Design and Analysis for a Five Regions Fiber Bragg Grating (FBG) using OptiGrating Simulation Software

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Abstract- This simulation was performed in this paper with version OptiGrating 4.2.OptiGrating is used to theoretically design the FBG under the influence of Five Bragg regions. A uniform Bragg Fiber (FBG) with Period (Linear chrip) and (Gaussian) Apodizatio with also Fiber Bragg Grating (FBG) (regularly having two grating regions) with Period (Linear chrip) and (Gaussian) Apodizatio was used to accomplish this work; where (1, 2,3,4 and 5) are notch areas that were used to study their performance. Where we used the length of grating is equal 10 mm. The FBG's transmitted and reflected spectrum was measured by the OptiGrating system and the bandwidth of the reflected spectrum was determined (0.48 - 0.5) nm, which increases with the increase in the number of grating regions, and these values are very good because the maximum value within the narrowband field is 1nm. Different spectrum types for the transmitted and reflected ray, namely: spectrum power, spectrum delay, spectrum duration, and spectrum dispersion, as well as having a grating index profile shift with grating length at different number of regions. The transmitted and reflected FBG spectrum was analyzed and measured for the different regions. They also measured the bandwidth and efficiency of these spectra. We note that the transmitted spectrum values decrease with the increase in the number of slit regions within the cable, while the reflected spectrum values increase with the increase in the number in slitting regions.

Keywords – principle of FBG, Reflectivity and tramsmission spectrum in FBG, periodic in FBG, Single mode fiber, Software Waveguide Grating.

I. INTRODUCTION

Fiber Bragg grating (FBG) is a periodic modulation of the refractive index along the length in the center of optical single mode fiber [1]. FBG is formed by exposing the fiber 's core to a periodic UV light pattern that induces permanent change in the core refractive index [2]. Thanks to its photosensitivity Germanium doped silica fibers are used for producing FBG. Photosensitivity is the ability to change the core refractive index upon exposure to UV light. Germanium doping must be higher for high reflectivity. FBG can be used in strain and temperature sensing [3].

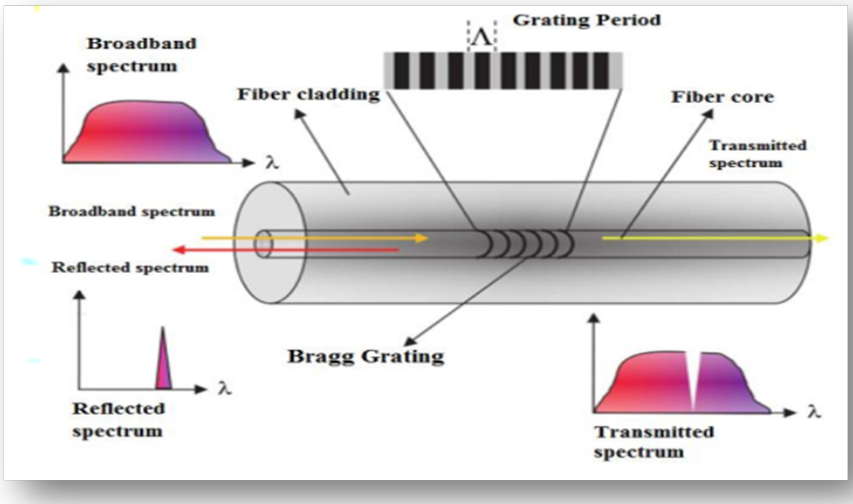
II. PRINCIPLE

2.1 FIBER BRAGG GRATING –

Bragg gratings are analyzed on the basis of the Bragg reflection principle, as shown in Figure(1). When light propagates through the fiber through periodically alternating refractive index regions, a part of the light is reflected back to the input from each period. Reflected light has a wavelength equal to the wavelength of Bragg, meaning the light reflects backwards. [5,6,7] When reflected light combines approximately half the wavelength of the input light coherently with one broad reflection at a given wavelength with the grating period. This is called the Bragg state, and the wavelength at which reflection takes place is called the Bragg wavelength [8,9].The condition for higher reflectivity is Bragg condition which is given by,

$$\lambda_B = 2n_{eff}\ \Lambda \qquad (1)$$

Where is the central wavelength of FBG, wavelength that satisfies Bragg condition. neff is the effective refractive index, is the grating period or pitch of the grating [10].



Figure(1): Fiber Bragg Grating [4]

2.2 *Parameters Of FBG–*

Fiber Parameters	Symbols	Values
Core refractive index	n_1	1.46
Cladd refractive index	n_2	1.45
Core radius	a_{co}	4.1 Mm
Cladd radius	a_{cl}	60 Mm
Length grating	L	10 mm
Bragg wavelength	λ_{B1}	1552.52 nm
	λ_{B2}	1551.72 nm
Grating manger	L,H,P	10000, 0.0006, 0.5322

2.3. *Software analysis (Optigrating)–*

Optigrating is a versatile user friendly program designed to incorporate multiple parameters. Many sensors and telecommunications devices, for example , work with the optigration Software Waveguide Grating. Agrating-assisted systems can be studied and designed by calculating spectra of light absorption , reflection and transmission, delay in phase groups, and dispersion. Since the calculation results depend on waveguide and grating parameters, the use of the correct calculation would greatly ease the design task. the software start by the manager grating as shown in figure (2) which is given the properties of the FBG which is used.

