Development of an Accurate Laser Power Testing Kit for Safety Assessment of Commercial Laser Pointers in Thailand

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Abstract: Recent advances in laser technology have enabled low-cost, more powerful, and more visible wavelengths of laser pointers. Large numbers of these high power lasers have found their way into people's lives and are being used by people who may be unaware of potential eye injury, resulting in increased reports of retinal injuries. Therefore, many countries have issued restrictions or regulations, on the power limit of laser pointers used for demonstration purposes. At present, there are none of these regulations on the sale and use of laser pointers in Thailand. In this research, an accurate, inexpensive, user friendly, laser pointer power testing kit will be built for the measurement of optical power emitted from handheld lasers. The setup consists of a thermopile power meter, optical bandpass filters, lens mounts, lens tube, and iris. Output power of about 20 laser pointers randomly purchased from various sources will be determined, including evaluation of measurement uncertainty. The safety level with respect to the limits imposed by the US Code of Federal regulations will be also discussed.

1 INTRODUCTION

Up-to-date, handheld lasers such as laser pen or laser pointers have been widely used around the world. The most common ones are laser pointers used in presentations and demonstrations, especially in classrooms. Some other uses of laser pointers are for toys, hobbies and entertainments, such as for special effects in concerts or in nightclubs. Due to rapid advances in laser technology, laser pointers have become cheaper, more affordable, and have more colors available. Not only the red He-Ne laser pointers that are cheap and popular, the green and violet, have become more available and most recently, blue laser pointers are now the new trend. Apart from the variety of colors, the power level of those lasers is also varied. From safe level of 1mW to very dangerous 1000mW can be easily purchased on the market despite many countries issuing the legal limit of handheld laser pointer at no more than 5mW (such as in the US) or as low as 1 mW (such as in the UK). Easily access of powerful laser pointers resulted in increasing report of eyes injury around the world (Wong, et al., 2007, Wyrsch, et al., 2010, Ziahosseini, et al., 2010). In 2008, the Australian government restricted the sale and importation of some laser items and also banned the importation of laser pointers that emit the power more than 1 mW, due to several cases of coordinated attacks on passenger jets in Sydney (Sydney Morning Herald, 2008). In 2010, the Federal Office of Metrology in Switzerland randomly tested laser pointers and found that a high percentage of laser pointers were not in compliance with the regulation (Blattner , 2011). More recently, researchers at the National Institute of Standards and Technology (NIST, USA) tested 23 laser pointers and found that 44 percent of red lasers pointers and 90 percent of green laser pointers were not in compliance with federal safety regulations (Joshua and Marla, 2013).

In Thailand, there is no rule or regulation regarding the sale or importation of laser devices. Laser pointers or laser gadgets of all colors and power range, from less than mw to many watts can be easily purchased in the stores and online. Misuse of these devices can be very dangerous, thus it is important to assess the power output of these laser pointers to determine both their hazard level and their class labels.

Even though there are many reports of green laser hazards published in scientific journals and the media, no report of violet laser pointer hazards has been published so far. In this work, 19 laser pointers of 3 different colors, red, green, and violet,

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randomly purchased from stores and online, were accurately measured and their hazard level determined. At the present time, there is no regulation of the sale or importation of laser devices in Thailand. In this work, the hazard level of laser pointers were determined according to the The US Code of Federal Regulations (CFR, 2012) which limits commercial class IIIa/3R lasers to 5 milliwatts (mW) and no more than 1 mW for dangerous IR.

1.1 Laser Class and Safety

The American Standard for the Safe Use of Lasers (ANSI 136.1-2007) classifies lasers into 4 classes, according to their hazard level. Table 1 illustrates the laser hazardous level.

Table 1: Laser classification under ANSI Z136.1-2007.

