Analysis of four channel CWDM Transceiver Modules based on Extinction Ratio and with the use of EDFA

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Abstract- **Optical communication systems are extremely complex and difficult to analyze. It is often hard to predict the effect of various characteristics of the devices used on the signal fidelity in a fiber optic link. This work involves simulation of coarse wavelength division multiplexing (CWDM) transceiver for end-to-end based on the effect of extinction ratio and with the use of EDFA. Simulation software is available commercially which can realistically model an optical link. Such simulation helps in analyzing the module under development and predicts the performance for a given link distance and the simulation output helps in eliminating any likely performance degradation before realizing the actual hardware. The objective of the fiber optic link is to transport data or communication signals reliably over a longer distance. The simulation objective is to ensure that the received pulses are of appropriate shape and of sufficient intensity, with minimized loss due to noise or attenuation, and to remove distortion present in the signal. The Q factor and BER obtained from either the eye diagram analyzer or the BER analyzer are used to analyze the degradation of the signal at the receiver components. In this paper, simulation results of CWDM transceiver modules are presented .Non-Return to Zero (NE) electrical signals from a Pseudo-Random Bit Sequence (PRBS) Generator are used as modulation input. Signals in the optical domain are detected at the PIN photo detector and are converted into electrical output signals. These electrical signals are amplified using a Trans-impedance Amplifier (TIA) and the amplified signals are filtered through a second order low pass Gaussian filter. Filtering removes distortion caused by noise or interference in the signal.**

I INTRODUCTION

The demand for bandwidth has increased in an extremely fast pace over the past few years and is likely to continue to do so for the near future. To be able to meet the customer's needs, telecommunication companies have to find solutions for increasing their channel capacity at the lowest cost possible. For most cases, wavelength division multiplexing (WDM) seems to be a promising solution. In WDM, several different wavelengths are transmitted over one single mode fibre at the same time. It can be classified in to two coarse wavelength division multiplexing (CWDM) and dense wavelength division multiplexing. Coarse Wavelength Division Multiplexing links are gaining acceptance in the metro network. This is because a CWDM system can carry more bandwidth for multiple metro applications and is less expensive than a dense-WDM (DWDM) system since the transmitters use uncooled, direct modulated laser diodes. In CWDM, a separate single wavelength transmitter, receiver, or transceiver module is used for each wavelength. Typically the wavelengths lie on a 20-nm spaced grid ranging from 1470 nm to 1610 nm. The outputs of each module are combined and separated using external, fiber-coupled wavelength multiplexers, demultiplexers, and add/drop multiplexers. This is essentially the same scalable, modular approach as DWDM, but with the wider channel spacing. CWDM transceivers leverage a great deal from parallel optics technology. The laser and detector arrays ark directly coupled to a tiny optical multiplexer and demultiplexer, giving the CWDM transceiver module a single optical output and a single optical input, preferably through a duplex connector. CWDM has a great potential to reduce optical link cost, but there is concern on size and cost of the system. In conventional CWDM link number of transmitter and receiver modules is equal to required wavelengths. A Compact and inexpensive system for CWDM link is possible with multi-channel optical modules. For CWDM application, compact low-cost optical modules with four channels have been reported, recently. As a cost-effective solution, Optical subassembly **(**OSA**)** is used for the assembly of CWDM modules. Optical alignment of different components is done on OSA without any requirement of mechanical accuracy. The CWDM transceivers consist of uncooled direct modulated laser diodes, pin photo diode, optical fibers, Optical multiplexer and demultiplexer, optical alignment and integrated circuits (ICs). CWDM transceiver, with uncooled laser diode, used for telecommunication systems need to be assured for reliability with respect to the different components degradation. In this study, effect of extinction ratio of laser diode, and the use of EDFA on optical link performance has been studied by optical simulation.

Optisystem, an optical communication software, is used for the simulation of the CWDM link. It is an innovative optical communication system simulation package for the design, testing and optimization of virtually any type of optical link in the physical layer of a broad spectrum of optical networks. A system level simulator based on the realistic modelling of fiber-optic communication systems, it possesses a powerful new simulation environment and a truly hierarchical definition of components and systems.

