# PRACTICAL EXPERIMENTS AND ANALYSIS FOR DETECTION OF SMOKE IN THE BLUE AND INFRARED LIGHT SPECTRUM

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*Abstract* – ***At the present stage of development, there is a steady tendency to increase the fire hazard. To prevent fires, technical means are used to automatically detect, limit and eliminate the fire. Fire detectors are the main elements for fire detection. This report will describe the research on detecting smoke aerosols in the most commonly used type of Optical Smoke Detectors. The aim is to benchmark and propose a solution for improving the efficiency of fire detection by using a pair of optical couplers in the blue spectrum of smoke detector light emitted during the combustion process.***

*Keywords* – **Optical smoke chamber, Optical smoke detector, Smoke aerosols**

## I. INTRODUCTION

The study and analysis of smoke detectors and smoke detection techniques in the blue light spectrum makes it possible to carry out research and apply an approach that is new to its smoke detection method.

In case of a fire of the substances, solid and liquid particles are formed along with gaseous products, which form smoke. Smoke is a dispersing system in which the dispersed phase is small particles - resins, oxides, water, etc., and the dispersed medium is gaseous - air, gaseous products of the fire. Smoke is often called an aerosol product of fire, and smoke particles - smoke aerosols. The smelting particles, after their generation, are in the range of 0.1 μm to 1.0 μm. in the dispersion system they move with the flow of hot gases and air. As an accompanying process of fire phenomena, the formation of aerosols plays a dominant role in the creation of means of fire detection. Many studies have been done on the particle size of different types of fires as well as its different phases. The overall conclusion is that in all cases the amount of invisible particles is greater than that of the visible particles. The amount of smoke in a given zone is expressed by weight concentration, number of smoke particles in unit volume, for example [obsc./foot] and optical density [%]. Optical density expresses the ability of the smoke to alter the optical properties of the environment by reducing its transparency.

The advantages of the method of detecting smoky or diffuse blue light smoke aerosols is that the use of blue light offers considerable advantage in the absorption and reflection of smoke aerosols of dimensions smaller than the respective wavelength. Compared with previously existing solutions with infrared light (940nm wavelength), the blue light spectrum is almost twice the wavelength (470nm). Blue light detection enters almost the whole range of smoke aerosols in the process of combustion of substances of different origins.As mentioned above, some substances emit a lot of dense smoke. Other substances emit considerably less smoke, with some derivatives burning without visible particles. It is precisely for those substances that have no visible particles in the combustion that the optical pair pairing with blue light will be effective.

The idea of using blue light is made possible with advancing technology and the ability to produce semiconductor LEDs with a wavelength of 470nm and high emission, which is in the visible area of the blue light.

## II. EXPLANATION

For comparative analysis and demonstration of the applicability of the method, an experimental laboratory device for measuring smoke aerosols under real conditions was constructed.

The installation consists of:

- Laboratory "tunnel" for test fires;
- Controller with input for analog signal measurement 3;
- Optical chambers where the examined optical pairs are mounted;
- Power supply;
- Oscilloscope for capturing and confirming data from photo sensors.

The laboratory plant for simulating fires is constructed of fire resistant plasterboard. It is proportional to the test fires room described in the European Standard EN-54-7.
At the top are placed the two test optical devices - the purpose of the survey, and on the bottom there is a small hearth where the materials that will burn and imitate a real fire will be put.

An optical smoke chamber is used for comparative analysis. The camera is designed and built on a 3D printer. The material used is black ABS. In the optical camera, infrared and blue light sources and photo receivers are mounted respectively. The geometric dimensions are so designed that the light emitted does not fall directly or indirectly into the photodetector. Fig. 1 and Fig.2 shows a model but the optical camera with which the tests were made.

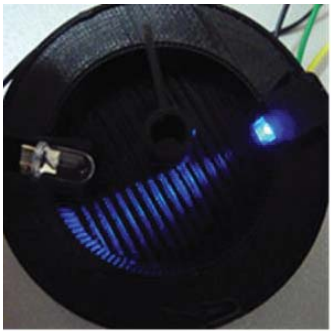

Fig. 1 Optical smoke chamber bottom

Fig. 2 Optical smoke chamber top

The experiment uses an LL-503IRT2E-2AC infrared LED with a selective characteristic.

