diagram

Analysis	
Max. Q Factor	19.799
Min. BER	1.51599e-087
Eye Height	2.69681
Threshold	1.77452
Decision Inst.	0.495117

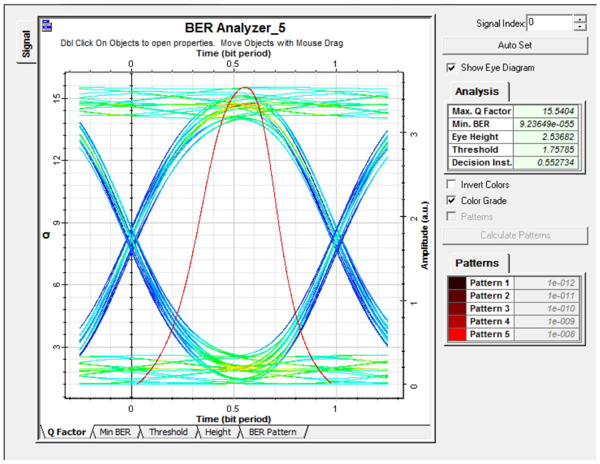
☐ Invert Colors

☑ Color Grade

☐ Patterns

Patterns	
Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.15. Eye diagram analysis of 16th.channel. Fig. 7.16. Eye diagram analysis of 24th channel.



BER Analyzer_5

Dbl Click On Objects to open properties. Move Objects with Mouse Drag

Signal Index: 0

☑ Show Eye Diagram

Analysis

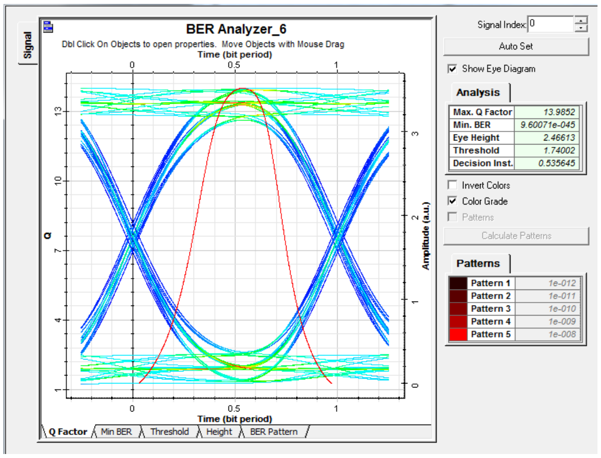
Max. Q Factor	15.5404
Min. BER	9.23649e-055
Eye Height	2.53682
Threshold	1.75785
Decision Inst.	0.552734

☐ Invert Colors
☑ Color Grade
☐ Patterns

Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.17. Eye diagram analysis of 32nd channel.



BER Analyzer_6

Dbl Click On Objects to open properties. Move Objects with Mouse Drag

Signal Index: 0

☑ Show Eye Diagram

Analysis

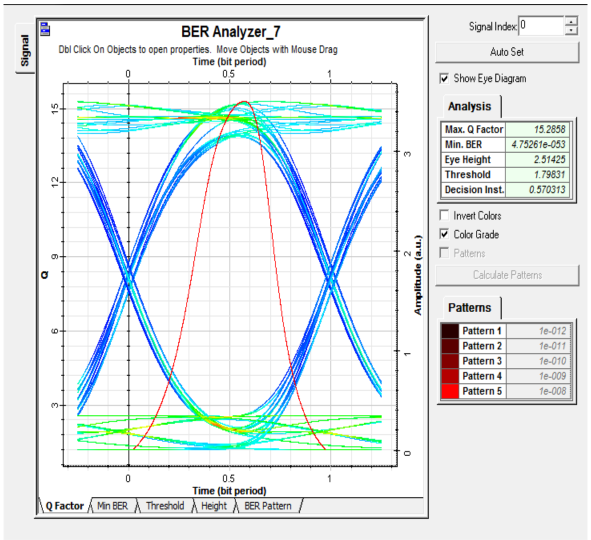
Max. Q Factor	13.9852
Min. BER	9.60071e-045
Eye Height	2.46613
Threshold	1.74002
Decision Inst.	0.535645

☐ Invert Colors
☑ Color Grade
☐ Patterns

Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.18. Eye diagram analysis of 40th channel.



BER Analyzer_7

Dbl Click On Objects to open properties. Move Objects with Mouse Drag

Signal Index: 0

☑ Show Eye Diagram

Analysis

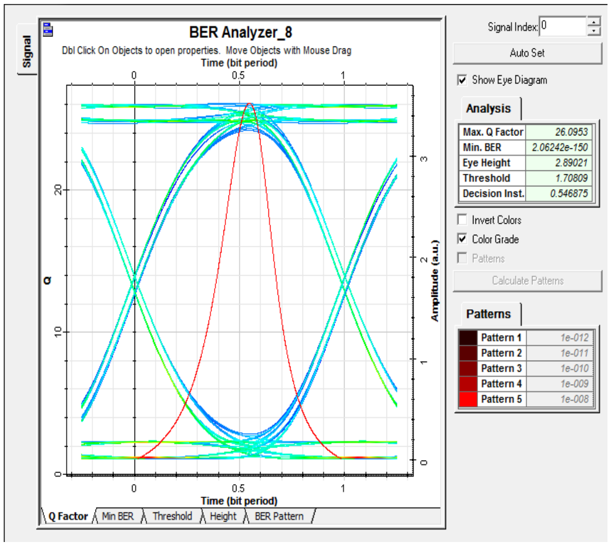
Max. Q Factor	15.2858
Min. BER	4.75261e-053
Eye Height	2.51425
Threshold	1.79831
Decision Inst.	0.570313

☐ Invert Colors
☑ Color Grade
☐ Patterns

Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.19. Eye diagram analysis of 48th channel.



BER Analyzer_8

Dbl Click On Objects to open properties. Move Objects with Mouse Drag

Signal Index: 0

☑ Show Eye Diagram

Analysis

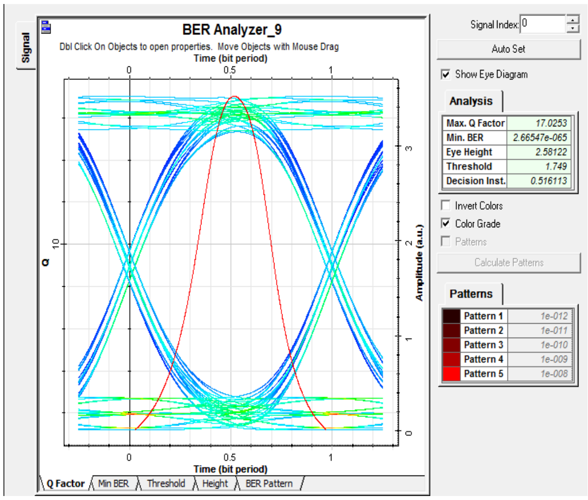
Max. Q Factor	26.0953
Min. BER	2.06242e-150
Eye Height	2.89021
Threshold	1.70809
Decision Inst.	0.546875

☐ Invert Colors
☑ Color Grade
☐ Patterns

Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.20. Eye diagram analysis of 56th channel.



BER Analyzer_9

Dbl Click On Objects to open properties. Move Objects with Mouse Drag

Signal Index: 0

☑ Show Eye Diagram

Analysis

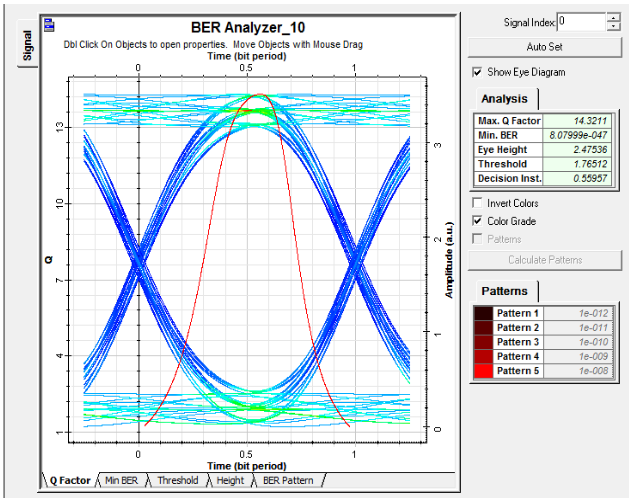
Max. Q Factor	17.0253
Min. BER	2.66547e-065
Eye Height	2.58122
Threshold	1.749
Decision Inst.	0.516113

☐ Invert Colors
☑ Color Grade
☐ Patterns

Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.21. Eye diagram analysis of 64th channel.



