

THE PRINCIPLE OF MEASURING THE VALUE OF THE SPECTRUM SEPARATED BY A DIFFRACTION GRATE THROUGH A CAMERA

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Abstract:

The article provides information about the diffraction grating and the camera, which are the main parts of the Spectrometer device. The types of sensors of the camera are presented. Algorithm according to the principle of operation of the diffraction grating and the camera is given and analyzed. The results of the experiment with the device are given. The experiment was conducted using LED and COB-LED artificial light sources used in the Arduino program. The light intensity of the LEDs was measured by a camera and images corresponding to the measured value were created in the python program.

Keywords: spectrometer, diffraction grating, digital camera, CCD, CMOS, Arduino, LED, COB-LED, spectrum.

INTRODUCTION

When we talk about light, we usually mean the electromagnetic spectrum, which includes all light waves from gamma rays to radio waves. Only a small portion of the electromagnetic spectrum is visible to the human eye, called visible light.[1]

A spectrometer is an optical device used in spectroscopic research to collect spectra, quantitatively process it and further analyze it using various analytical methods. The analyzed spectrum is obtained by recording the fluorescence after exposure to the test substance by any radiation (X-rays or laser). radiation, spark movement, etc.). Usually, the measured quantities are the intensity and energy (wavelength, frequency) of the radiation, but other properties, such as the state of polarization, may be recorded. The term "spectrometer" is used to refer to instruments that operate at a wide range of wavelengths from gamma to infrared.[2]

The spectrometer is used in various fields depending on the principle of application. According to the principle of operation, there are 5 types:

1. Infrared;
2. Atomic absorption and atomic emission;
3. Fluorescent;
4. Mass spectrometers;
5. Fourier spectrometers.

The infrared spectrometer is used in the chemical and petrochemical, pharmaceutical, perfumery and other industries. In addition, one of the main technical features of this spectrometer is ease of use. Therefore, such devices are often used in forensics, environmental control and other related fields that require rapid analysis results.

The atomic absorption spectrometer is used in drug analysis and clinical tests.

The fluorescence spectrometer is used in the processing of rare metals and in the mining industry. Mass spectrometers are spectrometers widely used in drug production and pharmaceuticals. A Fourier spectrometer is used to analyze the atmosphere of the earth and other planets. [3] In addition, spectrometers can now be used to analyze the spectrum of newly produced Li-Fi LEDs.

METHODOLOGY

Newton is traditionally regarded as the founder of spectroscopy, but he was not the first scientist to study and report on the solar spectrum. Works by Athanasius Kircher (1646), Jan Marek Marcy (1648), Robert Boyle (1664), and Francesco Maria Grimaldi (1665) preceded Newton's optical experiments (1666–1672).

He published his experiments and theoretical explanations of the propagation of light in the work "Optika". His experiments showed that white light could be split into its component colors using a prism and that these components could be recombined to produce white light. He showed that the prism does not give or create colors, but separates the components of white light. Newton's corpuscular theory of light was gradually replaced by wave theory. It was not until the 19th century that the quantitative measurement of scattered light was recognized and standardized. As with many later spectroscopy experiments, Newton's sources of white light included fire and stars, including the Sun. Later studies of the nature of light included Hooke, Huygens, Yang. was the first to show that spectra are uniquely connected with chemical constituents.

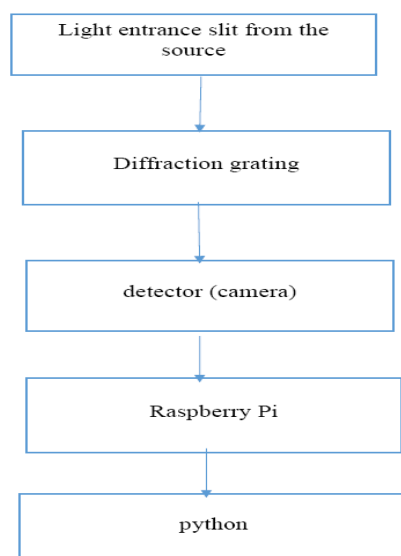
Scientists have observed the emission of distinct patterns of color when salts are added to an alcohol flame.[4]

1. Воропай, Е.С. Дисперсионный гиперспектрометр с реконфигурируемой входной апертурой на основе микрозеркальной матрицы / Е.С. Воропай, И.М. 2. Гулис, А.Г. Купреев [и др.] // Вестник БГУ. – 2009. – Сер. 1, № 3. – С. 31-35. – ISSN 0321-0367.

