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Analysis and Comparison of Apodized Fiber Bragg Grating and Uniform Fiber Bragg Grating in Optical Communication System

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Abstract – This paper presents the performance analysis of incorporating apodized Fiber Bragg Grating in optical communication system. Different apodized grating offers significant improvement in side lobe suppression while maintaining Reflectivity and narrow Bandwidth and these have been implemented and investigated. The variable file of FBG performance is visualized for the distinctive apodized capacity, including utilization in the NRZ beat generator. The framework throughout the optical fiber mode channel is simulated using Optisystem 12.0. Results show an appropriate correlation for the Gain, Noise Figure, Eye diagram and Q-Factor.

Index Terms – Optical Communication, FBG, Optisystem12.0, Q-factor, Apodized FBG.

1. INTRODUCTION

Optical communication is a way of propagating the information from transmitter to receiver with the help of light source and optical fiber as a medium. There are three main elements of optical communication system, light source as a transmitter side (convert electrical mode signal information in the optical mode), transmission medium (optical fiber) and light detector at receiver side (convert optical signal to electrical signal).FBG is an important element in optical fiber communication working as dispersion compensator, gain flattener and filter so, as to improve higher compression ratio. Optisystem simulator is innovative, advanced, easy, powerful design tool to simulate, test and evaluate broad area of spectrum almost in any type of optical communication system for LAN (local area network) and MAN (metropolitan area network) and is used in Fiber Optics modeling for an optical communication system, incorporating a library of various optical components.

In the past decades our lives have totally changed with the utilization of the fiber optics based systems because of the salient properties of its immunity to various natural as well as manmade interferences, better tolerance to have environments thus brought-up novel system in the field of optical fiber communication. In the uses of fiber optic, the specific developments in the channel are contrasted without change in the electrical properties. One of advance novel technique is the apodization of optical fiber core which make its utility in enhance performance of optical fiber based communication system as well as various type of sensors. The execution of FBG based sensor in the current and old studies contain many missing to influence a grouping of setup apodization. This paper introduces wide investigation and utilizing in apodization profile such as uniform, Gaussian and Tanh execution of FBG to build tried parameters to achieve enhance performance of various optical fiber systems showing better range, eye diagram etc.

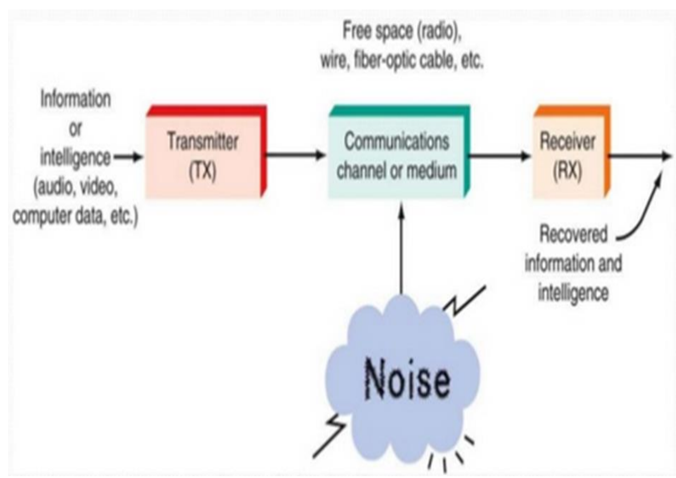


Figure 1: Block Diagram of Optical Communication System

2. FBG STRUCTURE

A fiber Bragg grating (FBG) is a type of distributed Bragg reflector constructed in a short segment of optical fiber that reflects particular wavelengths of light and transmitting all others. This is achieved by creating a periodic variation in the refractive index of the fiber core, which generates a wavelength-specific dielectric mirror.

A fiber Bragg grating can therefore be used as an inline optical filter to block certain wavelengths, or as a wavelength-specific reflector. FBG can also function as a simple and cost effective filter for selective wavelength which is essential for low cost and high efficient optical network. FBG has the quality of filtering and reflecting as well as highly efficient and low noises.

Furthermore, high wavelength selectivity with FBG technology will enhance the system performance. In optical fiber systems, the fiber Bragg grating could be considered as a small section, resulting in a specific wavelength reflection of light. In optic fiber, the mirror process in FBG divides the light center in optical fiber onto Bragg wavelength depending on two factors, the fiber grating length and refractive record.

