ANNOTATION

of dissertation for the Philosophy Doctor (PhD) degree in specialty "6D071900 – Radioengineering, electronics and telecommunications" by

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on the topic **"A optical fiber sensor of the refractive index of the environment with tilted fiber Bragg gratings"**

The dissertation work is devoted to the study of tilted fiber Bragg gratings (TFBG) with tilt angles of 6^0 and 8^0, transmission spectra and spectral parameters with linear dependence on the refractive index of the environment. It has been shown that some characteristics, such as the sensor spectrum width and minimum of the spectrum, can linearly depend on the refractive index of the environment. The linear dependence of the spectrum width on the refractive index is located in isolation at the angles of inclination (the dependence graphs do not intersect). The linear dependence of the minimum of the spectrum is observed only at an angle of tilt of 8^0, and the level of its linearity is the highest. The results of this work can be used to develop an environmental refractive index sensor based on optical fiber.

Relevance of the dissertation theme.

Technologies for using optical fibers as sensors have been proposed since the mid-twentieth century. Since then, fiber optic sensors (FOS) have been widely used on the international market to determine the environmental impact, changes in properties and parameters. With the introduction of automated control systems, new technological processes, accelerated development of the transition to an effective automated control system, the demand for sensors is growing. In addition to high metrological characteristics, sensors must have high strength, durability, stability, small size, lightness, energy efficiency and the ability to process information in accordance with microelectronic devices. Fiber-optic sensors (FOS) largely meet these requirements.

Simple sensors can only measure the physical parameters of the medium at the point of space in which they are located. Unlike other sensors, the FOS function can cover a wide range in space.

The listed fiber-optic sensors differ from traditional sensors in that they are passive, i.e. they do not have active elements that require isolation from moisture and the electrical network - transistor, resistor, capacitors, logic elements. In addition, the advantages of fiber-optic sensors over active sensors:

1. electromagnetic fields do not affect the measurement results;
2. absence of extraneous electromagnetic radiation (including radiation) ;
3. no cross channels;
4. no problems with grounding and shear stress at the junctions of various conductors;
5. no problems with electrical safety and the occurrence of arcs and sparks;

6. high resistance to harmful environmental influences;

7. easy multiplexing of signals;

8. the possibility of accurate estimation of spatial physical quantities by fiber;

9. high data transfer rate.

In addition, FOS:

1. can be used in explosive environments because of its explosion-proof;

2. it has high mechanical strength, small size, simple construction and high strength;

3. chemically inert;

4. it is made of dielectric materials, so no electric current passes through them;

5.resistant to high ambient temperatures, mechanical shocks, vibrations, etc.;

6. allows remote and non-contact measurements.

In cases where electronic devices cannot be used, or when their use causes serious problems and losses (for example, temperature measurement in high-voltage electrical devices, such as alternators, transformers; measurement of current and voltage in high-voltage power lines; rapid temperature measurement of a small surface in hard-to-reach places with low thermal conductivity and variable reflectivity) fiber-optic sensors can be used. The advantage of using FOS is the ability to observe the length and the space that the length of the fiber can cover from a single point (by changing, reducing the pressure of liquids and gases in main pipelines, large warehouses, sealing holes in the interior finishes of ships, aircraft, etc. vehicles).

There are types of FOS built on the nonlinear effects of optical fiber, i.e. the phenomena of light scattering. Using a reflectometer based on forced Mandelstam-Brullien scattering (FMBS), one of the nonlinear effects, they can detect at which point the temperature or pressure of the optical fiber environment changes. In addition to these sensors, FOS based on Bragg gratings are also used. It differs from FMBS sensors in that it is possible to obtain accurate data on what value the temperature or pressure changes along the fiber.

Numerous scientific studies have shown that the tilted fiber Bragg grating (TFBG) can more accurately measure the refractive index of the environment than the traditional fiber Bragg grating (FBG). For this reason, in this research paper, the tilted Bragg gratings is considered as an object of study for measuring the refractive index of the environment. In the works carried out so far, the dependence of the width and minimum of the spectrum on the refractive index of the environment is not provided, and the parameters reflecting the mutual isolation between the parameters of the spectrum of inclined Bragg gratings are not determined. Therefore, the following goals were set in this research work.

The purpose of the research

The main purpose of the work is to study the problems of developing an environmental parameter sensor based on the physical processes performed in an optical fiber.

To achieve the **goal** of the work , it is necessary to solve several tasks:

- Experimental study of the dependence of the spectrum of light passing through an tilted Bragg grating on the refractive index of the environment.

- Determination of the spectral characteristics of TFBG in such a way as to depend linearly on the refractive index of the environment.

- Determination of the spectral characteristic in such a way that the linear dependence of the refractive index provides a mutually isolated location at the angles of inclination. The search for spectral characteristics that provide an isolated location at the angles of inclination is necessary in order to be able to record Bragg gratings located at different angles of inclination along the same fiber.

The object of the research.

Tilted Bragg grating with tilt angles of 6^0 and 8^0

The subject of the research.

Study of changes in the spectrum of a light beam passing through tilted fiber Bragg gratings with tilt angles of 6^0 and 8^0, and determination of the values characterizing these changes

Research methods

Recording of tilted Bragg gratings on single-mode optical fiber by the phase mask method, experimental and analytical methods.

