The paper discusses the combined methods of increasing heat transfer, effects of adding nanoparticles and ultrasonic vibration in the radiator using radiator coolant (RC) as a base fluid. The aim of the study is to determine the effect of nanoparticles in fluids (nanofluid) and ultrasonic vibration on the overall heat transfer coefficient in the radiator. Aluminum oxide nanoparticles of 20–50 nm in size produced by Zhejiang Ultrasfine powder & Chemical Co. Ltd China were used, and the volume concentration of the nanoparticles varied from 0.25 %, 0.30 % and 0.35 %. By adjusting the fluid flow temperature of the radiator from 60 °C to 80 °C, the fluid flow rate varies from 7 to 11 lpm. The results showed that the addition of nanoparticles and ultrasonic vibration to the radiator coolant increases the overall heat transfer coefficient by 62.7 % at a flow rate of 10 liter per minute and temperature of 80 °C for 0.30 % particles volume concentration compared to pure RC without vibration. The effect of ultrasonic vibration on pure radiator coolant without vibration increases the overall heat transfer coefficient by 9.8 % from 385.3 W/m²·°C to 423.3 W/m²·°C at a flow rate of 9 liter per minute at a temperature of 70 °C. The presence of particles in the cooling fluid improves the overall heat transfer coefficient due to the effect of ultrasonic vibrations, nanofluids with a volume concentration of 0.25 % and 0.30 % increased about 10.1 % and 15.7 %, respectively, compared to no vibration. While, the effect of nanoparticles on pure radiator coolant at 70 °C enhanced the overall heat transfer coefficient by about 39.6 % at a particle volume concentration of 0.35 % compared to RC, which is 390.4 W/m²·°C to 545.1 W/m²·°C at 70 °C at a flow rate of 10 liter per minute.

Keywords: nanofluid, aluminum oxide, radiator coolant, ultrasonic vibration, overall heat transfer coefficient.

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ANALYSIS OF FAULT DIAGNOSIS OF DC MOTORS BY POWER CONSUMPTION PATTERN RECOGNITION (p. 14–20)

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Early detection of faults in DC motors extends their life and lowers their power usage. There are a variety of traditional and soft computing techniques for detecting faults in DC motors. Many diagnostic techniques have been developed in the past to detect such fault-related patterns. These methods detect the aforementioned potential failures of motors can be utilized in a variety of scientific and technological domains. Motor Power Pattern Analysis (MPPA) is a technology that analyzes the current and voltage provided to an electric motor using particular patterns and protocols to assess the operational status of the motors without disrupting production. Engineers and researchers, particularly in industries, face a difficult challenge in monitoring spinning types of equipment. In this work, we are going to explain how to use the motor power pattern/signature analysis (MPPA) of a power signal driving a servo to find mechanical defects in a gear train. A hardware setup is used to simplify the demonstration of obtaining spectral metrics from the power consumption signals. A DC motor, a set of metal or nylon drive gears, and a control circuit are employed. The speed control circuit was eliminated to allow direct monitoring of the DC motor’s current profiles. Infrared (IR) photo-interrupters with a 35 mm diameter, eight-hole standard servo wheel were employed to gather the tachometer signal at the servo’s output. The mean value of the measurements was 318 V for the healthy profile, while it was 330 V for the faulty gears power data. The proposed power consumption profile analysis approach succeeds to recognize the mechanical faults in the gear-box of a DC servomotor via examining the mean level of the power consumption pattern as well as the extraction of the Power Spectral Density (PSD) through comparing faulty and healthy profiles.

Keywords: monitoring, DC servomotor, power consumption, pattern recognition, power profile, mechanical faults.

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DETERMINING AN ADDITIONAL DIAGNOSTIC PARAMETER FOR IMPROVING THE ACCURACY OF ASSESSMENT OF THE CONDITION OF STATOR WINDINGS IN AN INDUCTION MOTOR (p. 21–29)

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This paper has proposed and substantiated the application of an additional diagnostic parameter for assessing the state of stator windings of induction motors during operation. The dependences of the values of phase shifts between phase currents and phase voltages have been obtained. These dependences showed that when an inter-turn short circuit occurs in the stator windings, the phase shifts are the same for all phases of the motor. That has made it possible to obtain the dependence of the change in phase shift on the change in the engine shaft rotation frequency.