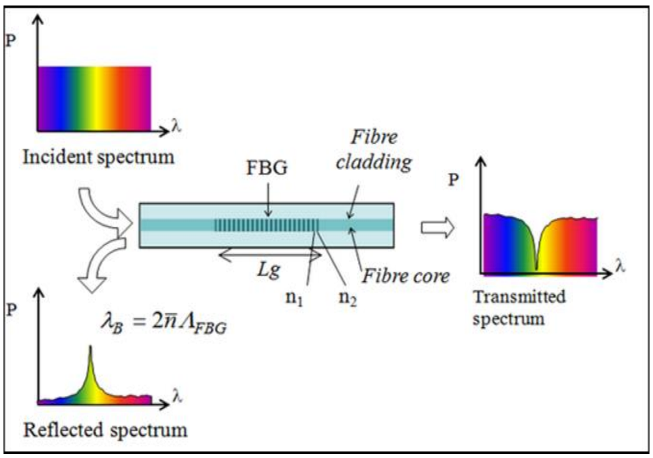
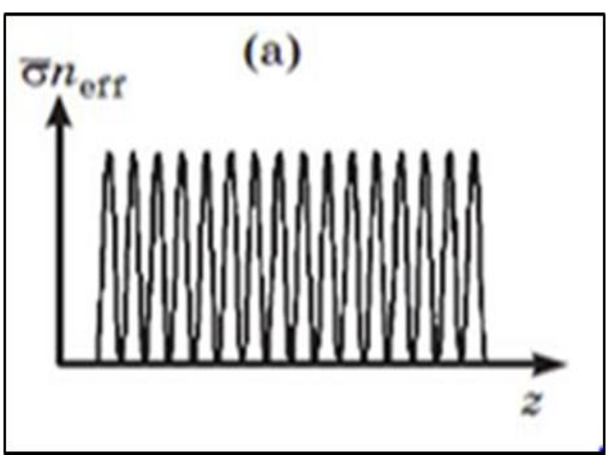
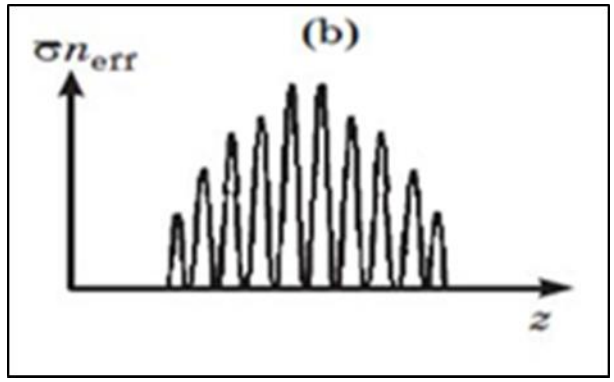


Figure 2: Fundamental of Bragg's light structure.

2.1 FBG Apodization

The term apodization refer to the grading of the refractive index to approach zero at end of grating. It offer significant improvement in side-lobe suppression while maintaining the reflectivity as well as bandwidth. Figure 3 explains the profile of apodization in FBG techniques mathematically, the apodization profile could represented by the following formula as uniform, Gaussian and tangent change as in.





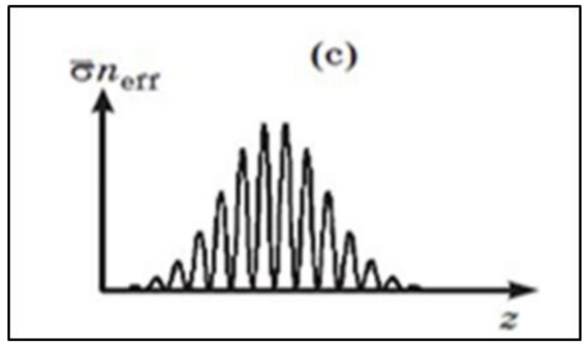


Figure 3: The apodization profile Refractive index

The non apodize mode is formulated as f (z)=1 . The hyperbolic tangent model is formed as

A. Uniform (no apodization):

$$f(z) = \text{Constant}$$

B. Hyperbolic Tangent:

$$f(z) = \tanh\left(\frac{S.Z}{L}\right).\tanh\left[S.\left[1-\frac{Z}{L}\right]\right] + 1 - \tanh^2\left(\frac{S}{2}\right)$$

C. Gaussian:

$$f(z) = \exp.\left\{(-4\log 2).\left(\frac{\left(\frac{Z-L}{2}\right)}{S.L}\right)^2\right\}$$

Where

L: Length of the grating.