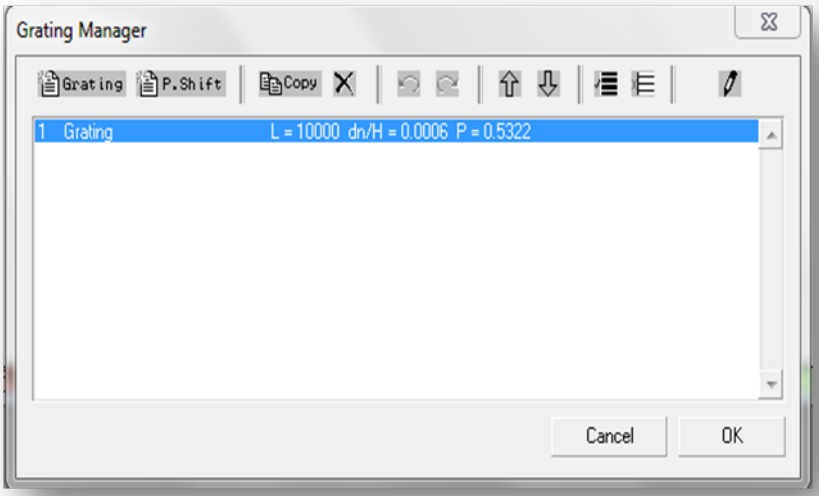
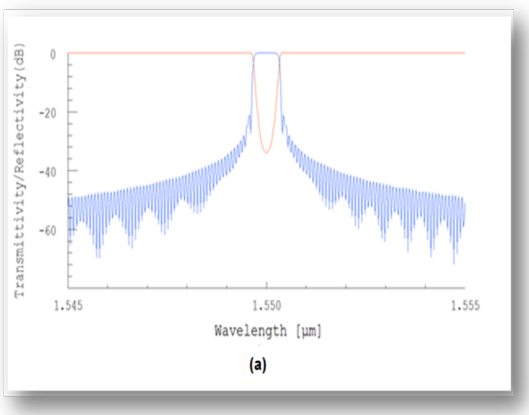


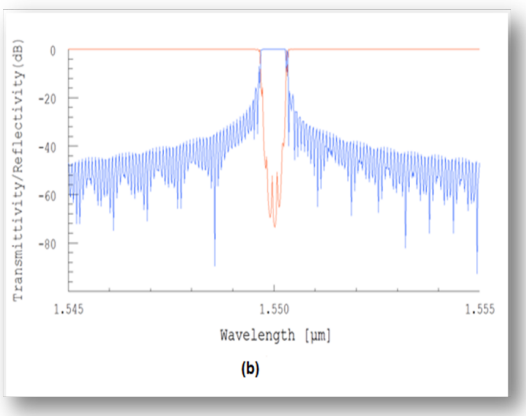
Figure (2): Grating Manager

III. Result and Analysis

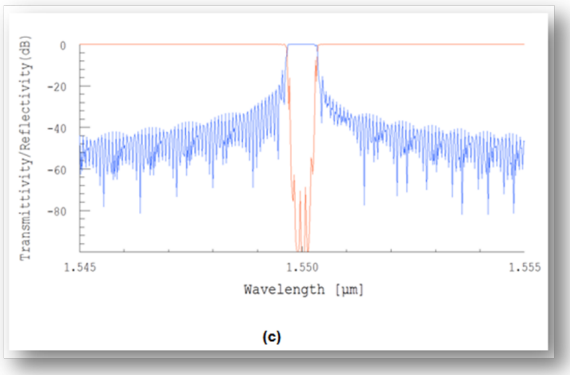
a. Spectrum Power

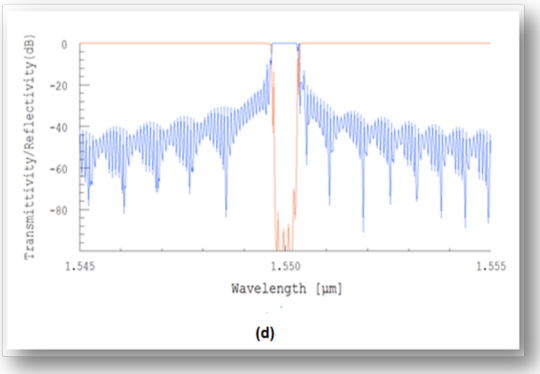
The Spectrum power:of the Uniform, Apodized, Linear chirped FBG in one region, Two region, three region, four region, and five region. This spectrum given the transmittivity (red line) and reflectivity (blue line) change with the wavelength.