Scientific novelty of the dissertation results

1. The proposed new spectral characteristic “sensor spectrum width” clarifies that optical fibers with tilted Bragg gratings can serve as sensors of the refractive index of a medium.

2. The function of the dependence of the “sensor spectrum width” on the refractive index is completely linear for Bragg gratings with tilt angles of 6 and 8 degrees, and the ranges of these functions do not intersect.

3. The error in determining the coefficient describing the linearity of the dependence of the “sensor spectrum width” on the refractive index of the medium was 4.6% for an inclined Bragg grating of 6 degrees and 3.7% for an 8-degree one. This is at least 11.1 percentage points lower than the previously known “local average” spectral characteristic. That is, the characteristic “spectrum width of the sensors” more accurately describes the change in the refractive index of the medium.

The main provisions for the defense.

1. New spectral characteristics “spectral width” and “spectral minimum” have been determined, clarifying that optical fibers with inclined Bragg gratings can serve as sensors of the refractive index of a medium.

2. The new characteristic, called the spectrum width, showed that the level of linear dependence on the refractive index of the environment is 11.1% higher than that of other characteristics that existed before

3. It has been established that the function of the dependence of the proposed new characteristic called “spectral width” on the refractive index of the medium relative to the angle of inclination of the Bragg grating is characterized by graphs located mutually isolated.

Practical and theoretical importance of the dissertation.

The results of the dissertation work allow us to prepare a sensor of the refractive index of the environment based on optical fiber, on which tilted Bragg gratings are recorded. Spectral characteristics linearly dependent on the refractive index of the environment are proposed.

The reliability and validity of the results

The reliability of the results achieved in the dissertation work is confirmed by the presence of publications in local journals recommended by the Committee for Quality Assurance in Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan, in foreign journals included in the Scopus (Elsevier, Netherlands) databases, and in the proceedings of international conferences, as well as consistency with the results of other authors.

The personal contribution of the author

The author participated in the research work at all stages of the dissertation work. As part of the curriculum, she conducted experimental work in the scientific laboratory of the Lublin Technical University, in particular, she took part in the process of recording TFBG on optical fiber, received TFBG transmission spectra, calculated the characteristics from the obtained spectra and analyzed the work. Approval of the tasks and work plan, discussion of the results were carried out jointly with the supervisor.

Publications

6 publications have been published on the topic of the dissertation, including 2 papers in the materials of international conferences, 3 papers in scientific publications recommended by the Committee for Quality Assurance in Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan, 1 articles in journals included in the international information resources Scopus (Elsevier, Netherlands).

Approbation of the dissertation.

An article with a high impact factor in publications included in the international scientific database Scopus:

Tolegenova A.A., Kisala P.A., Zhetpisbayeva A.T., Mamyrbayev O.Zh., Medetov B.Zh. Experimental determination of the characteristicsof a transmission spectrum of tilted fiber Bragg gratings//Metrology and measurement systems. – 2019. – P. 6-12.

Publications recommended by the Committee for Quality Assurance in Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan:

1. Толегенова А.А., Албанбай Н., Жетписбаева А.Т., Медетов Б.Ж., Исимова А.Т., Тайсариева Қ.Н. TFBG типтес оптоталшықтарды сенсор ретінде қолдану үшін қажетті спектралдық сипаттамаларды эксперимент жүзінде анықтау// Вестник КазНИТУ, серия Технические науки. – 2019. - №4
2. Липская М.А., Ерішова М.Ө., Толегенова А.А., Жетписбаев К. Талшықты Брэг торының негізіндегі оптикалық сенсорлар//ҚазККА хабаршысы. – 2020. – №4(115). – 311-317 б.
3. Tolegenova A., Yerishova M., Zhetpisbayeva A., Zhetpisbayev K., Tolegenova A. Investigation of the temperature dependence of TBFG with tilt angles of 2^0 and 4^0.// Торайғыров университетінің хабаршысы. – 2022. – №2

Publications in the materials of international conferences:

1. Harasim D., Tolegenova A., Tergeusizova A. The spectral properties of bended tilted fiber Bragg gratings //Optical Fibers and Their Applications 2018. – International Society for Optics and Photonics, 2019. – Т. 11045. – С. 110450B.

2. Толегенова А.А., Исимова А.А., Албанбай Н. TFBG спектралдық сипаттамаларының ортаның сыну көрсеткішіне тәуелділігін эксперимент жүзінде анықтау// "Фараби әлемі" атты Халықаралық жас ғалымдар мен студенттердің конференциясы". – 2019. – 288 б.

Certificate of copyright

Толегенова А.А., Медетов Б.Ж., Жетписбаева А.Т. Определение линейных зависимостей спектральных характеристик TFBG с углом наклона 6^0 и 8^0 от показателя преломления окружающей среды // Авторское свидетельство, 2023. №36971.

The scope and structure of the thesis.

The dissertation consists of an introduction, 3 sections, a conclusion, a list of used sources of 101 titles and three appendices, contains 106 pages of basic computer text, including 126 figures, 11 formulas and 4 tables.