Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 2, 2021, Pages. 4057 - 4066
Received 20 January 2021; Accepted 08 February 2021.

Multifunctional Optoelectronic Natural Resource Monitoring Systems

[1]Turaev BakhadirErgashevich,[2]Rakhimov Nematjon, [3]Rakhimova Mekhribonu, [4]Ulugov Bazar Dzhumaevich

[1]Director, Termez Branch of Tashkent State Technical University named after Islam Karimov, Termez, Uzbekistan.

[2]Branch of FGBOU VO USPTU in Oktyabrsky, City or Province Po Oktyabrsky, Russia.

[3]Ufa State Petroleum Technical University, Ufa, Russia

[4]Department of General Sciences, Faculty of Energy and Transport Systems, Termez Branch of Tashkent State Technical University named after Islam Karimov, Termez, Uzbekistan.

Abstract: This article provides the fundamentals of optical methods and the principles of constructing multifunctional optoelectronic systems for monitoring natural resources based on the effects of disturbed total internal reflection (TIR) and multiple TIR (MTIR). Optical systems with the use of the TIR effect and an analysis of the basic designs of TIR and MTIR sensors are considered, practical diagrams of optoelectronic non-destructive testing systems based on TIR and MTIR are presented.

Keywords: Open channel optocoupler; Optoelectronic sensor; TIR or MTIR elements

Introduction

The currently known most promising single-function optical methods and monitoring tools do not provide high measurement accuracy due to the wide range of the absorption spectrum of certain substances present in natural resources. At the moment, it is known [6] that optical methods are increasingly used to determine one substance in another using an open channel optocoupler. The use of multifunctional systems using the effect of disturbed total internal reflection (TIR) or MTIR, which simultaneously determine several parameters, makes it possible to simultaneously monitor both physicochemical indicators and physical processes accompanied by simultaneous and non-simultaneous changes in time of several physicochemical quantities.

Besides, the use of multifunctional optoelectronic systems not only increases the information content of measurements but also makes it possible to reduce errors from the influence of external factors, such as temperature, humidity, and vibration level, which can be taken into account when automatically correcting errors [2-5]. The oil industry currently uses dozens of optoelectronic methods and hundreds of optoelectronic devices, which are the basis for the determination of sulfur in petroleum products and are adopted in various standardization systems: ASTM, EN ISO, IP, GOST. In review, optical methods for the determination of total sulfur in oil and oil products are

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considered. Our work is based on different results and conclusions of research work carried out in the USA, Europe, and Russia, which were obtained by various optical methods in interlaboratory tests.

Optical methods approved for use by European specifications for petroleum products and Russian technical specifications are considered [8].

Organic sulfur compounds are a natural component of crude oil. Under thermal influence during oil refining, sulfur and its compounds are found in oil products in various concentrations. The main existing sulfur-containing compounds and sulfur in petroleum products have the following forms:

- Hydrogen sulfide H_2S, formed during thermal decomposition sulfur-containing compounds;
- Elemental sulfur, a product of hydrogen sulfide oxidation;
- Mercaptans R-SH;
- Sulfides or thioethers R-S-R;
- Disulfides and polychaete's R-S ... S-R;
- Thiophene C_4H_4 S and its derivatives, etc.

We know that the presence of these compounds is undesirable because they give the oil products an unpleasant odor, corrode equipment, and pollute the atmosphere during combustion. Also, sulfur compounds destroy expensive catalysts for oil refining and, releasing sulfur oxides into the atmosphere during combustion, create global environmental problems for us.

Several optical methods and devices have been developed in the world for the determination of sulfur in the ultraviolet, X-ray, near-infrared, and IR ranges. The choice of an appropriate optical method for solving this analytical problem depends on the nature and composition of the analyzed object, the required concentration range, accuracy, and budgetary possibilities of the laboratory [12, 13].

