DEVICE FOR FOG DENSITY CONTROL

Gonevski N. [1], Assoc. Prof. Ivanov O. [1], M.Sc. Todorov P. [1], Pulis V. [1], Prof. Pérez-Díaz J. L. [2]
Institute of Solid State Physics – Bulgarian Academy of Sciences[1]
Escuela Politécnica Superior, Universidad de Alcalá, Alcalá de Henares, Spain[2]

ogi124@yahoo.com

Abstract: A relatively inexpensive instrument (for fog density control), which works in the visible specter, is presented. Its purpose will be to alert the occurrence of fog or visible pollution in the air. It can also detect, if the cleaning fog has reached all areas. This equipment can be used to assess the density of fog. The device is designed for continuous monitoring of the atmospheric air and detection of dispersed agents in the form of aerosols. The total concentration of aerosols is measured and if it exceeds the pre-set threshold, an indication is given via a LED and the information can be exported to external systems. The principle of operation of the device is based on the spectrophotometric method. A beam of monochromatic light is passed through the investigated environment and its intensity is attenuated by the presence of pollutants. The hardware of the device is described, as well as its construction, software and the measuring procedure.

Keywords: FOG, DENSITY, CONTAMINATION, RADIATION, SPECTROPHOTOMETRIC METHOD

1. Introduction

Various sensors for detection of fog exist. They usually operate by evaluating the permittivity of the medium. One way is to estimate the visibility in the air and a common solution is to use cameras [1], [2], [3]. When fog or pollutants are present in the air, this decreases the visibility. Another possibility, which is more widely spread, is to use a light source (emitting from ultraviolet to infrared light) and a detector, placed at a certain distance ahead. The light intensity from the source decreases, when particles or droplets are present in the air, because of light scattering. It is also convenient to use LIDARs to survey the environment [4]. Sometimes humidity sensors are used to help fog presence detection. For fog density evaluation, radars can be successfully implemented [5].

The ideal device for continuous monitoring of atmospheric air and detection of dispersed agents in the form of aerosols should be small, inexpensive, with simple construction and stable in various conditions. It should be operated easily, even by a non-specialist, and should have the option to conduct on-line control. It should also be portable and easy to mount, without requiring special maintenance, with the ability to control small as well as large areas. High sensitivity and the ability to assess a large number of parameters are also required. It should be kept in mind that the fog is difficult to control object as it is ever changing – there are no two instances in which it has the same properties.

We have planned our work, in accordance with the abovementioned goals. Initially, suitable systems for experimental work were developed, investigations were carried out, which lead to the development of laboratory models of different sensors and finally, the device prototypes, each composed of the following components: detector, mechanical, optical and electronic part. Some systems have components for automation that control the transfer of fluids in a pre-defined cyclic manner, in order to ensure a correct measurement and sensor flushing.

The device, which we have designed, Fog Detector 4 (FD-4) measures the total concentration of aerosols and, if it exceeds a certain pre-set threshold, an indication is given, via a LED. This signal can also be exported to external systems. On Fig. 1 the general setup of the device is shown.

Fig. 1 *General setup of the device (1 – measuring device; 2 – aerosol generator; 3 – receiver; 4 – monochromatic filter 650 nm (optional); 5 – laser emitter)*

2. Principle of operation

The principle of operation is based on the spectrophotometric method. A beam of monochromatic light with a specific wavelength is passed through the investigated environment and its intensity is attenuated by the presence of pollutants. This attenuation depends on the size distribution of dispersed particles and their number concentration. The device measures two physical quantities. One of them is the permeability of the environment. It is defined as the ratio of the intensity of traversed light to the intensity of the emitted light. It is inversely proportional to the absorption coefficient. The other quantity is optical density (extinction). It bears information, regarding the aerosol concentration. When the distance for measuring the optical density of the aerosol is known in advance, the calculation of these two quantities is a simple task for modern microprocessor systems.

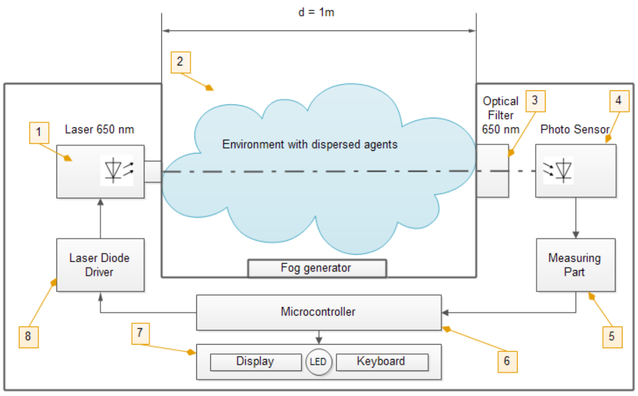

Fig. 2 *A diagram of the experimental setup for investigating environments with dispersed agents*

The general block diagram of the device is shown in Fig. 2. It consists of a light source (1), which is a laser emitting at wavelength 650 nm, an aerosol generator (2), optional monochromatic filter for the 650 nm wavelength (3), a photo sensor (4), an amplifier (5), a microcontroller (6), user interface (7) and a laser control block (8).

