MEASURING THE BLUE LIGHT INTENSITY PASSED SCREEN PROTECTOR OF SMART PHONE USING BH1750 SENSOR

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ABSTRACT

In this research, the BH1750 light sensor was used to measure the amount of blue light emitted from smartphone through various types of screen protectors, including ultra-clear glass, privacy filter, matte, ceramic, paper-like, anti-blue, and hydrogel. This sensor was calibrated with the EKO spectroradiometer model MS-710, which is a standard measuring device. Then, the researchers used the calibrated BH1750 sensor to measure the amount of blue light from smartphone with different types of screen protector at various distances according to the criteria of IEC/EN62471. The experimental results showed that privacy filter screen protectors could reduce blue light the most, followed by anti-blue screen protectors and hydrogel screen protectors, which could reduce blue light the least.

Keywords: blue light, sensor, screen protector, smartphone

1. INTRODUCTION

Currently, the use of information technology devices is rapidly increasing, such as the use of computers, mobile phones, and tablets. The bright light emitted from the screens of these devices still contains blue light that affects human eyes. Prolonged exposure to blue light may lead to eye fatigue, blurred vision, damage to the eye's optic nerve, and even contribute to sleep disturbances, impacting human circadian rhythm [1].

Blue light is part of the sunlight spectrum with a wavelength range between 400-500 nm [2]. Human eyes do not respond uniformly to blue light, as illustrated in Figure 1, depicting the response values based on the IEC/EN62471 standard [3,4].

According to Figure 1, it can be observed that the blue light most responsive to the human eye in the range of 435-440 nm. Within this wavelength range, it has been identified that the light emitted from Light Emitting Diode (LED) displays, commonly found in devices such as smartphones, tablets, and laptops, contributes significantly to blue light exposure. As a result, many researchers have endeavored to develop displays that reduce blue light emission or create tools capable of measuring blue light from information technology devices [1, 5-8].

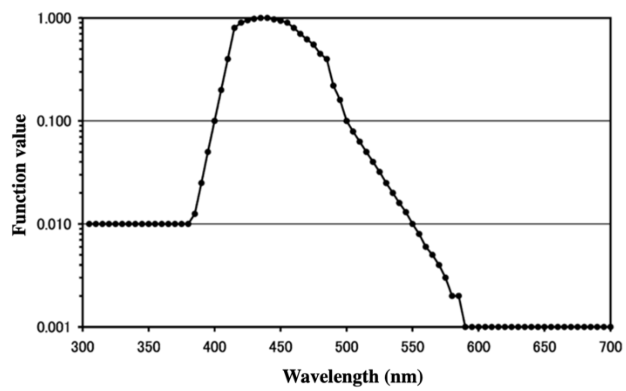

Figure 1. Graph of Blue Light Response Hazardous to Human Eyes.

For example, Moyono et al. [1] conducted a study on blue light emitted from various information technology devices, including 10 devices such as smartphones (5 devices), tablets (4 devices), and laptops (1 device). They compared the blue light emitted from these devices with sunlight. The findings revealed that the blue light emitted from technology devices ranged from 0.008-0.230 W/m^2, whereas sunlight emitted blue light in the range of 14.5-35.5 W/m^2. However, the blue light from the sun depends on location. In Thailand, the sunlight from the sun is 800-1000 W/m^2 approximately [6] and consist of blue light about 25% [7]. It is evident that the blue light from technology devices is significantly lower than sunlight. However, even in these lower quantities, it has a considerable impact on human eyes, potentially leading to eye diseases and sleep disturbances, especially with prolonged screen exposure.

Furthermore, Navarrete et al. [7] studied the blue light spectrum of LEDs from various devices, such as light bulbs, smartphones, tablets, and displays from different brands. They established standard equations to calculate the blue light intensity for each device. These equations are

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linear equations, allowing for the quantification of blue light from each device.

There are many types of screen protectors in the market. This research tried to measure blue light intensity using developed BH1750 sensor [12] that passes through different types of screen protector in order to find what type of screen protector is the best in blue light reducing.