This study’s result has established the dependence of the rates of change of the phase angle on the engine shaft rotation frequency for both one and two damaged phases with varying degrees of damage. When analyzing these dependences, it was found that with an increase in the number of damaged phases of the electric motor, the linear section of the dependences decreases. In addition, with an increase in the degree of phase damage, the angle of inclination of the linear sections of the characteristics decreases. That has made it possible to determine an additional parameter for diagnosing the place and degree of an inter-turn short circuit of the windings in an induction motor with a squirrel-cage rotor. The values of the additional parameter, termed by this paper’s authors as a “phase criterion” can be used to assess the condition and degree of damage to the stator winding of induction motors.

The values of the phase criteria for various types of damage were: when phase A is damaged by 90 %, \( \xi = 0.634, (\text{deg})/(\text{rpm}) \); when phase A is damaged by 80 %, \( \xi = 0.293, (\text{deg})/(\text{rpm}) \); when phase A is damaged by 80 % and phase B is damaged by 90 %, \( \xi = 0.25, (\text{deg})/(\text{rpm}) \); when phase A is damaged by 80 % and phase B is damaged by 90 %, \( \xi = 0.173, (\text{deg})/(\text{rpm}) \).

The results of this research could be used to select an effective method for diagnosing an inter-turn short circuit in the stator winding when building a diagnostic system for induction motors as part of drives of transport equipment.

**Keywords:** transport infrastructure, induction motor, inter-turn short circuit, phase currents, diagnostic parameters.

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Among the transformer-less DC-DC converters, the superiority of the conventional Cuk converter is obvious in its good properties. However, the output power is limited for all transformer-less converter types including the conventional Cuk converter. In order to get more supplied power from this converter, some changes in its design were necessary. One of these modifications is to add a transformer to transfer more power and to separate the output side from the input side. Supply of some applications such as the DC link of modular multilevel inverters, e.g. cascaded H-bridge (CHB) topologies required more than one output. Hence, this paper is concerned with the design, analysis and simulation of an isolated dual-output modified Cuk converter. The proposed converter is designed to deliver a total output power of 2,000 W using only one modulating switch. A complete design and detailed analysis of the high-frequency transformer with the ANSYS Maxwell platform is presented in this paper. The modeling and simulation results of the high-frequency transformer are validated by the experimental implementation results and good agreement was obtained with a small percentage of errors less than 0.25 %. A set of analytical equations has been derived and presented in this paper to represent a mathematical model of the converter. In addition, the entire converter circuit was simulated and analyzed using MATLAB/Simulink. The simulation results were checked and compared to the findings of the mathematical model, yielding an excellent match with a percentage error of less than 2.15 %. Finally, when the presented converter was tested under various loads, including unbalanced load situations, a reasonable output voltage regulation was achieved, with the two output voltages being nearly identical with a deviation of less than 0.25 % under a severe unbalanced load condition of 150 %.

Keywords: isolated Cuk converter, DC-DC converter, double-output high-power converter, high-frequency transformer.

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This paper proposes an approach to modeling the process of artificial ventilation of human lungs by their controlled filling with a fixed volume of air, using an incentive spirometer Coach 2. This makes it possible to simulate the ventilation process for a healthy person and to link the assigned respiratory volume to measurement data. The results of experimental studies of the developed system of multifrequency electric impedance tomography are presented. The tests were performed for the frequency range from 50 kHz to 400 kHz (with a pitch of 50 kHz) at assigned respiratory volumes from 500 ml to 4,000 ml (with a pitch of 500 ml) for five inhalation/exhalation cycles. The scheme of research: active inhalation – passive exhalation, the number of tested volunteers – 3 people from the developers of the system. As a result, the dependences of the measured values of changes in potentials on the frequency of injected current for different respiratory volumes in three test participants without pathologies of the respiratory function and the external respiration function were obtained. The obtained results of the experimental studies show that there is a dependence of the value of the measurement data both on the volume of inhaled air and on the frequency of the injected current. This feature can be used to develop a number of medical devices for personalized monitoring of human lung function. It was also revealed that there are frequencies at which the maximum spread of measurement data according to the results of a series of repeated experiments is observed. At the same time, the nature of the change in the measurement data of the EIT at an increase in the volume of inhaled air is the same for all test participants. It is assumed that this feature can also be used to increase the EIT personalization degree.

