International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-2 Issue-5, November 2013

Effect of Grating Length on Chromatic Dispersion in Polymer Coated Apodization Grating

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***Abstract*— This paper presents the modeling and simulation of apodized fiber Bragg grating as dispersion compensator and effect of grating length on dispersion coefficient is also observed. Grating length is a critical parameter which drastically affects the characteristics of grating. In this study, polymer coated grating has been used and results shows that as the refractive index of polymer is increased sensitivity of the grating is increased but dispersion compensation quality is reduced. Here three different apodization functions have been used for dispersion compensation among these Tanh function shows the best results as cosine function have significant no. of side lobes.**

***Index Terms*—Apodization grating, polymer coating, grating length, dispersion compensation.**

I. INTRODUCTION

Fiber Bragg grating is well known technology in optical communication systems. It was first demonstrated by K. O. Hill and his co-workers in 1978 using argon ion laser [1]. Fiber grating is mainly used as sensor in different environments to monitor different quantities like temperature, humidity, pressure etc [2]. It is very popular in health monitoring area also. After evolution of WDM and DWDM networks in optical communication use of fiber grating is increased very much because of it has the capability of reflection particular wavelength. This reflection of particular wavelength keeps the channel bandwidth narrow. One more application of fiber grating which is very useful is the dispersion compensation in an optical link.

Dispersion is a very critical issue in optical communication links as it reduces the system performance in terms of bandwidth as well as synchronization. Chirped fiber Bragg grating is used for dispersion compensation usually but here apodization fiber grating is used with polymer coating [3]. Apodization grating is nothing but the addition of some shading function in grating structure [4].

Here polymer coating increases the sensitivity of the grating as the higher refractive index polymer increased. One thing needs to be clear is that polymer coating increases sensitivity of the grating so that more precise the reflected signal but for dispersion compensation one needs to maintain a tradeoff between polymer index and the required compensation.

Revised Manuscript Received on 30 November 2013.
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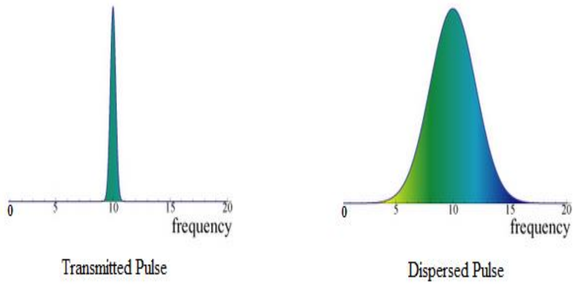

Fig 1 Dispersed Pulse

Figure 1 shows the effect of dispersion on the input pulse. In this study one more parameter is varied for optimize the performance of fiber grating as dispersion compensator that is grating length. As the length of fiber [5] is increased value of negative dispersion in the grating is also increased which will compensate the dispersion of fiber link.

II. THEORY

A. Fiber Bragg Grating

Modeling of fiber grating is done by using coupled mode theory and the transfer matrix method. Fiber grating with grating length L and period ʌ is shown in Figure 2. Fields of propagation can be written as [6].

$$E_r(z,t) = R(z)\exp^{i(\omega t-\beta z)} \quad (1)$$

$$E_t(z,t) = T(z)\exp^{i(\omega t+\beta z)} \quad (2)$$

Where z is the direction along which wave propagates, w is frequency, β is wave propagation constant and t is the time. For forward as well as backward propagating waves which enters in the grating boundary condition is given as, T(0)=T0 and R(L)=RL, substitute these value in (1) and (2),

$$r(z) = R(z)\exp^{-i\beta z} \quad (3)$$

$$t(z) = T(z)\exp^{i\beta z} \quad (4)$$

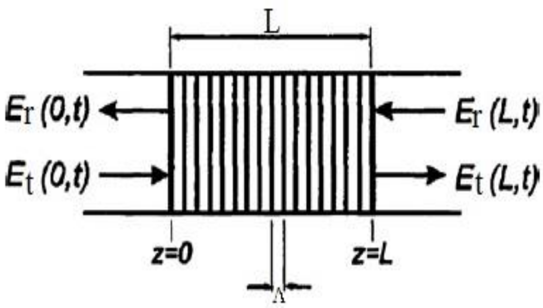

Fig 2 Wave Propagation in Fiber Grating

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Reflected and transmitted wave in scattering matrix can be given as,

$$\begin{bmatrix} r(0) \\ t(L) \end{bmatrix} = \begin{pmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{pmatrix} \begin{bmatrix} r(L) \\ t(0) \end{bmatrix} \quad (5)$$

