Letter

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Laser toys fail to comply with safety standards – case study based on laser product classification

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Abstract: The article describes the laser safety classification of a laser toy for children equipped with a laser aimer/illuminator with two radiation sources. Following the rules presented in EN 60825-1: 2014 standard, the tests and measurements of the accessible emission were carried out and the class of the laser product was determined to be 3R. It was shown that the laser toy does not comply with the requirements of the EN 62115: 2020 standard and the Public Health England Guidance. The potential hazards associated with Class 3R, indicated in the EN 60825-1: 2014 standard, are also discussed.

Keywords: eye safety; laser product classification; laser safety standard; laser toy.

1 Introduction

Lasers and laser devices developed over the last six decades have established themselves in many areas of human life. They can be found, in particular, in various fields of science, technology or industry, where their presence determines development and continuous progress. Their presence is also increasingly noticed in less prominent applications such as entertainment and toys. Despite the enormous benefits of the use of lasers, they also pose a huge threat to eyes and skin, causing injuries or burns. In extreme cases, they can even lead to blindness. Therefore, it is necessary to properly handle lasers and, in most cases, to use appropriate safety measures.

In most laser applications, adults are at risk and should be properly trained and equipped with safety measures. However, in the case of toys, children, usually several years old, who are not aware of the dangers, are exposed to laser radiation [1, 2].

The basic rules for defining whether a given laser device is safe are described in the international standard EN 60825-1: 2014 [3]. These rules allow for determination of the class of a laser product, of which the only safe class (especially in the case of children) seems to be Class 1. Potentially safe Class 2 is considered safe only for exposure duration not higher than 0.25 s. However such assumption may not be appropriate in case of children due to the fact that children's curiosity may take priority over common sense or the natural aversion to bright light. Longer exposition is more likely to produce different visual effects that are thought of as a great fun. Thus, toys with a laser of class greater than one should be considered potentially dangerous. An extensive literature overview covering the above issues was presented in Ref. [4]. That is why in the European Union toys equipped with lasers should be Class 1 according to the EN 62115: 2020 standard [5]. The same requirement is in the United Kingdom according to the Public Health England Guidance [6]. The above-mentioned standard and guidance very accurately meet the requirements of EU Toy Safety Directive 2009/48/EC that reads: "Toys must be designed and manufactured in such a way that they do not present any health hazards or risk of injury to eyes or skin from lasers, light-emitting diodes (LEDs) or any other type of radiation" [7].

The most common toys equipped with laser devices are rifles and pistols, where lasers are used as target aimer or illuminators. In many cases, such toys are equipped with appropriate certificates and approvals for sale where the laser device is of Class 1. However, a significant number of toys are sold in bazaars and street markets without any documentation, where the laser device is of a higher class, and the producers are either unaware or don't want to be aware of their obligation to properly classify and label the device [8].

The aim of this article is to present the results of measurement of laser radiation generated by a toy like a laser aimer/illuminator that was part of a seemingly harmless plastic rifle. On the basis of the conducted measurements,

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the laser class of the toy was determined and the basic possible eye hazards that children may be exposed to, indicated in the EN 60825-1: 2014 standard, are discussed. The results of the presented analysis may contribute to the reduction of the number of accidents among children caused by laser radiation emitted by potentially harmless laser toys.

2 Subject of the study

The subject of the study was a children's toy in the form of a laser aimer/illuminator, which was part of a seemingly harmless plastic rifle. The toy was confiscated by a teacher from a few years old child who brought it to kindergarden to play with peers. The device was characterized by a small size of few centimeters and emitted continuous red and blue radiation from two different sources. Red radiation was emitted by the laser source through an aperture of less than 4 mm in diameter located at the top of the toy. The source of blue radiation was the LED located in the central part of the reflector of approx. 17 mm in diameter, emitting a beam of radiation similar to a flashlight. The photo of the investigated toy is shown in Figure 1. Due to the unknown origin of the toy and the lack of any markings, its manufacturer was not identified.

3 Investigations

The EN 60825-1: 2014 international standard refers to products that emit laser radiation. Products incorporating LEDs, e.g. lamps, are more appropriately addressed by lamp safety standards. For example EN 62471: 2006 standard may be applied to determine the risk group of the product [9]. Therefore, the laser class of the toy was determined only on the basis of laser radiation. The blue radiation was also measured, but only for information purposes.

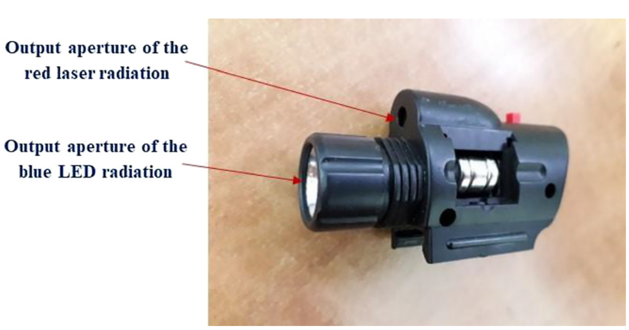

Figure 1: Picture of the investigated laser aimer/illuminator.

Moreover, due to the spatial separation of the sources of optical radiation of the LED and the laser, in the relevant distances from the product, the respective retinal images will also be separated and therefore the two sources can be treated separately with respect to retinal safety, and by the respective product safety standards (i.e. the LED under EN 62471 and the laser under EN 60825-1).