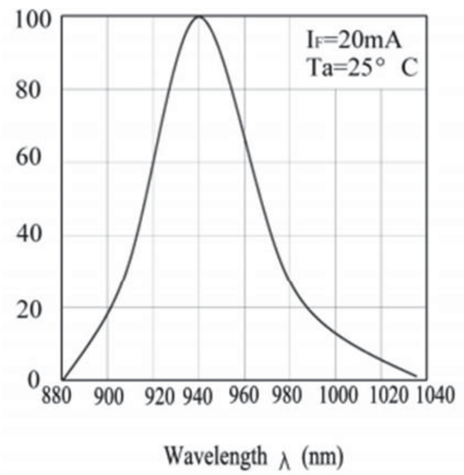


Fig.3 maximum radiation at wavelength 940nm

A blue LED for the tests is LUB50343 with a selective characteristic.

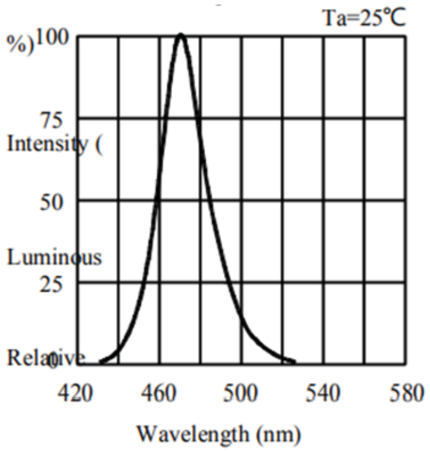


Fig.4 maximum radiation at wavelength 470nm

For both the source of the blue and infrared light using a photo detector SFH 203, with selective characteristic.

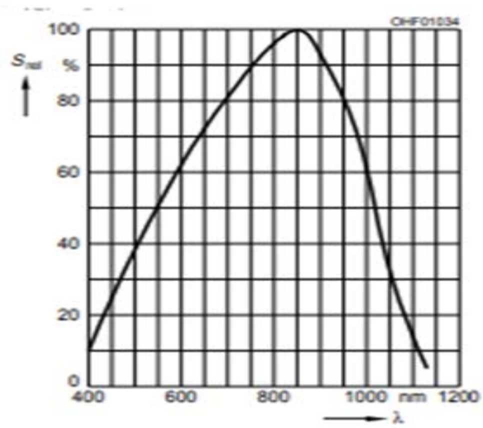


Fig.5 Wide spectrum including 470nm and 940nm

The terminals of the optical elements are connected to a circuit board that buffers input signals from a dedicated controller.