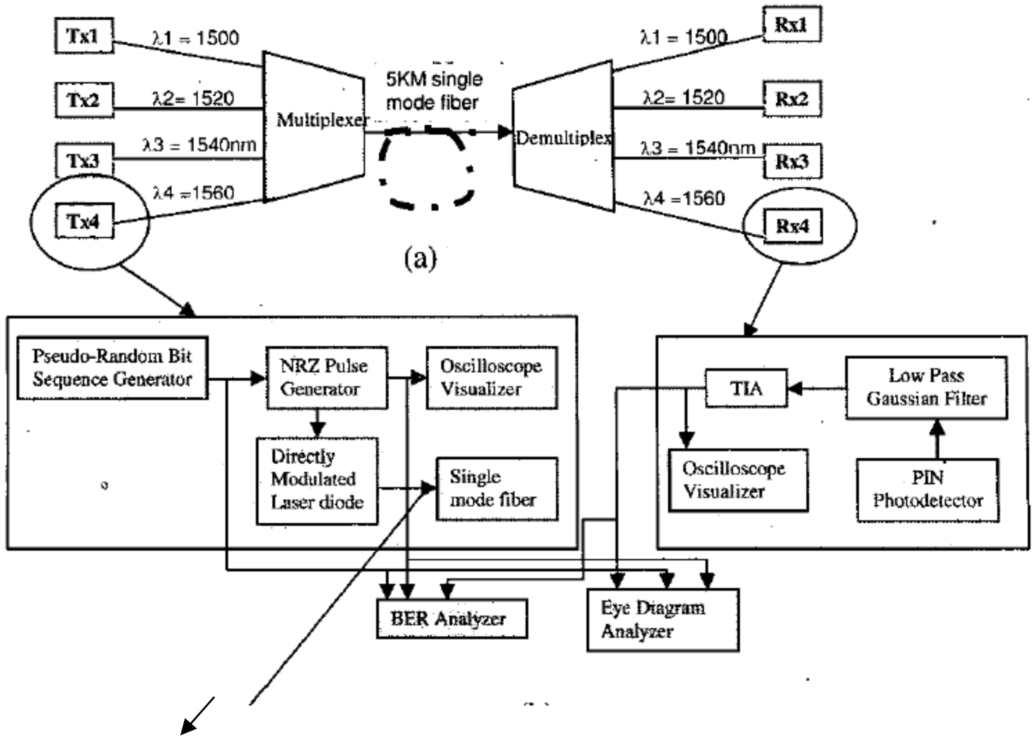


Fig. 1 Schematic of (a) 2.5 Gbps optical link using 4-channel CWDM transceiver, (b) optical transmitter **(Tx)** and receiver (Rx) for CWDM transceiver.

A schematic of optical link for 5KM with four channel CWDM Transceiver module **i**s shown in Figure 1.Detail of different components and their parameters are discussed in next section. Degradation of the optical link is determined by calculating the ***Q*** factor, BER and Eye diagram of the different channels of CWDM transceiver. Extinction ratio is an important measurement for characterizing the performance of optical transmitters. The extinction ratio of an optical transmitter used in digital communications is simply the ratio of the average energy in a transmitted logic level '1' to the average energy in a transmitted logic level '0'.The effect of change in laser diode extinction ratio on fiber optic link is considered in this paper.

II DESCRIPTION OF OPTICAL LINK AND CWDM TRNSCEIVER

In this simulation, optical links for various lengths are considered here. The main components of the optical link are 4-channel CWDM transceiver, single mode fiber, and BER analyzer, and Eye diagram analyzer for analyzing the performance of the link .A compact size CWDM transceiver, assembled on silicon submount, is designed for the applications with uncooled direct modulated laser (DML), PIN photodiode, nonzero dispersion Single mode fiber (NZDSMF), and electronic components like pseudo random bit generator, NRZ pulse generator, second order low pass Gaussian filter, and transimpedance amplifier (TIA).

