BER Analysis of WDM Optical Communication System With Different Bit Rate and Sample rate

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Abstract

The work aims to investigate the performance of DWDM system utilizing Eribium Dopped Fiber amplifiers EDFAs and Dispersion Compensating Fiber DCF for different length of optical fiber and bit rates. The most effective factors causes performance degradations are the attenuation and dispersion. EDFA was introduced in the proposed system model as a solution to encounter the effects of attenuation and scattering losses, while the DCF utilized to mitigate the effect of dispersion. BER is the measurement of bits that have errors relative to the total number of bits received in a transmission. There are so many different types of modulation techniques scheme is recommended for improvement of BER and Q-factor in fibre optic communications. The advanced scheme has been tested on optical fibre systems using Dense Wave Length Division Multiplexing (DWDM) operating with a non-return-to-zero (NRZ) format at transmission rates of up to 2.5 Gbps. Wavelength division multiplexing (WDM) network can offer a solution to these problems where the transmission of different signals can be done with a single-mode fibre. BER should be reduced to assured values, and the Q-factor must be increased. The investigation of WDM-RoF with different lengths of fibre at various channel spacing will be simulated using Optisystem software, and the RoF's receiver performance is measured and analyzed depending on the acquired BER, the value of the Q-factor, and the height of the opening of the eye diagram. The degradation factors effect such as attenuation and dispersion are significantly limited with the addition of an EDFA amplifier to a Single Mode Fibre (SMF).

Keywords:- WDM, DCF, BER, Q –factor, RoF.,

INTRODUCTION

Wavelength division multiplexing (WDM) is a technology which multiplexes multiple optical carrier signals on a single optical fiber by using different wavelengths of laser light to carry different signals. This allows for a multiplication in capacity of an optical fiber by adding new channels, each channel on a new wavelength of light, in addition to enabling bidirectional communications over one strand of fiber. [1]. The term wavelength-division multiplexing is commonly applied to an optical carrier (which is typically described by its wavelength), whereas frequency-division multiplexing typically applies to a radio carrier (which is more often described by frequency). Since wavelength and frequency are tied together through a simple directly inverse relationship, the two terms actually describe the same concept [2**].**

Wavelength-division multiplexing (WDM) gives better utilization of the large bandwidth of optical fiber and can increase the capacity of the cable network. Through WDM, signals from two or more line systems are transmitted over the same fiber [3]. The signal from different sources which combined by a multiplexer and fed into an optical fiber, channels combined are separated in the receiver unit by a demultiplexer and detected by photodetector [3]. In WDM, each electrical data channel i is modulated onto its optical carrier wave with a wavelength λi. Therefore one subdivides the optical transmission band

Bopt~20 THz, resp. Δλopt~200nm, into N (~100-1000) bands (B=Bopt/N). To extract a particular channel at the receiver, the demultiplexer has to filter one particular channel at the desired wavelength λi by a narrow band optical filter (Δffilter ~B) and direct it to the photodetector [4]. The optical multiplexing operation of different data channels occurs in the frequency domain into non-overlapping frequency bands B (because N transmission wavelengths λ1 - λN exist which are unrelated in time) [4]. This technique can be implemented to not only design ultra high capacity optical communication systems, but also upgrade the existing systems. WDM takes advantage of the almost infant amount of the fiber bandwidth and the availability of fiber amplifiers in the 1530-1560 nm wavelength windows [3]. The WDM devices at the transmitting unit is essentially a power combining referred to as a multiplexer. The device at the receiver unit is called a demultiplexer and should ideally separate out various channels with negligible loss and signal distortion. a large number of channels can be combined and separated with angularly dispersive multiplexing elements. At the output of the multiplexer, these light rays become co-linear and can be easily launched simultaneously into an optical fiber. A WDM works in exactly the reverse fashion, directing light beams of various wavelengths from a fiber into their respective channels [3]. Multiplexers and demultiplexers can be divided into either passive or active in design. Passive designs are based on prisms, gratings or filters, while active designs id a combination of passive devices with tunable filters [1].The primary challenges in these devices is to minimize cross-talk and maximaze channel separation. Cross talk is a measure of how well the channels are separated, while channel separation refers to the ability to distinguish each wavelength.

DISPERSION AND COMPENSATION

The main goal in any communication system is to increase the transmission distance. Loss and dispersion are the main factor that cause signal degradations and affect fiber-optical communication being the high-capacity develops. The EDFA is the gigantic change happened in the fiber-optical communication system; the loss is no longer the major factor to restrict the fiber optical transmission. Since EDFA works in 1550 nm wave band, the average single mode fiber (SMF) dispersion value in that wave band is very big, about 15-20ps / (nm.km- 1) [8]. It is easy to see that the dispersion become the major factor that restricts long distance fiber-optical transfers as the bit rate increases [9, 10]. Dispersion causes the time slot and profile of an optical pulse to change in the course of propagation, causing intersymbol interference ISI and hence causes bit errors in reception. Dispersion is typically measured as a time spread per distance traveled (s/km). In single-mode fiber performance is primarily limited by chromatic dispersion (also called group velocity dispersion), which occurs because the index of the glass varies slightly depending on the wavelength of the light, and light from real optical transmitters necessarily has nonzero spectral width (due to modulation) [11, 12]. Polarization mode dispersion, another source of limitation, occurs because although the single-mode fiber can sustain only one transverse mode, it can carry this mode with two different polarizations, and slight imperfections or distortions in a fiber can alter the propagation velocities for the two polarizations. This phenomenon is called birefringence. Mode birefringence Bm is defmed as the follow Formula

$$B_m = \frac{\left|\beta_x - \beta_y\right|}{k_o} = n_x \vert - n_y$$

n_x, n_y are the effective refractive of the two orthogonal polarizations. For a given B_m, its fast axis and slow axis components will be formed the phase difference after the light waves transmission L Km. Degree of pulse broadening can be expressed by different group delay Δτ [10].

$$\Delta\tau = \left| \frac{L}{\upsilon_{gx}} - \frac{L}{\upsilon_{gy}} \right| = \frac{d}{d\omega}(\beta_x - \beta_y)L =$$

$$\left(\frac{n_x - n_y}{c} + \frac{\omega d(n_x - n)_y}{c\,d\omega} \right)L$$

Dispersion increased the pulse shape distortion caused by the self-phase modulation dispersion (SPM); the other hand, dispersion in WDM systems can also increase the cross-phase modulation, four-wave mixing (FWM) and other nonlinear effects[10, 13, 14]. several dispersion compensation technologies were proposed[10, 15]. Amongst the various techniques proposed in the literature, the ones that appear to hold immediate promise for dispersion compensation and management could be broadly classified as: dispersion compensating fibers (DCF), chirped fiber Bragg gratings (FBG), and high-order mode (HOM) fiber [16].

There is positive second-order and third-order dispersion value in SMF (single mode fiber), while the DCF dispersion value is negative. So, by inserting a DCF, the average dispersion is close to zero [17]. As the local dispersion of higher transmission link, FWM and XPM were ignored; only to consider the role of SPM and dispersion, the signal transmission can be simulate by solve the nonlinear Schrodinger equation.

SYSTEM SIMULATION

The work aimed to study the performance of an eight channel DWDM system including the use of single mode fiber SMF, EDFA and DCF. The proposed system is shown in Figure (2). This system uses only SMF and consists of eight channels to be multiplexed using DWDM system. In each there is a digital data generates by Pseudo Random Bit Sequence (PRBS) which will be modulated using MZM modulator with varies number of subcarrier which was in gigahertz. The center frequency range of laser is 194.1-194.8 THZ each with power of 0 dBm. The NRZ (Non-Return to Zero) format was used for signal coding and the modulation used was on-off keying (OOK). These eight signals were multiplexed by the optical multiplexer to be launched into a single SMF. The optical multiplexer has 20GHz channel bandwidth and 100GHz channel frequency spacing is used to reduce the crosstalk between adjacent channels. The system was designed so that to minimize noise from the adjacent channels. At the receiver side, these signals were separated by the demultiplexer and each signal passed to a receiver that consists of PIN pdotodiode, filter and a bit error rate BER analyzer.