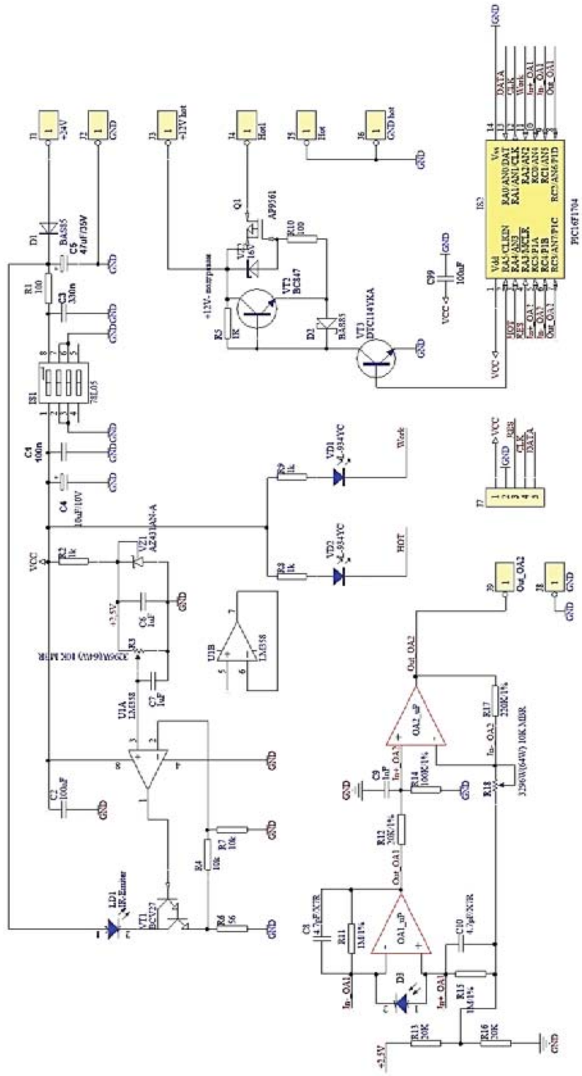

Fig.6 Schematic diagram of an optical meter

The controller produces pulses for the LEDs and reads with an analogue digital converter the values of the photo-current generated by the reflected light of the aerosol smoke particles. Data from the serial interface controller goes to a standard PC input where it can be visualized and processed in tabular form. The oscilloscope monitors the levels of the two optical elements to control the process and to visualize and confirm performance.

The idea for laboratory tests is to assess the difference in the level of registration of reflected aerosol smoke particles in both detection types at 430nm and 760nm wavelength, with different combustible agents and detection time.

For the laboratory tests the experimental set-up for three test fires according to EN54-7, TF1-burning wood was made. TF1 is characterized by the rapid burning of thin wooden sticks without smudging. The test is carried out in the following sequence: the chamber is ventilated, all laboratory instruments are run, the photodetector is measured and visualized by the oscilloscope photometer. This is the starting point of the process being measured.

Place wooden sticks on an electric heater. The heater switches on, causing smoldering and ignition of the tree. The photovoltaic current behavior of the receiver, which is a criterion for registering a fire situation, is monitored..

After increasing the smoke concentration, the oscillograms Fig. 7,8 and 9 show the increasing photoelectric current, which clearly demonstrates the process's efficiency.

The yellow graph shows the pulse output to the LED emitter, the blue graphic reflects the receiver's photoelectric current.

The sharp impulses of blue graphics at the beginning and end of the rise and fall of the front are parasitic and are not taken into account. They are due to transient processes in the scheme. The level of the useful signal is measured in the middle of the pulse.

The values of the photoelectric current are received by a computer that converts them into dB / m.

