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DEVELOPMENT OF AN OPTICAL MEASUREMENT CONVERTER MODEL FOR GAS (CARBON DIOXIDE) CONCENTRATION IN AIR

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Abstract
The study examines the features of the optical gas sensor's operation, particularly its transmission coefficient and sensitivity. The proposed sensor design, which utilizes LEDs and photodiodes, minimizes the impact of temperature and pressure variations on measurement results. This approach opens up new prospects for improving gas analyzers used for air quality monitoring.

Keywords: sensor, automated system, carbon dioxide, air, monitoring.

Introduction. Modern gas composition control technologies are increasingly focused on the use of optical sensors due to their high sensitivity, fast response, and compactness. In particular, infrared (IR) gas analyzers based on thermal radiation sources and narrowband detectors have certain limitations associated with the need for mechanical modulators and filters. In this regard, a promising direction is the development of a new element base for optical sensors, which will improve measurement accuracy, reduce energy consumption, and adapt devices to various operating conditions.

Study of the transmission coefficient and sensitivity of an optical gas sensor. Traditionally, IR analyzers use sensors based on thermal radiation sources and broadband detectors combined with narrowband (interference) filters. An example of such a structure is gas analytical systems (GAS) built on the principle of direct action.

The operating principle is as follows: IR radiation from the source enters two cuvettes positioned side by side and parallel to each other—one working and one reference. The working cuvette is filled with the gas being analyzed, while the reference cuvette contains air free of this gas, forming a comparison channel (with a closed inlet and outlet). However, a significant drawback is the necessity of selecting a reference cuvette according to various external conditions, which complicates the adaptation of the CO_2 concentration control system.

To address this issue, the implementation of both the working and reference channels follows the principle of open inlets and outlets for both cuvettes. The structural diagram of the reference and working optical channels is presented in Fig. 1.

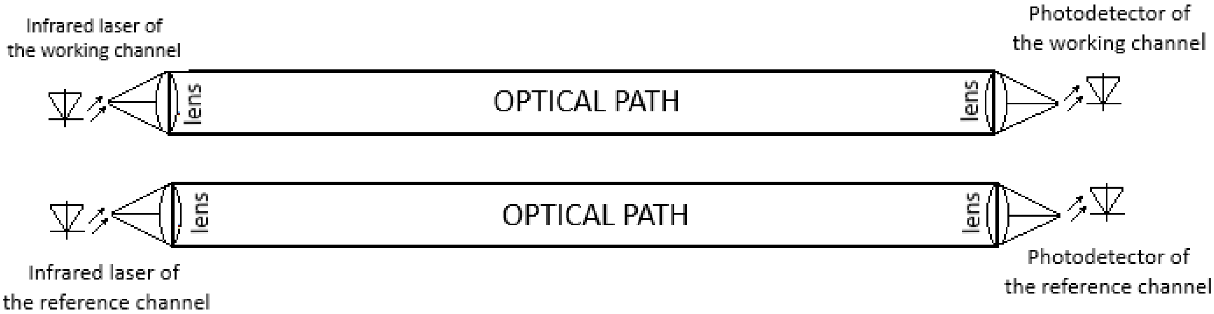

Fig. 1. Structural diagram of the reference and working optical channels

Structurally, the cuvettes are identical, differing only in the operating wavelengths of the laser-photodiode pair. The Beer-Lambert-Bouguer law can be expressed as:

$$U(C,\lambda,I_0) = U_0(I_0,\lambda)\cdot \exp\left[-\alpha(\lambda)\cdot L\cdot C\right] \quad (1)$$

A device that converts the input quantity C into the measured quantity *U (I C, λ)* is a measuring transducer. In the CO_2 concentration control system, the optical sensor functions as the measuring transducer.

In recent years, optical sensors have been developed based on light-emitting diodes (LEDs) and photodiodes [1,2], which introduce significant improvements to sensor design, such as eliminating mechanical modulators and interference filters, reducing energy consumption, and minimizing device size. Further advancements in IR gas analyzers are associated with the development of a new, more efficient component base for gas sensors, particularly IR radiation sources and detectors. The structural diagram of the developed optical sensor is presented in Fig. 2.