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Spectrometer



Scheme 1. Scheme of the principle of operation of the spectrometer.

Scheme 1 shows the working principle of the spectrometer in the form of a block diagram algorithm. In the scheme, the light source, after entering the slit, is separated into a spectrum through a diffraction grating. In the next step, the detector (camera) measures the value of the spectrum formed by the diffraction grating. The resulting result registers and collects the spectrum of light, digitizes the received signal depending on the wavelength, and passes to the next analysis process with the help of a computer.[5]

The spectrometer consists of a Raspberry Pi, a diffraction grating, a camera and a housing. The principle of operation of diffraction grating and camera is considered in the article.

DISCUSSION

Diffraction grating

A diffraction grating is an optical element that separates (disperses) light of different wavelengths (for example, white light) into wavelength components. The simplest type of grating consists of a large number of equally spaced parallel slits. When white light enters the grating, the light components are diffracted at angles determined by their respective wavelengths (diffraction).[6]

Digital Camera. The basic principle of the camera is that light rays reflected from photographed objects are focused by the camera lens and create a reduced image on a flat surface at a short distance from the lens. (Fig. 1)

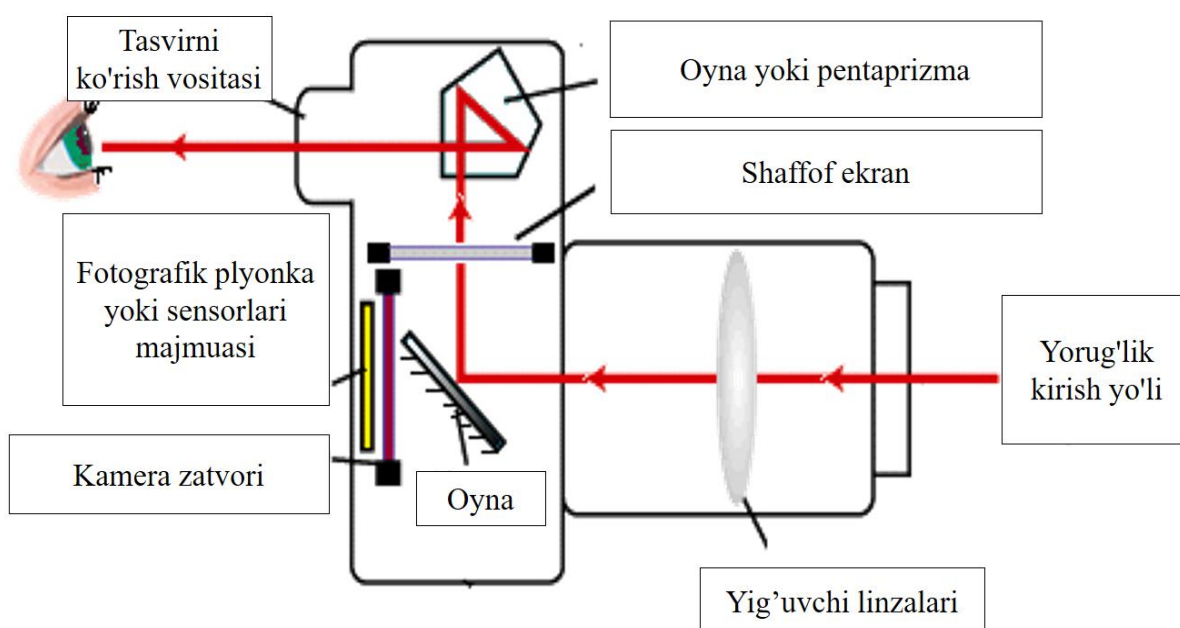


Figure 1. Focusing the light on the side of the lens and forming a small image through the mirror.[7] In a traditional camera, this surface is a photographic film, but in a digital camera, the rays fall on the sensor, whose task is to convert the photon flow (and these light rays) into a flow of electrons, that is, simply into an electric current. The stream is then amplified, converted into a set of bits, processed and finally written to the camera memory. The sensor is divided into parts called pixels - pixels with a size of several microns, each of which is responsible for registering one point of the image. (Fig. 2)