BER Analyzer_10

Dbl Click On Objects to open properties. Move Objects with Mouse Drag

Signal Index: 0

☑ Show Eye Diagram

Analysis

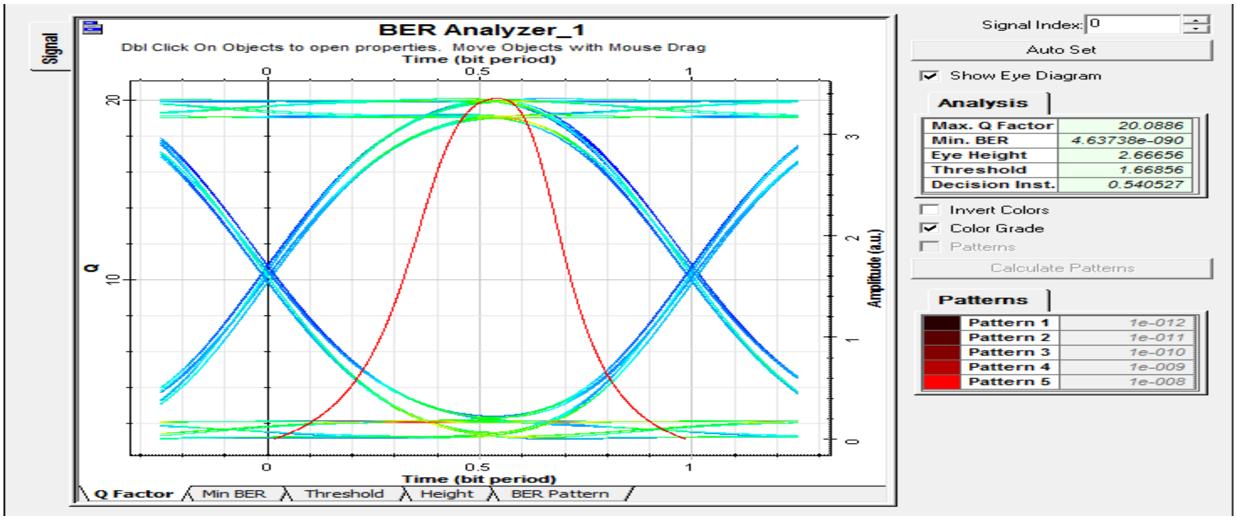
Max. Q Factor	14.3211
Min. BER	8.07999e-047
Eye Height	2.47536
Threshold	1.76512
Decision Inst.	0.55957

☐ Invert Colors
☑ Color Grade
☐ Patterns

Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.22. Eye diagram analysis of 72nd channel.



Signal Index: 0

☑ Show Eye Diagram

Max. Q Factor	20.0886
Min. BER	4.63738e-090
Eye Height	2.66656
Threshold	1.66856
Decision Inst.	0.540527

☐ Invert Colors
☑ Color Grade
☐ Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

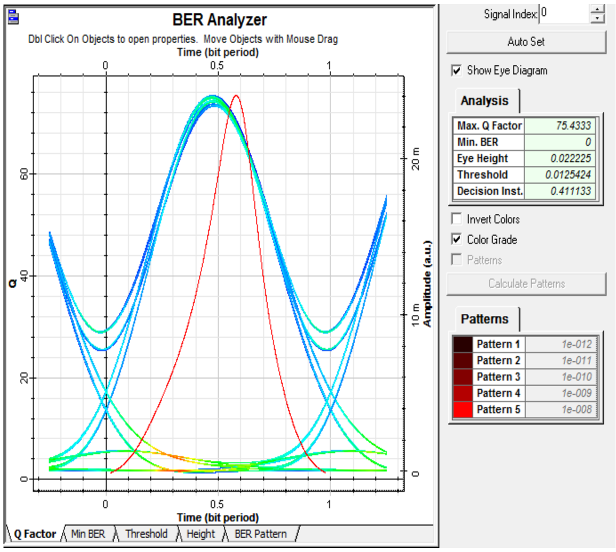
Fig. 7.23. Eye diagram analysis of 80th channel.

Channel no.	Max. Q factor	Min. BER	Eye height
1	19.808	1.24865e-087	2.66531
8	14.5085	5.33659e-048	2.48143
16	25.4846	1.46091e-143	2.88583
24	19.799	1.51599e-087	2.69681
32	15.504	9.23649e-055	2.53682
40	13.9852	9.60071e-045	2.46613
48	15.2858	4.75261e-053	2.51425
56	26.0953	2.06242e-150	2.89021
64	17.0253	2.66547e-065	2.58122
72	14.3211	8.07999e-047	2.47536
80	20.0886	4.63738e-090	2.66656

Table (vi): values of Q factor, BEr, eye height for various channels.

B. Analysis of DWDM system using RZ modulation format

The min. BER using RZ scheme is found to be 1.67915-120 and Q factor is found to be 23.3119 on channel 8 as shown in fig. 7.24. The eye diagram in fig. 7.25 shows the Q factor to be 19.7937 and BER to be 1.685e-087 for sixteenth channel. The eye diagram and other parameters for channel no. 1,8,16,24,32,40,48,56,64,72,80 are analyzed and as shown below:



Signal Index: 0

☑ Show Eye Diagram

Max. Q Factor	75.4333
Min. BER	0
Eye Height	0.022225
Threshold	0.0125424
Decision Inst.	0.411133

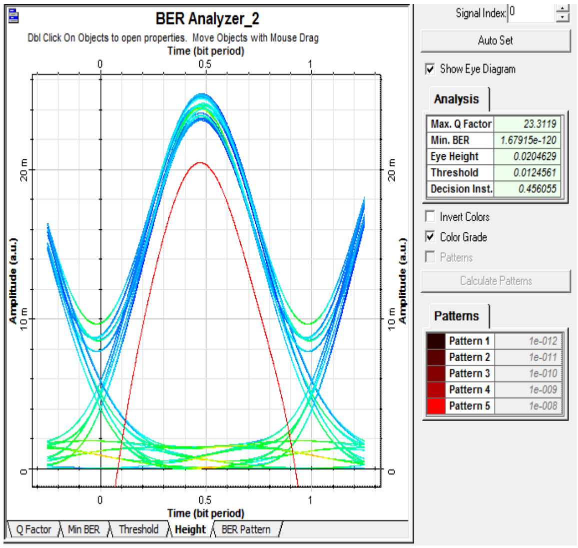
☐ Invert Colors

☑ Color Grade

☐ Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.24. Eye diagram analysis of 1st channel



Signal Index: 0

☑ Show Eye Diagram

Max. Q Factor	23.3119
Min. BER	1.67915e-120
Eye Height	0.0204629
Threshold	0.0124561
Decision Inst.	0.456055

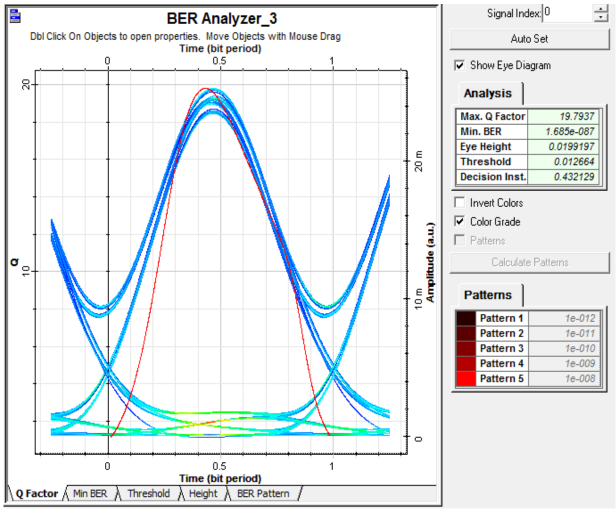
☐ Invert Colors

☑ Color Grade

☐ Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.25. Eye diagram analysis of 8thchannel



Signal Index: 0

☑ Show Eye Diagram

Max. Q Factor	19.7937
Min. BER	1.685e-087
Eye Height	0.0199197
Threshold	0.012664
Decision Inst.	0.432129

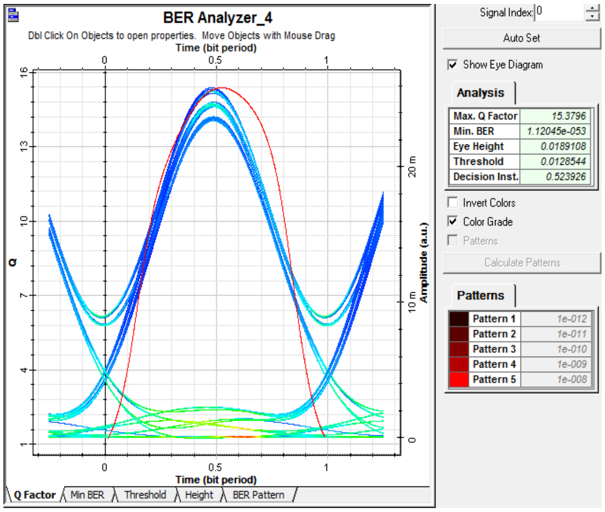
☐ Invert Colors

☑ Color Grade

☐ Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.26. Eye diagram analysis of 16th channel