Measurements are conducted in the following manner: the initial intensity of the light beam is measured by passing it through an aerosol-free environment. In order to avoid interference from external sources, the sensing element of the device can be fitted with a monochromatic filter. The signal received by the photo sensor is converted into a digital one and is stored in the microprocessor memory by pressing a button. This measurement is done only once and the value is stored.

When conducting measurements in an environment contaminated with aerosols, the device registers the reduced intensity of the laser beam, which is proportional to the aerosol concentration.

The microprocessor component analyses the values of the stored and the received signals determines the loss of optical power and visualizes the value on the screen in relative units.

The degree of absorption is indicated via a coloured LED. Five percentage intervals have been defined, which differ for the various environments. For each investigated environment (along with the agents dispersed in it) a scheme is selected in advance (Table 1), which takes into account its permeability coefficient.

***Table 1** FD-4 percentage thresholds of the colour indication*

Scheme number	Scheme (r1-r2-r3-r4)
1	2% – 4% – 7% –11%
2	3% – 6% – 10% –15%
3	4% – 7% – 11% –18%
4	5% – 8% – 16% –25%
5	6% – 10% – 18% –35%
6	8% – 15% – 30% – 50%

The percentage intervals given in the table are established experimentally by using different concentrations of aerosol particles and different dispersed agents. The relation between the colour indication and the absorption degree is as follows:

- High – red colour
- Medium – violet colour
- Moderate – blue colour
- Low – green colour
- Below the lowest threshold, there is no indication.

If the signal fluctuates and cannot settle in a narrow interval, an indication is given via a blinking yellow light. When such a situation arises, a new measurement of the incident laser beam intensity must be made in an aerosol-free environment and its new value is stored as a reference.

3. Hardware

The electronic components of the device hardware are shown in Fig. 3.

It consists of three modules – main measurement module, laser emitter and a photo sensor. The emitter and the photosensor are mounted on stands, one of which can be moved onto a support rail.

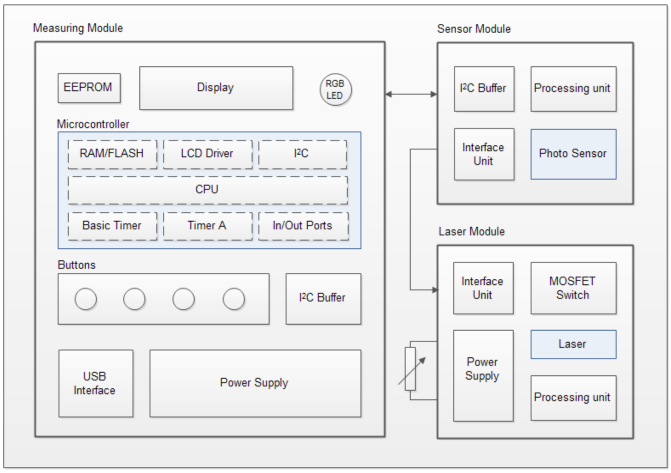

***Fig. 3** Structural diagram of the electronic hardware part*

- **Main measurement module**

The main measurement module of the device is based on the MSP430F microcontroller by Texas Instruments. It is connected to an LCD display, which is controlled directly by the LCD driver embedded in the microcontroller.

Depending on the intensity of the laser emitter and the optical permeability coefficient of the studied environment, the device can operate in four measurement ranges. The chosen range is shown on the display.

A Neo-Pixel RGB LED, controlled via a WS2811 driver is used to visualize the degree of absorption. It is controlled using three 8-bit sequences, transmitted via a one-wire interface.

The operating regime is set via buttons and from the menus shown on the display.

The connection to the sensor module is realized via a buffered I^2C interface.

A USB interface is also provided for connecting the device to other measurement systems.

- **Photo sensor module**

The photo sensor in the device is based on the TSL2561 device. It is a complete, intelligent receiver, which can be configured to operate in different regimes. Its detection range is 0.1 – 40000 Lux. The measured signal is converted into a digital code, which is delivered to the user via an I^2C interface. TSL2561 operates in a wide spectral range and covers the visible and near infrared ranges. Its block diagram and spectral characteristics are presented in Fig. 4 and Fig. 5, respectively.