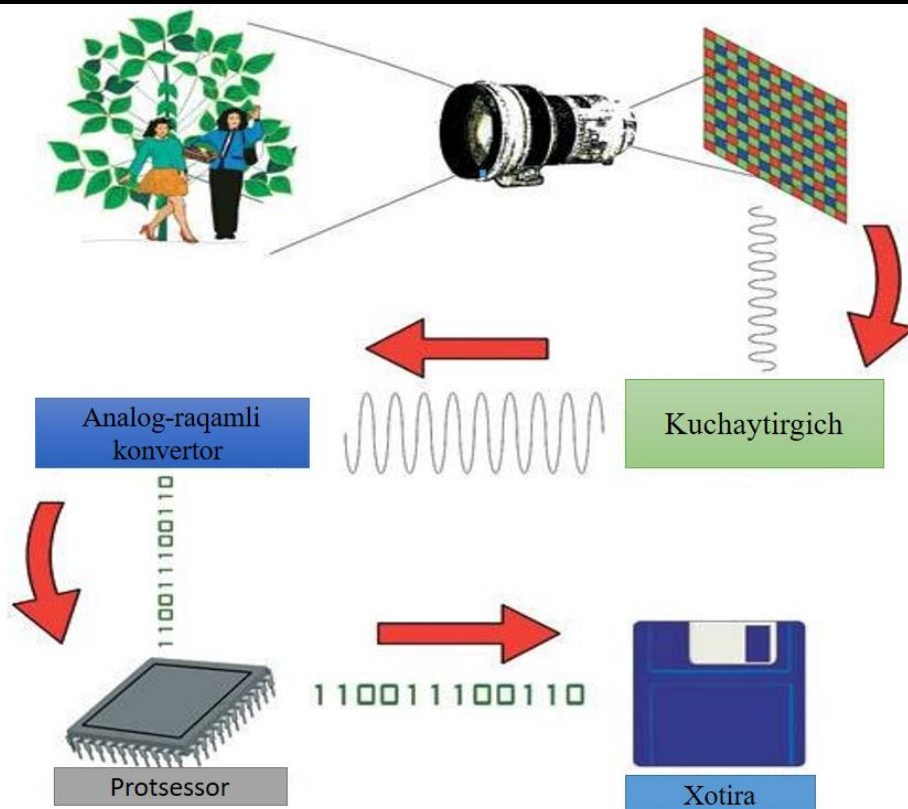


Figure 2. The principle of operation of the camera.

