VOL. 17, NO. 19, OCTOBER 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

EFFECT OF THE APODIZATION OF THE SHIFT PERIODIC BRAGG LATTICE ON THE POLARIZATION-MODE DISPERSION

Sanida Yessenbek[1], Nazym Kussambayeva[2], Abdurazak Kassimov[1] and Kuanyshbek Abdurazak[1]
[1]Almaty University of Power Engineering and Telecommunications, Almaty, Kazakhstan
[2]Academy of logistics and transport, Almaty, Kazakhstan
E-Mail: sanida.y.y@gmail.com

ABSTRACT

This article discusses the signal delay during transmission over a fiber-optic communication line and ways to reduce group delays at high transmission speeds using Bragg gratings. The contradiction between the need to transmit signals over fiber-optic communication lines and the resulting dispersion and group delay gives rise to the problem of developing the necessary calculation of the parameters of Bragg grids. The study aims to reduce the variance by determining the corresponding parameters of Bragg's lattice. There are several structures of fiber-optic Bragg gratings, for example, short-period and long-period gratings, slanted gratings, and alternating-period gratings with variable chirps. Variable-period gratings are used in optical networks, mainly to compensate for dispersion. The production of changeable-period (chirp) gratings consists of the narrowing and bending of the optical fiber during the application process and the linear stretching of the phase mask obtained by heating. In the production of the grid, chirp phase masks with a variable period are also used.

Keywords: dispersion, distortion, optical fiber, chirp, Bragg gratings, modeling.

INTRODUCTION

Polarization-mode dispersion (PMD) is the main property of single-mode fibers that affect the data transfer rate.

PMD occurs due to different energy propagation rates of the same wavelength, but different polarizations with perpendicular axes (shown in the diagram below).

The main causes of PMD are the non-roundness of the core and the effect of external influences on the fiber (macro-bending, micro-bending, twisting, and temperature changes).

Figure-1. PMD effect in optical fiber (differential group delay).

Concerning PMD, such a concept as the average value of the differential group delays (DGD) is used and is expressed in picoseconds (ps). It can also be used as the PMD coefficient, which is associated with the square root of the distance and is expressed in ps/√km [1, 2, 3].

PMD (denoted as DGD) extends the transmission pulse when transmitting over the fiber. This phenomenon introduces distortion, increasing the bit error rate (BER) of the optical system.

The impact of PMD limits the communication transfer rate. It is important to consider the PMD value of the fiber to calculate the transmission rate limits of the optical channel.

The study aims to compensate (reduce) the dispersion that occurs in fiber-optic communication lines by determining the corresponding parameters of Bragg grids.

The apodization function and the choice of parameters have a significant effect on the reflective compensation properties of Bragg gratings. Apodization is used to smooth out the sidebands of the reflection spectrum, which leads to a decrease in the dispersion but also has important values for the amplitude of the signal reflected from the apodized Bragg grating. Thus, the optimal apodization profile should have a favorable ratio to maximum sideband smoothing and maximum amplitude reflectivity. Selecting the appropriate apodization function can significantly change the characteristics of the reflected light signal, i.e., power and dispersion compensation, and reduce the cost of manufacturing the grating. The larger the chirp grid, as a rule, the longer it is, therefore, the more difficult it is to implement, which raises the price of such a solution. In practice, lattices are used from several mm to several cm. Therefore, it is reasonable to assume that the selection of the function, as well as the selection of the appropriate apodization parameters for controlling this function, is necessary to obtain optimal results.

RESEARCH METHODS

The apodization profiles presented by Sher Shermin A. Khan and Md. S. Islam [1] was analyzed to select the apodization function, and control their parameters, to improve the reflection coefficient of one-period Bragg lattices. The apodization functions take the following form [1]:

Tangent:

$$T(z) = 1 + \tanh\left[T\left(1 - 2\left(\frac{z}{L_g}\right)^a\right)\right] \quad (1)$$

VOL. 17, NO. 19, OCTOBER 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Hamming:

$$T(z) = \frac{1+H\cos\left(\frac{2\lambda z}{l}\right)}{1+H} \tag{2}$$

Gauss:

$$T(z) = exp\left[-G\left(\frac{z}{L_g}\right)^2\right] \tag{3}$$

Cos:

$$T(z) = cos^A\left(\frac{\pi}{L_g}z\right) \tag{4}$$

Cauchy:

$$T(z) = \frac{1-\left(\frac{2z}{L_g}\right)^2}{1-\left(\frac{2Bz}{L_g}\right)^2} \tag{5}$$