Signal Index: 0

☑ Show Eye Diagram

Max. Q Factor	15.3796
Min. BER	1.12045e-053
Eye Height	0.0189108
Threshold	0.0128544
Decision Inst.	0.523926

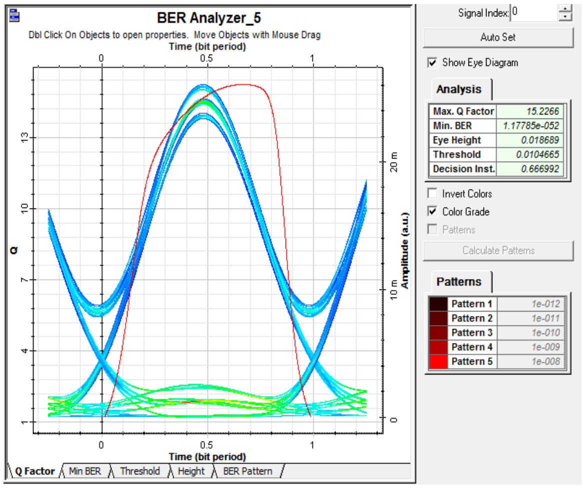
☐ Invert Colors

☑ Color Grade

☐ Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.27. Eye diagram analysis of 24th channel



Signal Index: 0

☑ Show Eye Diagram

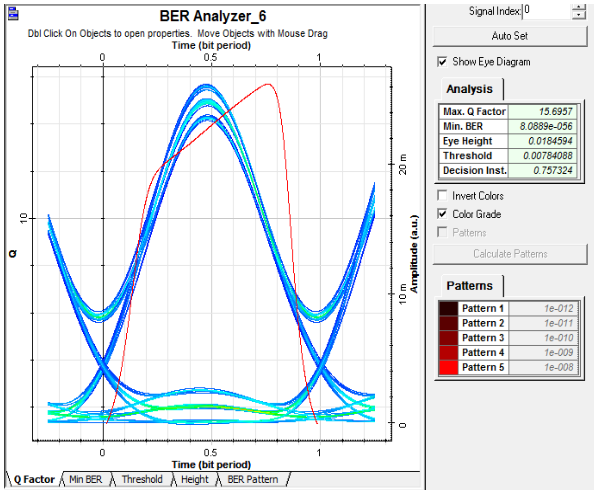
Max. Q Factor	15.2266
Min. BER	1.17785e-052
Eye Height	0.018689
Threshold	0.0104665
Decision Inst.	0.666992

☐ Invert Colors

☑ Color Grade

☐ Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008



Signal Index: 0

☑ Show Eye Diagram

Max. Q Factor	15.6957
Min. BER	8.0889e-056
Eye Height	0.0184594
Threshold	0.00784088
Decision Inst.	0.757324

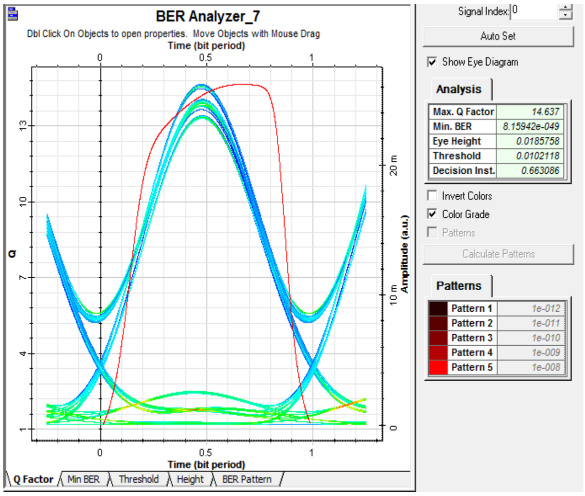
☐ Invert Colors

☑ Color Grade

☐ Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.28. Eye diagram analysis of 32nd channel Fig. 7.29. Eye diagram analysis of 40th. channel



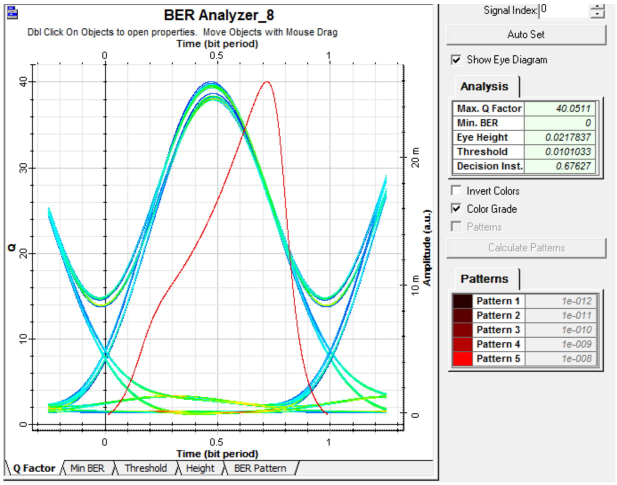
Analysis

Max. Q Factor	14.637
Min. BER	8.15942e-049
Eye Height	0.0185758
Threshold	0.0102118
Decision Inst.	0.663086

Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.30. Eye diagram analysis of 48th channel



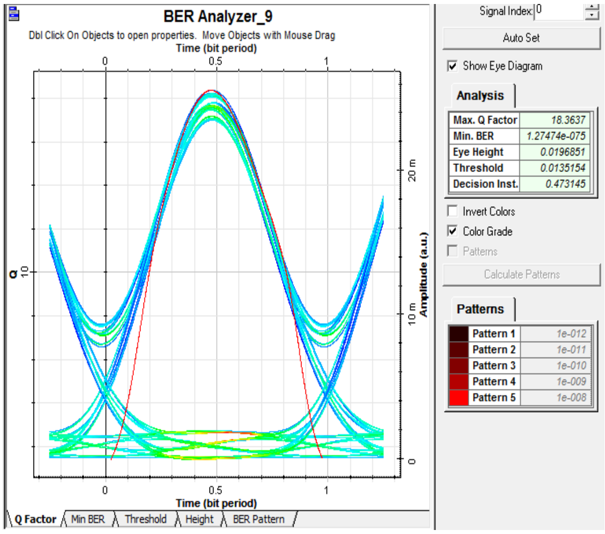
Analysis

Max. Q Factor	40.0511
Min. BER	0
Eye Height	0.0217837
Threshold	0.0101033
Decision Inst.	0.67627

Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.31. Eye diagram analysis 56th channel



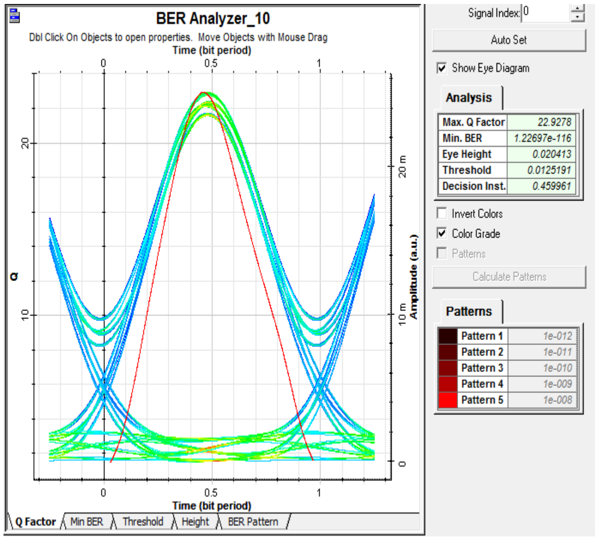
Analysis

Max. Q Factor	18.3637
Min. BER	1.27474e-075
Eye Height	0.0196851
Threshold	0.0135154
Decision Inst.	0.473145

Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.32. Eye diagram analysis of 64th channel