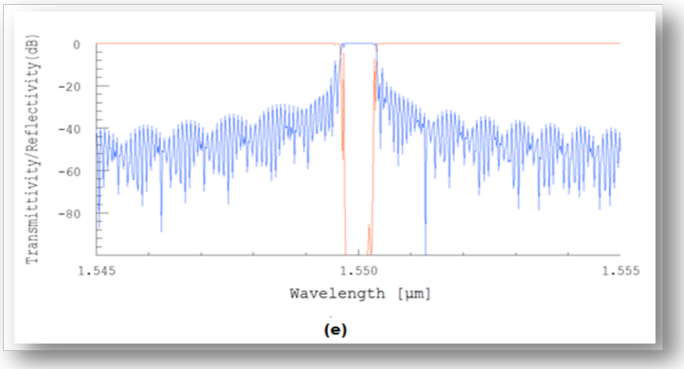


(a) (b)





(c) (d)



(e)

Figure 2 Spectrum power. (a) Uniform, Apodized, Linear chirped FBG in one region (b) Uniform, Apodized, Linear chirped FBG in Two region (c) Uniform, Apodized, Linear chirped FBG in three region (d) Uniform, Apodized, Linear chirped FBG in four region (e) Uniform, Apodized, Linear chirped FBG in five region.

Figure(3):shows the relationship between Transmittivity / Reflectivity and number of FBG regions.OptiGrating is used to design five FBG Gaussian apodized Devices with a length of 10 mm, = 1.45 and a composition index of 0.0005. 5 groups of FBGs are designed illustrated in this figure , indicating that the spectrum is identical to that provided by the OptiGrating Sample Library. Anyone who designed FBG in terms of linear and sensitive response to applied physical measurement. The first FBG is concentrated at 1550 nm assigned to it as FBG1, the second is concentrated at 1550.02 nm listed as FBG2, the third is concentrated at 1550.02 nm listed as FBG3, the fourth is at 1550.02 nm listed as FBG4, and the fifth is concentrated at 1549.86 nm listed as FBG5. Figure (3) shows, respectively, the characterization of their outcome for each OptiGrating region. Sufficient linearity is obtained, we notice that the more the number of FBG regions, the lower the transmission and the higher the reflected spectrum as shown in Figures (4) and (5) therefore the more bandwidth increases. The maximum value of the band width of FBG using in communication is 1nm, so the maximum value in this work is 0.5nm which is good value as show Figure (6). The band width simulation of different grating regions number of FBG as shown in table (1)

Table (1): Band width simulation of different grating regions number of FBG

Number Of regions Of FBG	Transmission (	Reflection 10^{-6}	Band Width (nm)
One Grating region(Linear chirped)	0.99999478	0.52184252	0.48
Two Grating regions(Linear chirped)	0.99998014	1.9864172	0.48
Three Grating regions(Linear chirped)	0.99995890	4.1104110	0.48
Four Grating regions(Linear chirped)	0.99993517	6.4829916	0.5
Five Grating regions(Linear chirped)	0.99991355	8.6453019	0.5

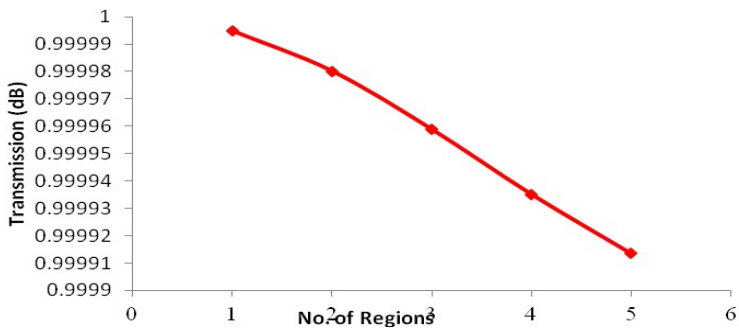


Figure (4): Graph of the transmitted spectrum figure versus Number of regions of FBG.

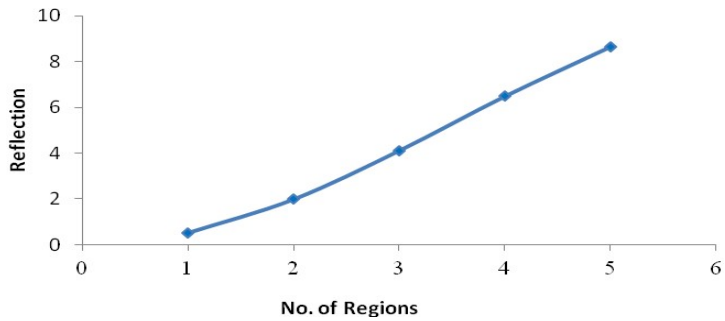


Figure (5): Graph of the Reflected spectrum figure versus Number of regions of FBG

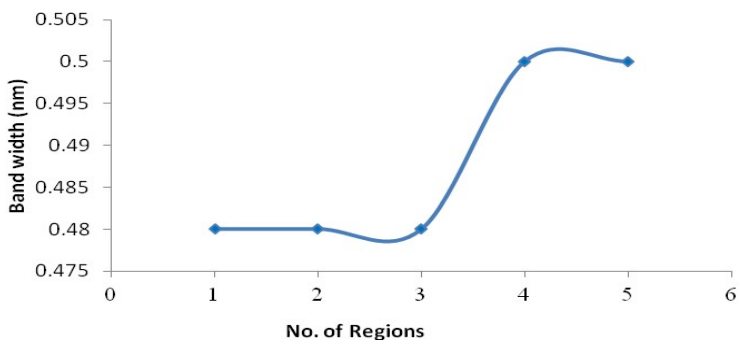
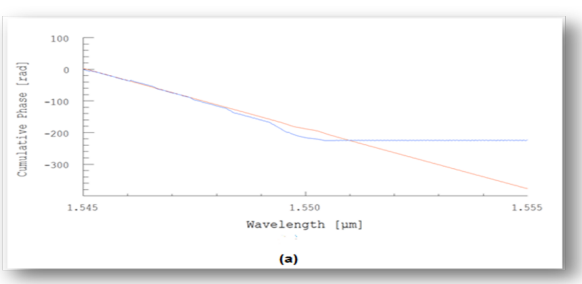
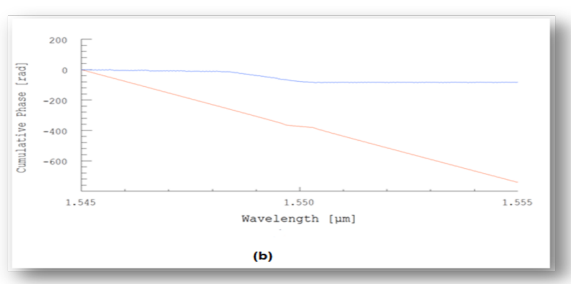