2. MATERIAL AND METHOD

In this research, the researcher utilized the BH1750 sensor for measuring light intensity, a sensor known for its versatile applications [9-11]. This choice was made due to its easy availability in the market and reasonable pricing. Additionally, it can be easily interfaced with Arduino or other boards, making it convenient for usage and further development. The independent variables of this research are the different types of screen protector, and the dependent variable is the amount of blue light passed through the screen protectors.

2.1. Screen Protector

Screen protectors for smart phone come in various types according to their usage characteristics. This research experiments with the properties of reducing blue light of 7 types of screen protectors, as follows:

2.1.1 Ultra-clear glass screen protector

This type of screen protector is hard, providing good protection for the screen, and allows a lot of light to pass through.

2.2.2 Privacy filter screen protector

This type of screen protector has a large number of tiny slits to control the light path straight to the user's eyes only. Light scattered in other directions is blocked to prevent peeping from surrounding people.

2.2.3 Matte screen protector

This type of screen protector has a smooth surface, reducing fingerprints effectively, but allows minimal light transmission.

2.2.4 Ceramic screen protector

This type of screen protector is similar to ultra-clear screen protector but made from ceramic material, providing durability and good scratch resistance.

2.2.5 Paper-like screen protector

This type of screen protector has a paper-like surface, suitable for writing or drawing on the screen.

2.2.6 Anti-blue screen protector

This type of screen protector is designed specifically to reduce the amount of blue light.

2.2.7 Hydrogel screen protector

This type of screen protector has a special thin profile, capable of self-healing scratches, and allows ample light transmission.

2.2. Sensor Calibration

The calibration of sensor war carried out at Silpakorn University, Nakhon Pathom (13.82oN, 100.04oE) during 6 to 21 September 2022. The data was separated to two groups, The first group for modeling and the second group for validation as the following details.

Step 1: Choosri, P. & Solos, S. [12] presents blue light intensity measurement using BH1750 sensor. According to their research, BH1750 sensor is connected to the Arduino Uno R3 board, linking it to the A4 and A5 pins. The sensor was also connected to the power supply with a voltage of 5 V. Subsequently, the Arduino Uno R3 board was interfaced with the Narrow Band Internet-of-Things (NB-IoT) board called AIS NB-Iot shield. This connection facilitated the transmission of sensor data to the Magellan platform, where the researcher could access and download the measured data. The configuration of the device connections is illustrated in Figure 2.

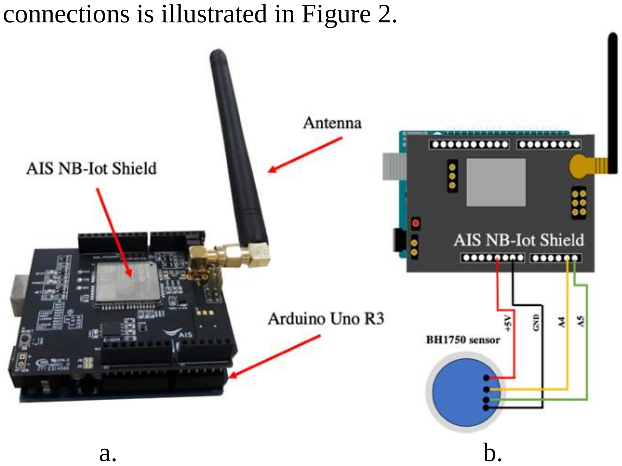

Figure 2. Proposed circuit of sensor and microcontroller.

a. Connection of AIS NB-Iot Shield and Arduino Uno R3

b. Diagram of sensor (BH1750) and microcontroller board

Step 2: The calibration is proceeded by installing the sensor connected to the control board. The calibration setup involved placing the sensor alongside a standard measuring instrument at the open sky area. The EKO spectroradiometer (MS-710) was selected due to its precision, accurately covering the wavelength range of 350-950 nm, and providing detailed measurements for each wavelength, including the blue light spectrum. The configuration of the equipment for calibration is depicted in Figure 3

