ANNOTATION

of N.K. Smailov's Dissertation work «Research and modeling of the fiber-optic temperature sensor based on the Bragg grating», submitted for the Ph.D. degree in the specialty 6D071900 Radio engineering, electronics and telecommunications

Actuality of work.

The development of fiber-optic technologies and incorporating them into the measuring systems creates a number of advantages of such systems over previously known electronic prototypes. Because of this, fiber-optic temperature sensors have recently found great practical application in various fields of science and technology, in particular when the point of temperature determination is at a great distance or where the temperature setting is a dangerous or complicated issue. Fiber-optic temperature sensors are widely used for measuring temperature and pressure in the explosive environments with intense electromagnetic radiation, in the oil and gas pipes, and at measuring temperature at the passage points of the main fiber networks.

Measurement of temperature is one of the important parameters for monitoring and ensuring the safety of power assets. Due to the properties of light and optical fiber, fiber-optic thermometers are able to measure temperature under conditions of strong electromagnetic interference with high temporal and spatial resolution and very high accuracy. To date, a number of developments are known in the field of measuring temperature by the fiber optic sensors and improvement of such systems is a promising direction in the measuring technology.

Fiber optic sensors shall meet the following requirements:

- high accuracy and reliability of the measurement;
- simplicity and feasibility of the design;
- ergonomics of weight and shape of the device;
- absence of metal elements
- low inertia of the sensor
- low cost.

The most basic requirement of the above is the lack of metal elements. Since the absence of active elements (transistors, resistors, capacitors, inductive coils, logic elements) allows unhindered mounting of the passive sensors to any hard-to-reach places - between internal and external layers in aircrafts and ships, regardless of pressure and humidity. Besides, when mounting the sensor inside the pipe used to transport various fluids, regardless of its length, it makes it possible to determine the pressure and temperature parameters at any point in the pipe.

Advantages of fiber optic sensors are: protection from electromagnetic fields, high sensitivity, reliability, reproducibility and wide dynamic range of measurements, small dimensions and weight, high resistance to corrosion and radiation, electrical insulation strength, fire safety, possibility of spectral and spatial multiplexing of sensitive elements located in one or in several optical fibers, a considerable distance to the place of measurement, a short response time.

One of the new and promising options for fiber optic sensors of temperature and mechanical strain are the sensors using refractive index fiber gratings (Bragg gratings) as a sensitive element - they have the property of reflecting radiation at a certain wavelength. Sensors based on the Bragg fiber grating technology, because of the linear temperature dependence, show a more accurate temperature measured by FBG compared to sensors based on other physical phenomena.

Therefore, the main purpose of the work is to study and simulate a fiber-optic temperature sensor based on the Bragg grating. It is impossible to construct a universal unit model suitable for all sensor models based on the use of Bragg gratings, since each individual sensor is constructed taking into account different temperature ranges and other external influences.

The ways of solving this problem are presented in the conclusions of numerous scientific works, and they are widely used now. When modeling and creating a Bragg grating, it is necessary to take into account a set of basic parameters of the grating, depending on each problem. In this regard, we consider more acceptable ways of solving problems using the proposed model. In addition, in this scientific work, for the spectrum of the reflected beam, the process of significant decrease of the second and third harmonic oscillations with the help of apodization is considered as a stable process, where the wavelength shift function, which depends on a certain temperature, can be solved by the matrix method, and this is a way of solving the posed task by the objective definition of the direct relationship.

Since the FBG backscatter spectrum is very thin, it is used in fiber lasers as a tool that identifies and determines fiber-optic data. When it is used as a tool for identifying fiber-optic data based on Bragg gratings, the measured conditions (temperature or pressure due to external forces) are based on the shift of the Bragg wavelength value (sent by fiber and back scattered light wave). The recording system transforms the length shift of the backscattered Bragg wave into «electronic signals». Almost all scientific works devoted to fiber-optic networks, establish the permanent use of the concepts of «electrical signal» and «optical signal» in order to specify the differences between them. In fact, both these signals are electromagnetic waves by nature; the only difference is that they have different wavelengths and densities. Since there are no active electronic devices in the part of the FBG identifying sensor that reacts to the influence of the external environment, and the sensor is a full-fledged passive device, it is widely used as a sensor operating on the FBG technology basis in explosive, aggressive environments, or in the environment with a powerful electromagnetic radiation, as well as at large distances.

Several Bragg gratings can be located on one fiber, where each grating is responsible for its wavelength, and therefore signals measuring different wavelengths can be used for different purposes. In this case, instead of the data detector at one point, we use a recording network multiplexed by wavelengths. Due to the use of light waves as an information parameter, it provides long-term and stable operation of the beam sources and receivers of the FBG data identifier

and generates expansion of the use sectors due to the round-the-clock operation of the system of emergency switching-off of the optical signal in the fiber.