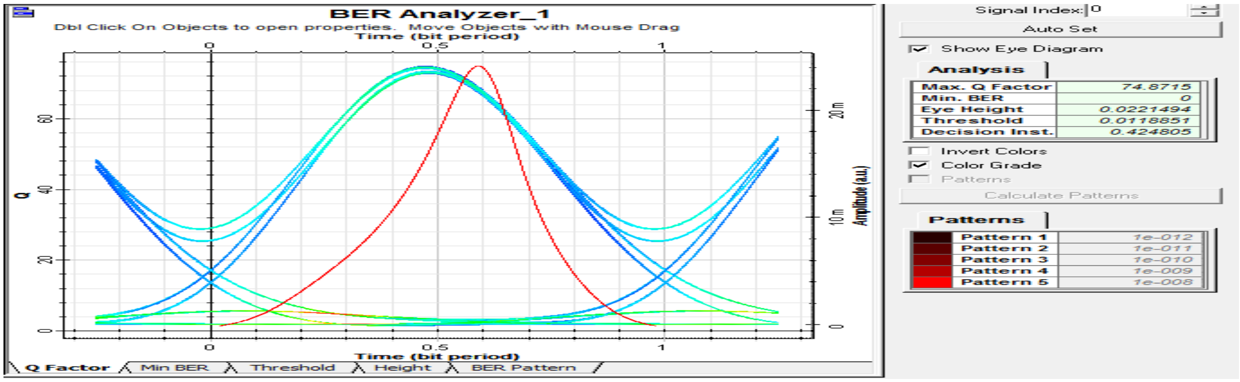
Analysis

Max. Q Factor	22.9278
Min. BER	1.22697e-116
Eye Height	0.020413
Threshold	0.0125191
Decision Inst.	0.459961

Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.33. Eye diagram analysis of 72nd channel



Analysis

Max. Q Factor	74.8715
Min. BER	0
Eye Height	0.0221494
Threshold	0.0118851
Decision Inst.	0.424805

Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.34. Eye diagram analysis of 80th channel

Channel no.	Max. Q factor	Min. BER	Eye height
1	75.4333	0	0.022225
8	23.3119	1.67915e-120	0.204629
16	19.7937	1.685e-087	0.0199197
24	15.3796	1.2045e-053	0.0189108
32	15.2266	1.17785e-052	0.018689
40	15.6957	8.0889e-056	0.0184594
48	14.637	8.15942e-049	0.0185758
56	40.0511	0	0.0217837
64	18.3637	1.2747e-075	0.0196851
72	22.9278	1.22697e-116	0.020413
80	74.8715	0	0.0221494

Table (vii): values of Q factor, BER, eye height for various channels.

C. *Comparison of RZ and NRZ modulation scheme*

Channel no.	Max. Q factor		Min. BER		Eye height	
Modulation format	RZ	NRZ	RZ	NRZ	RZ	NRZ
1	75.4333	19.808	0	1.24865e-087	0.022225	2.66531
8	23.3119	14.5085	1.67915e-120	5.33659e-048	0.204629	2.48143
16	19.7937	25.4846	1.685e-087	1.46091e-143	0.0199197	2.88583
24	15.3796	19.799	1.2045e-053	1.51599e-087	0.0189108	2.69681
32	15.2266	15.504	1.17785e-052	9.23649e-055	0.018689	2.53682
40	15.6957	13.9852	8.0889e-056	9.60071e-045	0.0184594	2.46613
48	14.637	15.2858	8.15942e-049	4.75261e-053	0.0185758	2.51425

56	40.0511	26.0953	0	2.06242e-150	0.0217837	2.89021
64	18.3637	17.0253	1.2747e-075	2.66547e-065	0.0196851	2.58122
72	22.9278	14.3211	1.22697e-116	8.07999e-047	0.020413	2.47536
80	74.8715	20.0886	0	4.63738e-090	0.0221494	2.66656

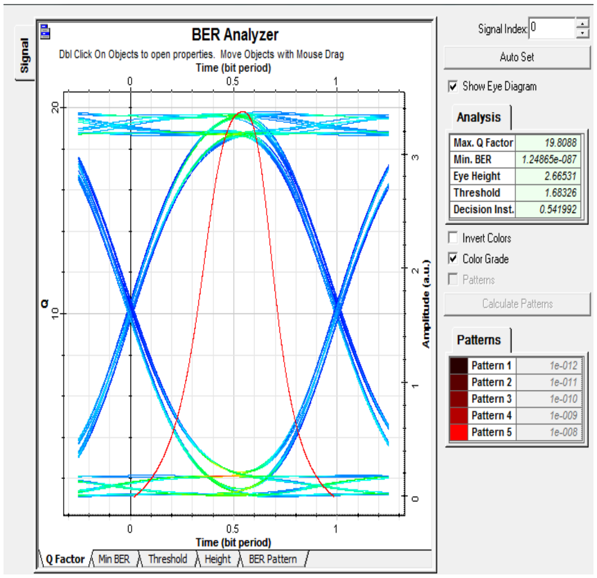
Table (viii): Comparison of NRZ and RZ factors

C. Performance Analysis of 80 Channel DWDM system using different wavelengths.

In this work simulation investigation of the optimized link for DWDM link using DCF at different wavelengths is carried out. Performance of dispersion compensating fiber is analyzed at two set of wavelengths i.e. 980nm, and 1555nm. By using the pre post compensation technique, we have optimized and established an 80 channel DWDM link.

A. Performance analysis at 1555 nm wavelength

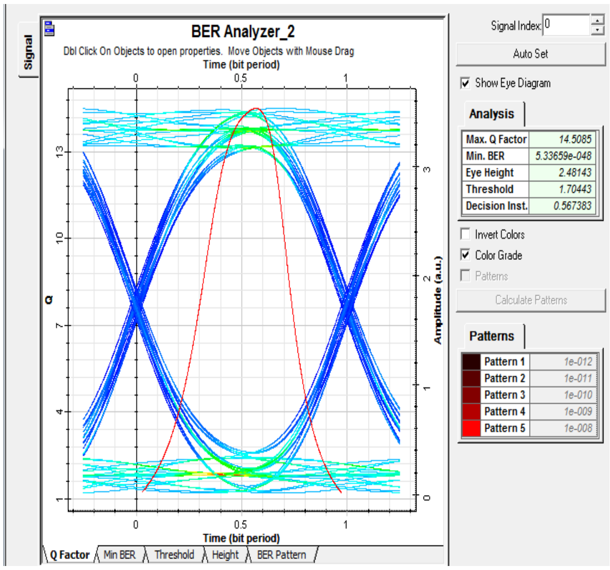
The min. BER is found to be 1.24865e-087 and Q factor is found to be 19.8088 on channel 1 as shown in fig. 7.35. The eye diagram in fig. 7.36 shows the Q factor to be 14.5085 and BER to be 5.33659e-048. The eye diagram and other parameters for channel no. 1,8,16,24,32,40,48,56,64,72,80 are analyzed and as shown below:



Max. Q Factor	19.8088
Min. BER	1.24865e-087
Eye Height	2.66531
Threshold	1.68326
Decision Inst.	0.541992

🟥	Pattern 1	1e-012
🟥	Pattern 2	1e-011
🟥	Pattern 3	1e-010
🟥	Pattern 4	1e-009
🟥	Pattern 5	1e-008

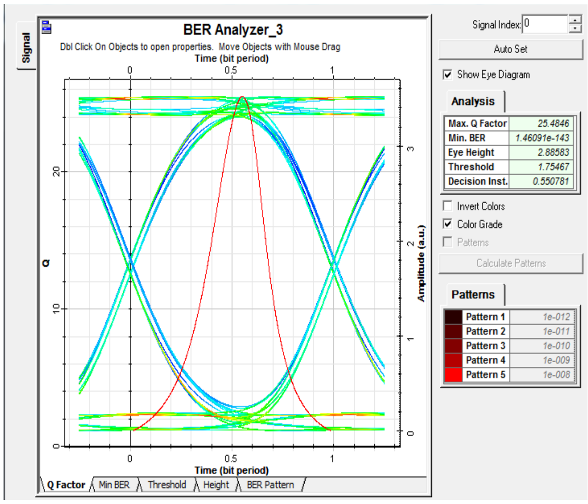
Fig.7.35. Eye diagram analysis of 1st channel



Max. Q Factor	14.5085
Min. BER	5.33659e-048
Eye Height	2.48143
Threshold	1.70443
Decision Inst.	0.567383

🟥	Pattern 1	1e-012
🟥	Pattern 2	1e-011
🟥	Pattern 3	1e-010
🟥	Pattern 4	1e-009
🟥	Pattern 5	1e-008

Fig. 7.36. Eye diagram analysis of 8th channel



Signal Index: 0

☑ Show Eye Diagram

Max. Q Factor	25.4846
Min. BER	1.46091e-143
Eye Height	2.88583
Threshold	1.75467
Decision Inst.	0.550781

