

The Effect of the Fiber Bragg Grating model & Index modulation on the Spectral Characteristics of Fiber Bragg Grating

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Abstract: Fiber Bragg Grating FBG Works as a filter within a specific range to counteract the light whose wavelength is within the filter range and allows the light whose wavelength is outside the filter to pass through the carrier light-medium. In communications fiber-optic, the FBG is used to separate the optical signals. The Apodization techniques are used to get the optimum reflection spectrum. In this paper, two comparisons used dependent on the types of grating apodization & change index mode of FBG. The FBG equations for the uniform pattern and the Apodization pattern are, Gaussian Apodized FBG and Hyperbolic tangent (tan hyp) Apodized FBG are processed by the optigrating (4.2.2) software to achieve the maximum Reflectivity and Narrow bandwidth that reduces the effect of sidelobe, then change the index modulation of the fiber grating to find the relation between the maximum reflectivity, bandwidth, and sidelobe with index mode. Results are obtained and installed with graphs and tables.

Keywords: Bandwidth, Fiber Bragg Grating, Grating Apodization, Index mode, Maximum reflectivity, Sidelobe.

1. INTRODUCTION

The Fiber Bragg Grating FBGs are usually used as a wavelength selective reflector. The Bragg reflection principle is FBG nats that act as spectral filters. The resulting light reflects the narrowest wavelength and sends other wavelengths [1]. The main characteristic of FBGs is that they reflect light in a narrow strip centered around the wavelength of Bragg. The optical fiber network (FBG) is one of the most important developments in the fields of optical fiber technology, due to its flexibility and unique performance in the field of filtering [2]. FBG is defined as the main components of the DWDM multiplexing based on low insertion loss, high wavelength selectivity, low polarization dependent loss, and low polarization dispersion conditional. Grating fibers can classify into two types, Bragg Grating and the Transmission Grid barriers [3]. Bragg grating is the pairing between traveling the waves in opposite directions. Grid barriers are called reflection or grid barriers for a short period. On the other hand, in transmission grid barriers, travel coupling occurs in the same direction. There is a different build for FBG like Uniform, Apodized, Chirping, Italic, and Long-period [4]. When light is spread across FBG, the reflected light will be within a narrow range of wavelengths and is called the Bragg wavelength. As for other waves, they are not affected by the Bragg network except for some side lobes in the reflection spectrum.

Side lobes can be eliminated using apodization techniques. The reflection bandwidth depends mainly on the length and strength of the refractive index adjustment. The reflected wavelength of the FBG also depends on temperature and pressure. So it can be used in sensor technology [5]. FBG can be apodized with the help of many methods like Gaussian, cosine, and rectangular algorithm. Each method has some special features and a different manufacturing method [1]. The principle of operation of the FBG is shown in figure (1). In this paper, the visual changes that occur for a wave after its passage with FBG are discussed, using different patterns of FBG and changing the modulation index to obtain the maximum reflection and the minimum bandwidth.

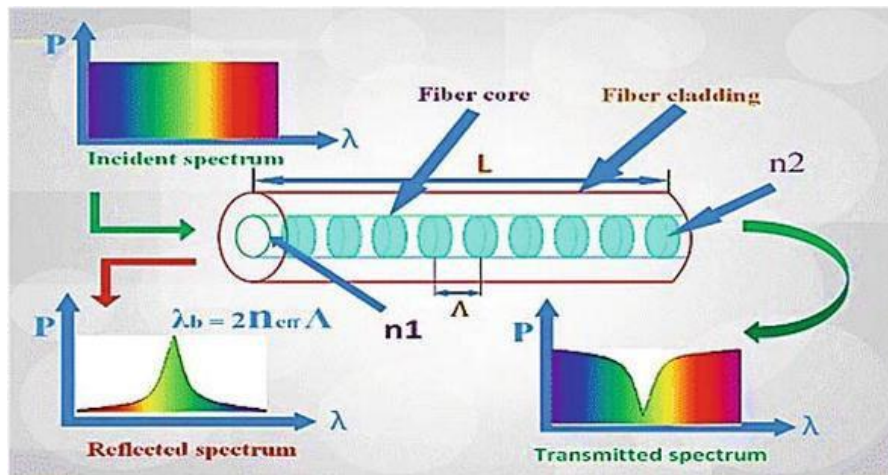


Figure (1) the principle operation of the FBG

2. FIBER BRAGG GRATING MODEL

The composition of the FBG can be expressed as a refractive index of the grating period. There are different types of the grating period, including uniform, gradient, translator, or distributed uniform in the superstructure. As for the refractive index, it has two main characteristics: the refractive index and the displacement profile. The refractive index is usually either standard or Apodized [6].