Sinc:

$$T(z) = sinc^X\left(\left|\frac{2\left(z-\frac{L_g}{2}\right)}{L_g}\right|^Y\right) \tag{6}$$

The parameters α, H, G, A, B and Y were used to model the apodization profiles to get the best option, and their ranges are represented as follows:

$\alpha, T \in [1,4]; H \in [0.1,0.9];$
$G \in [2,15]; A \in [0.15,2];$
$B \in [0.2,0.95]; X, Y \in [1,6].$

The analysis of the reflected spectra was carried out using simulations, and it was proved that the best-reflecting spectrum has a CFBG lattice apodized by the Gauss and SINC profile [1]. The compensation properties of CFBG meshes apodized by these profiles have not been analyzed here, so the results of modeling apodized Bragg gratings by Gauss and SINC profiles and their effect on reflection, variance, and group delay will be presented in the future [4-6].

The constructed mathematical model in the MATLAB software environment allowed modeling of the reflecting spectrum, dispersion, and group delay in the analyzed Bragg lattice. Below are the results of modeling a lattice with a constant period and a length of 2 cm without apodization for a narrow wavelength range from 1549 nm to 1556 nm (λ_D=1550 nm, n_{eff}= 1.45, the number of lattice sections M=200, v=1), which are shown in Figures 2, 3, 4.

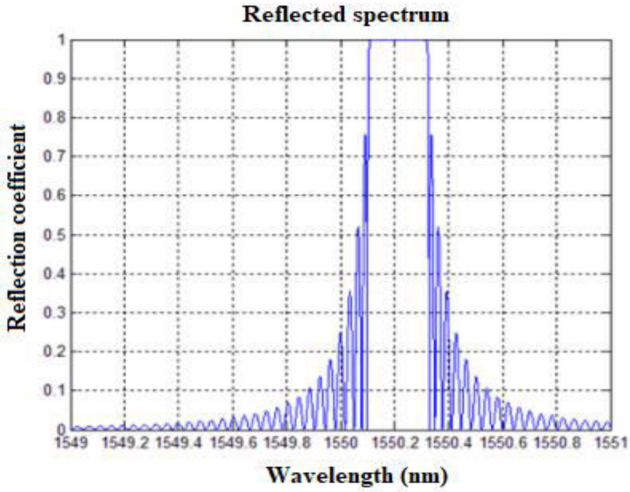

Figure-2. Reflected spectrum of the FBG Bragg lattice, 2 cm long, n_{eff}=1.45 (data obtained from the model, executed in the MATLAB program).

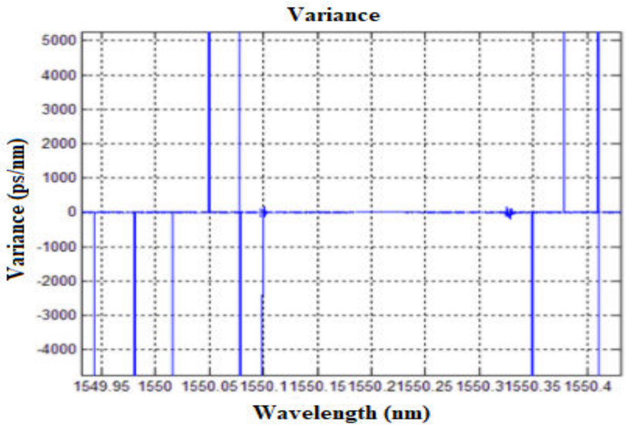

Figure-3. FBG dispersion around the Bragg lattice wavelength, 2 cm long, n_{eff}=1.45 (data obtained from the model, executed in the MATLAB program).

