Spectroscopic measurements on modern lighting sources and emitting displays: THE BLUE LIGHT RADIATION AS A HEALTH RISK FACTOR

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Abstract

The focus in spectroscopic measurements of radiation intensity and the spectral distribution of lighting sources as displays in TVs, computers, smart phones and tablets, which have a peak emission in the blue light range (400–490 nm) due to the use of LED technology, is justified as experimental evidence has indicated that exposure to blue light can affect many physiologic functions and ocular health.
In this work, a series of spectroscopic measurements have been taken as to track the absolute amount of the blue light intensity coming from different illumination sources and devices, against the rest of the spectrum. In addition, the effectiveness of protective means such as coated lenses and digital filters used to reduce the exposure to blue radiation, especially at the workplace, has been investigated.
The laboratory equipment needed to carry out the experimental procedure is relatively simple while the commercial devices which can be investigated are everyday used devices such as PC monitors, LCD TVs, smart phones, e-readers and tablets.

Keywords: Blue light, LED, visual fatigue, Electronic displays, Tablets, Mobile phones, Melatonin

Introduction

For many years, the effects of ultraviolet radiation on ocular health have been known. Gradually we place ourselves on more and more intense exposure to radiation coming from the near-ultraviolet and blue light emission spectrum. Nobody doubts that there is an exponential increase in the use of Liquid Crystal Display (LCD) devices worldwide. More and more time is spent in front of computer screens, tablets, mobile phones, etc. resulting in increased, age-related, visual fatigue in all age groups.

In addition, scientific research is now beginning to explore the relationship that links the use of these devices to some eye problems occurring to users as it is believed that the significantly higher intensity of blue light in the 450nm range emitted by LCD screens currently used, is the main risk factor for ocular health. More specifically, the Scientific Committee on Health, Environmental and Emerging Risks (SCHEER) following a request from the European Commission reviewed recent evidence to assess *potential risks to human health of Light Emitting Diodes (LEDs) emissions*

(2017)[1]. Furthermore, the American Optometric Association defined the Computer Vision Syndrome (CVS)[2], also referred to as Digital Eye Strain, where eye and vision-related problems that result from prolonged computer, tablet and smart phone use are described. As one of the most common problems associated with CVS is the dry eye symptom. Courtin R, et al., (2015) evaluated the prevalence and risk factors of dry eye disease (DED) in workers using visual display terminals (VDT). The findings of their work show that office workers experience symptoms associated with VDT use. The usage is especially associated with DED, but the prevalence is probably widely underestimated. Another symptom brought by devices emitting radiation at short wavelengths close to the peak sensitivity of melatonin suppression, is sleeping disorders. In recent studies the influence of the exposure of blue light from smartphone LED displays at night on humans was investigated (Brittany Wood et all., 2013, Jung-Yoon Heo, et all., 2016, Cajochen, C. et all. 2011).

In terms of technology, VDT's over the past decade use the backlighting technique, where light-emitting diodes (LEDs) have been adopted to illuminate the LCD layer. To a large extent, most electronic devices employ a backlit LCD screen where the light source, an array of LED's in this case, is set behind the screen thus allowing the use of these devices in poorly lit environments. As the LED technology is progressing the screens of the majority of electronic devices are now illuminated by white light LEDs which exhibit a peak emission in the blue range of the visible spectrum. It is possible that some of the negative effects of this emission originate from the point where its peak value (450 nm) coincides with the wavelength of maximum absorption of the melanopsin pigment of the retina (460 nm), which regulates the cycle of sleeping and waking in human biological rhythms (John D. Bullough 2013, Chang, et all., 2014).

The current study aims to examine spectra coming from different illumination sources which emit peak values around the blue light region and to investigate the effectiveness of protective means, such as coated lenses and digital filters used to reduce the exposure to blue radiation. As the procedure is carried out in the Physics (Optics) Laboratory, the students could become interested in exploring the risk factors associated with the blue light exposure. The fact that this phenomenon has an effect on human physiology could further stimulate their research curiosity.

