THE REPUBLIC OF AZERBAIJAN

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ELOBARATION OF SCIENTIFIC-METHODICAL BASIS FOR DEVELOPMENT OF HIGHLY INFORMATIVE MULTIFUNCTIONAL PHOTOMETRIC MEASURING SYSTEMS FOR RESEARCH OF NATURAL OBJECTS AND MATERIALS

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Applicant: Kamala Jumshud gizi Aliyeva

SYNOPSIS OF THESIS

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Scientific supervisor: Doctor of technical sciences, professor **Tofig Ibrahim oglu Suleymanov**

Official opponents: Corresponding member of ANAS, doctor of technical sciences, professor **Ismayil Mahmud oglu Ismayilov**
Corresponding member of ANAS, doctor of technical sciences, professor **Aminaga Bahman oglu Sadigov**
Doctor of Technical Sciences, Professor Ali Hasan oglu Nagiyev

Dissertation Council of the ED 2.41 at the Azerbaijan Technical University of the Higher Attestation Commission under the President of the Republic of Azerbaijan

Chairperson of the dissertation council:
Doctor of Technical Sciences, Professor

_______________ **Vagif Alijavad oglu Gasimov**

Scientific secretary of the dissertation council:
Ph.D. in Technology, assistant professor

_______________ **Vahid Gara oglu Farhadov**

Chairperson of scientific seminar:
Doctor of Technical Sciences, assistant professor

_______________ **Namiq Tahir oglu Abdullayev**

GENERAL CHARACTERIZATION OF THE WORK

Rationale. Development of portable outdoor photometers necessary for operational measurements is now an important and urgent issue that we face when we test materials and structures, identify various compounds thereof, exercise quality control on food products, and undertake geochemical and spectral analysis of water, etc. For instance, quality of water could be assessed effectively as soon as the problem of discovery of water sources in non- residential areas is addressed. It is therefore more appropriate to use portable photometers, which allow identifying the concentration of ions, anions and cations in water by measuring the color of the water and the light rays that pass through the solution. It is worth emphasizing that the cost of outdoor analyses is 10-15 times lower than those necessary in laboratory settings.

To address various problems of plant ecology, it is of great importance to examine tree leaves and chlorophyll content in the leaves, and to identify biochemical composition of the water, as well as the leaf mass per unit area.Water content monitoring on leaves is one of the most important operations carried out to detect whether or not the plants have been exposed to water stress effects. The study of the plant dehydration level is an important factor to predict potential fire risks in forest areas.

The above parameters of plants could be measured at field setting with the introduction of photometric control and diagnostic techniques. These photometric facilities rely on the principle of measuring the rate of light transmitted or reflected by an object. It is an obvious fact that outdoor photometric devices, which rely on spectral and narrow spectral (with filter) brightness measurements are not limited to addressing environmental monitoring issues. These measuring devices are necessarily used in transport, aviation machinery, industry, military, etc. Universalization, i.e., multi-functionality, continuous improvement, as well as increase to break-down point of the precision of the applicable measuring techniques – to the extent it reaches the precision level of laboratory measuring techniques are the overall development tendency observed on portable photometric systems. All of the above- mentioned confirms the relevance of the chosen topic of the thesis and of the urgency of the issue of concern.

State of the problem. Researches focused on achieving universalization and multi-functionality of portable photometric systems and devices helped to discover a number of important classification properties. These properties indistinctly reflect both the scope of their application and the level of development of non-destructive control and diagnostic methods used. According to the measurement technique, portable photometers are divided into differential and non-differential spectral measuring devices.

According to the types of radiative excitation, there are different types of fluorescent photometers. In installations like this, the object is exposed to radiation by a laser source. In the group of other photometers that use natural light, the solar radiation is measured only after it is reproduced from, absorbed by and get weakened when passing through the object under investigation. A wide range of radiometric correction techniques are used in the modern photometric systems. Examples include, first of all, wave-length slip correction, radiation spectrum deviations correction, temperature drift compensation of interference filters, and correction of dynamic changes in spectral characteristics. Objects subject to research using photometric systems are classified as static and dynamic by their spectral characteristics, and as homogeneous and non-homogeneous by their structures.