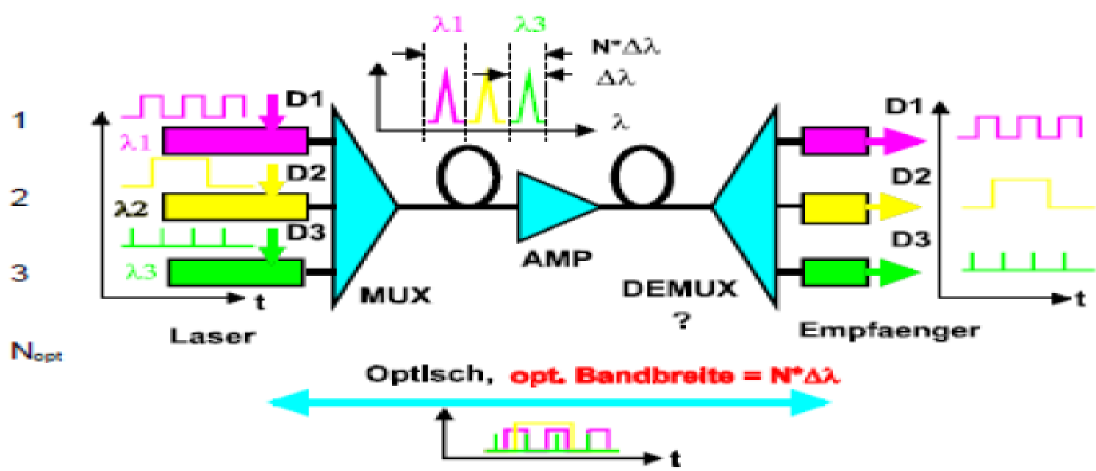


Figure 1: Basic Structure of WDM

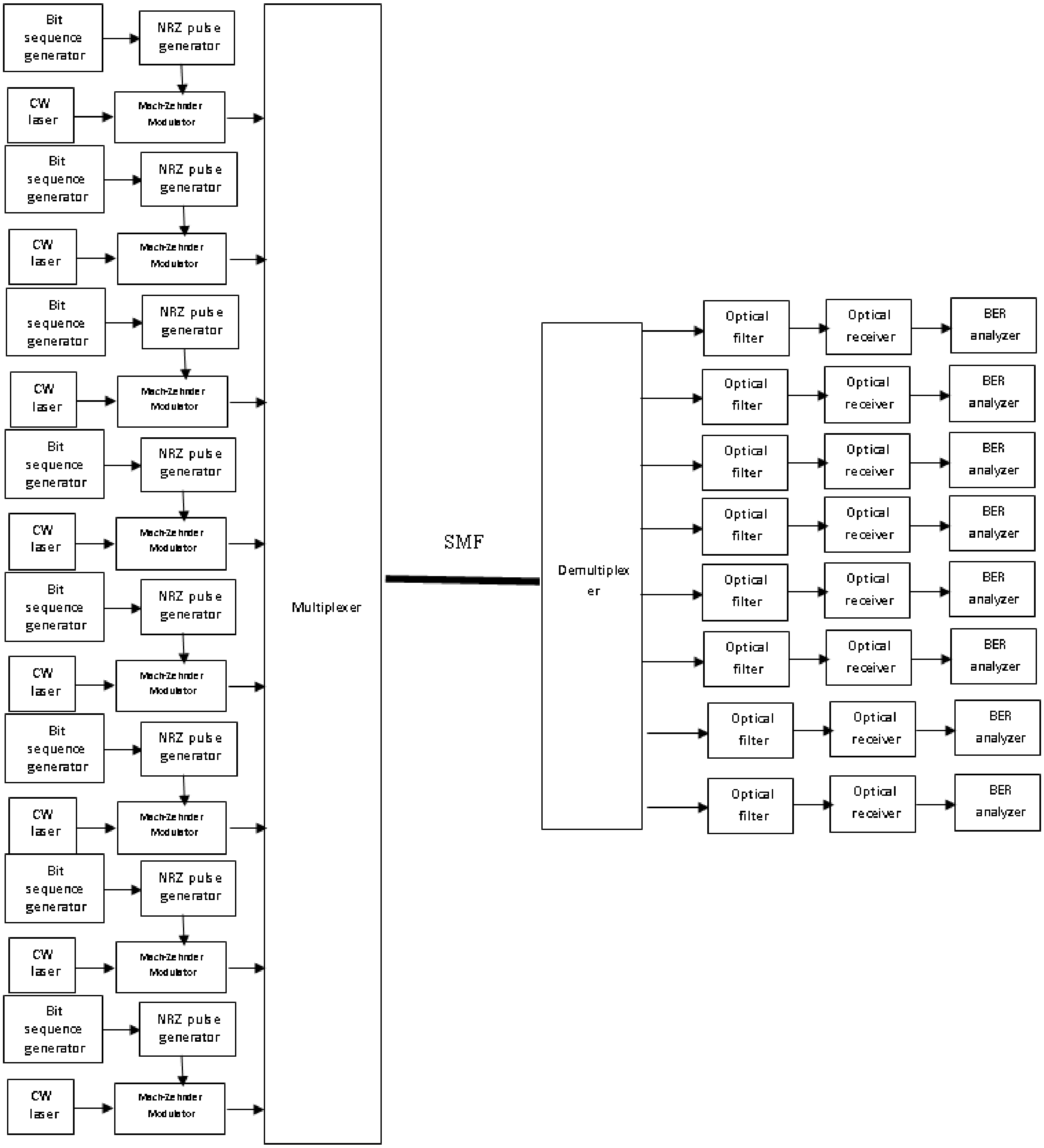
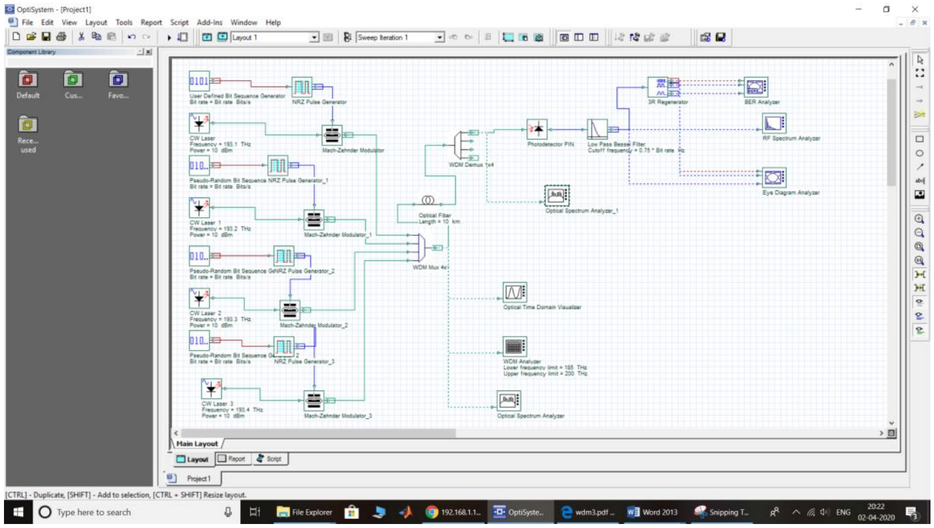


Figure 2: Block Diagram

EXPERIMENTAL RESULTS

The DCF is one technique used as a post compensation to reduce the effect of chromatic dispersion in the SMF and this even assists in increasing the operating bit rate and increased the length of the fiber communication link by reducing the inter symbol interference ISI. It improves the system performance greatly.