Materials & Methods

The spectrometer setup

The measurement unit consists of a micro-spectrometer (Ocean Optics - S2000) coupled with an optical fiber and a cosinus corrector at its tip. The spectrometer software (Ocean Optics Spectra Suite) and Origin 8.0 were used for collecting and processing of the measured data respectively (Figures 1 & 2).

[1]https://ec.europa.eu/health/sites/health/files/scientific_committees/scheer/docs/scheer_o_011.pdf
[2] https://www.aoa.org/patients-and-public/caring-for-your-vision/protecting-your-vision/computer-vision-syndrome?sso=y

A primary tungsten halogen light source (Ocean Optics - LS-1) was used to calibrate the spectrometer, while the total emitted light intensity of the individual screens was

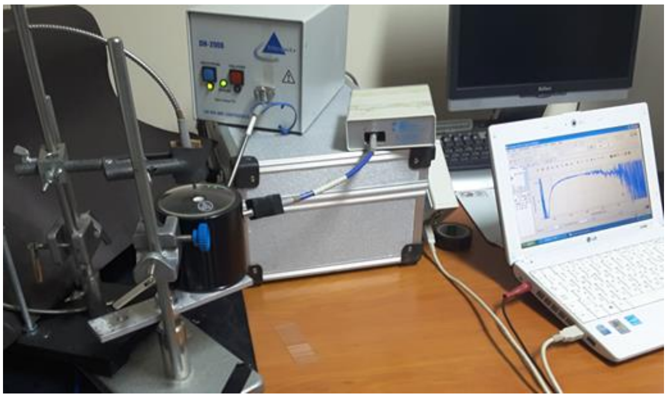


Fig.1. The Ocean Optics micro - spectrometer

Fig.2. Collecting data from tablet

measured by a calibrated power meter (Newport ST 851-UV). For the transmission measurements through the lenses an integrated sphere was used in combination with a balance tungsten light source (Ocean Optics DH-2000-BAL, FOIS-1)

Results

Determining the amount of blue light radiation

The intensity of the emitted radiation in the blue region from mobile screens, tablets and personal computers was determined by spectroscopic measurements as shown in the following spectra, where one can see how the relative intensities of various origins are formed in respect to each other.

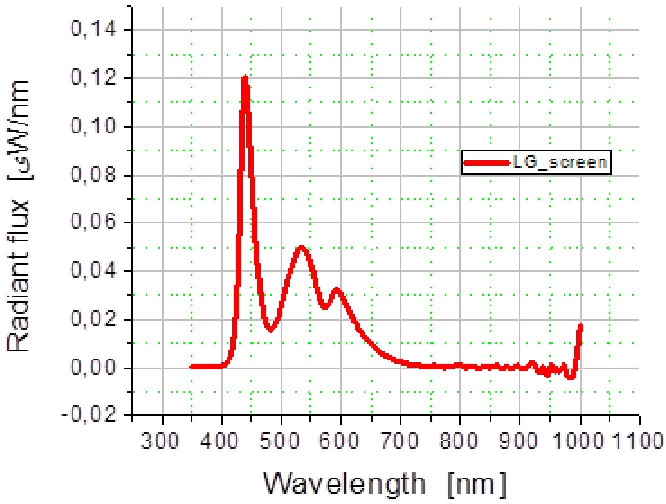


Fig.3. Radiation spectrum of a PC LED

Figure 3 shows the spectrum of the emitted radiation of a PC LCD monitor, as captured by the spectrometer. In addition, intensity measurements of total emitted radiation at user distance from the monitor were taken by a calibrated power meter and found to be 100 uW/cm^2. The intensity in the blue light region, after the processing of the spectrum was calculated at 30 % of the total value. The curve at 450 nm, which is the blue light band shows its intensity peak to be 2,5 times higher compared to the other two bands (green and red).