The disadvantage of laboratory optical methods is that the analysis takes a very long time and is difficult to automate the process. Wavelength-dispersive X-ray fluorescence analysis is designed to determine low sulfur levels in gasoline and diesel fuels. Determination of sulfur by energy dispersive X-ray fluorescence spectrometers is designed to determine the total sulfur content in petroleum products, such as gas oil, fuel oil, crude oil by the method energy dispersive X-ray fluorescence spectrometry, which is an accurate, non-destructive, cost-effective, and rapid method. But in the X-ray method for the determination of total sulfur in oil and petroleum products, it is necessary to change the film or cuvette whenever the measurement is repeated. Besides, the atoms of some elements existing in oil can emit in the same spectral range as sulfur atoms (lead, silicon, phosphorus, etc.) [1].

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Also used for control are spectrophotometers - two-beam scanning spectrophotometers of UV and visible spectral region for automatic measurements. They are distinguished by high stability, flexibility in the choice of analysis methods, ease of presentation, and processing of the obtained data. The devices can be equipped with cuvettes of various lengths and volumes, systems for automatic change of cuvettes and thermostatic of cuvettes with an autosampler, holders for solid samples and gels, an integrating sphere, and a fiber-optic system for remote analysis, but in the ultraviolet method for the determination of sulfur in laboratory conditions in oil and petroleum products, halogens interfere with and affect the measurement accuracy. This optical method is mainly used in laboratory conditions for measuring the proportion of sulfur in finished petroleum products (gasoline, diesel, etc.).

Monitoring of natural resources, i.e. determination of technological parameters of drinking water, air pollution, the content of one substance in another: the content of dustiness, fog, etc. closely related to the accuracy of the analysis.

The use of multifunctional systems with the use of the TIR or MTIR effect, which simultaneously determines several parameters, makes it possible to simultaneously monitor both physicochemical parameters (including their change in time, i.e., their dynamic state) and physical processes accompanied by a simultaneous and non-simultaneous change in time of several physicochemical quantities. Besides, the use of multifunctional optoelectronic systems not only increases the information content of measurements but also makes it possible to reduce errors from the influence of external factors, such as temperature, humidity, and vibration level, which can be taken into account when automatically correcting errors.

In this paper, based on the use of the TIR effect interacting with a controlled environment, the development of a new principle for constructing optoelectronic systems for monitoring natural resources is considered. The proposed idea consists in the simultaneous use of n radiation sources and TIR elements installed in the direction of radiation, in the form of a half-cylinder, and n measuring receivers of optical radiation (ROR), compensation (reference) ROR, optically connected directly to the reference radiation source.

Materials and Methods

In single-function optoelectronic control and measuring systems, the process of converting the measured value x1 into an informative parameter of an electrical signal should theoretically be described as

$$\Upsilon = F(x_1) \tag{1}$$

And in practical cases, this signal has the form

$$\Upsilon = f(x_1, y_1, y_2 \dots y_k) \tag{2}$$

Where y_1, y_2, y_k, - several changing physical quantities, the influence of changes in which significantly changes the value Y. Introducing a correction along with one of y, for example, y_i, requires the use of the second transformation, described as

$$Y_j = f_j(y_i) \tag{3}$$

Based on this, to extract information about the value of x from the multidimensional signal described by expression (2), it is necessary to obtain signals described by equation (3), which is very difficult to determine in practice. Multifunctional optoelectronic methods make it possible to determine physicochemical quantities by using a set of multidimensional signals, i.e. depending on many x_i, expand thepossibilities of the optoelectronic method for measuring non-electrical quantities.

The method is based on the fact that using a special TIR element (in this case, a semi-cylindrical one), it is possible to obtain n multidimensional signals, the informative parameters of which depend on n physical quantities in such a way that the equations describing these dependencies form a system of n independent equations:

$$\begin{gathered} Y_1=f_1 (x_1, x_2, \ldots,x_n) \\ Y_2=f_2 (x_1, x_2, \ldots,x_n) \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ Y_n=f_n (x_1, x_2, \ldots,x_n), \end{gathered} \tag{4}$$

Then in several cases, it is possible, using the values of the informative parameters Y_1, Y_2 …… Y_n, to determine the values of an individual or all n physicochemical quantities x_i that is amenable to optical control.

Determined parameters Y_1, Y_2 … Y_n, called primary signals, are measured sequentially one after the other, memorized, and only then the measurement spectrum is applied to determine the parameters x_i, orthey all arise simultaneously and are jointly used to generate output signals proportional to and subject to measurement x_i. The block diagram of the system that performs multifunctional monitoring with the simultaneous occurrence of all n primary signals Y_J is shown in Figure 1, Figure 2 is a view of the sensor along section A-A.