Z: direction of the light generation over the length for Fiber Bragg Grating.

S: called decrease measurable factor utilized in the exact setting of reflection range.

3. EXPERIMENTAL OBSERVATION

The transmitter, channel and receiver of optical framework has been designed and simulated using Optisystem 12.0. The length of 30 km SMF has been utilized in Transmitter channel with attenuation coefficient of 0.2 dB/km and photodetector in receiver path. The constant wave laser is the transmitter and the Mach-Zehnder modulator is used to modulate constant wave laser signal as data transmission signals. The wavelength of 1550nm is used as a laser constant signal with 0 dBm power balanced at 10Gbps in the proposed Mach-Zehnder modulation technique. The refraction index variation from 1.45 to 1.8, OFC length variation from 10 km to50 km and FBG length variation from 1mm to 5mm is used in Uniform, Gaussian and Tanh profiles. Additionally, EDFA is utilized with variable flag enhancement values. The EDFA utilization in the in the PIN photograph locator is spread throughout it. Through Bessel optical channel, the enhanced sign is gone due to several specifications in data transfer of 40GHz with a bearer wavelength of 1550nm in the suggested model as illustrated in Figure 4. The investigation outcome of the suggested techniques are shown in Table 1,Table 2, Table3,Table 4, Table 5, Table 6, Table 7, Table 8 and Table 9. The apodization capacities in FBG optical fiber group framework using optisystem12 shows correlation in examining parameters.

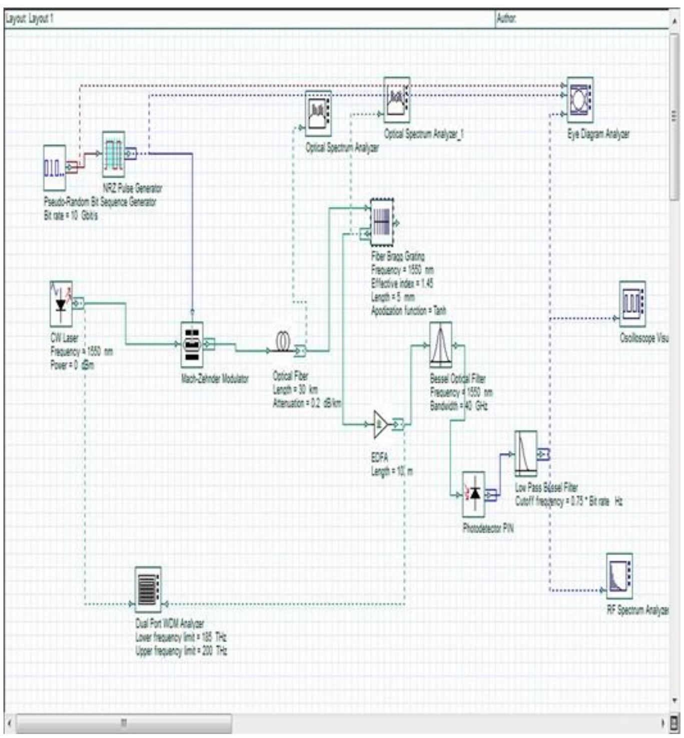


Figure 4: Proposed transceiver model

4. RESULTS AND DISCUSSION

During this work, examining the parametric usage and correlation of the distinctive apodization capacities of the FBG group in single mode optical fiber transmission framework is accomplished by optisystem-12.0. The outcome of the investigation, reproduction of the various refractive index list, OFC length list and FBG length list utilizing different FBG apodization capacities for a solitary transmission divert so as to clarify from Table 1, Table 2, Table 3 Table 4, Table 5, Table 6, Table 7, Table 8 and Table 9.

Table 1: Uniform format of FBG with different Refractive index

Refractive Index	Gain (dB)	Noise Figure(dB)	Q-Factor
1.45	16.412	14.630	25.76
1.5	16.417	14.631	26.92
1.6	16.419	14.641	31.46
1.7	16.419	14.641	35.15
1.8	16.421	14.643	39.90

Table 2: Gaussian format of FBG with different Refractive index.