The concept of creating a universal and multifunctional photometer involves maximizing the coverage of the above attributes on a single universal device. It is therefore an urgent issue to develop scientific and methodological framework for the creation of high precision and informative universal, multifunctional photometers that combine basic functions of both the laboratory and field photometers.

Goal and objectives of the work. The main goal of the thesis is to elaborate scientific and methodological basis for the development of a highly informative multifunctional photometric information-measuring system to exercise spectral control over the quality of materials and natural objects.

We set and addressed the following tasks to achieve the primary goal of the thesis:

1. Optimize photometrically active sensing systems for non-homogenous objects relying on the criteria of obtaining a maximum information.

2. Optimize diagnosing external environment in direct contact with nano-fiber light transmission that is connected to entrance of photometric systems.

3. Develop new photometric control techniques concerning food products exposed to stress factors to certain extent and have competitive attributes in spectral characteristics.

4. Apply new interferential filters used for the purpose of developing highly informative photometric measuring systems during the research of the properties of natural objects and materials, and elaborate on new techniques with high precision for research of spectral properties of composite materials relying on derivative spectroscopy approach.

5. Develop a new photometric measuring technique to eliminate the temperature drift of the spectral curves available in the emission strips of interference filter, elaborate on criteria for selecting filters controlled by adaptive photometric systems that are designed for research of dynamically shifting absorption spectra in physical and chemical structures.

6. Develop temperature slip compensation technique for interference filters emission strips by including into the system the electronically controlled liquid-crystal filter.

7. Develop a material status control technique based on the analysis of laser-induced fluorescence signal compensating the signal's damping effect.

8. Optimize from information perspective the X-ray fluorescence measuring procedure, select optimal measurement modes and study the dependence of the number of measurements on the thickness of the layer.

Scientific novelties:

1. An analytical expression for estimating the amount of information during photometric control was proposed as a result of optimization of photometrically active sensing systems for non-homogenous objects.

2. A transcendent equation enabling the calculation of the required number of repeated measurements will be obtained, which will facilitate the maximum emissivity of the measurement path to optimize the diagnostics of the external environment directly in contact with the nano-fiber light transmitter connected to the photometric system.

3. A new method of photometric control of food products with spectral characteristics, which were subjected to stress factors of various levels has been proposed and an algorithm has been developed to implement this method.

4. New methods and criteria for the use of interference filters have been proposed to improve the metrological performance of photometric measuring systems. A method has been developed to increase accuracy in the research of change of spectral properties of interference filters depending on the angle of incoming radiation based on derivative spectrometry of spectral properties of composite materials.

5. A method has been proposed to remove temperature drift of emission strips of filters via adaptive management of tightly placed emission strips of spectral emission curve of the object and interference filters with dual content. It has been developed a criteria to select the type of filters used in adaptive photometric systems, which are designed to research dynamically the varying absorption arrays in the physical and chemical structures.

6. It has been proposed a method of combining the temperature slip of emission strip of interference filter with the introduction into the system an electronically controlled liquid-crystal filter.

7. It has been proposed a method of controlling the state of materials based on laser-induced fluorescence analysis to compensate for the damping effect of the signal.

8. As a result of data optimization of the X-ray fluorescence measurement procedure, it is shown that in the optimal mode, the number of points repeats the scaled curve of the number of measured points, depending on the form of the function of dependence of the number of measurements on the thickness of the plate.

Practical value of the work. The results of the research can be used to check the quality of food and non-food products as well as to control various construction materials.

Basic provisions placed for defense.

1. Analytical expression of the assessment of the amount of information obtained in optimal mode as a result of optimization of photometrically active sensing system for non- homogenous objects.

2. The optimization criteria used to optimize the diagnosis of the environment in direct contact with the nano-fiber light transmitter connected to the photometric system. The transcendent equation proposed to calculate the required number of repeated measurements that provide maximum emittance of the measurement path.

3. Proposed photometric control method and its implementation algorithm for foodstuffs that are subject to varying degrees of stress factors and have competitive properties.

4. New methods and criteria for interference filters introduced to enhance the metrological performance of photometric measuring systems. The method used to research the changing spectral characteristics of interference filters depending on the angle of incoming radiation using derivative spectrometry technique for spectral properties of composite materials.