Figure (6): Graph of Band width figure versus Number of regions of FBG.

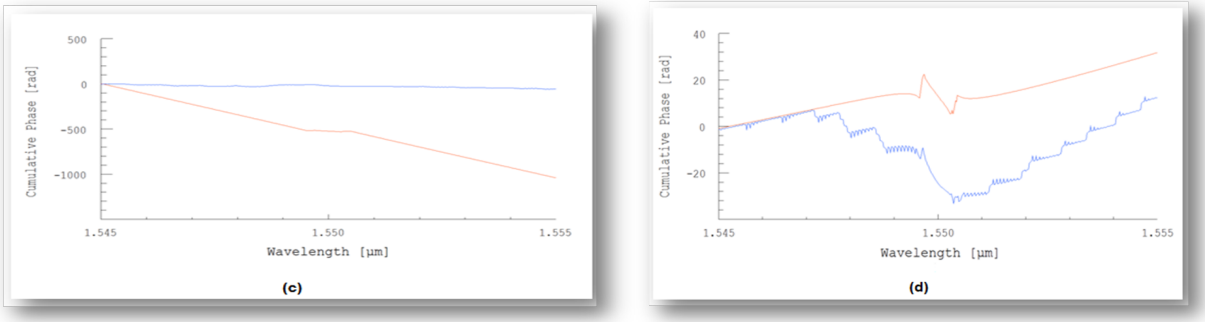
b. Spectrum Phase [rad]

The Spectrum phase (rad): **(**one region for Linear chirped FBG, Two region, Three region, four region, and five region . which is represented the spectrum of cumulative phase as a function of wavelength for the the transmittivity (red line) and reflectivity (blue line) spectrum.

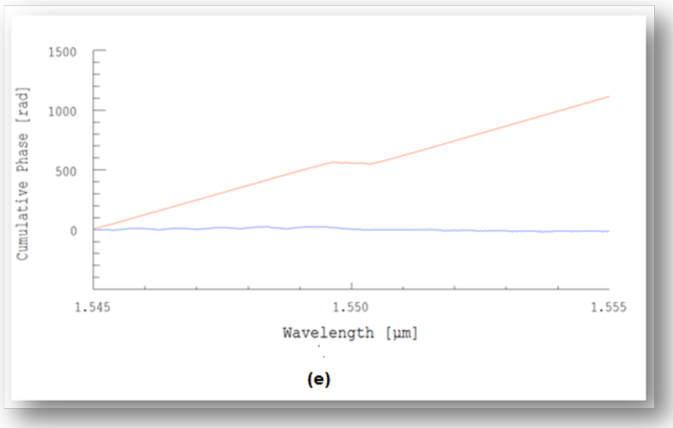




(a) (b)



(c) (d)



(e)

Figure 7 Spectrum phase (rad). (a) one region for Linear chirped FBG (b) Two region for Linear chirped FBG (c) Three region for Linear chirped FBG (d) four region for Linear chirped FBG (e) five region for Linear chirped FBG

Figure (7) shows that the value of the cumulative phase is decreasing approximately-constantly and is an inverse relationship as the transmitting channel wavelength increases, with a slight stability of 1550 for the transmitted wave as this wavelength is considered the lowest absorption and loss area and is the ideal length recommended by ITU (International Telecommunication Union).

We also notice that the power reflection increases slightly when the wavelength increases, and is less possible at 1550 nm in most areas. From the results in Figure (7 e and f) we note that the value of the cumulative phase increased when increasing the FBG areas, This is not ideal as previously stated, and the substantial change that occurred to the transmitter value and reflected at 1550 in Figure (7 e) can also be noted. The Transmission simulation and reflection of the number of different grating regions of the FBG in spectrum phase as shown in table (2).