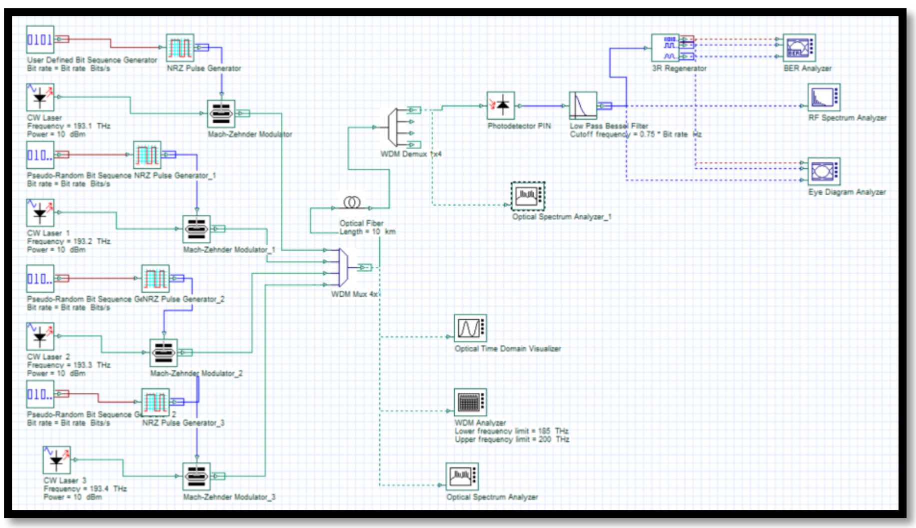
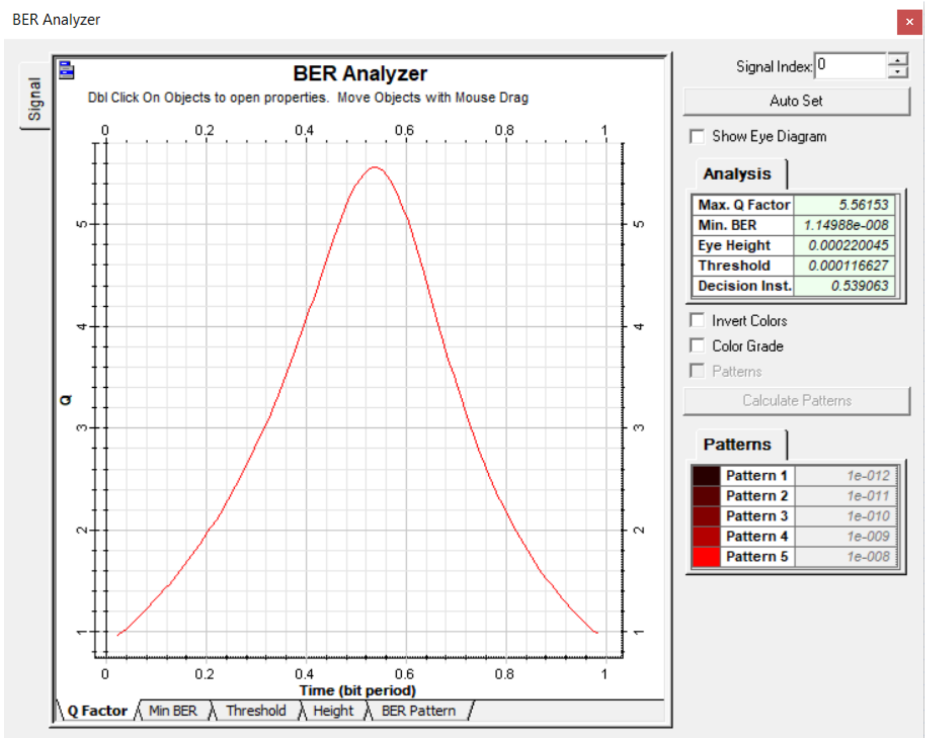
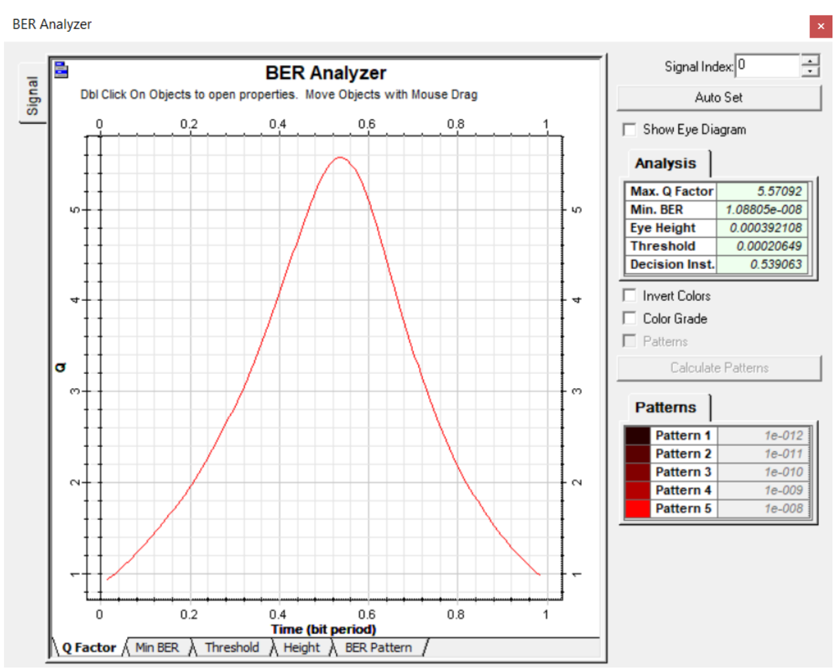


