Abstract

of the dissertation on the topic:
«Investigation of the use of an optical fiber sensor for determining mechanical voltage»

submitted for the degree of Doctor of Philosophy (PhD)
according to the educational program 8D06201 – "Radio Engineering, Electronics and Telecommunications"
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Relevance of the Topic. Accurate measurement of mechanical stress is one of the key challenges in ensuring the reliability and safety of materials in engineering and industrial applications. This is particularly significant in critical fields such as aerospace, aviation, construction, and transportation. Since traditional stress monitoring methods have certain limitations, there is a growing need to adopt modern technological advancements.

One such advancement is the use of fiber-optic sensors. This technology offers significantly higher sensitivity and precision compared to electrical and mechanical measuring instruments. Furthermore, fiber-optic sensors are distinguished by their resistance to electromagnetic interference, lightweight design, and long service life. These attributes enhance their applicability in complex engineering systems and extreme environments.

In Kazakhstan, the development of fiber-optic technologies is not only of scientific interest but also represents a strategic direction to meet industrial demands. Considering regional climatic conditions, studying the efficiency of such sensors provides an opportunity to ensure the resilience of domestic industries and infrastructure. Thus, exploring the potential of fiber-optic sensors in measuring mechanical stress is a vital step towards advancing scientific and technological progress and enhancing the country's economic potential.

The aim of this work is to investigation of the construction of an optical sensor model for measuring the parameters of mechanical deformations arising from the abundance of load on motorway bridge facilities

Research problems.

1. Fromthe teaching of methods of theoretical foundations of fiber optics and Bragg grid
2. Areview of the principles and technical ways of constructing systems for measuring mechanical stresses based on fiber-optic Bragg sensors.
3. Investigation of the effect of mechanical stresses using fiber-optic sensors.
4. Construction ofa mathematical model of mechanical stresses applied to road bridge structures using fiber-optic Bragg grid sensors.

Object of research. Bragg Fiber Mesh

Research methods. Methods of mathematical, computer and experimental modeling were used to solve the tasks.

Scientific novelty of the dissertation work:

1. For the first time, the spectral characteristic of the Bragg fiber grid in the wavelength range of 1562-1566 nm was experimentally studied, based on a model of a fiber-optic sensor for measuring mechanical stresses.

2. To calculate the effect of the load on solid materials, it is proposed to adapt the deformation parameters described by Hooke's law using a special mathematical expression using the Young's modulus.

3. A universal Bragg fiber sensor model has been developed to measure deformation parameters under mechanical action.

The main provisions submitted for protection:

- A Bragg lattice (wavelength 1662-1666 nm) made of fiber has been considered for the determination of mechanical stresses in the construction of automobile bridges.

- A technique has been developed for high-precision determination of deformation parameters in real time using optical sensors based on Bragg gratings.

- The operation of sensors based on FBG is modeled in Autodesk and Matlab Simulink programs. These models are aimed at solving specific engineering problems.

- The importance of conducting additional research on the adaptation and improvement of FBG technology to other infrastructure facilities, except for bridge structures, was emphasized.

Personal contribution of the author to scientific results. All the original results presented in the dissertation were obtained by the author while participating in laboratory experiments.

Testing the work. The research methods and results of the dissertation are presented at the following scientific conferences:

1. «Талшықты Брэгг торлары және оларды жазу әдістері». Kadirbaeva G. K., Chezhimbayeva K. S., International scientific conference of students and young scientists "FARABI ALEMI" Almaty, Kazakhstan, April 6-8, 2021.

2. «Талшықты Брэгг торларының пайда болу механизмдерін зерттеу». Kadirbaeva G. K., Chezhimbayeva K. S., VIII International Scientific and Practical Conference "Science and education in the modern world: challenges of the XXI century" technical sciences. Astana, Kazakhstan, April 16-22, 2021.

3. «Сигналды Брэгг талшықтары негізінде жасалған фазалық интерферометриялық сенсордан бөліп алудың математикалық әдісін зерттеу» Kadirbaeva G. K., Chezhimbayeva K. S., "International scientific and practical online conference" Integration of science, education and production - -the basis for the implementation of the National Plan", dedicated to the 30th anniversary of Independence of the Republic of Kazakhstan"(Sagin Readings No. 13). Karaganda, Kazakhstan, April 16-22, 2021.

4. «Талшықты Брэгг торларының пайда болу қағидалары және оны жазудың арнайы әдістері» Kadirbaeva G. K., Chezhimbayeva K. S., International Scientific and Technical Conference, Almaty, Kazan, October 20-21, 2022

Practical significance of the work. The scientific results of the dissertation were implemented as educational materials in the Laboratory of Optoelectronics of

the Lublin University of Technology (Lublin, Poland), at the Department of Teleinformatics and Electronics to study the influence of recording methods, spectral characteristics of Bragg gratings, and characteristics of sensors for measuring deformation under special stretches and bends.

Articles. Based on the main results of research and development, several scientific papers were prepared and published, including 2 papers published in publications included in the international Scopus database, 4 papers published in publications recommended by the Committee for Control in the field of Science and Higher Education of the Ministry of Education and Science of the Republic of Kazakhstan.

Structure and Scope of the Dissertation. The dissertation consists of an introduction, four chapters of main content, a conclusion, appendices, and a list of references comprising four sections. It spans 125 pages, includes 55 figures, and 18 tables.

The introduction outlines the general characteristics of the dissertation: the relevance of the research, its purpose, research questions, object of study, scientific novelty, practical significance, research methods, details of the research's approbation, and related publications. A brief overview of the dissertation's structure and content is also provided.

The first chapter presents an informational review of optical fibers. It extensively covers the types and classifications of optical fibers, analyzing their advantages and disadvantages. The fundamental principles of optical fiber operation and key standards defining optical fibers are discussed. The chapter examines the significant roles of optical fibers in various fields and applications, along with the theoretical basics of fiber Bragg gratings (FBGs). It also provides details about the types of FBGs, specific methods for writing gratings, and the sensitivity of Bragg gratings to strain and temperature.

The second chapter reviews and classifies existing methods for strain measurement, conducting a comparative analysis. Traditional sensors based on piezoelectric effects and fiber-optic sensors are considered. A study is conducted on the transmission characteristics of Bragg sensors, which determine the dependence of reflected wavelength on strain and temperature. The dependency of the reflected spectrum on mechanical strain or temperature is examined using Bragg wave function methods. Techniques for manufacturing Bragg gratings are explored, and a comparative analysis of data acquisition methods from strain and temperature sensors is presented.

The third chapter investigates the effect of mechanical stress using fiber Bragg gratings. It begins by examining the state of solid material structures, including the properties of concrete beams. Additionally, a structural health monitoring technology (SHMT) method is developed to enable real-time, highly accurate, long-term, and continuous monitoring without inducing structural changes. The dependence of material conditions on strain is calculated, with special graphs plotted based on the results.

The fourth chapter proposes a universal sensor model that can measure strain parameters under mechanical influence. This model is based on the

experimental method of measuring mechanical stress at two points and the central point using fiber Bragg grating sensors. Mathematical models for this graph are constructed in Autodesk and Matlab Simulink. The formula for Young's modulus for solid materials and the determination of Young's modulus for concrete beams are studied.

The conclusion summarizes the findings and results of the dissertation.