5. The method of removing the temperature drift in emittance of spectral emission curves of radiating elements and interference filters using adaptive control technique for tightly placed emission strips of the dual-content interference filters of photometric system, and criteria for selecting the type of filters compatible with adaptive-photometric systems, which are designed for the purpose of researching dynamically varying absorption spectra.

6. The method of compensating the temperature slip of the interference filter emission strip by including into the system an electronically controlled liquid-crystal filter.

7. Method for controlling the state of materials on the basis of laser-induced fluorescence analysis considering the compensation of damping effect of the signal.

8. Provision for the function of dependence of the number of measurements on the plate layer in the X-ray fluorescence measurement system on the basis of the form of repetition of the scaled form of the number of points measured by the thickness of the layer.

Approbation of the work. The major results of the thesis were discussed at the Scientific-Technical Council of the Scientific and Research Institute of Aerospace Informatics of the National Aerospace Agency, as well as at the following scientific conferences and forums:

- IX International Scientific and Practical Conference "Agrarian Science on Agriculture", Russia, Barnaul, 2014;
- VII International scientific-practical conference "Actual problems of ecology and labor protection", Russia, Kursk, 2015;
- V International Inter-Universities Scientific and Practical Conference “Enlightening the Future. The significance of the fundamental laws of chemistry, physics, and mathematics in the 21st century”, Russia, Velikiye Luki, 2015;
- X International Scientific and Practical Conference "Agrarian Science on Agriculture", Russia, Barnaul, 2015.

Name of the organization where the dissertation work is carried out. The dissertation work was carried out at the Institute of Informatics of the National Aerospace Agency of the Ministry of Defense Industry. The total volume of the dissertation with a sign, indicating the volume of the structural units of the dissertation separately. The introduction consists of 16697, Chapter I 45712, Chapter II 35068, Chapter III 39740, Chapter IV 53370 characters, the total volume of the dissertation with signs is 190 587 characters.

SUMMARY OF THE WORK

The introduction includes interpretation of the rational, purpose and objectives of the research, novelties of achieved scientific findings, practical importance of the findings, implementation of the findings of the paper.

The first chapter is dedicated to assessing the informative value of the system of photometric control on the material's quality.

It further presents a generalized flow chart (Figure 1) of the photometric system used to control the quality of the materials and the general structure scheme of the spectrophotometer (Figure 2).

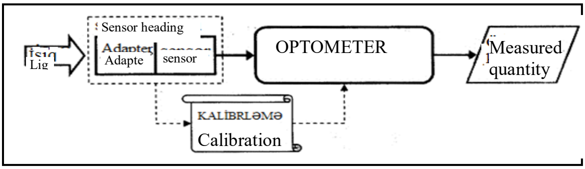

Figure.1. Generalized flow chart of the photometer

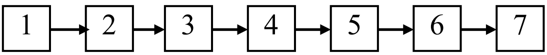

Fig.2. General structure chart of spectrophotometry: 1 - light source, 2 - collimator (lens), 3 mono-chromator, 4 - wavelength selector (crack), 5- sample solution, 6 - detector, 7 measuring device.

It has been noted that CCD type photo receivers have still some drawbacks. The fact that EMCCD (Electron-multiplying charge-coupled device) photo receivers, which are broadly used in spectrophotometry have a long-term wear effect, typical for amplifiers that necessitates periodic correction by increasing the amplitude of the beat impulses. However, the question of how to select the optimal value of the G (multiplication coefficient) parameter for the photo- receiver to remain stable throughout the entire life span remains unanswered. It is therefore proposed to review and apply a new indicator for EMCCD photo-receivers - the resource information capacity.

Resource information capacity (F_r) is determined based on the following formula:

$$\left(F_r\right) = \frac{T_f}{\Delta T} \cdot log_2 \frac{DR}{\Delta DR}. \qquad (1)$$

Here T_f – working period of photo- receiver, DR- dynamic range, ΔT-beat time.