2.1 UNIFORM FIBER BRAGG GRATING

The basic structure of the unified Bragg grating fibers was shown in Figure (1). As light travels through fibers that contain part of the FBG, part of the light will be reflected. The wavelength reflected by the light represents the wavelength of the Bragg so that this light is reflected in the inputs during the transfer of other waves. When we call the term “uniform” on the reflection index, this means that the grid period, Λ , and refractive index adjustment, δn , are constant along the grid. The reflected wavelength (λ_B), called the Bragg wavelength, is defined by the relationship [1],

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

Where Λ : The grating period, n_{eff} : is the effective refractive index of the grating in the fiber core.

We can determine the effective refractive index by calculating the speed of light diffusion compared to the speed of its diffusion in a vacuum. The bandwidth ($\Delta\lambda$), is (in the strong grating limit) given by,

$$\Delta\lambda = [2\delta n_0 \eta] \lambda_B \quad (2)$$

Where δn_0 is the variation in the refractive index ($n_3 - n_2$), and η is the fraction of power in the core [7].

2.2 APODIZED FIBER BRAGG GRATING

The use of FBG Apodized will improve the sidelobe reduction, but this reduction is at the expense of reducing peak reflection. Grating Apodization is a slowly varying envelope from a grating profile. Options for apodization defect are listed below, where s is the taper parameter =0.5 and L is a grating length. Equation (4) shows the index of the refractive index Apodized [8].

$$n(x, y, z) = n_0(x, y) + \Delta n_0 \cdot p(x, y) \cdot A(z) \cdot f\left[\frac{\Lambda(z)}{\cos\theta, z}\right] \quad (3)$$

Where: n_0 =waveguide refractive index, Δn =index modulation amplitude, θ =grating tilt angle, $f\left[\frac{\Lambda(z)}{\cos\theta, z}\right]$ =shape function, $\Lambda(z)$ =period chirp function, $A(z)$ =Apodization function

3. GRATING APODIZATION

Grating Apodization is a slowly varying envelope from a grating profile. Options for apodization defect are listed below, where s is the taper parameter =0.5 and L is a grating length

1. Uniform (no apodization)

$$A(z) = 1 \quad (4)$$

2. Gaussian

$$A_{(z)} = \exp\left\{-\ln 2 \cdot \left[\frac{2 \cdot (z-L/2)}{s \cdot L}\right]^2\right\} \quad (5)$$

3. Hyperbolic tangent

$$A_{(z)} = \tanh\left(s \cdot \frac{z}{L}\right) \cdot \tanh\left[s \cdot \left(1 - \frac{z}{L}\right) + 1 - \tanh^2(s/2)\right] \quad (6)$$

4. RESULT & DISCUSSION

The fiber Bragg grating used in this paper is single fiber, the period $\Lambda = 0.53381599$, the length of the grating $L=50\text{mm}$, the index modulation $=0.0006$. In this paper two types of FBG model use, uniform and Apodized FBG. The Grating Apodized is used, Gaussian and Hyperbolic tangent Grating, the Bandwidth, Ripple factor, Bragg wavelength, slope L, sidelobe for length, slope R, sidelobe for R, and maximum reflectivity are calculated and recorded in the table (1).

Table (1)

Apodizationprofile	Bandwidth (nm)	Ripple factor	Bragg wavelength (nm)	Slope L (dB/nm)	Sidelobe L (dB)	Slope R(dB/nm)	Sidelobe R (dB)	Max. Reflectivity
uniform	6.9	-0.984	1547.9	3.8140	-17.359	-27.004	-18.175	94%
Gaussian	6.34	-0.987	1550.52	8.5088	-31.986	-69.4806	-32.789	90.4%
Tan hyp	6.82	-0.979	1547.9	38.3884	-17.864	-32.014	-17.923	92.3%

In tables (2,3,4) shows the Bragg wavelength, the maximum reflectivity, bandwidth, the side lobe of the grating length for two FBG models when we change the index modulation and Install value of length grating $=50\text{mm}$.

