N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278 **https://doi.org/10.32014/2018.2518-170X.44**
Volume 5, Number 431 (2018), 137 – 152

UDC 681.7.068

W. Wojcik[1], A. U. Kalizhanova[2, 3], G. B. Kashaganova[2, 4], T. S. Kartbayev[3, 5], A. A. Doszhanova[5], F. U. Malikova[5], A. A. Taurbekova[5]

[1]Lublin technology university, Poland,
[2]Institute of Information and Computational Technologies CS MES RK, Kazakhstan, Almaty, Kazakhstan,
[3]Al-Farabi Kazakh National University, Almaty, Kazakhstan,
[4]Kazakh-American University, Kazakhstan,
[5]Almaty University of Power Engineering and Telecommunications, Kazakhstan.
E-mail: waldemar.wojcik@pollub.pl, kalizhanova_aliya@mail.ru, guljan_k70@mail.ru, kartbaev_t@mail.ru, d_alia.81@mail.ru, feruza-malikova@mail.ru, ainura_071@mail.ru

RESEARCH AND OPTIMIZATION OF BRAGG FIBER-OPTIC PARAMETERS

Abstract. Fiber Bragg Gratings (FBG) are widely used in different areas of the state-of-the-art fiber optics. Every task imposes specified requirements to the FBG spectral characteristics, which are scheduled at the gratings manufacturing stage.

Manufacturing and using the Bragg fiber-optic gratings is impossible without measuring their characteristics at every stage of manufacturing the gratings themselves and devices on their basis. To select FBG's optimal parameter we will compare the parameter SGW with several different the most widely used apodization functions. Upon manufacturing the FBG there applied strict requirements to their parameters. Recording or manufacturing the Bragg fiber gratings might be classified according to the type of the laser being used, radiation wave length, recording techniques, irradiation material and grating type.

The article is dedicated to the techniques of computing and measuring the FBG's principal parameters; it is necessary to define optimal parameters of the characteristics for the grating quality operation.

Keywords: Bragg fiber gratings, mathematical model, measurement methods, optimal parameters, spectral characteristics.

Introduction. Let's choose the apodized FBG as an example. Bragg's apodized gratings. Bragg's homogeneous gratings spectrum, being an addition to the base peak, also has undesirable high indirect side lobes, which generate cross-interference between neighboring channels.

FBG definite applications impose certain requirements to the reflectance spectrum form, which is specified by the grating refractive index profile, one of the common requirements to them is absence of side lobes. The phenomenon thereof is undesirable, because it strives to the wave liquidation.

Appearance of side lobes is connected with the fact that the Bragg grating structure, which has a finite length, quickly starts and finishes. It is of paramount importance to eliminate those side lobes reflective factors and bring it to the minimum. The most widely used method to eliminate the side lobes is the Bragg fiber gratings apodization. It means, that the reflection coefficient amplitude is modulated in such a manner, that it increases and decreases gradually in compliance with the applied function. Thus, the apodization is a highly valued instrument for smoothing the Bragg grating reflection spectrum, but it also influences at the gratings dispersion characteristics. Apodization might be reached by means of UV light action .

As it has been described above, an important element, defining the Bragg gratings quality is the size of the so-called side lobes, occurring in their spectral characteristics. In order to specify the gratings' quality let's introduce a new parameter which is called S_{GW}.

Bragg's apodized gratings. To select FBG's optimal parameter we will compare the parameter S_{GW} with several different the most widely used apodization functions. Upon manufacturing the FBG there applied strict requirements to their parameters. Paramount parameters of the fiber gratings is distribution of $\Delta n(x)$ reflection factor modulation amplitude and the law of the grating change period $\Delta\Lambda(x)$ along the fiber longitudinal axis. Those parameters deviation from the demanded values brings to worsening the FBG spectral characteristics.

Recording or manufacturing the Bragg fiber gratings might be classified according to the type of the laser being used, radiation wave length, recording techniques, irradiation material and grating type [1].

Lasers, used for FBG recording might be both uninterrupted and impulse with radiation wave length from intra-red (IR) to ultraviolet (UV) spectrum range. Difference data specifies spatial and time coherence of optical radiation sources being used for recording, which in its turn defines the selection of FBG recording appropriate method. Among the base methods of FBG recording there is pointed out the phase mask method (PhM), interferometer method and step-by-step approach.

Phase mask method is the simplest and most effective as it allows excluding from the recording scheme the expensive vibro-isolating tables, vibro-isolated foundation and footings, necessary upon multi-pulsed recording, and at that, receiving gratings with required characteristics (figure 1). At the first stage the phase mask is formed by means of flashing the quartz plate covered with photoresist material. Flashing is fulfilled either with an electronic beam, controlled by a computer, or by forming interference image mask on the photoresist material surface. Only after the flashed plate etching there is formed the mask with necessary period Λ_M.

At the second stage there is formed the diffraction grating in the fiber [2-5]. For that purpose, the ultraviolet beam from the irradiation source is directed on the phase mask surface, light diffraction, on which there applied a number of light beams of different orders.

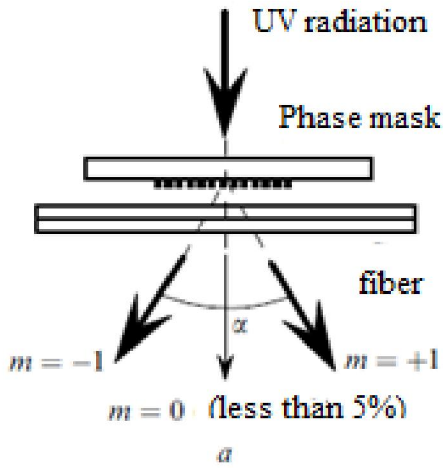

Figure 1 – Scheme of FBG recording by means of phase mask (direct recording)

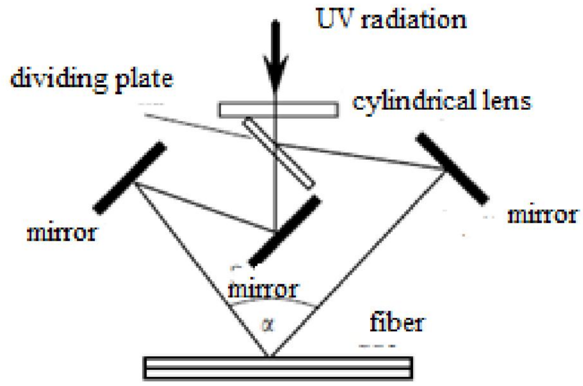

Figure 2 – Scheme of FBG recording in interferometer with beam amplitude separation of UV radiation

In virtue of FBG short period they are manufactured, as a rule, using interference methods (figure 2). As the necessary grating structure recording process might last a few tens of minutes, the quality grating manufacturing is possible at interference picture high stability.

Such conditions might be secured only under appropriate spatial and temporal coherence of photo-inducing radiation, which anticipates strict requirements to radiation sources for FBG recording.

One more recording method is the step-by-step approach. This method's attractiveness in that it eliminates the necessity of using the phase mask and allows recording the Bragg gratings with a resonance at any wave length [6].

Apart from that, the method thereof allows (Figure 3) forming any profiles of grating's separate slit and total distribution of the amplitude of directed Refraction Index (RI) in whole, as well changing the period along the grating length [7-9], i.e., creating the chip FBG without using phase mask with the period variable along the length.