Keywords: electric impedance tomography, multifrequency, measurement data, respiratory volumes, experimental studies, conductivity.

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CONSTRUCTING AND ANALYZING MATHEMATICAL MODEL OF PLASMA CHARACTERISTICS IN THE ACTIVE REGION OF INTEGRATED P-I-N-STRUCTURES BY THE METHODS OF PERTURBATION THEORY AND CONFORMAL MAPPINGS (p. 51–61)
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The results of mathematical modeling of stationary physical processes in the electron-hole plasma of the active region (i-region) of integral p-i-n-structures are presented. The mathematical model is written in the framework of the hydrodynamic thermal approximation, taking into account the phenomenological data on the effect on the dynamic characteristics of charge carriers of heating of the electron-hole plasma as a result of the release of Joule heat in the volume of the i-th region and the release of recombination energy. The model is based on a nonlinear boundary value problem on a given spatial domain with curvilinear sections of the boundary for the system of equations for the continuity of the current of charge carriers, Poisson, and thermal conductivity. The statement of the problem contains a naturally formed small parameter, which made it possible to use asymptotic methods for its analytical-numerical solution. A model nonlinear boundary value problem with a small parameter is reduced to a sequence of linear boundary value problems by the methods of perturbation theory, and the physical domain of the problem with curvilinear sections of the boundary is reduced to the canonical form by the method of conformal mappings. Stationary distributions of charge carrier concentrations and the corresponding temperature field in the active region of p-i-n-structures are obtained in the form of asymptotic series in powers of a small parameter. The process of refining solutions is iterative, with the alternate fixation of unknown tasks at different stages of the iterative process. The asymptotic series describing the behavior of the plasma concentration and potential in the region under study, in contrast to the classical ones, contain boundary layer corrections. It was found that boundary functions play a key role in describing the electrostatic plasma field. The proposed approach to solving the corresponding nonlinear problem can significantly save computing resources.

Keywords: asymptotic series, boundary layer correction, conformal mappings, singularity, electron-hole plasma, p-i-n-structure.

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APPLICATION OF PARTIAL AREA METHOD IN THE PROBLEM OF SOUND RADIATION BY A SPHERE IN A WAVEGUIDE WITH SOFT ACOUSTICALLY BOUNDARIES (p. 62–78)

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The paper considers the features of the formation of an acoustic field by a spherical source with complicated properties in a regular plane-parallel waveguide, which is of practical importance in marine instrumentation and oceanographic research. The calculation algorithm is based on the use of the Helmholtz equation and the Fourier method for each partial region and the conjugation conditions on their boundaries. The presented calculation allows one to get rid of the idealized boundary conditions on the source surface, with the subsequent determination of the excitation coefficients of the waveguide modes within the framework of the Sturm-Liouville problem. In this case, the attraction of the boundaries of the working space and the space of the waveguide, makes it possible to obtain the real distribution of the field in the vertical sections of the waveguide.

The obtained frequency dependences of the pressure and vibrational velocity components show their amplitude-phase differences, which reach 90 degrees, which partially explains the appearance of singular points in the intensity field in a regular waveguide. It has been determined that multiple reflections of sound waves from the boundaries of the working space and the space of the waveguide cause oscillations of the pressure components with a change in the amplitude level up to 6 dB. It was found that with an increase in the size of the source, a kind of resonance is formed in the working space, the frequency of which depends on the depth of the sea and corresponds to the region kr=x=5.8. It was found that when the acoustic field is formed in the working space, the frequency response of the impedance components is represented as a multiresonant dependence formed on the basis of the frequency characteristics of the lower modes and their combinations. Experimental studies have shown that the results of calculations of the mode composition of the acoustic field of the emitter, obtained in the conditions of the pool, correspond to the spatial characteristics of the mode components of the acoustic field with an error of up to 3 dB.