Table (2) uniform grating apodized

Index mode	Bragg wavelength(nm)	Max. Reflectivity	Bandwidth (nm)	Sidelobe L (dB)
0.0001	1552.64	8.49%	6.44	-29.656
0.0002	1547.38	29.4%	6.5	-23.674
0.0004	1547.4	73.37%	6.6	-19.717
0.0006	1547.44	94%	6.74	-16.204
0.0008	1547.44	99.1%	6.86	-13.46
0.001	1547.48	99.9%	7.1	-12.966

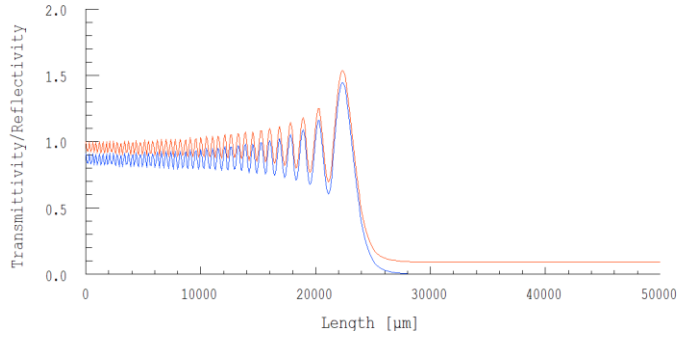
Table (3) Gaussian grating apodized

Index mode	Bragg wavelength(nm)	Max. Reflectivity	Bandwidth (nm)	Sidelobe L (dB)
0.0001	1549.98	6.31%	6.1	-47.5
0.0002	1549.98	22.99%	6.22	-41.515
0.0004	1550.08	64.86%	6.1	-35.654
0.0006	1550.08	90.37%	6.08	-30.753
0.0008	1550	98.3%	6.14	-30.332
0.001	1550	99.83%	6.3	-30.191

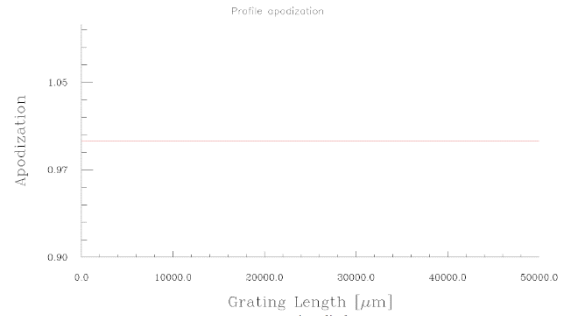
Table (4) tan hyp grating apodized

Index mode	Bragg wavelength(nm)	Max. Reflectivity	Bandwidth (nm)	Sidelobe L (dB)
0.0001	1552.64	7.67%	6.42	-47.5
0.0002	1547.38	25.57%	6.5	-41.515
0.0004	1547.4	69.88%	6.58	-35.654
0.0006	155258	92.29%	6.72	-30.753
0.0008	1547.44	98.75%	6.86	-30.332
0.001	1549	99.87%	7	-30.191

Figure (2) shows the propagation of the optical signal passes through uniform FBG, note that the relation between the power and the length of the Grating shown in figure (2A). The Apodized profile equals 1 as shown in figure (2B). In figure (3, 4, 5) shows the behavior of the reflectivity and output intensity with increasing the index modulation. The maximum reflectivity and bandwidth increasing, while the sidelobe decreasing with increasing the index modulation. Figure (6) shows the propagation of the optical signal passes through Gaussian Apodized FBG, note that the relation between the power and the length of the Grating is shown in figure (6A). The relation between the Apodization and Grating length as shown in figure (6B). In figure (7, 8, 9) shows the behavior of the reflectivity and output intensity with increasing the index modulation. The maximum reflectivity and bandwidth increasing, while the sidelobe decreasing with increasing the index modulation. Figure (10) shows the propagation of the optical signal passes through tan hyp FBG, note that the relation between the power and the length of the Grating shown in figure (10A). The relation between the Apodization and Grating length as shown in figure (10B). In figure (11, 12,13) shows the behavior of the reflectivity and output intensity with increasing the index modulation. The maximum reflectivity and bandwidth increasing, while the sidelobe decreasing with increasing the index modulation.