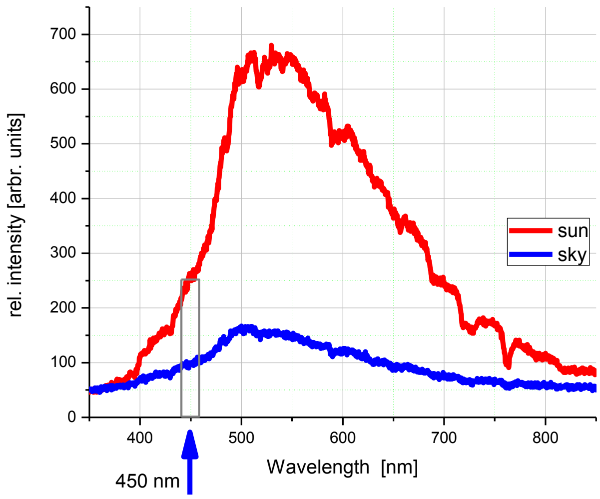


Fig.4. Radiation spectra of sun and clear sky (natural daylight)

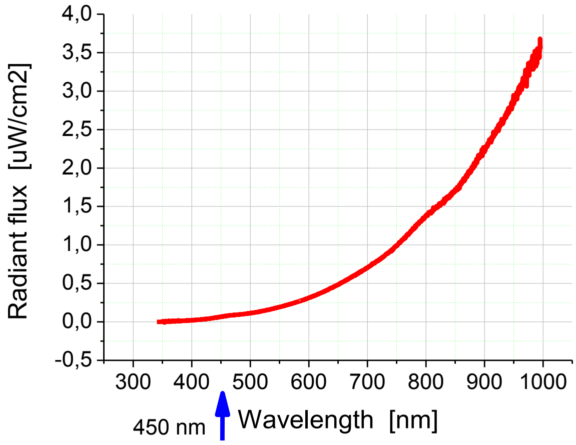


Fig.5. Radiation spectrum of an incandescent lamp

From the spectra in Fig. 4 & 5 which represent natural as well as conventional light sources, it is apparent that the blue radiation is much less compared to radiation emitted in the other bands of the spectrum. In contrast, this pattern changes dramatically in the case of a LED source, as seen in Figure 3, where the blue light band dominates the spectrum.

Spectral radiances from other illuminants, such as LEDs and LCD monitor devices were investigated as can be seen in Figures 6 & 7, where the emission peak in the blue light band is clearly demonstrated.

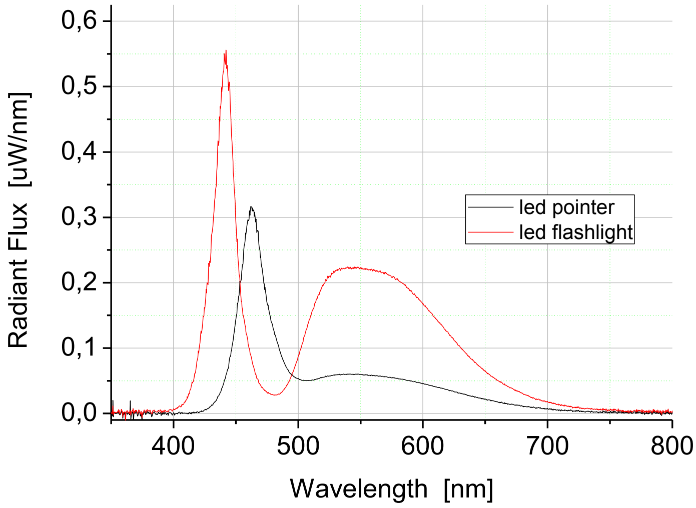


Fig.6. Radiation Flux spectra of pure LED sources led pointer and led flashlight).