Keywords: acoustic field, acoustic plane-parallel waveguide, spherical source, partial regions.
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MULTIFUNCTIONAL FIBER-OPTIC SENSORS FOR SPACE INFRASTRUCTURE (p. 80–89)

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Sensors used in rocket and space technology are subject to extreme external influences in terms of temperature, vibration, and shock. Therefore, the choice of the type of sensors is justified precisely by the resistance to such factors, as well as the ability to ensure the temporal and parametric stability of measurements. A new type of sensors – fiber-optic ones – meets these conditions. The basis for the selection and further improvement of such sensors were such requirements as minimum power consumption, high accuracy and stability of measurements, the ability to combine several measurements in one sensor. It is noted that for space infrastructure the factor of the possibility of simultaneous measurement of several parameters with one sensor is one of the important quality indicators. This is due to the possibility of reducing the number of sensors themselves, which reduces the mass and size parameters of space technology. This applies, first of all, to measurements of pressure and temperature, since they, in aggregate, account for at least 40% of all measurements in space products. The path of choosing the types of methods and sensor designs led to the combination of the amplitude conversion method and optical communication in one sensor. In this case, amplitude modulation of pressure and temperature is carried out by a microelectromechanical unit (module), and the modulated optical signal is transmitted by an optical module. Such a modular composition of the sensor makes it possible to dispense with optical analyzers (interrogators) and carry out further processing based on standard interfaces. A limitation of the proposed methods and designs is the need for microelectromechanical structures that measure certain physical quantities. Such structures for fiber-optic sensors are not mass-produced; therefore, their
manufacture can be established at instrument-making enterprises with microelectronic equipment.

**Keywords**: fiber-optic sensor, photodiode, laser light-emitting diode, Bragg grating, combined.

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У статті розглядаються комбіновані методи збільшення теплопередачі, вплив додавання наночастинок і ультразвукових коливань в радіатор з використанням холодоагенту радіатора (ХР) в якості основної рідини. Метою дослідження було визначити вплив наночастинок в рідині (нанорідині) і ультразвукових коливань на загальний коефіцієнт теплопередачі в радіаторі. Використовувалися наночастинки оксиду алюмінію розміром 20-50 нм виробництва Zhejiang Ultrafine powder & Chemical Co, Ltd, Китай з об’ємною концентрацією 0,25 %, 0,30 % і 0,35 %. Регулюючи температуру потоку рідини в радіаторі від 60 °C до 80 °C, швидкість потоку рідини варіюється від 7 до 11 л/хв. Результати показали, що додавання наночастинок і ультразвукових коливань в холодоагент радіатора збільшує загальний коефіцієнт теплопередачі на 62,7 % при швидкості потоку 10 літрів за хвилину і температурі 80 °C для об’ємної концентрації частинок 0,30 % в порівнянні з чистим ХР без вібрації. Вплив ультразвукових коливань на чистий холодоагент радіатора без вібрації збільшує загальний коефіцієнт теплопередачі на 9,8 % з 385,3 Вт/м²·°C до 423,3 Вт/м²·°C при швидкості потоку 9 літрів за хвилину при температурі 70 °C. Присутність частинок в охолоджуючій рідині підвищує загальний коефіцієнт теплопередачі на 62,7 % при температурі 80 °C для об’ємної концентрації частинок 0,30 % в порівнянні з ХР, який становить 385,3 Вт/м²·°C до 423,3 Вт/м²·°C при 70 °C при швидкості потоку 10 літрів за хвилину.

Ключові слова: нанорідина, оксид алюмінію, холодоагент радіатора, ультразвукові коливання, загальний коефіцієнт теплопередачі.
Ці залежності показали, що при виникненні міжвиткового замикання в обмотках статора фазні зсуві однакові для всіх фаз двигуна. Це дозволило отримати залежності зміни фазового зсуву від зміни частоти обертання валу двигуна.