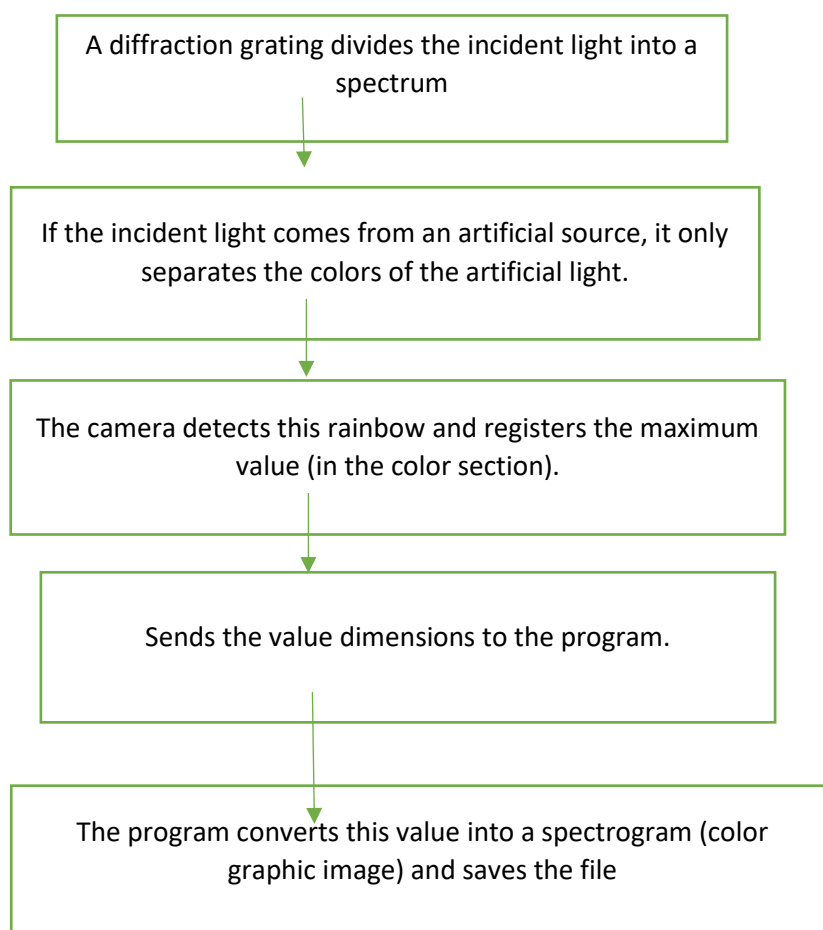
Photons falling on the surface of the sensor remove electrons from the outer orbit of silicon atoms and form electron-hole pairs. The camera uses two types of sensors (CCD or CMOS) that are currently widely used.

CCD

CCD (ChargeCoupled Device, CCD) is currently the most common type of sensor. The working principle of the CCD is based on the accumulation of electrons released as a result of the photoelectric process directly in the pixels of the matrix, and then based on linear movement. The line at the end moves pixel by pixel to one of the same corners, where the charges are transferred to the input of the amplifier and converted into electricity. A very thin layer of silicon oxide is applied to the surface of the silicon plate of the sensor, which acts as a dielectric, and behind it there is a metal layer (electrode) to which a positive potential is applied during "exposure". As a result, an electric field appears in the adjacent semiconductor, which repels holes and attracts free electrons. The longer the matrix and the more photons hit one sensor pixel, the more electrons are collected in the potential well of this pixel. If a high potential is applied to the electrode of the adjacent row of the matrix, the charge will move to the adjacent, potential well. Thus, during reading, charges are transferred to the edge of the matrix and to the amplifier. The amplified signal goes to the input of the analog-to-digital converter (ADC), and then it is converted into a digital signal.

CMOS

Another technology from digital camera sensors is CMOS (Complimentary Metal-Oxide-Semiconductor). Unlike CCD, CMOS performs charge-to-voltage conversion (i.e., amplification) directly at the pixel itself, and then stores the content of an arbitrary pixel as in computer memory. provides direct access. Random access to image elements allows for increased camera speed during pre-reading. The advantages of CMOS include significantly lower power consumption, as well as the compactness and low cost of the entire camera design, since the amplifier and ADC are no longer needed as separate components. However, until recently, CMOS was used only in the cheapest cameras, because it could not compete with CCD in terms of image quality: Since each pixel used its own amplifier, there was enough inconsistency in the resulting image. There were problems with the sensitivity of the matrix, because due to the large number of electronics in the matrix, there was not much space left for the photosensitive elements themselves. However, increased silicon wafer manufacturing quality, improved amplifier circuitry, and advanced noise reduction technologies now allow CMOS sensors to successfully compete with CCDs in terms of quality.[8]



Scheme 2. Spectrum of light in a diffraction grating the principle of measuring the separated values through the camera.