Substituting the values of r(L) and t(0) in (5), scattering parameters can be given as,

$$S_{11} = S_{22} = \frac{tse^{-iL\beta_0}}{-\Delta\beta\sinh(sL) + is\cosh(sL)} \quad (6)$$

$$S_{12} = \frac{k}{k^*} S_{21} e^{2iL\beta_0} = \frac{k\sinh(sL)}{-\Delta\beta\sinh(sL) + is\cosh(sL)} \quad (7)$$

Transfer matrix for the given grating can be written as,

$$\begin{bmatrix} r(0) \\ t(0) \end{bmatrix} = \begin{pmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{pmatrix} \begin{bmatrix} r(L) \\ t(L) \end{bmatrix} \quad (8)$$

Values of transfer matrix coefficients are given by [7],

$$T_{11} = T_{22}^* = \frac{\Delta\beta\sinh(sL) + is\cosh(sL)}{is} e^{-iL\beta_0} \quad (9)$$

$$T_{12} = T_{21}^* = \frac{k\sinh(sL)}{is} e^{-iL\beta_0} \quad (10)$$

This transfer matrix approach is the best approach for fiber Bragg grating modeling because of simplicity. One can divide the full long length grating into equal section for better understanding and for the sake of reduced length. Reflectivity R of grating is given by,

$$R(L,\lambda) = \frac{k^2\sinh^2(sL)}{\Delta\beta^2\sinh^2(sL) + k^2\cosh^2(sL)} \quad (11)$$

Here k is coupling coefficient, Δβ is detuning factor and $s=\sqrt{(k^2-\Delta\beta^2)}$ [6].

B. Dispersion Compensation

Dispersion in optical fiber is mainly caused by the delay in the system. Group delay of the system is given as [8],

$$T_g = 1/v_g = d\theta_p / d\omega \quad (12)$$

Where v_g is group velocity and θ_p is phase. Dispersion of optical fiber is directly proportional to the group delay and inversely proportional to the bandwidth of the reflected signal (FWHM). Dispersion coefficient (D) is given by [8],

$$D = \Delta T_g / \Delta\lambda_{BW} \quad (13)$$

III. RESULT AND DISCUSSION

In this study 3 different types of apodization functions have been used named: Cosine, Raised Cosine, Tanh and results of these are compared. Table 1 and Table 2 having the values of dispersion (ps/nm) for minimum length (1500µm) and maximum length (5000µm) respectively. Later different graphs have been included for the sake of illustration of dispersion values and also for the comparison. Simulation shows that as length of the grating is increased delay ripples of the system are reduced. As the delay ripples are reduced, dispersion curve have flat top band at center wavelength. It is clearly depicted from the graphs that Tanh shading function shows the best compensation of the dispersion and it is also visible that as the length of the grating is increased more compensation has been achieved. Cosine function have more negative dispersion but same as uniform grating problem it has some side lobes which are not desirable.

One more parameter which affects the results significantly is refractive index of polymer and is clearly seen in results. As the refractive index of polymer is increased the negative dispersion through the grating is reduced. So to reduce dispersion in any optical link it is desirable to put an apodization grating which have length at least more than 5mm whereas the coating on the grating must have lower refractive index. Figure 3-8 shows the dispersion characteristics for different shading functions.