Refractive Index	Gain (dB)	Noise Figure(dB)	Q-Factor
1.45	15.383	18.958	22.34
1.5	15.405	18.988	24.64
1.6	15.415	19.101	25.50
1.7	15.415	19.102	26.02
1.8	15.416	19.102	28.76

Table 3: Tanh format of FBG with different Refractive index.

Refractive Index	Gain (dB)	Noise Figure(dB)	Q-Factor
1.45	16.392	14.736	27.00
1.5	16.393	14.804	27.11
1.6	16.393	14.805	29.91
1.7	16.394	14.873	34.83
1.8	16.416	14.874	38.34

Table 4: Uniform format of FBG with different OFC lengths.

OFC Length (km)	Gain (dB)	Noise Figure (dB)	Q-Factor

10	16.911	10.550	129.75
20	16.810	12.571	49.33
30	16.410	14.633	25.20
40	15.966	16.818	20.68
50	15.377	18.975	17.62

Table 5: Gaussian format of FBG with different OFC lengths.

OFC Length (km)	Gain (dB)	Noise Figure (dB)	Q-Factor
10	16.413	14.618	101.41
20	15.970	16.801	338.49
30	15.383	18.956	21.53
40	14.658	21.063	18.41
50	13.719	23.316	16.11

Table 6: Tanh format of FBG with different OFC lengths.

OFC Length (km)	Gain (dB)	Noise Figure (dB)	Q-Factor
10	16.907	10.655	127.36
20	16.707	12.601	44.87
30	16.392	14.736	24.94
40	15.924	16.993	20.65
50	15.345	19.079	16.01

Table 7: Uniform format of FBG with different FBG lengths.

FBG Length (mm)	Gain (dB)	Noise Figure (dB)	Q-Factor
1	11.747	27.166	15.13
2	14.652	21.079	16.41
3	15.729	17.756	19.89
4	16.190	15.802	22.06
5	16.410	14.632	27.42

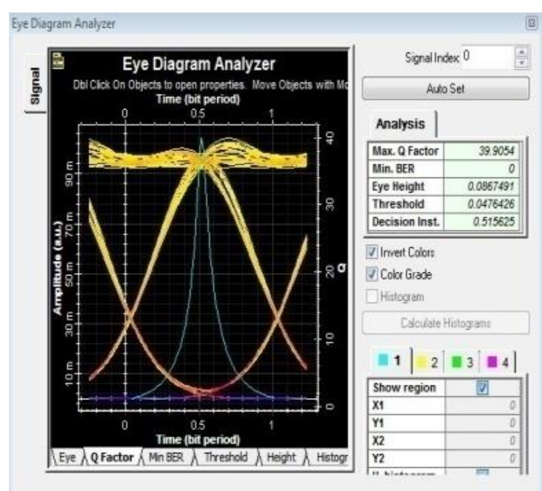
Table 8: Gaussian format of FBG with different FBG lengths.

FBG Length (mm)	Gain (dB)	Noise Figure (dB)	Q-Factor
1	7.801	33.130	11.97
2	11.931	26.840	15.07
3	13.705	23.347	17.18
4	14.817	20.637	18.98
5	15.405	18.886	22.36

Table 9: Tanh format of FBG with different FBG lengths

FBG Length (mm)	Gain (dB)	Noise Figure (dB)	Q-Factor
1	11.600	27.421	14.10
2	14.585	21.254	16.86
3	15.707	17.839	19.02
4	16.178	15.861	22.58
5	16.404	14.668	25.78

The eye diagram of optical channel with 30 km length and 5 mm FBG , optical channel with 1.45 refractive index and 5mm FBG and optical channel with 30 km length and 1.45 refractive index is illustrated in Figure 5 , Figure 6 , Figure 7 which represent the Uniform, Gaussian and Tanh technique respectively.



