Studying optoelectronic method of determining one substance in the other in petroleum production

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Abstract. This paper introduces optoelectronic method of determining one substance in the other in petroleum production with a fiber-optic sensor (FOS). This method application is important for solving problems of contemporary oil, gas and petroleum production.

1. Introduction
Nowadays one of the fast developing trends in physics, semiconductor physics, optics and electronics is optoelectronics. Technical grounds for optoelectronics are constructive-technological conceptions of modern electronical technology: element minimization, preferable development of solid flat works, integration of elements and functions, commitment to special ultrapure materials, application of group-machining methods.

Developments of optoelectronic systems for non-destructive testing of various purposes are widely used worldwide, especially in such countries as the USA, Japan, Germany, except Russia. Designing multifunctional systems for optoelectronic testing of physico-chemical substance parameters has its peculiarities and challenges requiring new scientific, technical and technological solutions [1-2]. Here deep understanding of physical processes in elements of frustrated internal reflectance (FIR) and fiber optics (FO), radiation sources and measuring tools, as well as developing on their bases highly sensitive monitoring sensors are important.

2. Materials and methods
In monofunctional optoelectronic control-measuring systems conversion of the measurable value \(x_1\), into an information bearing parameter of an electrical signal theoretically should be described as

\[ Y = F(x_1). \]

(1)

And in practical cases this signal is represented as

\[ Y = f(x_1, y_1, y_2 \ldots y_k), \]

(2)

where \(y_1, y_2 \ldots y_k\) is a range of variable physical quantities, whose changes influence significantly value \(Y\).

Correcting one \(y\), for example, \(y_i\) requires second transformation described as [3]

\[ Y_j = f_j(y_i). \]

(3)
Basing on this, to receive information on value $x$ from the multidimensional signal described by the expression (2), it is necessary to receive signals described by equation (3), which is very difficult to determine in practice.

Multifunctional optoelectronic methods allow determining physico-chemical values by application of several multidimensional signals that is depending on plural $x_i$, they expand opportunities of optoelectronic method of measuring non-electrical quantities. This method is based on applying a special element of FIR (in this case semitubal), we can receive $n$ of multidimensional signals, whose informative parameters depend on $n$ physical quantities, so that equations describing these dependencies make system $n$ of independent equations:

$$Y_1 = f_1(x_1, x_2, ..., x_n)$$
$$Y_2 = f_2(x_1, x_2, ..., x_n)$$
$$Y_n = f_n(x_1, x_2, ..., x_n),$$

then in a range of cases it is possible to determine values of all or separate $n$ physical-chemical values $x_i$, accessible for optic control with the help of information-bearing parameters values $Y_1$, $Y_2$……$Y_n$ [4-5].

The determined parameters $Y_1$, $Y_2$…… $Y_n$, which are called primary signals, measured successively, recorded and only then range of measurements is applied for determining parameters $x_i$, or all of them appear simultaneously and are mutually applied for output signal formation, proportional and measurable $x_i$.

3. Results and discussion

This article describes application of an optoelectronic method of determining one substance in the other in petroleum production with fiber-optics sensors. Our aim is to introduce a simplified and cheap optoelectronic device operating on frustrated internal reflectance (FIR) and multiple frustrated internal reflectances (MFIR) that will improve accuracy of determining the percent of sulfur-containing elements in oil and petroleum products. This optoelectronic device is safe for oil and petroleum products. The electrical part is at some distance to avoid bursts and fires which is made possible thanks to fiber optics communication lines (FOCL). With FOCL optical signal is translated or received at distance with radiation sources and optical signals receivers [6].

Many of the sensors do not satisfy such parameters as size, precision, permissible operation conditions. Recently there appeared a trend to apply optical radiation and properties of optical devices for registering different physical impacts. This was promoted by success in production technologies of fiber optic guides which resulted in their wide application for transmission of channel signals. Fiber optic sensors substitute traditional sensors when the latter’s parameters do not meet the requirements. Nowadays, it is a recognized trend of sensing device development which resulted in creation of pressure, speed, acoustic loads sensors and so on.

Suggested optoelectronic device increases accuracy of measuring by multiple volumetric measuring of parameters of the studied oil and petroleum products with fiber optics communication lines (FOCL). In optoelectronic device a cylindrical element of FIR is applied which is used for transmitting optical signal or allowing absorbing the signal. The device operates in the range from X-ray to ultra-red. Here in this wide optical range a part of one substance is measured in the other. The sensor is used for determining any fluid or gaseous additives in oil. For this it is important to know what additive is determined in order to set the sensor in a proper way. This optoelectronic sensor can be applied in any industry as an individual sensor or in laboratories for studying fluid or gaseous additives [7, 8].