The indicator DR is the decreased function of G and in the first approximation, it is determined as the following formula :

$$DR = \frac{C_1}{a_1 + G}. \qquad (2)$$

Here $C_1 = const, a_1 = const.$

G is the exponentially decreased function of T_f and in the first approximation, it is determined as follows:

$$G = a_2 + a_3\, exp\left(-a_4 T_f\right);\ a_2, a_3, a_4 = const. \qquad (3)$$

In view of (2) and (3) expressions, we find

$$DR = \frac{C_1}{a_5 + a_3 \exp\left(-a_4 T_f\right)};\ a_5 = a_1 + a_2 \qquad (4)$$

It is found based on the expressions (1) and (4):

$$F_r = \frac{T_f}{\Delta T} \cdot \log_2 \frac{C_1 / \Delta DR}{a_5 + a_3 \exp(-a_4 T_f)} \qquad (5)$$

Stabilization of G in the level of G_0, allowed to determine T_f based on the following formula:

$$T_f = \frac{1}{a_4} \cdot ln \frac{a_3}{G_0 - a_2}. \qquad (6)$$

Thus, when the amplifier is stabilized at G0 level, the information resource set by the formulas (5) and (6) of the EMCCD photo receiver will be provided. It allows to examine the resource information indicator, which is received from the formula of Fr (1) and characterize, according to Shannon's information theory, the TF and DR together at the appropriate price.

The first chapter further discusses the issue of estimating the limit of information properties of multi-channel remote controlled photometric control systems of non-homogenous objects. The research problem is set as follows: To study the impact of indefinite situation arisen as the result of a drift in emission characteristics of tungsten quartz radiators with forelock on informative value of remote control system and to determine basic quantity indicators necessary for assessment of informative value. To this end, a general logic diagram of remote controlled active photometric control and sensing systems of non- homogenous objects was reviewed.

The non- homogenous object that has been examined consists of the combination of *n* number of different materials that differ according to their spectral properties. In this case, it was required to study *i* material using wave length in *i* number ($i=1,2,....,n$) and the length of waves were defined as $\lambda_{s\ddot{u}r.i} = i \cdot \Delta\lambda_{s\ddot{u}r}$. Here, $\lambda_{s\ddot{u}r}$ is the sliding value of the length of the strip and is specified by: $\lambda_{s\ddot{u}r}=\lambda -\lambda_0$; Thus, λ is the current wavelength, while λ_0 is the initial wavelength.

Here $\lambda_{s\ddot{u}r}$ -is the sliding value of the wave length, which is set as following: $\lambda_{s\ddot{u}r}=\lambda -\lambda_0$; here: λ-current wave length, λ_0-fixed starting wave length.

To find optimal alternative of $f(\lambda_{s\ddot{u}r})$, it s solved using Euler technique based on unconditional variation optimization function, and $f(\lambda_{s\ddot{u}r}) = \frac{2c}{\lambda_{s\ddot{u}r}}$ is set as optimal. The respective reports have shown that when multi- wave photometric control is exercised on mosaic type non- homogenous objects, the ratio of maximum quantity of information generated from this system is equal to $n / 2$.

Further, the first chapter discusses the issue of optimizing information indicators of photometric spectral and control measurements of environmental characteristics using nano-fibers, and provides a technical implementation alternative for reflectometric interference spectroscopy (Figure 3).

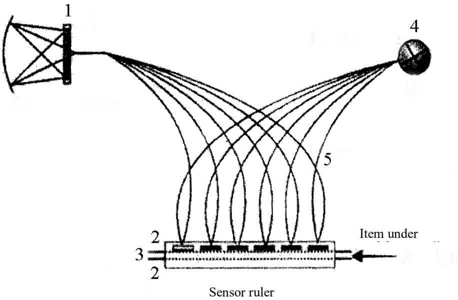

Figure.3. Technical realization reflexometric- interferometric spectroscopy principle: 1-spectrometer, 2- optical layer under mutual influence, 3-sensitive polymer layer, 4-light source, 5-light conducting fibers

Where a multiple repeated measurements are used, it has been indicated that σ_Σ final noise signal saw significant weakening and reached $\frac{\sigma_\Sigma}{\sqrt{n}}$ (n- number of repeated measurements) at the end. On the other hand, given that the low life expectancy of fluorescence radiation makes it necessary to carry out the measurement experiment as soon as possible, it is used as Emission Capacity (C), defined by $C = \frac{M}{T}$ (M- quantity of measurement information developed) as the optimization criteria for measurements. Where the repeated measurements is taken into account, it has been indicated to introduce transcendental equation for n quantity of repeated measurements $\frac{1}{k+n}\log_2 \psi\sqrt{n} = \frac{1}{2 \cdot n \ln 2}$ in order to get extremal value of the indicator C of the obtained information. Here $k = \frac{T_0}{T_1}$; $\psi = \frac{U}{\sigma_\Sigma}$. U is the maximal value of outgoing signal, T_0 – duration of initial measurement switches happening in the system (excluding multiple measurements), and T_1 is a duration of one measurement repeated n times.