The transmitter side consist of direct modulated LASER where parameters such as extinction ratio, line width, chirp, side mode, suppression and relative intensity noise (RIN) are varied. Extinction ratio is an important measurement for characterizing the performance of optical transmitters. The extinction ratio of an optical transmitter used in digital communications is simply the ratio of the average energy in a transmitted logic level '1' to the average energy in a transmitted logic level '0'In high speed optical communication systems, in order to avoid undesirable effects large modulation depth is required along with large modulation frequency and minimal power loss**.** A high modulation depth is desirable, because the optical signal will exhibit a greater margin to resist the noise

Extinction ratio (ER) can be defined as a linear ratio, in decibels, or as a percentage:

ER linear = E (1)/E (0)

ER (dB) = 10 log10(ER linear)

ER (%) = 100 (E (0)/E (1))

Where E (1) = average energy in a logic 1 pulse
E (0) = average energy in a logic 0 pulse.
Erbium-doped fiber amplifiers(EDFA) are the by far most important fiber amplifiers in the context of long-range optical fiber communications; they can efficiently amplify light in the 1.5-μm wavelength region, where telecom fibers have their loss minimum.

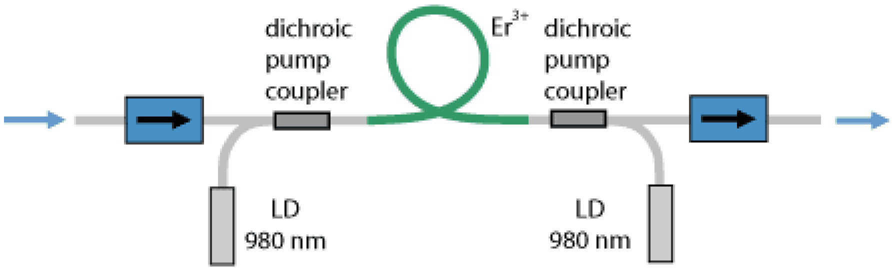


TABLE I

Slno	Module	Parameter	Value
1.	NRZ Pulse Generator	Amplitude	1
		Rise Time	0.05bit
		Fall Time	0.05 bit
2.	DM LASER	Extinction ratio	6,6.5,7,8
		Power	10dBm
		Undershoot	30%
		Overshoot	30%
3.	MUX and DMUX	Filter order	2
4.	Optical fiber	Length	5,40,80,100,120km
		Attenuation	0.25db/km
5.	Photo detector	Responsivity	1A/W
		Dark Current	10nA
6.	TIA	Voltage gain	10ohm

III OPTICAL SIMULATION

Optical simulation of the CWDM fiber optic links is performed with Optisystem, which allows users to design and test a variety of optical links and optical networks. Optisystem has a powerful simulation environment and an extensive library of active and passive components. The components provided in the default library are able to reproduce the actual behaviour of the real Device and the required effects. In this simulation, the fiber optics link is created by selecting components from the default library.The simulation of a fiber optic link involves the generation of random binary bits, by the Pseudo-Random Sequence Generator. The NE Pulse Generator produces the electrical signals from the binary bits. The electrical signals are converted into light pulses by DMLs which are coupled onto the end of a fiber core. Multiplexer combined the different channel optical signal to produce a Single optical signal. The optical signal is carried on a single NZDSMF of 5KM, where it is demultiplexed in four different wavelengths Signals. The Photo detector PIN detects the incoming light pulses and converts them into electrical signals. The objective is to ensure that the received pulses are of appropriate shape and of sufficient intensity to be correctly detected, to minimize loss due to noise or attenuation, and to remove distortion present in the signal. The oscilloscope visualizer is used to obtain the electrical signals at the NRZ pulse generator and transimpedance amplifier. The Q factor and BER obtained from either the Eye Diagram Analyzer or the BER Analyzer are used to analyze the degradation of the signal at the receiver components.