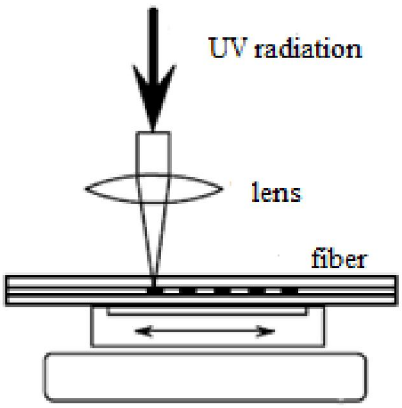

Figure 3 – Scheme of FBG recording by means of step-by-step approach

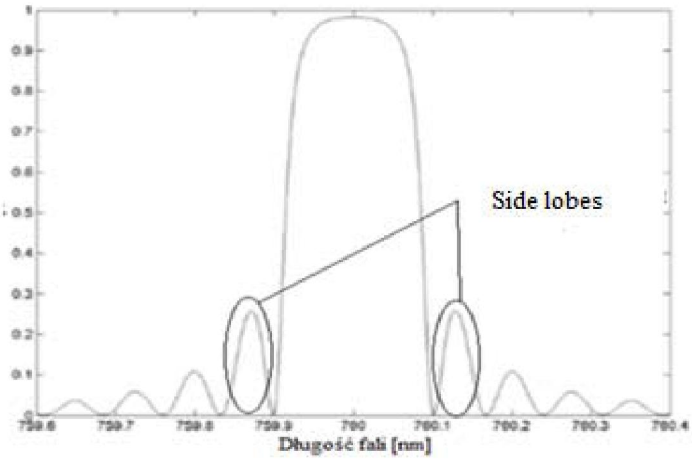

Figure 4 – Reflection spectrum of Bragg fiber grating

Growing interest to the Bragg optic fiber gratings results in occurrence of their multiple varieties.

The most important property of the Bragg fiber gratings is the narrow-band optical radiation, the relative spectral width of which might constitute 10^{-6} and less. Fiber gratings advantages comparing to the alternative technologies (for instance, interference mirrors and volume gratings) are obvious: the wide variety of being received spectral and dispersive characteristics, most of which can be implemented only based on the fiber gratings refraction factor; completely fiber fulfillment; low optical losses; relative ease of fabrication and others [10-12].

The Bragg's ideal fiber grating functioning is passing the beam crosswise, excluding passing the wave's one length infinitely thin. Only the wave's lengths, satisfying Bragg's condition will be reflected and spread out in opposite direction. Sure enough, transmission and characteristics of reflection are distorted by the so called side lobes. This phenomenon, as it is shown in figure 4, is undesirable, as it strives to the wave liquidation [13-16].

It is very important to eliminate reflecting power of the side lobes thereof and lead them to the minimum. The most widely used method for eliminating the side lobes is Bragg fiber grating apodization [17]. It means, that refraction index amplitude is modulated in such a manner, that it grows and decreases in compliance with the applied function [18]. Thus, apodization is a valuable tool for smoothing the Bragg grating reflection spectrum but, as well, influences at grating dispersive characteristics. Apodization can be reached by means of UV-radiation impact.

Figure 5 shows the difference in sizes of the side lobes of Bragg fiber gratings reflection spectrum with apodization and without it.

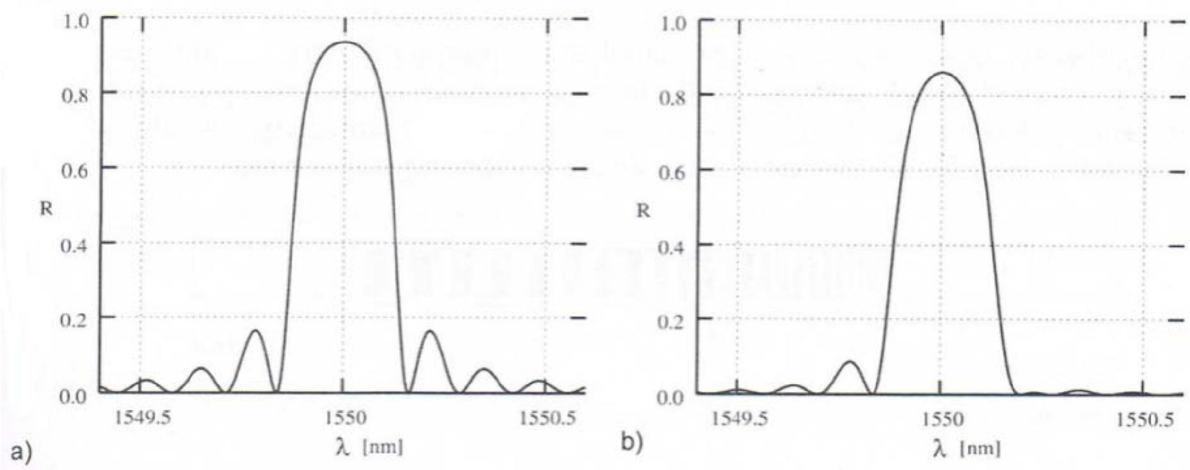

Figure 5 – Reflection spectrum of Bragg fiber grating: a) without apodization, b) apodized

In case of apodized Bragg gratings the amplitude modulation increases and gradually decreases. Under amplitude modulation method the ups and downs speed occurs along the fiber axis and depends on the apodization function.

The technology thereof has opened new possibilities for creating and optimizing the fiber-optic elements, in particular, the filters, dispersion compensation modules, lasers with the distributed feedback and fiber-optic sensors for different parameters measuring.

The most widely used method for eliminating the side lobes is the Bragg fiber gratings apodization.

Side lobes suppression is reached at the expense of securing the smooth modulation amplitude change and leveling the average value of the directed refraction index along the grating, the so called grating profile apodization.

There exist a lot of refraction index profiles, which allow receiving the FBG spectrum with suppressed side lobes [19], at that, practical implementation of most of them requires technologically complicated scanning techniques.

Apodization primary functions or apodization profiles and their formulae:

– Gauss function $g(z) = exp\left[-a\left(\frac{z-\frac{L}{2}}{L}\right)^2\right]$;

– Raised sine function $g(z) = sin^2\left(\frac{\pi z}{L}\right)$;

– Sinc function $g(z) = sinc^X\left(\left|\frac{2(z-L/2)}{L}\right|^Y\right)$;

– Tanh function $g(z) = 1 + tanh\left[T\left(1 - 2\left(\frac{z}{L_g}\right)^\alpha\right)\right]$;

– Blackman function $g(z) = 0{,}42 + 0{,}5cos\left(\frac{\pi z}{a}\right) + \frac{2}{25}cos\left(\frac{2\pi z}{a}\right)$;

– Hamming function $g(z) = \frac{1+Hcos\left(\frac{2\lambda z}{l}\right)}{1+H}$;

– Cosine function $g(z) = cos^A\left(\frac{\pi}{L_g}z\right)$;

– Cauchy function $T(z) = \frac{1-\left(\frac{2z}{Lg}\right)^2}{1-\left(\frac{2Bz}{Lg}\right)^2}$.

The most widely applied apodization functions are: Gauss function, Sinc function, Blackman function and Cosine function.

Let's consider the widely used apodization functions and their influence at spectral characteristics of Bragg fiber gratings.

Gauss function is expressed by the formula [20]:

$$g(z) = exp\left[-a\left(\frac{z-\frac{L}{2}}{L}\right)^2\right], \tag{1}$$

Numerical solution

Examples of Gauss profiles for various parameters values a are represented in figures 6–9.