Note in Figure (8) that the reflection energy increases and decreases sinusoidally and that its highest value is in the third region. Figure, while we notice in figure (9) that when the number of regions increases, the value of the reflected energy decreases linearly

Table (2): Transmission simulation and reflection of the number of different grating regions of the FBG in spectrum phase

Number Of regions Of FBG	Transmission (	Reflection
One Grating region(Linear chirped)	2.9198837	- 0.64973998
Two Grating regions(Linear chirped)	-0.44341559	-0.87144666
Three Grating regions(Linear chirped)	2.4764744	- 1.0931493
Four Grating regions(Linear chirped)	-0.88681578	-1.3148469

Five Grating regions(Linear chirped)	2.0330844	-1.5365393

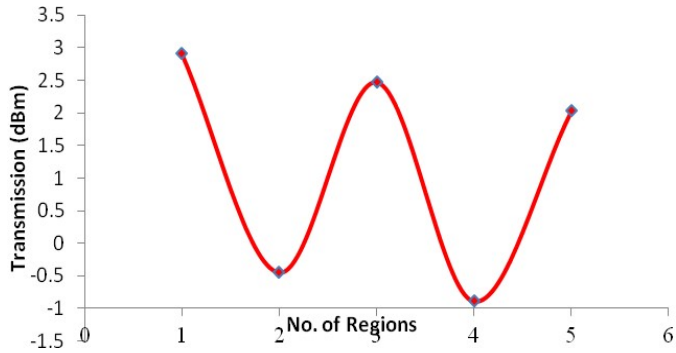


Figure (8): The Transmitted spectrum figure versus Number of regions of FBG in spectrum phase

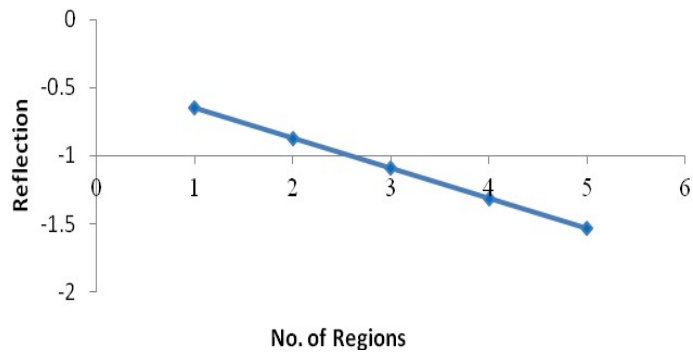
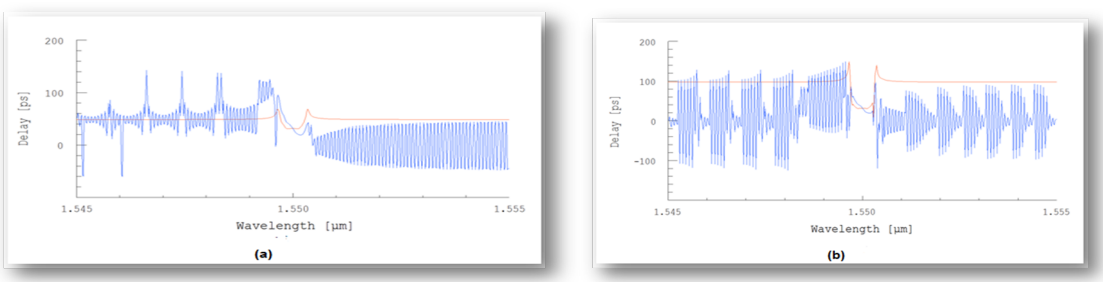
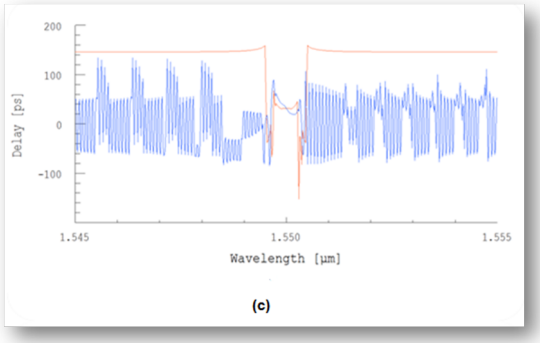


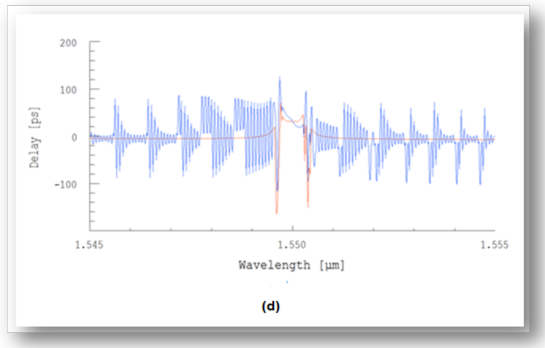
Figure (9): Graph of the Transmitted spectrum figure versus Number of regions of FBG in spectrum phase.

c. Spectrum delay [ps]

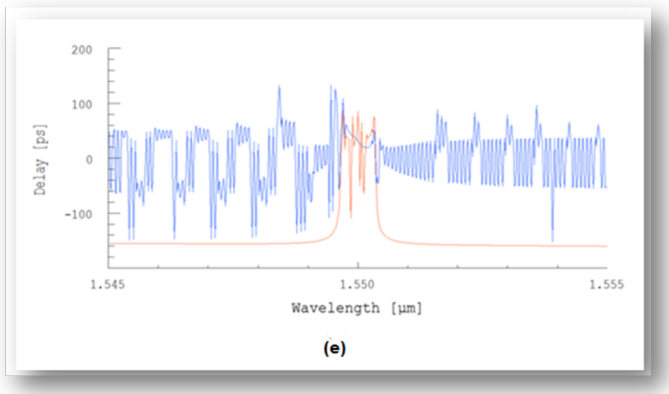


(a) (b)





(c) (d)



(e)

Figure 10 Spectrum delay [ps]. (a) one region for Linear chirped FBG (b) Two region for Linear chirped FBG (c) Three region for Linear chirped FBG (d) four region for Linear chirped FBG (e) five region for Linear chirped FBG

In figure (10a) it can be seen that the delay mark has a small wave in the scroll range. When the delay is increased, a huge amount of spikes appear as shown in figure (10) (b, c, d, e and). This degrades the performance of the system as a result and is called the ripple tuning delay. FBG can work well in a certain degree of negativity. The Transmission simulation and reflection of the number of different grating regions of the FBG in spectrum delay can be show in table (3).