Figure 3:Transmitting power is changed from 0dBm to 10dBm


BER Analyzer
BER Analyzer
Dbl Click On Objects to open properties. Move Objects with Mouse Drag
Signal
Q
Time (bit period)
Q Factor
Min BER
Threshold
Height
BER Pattern
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 5.56153
Min. BER 1.14988e-008
Eye Height 0.000220045
Threshold 0.000116627
Decision Inst. 0.539063
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
Pattern 1 1e-012
Pattern 2 1e-011
Pattern 3 1e-010
Pattern 4 1e-009
Pattern 5 1e-008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BER Analyzer
Dbl Click On Objects to open properties. Move Objects with Mouse Drag
Signal
Q
Time (bit period)
Q Factor
Min BER
Threshold
Height
BER Pattern
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 5.57092
Min. BER 1.08805e-008
Eye Height 0.000392108
Threshold 0.00020649
Decision Inst. 0.539063
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
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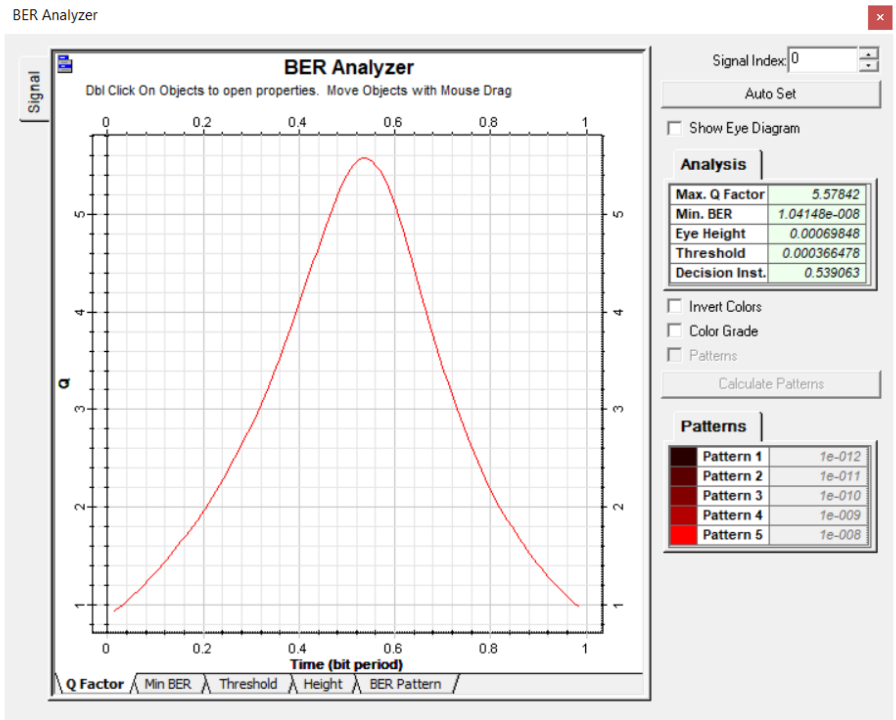
Pattern 2 1e-011
Pattern 3 1e-010
Pattern 4 1e-009
Pattern 5 1e-008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Signal
BER Analyzer
Dbl Click On Objects to open properties. Move Objects with Mouse Drag
Q
Time (bit period)
Q Factor
Min BER
Threshold
Height
BER Pattern
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 5.57842
Min. BER 1.04148e-008
Eye Height 0.00069848
Threshold 0.000366478
Decision Inst. 0.539063
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
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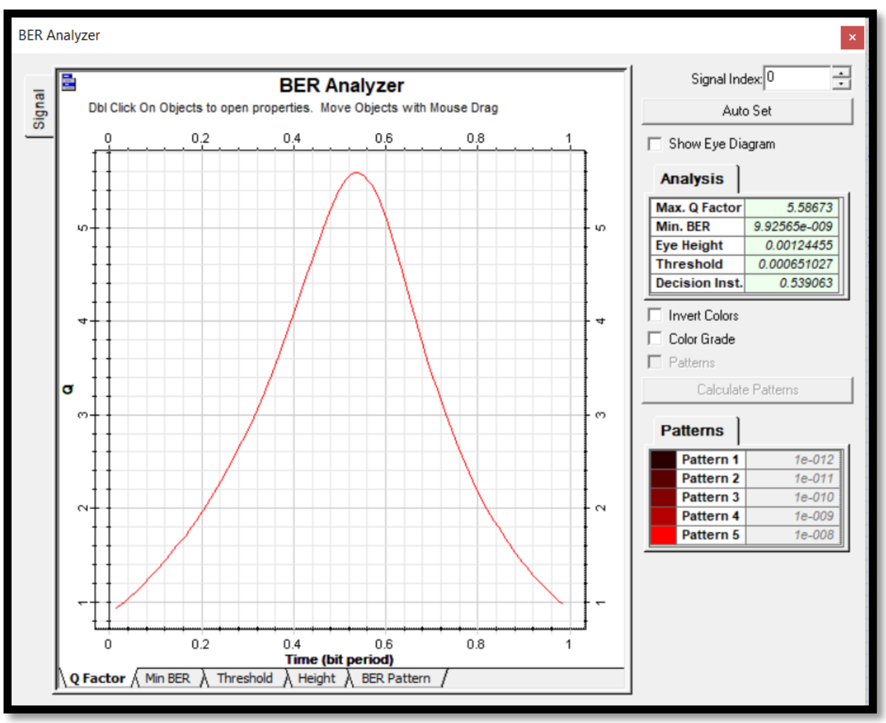
Pattern 2 1e-011
Pattern 3 1e-010
Pattern 4 1e-009
Pattern 5 1e-008


BER Analyzer
Signal
BER Analyzer
Dbl Click On Objects to open properties. Move Objects with Mouse Drag
Q
Time (bit period)
Q Factor
Min BER
Threshold
Height
BER Pattern
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 5.58673
Min. BER 9.92565e-009
Eye Height 0.00124455
Threshold 0.000651027
Decision Inst. 0.539063
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
Pattern 1 1e-012
Pattern 2 1e-011
Pattern 3 1e-010
Pattern 4 1e-009
Pattern 5 1e-008