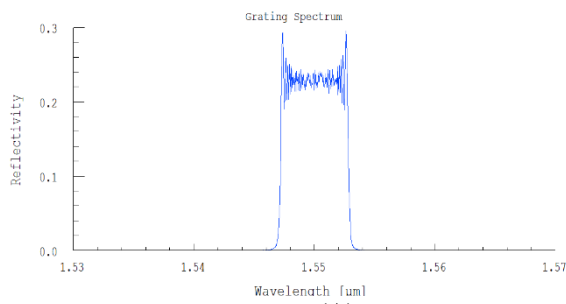


(A)

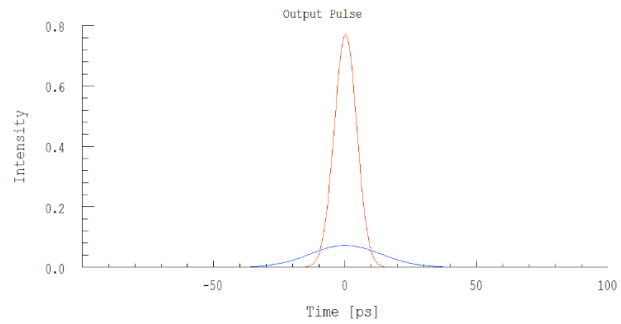


(B)

Figure (2) for uniform Grating apodization. (A) Relationship between power & length (B) Grating Apodization profile



(A)



(B)

Figure (3) for uniform apodized, index mode=0.0002(A) relationship between Reflectivity & wavelength. (B) The relation between the intensity & time.

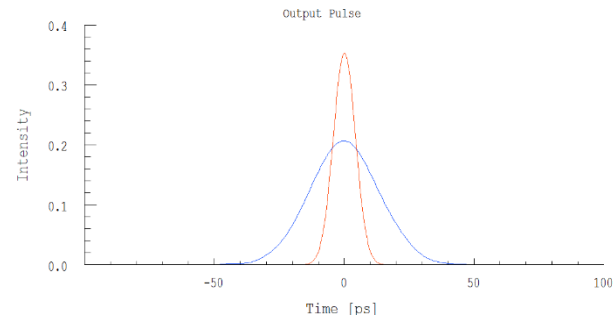
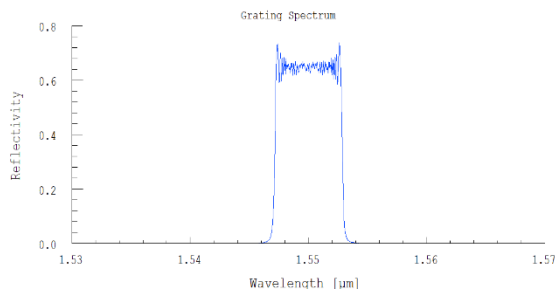


Figure (4) for uniform apodized, index mode=0.0004(A) relationship between Reflectivity & wavelength. (B) The relation between the intensity & time.

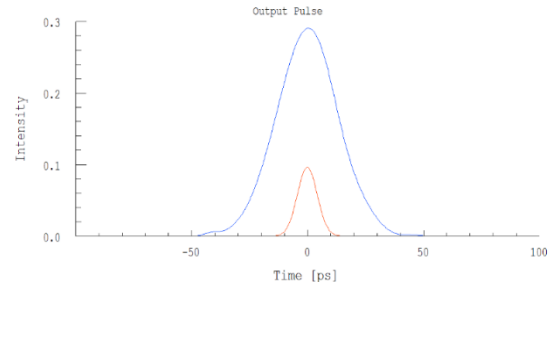
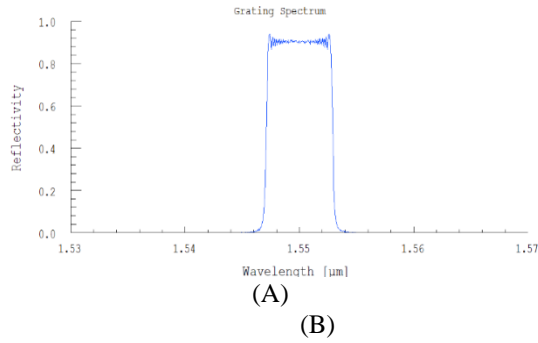


Figure (5) for uniform apodized, index mode=0.0006(A) relationship between Reflectivity & wavelength. (B) The relation between the intensity & time.

