Emission and Absorption Spectroscopy with Bahaghari DIY Spectrometer

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Abstract

In this experiment, we examine the emission and absorption spectra of various sources using the do-it-yourself Bahaghari spectrometer. The spectrometer was calibrated using a CFL lamp. Emission of tungsten, laser, and LED was investigated. Absorption of CPL, UV, and ND camera filters and liquids with different color food dyes were also examined.

Keywords: spectroscopy, Bahaghari spectrometer

1 Introduction

Spectroscopy is a technique utilized in the investigation and measurement of spectra produced from light-matter interactions. Every chemical compound absorbs, transmits, or reflects light over a certain range of wavelength. Hence, spectroscopy offers information concerning structure and properties of matter. Spectroscopic techniques are widely used analytical methods in various fields today[1].

The basic operating principle of a spectrometer is to take in light from a source through a narrow slit and the electromagnetic spectrum is obtained when the light passes through a diffraction grating, breaking it into its spectral components. The signal is then digitized as a function of wavelength[2].

A plane wave light that is incident on a diffraction grating gives rise to a transmitted beam and various diffracted beams. The angle of the diffracted beams depends on the wavelength of the incident light. The diffraction grating function is given by the relation:

$$d(\sin\theta_m - \sin\theta_i) = m\lambda \tag{1}$$

where d is the grating period, $\sin\theta_m$ is the diffracted ray angle, and $\sin\theta_i$ is the incident ray angle to the grating normal. Thus, a grating separates a beam of light in its wavelengths components.

In this paper, different spectral investigations was conducted using the do-it-yourself (DIY) Bahaghari spectrometer. The Bahaghari spectrometer is a grating-type laptop webcam spectrometer developed for educational instruction [3].We will examine the emission spectra of various light sources as well as the absorption of various samples and filters.

2 Methodology

2.1 Bahaghari Spectrometer

The main components of the Bahaghari spectrometer are: (1) grating film, (2) sharp-edged narrow slit, and (3) a cardboard cutout that house the optical components. The spectrometer is typically mounted and aligned to a laptop webcam which captures the spectra for analysis using the Theremino software.

2.2 Calibration

A compact fluorescent lamp(CFL) was used a the calibration light source. The CFL was placed approximately 1 meter away at the same height from the mounted spectrometer. The Trim point indicators are adjusted to coincide the 2 known CFL peak wavelengths, specifically 436 nm and 546 nm.

The alignment and position of the experimental set-up is maintained throughout the experiment.

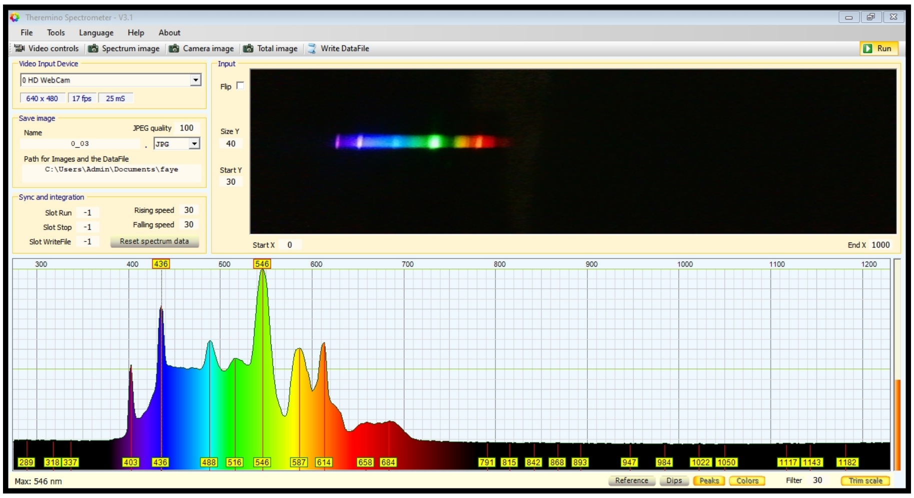


Figure 1: Calibration using a CFL light bulb

2.3 Emission and Absorption Spectra

The emission spectra of an light emitting diode (LED) lamp, incandescent lamp, and laser pointer is obtained. The CFL was replaced by the LED lamp and incandescent lamp to obtain their emission spectra. The emission spectrum of a laser is obtained by placing a bond paper before the laser pointer at the same distance and height of the previous light sources to diffuse the laser. Furthermore, we also examine the emission of a UV LED nail lamp and IR from a remote control. However, we do note that the camera used in the experiment contains a UV/IR cut filter.

The absorption spectra of red and green food dye was also obtained. A clear container with water was placed between the slit and a broadband light source. The initial spectrum of the clear water was recorded and set as the reference spectrum. Food dye was mixed with the water and the resulting absorption spectrum is recorded. Additionally, the spectra of light passing through a neutral density camera filter was also obtained.