c

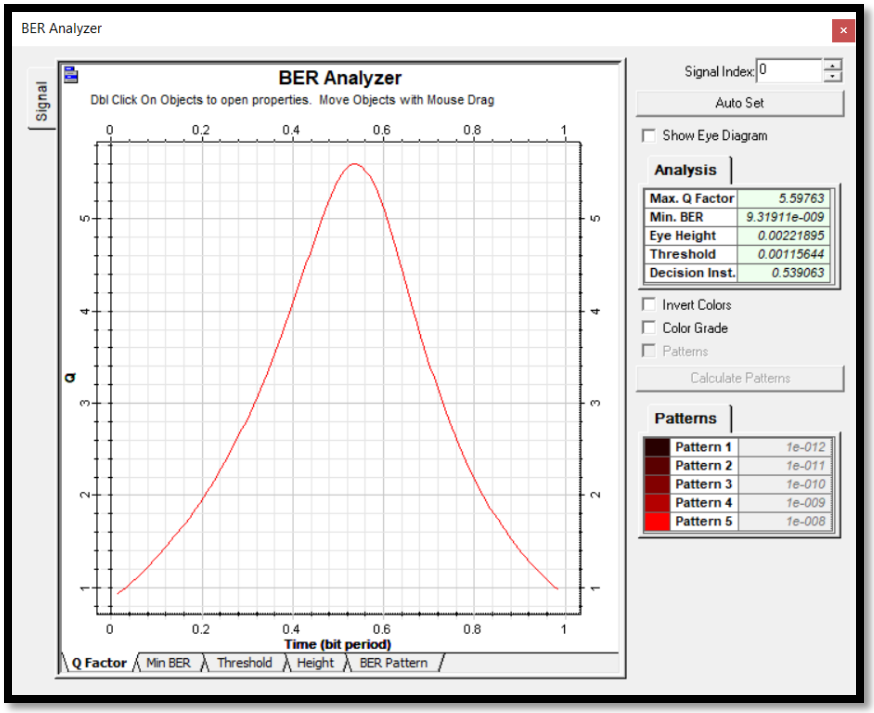
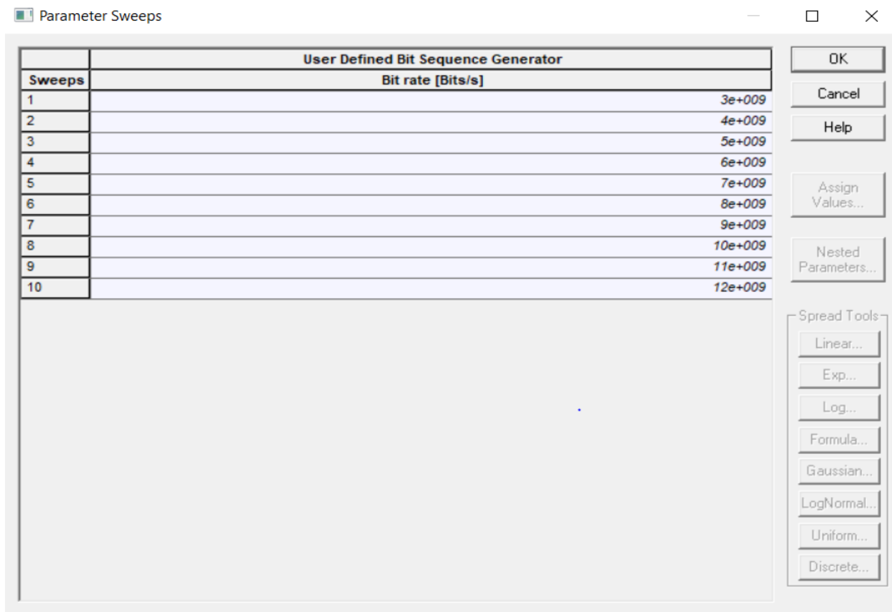
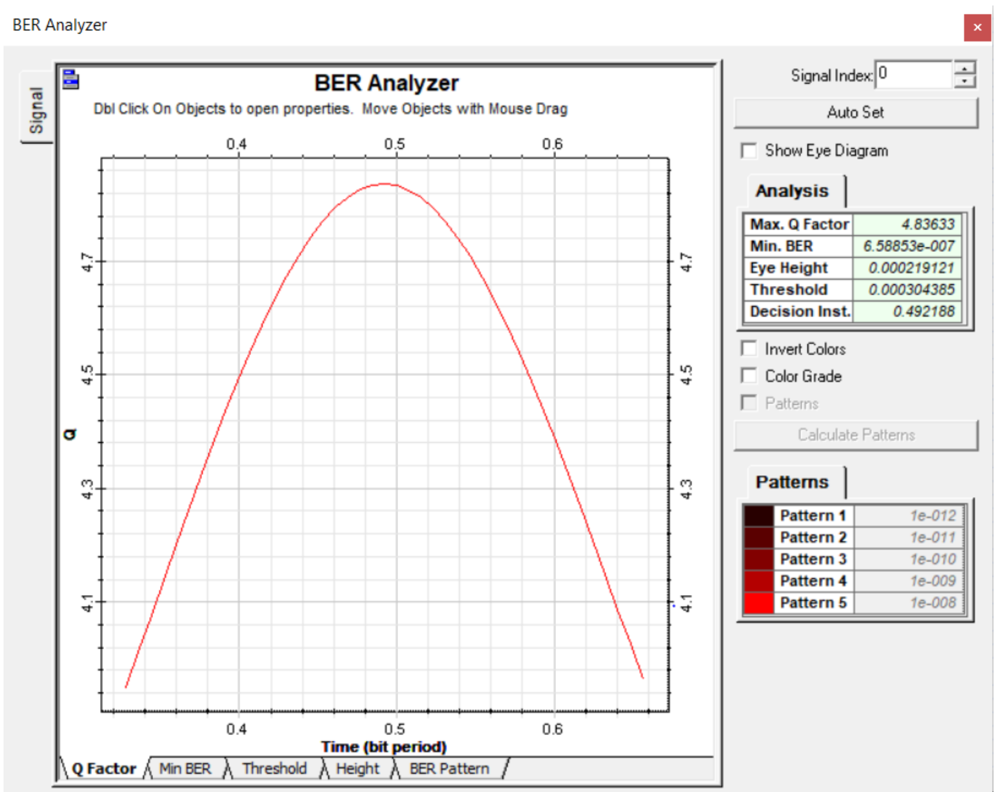


Table 1: It is clearly seen as Transmitting power increases, Q factor increases and BER reduces Bit Rate is changed

	CW Laser	BER Analyzer	
Iteration no	**Transmitter Power (dBm)**	**Max Q Factor**	**Min BER**
1	0	5.56153	1.1498*10^-8
2	2.5	5.57092	1.088*10^-8
3	5	5.57842	1.0414*10^-8
4	7.5	5.58673	9.925*10^-9
5	10	5.5976	9.998*10^-9


Parameter Sweeps
User Defined Bit Sequence Generator
Sweeps
Bit rate [Bits/s]
1 3e+009
2 4e+009
3 5e+009
4 6e+009
5 7e+009
6 8e+009
7 9e+009
8 10e+009
9 11e+009
10 12e+009
OK
Cancel
Help
Assign Values...
Nested Parameters...
Spread Tools
Linear...
Exp...
Log...
Formula...
Gaussian...
LogNormal...
Uniform...
Discrete...


BER Analyzer
Signal
BER Analyzer
Dbl Click On Objects to open properties. Move Objects with Mouse Drag
Q
Time (bit period)
Q Factor
Min BER
Threshold
Height
BER Pattern
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 4.83633
Min. BER 6.58853e-007
Eye Height 0.000219121
Threshold 0.000304385
Decision Inst. 0.492188
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
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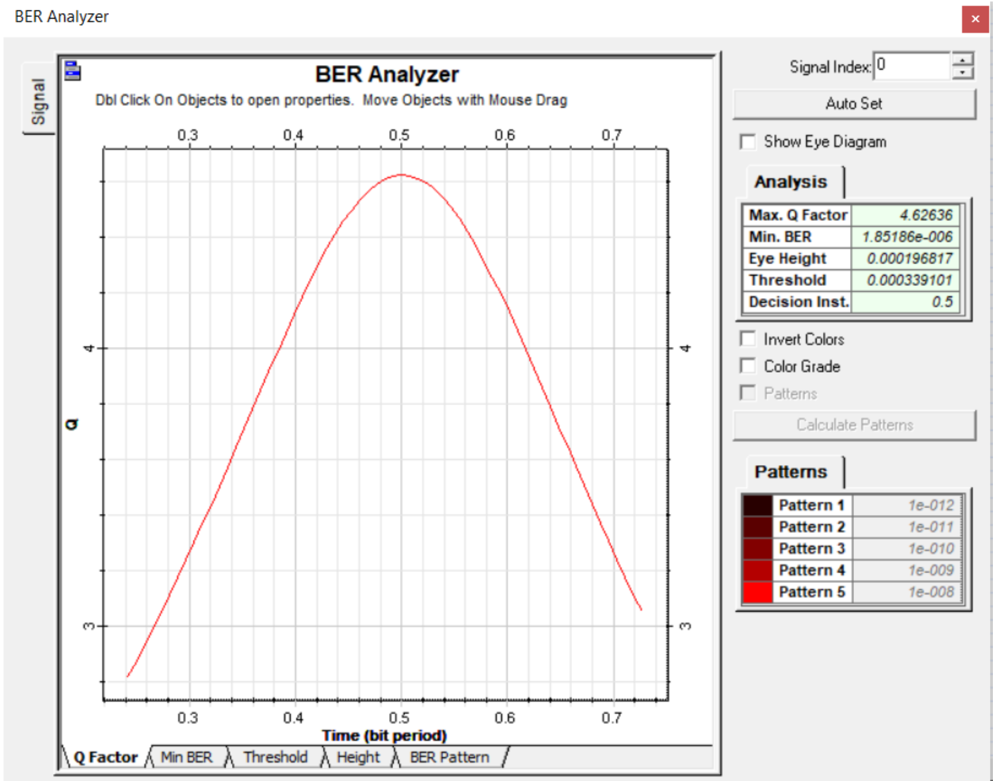
Pattern 2 1e-011
Pattern 3 1e-010
Pattern 4 1e-009
Pattern 5 1e-008