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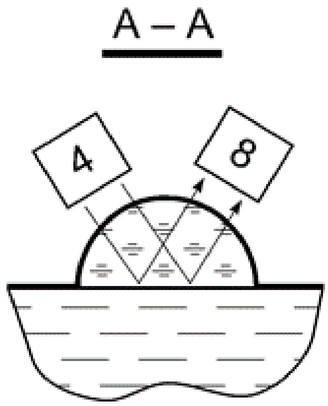

Fig. 1. Sensor type

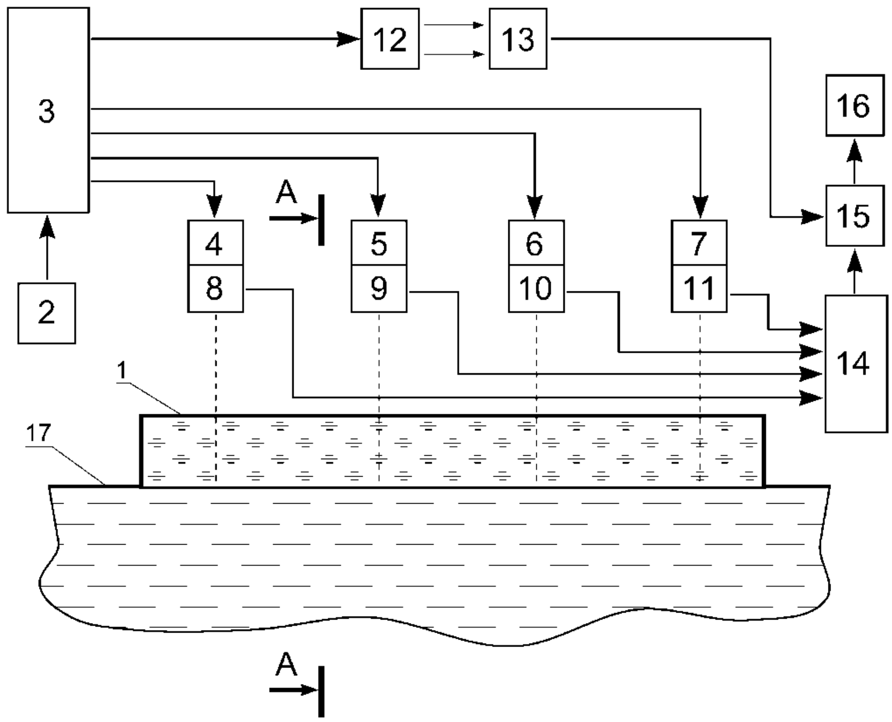

Fig. 2.Functional diagram of the system.

The authors have developed several optoelectronic devices [9-11] using the TIR element to solve the problems of automatic analysis of the structure-group composition. An optoelectronic TIR device for monitoring natural resources has been created. The TIR monitoring method has the advantage over other physicochemical methods in the accuracy and simultaneous determination of several optical parameters. Also, the TIR method surpasses the named methods in efficiency and simplicity, while providing non-destructive testing at the same time.

To determine the qualitative and quantitative content of microparticles in the air, you can use the trapezoidal multiple total internal reflection (MTIR) element attachments. Despite other physicochemical methods, in the accuracy and convenience of determining the optical parameters,

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the TIR-method surpasses them in expression, at the same time providing non-destructive testing [6].

This article proposes an optoelectronic system for multifunctional monitoring based on the TIR element of the physical and chemical parameters of drinking water, air pollution, as well as the content of one substance in another: the content of dustiness, fog, etc.

The system includes an ATR sensor made in the form of a half-cylinder 1, along the entire length of the half-cylinder 1 on its cylindrical surface there are radiation sources 4 - 7, optically connected to the measuring photodetectors 8 - 11. The system also includes a compensation radiation source 12 and a photodetector 13, optically connected between itself, the master oscillator 2 connected to the switch 3, one output of which is connected to the compensation radiation source 12, and the other outputs to the radiation sources 4 - 7, the output of each measuring photodetector 8 - 11 is connected to one of the inputs of the amplifier 14, the output of which is connected with the first input of the photoelectric signal processing unit 15, the second input of which is connected to the compensation photodetector 13, and the output to the recording device 16. Each radiation source 4-7 are optically connected through the measuring face of the half-cylinder 1 with the corresponding measuring photodetector 8-11. Instead of recording device 16, a computer can be used. LEDs can be used as radiation sources 4 - 7 and a compensating radiation source 12.