Class	Hazard level
Class 1	Non-hazardous level under normal use
Class 2	Non-hazardous level under normal use, for visible laser only, laser power < 1 mw
Class 3R	Potentially hazardous level if viewing for extend period of time, includes both visible and non-visible lasers, laser power < 5mW
Class 3B	Hazardous to skin and eyes, , includes both visible and non-visible lasers, laser power < 500mW
Class 4	Very hazardous, laser power >500 mW, can burn skin

1.2 Laser Pointer Technology

Recent advance in laser technology made laser pointer in the markets become cheaper, smaller, and more powerful. Modern red laser pointers are constructed from vertical-cavity surface-emitting laser (VCSEL) diodes technology, emitting deep red light near 650 nm, which are the least expensive red laser pointers. Newer version red laser pointers (but slightly more expensive ones) emit red-orange light at 635 nm, which is more visible to human eyes. Green laser pointers, are now the most popular since human eyes are most sensitive to the green region of the spectrum at low power. Green lasers are DPSS lasers (or so called DPSSFD for "diode pumped solid state frequency-doubled"). The green light is indirectly generated from using infrared AlGaAs laser diode operating at 808 nm to pumps a Nd:YVO4 or Nd:YAG crystal. The crystal then emits laser light in the IR region at 1064 nm. Second harmonic generation at the KTP crystal generate the green laser light at 532 nm. All of the light with 3 different wavelengths are then focused and emitted the green color. Since the emitting light includes both IR and VIS, high quality green laser pointer must be equipped with a filter that can block or allow IR wavelength (both 808 nm and 1064 nm) to transmit with lowest level of power as possible (less than 0.63 mW at 808 nm and 1.92 mW at 1064 nm), referred to ANSI (ANZI, 2007) and IEC (IEC, 2007).

Violet lasers emitting a violet light at 405 nm are constructed from GaN (gallium nitride) semiconductors. This type of laser directly emits 405 nm without frequency doubling as the DPSS green laser, thus emitting none of the dangerous IR emission but can emit high power in excess of the CFR limit.

2 EXPERIMENTAL DESIGN

The goal of the research is to conveniently, safely, and accurately measure the laser power output of the laser pointers without expensive parts. The apparatus must be able to measure all of the power emitting from red, green and violet laser pointers, both in visible and IR regions.

2.1 Measurement Apparatus

The apparatus is built concerning the safety of operation with accurate and repeatable measurement results. The design is inspired from Joshua's prototype (Joshua and Marla, 2013), which is composed of a power meter, a selectable filter wheel, a lens tube, an iris, self-centering lens mounts, and laser pointer under tested, as shown in figure 1.

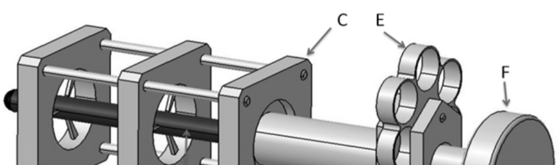

Figure 1: Measurement apparatus. A laser pointer (A) is mounted using 2 self-centering lens mounts (B) for hand free, and repeatable measurement. The adjustable iris (C) closed around the laser pointer and the lens tube (D) cover the laser path to protect operator from laser light. Bandpass filters are mounted in a selectable filter wheel (E). A power meter (F) reads the power output of the laser at the other end of the filter.

2.2 Power Meter

In this work, the thermopile detector was used, due to its spectrally flat responsivity, low cost, and ease of operation. The spectral range of the detector (Model 3A-P, Ophir) is 0.15-6 um, covering a power range of 60 µW to 3 W. To determine the calibration factor and uncertainty, standard calibration procedures of laser power detector at National Institute of Metrology (Thailand) were followed. The power meter was calibrated by direct comparison with laser power reference standard, which was directly compared with the laser Calorimeter (traceable to SI units). The calibration results are discussed in Appendix.

2.3 Band Pass Filter

The DPSS green laser pointers emit the laser not only at green visible (532 nm) but at wavelength both 808 nm (the pump) and 1064 nm (the fundamental). The bandpass filters used in this measurement were the 800 ± 8 nm, FWHM = 40 ± 8 nm, and 1064 ± 2 nm, FWHM = 10 ± 2 nm. The transmission was tested with a Nd:YAG laser at 1064 nm and 532 nm, for the 1064 nm bandpass filter. The transmission of the 800 nm filter was also tested with the Nd:YAG laser and assumed to have the same uncertainty. The calibration results are discussed in Appendix.