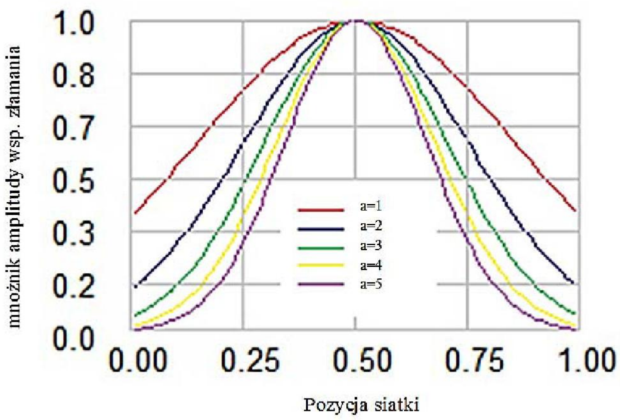

Figure 6 – Gauss apodization profiles for different values of parameter *a*

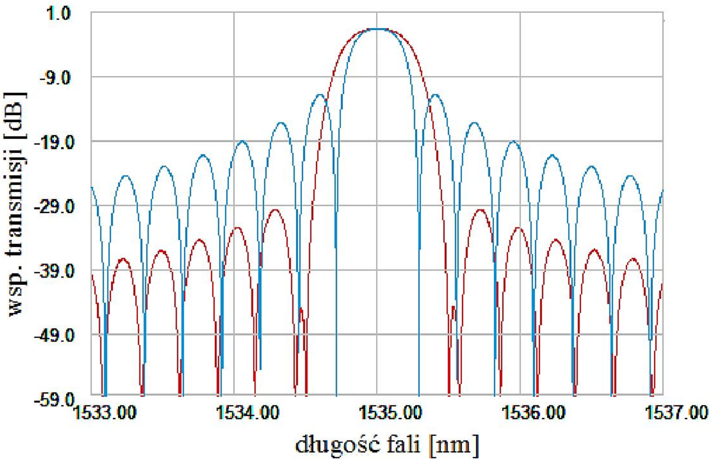

Figure 7 – Comparison of Bragg fiber gratings characteristics without apodization – blue line and apodized Gauss function at a = 2 – red line

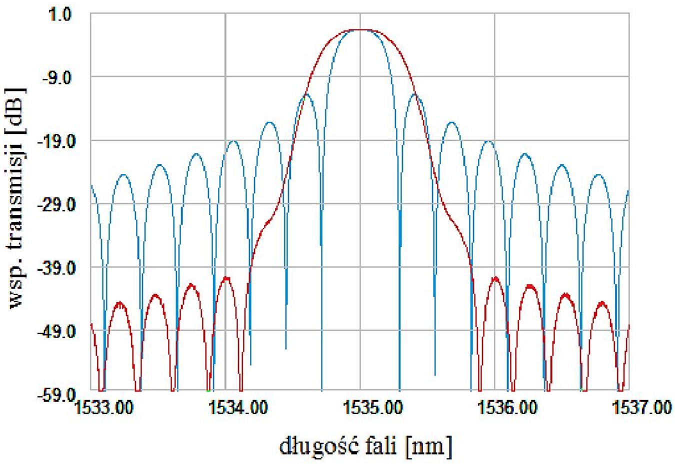

Figure 8 – Comparison of Bragg fiber gratings spectral characteristics without apodization – blue line and apodized Gauss function at a = 3 – red line

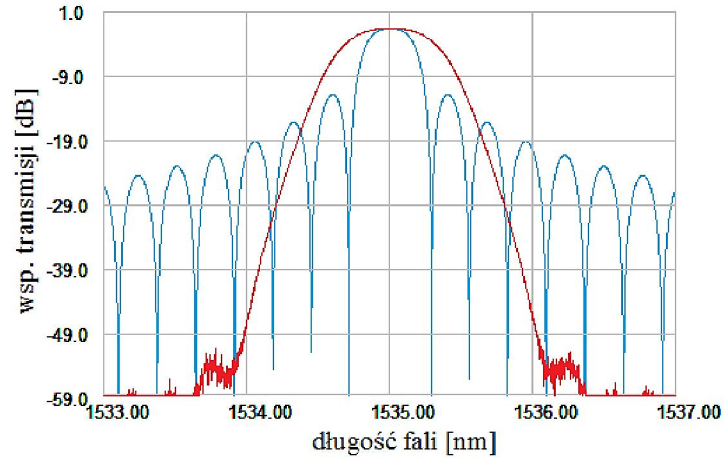

Figure 9 – Comparison of Bragg fiber gratings spectral characteristics without apodization – blue line and apodized Gauss function at a = 5 – red line

Figures 7, 8 and 9 show differences in Bragg fiber gratings spectral characteristics without apodization and with apodization using Gauss function with different values of the parameter a. From the schemes thereof it is seen, that the number of side lobes decreases in apodized Bragg fiber gratings.

Another widely used apodization function is cosine one. The function is expressed by the formula [10]:

$$g(z) = cos^A\left(\frac{\pi}{L_g}z\right), \tag{2}$$

where A is the function parameter. Examples of profiles for different values of the parameter *A* are given in figure 8.

It is clearly seen from the charts that the side lobes are decreased in apodized gratings.

One more function is used for Bragg grating apodization, it is the so called Blackman function. The function is described by the formula [12]:

$$g(z) = 0{,}42 + 0{,}5cos\left(\frac{\pi z}{a}\right) + \frac{2}{25}cos\left(\frac{2\pi z}{a}\right), \tag{3}$$

where a is the function's parameter. Figure 14 shows Blackman function for different values of the parameter a.

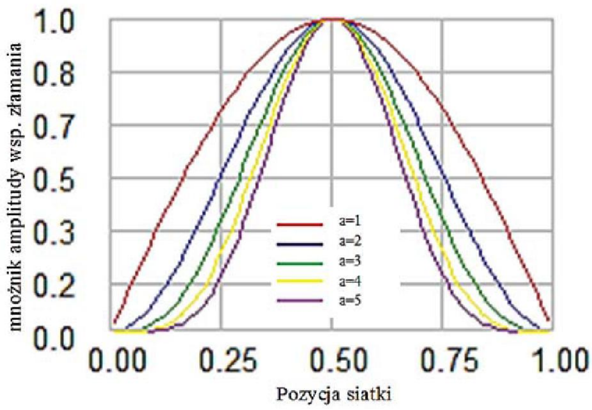

Figure 10 – Cosine apodization function for different values of the parameter A

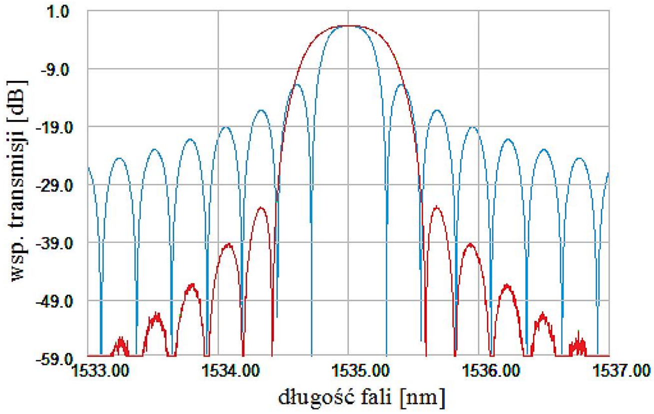

Figure 11 – Comparison of Bragg fiber gratings spectral characteristics without apodization – blue line and apodized cosine function for wsp. A = 2 – red line

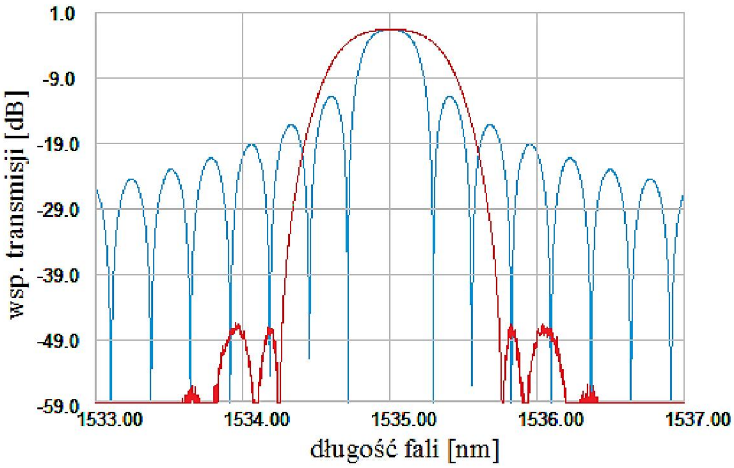

Figure 12 – Comparison of Bragg fiber gratings spectral characteristics without apodization – blue line and apodized cosine function for wsp. A = 3 – red line