The system works as follows. The master generator 2 generates rectangular pulses with a repetition rate of 8 - 10 kHz, arriving at the input of switch 3, which divides them into two parts. One part of the pulses goes to the radiation sources 4 - 7, and the other part - to the compensating radiation source 12. The radiation fluxes from the radiation sources 4 - 7 are focused on the measuring edge of the half-cylinder 1, reflected and fed to the measuring photodetectors 8 - 11, where the optical signal is converted into electricity, which is fed to the inputs of the adder 14 and is summed in it. Optical radiation from the compensation radiation source 12 is fed to the compensation photodetector 13.

The electrical signals from the output of the amplifier 14 and the compensation photodetector 13 enter the photoelectric signal processing unit 15, where the ratio of the values of the electrical signals corresponding to the compensation flow and the measuring radiation fluxes is determined, which are proportional to the content of air pollution, the content of one substance in another: the content of dustiness, gases, fog, etc. The electrical signal from the output of the photoelectric signal processing unit 15 is fed to a recording device 16 (or a computer), according to the indication of which the air pollution, the content of one substance in another: the content of dustiness, fog, etc. is judged. The proposed optoelectronic device increases the accuracy for determining the sulfur content in oil and oil products due to the MTIR element. In this optical method, we adopt an MTIR element to improve the quality of the analysis of the sulfur content in the product under study.

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When the IR beam passes through the MTIR element if the product under study contains sulfur, part of the beam from the dense optical medium is transferred to the less dense optical medium.

The rest of the beam is completely reflected from the upper part of the MTIR element since the upper part of the MTIR element is a denser medium. Fully reflecting from the upper part of the MTIR element, the IR beam again enters the lower part of the MTIR element, part of the beam is absorbed on the investigated product since the product under study contains sulfur. Thus, the IR beam will be reflected and absorbed until it is received by the optical receiver. Recently, IR spectroscopy is increasingly used to analyze the content of one substance in another. The essence of the IR method using the ATR effect is that the wavelength of the measuring LEDs lies in the absorption band of the IR spectrum of moisture, microparticles, various gases, salts, and the reference LEDs are outside the absorption band, but close to the wavelength of the measuring LEDs and serves to compensate for uninformative parameters.

Results and Discussion

The use of computers in the construction of optoelectronic multifunctional automatic control and measuring systems (OMACMS) for solving specific problems of analyzing the composition and properties of liquid media is a stage in the furthermore perfect development of the structure of optical devices. The computers provide the implementation of analog-to-digital measuring conversions, computational procedures, the issuance of the received information, the formation of command, and other service information necessary for the operation of OMACMS. It should be noted that the creation of analytical measuring and computing systems using microprocessor technology is one of the main directions of development of integrated automated analytical control systems (IAACS) of the quality of oil and oil products [7].

Using a highly sensitive method based on the TIR element, it is possible to create IAACS for qualitative and quantitative monitoring of natural resources. In figure 3 shows a block diagram of IAACS monitoring of natural resources based on OMACMS. With the help of this system, the following parameters can be measured simultaneously: density, water, salt, sulfur content, as well as consumption.