Light from an artificial source falls into the light entrance slot of the body. The light falling through the slit is separated into a spectrum on a diffraction grating. The camera detects the size of this spectrum. The detected light measurements are sent to the code written in the python program written on the

Raspberry Pi microcomputer. The program creates an image corresponding to the entered size. (Scheme 2)

RESULTS

Here are some results from this spectrometer:

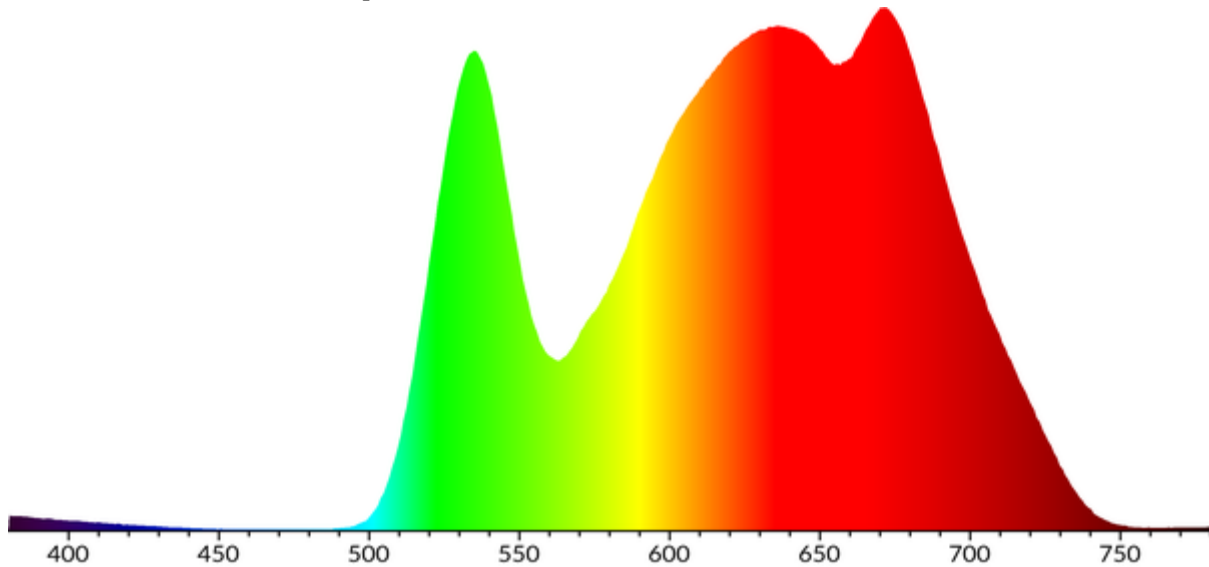


Figure 3: Light spectrogram of an Android phone.

Figure 3 shows an experiment using the light source of an Android phone. According to the result, it can be observed that red, green and yellow colors are combined to produce white light on Android phone.