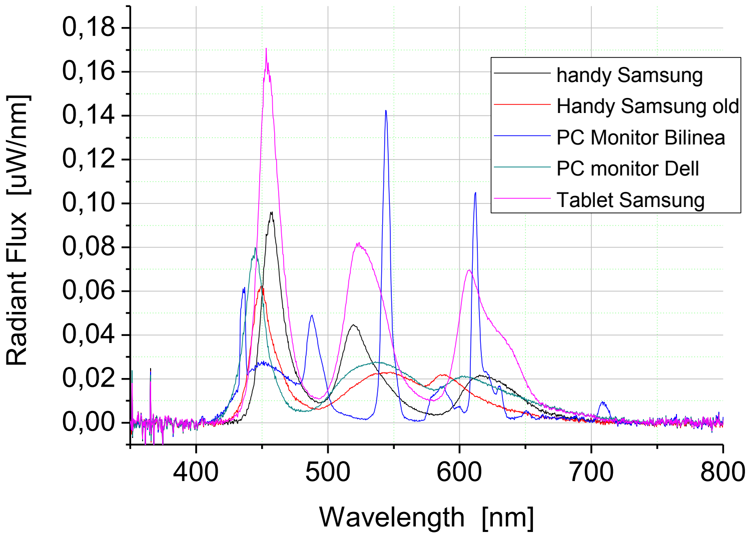


Fig.7. Screen spectra taken from various monitor devices where digital filters are not implemented

Filtering the blue light spectral radiance

The reduction in blue light emission reaching the eyes of various self-luminous display users, requires the use of protectors such as classical transmission filters that selectively attenuate certain regions of the visible spectrum or software applications to control the relative weight of the signal emitted by each color pixel, attenuating in that way some of the spectral bands. The blue light hardware filters used to measure the transmitted irradiance were various coatings incorporated in commercially available ophthalmic lenses. As for the software filters, the Blue Light application for androids was used and the strength of the filtering effect was determined by changing the digital color filters.

Figure 8 shows transmission spectra from three different ophthalmic lenses, coated with blue light blocking optical materials. The spectrum in Figure 9 shows the intensity of the irradiation emitted from the screen of a common tablet, when digital color filters were applied.

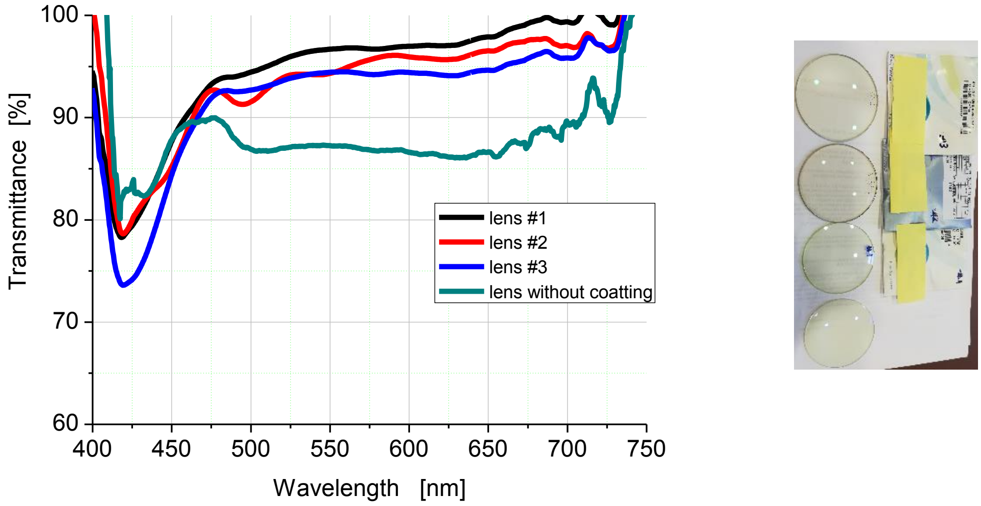


Fig.8. Transmission spectra of three different types of coated lenses in comparison with an uncoated lens