BER Analyzer
Signal
BER Analyzer
Dbl Click On Objects to open properties. Move Objects with Mouse Drag
Q
Time (bit period)
Q Factor
Min BER
Threshold
Height
BER Pattern
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 4.62636
Min. BER 1.85186e-006
Eye Height 0.000196817
Threshold 0.000339101
Decision Inst. 0.5
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
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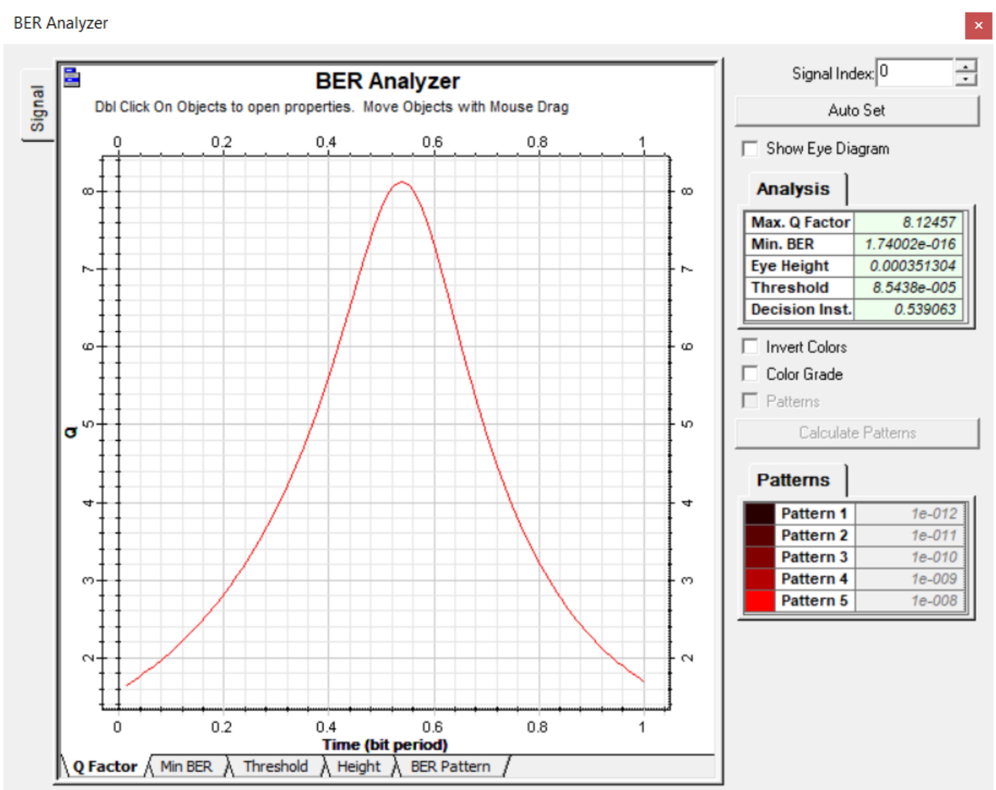
Pattern 2 1e-011
Pattern 3 1e-010
Pattern 4 1e-009
Pattern 5 1e-008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BER Analyzer
Dbl Click On Objects to open properties. Move Objects with Mouse Drag
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Time (bit period)
Q Factor
Min BER
Threshold
Height
BER Pattern
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 8.12457
Min. BER 1.74002e-016
Eye Height 0.000351304
Threshold 8.5438e-005
Decision Inst. 0.539063
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
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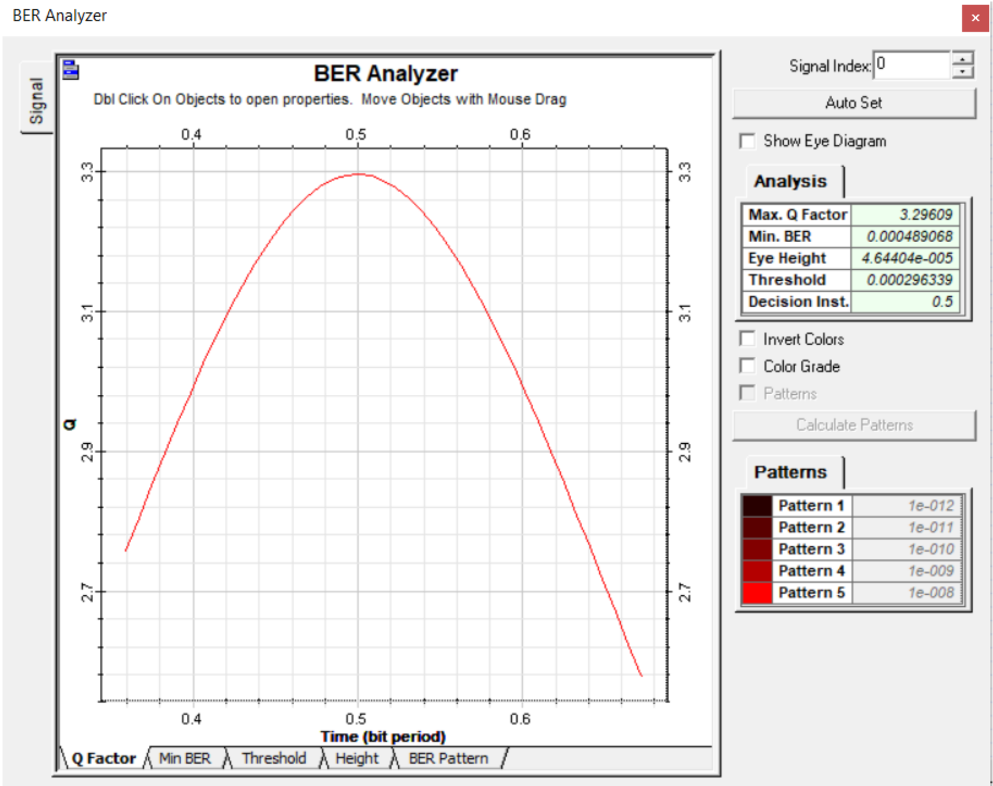
Pattern 2 1e-011
Pattern 3 1e-010
Pattern 4 1e-009
Pattern 5 1e-008


BER Analyzer
Signal
Dbl Click On Objects to open properties. Move Objects with Mouse Drag
Q
Time (bit period)
Q Factor
Min BER
Threshold
Height
BER Pattern
Signal Index:
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 3.29609
Min. BER 0.000489068
Eye Height 4.64404e-005
Threshold 0.000296339
Decision Inst. 0.5
Invert Colors
Color Grade
Patterns
Calculate Patterns
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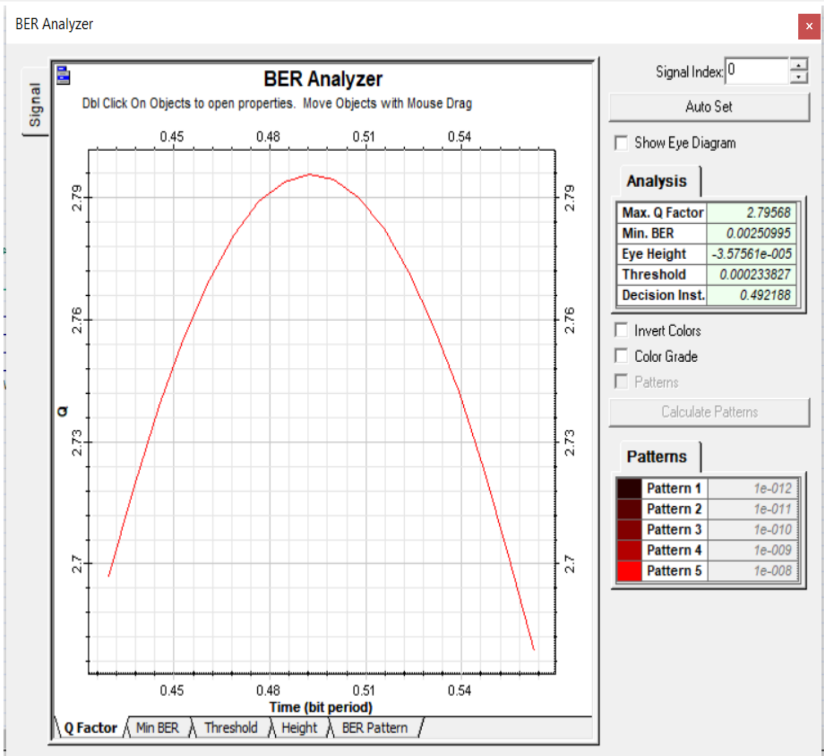
Pattern 2 1e-011
Pattern 3 1e-010
Pattern 4 1e-009
Pattern 5 1e-008