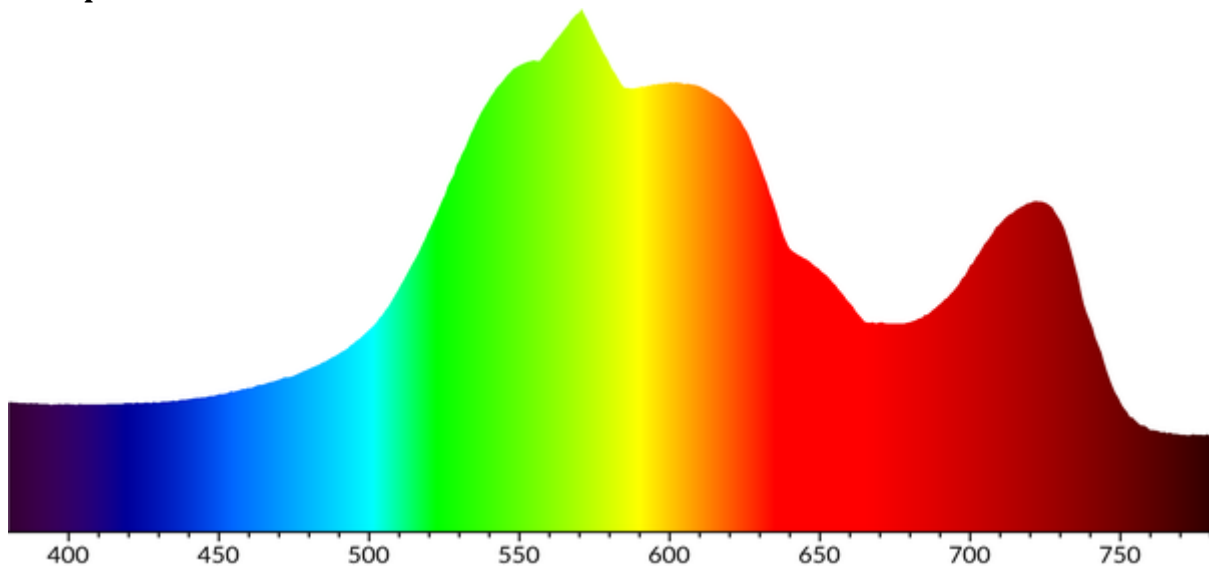


Figure 4: White spectrogram of a 5-matrix light source.

Figure 4 shows the experience of the light source used on the 5-matrix Arduino platform. According to the results of the experiment, it can be observed that the white light is separated into a spectrum and the image of all colors is fully spread. An Arduino microcontroller was used to monitor the experiment.

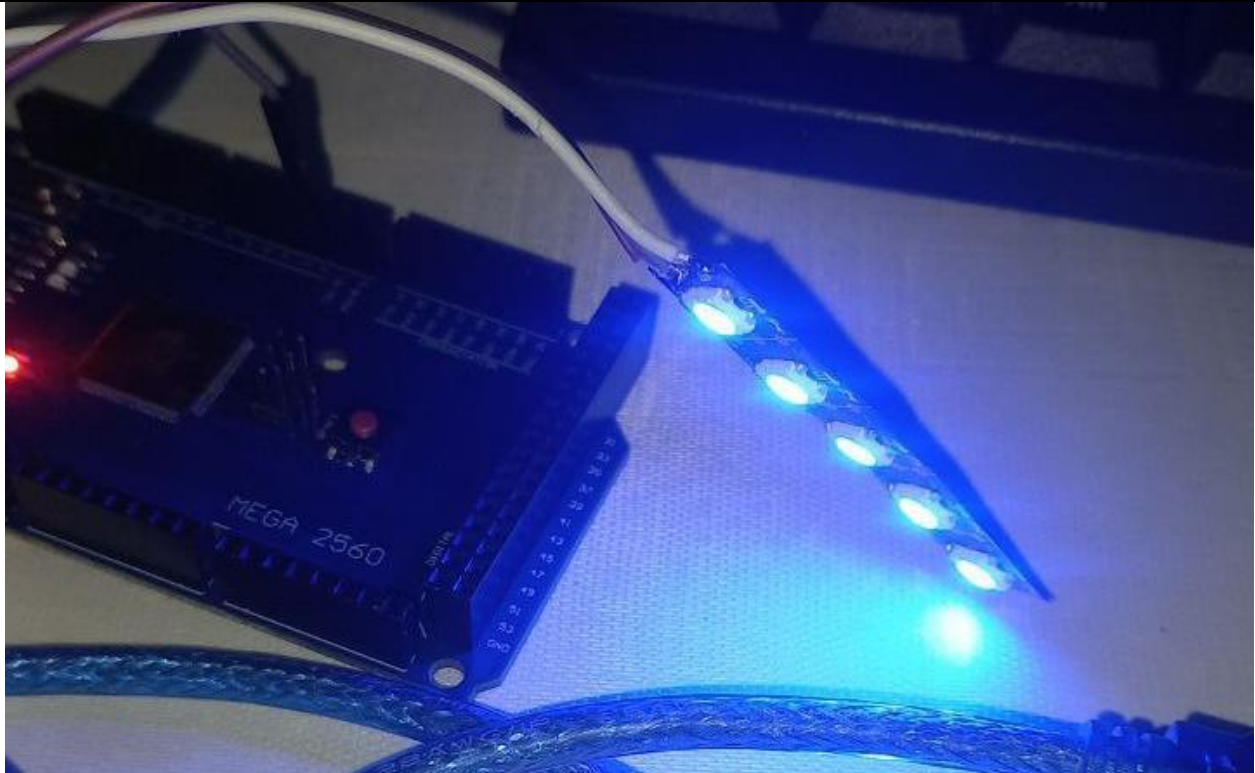


Figure 5. 5 matrix led running on arduino microcontroller.