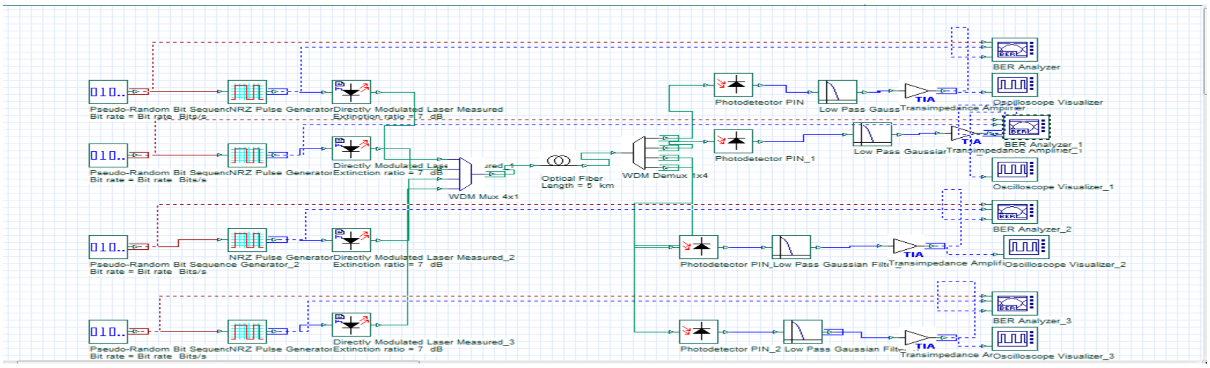


Fig 2 Circuit Schematic of CWDM system for the different extinction ratios

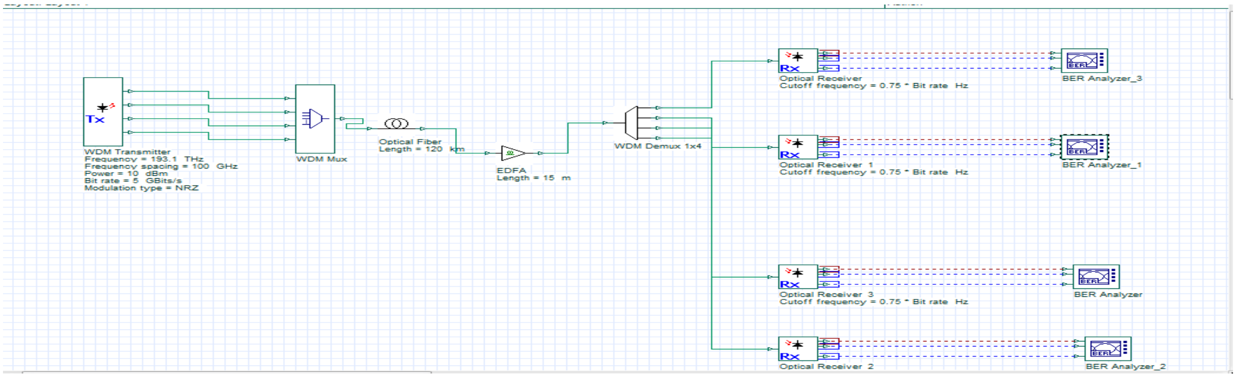


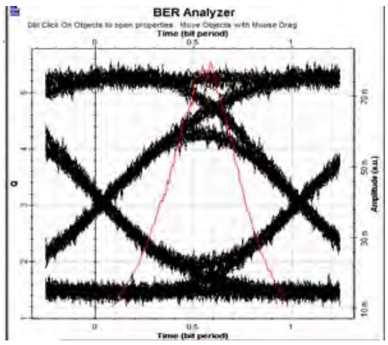
Fig 3 Circuit schematic of CWDM system with the use of EDFA for different optical lengths

IV RESULTS AND DISCUSSIONS

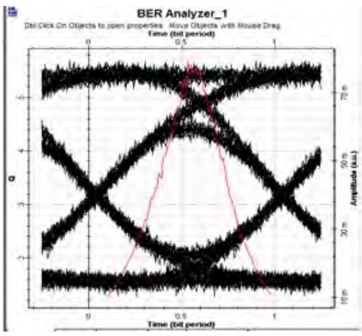
Case1:Effect of variation of Extinction ratio on fiber optic link.