BER Analyzer
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Dbl Click On Objects to open properties. Move Objects with Mouse Drag
Q
Time (bit period)
Q Factor
Min BER
Threshold
Height
BER Pattern
Signal Index:
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 2.79568
Min. BER 0.00250995
Eye Height -3.57561e-005
Threshold 0.000233827
Decision Inst. 0.492188
Invert Colors
Color Grade
Patterns
Calculate Patterns
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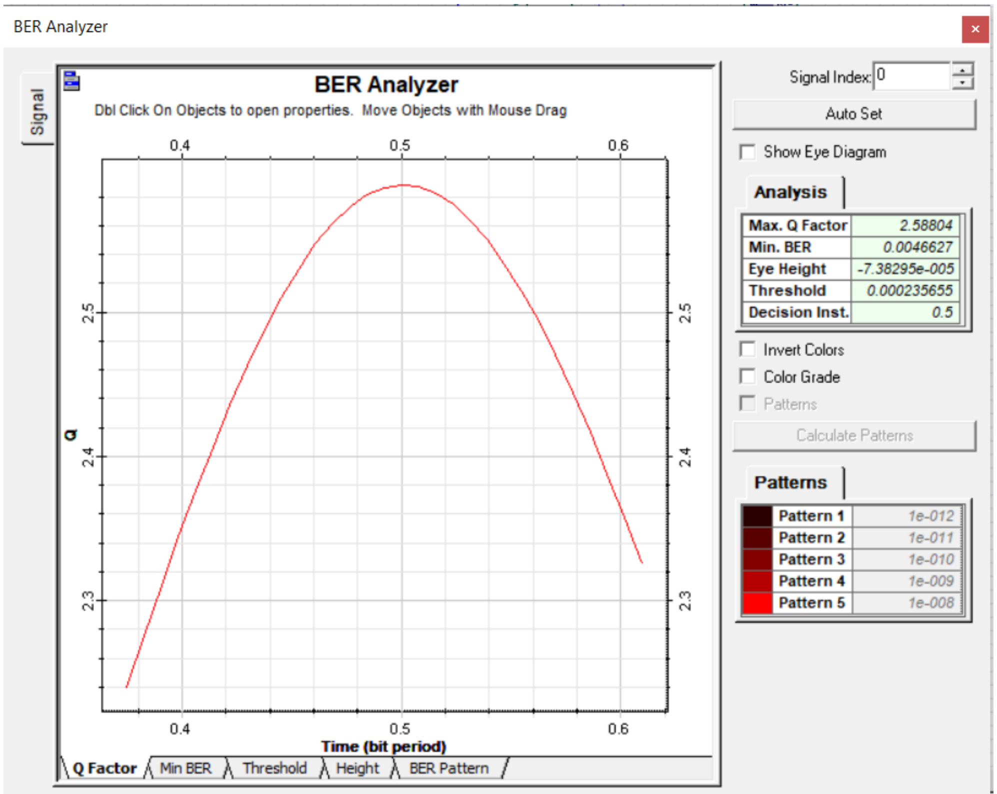
Pattern 2 1e-011
Pattern 3 1e-010
Pattern 4 1e-009
Pattern 5 1e-008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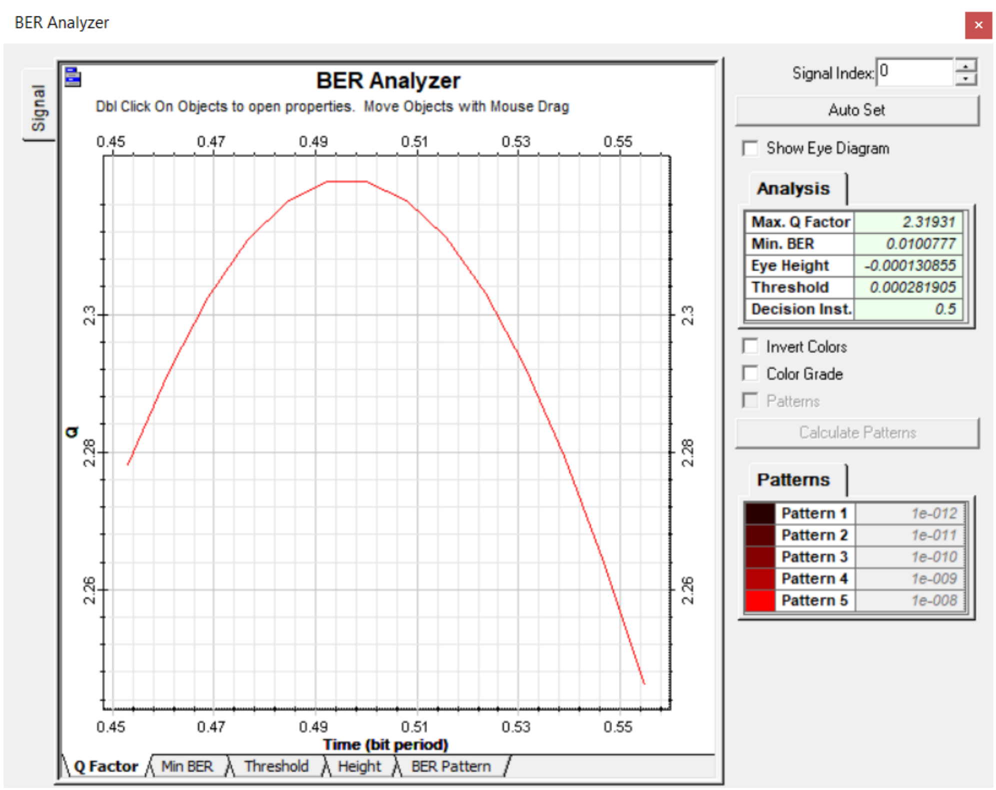
Signal
BER Analyzer
Dbl Click On Objects to open properties. Move Objects with Mouse Drag
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 2.58804
Min. BER 0.0046627
Eye Height -7.38295e-005
Threshold 0.000235655
Decision Inst. 0.5
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
Pattern 1 1e-012
Pattern 2 1e-011
Pattern 3 1e-010
Pattern 4 1e-009
Pattern 5 1e-008
Q
Time (bit period)
Q Factor
Min BER
Threshold
Height
BER Pattern