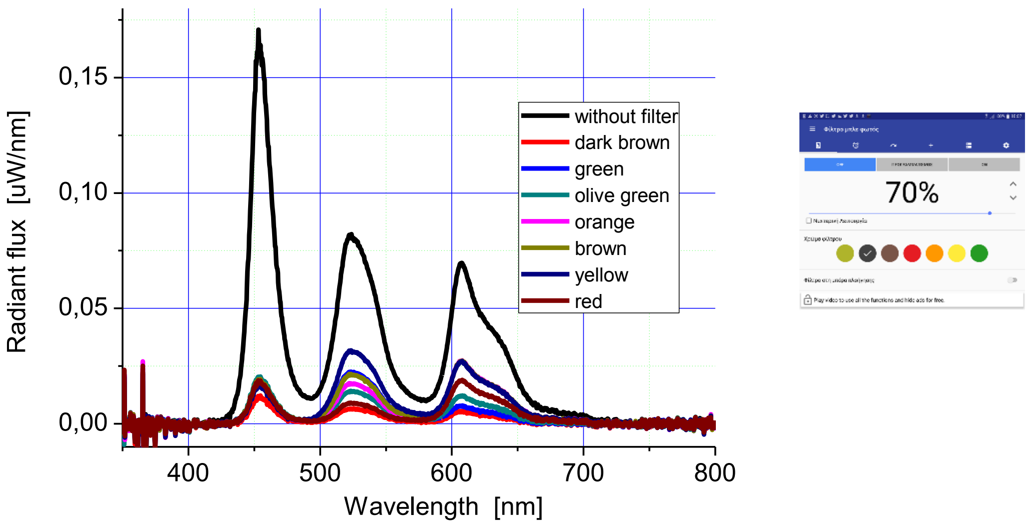


Fig.9. Radiant Flux spectra taken off from a tablet's screen, where blue radiation has been reduced or minimized after passing through digital filters.

Discussions

The spectra

In this study, the emitted spectrum of direct light sources and self-luminous displays was examined as to demonstrate their emission peak in the blue light band. Along with this, the transmission spectra involving hardware and software attenuating filters were also investigated. In all cases, the sun's spectral radiance is also plotted for comparison purposes.

The emission spectrum for natural light generally follows the Planck distribution in the visible part of the spectrum, as we can see in Figure 4. No color is dramatically favored over another, although the intensity is highest in the region, around 470 - 480 nm). On the other hand an incandescent bulb emits a greater proportion of red light than natural daylight. Emission even extends into the infrared part of the electromagnetic spectrum (Figure 5). Looking in the emission spectrum in Figure 3, we see that nearly all the power is emitted within the blue light region, peaking at 450 nm. The same goes for other direct LED sources such as led pointers and flashlights.

The optical transmission spectra of coating over ophthalmic lenses are shown in Figure 8, in comparison with an uncoated lens. As we can see, these hardware filters attenuate all wavelengths within a range. Lastly, a tablets screen was set at the maximum brightness and as digital filters were applied in succession the corresponding spectra were recorded (Figure 9). The baseline spectrum was also measured for comparison with the application deactivated. The radiant flux measured for all digital filters shows a dramatic drop in value compared to baseline radiation.

Blue-light-induced net damage

The biological effects of blue light on human vision, known for a long time, have become particularly important in recent years and are at the forefront of discussions, mainly due to the rapid deployment of LED technology even in household lighting (JB O'Hagan, 2016). Particularly, the manufacture of television screens, computer monitors, mobile phones and tablets also are LED-based blue light sources, emitting disproportionately large amounts of blue light in the area around 450 nm, relative to the other spectral components of white light. As a result, the eyes are exposed to ever greater intensities of this spectral range.