Figure 5 shows an image of a LED, which is an artificial light source, in working condition.

The Arduino code was written as follows:

```
#include <FastLED.h>
#define NUM_LEDS 5
#define OUT_PIN 3
CRGB led [NUM_LEDS];
int my_patch2[5]={1,1,1,1,1};
void setup() {
FastLED.addLeds<NEOPIXEL, OUT_PIN>(led, NUM_LEDS);
}
void F2() {
  int pattern = 0 ;
  for (int i=0; i<5; i++)
  {
    if(my_patch2[i] != pattern) {
      led [i]=CRGB(255,255,255);
    }
  }
  FastLED.show();
}
void F3() {
  int pattern = 0 ;
  for (int i=0; i<5; i++)
  {
```

```
    if(my_patch2[i] != pattern) {
        led [i]=CRGB(255,0,0);
    }
}
FastLED.show();
}
void F4() {
    int pattern = 0 ;
    for (int i=0; i<5; i++)
    {
        if(my_patch2[i] != pattern) {
            led [i]=CRGB(0,255,0);
        }
    }
    FastLED.show();
}
void F5() {
    int pattern = 0 ;
    for (int i=0; i<5; i++)
    {
        if(my_patch2[i] != pattern) {
            led [i]=CRGB(0,0,255);
        }
    }
    FastLED.show();
}
void F6() {
    int pattern = 0 ;
    for (int i=0; i<5; i++)
    {
        if(my_patch2[i] != pattern) {
            led [i]=CRGB(255,0,255);
        }
    }
    FastLED.show();
}
void loop() {
    delay (500);
    F2();
    delay (10000);
    F3();
    delay (10000);
    F4();
```



```
delay (10000);  
F5();  
delay (10000);  
F6();  
delay (10000);  
}
```

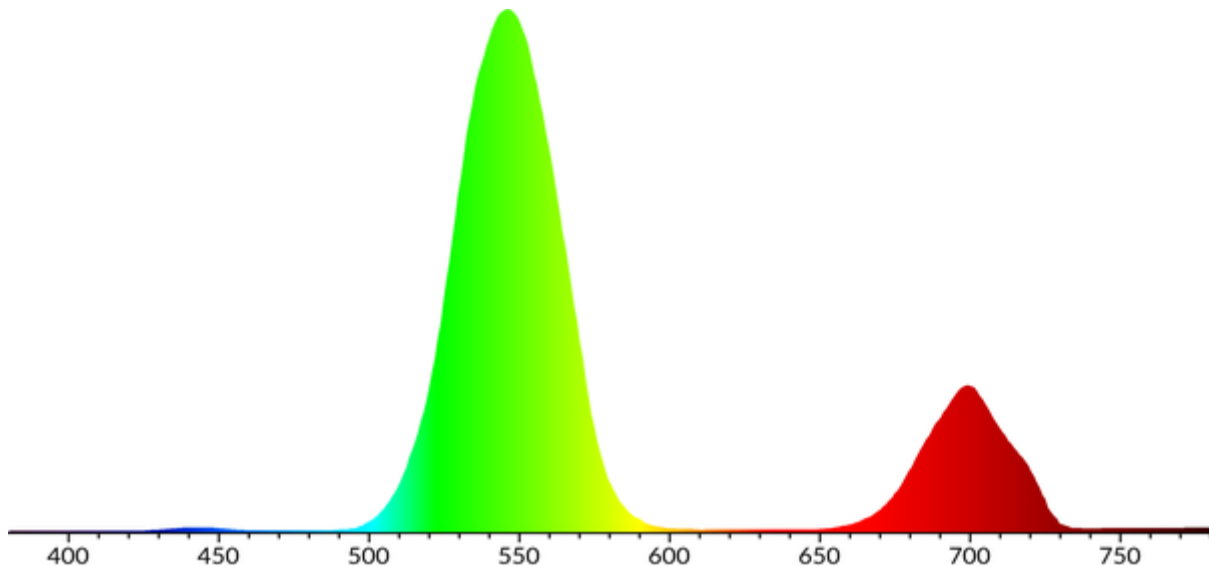


Figure 6: Green color spectrogram of a 5-matrix light source.