In figure (11) it is clear that the value of transmitted energy increases in the second and third regions, and after that it decreases directly in the fourth and fifth regions, while we notice in figure (12) as the reflection energy increases and decreases sinusoidally, and its highest value is in the third region

Table (3): Transmission simulation and reflection of the number of different grating regions of the FBG in spectrum delay

Number Of regions Of FBG	Transmission (	Reflection
One Grating region(Linear chirped)	48.604529	52.316140
Two Grating regions(Linear chirped)	97.209221	1.3900261
Three Grating regions(Linear chirped)	145.81387	49.994674
Four Grating regions(Linear chirped)	-4.6427061	-0.93109464
Five Grating regions(Linear chirped)	-155.09937	47.673851

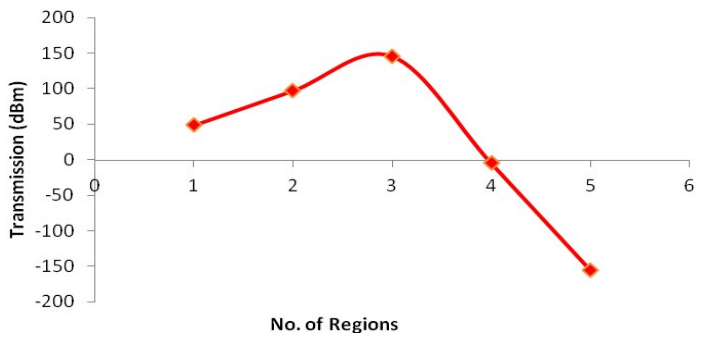


Figure (11): The Transmitted spectrum figure versus Number of regions of FBG in spectrum delay.

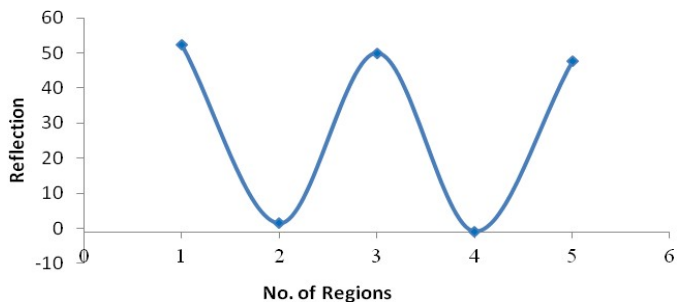
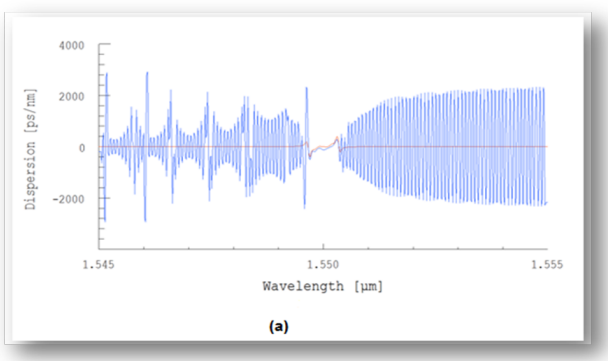
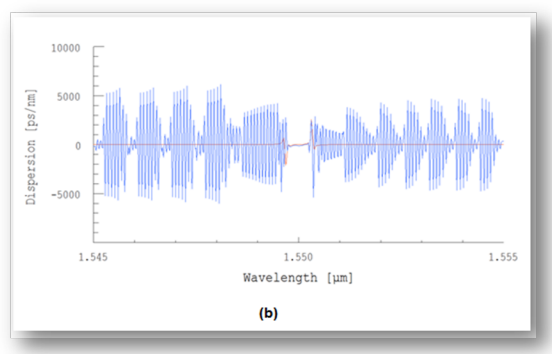


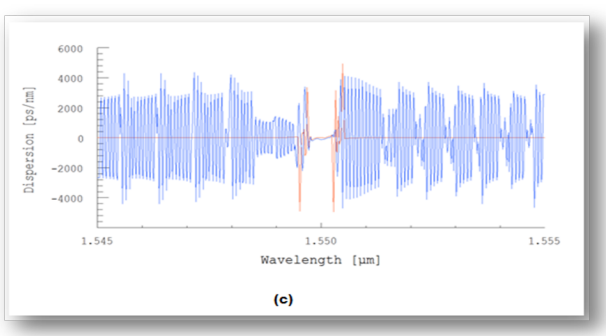
Figure (12): The Reflected spectrum figure versus Number of regions of FBG in spectrum delay.