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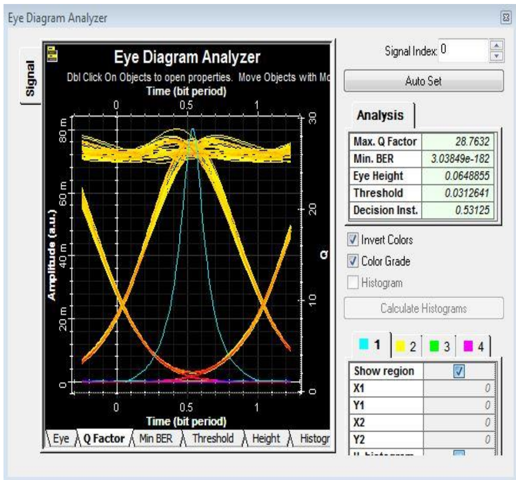

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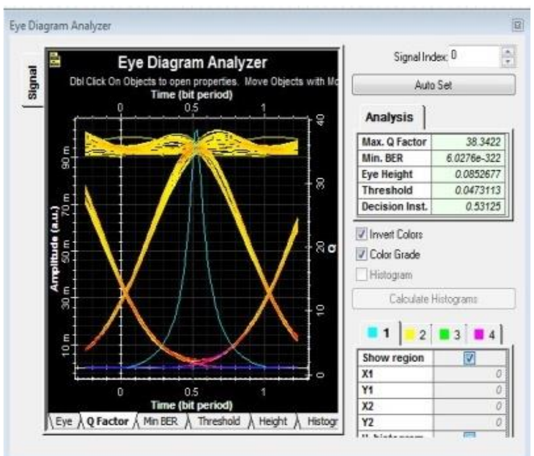

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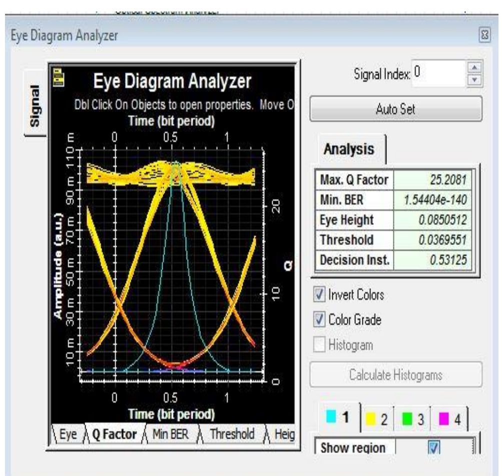
Figure 5: Uniform, Gaussian and Tanh eye diagram.



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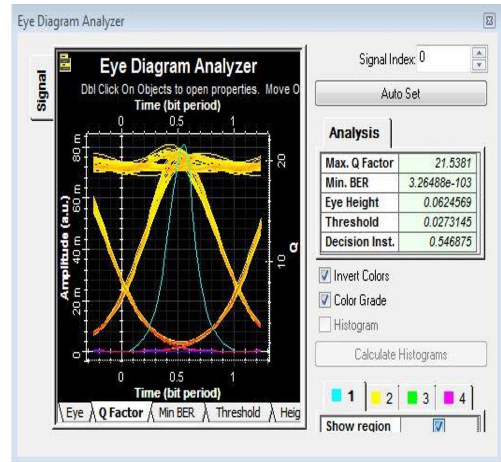

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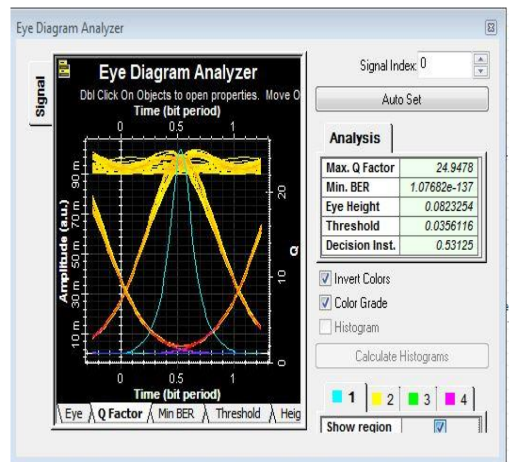

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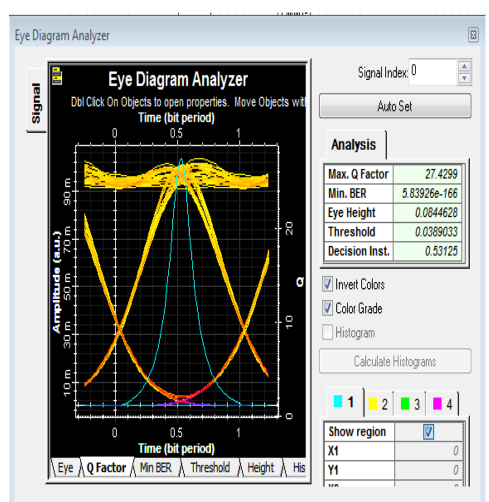
Figure 6: Uniform, Gaussian and Tanh eye diagram.