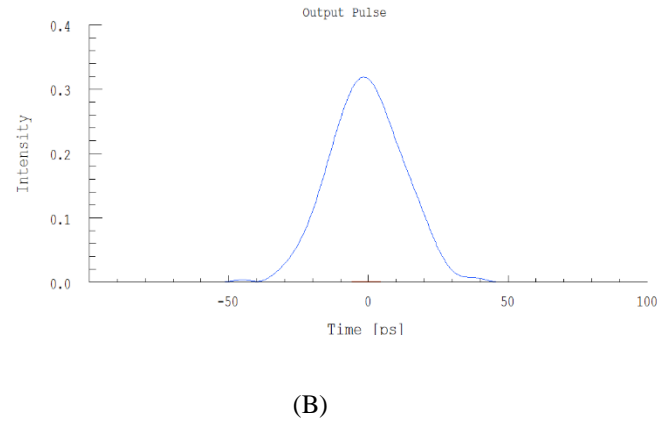
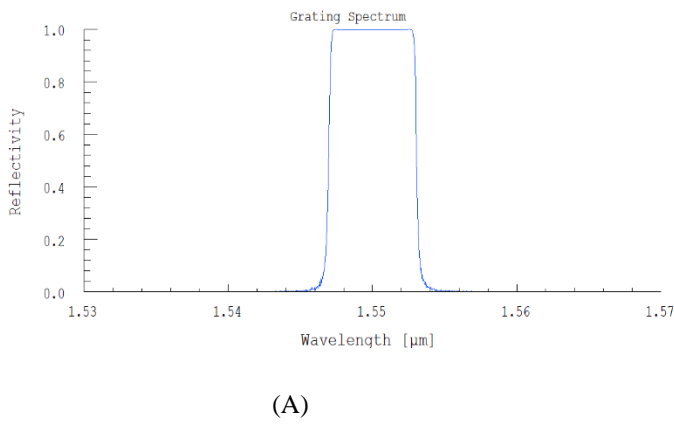


Figure (6) for uniform apodized, index mode=0.001(A) relationship between Reflectivity & wavelength. (B) The relation between the intensity & time.

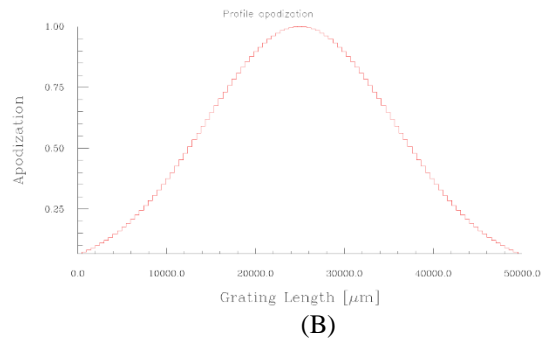
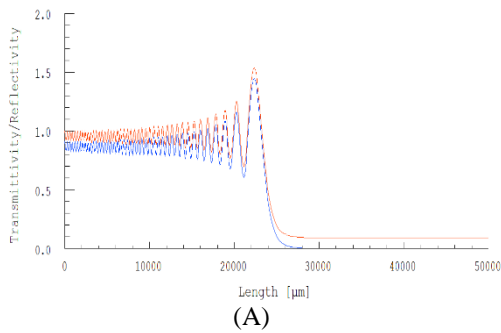
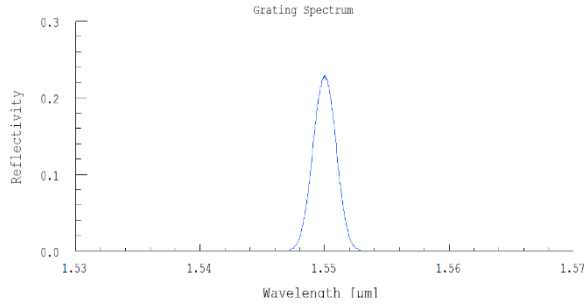
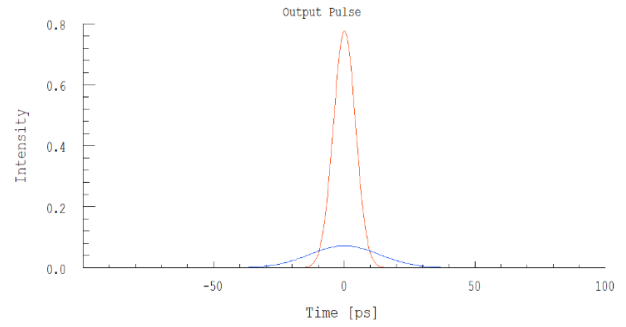