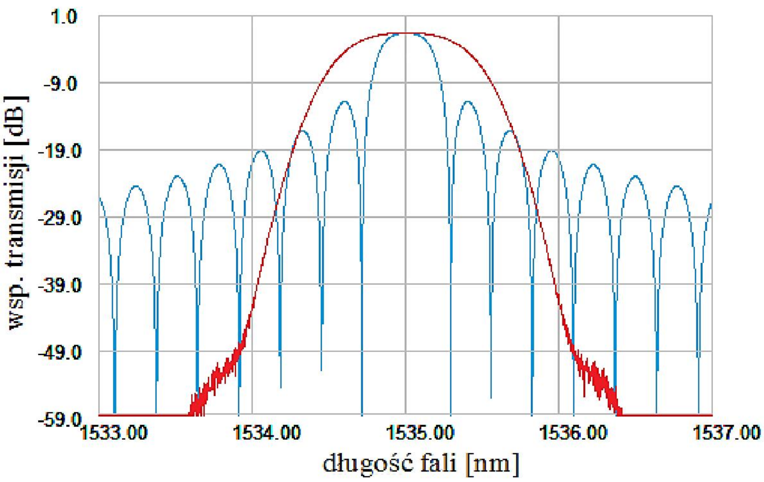

Figure 13 – Comparison of Bragg fiber gratings spectral characteristics without apodization – blue line and apodized cosine function for wsp. A = 5- red line

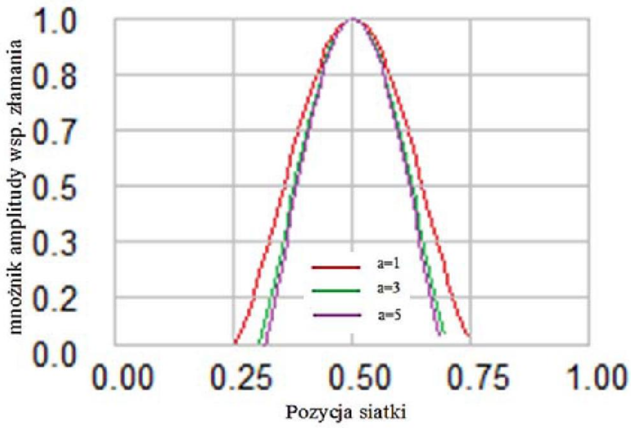

Figure 14 – Blackman apodization function for different values of the parameter *a*

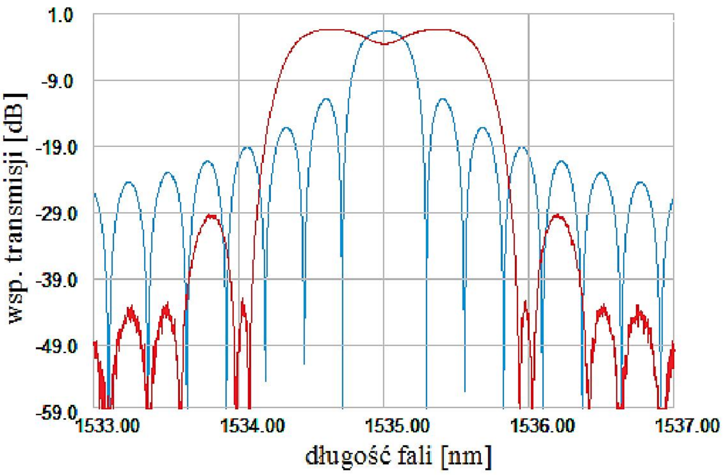

Figure 15– Comparison of Bragg fiber gratings spectral characteristics without apodization – blue line and apodized Blackman function wsp.
a = 2- red line

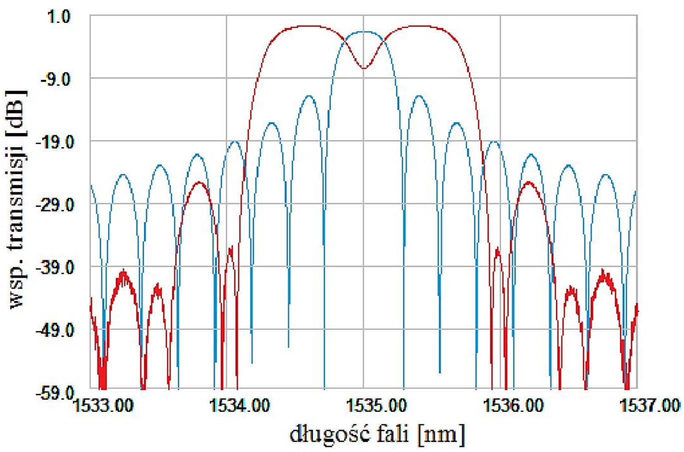

Figure 16 – Comparison of Bragg fiber gratings spectral characteristics without apodization – blue line and apodized Blackman function wsp.
a = 5 – red line

In figure 14, you can see, that Blackman function does not bring to big changes comparing to Gauss function. An important factor in case of applying Blackman apodization function is the occurrence of local minimum, which breaks down the base peak into two parts [13]. Charts 15 and 16 show, that the value rise as well increases the importance of the minimum thereof.

One more is the sine function. This function differs from others by the fact that it has two parameters. The formula describes the function as follows [21]:

$$g(z) = sinc^X \left(\left| \frac{2(z-L/2)}{L} \right|^Y \right), \tag{4}$$

where X and Y are functional parameters.

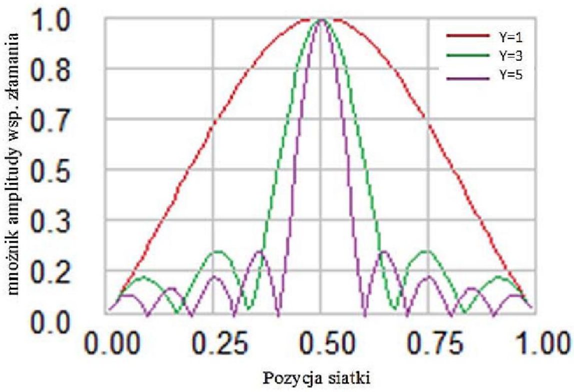

Figure 17 – Sine apodization function for different values of the parameter Y at constant value X=1

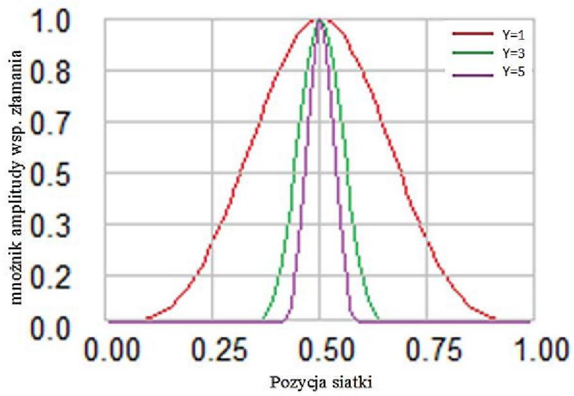

Figure 18 – Sine apodization function for different values of the parameter Y at constant value X=3