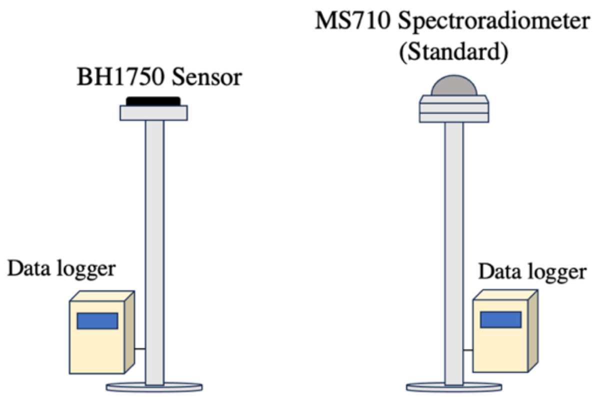

Figure 3. Configuration of the calibration tool positioning.

Step 3: For data collection during the calibration process, the researcher chose days with clear skies, no clouds covering the entire sky, or rainy periods, as clouds significantly impact sunlight intensity changes, leading to variable measurements.

Step 4: The data quality is controlled by using sky images to select days with clear skies, no clouds, or clouds covering less than 2/10 of the sky for analysis. Sky images were obtained from the Sky view device.

Step 5: Before proceeding with the analysis of the calibration results, the spectrum of sunlight obtained from the EKO spectroradiometer (MS-710) is converted into the blue light spectrum. In this step, the researcher will multiply the blue light response values (Figure 1) by the measured spectrum values at each wavelength. This process is represented by Equation (1) [3].

$$BL = \int_{400}^{500} L(\lambda)R(\lambda)d\lambda \qquad (1)$$

where *BL* = The quantity of blue light (W/m^2)
L(λ) = The quantity of light at each wavelength ($W/m^2\mu m^{-1}$)
R(λ) = The response values at each wavelength (-)

After converting the spectrum of sunlight from the standard measuring instrument into the form of blue light, the next step involves plotting a graph comparing the quantity of blue light obtained from the standard instrument with the light quantity measured by the sensor. This is done to observe the relationship and establish an equation for correcting the values from the sensor.

Step 6: Once the correction equation for the sensor is derived, the researcher will proceed to validate the accuracy of the sensor measurements. This involves conducting additional measurements of blue light intensity and comparing them with the readings from the standard measuring instrument. This validation step ensures the reliability of the sensor measurements before its actual deployment.

The relation between EKO spectroradiometer (MS-710) and BH1750 sensor is presented by Choosri, P. & Solos, S. [12] The blue light intensity from BH1750 sensor is compared EKO spectroradiometer (MS-710) shown in equation (2) [12].

$$BL = 0.001683(Lux) - 0.125892 \qquad (2)$$

where *BL* = The quantity of blue light (W/m^2)
Lux = Illuminance from BH1750 sensor (lx)

Therefore, equation 2 was used to convert illuminance to blue light intensity.

The calibration schedule, BH1750 sensor will be calibrated every two years and during the experiment the sensor was verified by intermediate check.

Process of intermediate check, the sensor measured the blue light intensity emitted by a black and white screen in a dark room. The sensor must have a maximum permissible error of measurement (MPE) values less than ±5 mW/m^2.

2.3. Measurement of Blue Light Intensity

When the sensor is successfully calibrated, it was assembled into a box and a display screen. Subsequently, this prototype uses to measure the blue light emitted from mobile phones, tablets, and computers. The specification of smartphone used in this experiment is OLED 5.8 inch of display which has 625 cd/m^2 maximum brightness. The measurement process involves the following steps:

Step 1: To quantify the blue light from the smartphone, it is measured in two scenarios. First, it is measured the light in a typical room lighting condition, simulating everyday usage with the lights on. Second, it is measured in a completely dark room, considering only the light emitted from the screen of the smartphone.