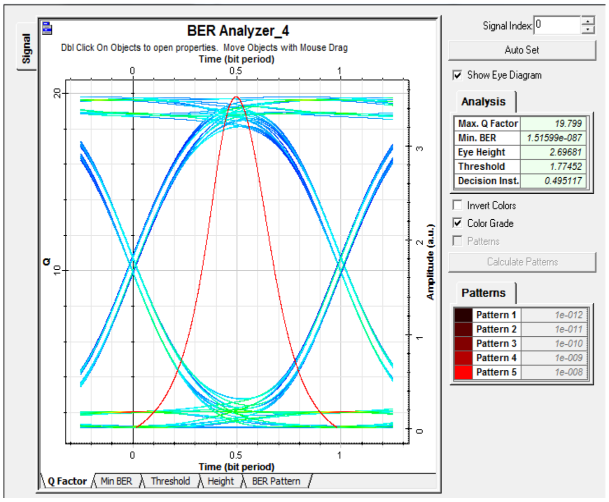
☐ Invert Colors

☑ Color Grade

☐ Patterns

■	Pattern 1	1e-012
■	Pattern 2	1e-011
■	Pattern 3	1e-010
■	Pattern 4	1e-009
■	Pattern 5	1e-008

Fig.7.37. Eye diagram analysis of 16th channel



Signal Index: 0

☑ Show Eye Diagram

Max. Q Factor	19.799
Min. BER	1.51599e-087
Eye Height	2.69681
Threshold	1.77452
Decision Inst.	0.495117

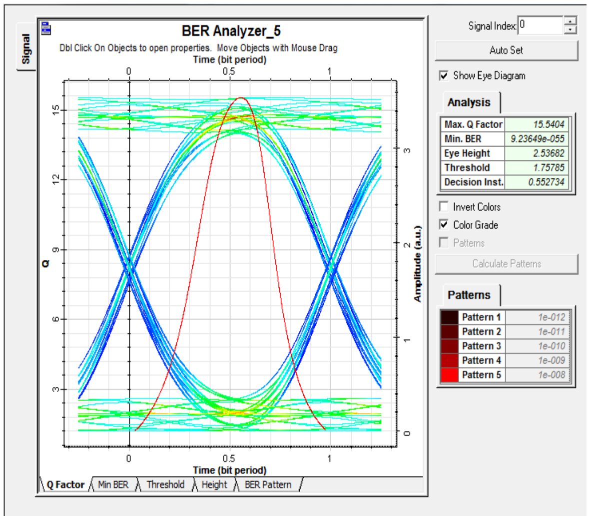
☐ Invert Colors

☑ Color Grade

☐ Patterns

■	Pattern 1	1e-012
■	Pattern 2	1e-011
■	Pattern 3	1e-010
■	Pattern 4	1e-009
■	Pattern 5	1e-008

Fig.7.38. Eye diagram analysis of 24th channel



Signal Index: 0

☑ Show Eye Diagram

Max. Q Factor	15.5404
Min. BER	9.23649e-055
Eye Height	2.53682
Threshold	1.75785
Decision Inst.	0.552734

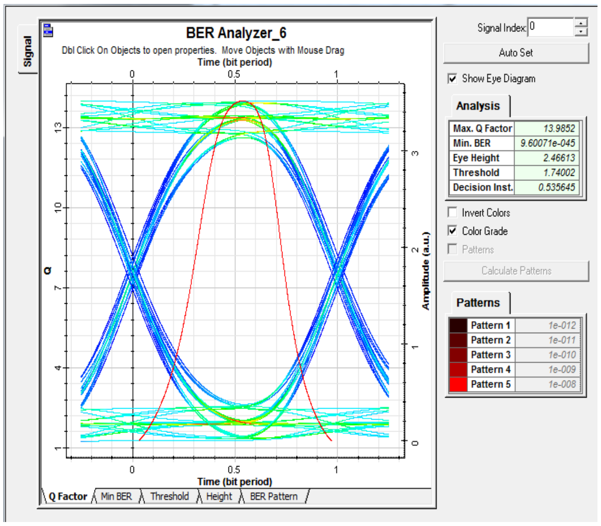
☐ Invert Colors

☑ Color Grade

☐ Patterns

■	Pattern 1	1e-012
■	Pattern 2	1e-011
■	Pattern 3	1e-010
■	Pattern 4	1e-009
■	Pattern 5	1e-008

Fig.7.39. Eye diagram analysis of 32nd channel



Signal Index: 0

☑ Show Eye Diagram

Max. Q Factor	13.9852
Min. BER	9.60071e-045
Eye Height	2.46613
Threshold	1.74002
Decision Inst.	0.535645

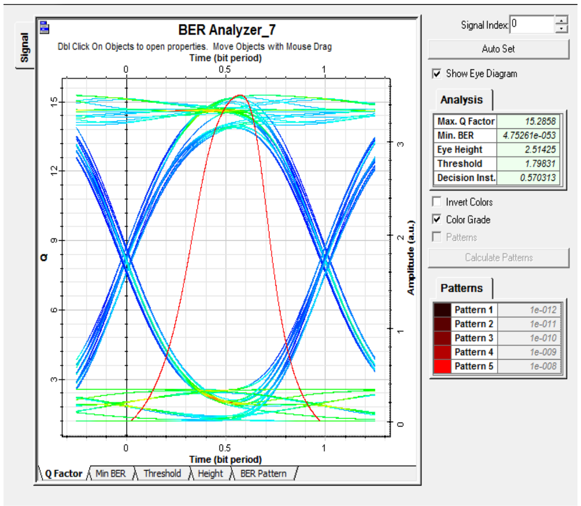
☐ Invert Colors

☑ Color Grade

☐ Patterns

■	Pattern 1	1e-012
■	Pattern 2	1e-011
■	Pattern 3	1e-010
■	Pattern 4	1e-009
■	Pattern 5	1e-008

Fig.7.40. Eye diagram analysis of 40th channel



Signal Index: 0

☑ Show Eye Diagram

Max. Q Factor	15.2858
Min. BER	4.75261e-053
Eye Height	2.51425
Threshold	1.79831
Decision Inst.	0.570313

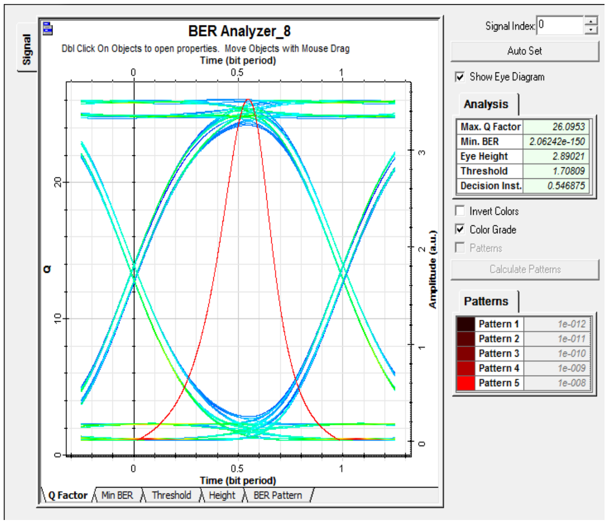
☐ Invert Colors

☑ Color Grade

☐ Patterns

■	Pattern 1	1e-012
■	Pattern 2	1e-011
■	Pattern 3	1e-010
■	Pattern 4	1e-009
■	Pattern 5	1e-008

Fig.7.41. Eye diagram analysis of 48th channel



Signal Index: 0

☑ Show Eye Diagram

Max. Q Factor	26.0953
Min. BER	2.06242e-150
Eye Height	2.89021
Threshold	1.70809
Decision Inst.	0.546875

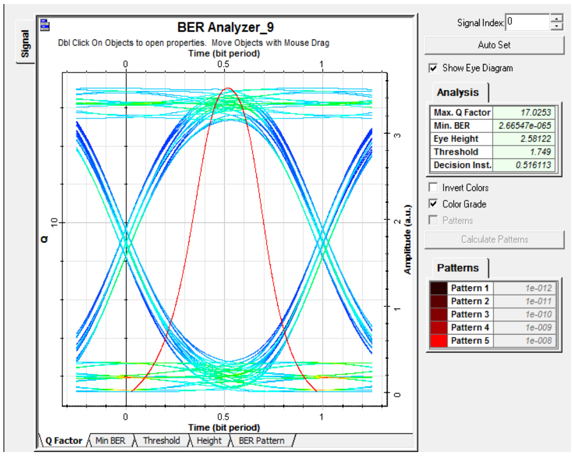
☐ Invert Colors

☑ Color Grade

☐ Patterns

■	Pattern 1	1e-012
■	Pattern 2	1e-011
■	Pattern 3	1e-010
■	Pattern 4	1e-009
■	Pattern 5	1e-008