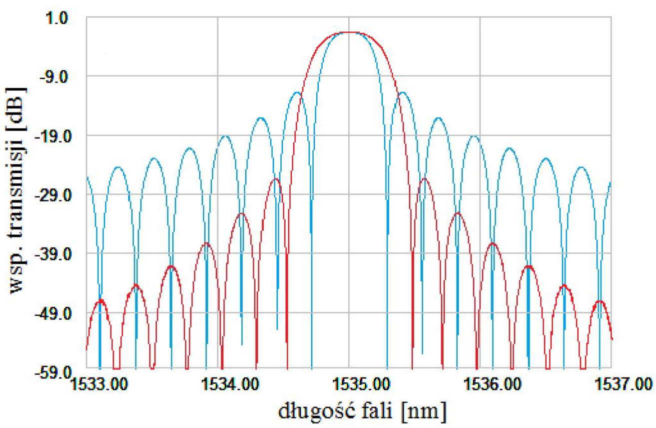

Figure 19 – Comparison of Bragg fiber gratings spectral characteristics without apodization – blue line and apodized sine function for wsp. X=1 and Y=1 – red line

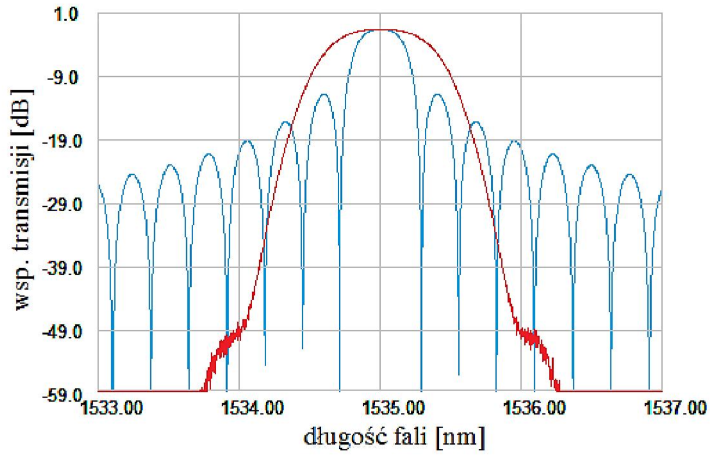

Рисунок 20 – Comparison of Bragg fiber gratings spectral characteristics without apodization – blue line and apodized Blackman function for wsp.
X=3 and Y=1 –red line

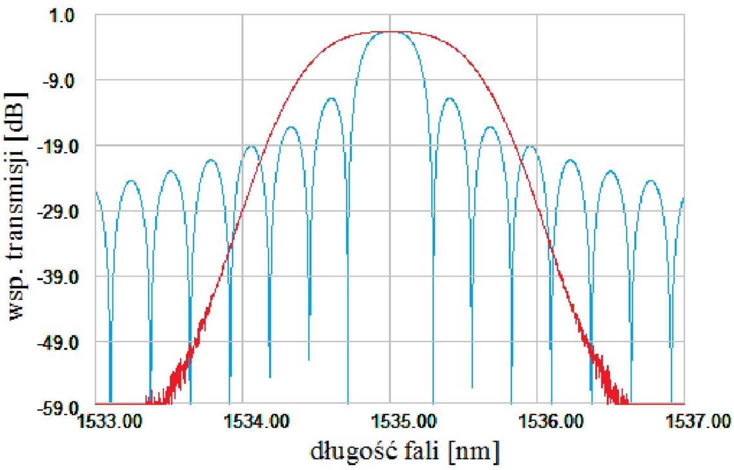

Figure 21 – Comparison of Bragg fiber gratings spectral characteristics without apodization – blue line and apodized sine function for wsp.
X=5 and Y=1 – red line

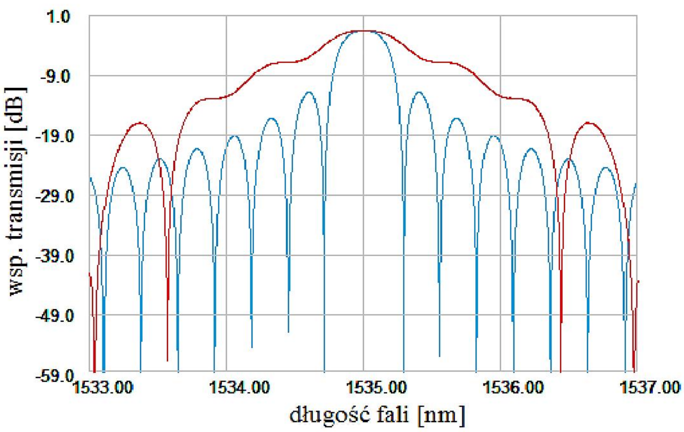

Figure 22 – Comparison of Bragg fiber gratings spectral characteristics without apodization – blue line and apodized sine function for wsp.
X = 1 and Y = 3 – red line

Figures 17 and 18 show, that in a proper way, in virtue of X and Y parameters change, it is possible to get several apodization profiles. At the same time from spectral characteristics charts in the figures 20-22 it is seen, that the side lobes exclude the parameter increase, but they introduce noise characteristics. By contrast, with raising the parameter Y the side lobes become a part of the base peak, which sufficiently distorts the grating characteristics.

It is said above, that the important element defining the Bragg grating quality is the size of the so called side lobes occurring in its spectral characteristics. In order to define the grating quality let's introduce a new parameter which is called S_{GW}. This parameter is the ratio of the base peak power to the peak power of the biggest side lobe occurring in the grating characteristics. It is expressed by the following formula:

$$S_{\mathrm{GW}} = \frac{P_G}{P_W} \tag{5}$$

where P_G is the base peak power; P_W – peak power of the biggest side lobe. Definite Bragg grating characteristics with different Bragg waves and different values of reflection index and various grating lengths. The research assumes apodization of several most widely used functions and apodization functions factors change. Designed half-width and fiber strand width is 20 dB. Figure 23 shows the means of S_{GW} parameter to define capacity maximum peak of the first lobe density. In contrast, Figure 24 shows the case when the higher order nets have the higher peak capacity.

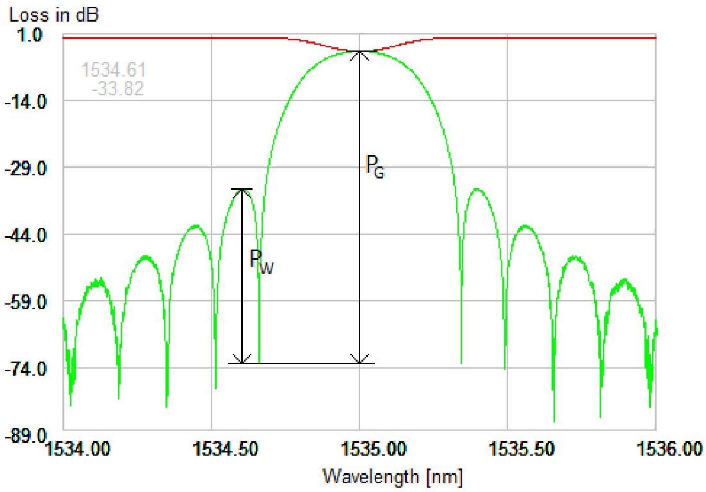

Figure 23 – Technique of defining P_G and P_W, when the first-line peak capacity is high

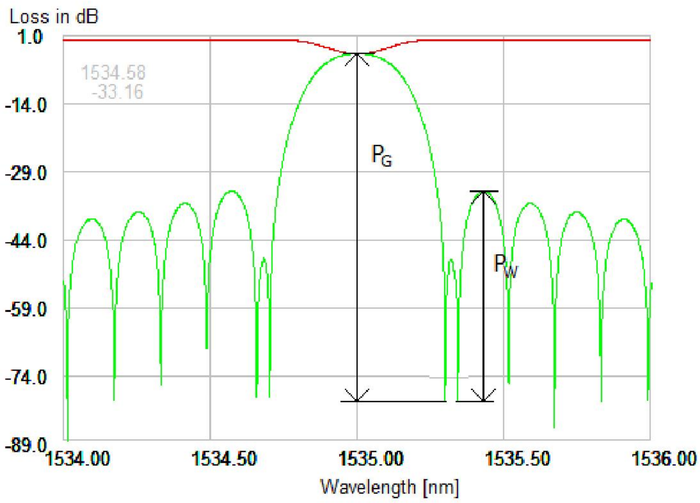

Figure 24 – Technique of defining P_G and P_W,
when the first-line peak capacity is less than the peak capacity of the higher order

Side lobes analysis has been conducted using five base apodization functions In any case you will alter coefficient values of functions and data stored in the table. Modeling has been carried out for the fixed length value L=3mm of the grating and reflection index R=69,8%. Bragg wave length has been set at 1535Nm. Each apodization function is provided with the table and chart of SGW index dependence on the apodization function. Due to the big size of the tables it was decided to show only functions charts in the work herein.
Figure 25 shows interrelation between S_{GW} parameter and Gauss function parameter.