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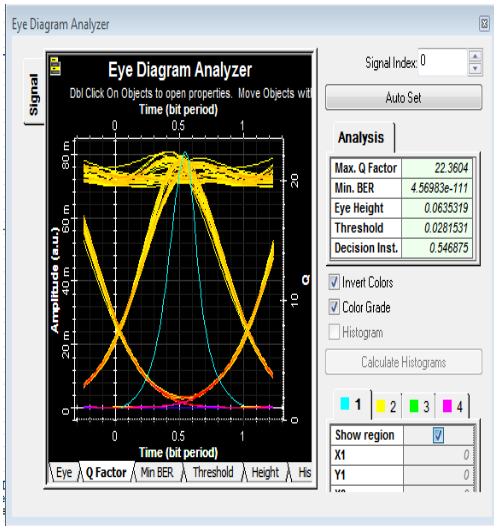

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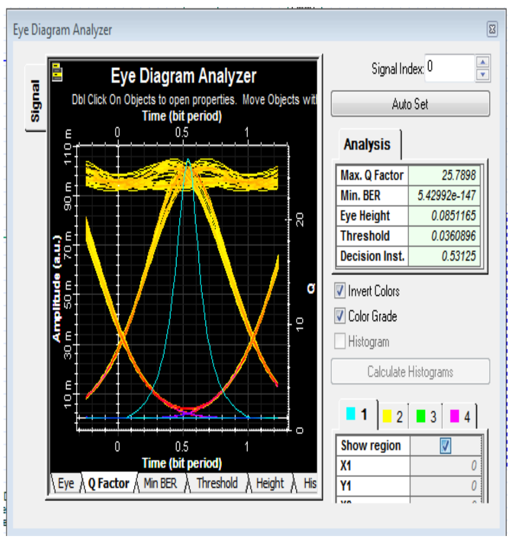

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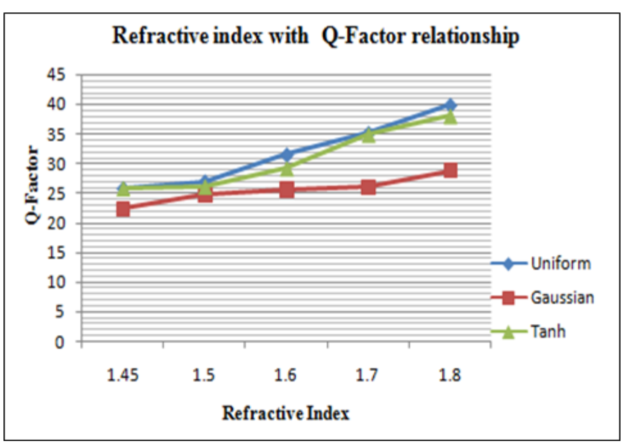
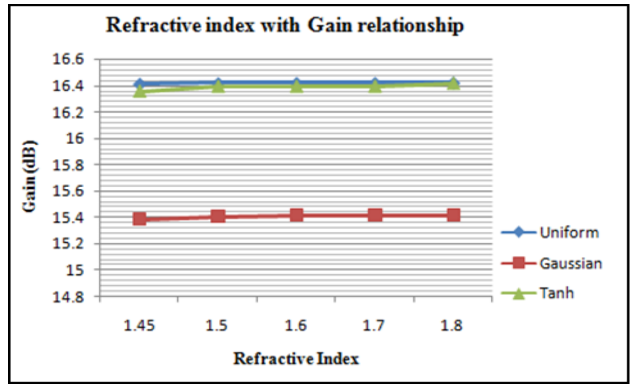
Figure 7: Uniform, Gaussian and Tanh eye diagram.