3 MEASUREMENTS AND RESULTS

For red and violet laser pointers, which are single wavelength lasers, no bandpass filters were used. The power is

$$P_{red,violet} = \frac{P_{total}}{C_n} \quad (1)$$

For green laser pointers, the power of the laser is

$$P_{532} = \frac{P_{total}}{C_n} - [P_{808} + P_{1064}] \quad (2)$$

$$P_{808} = \frac{P'_{808}}{C_n} \quad (3)$$

$$P_{1064} = \frac{P'_{1064}}{C_n} \quad (4)$$

Where C_n is the calibration factor of the power meter, obtained from calibration. For each measurement, the laser was energized for 30 s and the output power was recorded using the maximum power reading of the power meter. Measurement results are shown in figures 2-4.

A total of 19 lasers pointers (12 red, 4 green, and 3 violet) were randomly purchased from Thailand stores and online markets. All of the pointers were advertised as laser pointers for demonstration purposes and all are in class 3R or below. In the red laser samples, 3 out of 12 laser pointers emitted the power of more than 5 mW, in excess of the CFR limits. For green laser pointers, 2 out of 4 pointers emitted the power in excess of the CFR limits (Class 3R visible accessible emission limit (AEL) and Class 1IR AEL). For visible green wavelength, one emitted the power at ~70 mW, and another at ~ 20 mW. At 1064 nm, one emitted the IR power at ~ 10 mW and another at ~20 mW. At 808 nm, both lasers emitted the power at ~ 1.5 mW. For blue laser pointers, all with the < 5 mW label, the measurement results revealed that all the 3 pointers emitted the power in excess of the CFR limit.

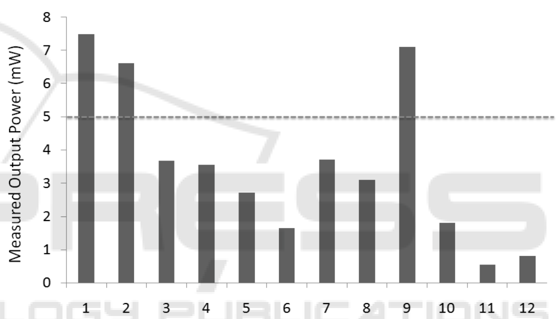

Figure 2: Measured output power of 12 red laser pointers. The horizontal dashed line represents the class 3R visible AEL limit of 5 mW. 3 out of 12 red pointers emitted power in excess of the CFR limits.

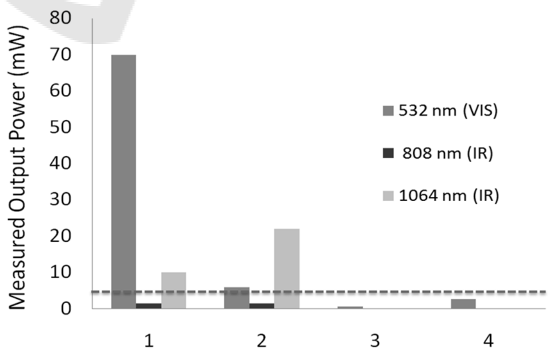

Figure 3: Measured output power of 4 green laser pointers. The horizontal dashed line represents the class 3R visible AEL limit of 5 mW. 2 out of 4 green pointers emitted power in excess of the CFR limits for both visible and IR wavelengths.

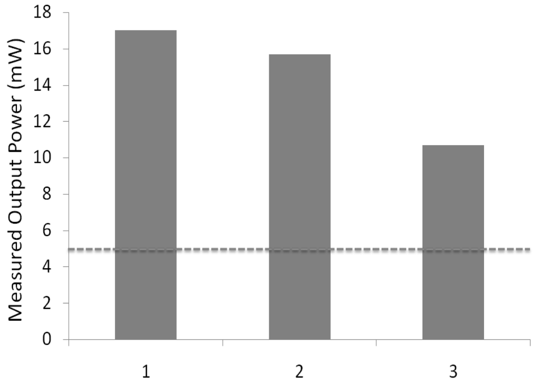

Figure 4: Measured output power of 3 violet laser pointers. The horizontal dashed line represents the class 3R visible AEL limit of 5 mW. All of the violet pointers emitted power in excess of the CFR limits.