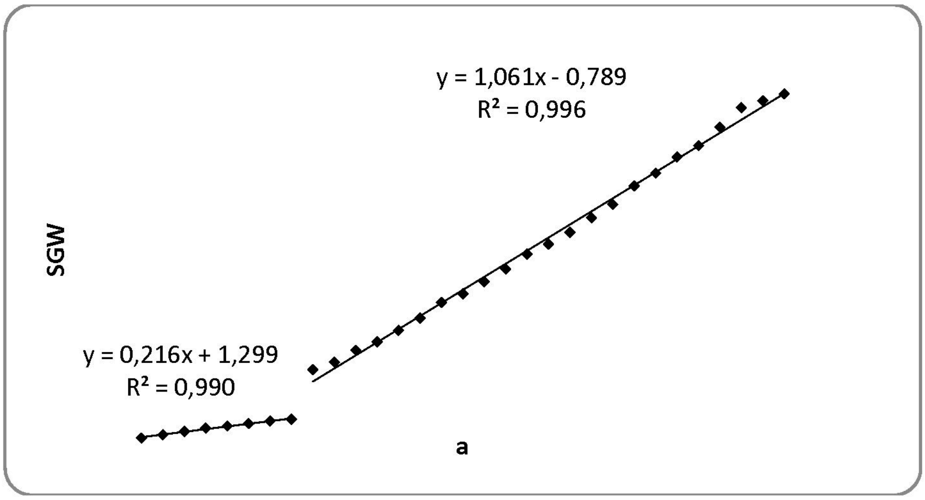

Figure 25 – Chart of the parameter S_{GW} and Gauss function parameter

Figure 25 shows that the chart is broken down into two parts. It is due to the fact, that the parameter a = 2,8 of the first-line side lobes becomes a part of the base peak. The chart shows that the apodized grating peak value is the ultimate of the signal backward reflection. The linear function value is approximated with two functions. First curve:

$$y = 0{,}21x + 1{,}3, \tag{6}$$

Second curve:

$$y = 1{,}06x - 0{,}79. \tag{7}$$

Next function for research is the cosine function.

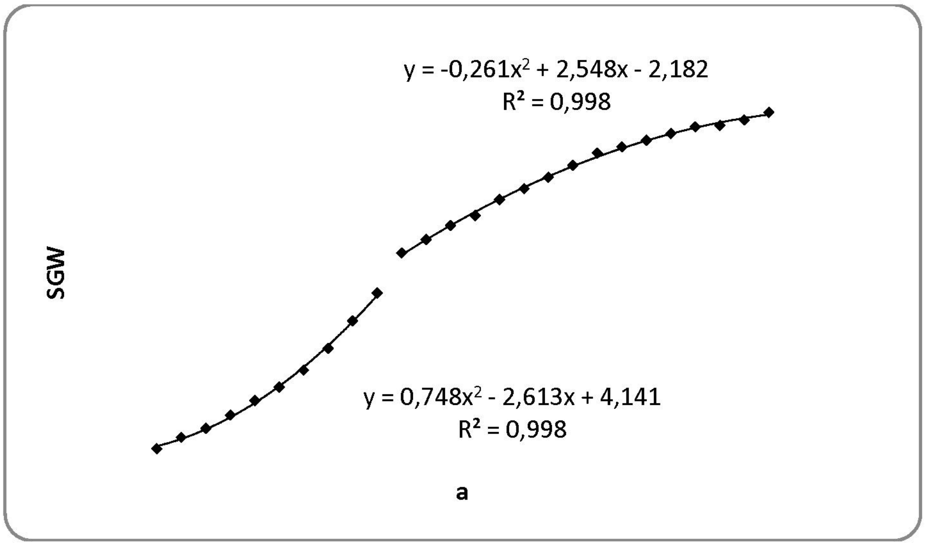

Figure 26 – Chart of S_{GW} parameter and cosine function parameter

Figure 26 shows that the scheme of dependences is broken down into two parts as in case of Gauss function. From the chart it is seen, that the first side lobes are decreased quicker, than the other succeedent. At value a=3, the side lobes of the second order become big.

In the chart it can also be seen, that at parameter increasing the side lobes capacity is decreased slower. At value a=4,5 the side lobes disappear completely. In spite of side lobes disappearance there exists rising noisiness, which distorts the spectrum characteristics. Dots on the chart are approximated by quadratic function.

First curve:

$$y = 0{,}75x^2 - 2{,}61x + 4{,}14, \tag{8}$$

Second curve:

$$y = -0{,}26x^2 + 2{,}55x - 2{,}18. \tag{9}$$

Next part of the work shows modeling, conducted for apodized Bragg grating by means of Blackman function. Figure 27 shows the chart of the parameter S_{GW} and Blackman function parameter.

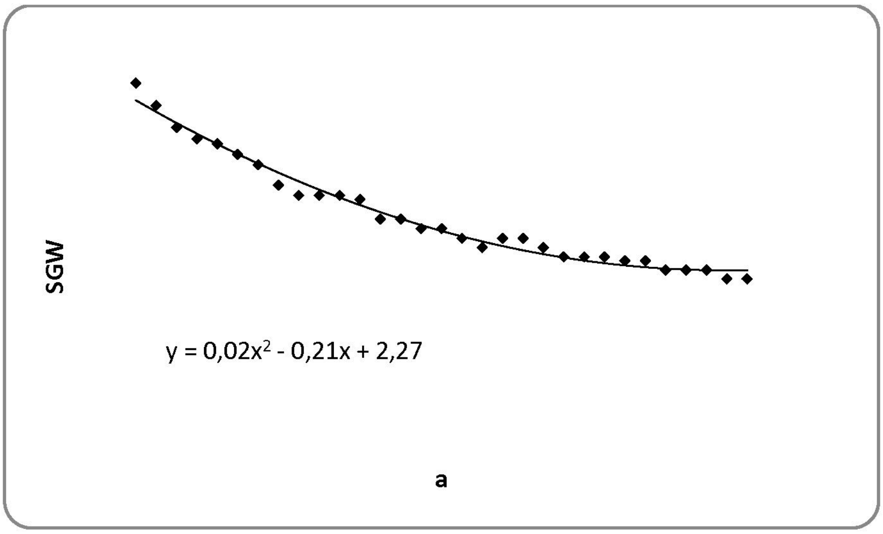

Figure 27 – Chart of S_{GW} parameter and Blackman function parameter

Figure 27 shows the parameter value, indicating decrease of S_{GW} along with increase of parameter a.