В результаті досліджень отримано залежноності швидкості зміни фазового зсуву від частоти обертання валу двигуна як для однієї, так і для двох пошкоджених фаз з різним ступенем пошкодження. При аналізі цих залежностей встановлено, що збільшення числа пошкоджених фаз електродвигуна зменшується лінійна діаграма залежностей. Крім того, зі збільшенням ступені пошкодження фаз зменшується кут нахилу лінійні діаграма залежностей. Це дозволило визначити додатковий параметр для діагностики місця і ступеня міжвиткового замикання обмоток асинхронного двигуна з короткозамкненим ротором. Значення додаткового параметра, названого авторами «фазовий критерій» можуть бути використані для оцінки стану і ступені пошкодження обмоток статора асинхронних двигунів. Значення фазових критеріїв для різних видів ушкоджень складають: при пошкодженні фази А на 90 %, \(\xi=0.634\), (deg)/rpm; при пошкодженні фази А на 80 % \(\xi=0.393\), (deg)/rpm; при пошкодженні фази А на 80 % і фази В на 90 % \(\xi=0.25\), (deg)/rpm; при пошкодженні фази А на 80 % і фази В на 80 % \(\xi=0.173\), (deg)/rpm.

Результати проведених досліджень можуть бути використані для вибору ефективного методу діагностики міжвиткового замикання в обмотці статора при побудові системи діагностики асинхронних двигунів в складі приводів транспортного устаткування.

**Ключові слова:** транспортна інфраструктура, асинхронний двигун, міжвиткова заміка, фазні струми, діагностичні параметри.

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**ПРОЕКТУВАННЯ ТА МОДЕЛЮВАННЯ ВИСОКОПОТУЖНОГО ДВОВИХІДНОГО ІЗОЛЬОВАНОГО ПЕРЕТВОРЮВАЧА ЧУКА (с. 30–38)**

Yasir M.Y. Ameen, Harith Al-Badrani, Mohamed N. Abdul Kadir

Серед безтрансформаторних перетворювачів постійного струму очевидна перевага звичайного перетворювача Чука завдяки його гарним властивостям. Однак вихідна потужність обмежена для всіх типів безтрансформаторних перетворювачів, включаючи звичайний перетворювач Чука. Для отримання більшої потужності від цього перетворювача, потрібні були деякі зміни в його конструкції. Одна з них полягає в додаванні трансформатора для передачі більшої потужності і відділення відповідної обмотки від первинної. Для живлення деяких компонентів, таких як ланка постійного струму модульних багаторівневих інверторів, на приклад каскадний H-мостовий (КHM), потрібно більше одного виходу. Тому, дана робота присвячена проектуванню, аналізу та моделюванню ізольованого модифікованого двовхідного перетворювача Чука. Запропонований перетворювач розрахований на загальну вихідну потужність 2000 Вт використовуючи тільки одного модульного перемикача. За допомогою платформи ANSYS Maxwell представлена нова конструкція і детальний аналіз високочастотного трансформатора. Результати моделювання високочастотного трансформатора підтверджуються результатами експериментальної реалізації, було отримано хороші результати з урахуванням шуму від глибоких підніманих індуктивностей вихідних обмоток.

**Ключові слова:** ізольований перетворювач Чука, перетворювач постійного струму, двовхідний високопотужний перетворювач Чука, високочастотний трансформатор.

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**ЕКСПЕРИМЕНТАЛЬНІ ЗАЛЕЖНОСТІ ВИМІРЮВАЛЬНИХ ДАНИХ ВІД ОБСЯГІВ ВДИХУВАНОГО ПОВІТРЯ ПРИ БАГАТОЧАСТОТНОЙ ЕЛЕКТРОІМПЕДАНСНОЙ ТОМОГРАФІЇ (с. 39–50)**