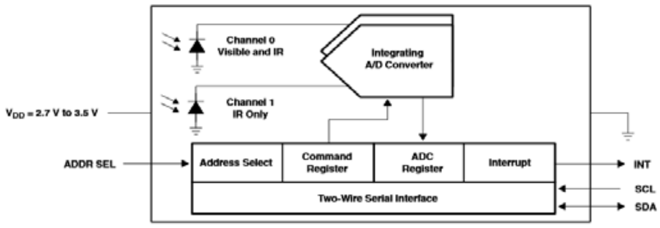

***Fig. 4** Block diagram of optical sensor TSL2561*

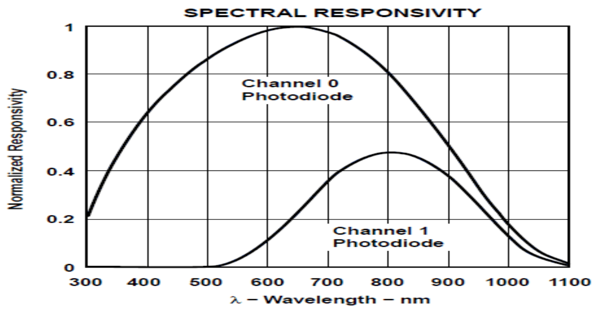

***Fig. 5** Spectral characteristics of optical sensor TSL2561*

- **Laser module**

A Laserfuchs LFD650-1-12 laser diode (wavelength – 650 nm, power – 1 mW) is used as the emitter in the device, for registering dispersed agents. Its intensity can be adjusted manually. The laser diode is powered by a power supply block, which provides stable voltage in the range 2 – 12V and currents up to 500 mA. The main characteristics of the laser emitter are given in Table 2 and Table 3.

***Table 2** Main parameters of the LFD650-1-12 laser diode*

Main Parameters	Min.	Typical	Max	Unit
Wavelength		650		nm
Optical Diode Power	0.5	0.75	1	mW
Operating Voltage	3	3	12	V DC
Operating Current	15	25	30	mA
Operating Temperature	-20		40	°C
Storage Temperature	-40		80	°C

***Table 3** Optical parameters of LFD650-1-12*

Optical Parameters	
Beam Shape	Dot
Laser Class	2
Divergence	1 mrad
Beam Diameter	3 mm
Size of Laser Dot	< 3÷4 mm (at 5m)
Operating Distance	10 m
Optics	acrylic lens
Laser technology	Diode
Focus	fixed (5000 mm)

The laser emitter has the following three operational regimes:

- Off
- Continuous
- Pulsed

When working in pulsed mode, the laser diode can be modulated at one of the following frequencies: 500, 1000, 2000 or 5000 Hz. If needed, the hardware resources of the device allow the generation of chosen modulation frequencies in the range 1÷50 kHz, with an arbitrary duty cycle.

The operating regime of the laser is shown on the display as a bar graph.

- **Monochromatic filter**

In the case of unstable background light of the studied environment, it is advised to use the E361415 monochromatic filter, in order to obtain maximum sensitivity only to the emitter wavelength – 650 nm. The characteristics of the monochromatic filter are given in Table 4.

***Table 4** Parameters of E361415 monochromatic filter*

Parameter	Value
Size	Ø50 mm
λ	650 nm
λ_{max}	646 nm
T_{max}	39,0 %
FWHM	7,5 nm

4. Software

The structural diagram of the device's software is shown in Fig. 6 and Fig. 7. When power is supplied, the software begins system initialization, during which the peripheral devices and default parameters are configured. The control is then transferred to the main program cycle. When a button is pressed, the software performs the function, which is related to it.

The photo sensor data is transferred for processing via the I^{2}C interface after an intermission has been received by it. Mathematical processing of data is performed by the software - normalization, numerical filtration, percentages calculation and conversion to a form, which is suitable for visualization. The information on the display can be refreshed every second.