The second chapter describes some scientific and methodological issues associated with photometric control of homogenous and non-homogenous materials, and proposes a photometric method for research of the quality of materials.

The general mathematical model for photometric control of materials that comprise a single composite material and have conflicting optical characteristics is provided as the linear folding of two absorption coefficients:

$$F_1 = \alpha_1 \cdot m_1(x_1, \lambda) + \alpha_2 \cdot m_2(x_2, \lambda). \tag{8}$$

Here, $\alpha_1 + \alpha_2 = 1;$ $m_i(x_i, \lambda)$ is the wheat absorption coefficient of i material where it is viewed in concrete, whereas $i = 1, 2;$ x_i is a stress factor that affect the material under investigation. Stress factor refers to the degree of fungal disease infected. A generalized model of scalar linear folding of absorption coefficients for such materials is defined as follows:

$$F_0 = \alpha_1 \cdot A_1 \cdot e^{-x_1 \lambda} + \alpha_2 \cdot A_2 \cdot e^{x_2 (\lambda - \lambda_0)^2}. \tag{9}$$

Here A_1 is the value of absorption coefficient of the first component when $\lambda=0$, and A_2 is the value of the absorption coefficient of the second component when $\lambda=\lambda_0$. It has been shown that when the stress factor x_1 is known, it is possible to calculate the wave length λ_{ext} and the stress factor x_2 experimentally determining the value F_{0min}, which set the minimal value of the expression (9). This method allows to improve the accuracy of the measurements. Thus, when the minimum value F_0 is found, it is possible to calculate x_2 with a high degree of accuracy within a maximum value of signal / noise ratio.

Then, Chapter 2 presents a technique for controlling mixed materials based on the differential spectroscopy method. To do so, it has been considered the reduced central wave length and emittance coefficient of the radiation emission strip and extended emission strip of the filter following the violation of the incoming radiation in the interference filters. The functional diagram of the absorption differential spectrometry built on the basis of the interference filter is shown in Figure 4. It is presented the possibility of a separate study of the components of Semrock interference filter based on derivative spectroscopy technique of composite materials using the specific properties of the filter.

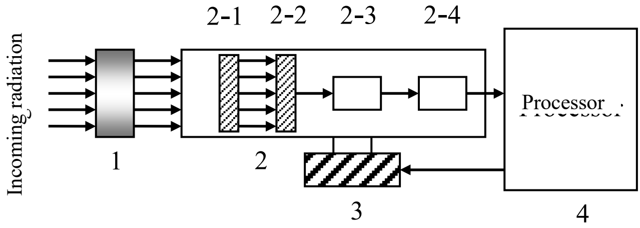

Figure.4. Functional diagram of differential spectrometer: 1- the substance under investigation, 2-spectrometer, 2-1-interference filter, 2-2-limiter, 2- 3-photo amplifier, 2-4-amplifier, 3-spectrometry orientation and rotation device, 4- processor

The second chapter also addresses the issue of improving the generative reflection model of the non-homogenous surface with the introduction of two episcotisters. Based on the Talbot theory, the episcotister was taken as a homogenous surface with partial emission. According to the theory, if the *a* and *b* are the reflection coefficients of two different zones of the non- transparent surface below the cleft disk, the final mixture of achromatic colors is calculated as follows when the disk is rotated with high speed, should the reflection of the surface of episcotister is equal to d t_1 and the size of the removed sector of the disk to α:

$$p_1 = \alpha_1 a + (1-\alpha_1)t_1\ ; \quad q_1 = \alpha_1 b + (1-\alpha_1)t_1. \tag{10}$$

Thus, it is proposed to improve the generative model of Talbot as follows:

- place the second on the non-transparent disc with a sector being removed and the rotation axes of both being overlapped;

- Assess the second additional disk reflection coefficient as t_2 and the size of the sector excluded from this disc as ($1-\alpha_2$);

- Where V_1 is the rotation speed of the first disc, determine the rotation speed of the second disc as $V_2 = 2 \cdot V_1$.