Fig. 7.42. Eye diagram analysis of 56th channel



Signal Index: 0

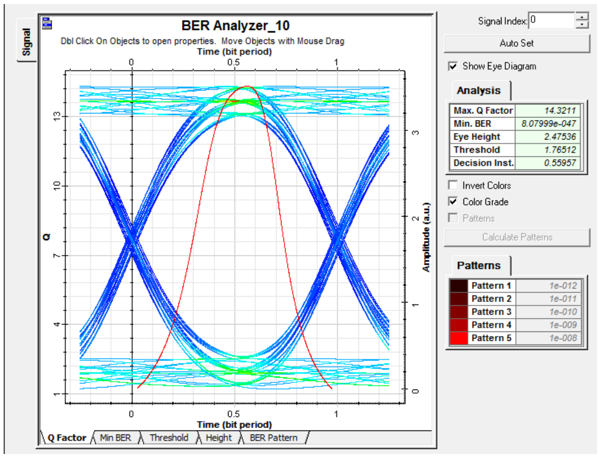
☑ Show Eye Diagram

Analysis	
Max. Q Factor	17.0253
Min. BER	2.66547e-065
Eye Height	2.58122
Threshold	1.749
Decision Inst.	0.516113

☐ Invert Colors
☑ Color Grade
☐ Patterns

Patterns	
Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig.7.43. Eye diagram analysis of 64th channel



Signal Index: 0

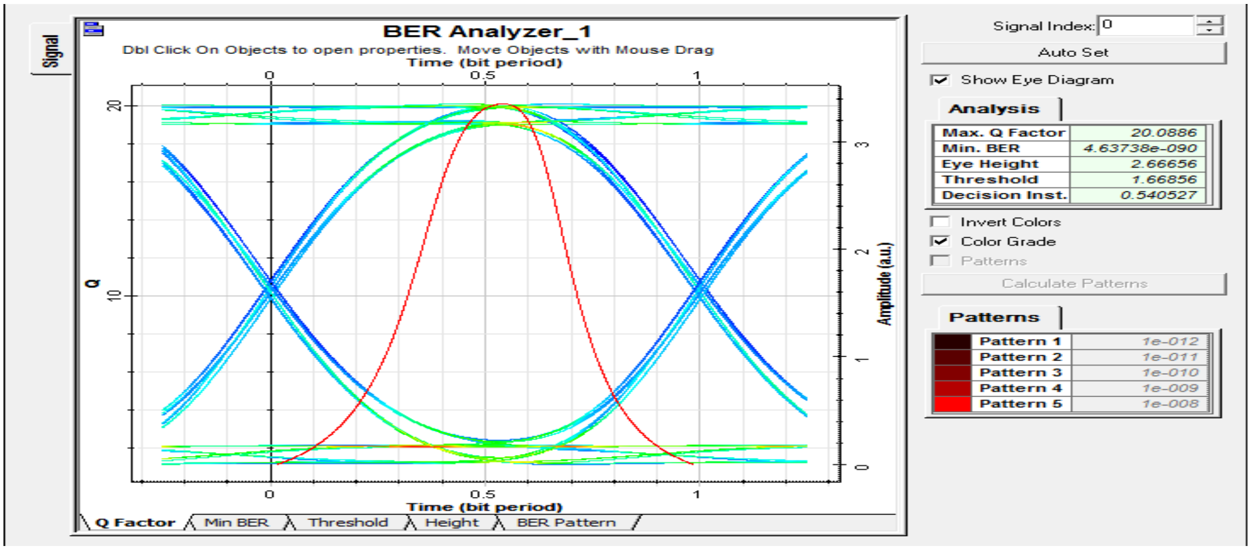
☑ Show Eye Diagram

Analysis	
Max. Q Factor	14.3211
Min. BER	8.07999e-047
Eye Height	2.47536
Threshold	1.76512
Decision Inst.	0.55957

☐ Invert Colors
☑ Color Grade
☐ Patterns

Patterns	
Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.44. Eye diagram analysis of 72ndchannel



Signal Index: 0

☑ Show Eye Diagram

Analysis	
Max. Q Factor	20.0886
Min. BER	4.63738e-090
Eye Height	2.66656
Threshold	1.66856
Decision Inst.	0.540527

☐ Invert Colors
☑ Color Grade
☐ Patterns

Patterns	
Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

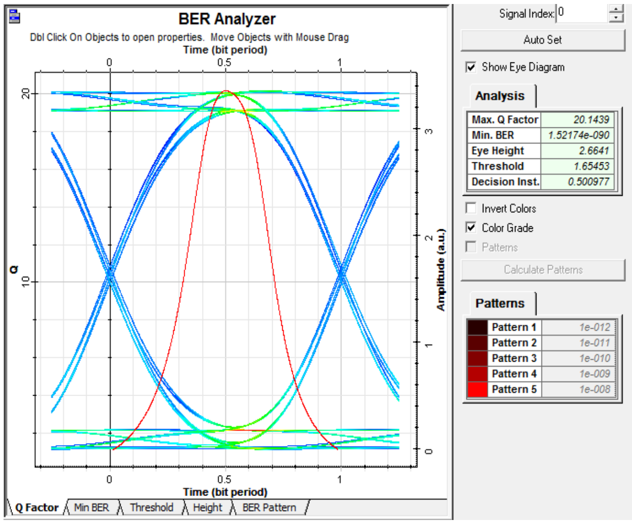
Fig.7.45. Eye diagram analysis of eightieth channel

Channel no.	Max. Q factor	Min. BER
1	19.808	1.24865e-087
8	14.5085	5.33659e-048
16	25.4846	1.46091e-143
24	19.799	1.51599e-087
32	15.504	9.23649e-055
40	13.9852	9.60071e-045
48	15.2858	4.75261e-053
56	26.0953	2.06242e-150
64	17.0253	2.66547e-065
72	14.3211	8.07999e-047
80	20.0886	4.63738e-090

Table (ix): Values of Q factor and BER for various channels

B. Performance analysis at 980 nm wavelength

The min. BER is found to be 1.52174e-090 and Q factor is found to be 20.1439 on channel 1 as shown in fig. 7.46. The eye diagram in fig. 7.47 shows the Q factor to be 15.0736 and BER to be 1.20644e-051 for eighth channel. The eye diagram and other parameters for channel no. 1, 8,16,24,32,40,48,56,64,72,80 are analyzed and as shown below:



Signal Index: 0

☑ Show Eye Diagram

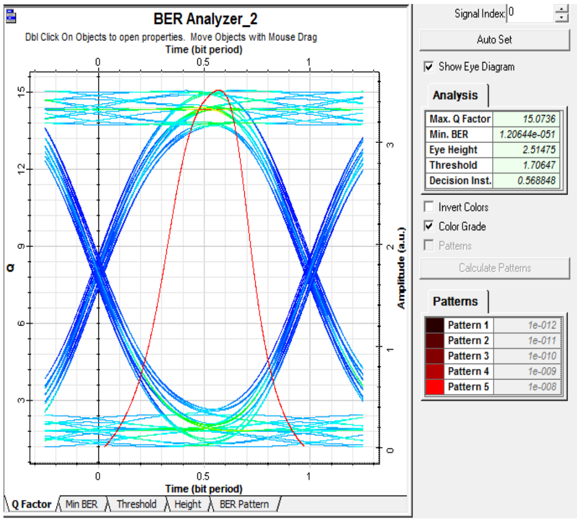
Analysis

Max. Q Factor	20.1439
Min. BER	1.52174e-090
Eye Height	2.6641
Threshold	1.65453
Decision Inst.	0.500977

☐ Invert Colors
☑ Color Grade
☐ Patterns

Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008



Signal Index: 0

☑ Show Eye Diagram

Analysis

Max. Q Factor	15.0736
Min. BER	1.20644e-051
Eye Height	2.51475
Threshold	1.70647
Decision Inst.	0.568848