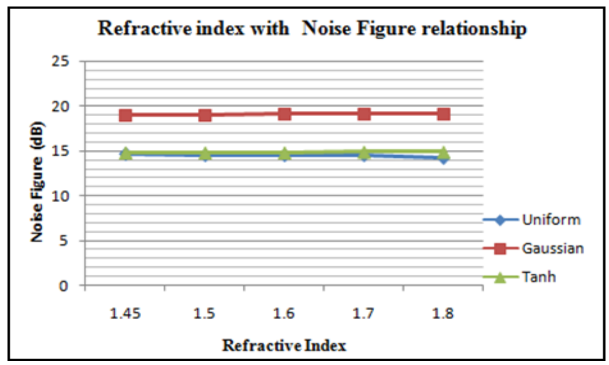
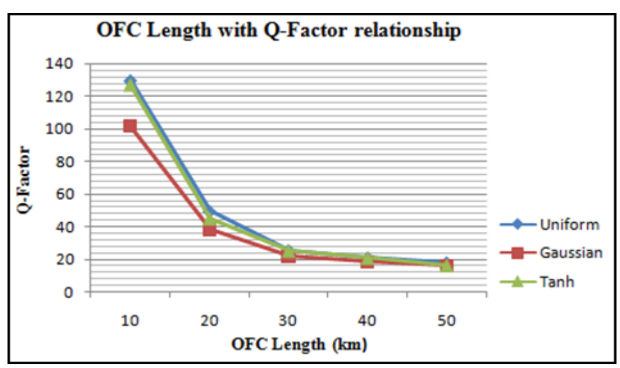
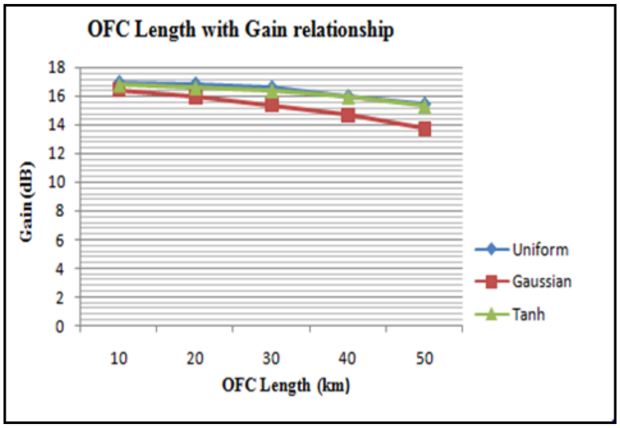


Figure 8

The relationship among refractive index list, OFC length list and FBG length list with specified parameters for various apodization FBG profiles of Uniform, Gaussian and Tanh profile is illustrated in Figure 8, Figure 9, Figure10.

Figure 8 shows the variation of Refractive index with Gain, Noise Figure and Q-Factor. On varying the Refractive index steps from 1.45 to 1.8 it is observed that at1.45 with FBG length 5mm, OFC length 30km, then the parameters calculated for an apodized Uniform profile the parameters like Gain=16.421dB, Noise Figure=14.643dB, Q-Factor=39.90; while with Gaussian apodization these parameters are having the values Gain=15.416dB, Noise Figure=19.102dB, Q-Factor=28.76, and with Tanh apodization Gain=16.416dB, Noise Figure=14.874dB, Q-Factor=38.34.