In case of applying the Blackman apodization function the base peak consists of two parts with equal values of peak power. With increasing the function parameter the base peak is deepened. It gives the possibility to use Bragg apodized gratings with Blackman function for two different aims. Function value is approximated with the function, being described through the formula:

$$y = x^2 - 0{,}21x + 2{,}27. \tag{10}$$

Another feature, subjected to modeling, in order to define the Bragg grating apodization quality is quadratic function. Figure 28 shows the chart of S_{GW} parameter and quadratic function.

Figure 28 shows that S_{GW} parameter value sufficiently decreases with increase of the parameter a. That is, in order to eliminate the side lobes, the parameter ‘a’ shall be as small as possible comparing to a quadratic function. Apart from that, you can see that parameter S_{GW} has the highest value, which equals to 1,41. That is, quadratic function is not effective for eliminating the side lobes, as it is described further in the function section herein. Dots on the chart have been approximated with quadratic function according the preset formula:

$$y = 0{,}02x^2 - 0{,}22x + 1{,}77. \tag{11}$$

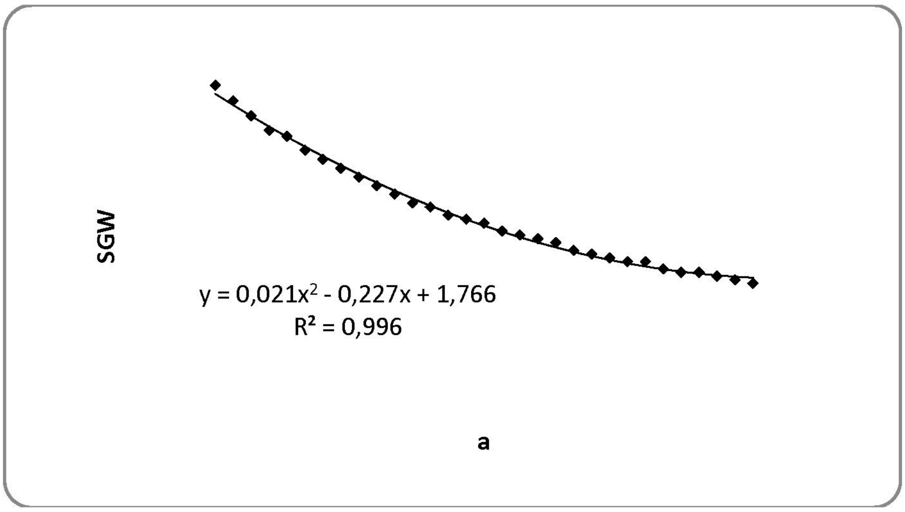

Figure 28 – Chart of S_{GW} parameter *a* and quadratic function

As the final apodization function the sinc-function has been tested. This function has two parameters X and Y. Figure 29 shows the chart 3D of S_{GW} parameter dependence on two functional parameters of sinc function.

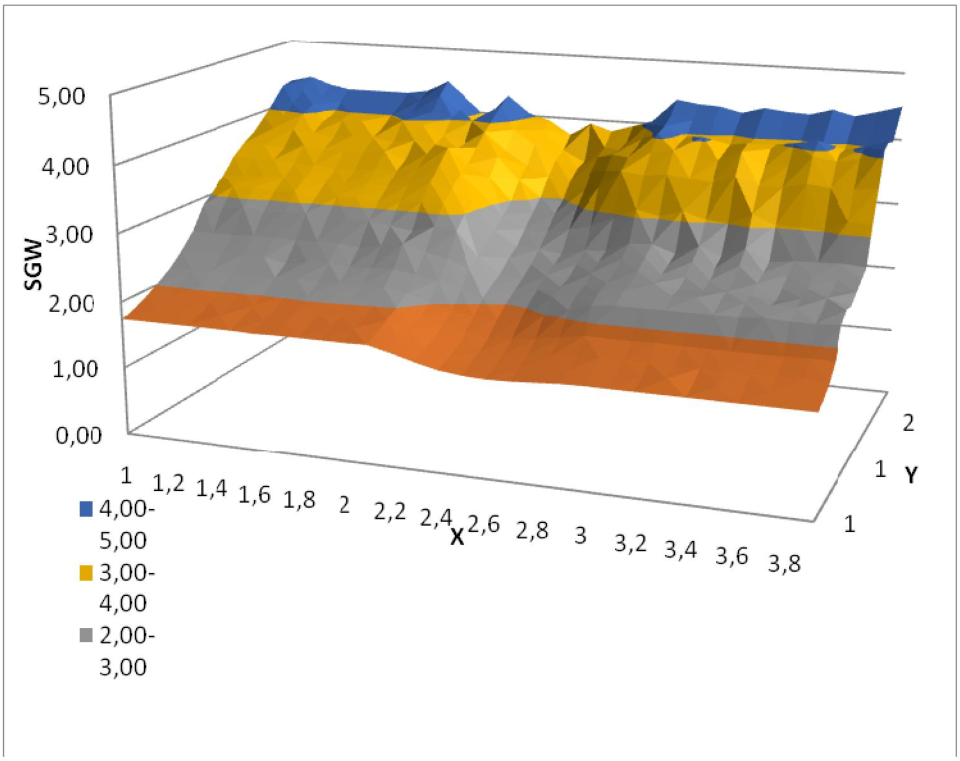

Figure 29 – Chart of the parameter S_{GW} and parameters X and Y of the sinc- apodization function

The chart on the figure 29 shows, that the parameter change does not considerably affect the side lobes sizes. Exclusion is the local minimum for values of the parameter X = 2.4. The chart shows, that with the parameter Y size growing the side lobes sufficiently decrease and the value of the parameter Y = 2,8 disappears completely leaving noise bands in the spectrum.

Conclusion. Proceeding from the above-received outcomes of testing the different apodization functions with the aim of quality check and optimization of FBG spectral characteristics there can be drawn the following conclusions:

– the most proper functions for minimizing the side lobes are: Gauss function, cosine and sine functions;

– Bragg grating length does not influence at the side lobes size.

This work is supported by grant from the Ministry of Education and Science of the Republic of Kazakhstan within the framework of the Project № AP05132778 «Research and development of signals interrogation system with fiber-optic refractometer in telecommunication networks».

REFERENCES

[1] Kashyap R. (1999). Fiber Bragg gratings, Academic Press, London.

[2] Vasiljyev S.A., Medvedkov O.I., Medvedkov I.G., Korolyev A.S., Bozhkov A.S., Kurkov Ye.M., Dianov (2005). Fiber gratings reflection index and their application, Quantum electronics, 35(12): 1085-1103.

[3] Hill K.O., Fujii F., Johnson D.C., Kawasaki B.S. (1978). Photosensitivity on optical fiber waveguides; application to reflection filter fabrication, Applied Physycs Letter, 32: 647-649.

[4] Amirgaliyev Y.N., Kunelbayev M., Wójcik W., Kalizhanova A.U., Auelbekov O.A., Kataev N.S., Kozbakova A.K., Irzhanova A.A. Solar-driven resources of the Republic of Kazakhstan // News of the National Academy of Sciences of the Republic of Kazakhstan. Series of Geology and Technical Sciences. https://doi.org/10.32014/2018.2518-170X, 4(430): 18-27. ISSN 2518-170X (Online), ISSN 2224-5278 (Print)

[5] Kersey A.D., Davis M.A., Patrick H.J., LeBlanc M., Koo K.P., Askins C.G., Putnam M.A., Friebele E.J. (1997). Fiber grating sensors // Light wave Technology, 15(8): 1442-1463.

[6] Lopez-Higuera J.M. (2002). Handbook of optical fiber sensing technology, John Wiley & sons. P. 795.

[7] Bilodeau F., Johnson D.C., Theriault S., Malo B., Albert J., Hill K.O. (1995). An all-fiber dense-wavelength multiplexer/DE multiplexer using photo imprinted Bragg gratings, IEEE Photonics Technology Letters, 7(4):388-390.