BER Analyzer
Signal
BER Analyzer
Dbl Click On Objects to open properties. Move Objects with Mouse Drag
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 2.31931
Min. BER 0.0100777
Eye Height -0.000130855
Threshold 0.000281905
Decision Inst. 0.5
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
Pattern 1 1e-012
Pattern 2 1e-011
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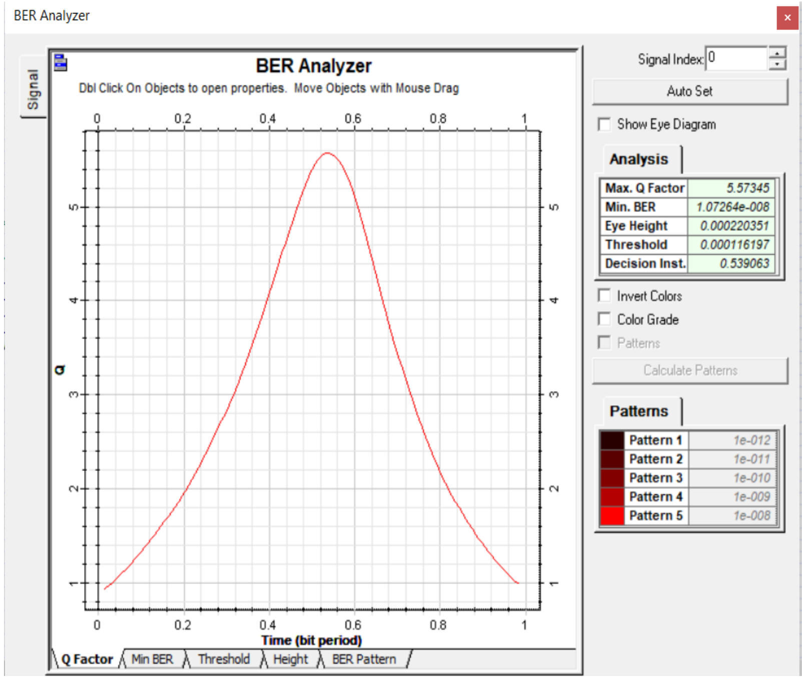
Pattern 5 1e-008
Q
Time (bit period)
Q Factor
Min BER
Threshold
Height
BER Pattern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BER Analyzer
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Auto Set
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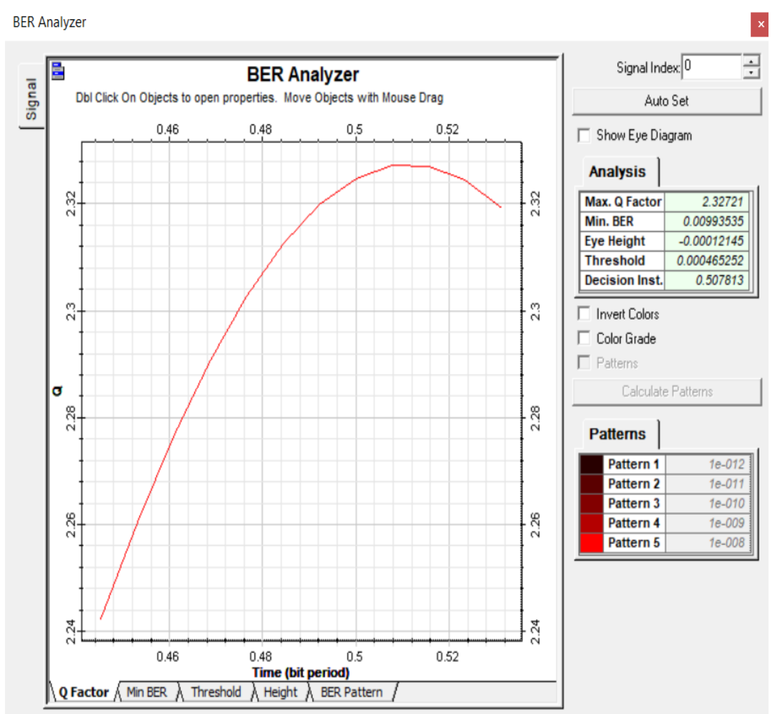
Eye Height 0.000220351
Threshold 0.000116197
Decision Inst. 0.539063
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
Pattern 1 1e-012
Pattern 2 1e-011
Pattern 3 1e-010
Pattern 4 1e-009
Pattern 5 1e-008
Time (bit period)
Q Factor
Min BER
Threshold
Height
BER Pattern


BER Analyzer
BER Analyzer
Dbl Click On Objects to open properties. Move Objects with Mouse Drag
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
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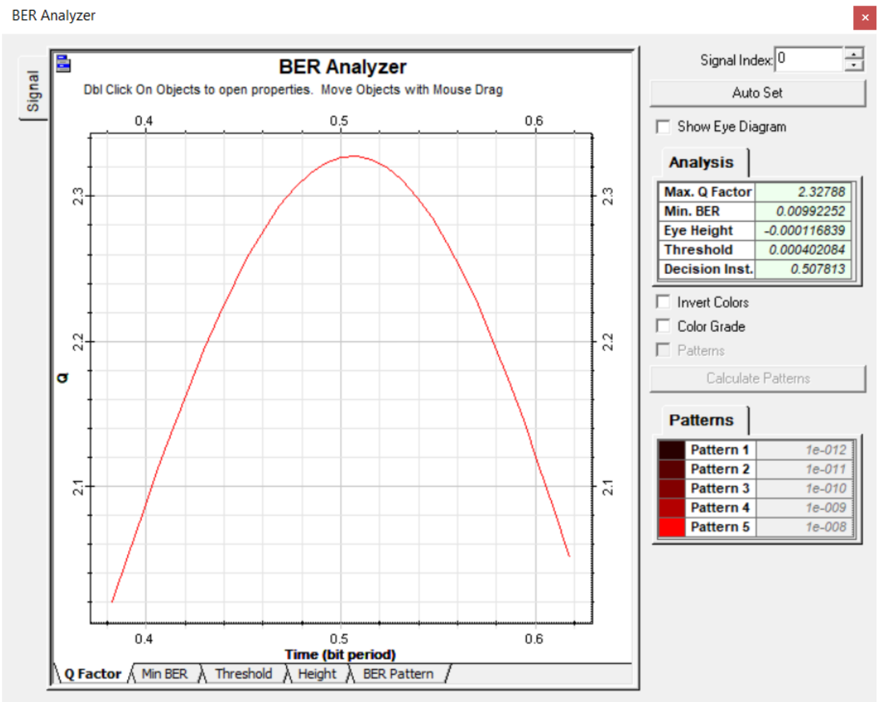
Min. BER 0.00993535
Eye Height -0.00012145
Threshold 0.000465252
Decision Inst. 0.507813
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
Pattern 1 1e-012
Pattern 2 1e-011
Pattern 3 1e-010
Pattern 4 1e-009
Pattern 5 1e-008
Time (bit period)
Q Factor
Min BER
Threshold
Height
BER Pattern



Many interesting things are observed from the graphs. As bit rate is increased, initially Q factor decreases and BER increases. The Q factor increases slightly but the best and most appropriate Q factor and BER is achieved at the bit rate of 10*10^9 bits/second.

	Bit Generator	**BER Analyzer**	
Iteration no	**Bit Rate (10^9)**	**Max Q Factor**	**Min BER**
1	3	4.8363	6.588*10^-7
2	4	4.626	1.851*10^-6
3	5	6.1245	1.740*10^-6
4	6	3.296	0.000489
5	7	2.7958	0.002509
6	8	2.58804	0.0046627
7	9	2.31931	0.0100777
8	10	5.57345	1.0726*10^-8
9	11	2.32721	0.00993535
10	12	2.32788	0.00992252

CONCLUSION

Based on the results work the transmitter side of the optical communication system and it is found that with increase in transmitting power of the CW Laser, Q factor increases but BER decreases. Also it is seen that as bit rate of the bit generator is creased, Q factor and BER show a random change and the beat and most appropriate results for Q factor and BER is achieved at 10*10^9 bits/second and this is the reason this bit rate is widely used in WDM networks.

FUTURE WORKS

1. Instead of calculating one path from source to destination, several alternate paths may be calculated.
2. Advance analytical models may be employed for probabilistic analysis.
3. For architectural design PM-QPSK model may be considered for achieving high speed.
4. Advanced signal processing techniques may be employed for decision-circuit implementation.

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