Step 2: The researchers measured the blue light from smartphone at various distances—10, 20, 30, 40, 50, and 60 cm. The selected distances adhere to the criteria of IEC/EN62471 and Moyono et al [1], as depicted in Figure 4.

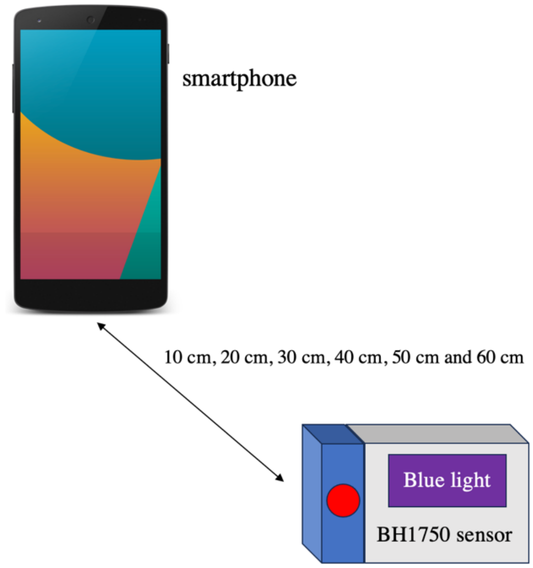

Figure 4. The different distances at which the blue light from smart phone was measured.

Step 3: Before measuring the blue light, the screen brightness must be set to 100%. Each type of screen protectors is placed on the smartphone screen. Then, measure the blue light from device passed through the screen protector. Perform 3 measurements for each type of screen protector, and the average blue light intensity obtained.

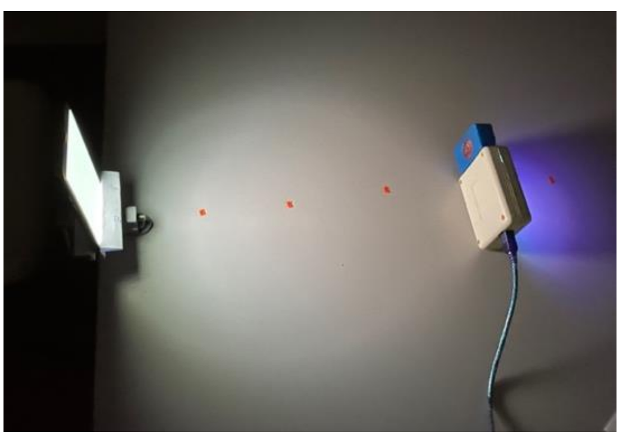

Figure 5. The different distances at which the blue light from smartphone was measured.

3. RESULTS

Each type of screen protector has difference of features. This research measures blue light intensity passed 7 types of screen protector which are ultra-clear glass, privacy filter, matte, ceramic, paper like, anti-blue and hydrogel. Each type of screen protector is measured 3 times. The average of each measurement is shown in Table 1 and Table 2.

Table 1. The average and standard deviation value of blue light intensity passed difference type of screen protector in typical room lighting condition.

Type of screen protector	Average blue light intensity)mW/m^2(											
	10 cm	SD	20 cm	SD	30 cm	SD	40 cm	SD	50 cm	SD	60 cm	SD
No protector	614.17	22.59	356.12	6.65	298.49	5.29	289.16	3.23	290.56	3.23	290.56	2.14
Ultra-clear	601.64	15.58	346.53	16.40	296.16	5.65	282.63	1.40	281.23	1.40	283.56	3.52
Privacy filter	402.03	21.69	285.90	10.86	262.58	8.55	263.97	1.62	275.17	2.14	283.57	2.15
Matte	596.04	36.19	336.27	6.62	281.22	4.22	266.31	5.29	267.24	5.05	273.37	5.74
Ceramic	597.44	32.27	337.66	5.82	282.63	1.40	267.24	2.42	268.17	3.52	276.57	3.52
Paper like	599.78	42.47	350.19	6.53	289.16	3.52	277.50	4.27	278.43	1.40	282.63	4.20
Anti-blue	574.59	14.15	333.93	3.52	281.70	2.91	264.44	3.70	267.24	6.41	273.77	0.81
Hydrogel	609.23	4.54	354.65	5.83	289.16	3.23	277.04	0.00	276.10	3.52	282.63	1.40

According to Table 1, the data can be plotted between blue light intensity (mW/m2) and distance (cm) shown in Figure 6.