Figure (7) for Gaussian Grating apodization. (A) Relationship between power & length (B) Grating Apodization profile

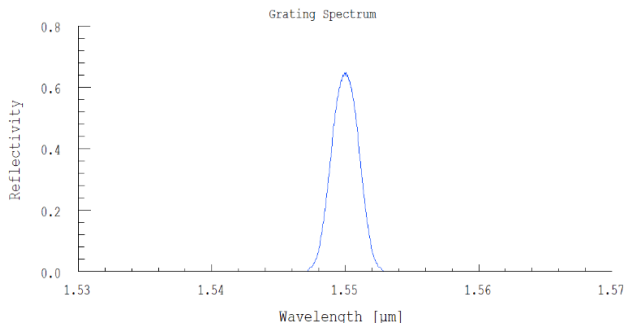


(A)

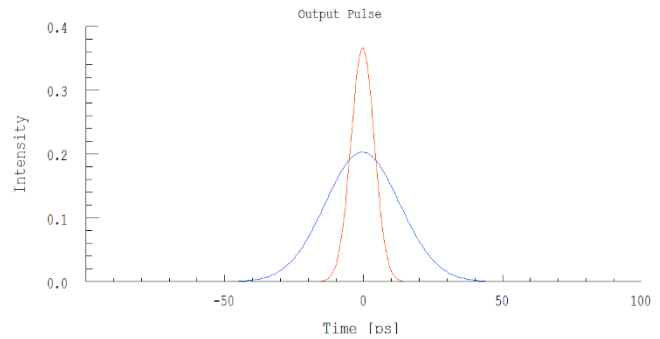


(B)

Figure (8) for Gaussian apodized, index mode=0.0002(A) relationship between Reflectivity & wavelength. (B) The relation between the intensity & time.

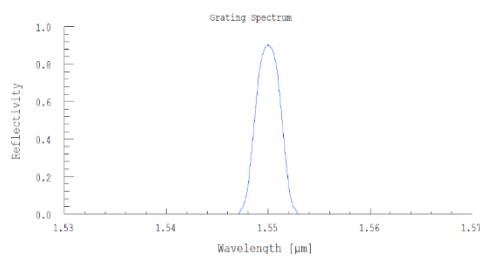


(A)

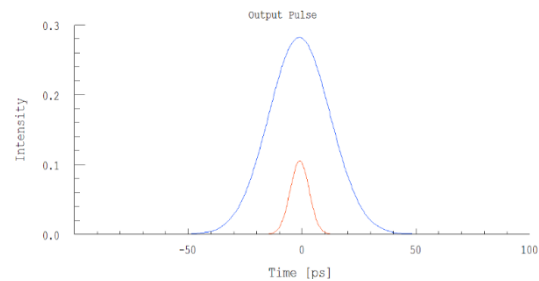


(B)

Figure (9) for Gaussian apodized, index mode=0.0004(A) relationship between Reflectivity & wavelength. (B) The relation between the intensity & time.

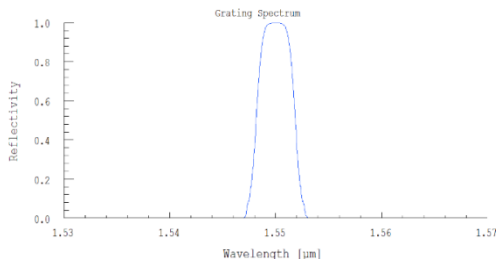


(A)

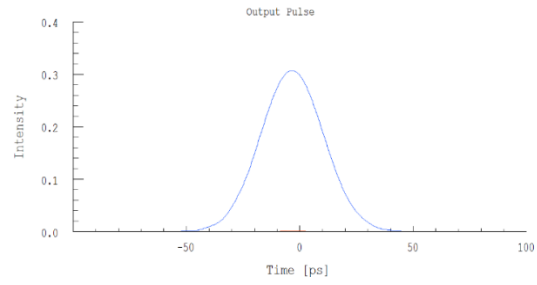


(B)

Figure (10) for Gaussian apodized, index mode=0.0006(A) relationship between Reflectivity & wavelength. (B) The relation between the intensity & time.