3 Results and Discussions

3.1 Emission

3.2 Incandescent light

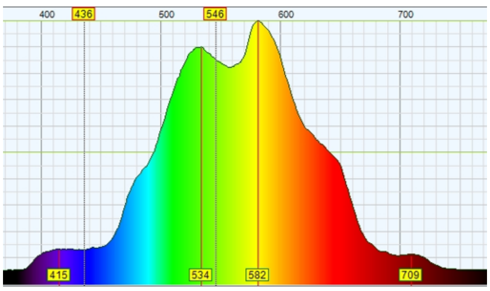
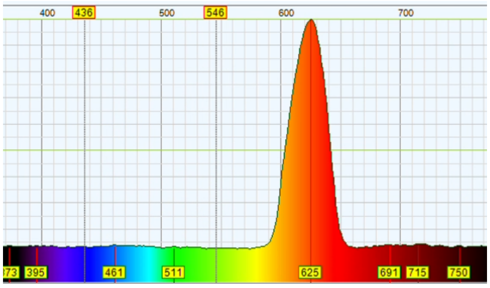


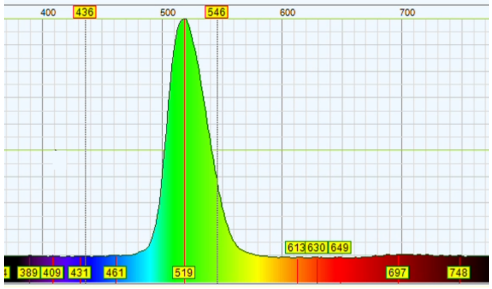
Figure 2: Emission spectra of an incandescent light bulb

As shown in Figure 2, the light from an incandescent bulb returns a broadband spectrum particularly in the yellow-green regions. It relates to the continuous spectrum which is produced by hot dense objects such as the incandescent light. This is in line with the method from which an incandescent lamp produces light by the temperature of the lamp filament. This is different from the emission spectra of a CFL shown in Figure 1 where it appears to be quantized.

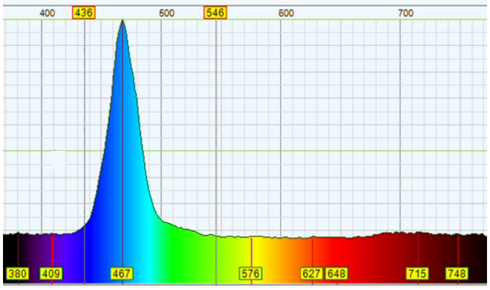
3.3 LED Light



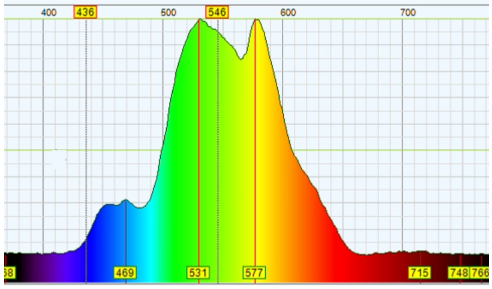
(a) Red



(b) Green



(c) Blue



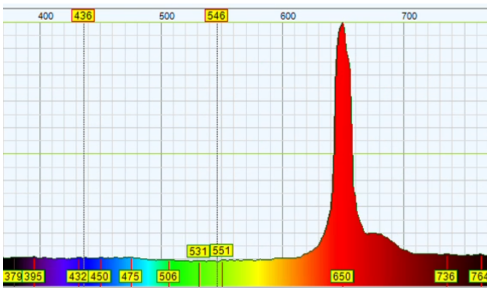
(d) White

Figure 3: Emission spectra of different color LED lights

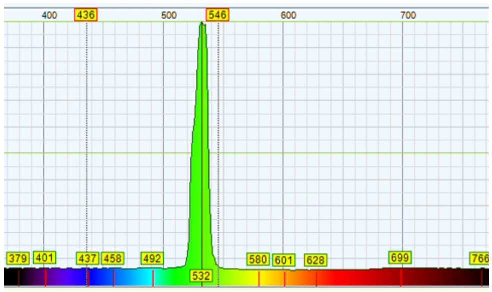
Here we exhibit the different emission spectra of LEDs of different wavelengths. Figure 1 shows the high intensity of visible light emitted occurred in their corresponding color bands, i.e. red wavelengths for red LED. Meanwhile, White light shares the same characteristic as the incandescent light such that there is an almost even distribution and wider range of wavelengths throughout the spectrum.

Other colors for LEDs were also tested. Results can be found in this link. We notice that the wavelengths for other colors of LEDS outside red, green, blue, and white are combinations of the peaks shown in Figure 3 (a-c) with varying intensities.