[8] Chai J., Yu Z., Liu Y. (2006). Analysis of the apodization parameter of linearly chirped Bragg gratings for dispersion compensation, School of Science, Beijing University of Posts and Telecommunications, Beijing.

[9] Zhang H. (2014). A novel method of optimal apodization selection for chirped fiber Bragg gratings, Optik 125, 1646-1649.

[10] 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, Bangladesz.

[11] Wójcik W., Kashaganova G.B. (2015). Study of Bragg fiber gratings spectral characteristics // Materials of the II International scientific-practical conference «Information and telecommunication technologies: education, science, practice», Almaty, Kazakhstan, December 3-4, II vol., p. 77-81.

[12] Kashaganova G.B. (2016). The influence of various apodization functions on the spectral characteristics of fiber Bragg gratings, Bulletin of KazNTU named after Satbayev K.I., 3(115): 302-311.

[13] Li X., Chen X., Yin Y. and Xie S. (2003). A novel apodization technique of variable mark-space ratio for fabricating sampled fiber bragg grating, Tsinghua University, China.

[14] Albert J. et al. (1995). Apodisation of the spectral response of fibre Bragg grat-ings using a phase mask with variable diffraction efficiency, Electronic Letters, 31: 222-223.

[15] Malo B., et al. (1995). Apodised in-fiber Bragg grating reflectors photoim- printed using a phase mask, Electronic Letters, 31: 223-225.

[16] Pastor D. et al. (1996). Design of apodized linearly chirped fiber gratings for dispersion compensation, J. Lightwave Technology, 14: 2581-2588.

[17] Keitmann-Curdes O., Brendel B., Marg C., Ermert H. (2002). Optimization of apodization based on the sidelobe pressure energy in simulated ultrasound fields, in: Proc. IEEE Int. Ultrason. Symp., 1677-1680.

[18] Abdullina S.R., Babin S.A., Kablukov S.I., Vlasov A.A. (2007). Simple technique of fiber Bragg gratings apodization by use Proc, Laser Optics 2006: Diode Lasers and Telecommunication Systems, ed. Nikolay N. Rosanov, 6612: 661201 (1-10).

[19] Chuang K.P. et al. (2004). Pure apodized phase-shifted fiber Bragg gratings fabricated by a two-beam interferometer with polarization control, IEEE Photonics Technology Letters, 16: 834-836.

[20] Othonos A., Kalli K. (1999). Fiber Bragg gratings. Artech House.

[21] Albert J., Hill K. O., Malo B. (1995). Apodization of spectral response of fiber Bragg gratings using phase mask with variable diffraction efficiency, Electronic Letters, 31(3): 222-223.

В. Вуйцик[1], А. У. Калижанова[2, 3], Г. Б. Кашаганова[2, 4],
Т. С. Картбаев[3, 5], А. А. Досжанова[5], Ф. У. Маликова, [5], А. А. Таурбекова, [5]

[1]Люблин техникалық университеті, Польша,
[2]БжҒМ ҒК Ақпараттық және есептеуіш технологиялары институты, Алматы, Қазақстан,
[3]әл-Фараби атындағы Қазақ ұлттық университеті, Алматы, Қазақстан,
[4]Қазақ-Американдық университет, Қазақстан,
[5]Алматы энергетика және байланыс университеті, Қазақстан

ТАЛШЫҚТЫ ОПТИКАЛЫҚ БРЭГ ТОРЛАРЫ ПАРАМЕТРЛЕРІН ЗЕРТТЕУ ЖӘНЕ ОҢТАЙЛАНДЫРУ

Аннотация. Қазіргі уақытта талшықты Брэгг торлары (ТБТ) талшықты оптиканың әртүрлі құрылғыларында негізгі элементтердің бірі болып табылады. Оптикалық талшықты Брэгг торлары – сыну көрсеткіші талшық ұзындығы бойымен периодты өзгеретін оптикалық талшықтың кесіндісі.

Бұл мақала ТБТ негізгі сипаттамаларын есептеу және өлшеу әдістері туралы жазылған. Сонымен қатар, ТБТ сапалы жұмыс істеу үшін оның оңтайлы параметрлерін анықтау толық ашып жазылған.

Түйін сөздер: Брэг талшықты торлары, математикалық модель, өлшеу әдістері, тиімді параметрлер, спектралды сипаттамалар.

В. Вуйцик[1], А. У. Калижанова[2, 3], Г. Б. Кашаганова[2, 4],
Т. С. Картбаев[3, 5], А. А. Досжанова[5], Ф. У. Маликова, [5], А. А. Таурбекова, [5]

[1]Люблинский технический университет, Польша,
[2]Институт информационных и вычислительных технологий КН МОН РК, Алматы, Казахстан,
[3]Казахский национальный университет им. аль-Фараби, Алматы, Казахстан,
[4]Казахско-Американский университет, Казахстан,
[5]Алматинский университет энергетики и связи, Казахстан

ИССЛЕДОВАНИЕ И ОПТИМИЗАЦИЯ ПАРАМЕТРОВ ВОЛОКОННО-ОПТИЧЕСКИХ РЕШЕТОК БРЭГГА

Аннотация. Волоконные решетки Брэгга (ВРБ) широко используются в различных областях современной волоконной оптики. Каждая задача предъявляет особые требования к спектральным характеристикам ВРБ, которые задаются на стадии изготовления решеток. Изготовление и использование волоконно-оптических решеток Брэгга не представляется возможным без измерения их характеристик на каждом этапе изготовления самих решеток и приборов на их основе. Чтобы выбрать оптимальный параметр ВРБ, мы сравним параметр SGW с несколькими различными наиболее широко используемыми функциями аподизирования. При изготовлении ВРБ к их параметрам предъявляются жесткие требования. Наиболее важными параметрами волоконных решеток являются распределение амплитуды модуляции показателя преломления и закон изменения периода решетки вдоль продольной оси волокна. Отклонение этих параметров от требуемых значений приводит к ухудшению спектральных характеристик ВРБ. Запись или изготовление волоконных решеток Брэгга может быть классифицирована по типу используемого для записи лазера, длине волны излучения, методу записи, облучаемому материалу и типу решетки.

Статья посвящена методикам расчета и измерения основных параметров ВРБ, для качественной работы решетки необходимо определение оптимального параметра их характеристик.

Ключевые слова: волоконные решетки Брэгга, математическая модель, методы измерения, оптимальные параметры, спектральные характеристики.

Information about authors:

Waldemar Wojcik, professor of the Lublin technical university (Poland); Waldemar.wojcik@pollub.pl; https://orcid.org/0000-0002-0843-8053

Kalizhanova Aliya Ualievna, candidate of physical-mathematical sciences, associated professor of Almaty university of power engineering and telecommunications; Kalizhanova_aliya@mail.ru; https://orcid.org/0000-0002-5979-9756

Kashaganova Gulzhan Bakhytovna, PhD, Kazakh-American University; guljan_k70@mail.ru; https://orcid.org/0000-0001-8150-1621

Kartbayev Timur Saatdinovich, PhD, head of the Department “IT-engineering” Almaty university of power engineering and telecommunications. Academician of the IIA; kartbaev_t@mail.ru

Doszhanova Aliya Amantayevna, PhD, associated professor of the Department “IT-engineering” Almaty university of power engineering and telecommunications; D_alia.81@mail.ru; https://orcid.org/0000-0002-6932-6282

Malikova Feruza Umirzahovna, associated professor of the Department “IT-engineering” Almaty university of power engineering and telecommunications; feruza-malikova@mail.ru; https://orcid.org/0000-0003-0527-322X

Taurbekova Ainur Adilgazyevna, Almaty university of power engineering and telecommunications; ainura_071@mail.ru; https://orcid.org/0000-0001-5433-8347