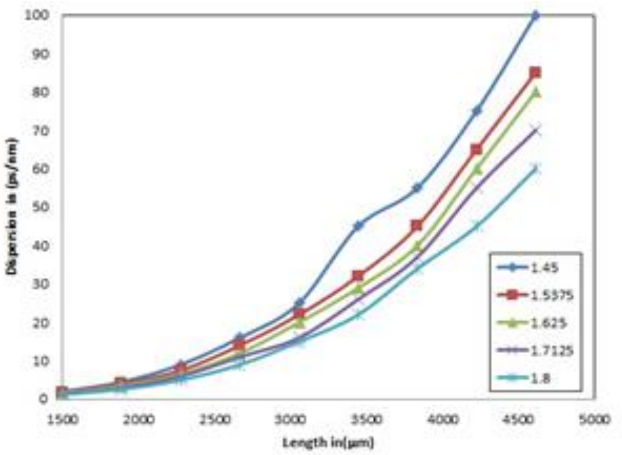

Fig 3 Dispersion in Cosine Function with Gaussian index

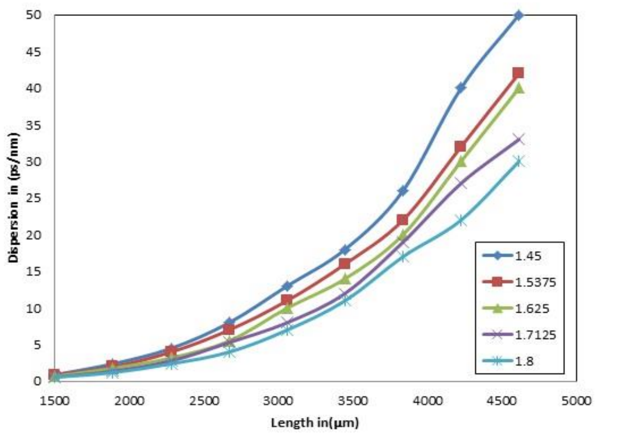

Fig 4 Dispersion in R. Cosine Function with Gaussian index.

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Table I DISPERSION (ps/nm) FOR GRATING LENGTH (1500µm)

Refractive Index	Apodization shading function					
	Gaussian function			Step function		
	Cosine	R. cosine	Tanh	Cosine	R. cosine	Tanh
1.4500	1.90	0.95	1.25	3.00	1.40	1.65
1.5375	1.70	0.90	1.05	2.40	1.15	1.50
1.6250	1.50	0.75	0.95	2.10	1.00	1.20
1.7125	1.20	0.60	0.75	1.80	0.85	1.10
1.800	1.10	0.55	0.55	1.60	0.80	0.95

Table II. DISPERSION (ps/nm) FOR GRATING LENGTH (5000µm)

Refractive Index	Apodization shading function					
	Gaussian function			Step function		
	Cosine	R. cosine	Tanh	Cosine	R. cosine	Tanh
1.4500	130	65	75	170	80	100
1.5375	110	57	70	150	70	90
1.6250	100	52	60	130	65	80
1.7125	90	45	55	120	55	75
1.800	80	40	50	100	50	65