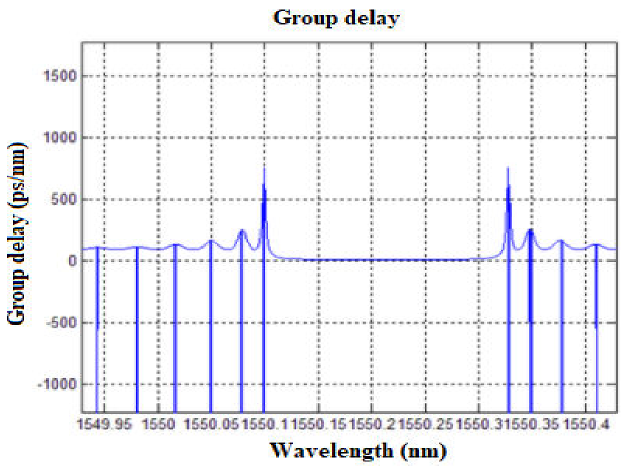

Figure-4. Group delay FBG around the Bragg lattice wavelength, 2 cm long, n_{eff}=1.45 (data obtained from the model, executed in the MATLAB program).

CONCLUSIONS

The reflection strength of the modeled Bragg lattice takes 100% of the result, so the lattice can be called strong. The slope of the line depends on the group delay, i.e. a constant function, which means that all waves reflected from the grating will experience an equal group delay.

For the same grid parameters, but included with the chip ($\delta n_{eff} = 2e^{-4}$, $\phi = 0.3e^{-7}$), the view of the reflecting spectrum, group delay, and variance are presented in Figures 5, 6, and 7.

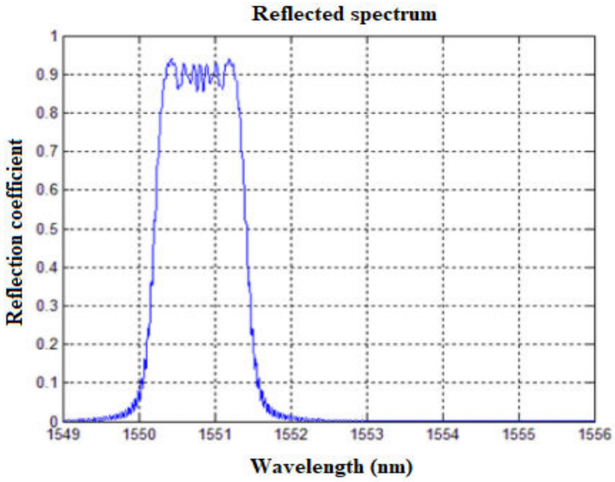

Figure-5. Reflected spectrum of CFBG, grating length 2 cm long, $\delta n_{eff} = 2e^{-4}$, $\phi = 0.3e^{-7}$ (data obtained from the model, executed in the MATLAB program).

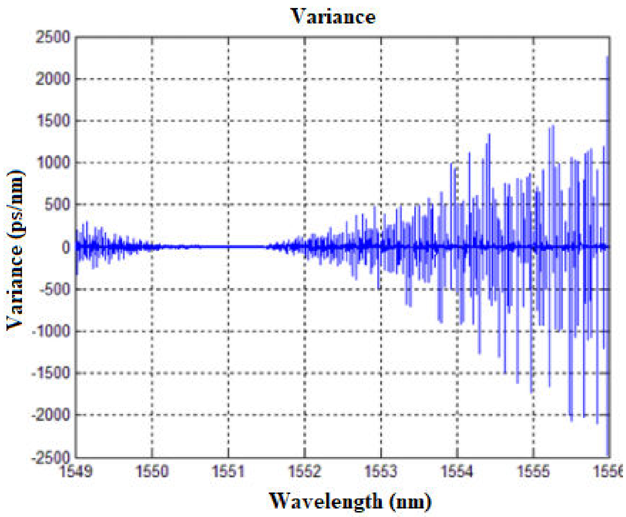

Figure-6. CFBG dispersion grid length 2 cm long, $\delta n_{eff} = 2e^{-4}$, $\phi = 0.3e^{-7}$ (data obtained from the model, executed in the MATLAB program).

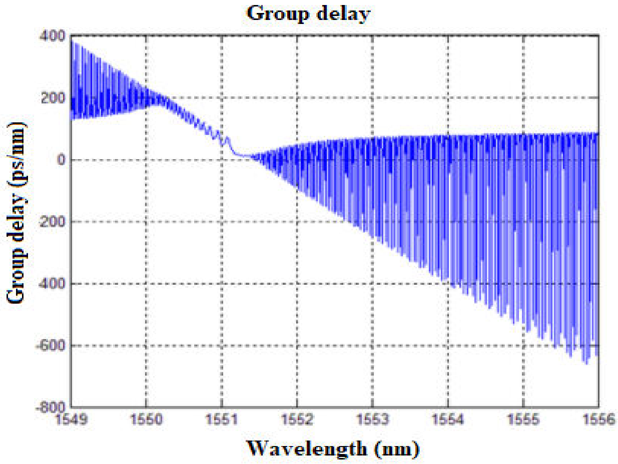

Figure-7. Group delays CFBG, grid length 2 cm long, $\delta n_{eff} = 2e^{-4}$, $\phi = 0.3e^{-7}$ (data obtained from the model, executed in the MATLAB program).