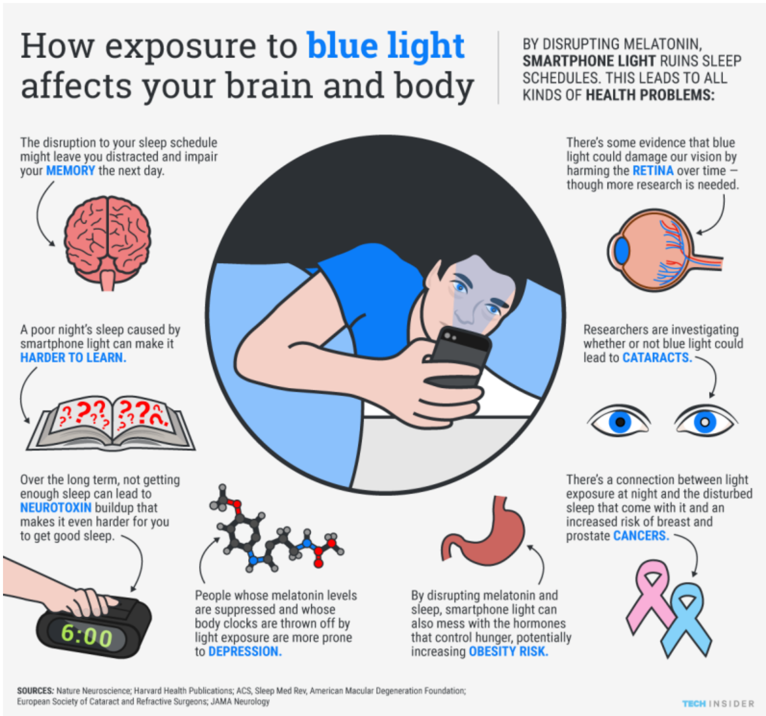
Exposure to blue light has been shown to affect health. Natural exposure to blue light during the day drives the energy, alertness and mood of people. However, prolonged exposure to radiation emitted by day-to-day devices, such as monitors, tablets, and televisions, especially at night in darkness, may disturb the circadian rhythm and cause various health effects, including interruption of regular sleep schedules (Hysing M. et all., 2015, Frida H. et all., 2016)

To the extent that the eye can not spectrally distinguish the percentage of blue radiation into the white light it perceives, significant spectral measurements are required to control and assess the risk of light emitted by various devices of daily use.
The biological effect of blue light includes the fatigue areas (400-420 nm), macular damage (400-440 nm) and sleep fluctuations (460-484 nm).

- The results of various in vitro studies show that a permanent exposure to visible blue light has a damaging effect on the retina.
- The presence of fluorescent lipofusin A2E appears to play an essential role in the blue light-induced net damage. The pigmented layer (retina or retinal pigment epithelium, RPE) cells of elderly people contain a lot of A2E and are thus sensitive to blue light-induced cell damage according to some studies. In addition, the age-dependent macular degeneration is associated with the long-term irradiation of blue light.
- The steep increase in the toxic effect of blue light (400 nm - 500 nm) on the retina is called "blue hazard" or "blue light hazard". At a wavelength of 440 nm, the sensitivity of the retina to photochemical stress is maximal (Youssef PN. 2010)
- There is (so far) no reliable knowledge about the damage of the blue light fraction of polychromatic light to a retina in the living eye of humans (in vivo).

How exposure to blue light affects your brain and body

- The disruption to your sleep schedule might leave you distracted and impair your MEMORY the next day.
- By disrupting melatonin, smartphone light ruins sleep schedules. This leads to all kinds of health problems.
- A poor night's sleep caused by smartphone light can make it HARDER TO LEARN.



- Over the long term, not getting enough sleep can lead to NEUROTOXIN buildup that makes it even harder for you to get good sleep.
- People whose melatonin levels are suppressed and whose body clocks are thrown off by light exposure are more prone to DEPRESSION.
- There's some evidence that blue light could damage our vision by harming the RETINA over time —though more research is needed.
- Researchers are investigating whether or not blue light could lead to CATARACTS.
- There's a connection between light exposure at night and the disturbed sleep that come with it and an increased risk of breast and prostate CANCERS.
- By disrupting melatonin and sleep, smartphone light can also mess with the hormones that control hunger, potentially increasing OBESITY RISK.

Conclusion

The results of our measurements reinforce the common sense that the blue light radiation originating from contemporary light sources, such as screens of tablets, mobile phones, monitors of personal computers and TVs, dramatically dominates the spectrum. The disproportionally high value of blue light radiation intensity from LED-based lighting devices affects the human physiology and also could be dangerous to ocular health.

The use of protective means, such as eye glasses coated with blue light blocking optical materials or minimizing this damaging radiation implementing appropriate digital filters to the devices, has to be a priority for everyone.

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