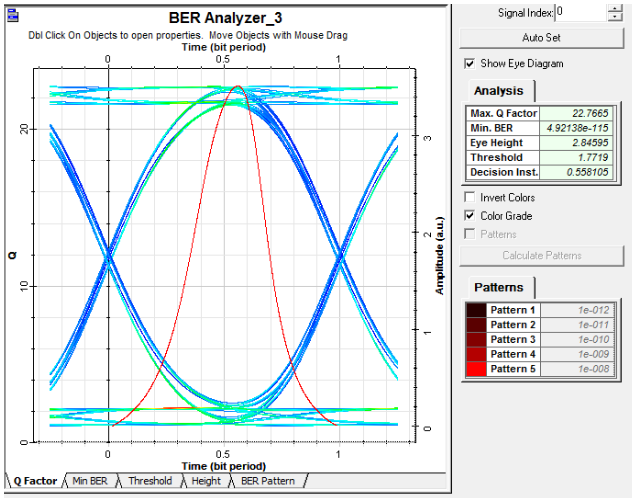
☐ Invert Colors
☑ Color Grade
☐ Patterns

Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig.7.46. Eye diagram analysis of 1st channel

Fig.7.47. Eye diagram analysis of 8th channel



Signal Index: 0

☑ Show Eye Diagram

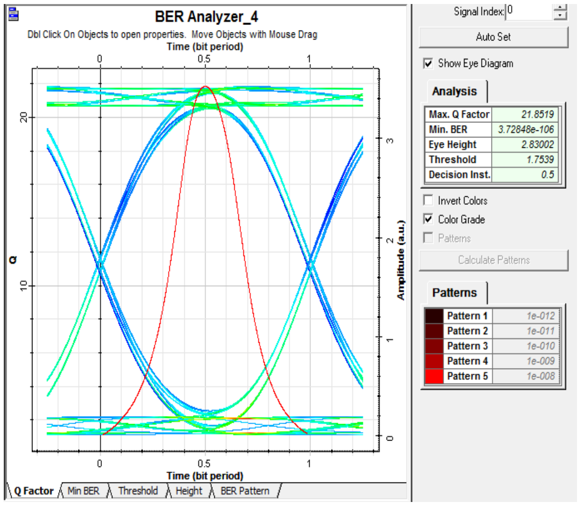
Analysis

Max. Q Factor	22.7665
Min. BER	4.92138e-115
Eye Height	2.84595
Threshold	1.7719
Decision Inst.	0.558105

☐ Invert Colors
☑ Color Grade
☐ Patterns

Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008



Signal Index: 0

☑ Show Eye Diagram

Analysis

Max. Q Factor	21.8519
Min. BER	3.72848e-106
Eye Height	2.83002
Threshold	1.7539
Decision Inst.	0.5

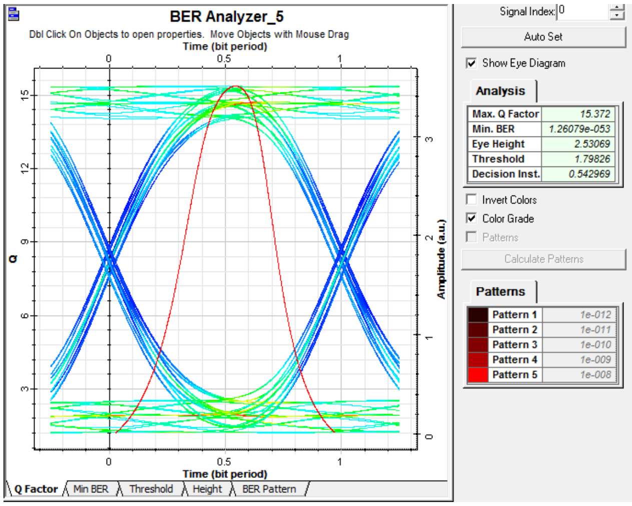
☐ Invert Colors
☑ Color Grade
☐ Patterns

Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig.7.48. Eye diagram analysis of 16th channel

Fig.7.49. Eye diagram analysis of 24th channel



Signal Index: 0

☑ Show Eye Diagram

Max. Q Factor	15.372
Min. BER	1.26079e-053
Eye Height	2.53069
Threshold	1.79826
Decision Inst.	0.542969

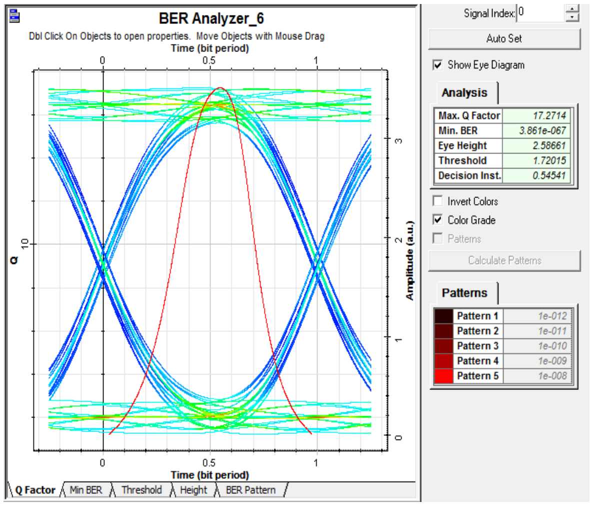
☐ Invert Colors

☑ Color Grade

☐ Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig.7.50. Eye diagram analysis of 32nd channel



Signal Index: 0

☑ Show Eye Diagram

Max. Q Factor	17.2714
Min. BER	3.861e-067
Eye Height	2.58661
Threshold	1.72015
Decision Inst.	0.54541

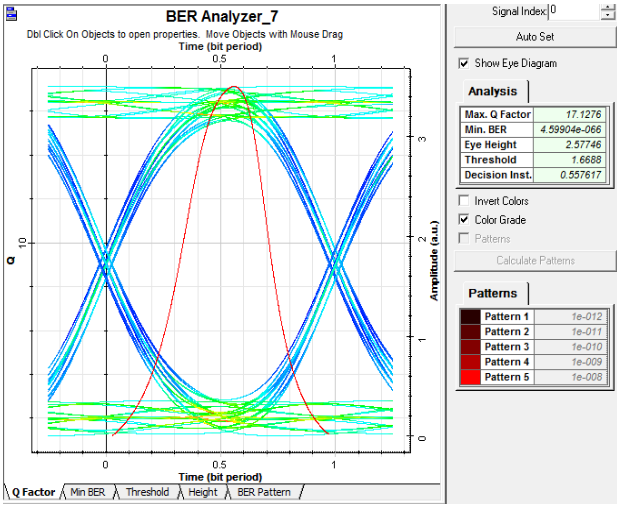
☐ Invert Colors

☑ Color Grade

☐ Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig.7.51. Eye diagram analysis of 40th channel



Signal Index: 0

☑ Show Eye Diagram

Max. Q Factor	17.1276
Min. BER	4.59904e-066
Eye Height	2.57746
Threshold	1.6688
Decision Inst.	0.557617

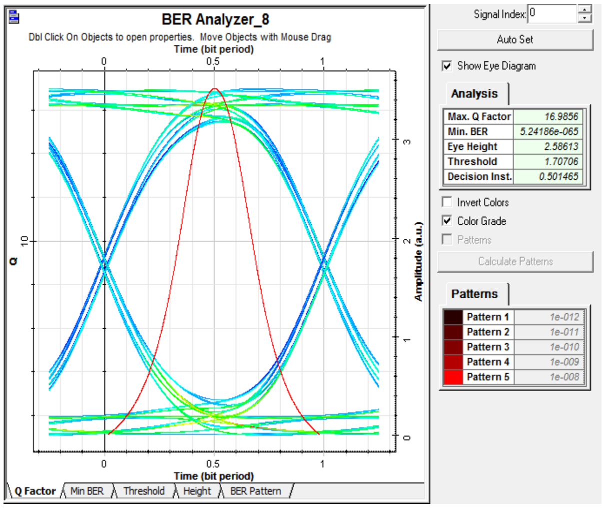
☐ Invert Colors

☑ Color Grade

☐ Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig.7.52. Eye diagram analysis of 48th channel



Signal Index: 0

☑ Show Eye Diagram

Max. Q Factor	16.9856
Min. BER	5.24186e-065
Eye Height	2.58613
Threshold	1.70706
Decision Inst.	0.501465

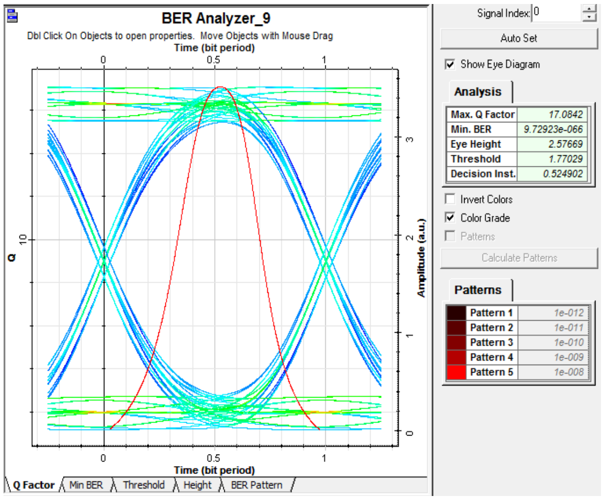
☐ Invert Colors

☑ Color Grade

☐ Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig. 7.53. Eye diagram analysis of 56th channel