In the present case, the basic formulas have been proposed for the calculation of achromatic colors p_2, q_2 received at the end analogically to the expression (10):

$$p_2 = (1-\alpha_2)\cdot p_1 + \alpha_2 \cdot t_2 \,; \qquad q_2 = (1-\alpha_2)\cdot q_1 + \alpha_2 \cdot t_2 .$$

So, a method has been proposed to calculate the p_2 and q_2 achromatic signals by the introduction of two episcotisters. It was further found that the practical importance of generating a non-homogeneous surface reflection model in photometry involves the possibility of adjusting the contrast between different areas of the non-homogenous object by selecting the α and t parameters.

The second chapter also discusses the issue of optimizing the spectral control of materials surface in the coastal areas. The solution showed that the presence of a thin sea water layer and its effect on surface under investigation must be taken into account during the spectrometric diagnostics in order to detect separate harmful mixtures on the surfaces of different sea and coastal materials. It was noted that the consideration of these features may enhance the overall effectiveness of diagnostic control under high humidity conditions.

The third chapter deals with the correction of interference filters and instabilities of radiating elements in photometric systems. Initially we propose an adaptive control method for slip of emission strip of a filter in order to take into account the emission spectra slip of radiating element in the optical-electronic measurement systems.

One of the research concerns has been the synthesis of optical-electronic systems, which compensates for the maximum spectral slip of radiating elements with the adaptive control of the interference filter emission strips. It was proposed to use two-part interference filters implemented in this system in order to eliminate the emission spectra of the radiating elements and the asynchronous slip effect of emission strips of interference filters depending on the temperature.

The following algorithm has been proposed for the implementation of the method:

1. The optical incoming radiation entering the measurement system is divided into two equal parts.

2. The first part of the incoming optical radiation is emitted from the first interference filter with the emission strip ($\lambda_1 - \lambda_0$).

3. The second part of the incoming optical radiation is emitted from the second interference filter with the emission strip ($\lambda_0 - \lambda_1$).

4. Synchronism of slips of filters emission strips and radiating elements emission spectra because of the temperature under the conditions of full identity of stripped interference filters and the symmetry of the emission lines is generated under the condition of equation of the signals developed on the two optical-electronic channels.

5. When the equations of the two optical-electronic channels are violated, the control signals affecting filters are created to meet the equality of these signals.

The third chapter further analyzes the selection of adaptive interference filters in photometric systems to study dynamically changing spectral absorption curves.

It has been established that time-wise control on the physical processes characterized by dynamic variation in the shape of absorption spectrum can be exercised using adaptive photometric systems with regulated emission strip.

Figure 5 shows the functional scheme of an adaptive photometric system designed to study physical and chemical processes with dynamically changing spectral characteristics.

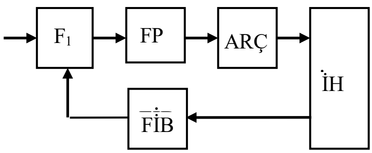

Figure 5. Functional scheme of adaptive photometric system: *F_1* -controlled narrow stripped interference filter, *FP_2* – photo- receiver, FIB -filter control block, ARÇ -analog-digital converter, IHG-controlling-computing device

It has been shown that the system's operation principle involves implementing the dynamic optical signal survey in wave lengths λ_i, $(i = 1,...,n)$ and finding one λ_0 in the numerical way so that the extremal in the outlet of photometer has the minimum value. The optical signal survey was carried out on a periodic basis through a dynamically adjustable narrow- band filter.

Later, the chapter proposes a method for narrow-band spectral photometric control, which compensates for the temperature drift of the interference filters. Slip for temperature in the central wave length of interference filters emission strips has been indicated as the main cause of their specific defects.

A functional scheme has been developed for the corrected narrow- band photometric spectral control (Figure 6). This system carries out the identification of 1 object based on the narrow- bad spectral control method using the object's reflection spectrum.