SUMMARY

The introduced chirps for the same grid length (2 cm) cause a decrease in reflectivity but also brought the desired effect, which is the slope of the group delay (Figure-7). During signal transmission, longer waves experience a greater positive group delay than waves with a shorter length. The slope of the group delay means that the reflected waves from the long-length Bragg grids experience less positive delay than the shorter-length waves, and this is the opposite in signal transmission. Thus, the blurred (fuzzy) pulse returns to its original shape, resulting in dispersion compensation for more than one wavelength.

REFERENCES

[1] Wójcik W. 2011. Systemy teleinformatyczne, Politechnika Lubelska, ISBN: 978-83-62596-64-5, Lublin, Poland.

[2] Khan S., Islam S. 2012. Determination of the Best Apodization Function and Grating Length of Linearly Chirped Fiber Bragg Grating for Dispersion Compensation, Bangladesh University of Engineering and Technology, Bangladesh. Journal Communications, Russia.

[3] Vasileva S. A., Medvedkov O. I., Bojkov A. S., Korolev I. G., Dianov E. M. 2006. Modifikatsiya poley obolochechnykh mod pri rastvorenii H2 v volokonnykh svetovodakh i yeye vliyaniye na spektral'nyye kharakteristiki dlinnoperiodnykh reshotok, Kvantovaya elektroniki. 36, 1, 61-66 s., Russia.

[4] Harasim D., Kashaganova G., Kussambayeva N. 2015. Accuracy improvement of Fiber Bragg Grating

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

peak wavelength demodulation using wavelet transform and various center wavelength detection algorithms. 9th International Conference "New Electrical and Electronic Technologies and their Industrial Implementation" NEET 2015, which will be held on June 23-26, 2015 in Zakopane, Poland (Scopus).

[5] Alexander V. Osadchuk, Iaroslav A. Osadchuk, Andrzej Smolarz, N. Kussambayeva. 2015. The pressure transducer of the based on reactive properties of transistor structure with negative resistance. Optical Fibers and Their Applications [9816-72] Lublin-Naleczow, Poland (Scopus).

[6] Zabolotna N. I., Pavlov S. V., Radchenko K. O., Stasenko V. A., Wójcik W., Kussambayeva N. 2015. Diagnostic efficiency of Mueller - matrix polarization reconstruction system of the phase structure of liver tissue. Optical Fibers and Their Applications. [9816-48]. Lublin-Naleczow, Poland (Scopus).

[7] Sanida Yessenbek, Abdurazak Kasymov, Salima Nugmanova and Lidiya Taimuratova. 2020. New Technology of Data Transmission: Li-Fi, Arpn Journal of Engineering and Applied Sciences, 15(24): 3001-3005, (Scopus).

[8] K. M. Makhanov, K. T. Ermaganbetov, L. V. Chirkova, A. O. Kassimov, M. A. Maukebayeva, E. T. Arinova, K. M. Turdybekova, Noise immunity of radio and mobile communications, Bulletin of Karaganda University Series Physics. No. 4(92)/2018 October-November-December December 30, 2018.

[9] Sansyzbay, K. M., Bakhtiyarova, Y. A., Kuandykov, A. A., Vlasenko, S. V., Mamyrbayev, O. Z. H. 2020. Radio communication channel interaction method, maintaining train performance information security, Journal of Theoretical and Applied Information Technology, 98(6): 957-969, (Scopus).

[10] Altayeva A., Baisholanova K., Lyailya Tukenova, Bayan Abduraimova, Marat Nurtas, Zharasbek Baishemirov, Sanida Yessenbek, Bauyrzhan Omarov, B. Omarov. 2021. Towards Smart Building: Exploring of Indoor Microclimate Comfort Level Thermal Processes. Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 12608 LNCS, стр. 59-67.