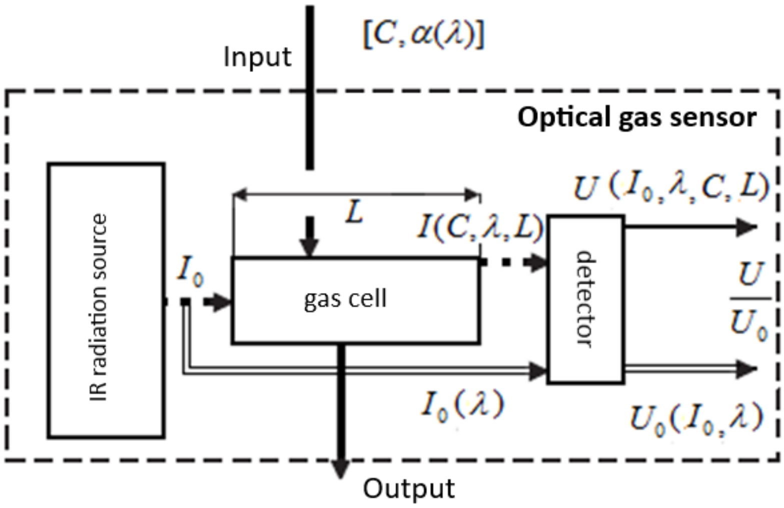

Fig. 2. Structural diagram of the developed optical gas sensor

As the output signal of the optical sensor, we represent the transmission coefficient of the irradiation in the cuvette with the gas

$$k_{np}(C, L, \alpha(\lambda)) = \frac{U(I_0, \lambda, C, L)}{U_0(I_0, \lambda)}. \tag{2}$$

When using photodiodes (PD) and detectors (FD) with spectral characteristics that overlap a certain frequency range $\lambda = \lambda_2 - \lambda_1$, the shift in the spectral characteristics of the source and detector due to changes in temperature and pressure is inherent to all PDs and FDs. To assess the impact of temperature and pressure on the optical sensor and, consequently, on the gas concentration value, we introduce the parameters T and P as functions of the spectral characteristics of the source and detector of infrared radiation. The photodetector measures the integral signal, and the transfer function of the optical sensor is described by the integral expression

$$k_{np}(C, L, P, T) = \frac{\int_{\lambda_1}^{\lambda_2} S_{PhD}(\lambda, T, P) \cdot I_{LED}(\lambda, T, P) \cdot \exp[-\alpha(\lambda) \cdot L \cdot C] d\lambda}{\int_{\lambda_1}^{\lambda_2} S_{PhD}(\lambda, T, P) \cdot I_{LED}(\lambda, T, P) d\lambda}, \tag{3}$$

where SPhD (λ, T) - is the spectral sensitivity of the photodetector, ILED (λ, T) - is the spectral power of the source, α(λ) - is the absorption coefficient spectrum of the gas, L – is the length of the optical path (the length of the interaction of the radiation with the gas).

Conclusions. The study investigates the transmission coefficient and sensitivity of an optical gas sensor that uses light-emitting diode (LED) radiation sources and photodiodes. The proposed sensor design eliminates the drawbacks of traditional IR gas analyzers, in particular, the dependence on mechanical modulators and interference filters. It is shown that the implementation of open reference and measurement channels improves the accuracy and adaptability of the measurements, which is particularly important for monitoring the composition of flue gases in boiler installations. The introduction of new component bases, particularly advanced infrared radiation sources and detectors, will contribute to the increased efficiency of optical sensors and expand their use in gas analysis systems.

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РОЗРОБКА МОДЕЛІ ОПТИЧНОГО ВИМІРЮВАЛЬНОГО ПЕРЕТВОРЮВАЧА КОНЦЕНТРАЦІЇ ГАЗУ (ДВООКИСУ ВУГЛЕЦЮ) У ПОВІТРІ

Анотація. У роботі розглядаються особливості функціонування оптичного газового сенсора, зокрема його коефіцієнт передачі та чутливість. Запропонована схема сенсора, що використовує світлодіоди та фотодіоди, дозволяє мінімізувати вплив температурних і тискових змін на результати вимірювань. Використання такого підходу відкриває нові перспективи вдосконалення газоаналізаторів, що застосовуються для моніторингу якості повітря.

Ключові слова: автоматизована система, двоокис вуглецю, повітря, контроль.

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