Г. К. Александри

У роботі запропоновано підхід до моделювання процесу штучної вентиляції легенів людини шляхом їх керованого наповнення фізикованим об’ємом повітря Coach 2. Це дозволяє змінювати процес вентиляції для здорових людей і пригнічіти задаток дихального об’єму до вимірювальних даних. Наведено результати експериментальних досліджень розробленої системи багаотчаточаточній електроімпедансної томографії. Випробування виконувалися для діапазону частот від 50 кГц до 400 кГц (з кроком 50 кГц) при заданому розподілі вихідних об’ємів у відповідності стану і ступеню пошкодження обмоток. Перетворювач розроблено для відсікання вторинної обмотки від первинної. Для живлення деяких компонентів, таких як ланка постійного струму модульних багаторівневих інверторів, на приклад каскадний H-мостовий (KHM), потрібно більше одного виходу. Тому, дана робота присвячена проектуванню, аналізу та моделюванню ізольованого модифікованого двовхідного перетворювача Чука. Запропонований перетворювач розрахований на загальну вихідну потужність 2000 Вт використовуючи тільки одного модульного перемикача. За допомогою платформи ANSYS Maxwell представлена нова конструкція і детальний аналіз високочастотного трансформатора. Результати моделювання високочастотного трансформатора підтверджуються результатами експериментальної реалізації, було отримано хороші результати з урахуванням шуму від глибоких підніманих індуктивностей вихідних обмоток.

**Ключові слова:** штучна вентиляція легенів, визначення дихального об’єму, електроімпедансна томографія, багаотчастотність, вимірювальні дані, дихальні обсяги, експериментальні дослідження.
А. Я. Бомба, І. І. Мороз, М. В. Бойчура

Приведені результати математичного моделювання стаціонарних фізичних процесів в електронно-дірковій плазмі активної області (i-области) інтегральних р-і-n-структур. Математична модель записана в рамках гідродинамічного теплового наближення з врахуванням феноменологічних даних про вплив на динамічні характеристики носіїв заряду розсійну електронно-діркової плазми внаслідок відхилення в об’ємі i-области Джоулевої теплі та вивільнення енергії рекомбінації. Основу моделі складає неіншій радіо задача на заданій просторовій області з криволінійними ділянками границі для системи рівняння неперервності струму носіїв заряду, Пуассона та теплопровідності. Постановка задачі містить природним чином сформованій малий параметр, що забезпечує можливість залучити асимптотичні методи для її аналітично-числового розв’язання. Моделька неіншій розрахунка задача з малим параметром приведена до послідовності лінійних крайових задач методами теорії збурень, а фізична область задачі з криволінійними ділянками межі до канонічного виду – методом конформних відображень. Отримано стаціонарні розподіли концентрації носіїв заряду і відповідне температурне поле в активній області р-і-n-структур у вигляді асимптотичних рядів за степенями малого параметра. Процес уточнення розв’язків ітеративний, з почерговою фіксацією невідомих задачі на її границях. Асимптотичні ряди, які описують поведінку концентрації плазми і потенціалу у сідлівчатій області, на відміну від класичних, містять примежові поправки. Збуджено, що примежові функції відіграють ключову роль в описі електростатичного поля плазми. Запроектований підхід до розв’язання відповідної неелементарної задачі забезпечує можливість суттєвої економії обчислювальних ресурсів.

Ключові слова: асимптотичний ряд, примежова поправка, конформне відображення, сингулярність, електронно-діркова плазма, р-і-n-структура.
у космічних виробах. Шлях вибору типів методів та конструкцій датчиків призвів до поєднання амплітудного методу перетво-рення та оптичної комунікації в одному датчику. При цьому амплітудна модуляція тиску та температури здійснюється мікроелектромеханічним блоком (модулем), а промодульований оптичний сигнал передається оптичним модулем. Така модульна композиція датчика дозволяє відмовитися від оптичних аналізаторів (інтерогаторів) та здійснювати подальшу обробку на осно-ві стандартних інтерфейсів. Обмеженнями запропонованих методів та конструкцій є необхідність у мікроелектромеханічних структурах, що вимірюють певні фізичні величини. Такі структури для волоконно-оптичних датчиків не виробляються серійно, тому їх виготовлення може бути налагоджено на підприємствах приладів, що мають мікроелектронне обладнання.

Ключові слова: волоконно-оптичний датчик, фотодіод, лазерний світлодіод, ґратки Брегга, суміщений.