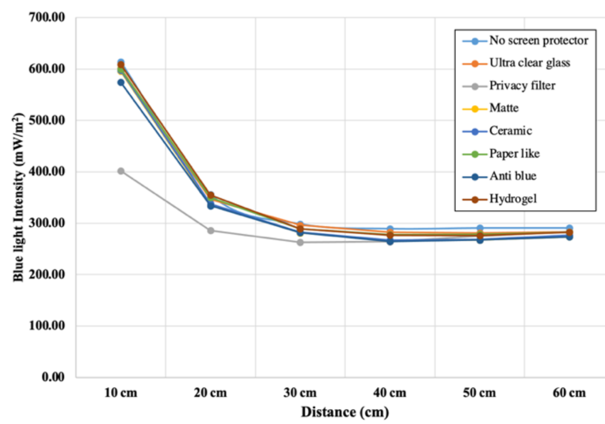

Figure 6. Relation between blue light intensity (mW/m^2) and distance (cm) in typical room lighting condition.

Table 2. The average and standard deviation value of blue light intensity passed difference type of screen protector in dark room condition.

Type of screen protector	Average blue light intensity)mW/m^2(											
	10 cm	SD	20 cm	SD	30 cm	SD	40 cm	SD	50 cm	SD	60 cm	SD
No protector	223.40	13.59	68.09	3.52	29.85	0.81	17.72	0.81	11.19	0.00	8.40	0.00
Ultra-clear	195.55	2.50	63.89	3.52	28.91	0.81	15.86	1.62	9.79	0.00	7.00	0.00
Privacy filter	106.34	6.10	38.71	0.81	18.19	0.00	11.19	0.00	7.00	0.00	5.60	0.00
Matte	223.40	12.06	64.89	1.50	30.31	1.62	15.86	0.81	10.72	0.81	7.00	0.00
Ceramic	207.87	5.69	64.63	1.10	29.38	1.40	17.26	1.62	11.19	0.00	8.40	0.00
Paper like	206.59	7.04	65.89	1.14	30.78	1.40	16.79	0.00	10.72	0.81	7.93	0.81
Anti-blue	177.69	2.80	61.10	6.61	27.98	2.42	16.32	0.81	10.36	0.98	7.47	0.81
Hydrogel	177.64	8.62	65.43	0.90	30.31	2.14	17.72	0.81	11.19	0.00	7.93	0.81

According to Table 2, the data can be plotted between blue light intensity (mW/m^2) and distance (cm) shown in Figure 7.

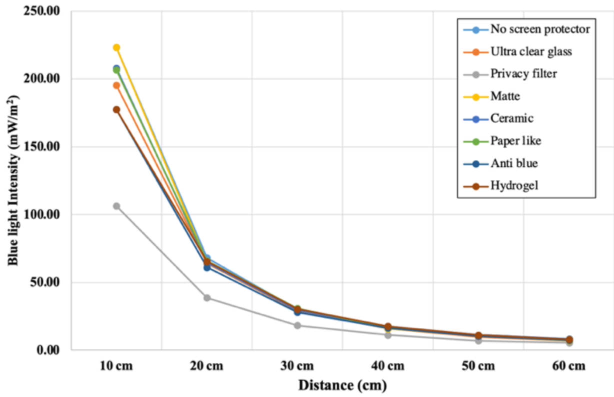

Figure 7. Relation between blue light intensity (mW/m^2) and distance (cm) in dark room condition.