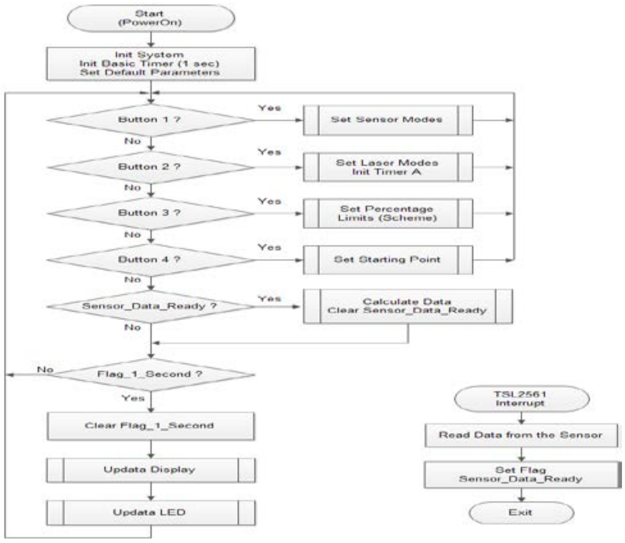

***Fig. 6** – Block diagram of the control algorithm of the measurement system*

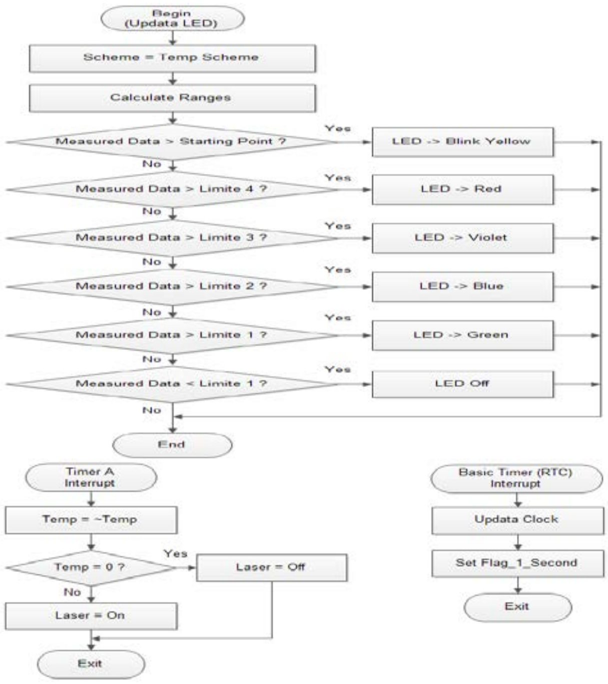

***Fig. 7** – Block diagrams of the sub-programs serving the main algorithm*

5. Construction

The device for registering dispersed agents has a 1-meter long rail as its base. Two stands are placed on it – a fixed one and a mobile one. Their elements are identical and interchangeable. The overall construction resembles a U-shape. Two mechanical elements are provided for fitting the monochromatic filter (Ø50mm) on the receiver. Two additional stands are also provided for mounting fans that blow at the protective glasses of the emitter and receiver, if condensation appears or in case water droplets form on them. These are powered with 5V by an external DC converter. The main measurement block is powered via a network adapter (9V/0.6A). The total weight of the system does not exceed 5 kg. In order to ensure easier movement of the mobile stand, a ball bearing slide rail with gradually adjustable length in the range 0.5÷1 meter is included as a spare one for replacement. This rail requires one of its ends to be mounted on a base for stability.

6. Conclusion

We have presented the measuring device, which we have developed - Fog Detector 4. It is intended for measurements of optical transparency of environments of different nature - aerosol mists, smokes, dust and other. We have achieved the main goals of this work - our device is lightweight, portable, easily operated, and relatively low-cost. The principle of operation of the device was described, as well as its main components, construction and software.

Acknowledgements

This work has been funded by EU FP7 Security program under contract 312804.

References

[1] Hautière, N., Tarel, J. P., Lavenant, J., Aubert, D. Automatic fog detection and estimation of visibility distance through use of an onboard camera. Mach. Vis. Appl., 17(1):8–20, 2006.

[2] Hautière, N., Labayrade, R., Aubert, D. Estimation of the visibility distance by stereovision: A generic approach. IEICE Transactions on information and systems, 89(7):2084–2091, 2006.

[3] Kuwon, T. Atmospheric visibility measurements using video cameras: relative visibility. Center for transportation studies of Minnesota, no. CTS 04-03, July 2004.

[4] Dannheim, C., Icking, C., Maeder, M., Sallis, P., Fischer, V. Air pollution and fog detection through vehicular sensors. Modelling Symposium (AMS), 8th, 2014. DOI: 10.1109/AMS.2014.43.

[5] Mori, K., Kato, T., Takahashi, T., Ide, I., Murase, H., Miyahara, T., Tamatsu, Y. Visibility estimation in foggy conditions by in-vehicle camera and radar. Proc. International Conference on Innovative Computing, Information and Control, Vol. 2, pp. 548-552, Aug. 2006.