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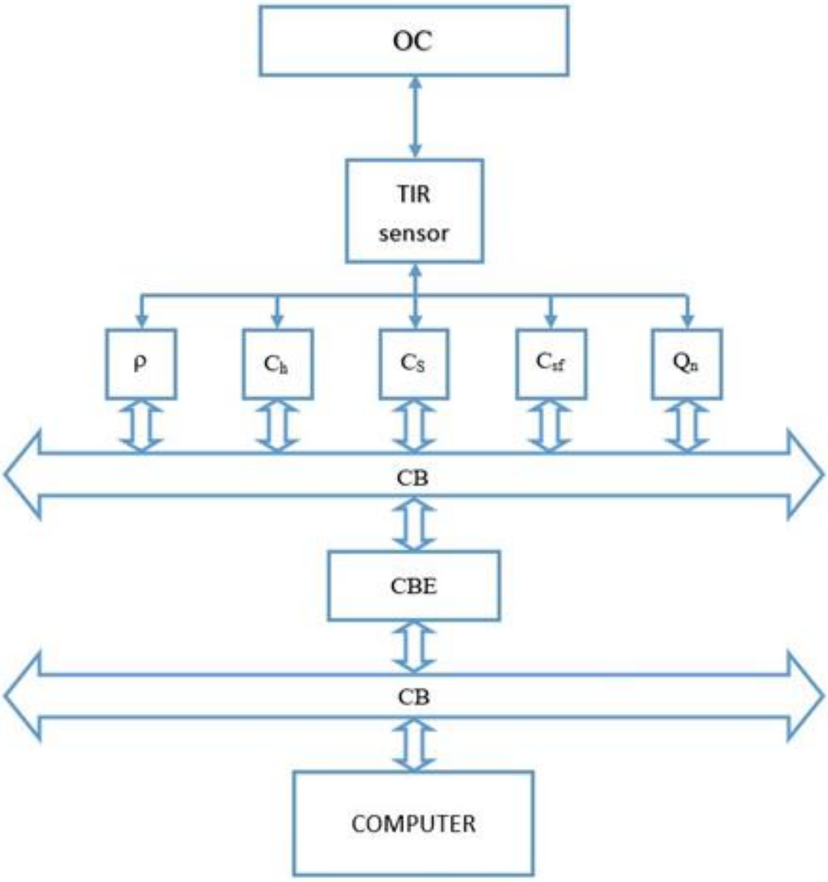

Fig. 3. Block diagram of IAACS for the quality of oil and oil products based on OMACMS: OC - object of control; CB - common bus; CBE - common bus expander. automatic meters: r - density; Ch - humidity; Cs - salts; Csf - sulfur; Qn - consumption.

Conclusion

In all types of optoelectronic systems designed to control the quality of oil and oil products using the TIR method, it is planned to use microprocessors and computers, which will expand the functionality of the systems and increase the accuracy of the analysis by introducing automatic correction of external factors, for example, ambient temperature.

The embedding of a modern computer makes it possible to automate the OMACMS calibration, adjustment, and diagnostics processes.

The creation of a highly sensitive, simple, and reliable IAACS, providing monitoring of oil-containing media, is still an unsolved problem in our time. However, as shown in this article, there are various and fairly effective ways to achieve this goal.

In TIR measurements, in comparison with the transmission method, additional equipment is required; a thoughtful choice of the refractive index of the TIR element and the angle of incidence of light is required. Consideration should be given to the possible corrosive effect of the sample on the TIR element and the need to periodically replace the latter due to damage during operation. TIR elements are often expensive and require high-quality surface treatment. Since the achievable effective thickness does not exceed a fraction of a millimeter, even with several reflections above 100, the TIR method should not be used for very weakly absorbing samples. This applies to the study of gases, experiments on titration of solutions, etc., where the spectral study requires a sample several millimeters thick.

ATR is generally unsuitable for investigating materials with a highly variable refractive index (e. g. quartz). In these cases, it is not possible to maintain the angle of incidence above the critical value over the entire wavelength interval.

In the absence of sufficiently good contact between the sample and the ATR element, the obtained values of the relative intensity of the bands cannot be considered reliable.

In certain cases, the ATR method should be used with caution. For example, when analyzing mixtures of substances, the relative concentration of the components near the surface of the ATR element may turn out to be different due to the difference in potentials at the surface. In this case, the ATR spectrum will not characterize the mixture as a whole.

The intensities, contours, and positions of bands in the ATR spectra depend to some extent on the angle of incidence of the light beam and the refractive index. As a consequence, one should be careful when comparing them with similar parameters of the transmission spectra.

Acknowledgments

The authors thank the Department of General Sciences of the Faculty of Energy and Transport Systems, Termez branch of the Tashkent State Technical University named after Islam Karimov for supporting this research.