Signal Index: 0

☑ Show Eye Diagram

Max. Q Factor	17.0842
Min. BER	9.72923e-066
Eye Height	2.57669
Threshold	1.77029
Decision Inst.	0.524902

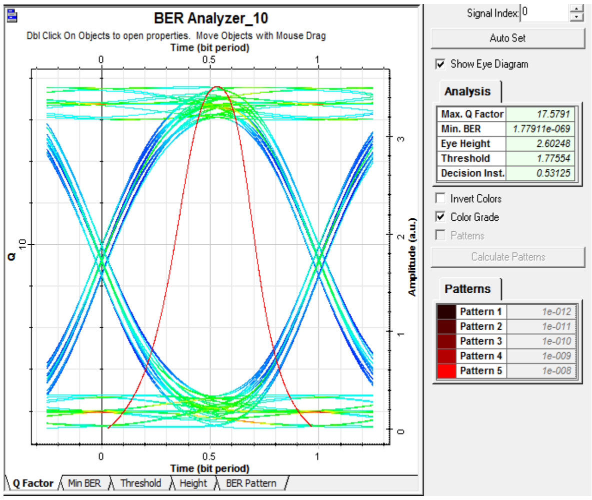
☐ Invert Colors

☑ Color Grade

☐ Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig.7.54. Eye diagram analysis of 64th channel



Signal Index: 0

☑ Show Eye Diagram

Max. Q Factor	17.5791
Min. BER	1.77911e-069
Eye Height	2.60248
Threshold	1.77554
Decision Inst.	0.53125

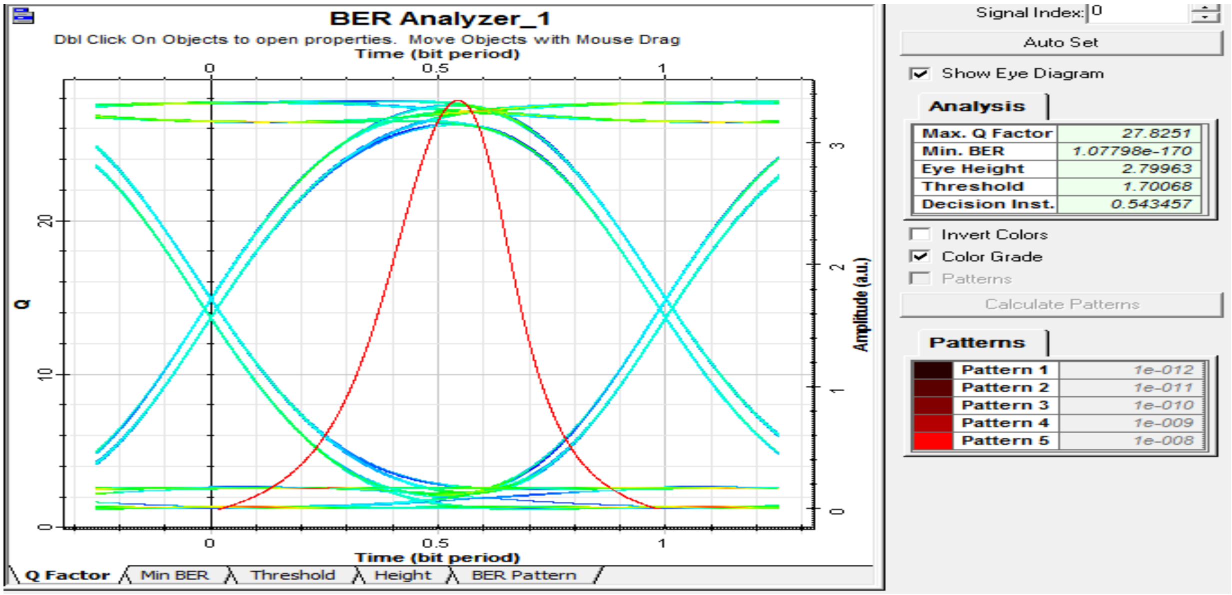
☐ Invert Colors

☑ Color Grade

☐ Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig.7.55. Eye diagram analysis of 72nd channel



Signal Index: 0

☑ Show Eye Diagram

Analysis

Max. Q Factor	27.8251
Min. BER	1.07798e-170
Eye Height	2.79963
Threshold	1.70068
Decision Inst.	0.543457

☐ Invert Colors

☑ Color Grade

☐ Patterns

Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Fig.7.56. Eye diagram analysis of eightieth channel

Channel no.	Max. Q factor	Min. BER
1	20.1439	1.52174e-090
8	15.0736	1.20644e-051
16	22.7665	4.92138e-115
24	21.8519	3.72848e-106
32	15.372	1.26079e-053
40	17.2714	3.861e-067
48	17.1276	4.59904e-066
56	16.9856	5.24186e-065
64	17.0842	9.72923e-066
72	17.5791	1.77911e-069
80	27.8251	1.07998e-170

Table (x): Values of Q factor and BER for various channels.

C. Comparison of 980 nm and 1555 nm wavelength

Channel no.	Max. Q factor		Min. BER	
Wavelength	980	1555	980	1555
1	20.1439	19.808	1.52174e-090	1.24865e-087
8	15.0736	14.5085	1.20644e-051	5.33659e-048

16	22.7665	25.4846	4.92138e-115	1.46091e-143
24	21.8519	19.799	3.72848e-106	1.51599e-087
32	15.372	15.504	1.26079e-053	9.23649e-055
40	17.2714	13.9852	3.861e-067	9.60071e-045
48	17.1276	15.2858	4.59904e-066	4.75261e-053
56	16.9856	26.0953	5.24186e-065	2.06242e-150
64	17.0842	17.0253	9.72923e-066	2.66547e-065
72	17.5791	14.3211	1.77911e-069	8.07999e-047
80	27.8251	20.0886	1.07998e-170	4.63738e-090

Table (xi): comparison of 980 nm and 1555 nm factors

Chapter 8

Conclusion and future work

8.1 Conclusion

In this work, an optimized DWDM link using dispersion compensation technique is presented. The 80 channel DWDM system is presented with operating frequency 1555 nm and frequency spacing of 100 GHz. The optical communication channel used Dispersion compensating fiber to deliver the optical signal at its best quality to the receiver. Various EDFA's are used to amplify and regenerate the optical signal. Management of dispersion is an important part in designing a DWDM system, since dispersion can affect the penalties caused by non-linearity of fibers. Single mode fiber is much more preferred as compared to multimode fiber. We have analyzed the dispersion effect using Optisystem 7.0 simulator. The performance of the system is further enhanced by Dispersion Compensating Fiber. Following are the conclusions drawn after doing performance analysis of the designed DWDM system:

1. The system performance is limited by the dispersion. In order to compensate this we have used Dispersion compensation fiber. By using this we have successfully designed a 80 channel DWDM system with 10 Gbps data rate with frequency spacing 100 GHz. Various EDFA's are also used to amplify and regenerate the signal.

2. RZ modulation is preferred as compared to NRZ modulation for large input laser power. But when dealing with large DWDM systems, NRZ modulation is superior to RZ modulation as RZ modulation causes a significant eye closure penalty near end channels.

3. At the wavelength of 1555nm, the performance of the link represents better performance as compared to 980nm wavelength. The optimized WDM link at 1555nm using dispersion compensating fiber along with single mode fiber for link length of 50 km operating at data rate of 10Gb\s with 80-channel of DWDM System is achieved for NRZ format.

8.2 Future Scope

We are facing the challenge of increasing capacity while decreasing costs, carriers now have two options: Install new fiber or increase the effective bandwidth of existing fiber. It is realized that, in coming future, DWDM can emerge as a promising technique to increase the capacity and meet the bandwidth requirement. This work can further be extended to more number of channels i.e.

100 channels or more with even smaller frequency spacing there by increasing the capacity of the already installed infrastructure to a great extent by simple re configurations.

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Appendix

EDFA- Erbium Doped Fiber Amplifier
WDM - Wavelength Division Multiplexing
BER - Bit Error Rate
Q-Factor - Quality Factor
SMF – Single Mode Fiber
DCF – Dispersion Compensating Fiber
SOA – Semiconductor Optical amplifier
SNR – Signal to Noise Ratio
NF – Noise Figure
NRZ- Non Return-to-Zero
RZ - Return to Zero