The purpose of the dissertation work. The main purpose of the work is to build a sensor model with a Bragg grating, and to investigate the main characteristics of the sensor and compare them with practical results in the process of building the model.

To achieve this purpose, the following tasks were completed:

- analysis of the current state of fiber-optic temperature sensors;
- research and modeling of the structure of the fiber-optic temperature sensor, which does not contain metallic and semiconductor elements;
- Determination of the regularity of the temperature dependence of the sensor operating on the basis of the Bragg gratings technology on the effective refraction index and the value of the Bragg grating period;
- in order to establish the above-mentioned regularities, to organize a practical laboratory and approve the spectral characteristics of the temperature range of the sensor;
- analysis of the obtained experimental and theoretical results.

The object of the study is simulation of a temperature sensor operating on the basis of the fiber Bragg gratings technology. The essence of the study is to analyze the best results of the characteristics of the FBG spectrum.

Scientific novelty of the dissertation work:

- The regularity of the temperature dependence of effective refraction is determined;
- The regularities of the temperature dependence of the Bragg grating period were obtained for the first time;
- New data are obtained on the spectral and temperature properties of the optical fiber sensor operating on the Bragg grating technology;
- The spectral and temperature characteristics of an optical fiber sensor operating on the Bragg grating technology have been studied.

Methods of research.

In the process of achieving the purposes, the practical researches were carried out and the obtained results were compared with the results of mathematical modeling.

Practical significance of the work.

The scientific and practical results of the dissertation work will find application in the creation of fiber-optic measuring systems, insensitive to the influence of strong electrical and magnetic noise, which increase the ability to simulate a temperature sensor.

The scientific results obtained in the dissertation work are useful in the educational process of technical universities for creating modern courses of lectures. Based on the results of this dissertation work, the Act of introducing was obtained at manufacturing the fiber Bragg gratings and studying their spectral characteristics at the Optoelectronics laboratory of the Lublin Technical University (Poland, Lublin).

Approbation of the work. The results of the dissertation work were discussed at the following conferences: the International Satpayev Readings «The role and place of young scientists in the implementation of the new economic policy of Kazakhstan» (Almaty, 2015, 2016); the II International Scientific and Practical Conference «Information and telecommunication technologies, education, science, practice» (Almaty, 2015); Joint issue on the materials of the international scientific conference «Computational technologies» and the Bulletin of the Al - Farabi KazNU, Mathematics, Mechanics and Informatics Series, №3 (86), Part II, Almaty - Novosibirsk, 2015; Proceedings of the II International Conference «Spring scientific readings», Center of scientific publications «VELES», Kiev, April 28, 2016, «Competitiveness of Engineering Science and Education» devoted to the 25th anniversary of independence, Volume II, Almaty, 2016; Science and data center «Znanie», proceedings of the 20th international conference «Development of science in the XXI century», Kharkov, 2016.

Publications. The results of the scientific work were reflected in 12 publications, where 3 articles - in the scientific publications recommended by the Committee of Science of the Ministry of education and science of the RK, 2 publications - in the journals included in the Scopus database, 7 publications - in the proceedings of the international conferences, 3 of them are in the proceedings of foreign conferences.

The volume and structure of the dissertation work.

The dissertation consists of introduction, four chapters, conclusion, list of references and appendix. The total volume of the dissertation is 142 pages, 82 drawings, 6 tables, the list of references contains 90 titles.

In the introduction, the actuality of the dissertation topic is substantiated, the purpose and objectives of the work are formulated, the structure of the work and its content are briefly presented, the scientific novelty is presented, and the practical value of the results is determined and the main provisions to be defended are listed.

The first chapter is devoted to the review of the current state of the problem of fiber-optic acoustic sensors and the formulation of research problems. The Bragg grating sensors are considered in details. The chapter covers conditions and range of measuring temperature of the environment, as well as changes in the wavelength range which coincides with the Bragg grating ranges. The features and disadvantages of manufacturing technology for describing the Bragg grating spectra are presented. At the end of the chapter, the main tasks of the work are formulated and the methods for their solution are chosen.

The second chapter specifies the main parameters describing the changes in the Bragg grating regularity, and the structure logics of the Bragg grating and the relationship between them.

The third chapter is devoted to the search for ways of creating and studying the sensitive elements of the fiber-optic acoustic sensor on Bragg gratings. Experimental study of the relative increase in the sensitivity of the Bragg grating was carried out. It is determined at the effective refractive indices Λ and n_{eff}. The study showed that these two parameters are dependent on external

temperature and pressure. Due to the dependence, studies of the sensor based on the Bragg grating were performed.