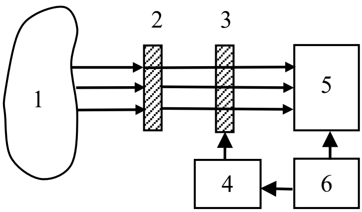

Fig.6. Flow chart of the narrow- band control system of objects on reflection spectrum: 1 - object, 2 – interference filter, 3 – controlled filter with liquid crystal, 4 – filter's control unit, 5 – acceptance and operation unit, 6 – control unit

In addition to 2 interference filters, additional 3 electronically controlled filters that allow compensation of emission strip because of the temperature have been placed in the optical path of the system. A method for compensating the slip was proposed and an algorithm was developed.

At the end, the Chapter Three analyzes the emission uncertainties of the radiation sources of photometric devices. The case under investigation showed that d_1 and d_2 weight coefficients have been set by experts and the following restrictive conditions have been met:

$$C_1 \geq d_{11}\sigma^2(y_1) + d_{21}\sigma^2(y_2); \qquad C_2 \geq d_{12}\sigma^2(y_1) + d_{22}\sigma^2(y_2);$$
$$C_3 \geq d_{13}\sigma^2(y_1) + d_{23}\sigma^2(y_2).$$

Here $C_i, (i = \overline{1,3})$ -restrictions that have been set, $d_{ij}\ (i = \overline{1,2};\ j = \overline{1,3})$ - expert values; y_1, y_2-λ_1 and λ_2 uncertainty of incoming optic signals in the wave length. The goal has been expressed with the function

$$F = d_{1,4}\sigma^2(y_1) + d_{2,4}\sigma^2(y_2);\ d_{1,4} = \frac{1}{3}\sum_{j=1}^{3} d_{1,j}\ ;\ \ d_{2,4} = \frac{1}{3}\sum_{j=1}^{3} d_{2,j}\ .$$

The essence of the optimization problem solved was to find the optimal $\sigma(y_1)$ and $\sigma(y_2)$ values that allows F to reach minimal prices, and a graphical solution to the linear programming problem was presented.

At the end of the chapter, the causes of uncertainty in the radiation intensity included among others the instability and outdated nature of an exemplary support source current, resistance of the resistor available in the food source cycle, the distance between the radiation element and the receiver, and constructive parameters of the radiating element.

The Chapter Four focuses on issues associated with improvement of the efficiency of fluorescence photometric control systems. Referring to the theoretical bases and practical examples of laser-induced fluorescence systems, deactivation of the fluorescent signal in a short time has been provided as a major barrier to the much broader use of the informative attributes of the fluorescence signal. In the light of these, the paper discussed the possibility of compensating the deactivation of fluorescence signal in the load-related devices base. The research showed that with the application of the integrated photo-sensitive receivers in different integrating modes can eliminate the fluorescence signal damping effect, in principle, if the time of reception of information is T_x. Further the fourth chapter discusses how to optimize the measurement of the thickness of the metal sheets deposited on the layers using X-ray fluorescence spectroscopy method.

A flow diagram of the X-ray fluorescence spectroscopy system has been examined (Figure 7). The operating principle of the system can be explained as follows: X-ray generator based on the command given from block 4 excites the molecules of the upper metal layer of the plate with own radiation; fluorescence radiation of metal atoms enters the inlet of 3 photometric measuring devices; that emission signal enters the entry of the block 4 and realizes the algorithm required here.

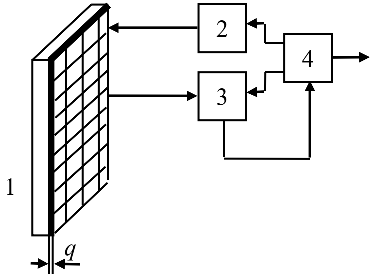

Figure.7. Flow diagram of X-ray fluorescence spectroscopic system: 1 a sheet with removed metal plate, 2 scanner type X-ray generators, 3-fluorescent signal photometric measuring device, 4 controlling calculator

The general uncertainty of measuring the thickness of the metal sheet σ_q is shown as the geometric sum of the individual components.