4 CONCLUSIONS

Power outputs of 19 laser pointers of 3 different colors (red, green and violet) randomly purchased from Thai markets, were accurately measured to verify their compliance with the guidelines of US CFR and ANSI. The output power of measurement set up has an uncertainty of 1%. The uncertainty was determined from the calibration of the power detector and the bandpass filter. The calibration of power detector was performed using standard practice of National Institute of Metrology (Thailand) laser power calibration and is traceable to SI units. The bandpass filter were calibrated following the procedure given by Joshua (Joshua and Marla, 2013). The measuring results including the measurement uncertainty of 1 % show that majority of red laser pointers are in compliance with the CFR regulations while 50% of green laser pointers were exceeded the class 3R limit at both visible and IR wavelengths. For violet laser pointer measurement, all of the pointers were non-compliance with CFR. This work provides the first and the most accurate results of the laser pointers safety assessment level in Thailand. At the present, there is no rule or regulation regarding the sale or importation of laser devices in Thailand. The results could be used as guidance for the Thai (or similar countries) regulation and standardization bodies, when issuing regulations regarding the sale or importation of laser devices. The apparatus could be used by any institutions, universities, organizations and companies, to determine the safety level of their laser pointers.

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REFERENCES

Wong, R., Sim, D., Rajendram, R., and Menon, G., 2007. Class 3A laser pointer-induced retinal damage captured on optical coherence tomography. In *Acta Opthal mol. Scand*. 85227–8.

Wyrsch, S., Baenninger, P. B.., and Schmid, M K., 2010. Retinal injuries from a handheld laser pointer. In *N. Engl. J. Med.* 3631089-91.

Ziahosseini, K., Doris, J. P., and Turner, G. S., 2010. Maculopathy from handheld green diode laser pointer. In *BMJ* 340c2982.

Laser pointers restricted after attacks. *Sydney Morning Herald*. 2008-04-06. Retrieved 2008-04-06.

Blattner, P., 2011. The underrated hazard potential of laser pointers. In *METinfo*18.

Joshua, H., Marla, D., 2013. Accurate, inexpensive testing of laser pointer for safe operation. In *Meas. Sci. Technol*. 24(2013) 045202 (7pp).

CFR 2012 Code of Federal Regulations Title 21. Food and Drug; Part 1040: Performance Standards for Light-Emitting Products; Section 1040.10 Laser Products (US 21 CFR 1040.10).

ANSI 2007 American National Standard for the Safe Use of Lasers (Orlando: Laser Institute of America) ANSI Z136.1.

IEC 2007 Safety of Laser Products. Part 1: Equipment classification and requirements (International Electrotechnical Commission) EN 60825-1 ed.2.

Taylor, N., Kuyatt, C., 1994. *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*, NIST technical Note 1297.

APPENDIX

The uncertainty of the measurement were estimated following guideline from Taylor and Kuyatt (Taylor and Kuyatt, 1994). In this work, the estimated total uncertainty, u_T , of the system is

$$u_T = \sqrt{u_d^2 + u_f^2} \tag{A.1}$$

where u_d is the uncertainty of the power detector and u_f is the uncertainty of the bandpass filter.

The uncertainty of the power detector is determined by calibration with laser power meter reference standard, which was directly compared with the laser Calorimeter (traceable to SI units). The calibration was performed at wavelength 633 nm, 515 nm and 488 nm. The calibration results are shown in table 2.

The uncertainties of the bandpass filters were estimated from transmission calibration with a Nd:YAG laser at 1064 nm and 532 nm. For the 1064 nm bandpass filter, the transmission value is the ratio of the laser power reading on the standard pyroelectric detector with and without the filter. The calibration results are shown in table 3. For the 800 nm filter, the transmission at 1064 nm and 532 nm were tested. The calibration results are shown in table 3.

Using (A.1), the total uncertainty of the system is 1%.

Table 2: Power detector calibration results.

Wavelength (nm)	Power	Calibration Factor, $\mathbf{C_n}$	Uncertainty, $\mathbf{u_d}$
633	1 mw	1.015	0.6%
	3 mw	1.012	0.6%
515	5 mW	1.025	0.9%
	10 mW	1.025	0.9%
488	5 mW	1.009	0.9%

Table 3: Bandpass filters calibration results.

Filter center wavelength (nm)	Laser wavelength	% Transmission	Uncertainty, $\mathbf{u_f}$
800	532	0.00	-
	1064	0.00	
1064	532	0.00	-
	1064	84.92%	0.1 %