The fourth chapter presents the results of tests implemented on the basis of mathematical simulation in order to verify practical results by means of the computers, for this purpose the matrix methods and input parameters of the Bragg grating sensor were used. The test results show that the proposed concept is promising, and can be used to create fiber-optic sensors.

The conclusion covers the main results and summaries of the dissertation work.

12 articles were published on the theme of the dissertation work:

1 Zhunussov K.H., Kasimov A.O., Smailov N.K. // Investigation of attenuation methods for the fiber-optic communication line. The International Satpayev Readings «Role and place of young scientists in the implementation of the new economic policy of Kazakhstan», Volume IV // Almaty 2015, pp.174-177

2 Pioter Kisala, Wojcic W., Smailov N., Kalizhanova A., Damian H. Elongation determination using finite element and boundary element methods. Journal of Electronics and Telecommunications, 2015, VOL. 61, No. 4, pp. 389-394 Manuscript received October 15, 2015; Revised December, 2015. DOI: 10.2478 / eletel-2015-0051

3 WojcicW., Zhunusov K.Kh., Smailov N.K. // Determination of the dependence of modern fiber optic communication lines and Bragg grating on temperature. Proceedings of the II International Scientific and Practical Conference «Information and telecommunication technologies, education, science, practice» // Almaty, Kazakhstan, December 3-4, 2015, Volume II, pp. 306-309

4 Utepbergenov I.T., Orazimbetova A,K,, Smailov N.K. // Duration of the pulse introduced at an angle to the axis, from the temperature influence on the MRW. Bulletin of PSU, Energetics series, // №4 (2015), Pavlodar, pp.97-101

5 Mykhailo M. Kutsyk; Yosyp Y. Ráti; Vitalii Y. Izai; Ivan I. Makauz; Ihor P. Studenyak; Sandor Kökényesi; Paweł Komada; Yerkin Zhailaubayev., Smailov Nurzhigit. // Temperature behavior of the optical parameters in (AG3ASS3) 0.3 (AS2S3) 0.7 THIN FILMS Proceedings of SPIE - The International Society for Optical Engineering 201019816, Optical Fibers and Their Applications 2015, 98160B (December 18, 2015); Doi: 10.1117 / 12.2229336

6 Utepbergenov I.T., Ospanov N.A., Smailov N.K. // Algorithm for finding faults in the OFTS. The Bulletin of the PSU Energetic series // Published since 1997, No. 4 (2015), Pavlodar

7 Waldemar Wojcik., Zhunisov K.Kh., Smailov N.K., Zhetpisbaev K.U., Medetov B.Zh. // Simulation of fiber-optic temperature sensors based on the Bragg grating. The International multi-disciplinary conference «Spring scientific readings» // April 28, 2016. Kiev, pp. 102-109

8 WojcicW., Zhunusov K.K., Smailov N.K. // Investigation of the spectral characteristics of fiber optic temperature sensors // Bulletin of KazNIITU, Technical Sciences No. 1 (113) Almaty, 2016, January. pp. 293-297

9 Wojcic W. Zhunusov K.Kh., Smailov N.K. / / Research of characteristics of the temperature sensor on the Bragg grating. // Proceedings of the International

Satpayev Readings «Competitiveness of Engineering Science and Education», dedicated to the 25th Anniversary of the Independence of the Republic of Kazakhstan, Almaty, April 12, 2016

10 Wojcic W., Kalizhanova A., Kashaganova G., Smailov N. // Elongation determination using finite element and boundary element method // Joint issue on the materials of the international scientific conference «Computational technologies» and the Bulletin of the Al - Farabi KazNU, Mathematics, Mechanics and Informatics Series, №3 (86), Part II, Almaty - Novosibirsk, 2015, pp. 145-151, ISSN 1560-7534, ISSN 1563-0285.

11 Ibrayev A.T., Zhunussov K., Smailov N., Tleumuratova K.T. // Study of temperature sensors based on Bragg grating. Magyar Tudomanyos Journal (Budapest, Hungary) The journal is published in Hungary. // The journal publishes scientific studies, reports and reports about achievements in different scientific fields. No. 4 (2017) ISSN 1748-7110 P.62-67

12 Ibrayev A.T., Smailov N.K. // Study parameters of fiber optic temperature sensors. // Scientific and Information Center «Znanie». // Proceedings of the 20th International Conference «Development of Science in the 21st Century» 12/13/2016, part 1, Kharkov 2016, ISSN 5672-2605