To optimize the measuring mode, the final average has been calculated as the squared tendency $\sigma_q(n) = \frac{\sigma_{q_0}}{\sqrt{n}}$ during the repeated measurements using the known result of the multiple repeated measurement theory. The number of measuring points on a sheet with metal layer thickness q is $\boldsymbol{N}$, where the functional linkage with the layer thickness is assumed to be $N = N(q)$, the condition of restriction on the dependence of n on q has been reviewed as follows:

$$\int_0^{q_m} n(q)dq = C_1 \quad . \tag{11}$$

The thickness of the metal sheet q is indicated as the maximum value of the fluorescence signal U_{max}, and the information functionality assessed for the study of its non- homogeneity is defined as follows:

$$F_1 = \int_0^{q_m} N(q) \cdot log_2 \frac{U_{max}\sqrt{n(q)}}{\sigma_{q_0}} dq \, . \tag{12}$$

λ - if there is a Lagrange multiplier, it is calculated by taking into account the expressions (7) and (8):

$$F_2 = F_1 + \lambda \cdot C_1 = \int_0^{q_m} N(q) \cdot log_2 \frac{U_{max}\sqrt{n(q)}}{\sigma_{q_0}} dq + \lambda \int_0^{q_m} n(q)dq \, . \tag{13}$$

According to Euler's equation, the optimal function $n(q)$ can be calculated under the following conditions:

$$n(q)=\frac{N(q)}{C_1}\cdot\int_0^{q_m}N(q)dq\,. \tag{14}$$

Consequently, when the condition (14) is fulfilled, (9) receives an extreme value.

The chapter also discusses the optimization of the hyperspectral fluorescence testing system for food products. The paper analyzed the working mode of the automated device designed for hyperspectral fluorescence diagnosis of fruits. As a result of the analysis, the basic formulas for the implementation of fluorescence hyperspectral diagnostics in single and multiple (repeat) measurement modes were obtained.

At the end, the chapter four discussed the accuracy of complex indices in fluorescent hyperspectral method used to estimate chlorophyll content in plant leaves. It shows the possibility of using both linear folding and multiplicative complex multi-criteria optimization method where there are reciprocal inversion criteria and multi-criteria optimization has been carried out. It is noted that at this time the optimal points in both complex criteria coincides, but the linear-folding criterion reaches the maximum at the optimal point. The results show that these criteria allow to use for optimization of the joint use of fluorescence and hyperspectral indices in order to accurately determine the stress state of plants.

MAIN RESULTS

1. The measurement procedure used for research of optical parameters of non-homogenous objects through photometric control systems has been optimized, and a new formula has been proposed to estimate the amount of information obtained.

2. To diagnose the environment in contact with nano- fiber light transmitter at the entry of the photometric system, the transmitter has been placed at the entrance of photometric system, and the criteria have been proposed to optimize the diagnosis. To obtain maximum emission capacity of the photometric system with nano- fiber light transmission, the mathematical expression of the calculation of the number of necessary repeated measurements have been generated.

3. A photometric control method and appropriate algorithm have been developed taking into account the extreme characteristics of the optical parameters of food products, which are exposed to the stress factor at different levels and have changing absorption coefficients.

4. Further studies focused on the regularity of changing the spectral characteristics depending on the angle of incoming radiation of the interference filters, and possibilities of using this property based on derivative spectroscopy method for improvement of accuracy in setting spectral properties of composite materials have been proposed.

5. The criteria for selecting the type of filters used in adaptive photometric systems have been proposed to study the changing absorption spectra of dynamical physical and chemical processes.

6. The method of compensating the temperature slip of the emission strip of the electronically controlled liquid-crystal interference filter has been developed.

7. A method of photometric control of the state of materials have been proposed by compensating the damping effect of laser-induced fluorescence radiation.

8. The X-ray fluorescence measurement procedure has been optimized based on the information criterion. The thesis found out

that the dependence of the number of measurements on the thickness of the layer, according to its form, repeats the dependence of the number of measured points on the thickness of layer in the optimal mode.

The main results of the thesis paper have been published in the following scientific papers

1. Alieva K.J. A new method of photometric quality control of materials // Special equipment.- 2014.- No. 4.- p.35-38.

2. Aliyeva K.J. The method of photometric control of non-homogeneous materials using the differential spectroscopy methodology // Measuring equipment.- 2014.- No. 10.- p.28-30.

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16. Kasumov V.A. Alieva KJ Reliability of complex indices for fluorescent-hyperspectral method of assessment of chlorophyll content in plant leaves // Problems of informatization and management. Kiev-2021.-issue.65.s.25-30.

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