In high speed optical communication systems, in order to avoid undesirable effects large modulation depth is required along with large modulation frequency and minimal power loss. A high modulation depth is desirable, because the optical signal will exhibit a greater margin to resist the noise

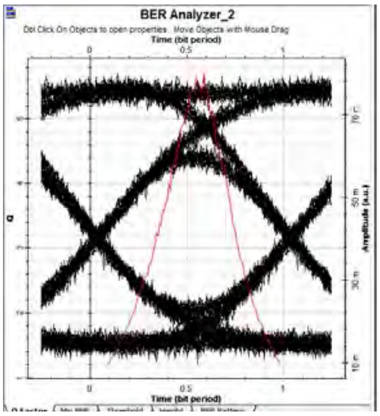
Extinction ratio (ER) is a measure of the modulation depth of a source transmitter and it expresses the proportional relationship between the power levels of the binary 'I' and'0' signals, averaged while transmitting a pseudo-random binary-sequence signal filtered at 75% of the maximum bit rate.



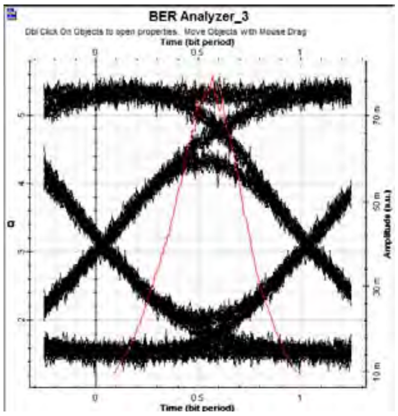
4(a)



4(b)



4(c)



4(d)

Effect of the laser diode extinction ratio variation on the Q factor and BER for 193.3THz frequency is shown in Fig 4(a,b,c,d)

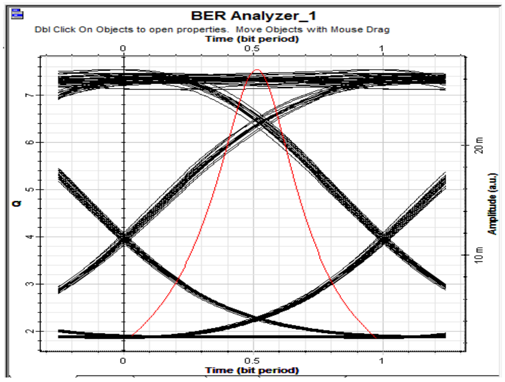
	Frequency(THz)	Q-factor	BER
Extinction Ratio 6dB	193.1	5.49126	1.88926e-008
	193.2	5.63389	8.80184e-009
	193.3	5.65373	7.54674e-009
	193.4	5.514499	1.68438e-008

	Frequency(THz)	Q-factor	BER
Extinction Ratio 6.5dB	193.1	5.52068	1.57729e-008
	193.2	5.65083	6.00858e-009
	193.3	5.67084	6.52169e-009
	193.4	5.69531	1.36958e-008
	Frequency(THz)	Q-factor	BER
Extinction Ratio 7dB	193.1	5.55192	1.31138e-008
	193.2	5.69524	5.81815e-009
	193.3	5.71128	5.29925e-009
	193.4	5.70244	1.1831e-008

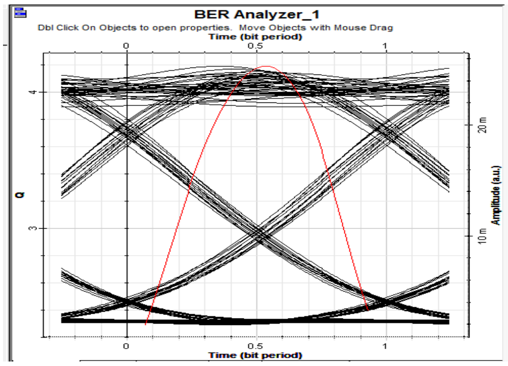
	Frequency(THz)	Q-factor	BER
Extinction Ratio 8dB	193.1	5.6439	7.6599e-008
	193.2	5.71808	5.02412e-009
	193.3	5.80907	2.92044e-009
	193.4	5.95266	7.39307e-008