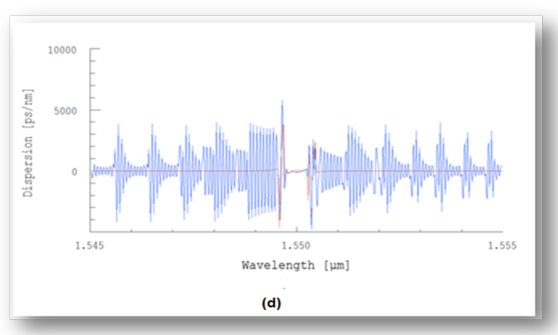
d. Spectrum dispersion [ps/nm]





(a) (b)





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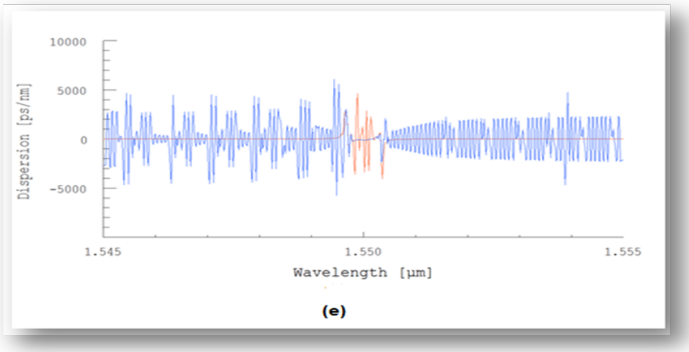


(e)

Figure 13 Spectrum dispersion [ps/nm]. **(a)** one region for Linear chirped FBG (b) Two region for Linear chirped FBG (c) Three region for Linear chirped FBG (d) four region for Linear chirped FBG (e) five region for Linear chirped FBG

In Figure (13), ripples and an increase in dispersion values were observed in all regions of most of the wavelengths shown. This indicates instability and poor system quality, except for 1550. Stability occurs and scatter values approach zero as the number of the region increases, especially between digits (13 a and f) and the Transmission simulation and reflection of the number of different grating regions of the FBG in spectrum dispersion

As shown in table (4).

Figure (14) When the spectrum is dispersed, the value of the transmitted energy takes a slight increase on the third region, then we notice a gradual decrease in the fifth region and that the increase in the number of regions reduces the dispersion and this increases the efficiency of the system because there is preservation of the transmitted data when the dispersion decreases and decreases, Also in the fifth region when reflective, as in figure (15)**.**

Table (4): Transmission simulation and reflection of the number of different grating regions of the FBG in spectrum dispersion

Number Of regions Of FBG	Transmission (	Reflection
One Grating region(Linear chirped)	0.022077590	-192.02917
Two Grating regions(Linear chirped)	0.036718797	-192.14337
Three Grating regions(Linear chirped)	0.054708227	-2680.5244
Four Grating regions(Linear chirped)	-0.20321881	-192.25447
Five Grating regions(Linear chirped)	-0.45588798	-2680.6484

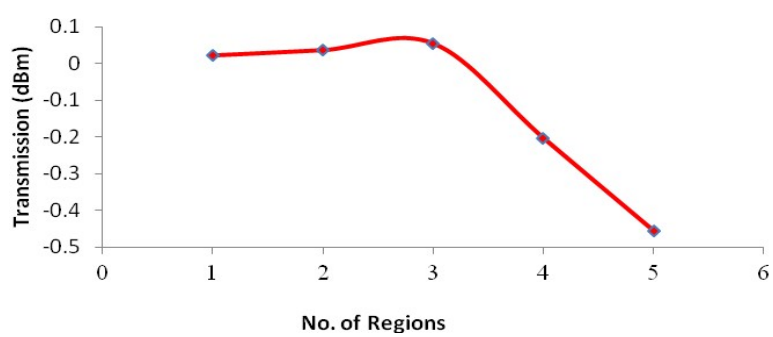


Figure (14): The Transmitted spectrum figure versus Number of regions of FBG in spectrum dispersion.