Figure 6 shows the spectrogram of green light, which is the second color of a 5-matrix LED. As a result of observation, it is possible to see the maximum value of the green color and the minimum values of the infrared spectrum. The experiment was carried out in the same sequence of operations as described above with white light.

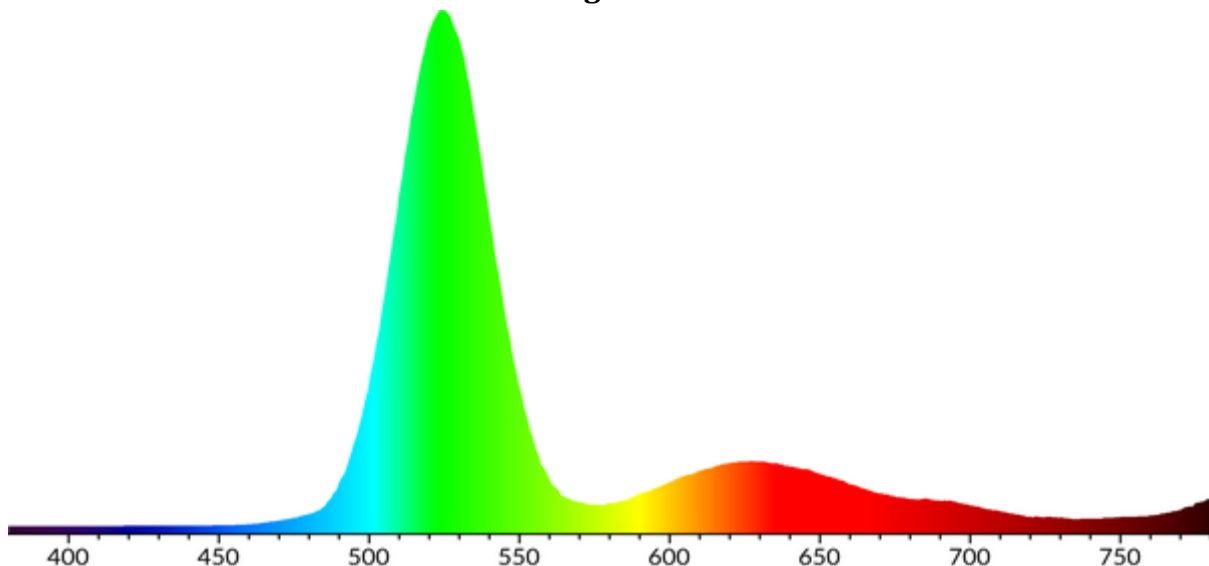


Fig. 7. Spectrogram of COB-LED source.

Figure 7. Spectrogram of COB - LED source observed.

LED devices of this type are a matrix in which a large number of crystals are installed without individual cases. Semiconductors are located close to each other, connected in series and located under a common phosphor layer. Due to the high concentration of crystals (up to 70

units/1 cm²), COB-LED emits radiation with a high optical density. The absence of additional shells ensures high brightness and reduces light scattering.



8-rasm.COB- LED

Figure 8 shows the view of the COB matrix. The operation of COB matrices is similar to other types of LEDs. The device includes p-n junctions, in which when a direct voltage is applied, the charges recombine with the emission of photons. As a result, a monochromatic light stream with a narrow spectrum is formed. The emission of LEDs causes the glow of phosphor, the change in its content allows to expand the range of shades and colors.

CONCLUSION

In this article, the separation of light into a spectrum when it passes through a diffraction grating and its detection by a camera is studied. The principle of operation is studied using a spectrometer device. Spectrometer structural scheme is given. An operation algorithm was created for the diffraction grating and the camera. It was mentioned how the camera transforms spectrum values into an image. Based on the created algorithm, spectrum analysis of 3 different LEDs was carried out in the spectrometer.

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