References

1. Bozorovich, E. F., Eshmuminovich, R. J., & Dzhumaevich, U. B. (2020). Research of morphology and optical properties of complex-forming the ionit and their complex compounds of certain metals. Eurasian Journal of BioSciences, 14, 6045-6050.
2. Ioffe BV. Refractometric methods in chemistry. L.: Chemistry. 1983.
3. KhushbokovBKh, Ulugov BD, JurayevACh, Odinayev RQ, Turaxonov MI. The problem of measuring large currents with the help of current sensors. EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal, 2020;6(10): 312-318.
4. Kutenkova EY, Rakhimov NR, MadumarovShI, Islomov D. Mathematical model of an optoelectronic converter for monitoring liquid media.Collection of scientific works of NSTU. / automation and software engineering., 2012; 2: 36-40.
5. KhushbokovBKh, Ulugov BD, KhudaynazarovSKh, &Omonov F. Comparative analysis of modern current converters.EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal, 2020;6(10): 319–325.
6. Nosirov F, Urishev BU, Ulugov BD, Dustmurodov J, &Khaliyarov P. Reduced Pump Power Consumption Micro Accumulating Power Plants. International Journal of Advanced Science and Technology, 2020;29(7): 2128-2136.

7. Rakhimov N.R. Optoelectronic systems using the ATR effect for analyzing the composition of oil and oily media/book. "Modern problems of geodesy and optics". Novosibirsk: 2004; p. 163-167.
8. Rakhimov NR, TozhievRZh, SaidakhmedovShM, Khaidarov IM. Probe sensor for monitoring moisture and water content in oil and oil products. Uzbek Journal of Oil and Gas, (2001, 2); p. 39-40.
9. Rakhimov NR, TozhievRZh, Tilavoldiev O, AkhunovKKh. Optoelectronic colorimeter for monitoring color differences in petroleum products. Uzbek Journal of Oil and Gas, (2003, 3); p. 39-42.
10. Rakhimov NR, Zhmud VA, MadumarovSh.I. Investigation of the optoelectronic method for the determination of sulfur in oil and oil products using water.Collection of scientific works of NSTU. / Automation and software engineering, 2012; 1.
11. Rakhimov, NR. Optical control in oil refining/monograph. Technics, 2004; p. 91
12. Rakhimov NR. Optoelectronic systems based on the ATR effect for monitoring the technological parameters of oil and oil products.Izv.universities. Instrument-making, 2005;10: 41-45.
13. Fakhriddin Abdikarimov, Kuralbay Navruzov. Mathematical method of calculating the volume of the cavities of the heart ventricles according to echocardiography. European Journal of Molecular & Clinical Medicine, 2020, Volume 7, Issue 8, pp. 1427-1431.
14. Fakhriddin Abdikarimov, Kuralbay Navruzov. Mathematic modeling of pulsation movement of blood in large arteries. European Journal of Molecular & Clinical Medicine, 2020, Volume 7, Issue 8, pp.1438-1444.
15. Rakhimov NR, Turaev BE, &Ulugov BD. Optoelectronik devices based on nanocrystal semiconductor (CDTE) AFN films.(Оптоэлектроныеприборынаосновенанокристаллическихполупроводниковых (CDTE) АФН-пленок).Zbiórartykułównaukowychrecenzowanych., 28. Conference: MonografiaPokonferencyjna Science, Research, Development, 2020;33/2. At: http://xn--e1aajfpcds8ay4h.com.ua/files/105_06_x_2020_s.pdf,
16. Abdullaev, I., Doschanova, M., Abdikarimov, F., Iskandarov, A. Role of BeauveriaTenella (Del) Siem bd-85 in the control of the populations of termites from the genus Anacanthotermes Jacobson. EurAsian Journal of BioSciences, 2019, 13(2), pp. 1501–1507
17. Rakhimov NR, Turaev BE, &Ulugov BD. (2020, 9). Development of a small photogenerator based on the effect of anomalous photo voltage.(Разработкамалогабаритногофотогенератора на основе эффекта аномального фотонапряжения). Zbiórartykułównaukowychrecenzowanych., 28. Conference: MonografiaPokonferencyjna Science, Research, Development, 2020;33/2: At: http://xn--e1aajfpcds8ay4h.com.ua/files/105_06_x_2020_s.pdf,