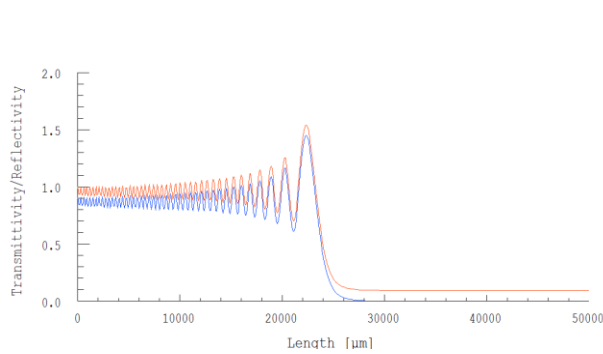


(A)

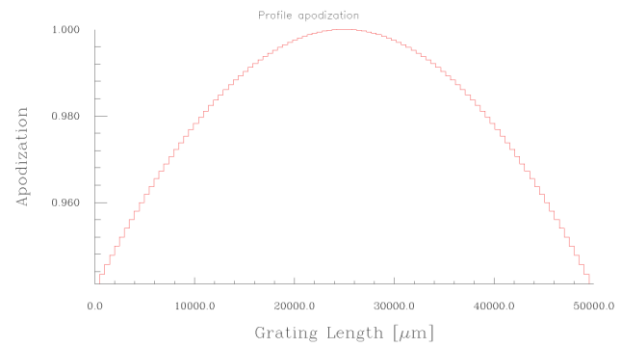


(B)

Figure (11) for Gaussian apodized, index mode=0.001(A) relationship between Reflectivity & wavelength. (B) The relation between the intensity & time.

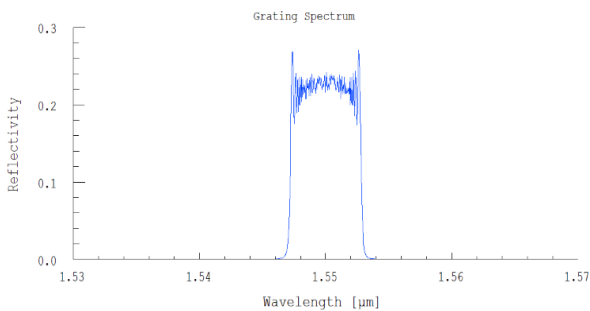


(A)

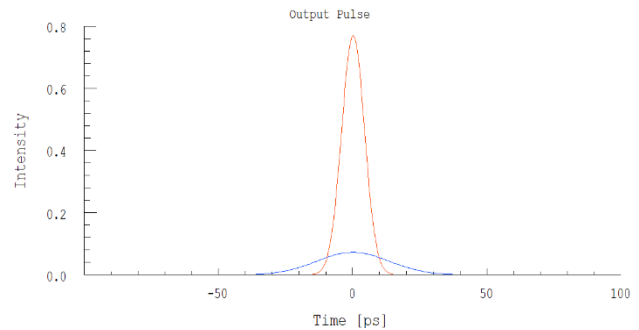


(B)

Figure (12) for tan hyp Grating apodization. (A) Relationship between power & length (B) Grating Apodization profile

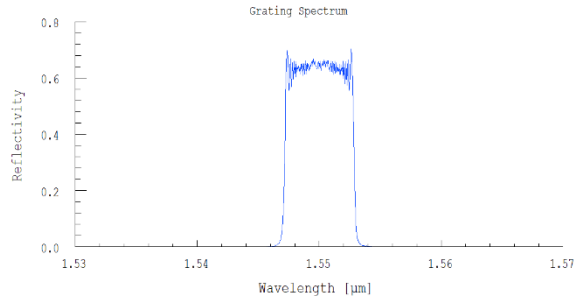


(A)