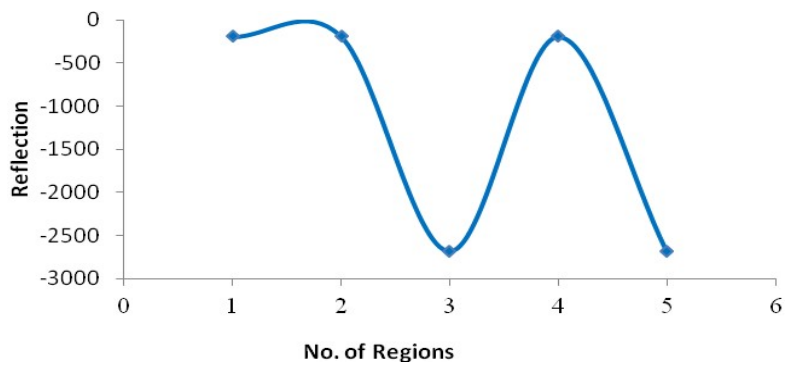
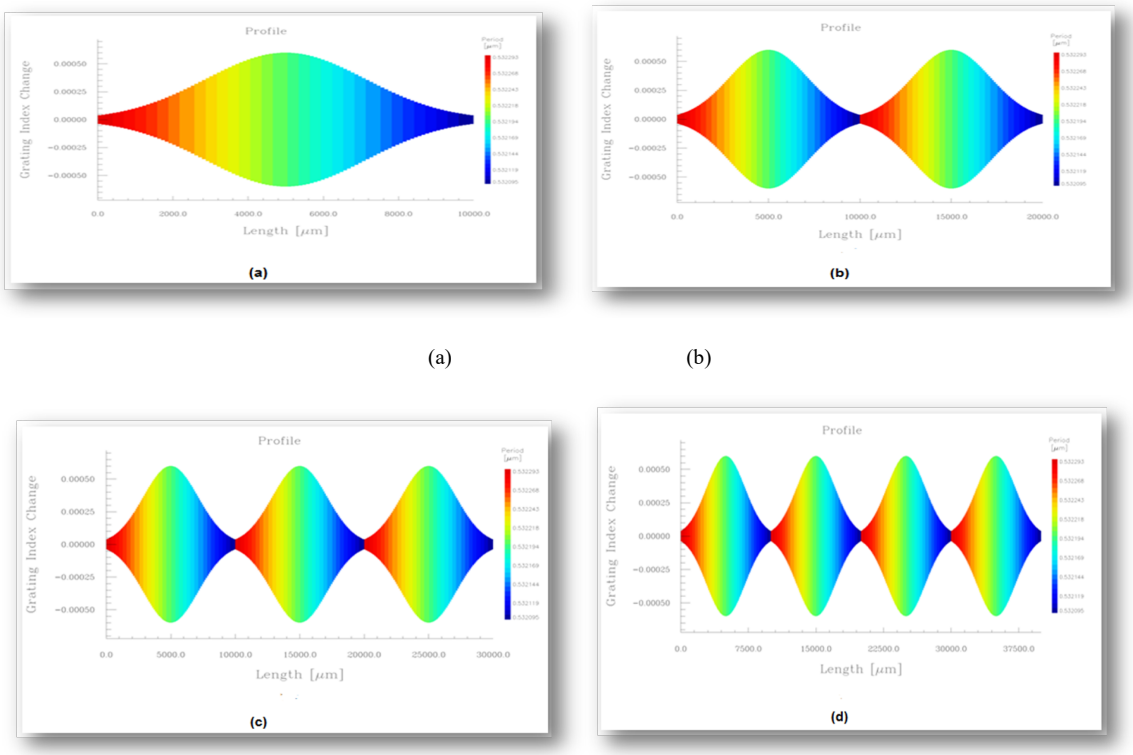


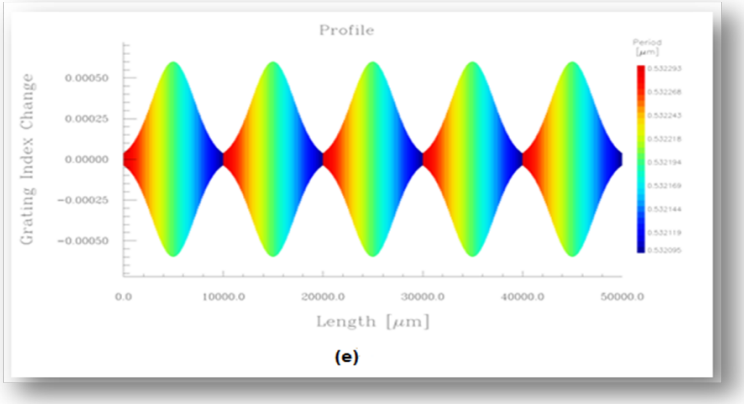
Figure (15): The Reflected spectrum figure versus Number of regions of FBG in spectrum dispersion.

e. Calculate Profile



(a) (b)

(c) (d)



(e)

Figure 16 Profile Grating Index Change. (a) one region for Linear chirped FBG, (b) Two region for Linear chirped FBG, (c) Three region for Linear chirped FBG, (d) four region for Linear chirped FBG, (e) five region for Linear chirped FBG

Table (5): The Period readings are tabulated by varying the Number of regions.

Number Of regions Of FBG	Period max (Mm)	Period min (Mm)
One region(Linear chirped)	0.532293	0.532095
Two regions(Linear chirped)	0.532293	0.532095
Three regions(Linear chirped)	0.532293	0.532095
Four region(Linear chirped)	0.532293	0.532095
Five region(Linear chirped)	0.532293	0.532095

The simulation result is displayed in the FBG profile for five regions, so the period value in the other regions is equal to the maximum and minimum values. Peter G. in the 2017 reference [74] had the same result for me, the period is standard with the FBG being used differently, the period in this thesis was set at (0.5338), and I noticed by comparison that it is very close to mine.

IV.CONCLUSION

We conducted a comparative analysis of Five FBG areas using Optigrating in this paper and calculated the following results for two regions: Spectrum Power, Spectrum Phase [rad], Spectrum dely [Ps], Spectrum dispersion [Ps / nm], Calculate Profile. In addition, the transmission, reflection and bandwidth is determined for all FBG regions, we note that the higher the number of FBG regions, the lower the transmission and the higher the reflected spectrum and thus the higher the bandwidth increases, the measurement of the FBG regions (maximum) and (minute) periods is approximately constant for all regions.

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