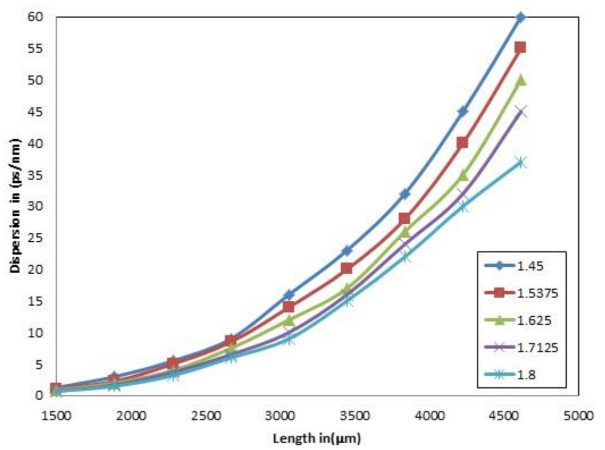

Fig 5 Dispersion in Tanh Function with Gaussian index

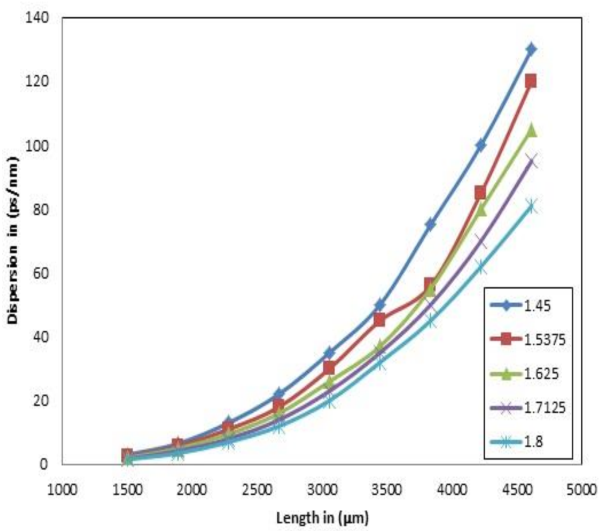

Fig 6 Dispersion in Cosine Function with Step Index

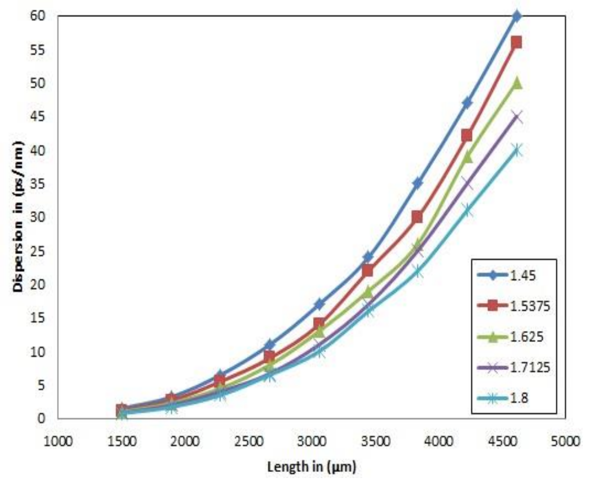

Fig 7 Dispersion in R.Cosine Function with Step Index

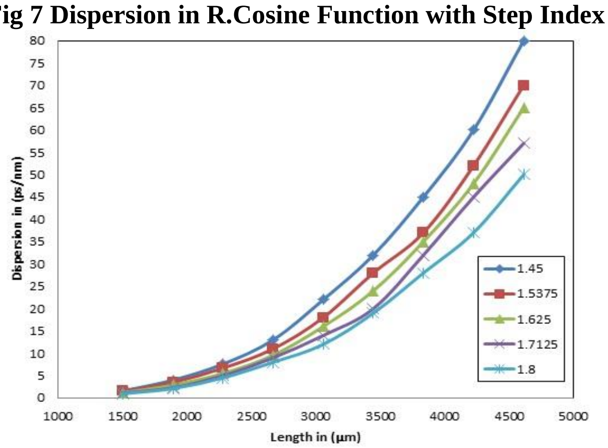

Fig 8 Dispersion in Tanh Function with Step Index

IV. CONCLUSION

Simulation result shows that grating length plays an important role for dispersion compensation.

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As well as polymer coating made grating more sensitive and affects the dispersion in optical link. From the results it is clear that different apodization function affects the dispersion differently. From all the shading functions Tanh function gives the best characteristics.

Using Tanh function with lower refractive index coated we have got the dispersion up to 100 ps/nm with step index profile. This study also depicts that Gaussian index profile is better than step index profile for sensing but for dispersion compensation step index profile is better. Consequently, we can say that polymer coated apodization grating with grating length 5000μm or greater is a good solution of dispersion problem in optical link.

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AUTHOR PROFILE

Sajal Agarwal, full time M.Tech scholar of SVNIT Surat, has completed her B.Tech in Electronics and Communication from SRMS, Uttar Pradesh Technical University, Bareilly. She has 2 year of experience as a lecturer. She has published 2 conference research papers in international conferences.

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