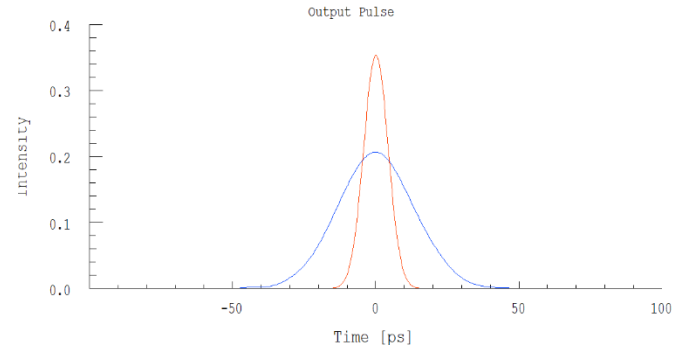


(B)

Figure (13) for tan hyp apodized, index mode=0.0002(A) Relationship between Reflectivity & wavelength. (B) The relation between the intensity & time.

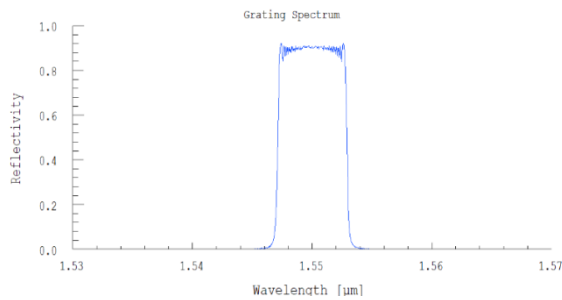


(A)

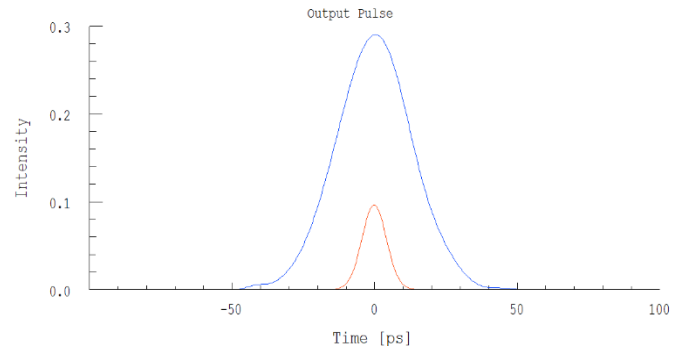


(B)

Figure (14) for tan hyp apodized, index mode=0.004(A) Relationship between Reflectivity & wavelength. (B) The relation between the intensity & time.

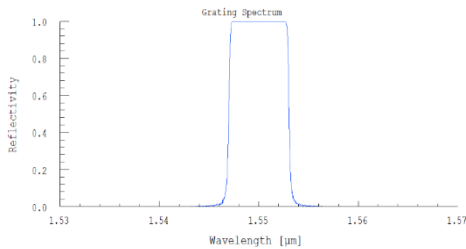


(A)

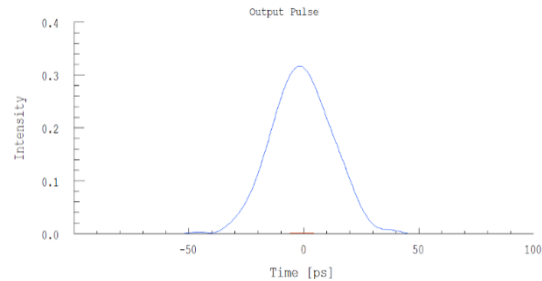


(B)

Figure (15) for tan hyp apodized, index mode=0.0006(A) Relationship between Reflectivity & wavelength. (B) The relation between the intensity & time.



(A)



(B)

Figure (16) for tan hyp apodized, index mode=0.001(A) Relationship between Reflectivity & wavelength. (B) The relation between the intensity & time.

5. CONCLUSION

In this paper two types of FBG model use, uniform and Apodized FBG. The Grating Apodized is used, Gaussian and Hyperbolic tangent Grating, We conclude after comparing the result in a table (1) of three FBG models with constant fiber grating length and Grating period, that the uniform FBG has maximum reflectivity but large sidelobe than other Apodization FBG, When

compared the tables (2, 3, 4) conclude that the maximum Reflectivity and Bandwidth direct proportion with index mode. While the sidelobe L is inversely proportional to index mode. Therefore, the uniform FBG with index modulation 0.001 has maximum reflectivity but a larger sidelobe than Apodization FBG.

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