Figure 1 shows a block-scheme of the device for determining sulfur-content in oil and petroleum products. This device, when used in automated process, in our case in oil refining or oil extraction (drilling), provides a high quality control and is fire safe for the controlled fluids. Nowadays in estimating the quality of oil and petroleum products internationally it is necessary to determine percentage of sulfur-content. In oil production there are no flow devices for determining sulfur content in oil and petroleum products with minimal costs and time consumption or for regular automated process control [9].
Figure 1. Block-scheme of an optoelectronic system for determining one substance in the other in petroleum production with the help of FOCL and FOS.

The device (the figure) includes a FIR sensor in the form of a cylinder 1, with a slit 2 inside. Around cylinder 1 and along it there are fiber optics radiators 3’ – 8’, they are connected by fiber optics of ORD 9’ – 14’. The optoelectronic device also includes a compensatory optron and is connected via fiber optics 15 and 16, the driving generator 17, connected with bistable latch 18, one of outlets of which is connected with the compensational source via fiber optics 15, and other outlets are connected with radiation sources 3 – 8, radiation sources are connected with radiators via fiber optics 3’ – 8’, the outlet of every fiber optic sensor is connected with fiber optic sensor receivers 9’ – 14’, which are connected with ORD 9 – 14. ORD 9 – 14 are connected with one of the summation unit outlets 19, whose outlet is connected with the first inlet of the block 20 of information processing, whose second inlet is connected with the compensatory receiver via fiber optics 16, and the outlet is connected with the registering device or PC 21.

4. Conclusion
The advantages of this system comparing with the analogues are those that contrary to sensors using electrical current, optoelectronic FIR and optoelectronic sensors do not need insulation, lenses and light conducting fibers do not corrode and provide process automation. At the contemporary stage of the technological process systems of automated control for production process and quality control are important. No doubts, automation has the most significant economic effect for petroleum production, which is characterized by large amounts of the released product [10].

Development of production processes automation control is characterized by constant enhancement of its hardware base – primary measuring transducers (PMT) and in particular optoelectronic PMT.

Optoelectronic PMT of automated devices applied in petroleum production should control main technological parameters, determining optimal flow of the technological processes, such as humidity or
water content, density, color, presence of one substance in the other, and other characteristics which can be visibly controlled.

Nowadays fiber optic systems (FOS) are applied in all spheres of our life. One of fiber optic systems (FOS) is fiber optic detectors (FOD). Nowadays simple detectors or pressure and temperature sensors developed 40 years ago are far behind these new devices.

References
[1] Korn G A and Korn T M 1984 Mathematical Handbook for Scientists and Engineers: Definitions, Theorems, and Formulas for Reference and Review (Moscow: Nauka)
[2] Alireza Safaria, Mojtaba Moradi Dowlatabad, Ali Hassani and Fariborz Rashidi 2016 Numerical simulation and X-ray imaging validation of wormhole propagation during acid core-flood experiments in a carbonate gas reservoir J. Nat. Gas. Sci. Eng. 30(3) 539-547
[3] Yamamoto Hisaaki 1987 Fiber optical sensors and its application Otomesen: Automation 32(5) 31–35
[4] Golub V P, Pavlyuk Y V and Fernati P V 2017 Determining parameters of fractional–exponential heredity kernels of nonlinear viscoelastic materials Int. Appl. Mech+ 53(4) 419-433
[5] Hara S, Yamada Y, Ito K and Morita Y 2011 A vibration control method for power-assisted moving vibration systems IEEJ Transactions on Electrical and Electronic Engineering 6(2) pp 190-192
[6] Akhmetov R T and Mukhametshin V V 2018 Estimation of displacement coefficient with due account for hydrophobization of reservoir using geophysical data of wells IOP C. Ser.: Earth Env. 194(6) 062001
[7] Rakhimov N R, Ser'Eznov A N, Rakhimov B N and Alijanov D D 2017 Jig-sensitive optical detectors based on semiconductor films with anomalous photovoltage 13th Int. Sci.-Technical Conf. on Actual Problems of Electronic Instrument Engineering (APEIE 2016)
[8] Almukhametova E M and Gizetdinov I A 2018 Optimization of FPM system in Barsukovskoye deposit with hydrodynamic modeling and analysis of inter-well interaction J. Phys: Conf. Ser. 1015(3) 032006
[9] Mukhametshin V V and Andreev V E 2018 Increasing the efficiency of assessing the performance of techniques aimed at expanding the use of resource potential of oilfields with hard-to-recover reserves Bulletin of the Tomsk Polytechnic University. Geo Assets Engineering 329(8) 30–36
[10] Rakhimov N R, Rakhimov B N and Berdiyev A A 2018 Locate Objects Mechanical Damage Based on Fiber-Optic Communication Systems 14th Int. Sci.-Technical Conf. on Actual Problems of Electronic Instrument Engineering (APEIE 2018)