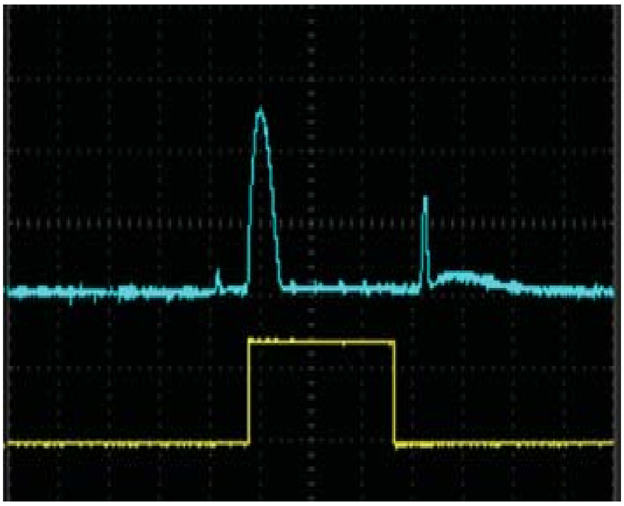

Fig.7 without smoke aerosols

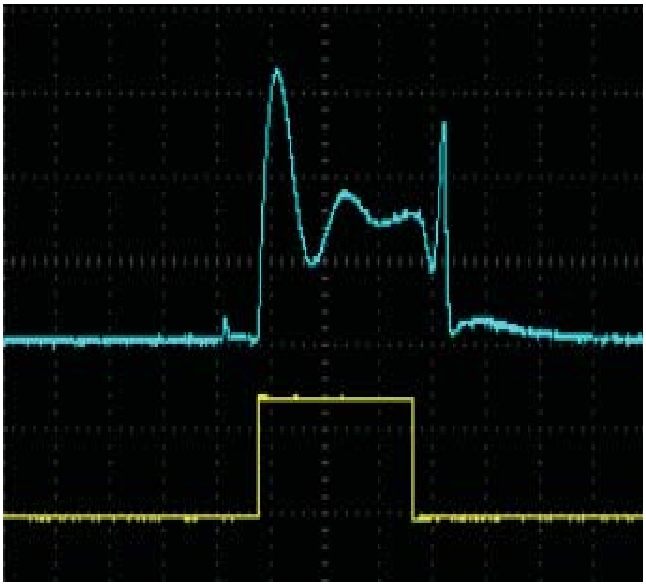

Fig.8 a low concentration of smoke aerosols

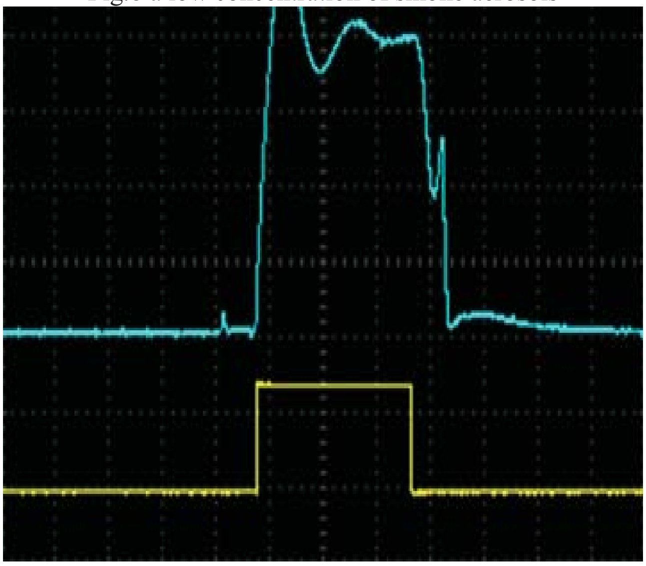

Fig.9 high concentration of smoke aerosols

For the quantitative judgment of the sensitivity of the optical detectors, the term "absorption index" is inserted as follows:

$$m = \frac{10}{d} \cdot \log_{10} \frac{P_0}{P} \quad [\text{dB / m}], \qquad (1)$$

where:

d [m] - optical beam length in the measuring chamber (maximum 1.1m);

P0 - the light output, measured without aerosols in the chamber;

P - the received light output, measured when there are aerosols in the chamber at the time of commissioning, of the fire detectors.

On this basis, photocurrent conversion is made in dB/m.

Test results obtained in tabular form are for the graphical picture.

From the table results, the graph is built.

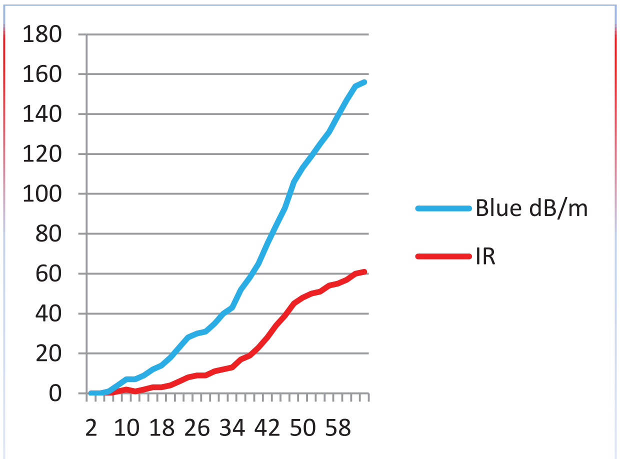


Fig.10 At the same levels of smoke aerosol concentration, the optical pair with blue light has nearly twice as high levels of the electrical signal

- The top curve of the chart is that of the blue light detector.
- The bottom curve of the chart is an infrared detector.

After building the graph, you can see the advantages of the optical pair using blue light to detect smoke aerosols.

## Conclusion

The conclusion is that blue light with its spectrum and wavelength 430nm reflects most of the smoke particles, respectively, resulting in greater sensitivity and signal processing capability to prevent false alarm signals, which is a drawback of so far used mass smoke detectors.

The selected optical couple: LUB50343 blue light transmitter and SFH 203 receiver have good general characteristics and can be used as base elements of an innovative smoke detector.

## References

[1] Benchev R., Fire alarm systems, Sofia 1989.
[2] EN54-7 Fire detection and fire alarm systems P.7 Point – type smoke detectors – Detectors using scattered light, transmitted light or ionization