The appropriate distance between the smart phone and the eyes often depends on several factors such as the size and resolution of the screen, the proportion of screen brightness, and many other factors. However, there are recommended guidelines that suggest the suitable distance is between approximately 40 to 60 centimeters. Therefore, the distance of 40 cm. is set to the reference point which is the shortest suitable distance for smartphone using, and the blue light radiated without screen protector is set to control. The blue light intensity from each type of screen protectors is compared to control in order to find blue light reducing efficiency of each screen protector.

Table 3. The blue light reducing efficiency of each screen protector at 40 cm. (Typical room lighting condition)

Type of screen protector	The percentage of blue light reducing efficiency
No protector)control(	-
Ultra-clear glass	2.26%
Privacy filter	8.71%
Matte	7.90%
Ceramic	7.58%
Paper like	4.03%
Anti-blue	8.55%
Hydrogel	4.19%

Table 4. The blue light reducing efficiency of each screen protector at 40 cm. (Dark room condition)

Type of screen protector	The percentage of blue light reducing efficiency
No protector)control(	-
Ultra-clear glass	10.52%
Privacy filter	36.85%
Matte	10.52%
Ceramic	2.61%
Paper like	5.25%
Anti-blue	7.88%
Hydrogel	0.00%

4. DISCUSSION

According to result, in typical room lighting condition, the privacy filter screen protector is most effective in reducing blue light because it has numerous tiny ridges to allow only straight-line light to pass through to the user. Light dispersed in other directions is completely blocked, including blue light. At the distance of 40 cm., the results in the privacy filter screen protector having the maximum ability to reduce blue light (8.71%). The anti-blue screen protector is the second effective in reducing blue light (8.55%). However, it is designed to reduce blue light, the light from screen still radiates more than privacy filter type. The hydrogel screen protector is the lowest blue light reducing efficiency because it is very thin comparing with other types of screen protector. Therefore, the light from screen can pass through easily. From a distance of 40 cm. onwards, the measured blue light intensity values are relatively close to each other and remain constant because there is blue light from the external environment interfering with the BH1750 sensor.

According to dark room condition, there are no other lights to interfere the sensor which is the appropriate condition for blue light measurement. In this condition, the privacy filter screen protection also has the most effectiveness in reducing blue light significantly. At the distance of 40 cm., it reduces 36.85% of blue light intensity. The matted screen protector is the second in blue light reducing (10.52%) because it has a frosted appearance and low light transmission. The anti-blue screen protector is the third in blue light reducing (7.88%) because it has more light transmission than matte screen protector. The blue light intensity measured in dark room condition is the only blue light values that radiate from screen of smartphone without interfering.

At 30-centimeter of dark room environment, the blue light value of paper like, Matte and Hydrogel screen is higher than no screen protector. This is the error caused by the experiment such as distance and angle between smartphone and sensor. Moreover, the paper like, matte and hydrogel have low blue light reducing. Therefore, the amount of blue light passed these screen protectors closes to the amount of blue light of smartphone without screen protector. However, it is small error that is not over 1 mW/m^2.

The results of this research experiment enable the selection of a suitable screen protector for devices, including the intensity of blue light that passes through different types of screen protectors. According to the result in Table 3 and Table 4, at distance of 40-centemeter the privacy filter screen protector is the best in blue light reducing efficiency both in typical lighting and dark room conditions. In typical room lighting, ultra-clear glass screen protector is the lowest blue light protection, but in dark room condition, the hydrogel is the lowest blue light protection. This information allows users to safely use smart phone without harming their eyes.

5. CONCLUSION

This research use BH1750 sensor to measure blue light passed the screen protector of smart phone. The BH1750 sensor is calibrated by standard EKO spectroradiometer (MS-710). The results show that privacy filter screen protector is the most effective in reduce blue light. The hydrogel is the lowest blue light reducing efficiency. In the future, more devices using screen protector such as tablet and laptop are planned to be experimented.

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