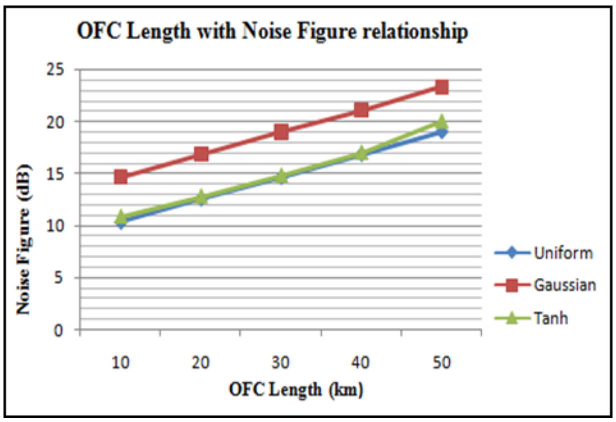
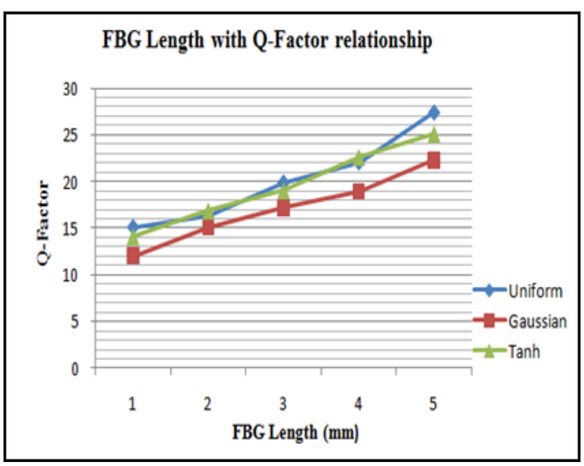
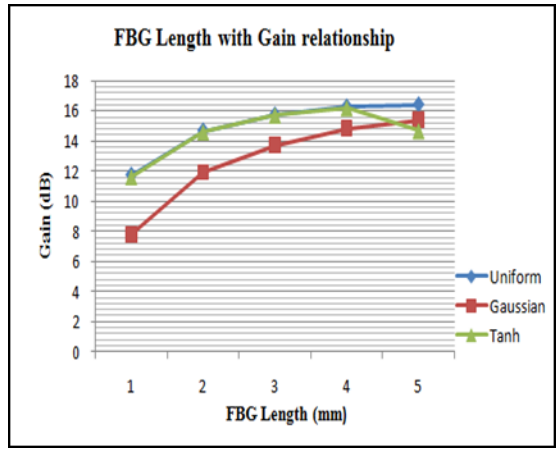


Figure 9 shows the variation of OFC length with Gain, Noise Figure and Q-Factor. On varying the OFC length from 10 to 50km it is observed that at 30km with FBG length 5mm, Refractive index 1.45, the parameters calculated for an apodized Uniform profile the parameters like Gain=16.410dB, Noise Figure=14.633dB, Q-Factor=25.20; while with Gaussian apodization these parameters are having the values Gain=15.383dB, Noise Figure=18.956dB, Q-Factor=21.53, and with Tanh apodization Gain=16.392dB, Noise Figure=14.736dB, Q-Factor=24.94.





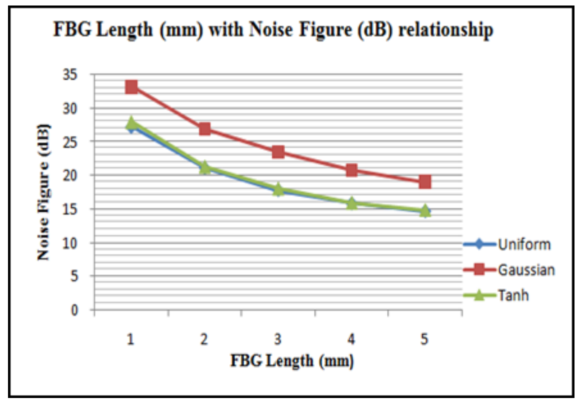


Figure: 10

Figure 10 shows the variation of FBG length with Gain, Noise Figure and Q-Factor. On varying the FBG length from 1 to 5mm it is observed that at 5mm with OFC length 30km, Refractive index 1.45, then the parameters calculated for an apodized Uniform profile the parameters like Gain=16.410dB, Noise Figure=14.632dB, Q-Factor=27.42; while with Gaussian apodization these parameters are having the values Gain=15.405dB, Noise Figure=18.886dB, Q-Factor=22.36, and with Tanh apodization Gain=16.404dB, Noise Figure=14.668dB, Q-Factor=25.78.

So by the results we have obtained, it is observed that the Uniform profile gives best results and have low Noise Figure with higher Gain and Quality Factor.

5. CONCLUSION

On the basis of the observed results while comparing and analyzing various apodization profiles in optical communication systems, it is revealed that the apodized FBG technique provide enhanced system performance incorporating an expanding refractive index, OFC length and apodized FBG length considering the parameters like Gain, Noise Figure, and Q-Factor. With the variation in Refractive index, OFC length, apodized FBG length, a comparison was made among Uniform, Gaussian and Tanh apodization with respect to Q-Factor, Gain and Noise Figure it was found with the corresponding Graph, that the Uniform profile gives better result among the three with low Noise Figure, high Gain & Q-Factor.

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