3.4 Laser



(a) Red

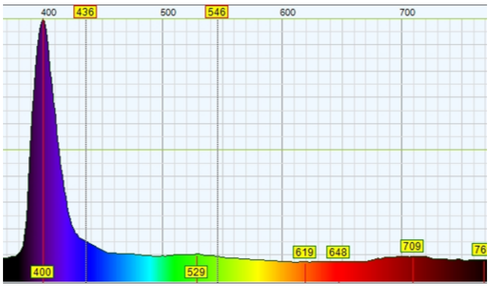


(b) Green

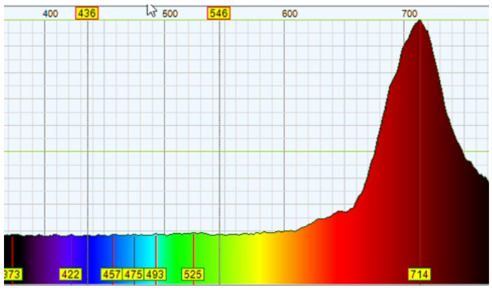
Figure 4: Emission spectra of different color of lasers

A laser diode emits a very narrow coherent low-powered laser beam of visible light, ideally emitting one particular wavelength of light. The spectral profile shows the narrow bandwidth characteristic of lasers. The wavelengths emitted by the red and green lasers are 650nm and 532nm, respectively.

3.5 Near IR and Near UV



(a) Near UV

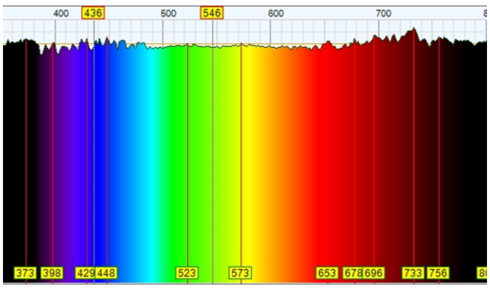


(b) Near IR

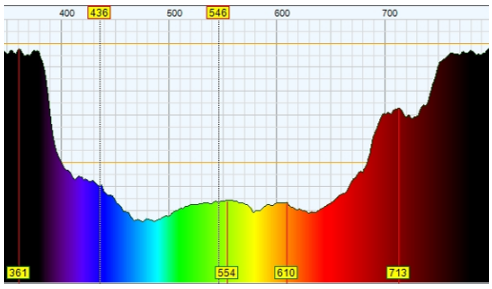
Figure 5: Near UV and Near IR emission spectra

In Figure 5(a), it is shown that the maxima for the emission of an UV LED lamp occurs at 400nm, which is within the range of Near UV (200-400 nm) and visible violet light. For the IR remote control, the emission spectra is beside the range for the Near IR spectrum (750nm-800nm). However, we do have to consider the filters in the camera for IR and UV, hence the spectrum shown in Figure 5 may not be entirely the correct spectrum. It is possible that the spectrum can be shown to be at the infrared region or ultraviolet regions, given that the filters are removed from the camera equipment[4].

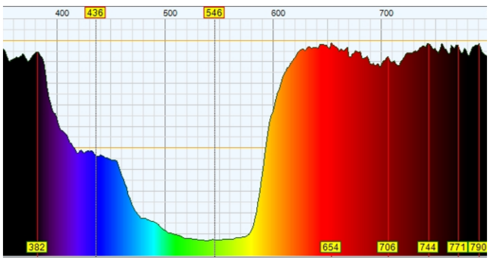
3.6 Absorption



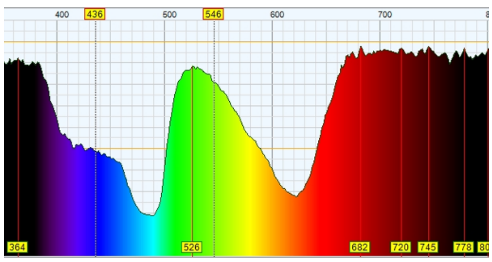
(a) Reference spectrum



(b) Neutral density



(c) Random



(d) Spherical

Figure 6: Absorption spectrum of (b) neutral density camera filter and (c-d) different color food dyes

The absorption spectrum for the red dye shows a dip from the orange to violet wavelengths. For the green dye, there are dips between the red to green region and green to violet regions. These dips indicate the colors or wavelengths being absorbed by the sample.

For the ND filter, there are no distinguishable dips in wavelengths but rather a general dip throughout the spectrum. This is expected from the ND filter, which purpose is to reduce or modify the intensity of all wavelengths of light with no changes in hue of color rendition. Standard ND filters typically reduces the amount of light entering the lens of a camera.

4 Conclusions

The basic technological and practical aspects of spectroscopy has been described. A homemade set-up was constructed using the Bahaghari spectrometer and a laptop webcam. We have qualitatively described the emission spectra of various light sources. We show the broadband spectra of incandescent light and white LED light as well as the specific color wavelengths for different color LEDs. We have also obtained the 532 nm and 650 nm wavelengths emitted by green and red lasers, respectively. We also characterized the spectra of a UV LED light and IR remote control, although the results could be improved upon removal of the cut filter from the camera. The absorption of an ND camera filter, red and green food dye was exhibited by the dips in the obtained spectra according to a reference spectrum.

References

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