Case2: Effect of EDFA on fiber optic link

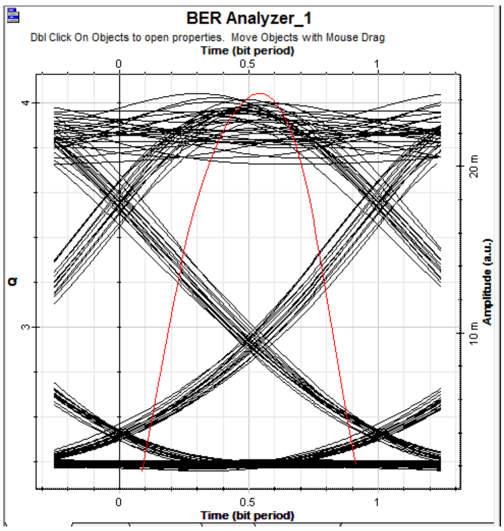
EDFA's are particularly useful for long distances fibre cabling such as transoceanic submarine cables. They eliminate the use of repeaters along the cable and there is no bottleneck congestion.



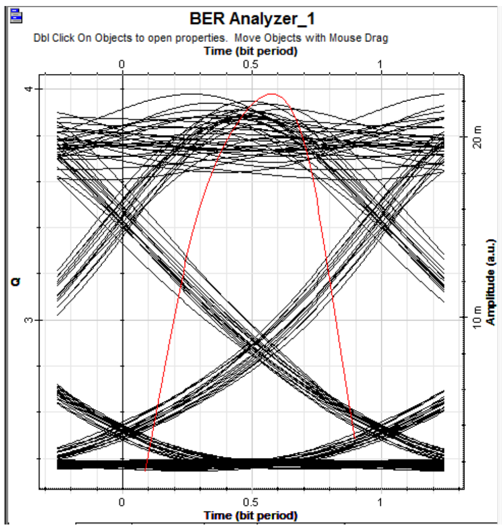
5(a)



5(b)



5(c)



5(d)

Effect of BER for various optical lengths 5(a,b,c,d)

	Frequency(THz)	Q-factor	BER
Optical fiber length-40km	193.1	7.3529	8.9425e-014
	193.2	7.5394	2.0976e-014
	193.3	7.4495	4.45787e-014
	193.4	7.38513	6.9351e-014

	Frequency(THz)	Q-factor	BER
Optical fiber length-80km	193.1	3.93326	3.67006e-005
	193.2	4.19142	1.3177e-005
	193.3	3.78848	6.3445e-005
	193.4	4.00781	2.78093e-005

	Frequency(THz)	Q-factor	BER
Optical fiber length-100km	193.1	3.91581	4.0556e-005
	193.2	4.04133	2.60268e-005
	193.3	3.68299	9.95755e-005
	193.4	3.85884	5.4044e-005

	Frequency(THz)	Q-factor	BER
Optical fiber length-120km	193.1	3.77428	7.36058e-005
	193.2	3.97956	3.40584e-005
	193.3	3.6913	0.000121453
	193.4	3.827	6.222718e-005

In this paper we have simulated a four channel optical link CWDM transceiver system, using direct modulated LASER diodes. CWDM is an ideal solution for increasing the bandwidth needs and low cost optical module demand. The performance of CWDM system degraded significantly with the decrease in laser extinction ratio. EDFA is useful in the case where fiber optic length is more than 40km.However the use of EDFA with Raman amplifiers can increase the optical power as distance increases. Thus it is important to consider the reliability of other components and assembly process during the design of CWDM transceiver for achieving a long life of the module.

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