In order to classify the device, the generated radiation was tested and measured in accordance with the EN 60825-1: 2014 standard. First, the radiation wavelength was measured for both sources using the AvaSpec-3648-USB2 spectrometer from AVANTES with resolution of 0.5 nm. Then the accessible emission was determined with the 3A-P sensor and VEGA power meter from Ophir.

The source generating red (R) radiation of 653.8 nm wavelength was characterized by a beam divergence of less than 1.5 mrad. Thus, the angular size of the source was assumed to be less than 1.5 mrad. Therefore, a default (simplified) evaluation for classification was used. Because the visible source was located inside the protective housing the accessible emission was measured at the closest point of human access (in the immediate vicinity of the housing) through an aperture of 7 mm diameter (condition 3) and at a distance of 2000 mm from the closest point of human access through an aperture of 50 mm diameter (condition 1). Because the generated beam diameter was below 4 mm and the beam was characterized by small divergence, the measured accessible emission for both conditions was the same and was equal to 1.7 mW.

The source generating blue (B) radiation of 455.4 nm wavelength was characterized by a divergence of more than 1.5 mrad. The accessible emission was measured under the same conditions as in the case of the R source. The accessible emission for condition 3 was 0.8 mW while for condition 1 it was 0.07 mW. Since the beam diameter for condition 2, after passing through the limiting aperture, was greater than the diameter of the sensor input aperture, an optical system with a diameter larger than the limiting aperture and with determined transmission was used.

The measurement conditions and results are presented in Table 1. The scheme of the measurement system is shown in Figure 2.

4 Classification

The classification was carried out in accordance with the guidelines presented in the international standard EN 60825-1: 2014 taking into account only R laser radiation.

As was already mentioned for the R source the simplified evaluation was used for classification, because

Table 1: Measurement conditions and results.

Parameter	*R* radiation	*B* radiation
Wavelength [nm]	653.8	455.4
Type of operation	cw	cw
Divergence [mrad]	<1.5	>1.5
Measurement distance for condition 3 [mm]	0	0
Aperture diameter for condition 3 [mm]	7	7
Measurement distance for condition 1 [mm]	2000	2000
Aperture diameter for condition 1 [mm]	50	50
Accessible emission for condition 3 [mW]	1.7	0.8
Accessible emission for condition 1 [mW]	1.7	0.07

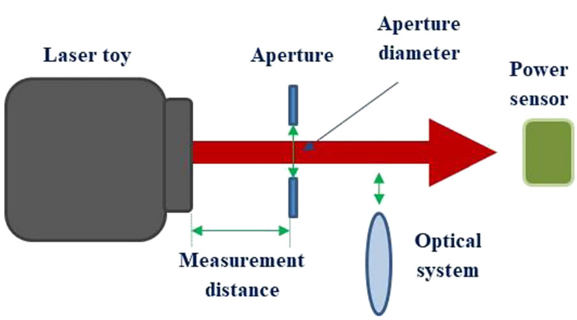

Figure 2: Scheme of the measurement system.

the angular size of the source was smaller than 1.5 mrad. Therefore the correction factor C6 is equal to 1. The time base for Classes 1 and 1 M is equal to 100 s, while for Classes 2, 2 M and 3R equals 0.25 s. Thus, the accessible emission limit (AEL) for Class 1 and 1 M is equal to 0.39 mW, for Class 2 and 2 M equals 1 mW and for Class 3R equals 5 mW. Because the accessible emission for conditions 1 and 3 is less than the AEL of Class 3R and the accessible emission for condition 3 exceeds the AEL for Class 1 and Class 2 the laser toy should be classified as Class 3R.

The classification parameters and results are presented in Table 2.

Table 2: Classification parameters and results.

Parameter	Value
Wavelength [nm]	653.8
C6	1
AEL for Class 1 and 1 M [mW]	0.39
AEL for Class 2 and 2 M [mW]	1
AEL for Class 3R [mW]	5
Assigned class	3R

5 Discussion

According to the EN 60825-1: 2014 standard, the accessible emission limit for Class 3R is five times greater than for Class 2 for visible radiation and also five times greater than for Class 1 for invisible radiation. Consequently, the risk of eye injury is relatively low. Hence the reduced requirements for manufacturers and users of such devices compared to Class 3B. The risk of eye injury is limited mainly because the unintentional exposure would rarely reflect worst-case condition such as beam alignment with a large pupil and worst-case accommodation with the entire beam entering the eye. In addition, the accessible emission limits were determined with an appropriate safety margin. Moreover, the natural aversion behavior for exposure to bright visible radiation protects against eye injury. It is also worth to mention that according to the studies by Robertson et al. and Schulmeister and Jean [10, 11], an intraocular power of 1.7 mW for a wavelength in the red wavelength range can be scientifically characterized as “negligible risk” also for intentional exposure over many seconds.

On the other hand, according to the EN 60825-1: 2014, “the risk of injury increases with exposure duration, and exposure may be hazardous for ocular exposure under worst-case conditions or for intentional direct intrabeam viewing,” which in the case of children may be typical situation due to their curiosity. Due to the varying range of risks associated with this class of laser devices, the standard indicates the need for the detailed instructions regarding administrative controls and personal eye protection. In the case of several-year-old children, it is difficult to imagine that they would read and follow the manual.

The standard also warns that the devices of Class 3R may cause dazzle, flash-blindness and afterimages as a result of exposure to visible light, especially under low ambient light conditions. There may also be temporary disturbances of vision, which could be of particular concern if experienced during performing activities where such a disturbance can lead to a tragedy.

The standard clearly states that laser devices of Class 3R should only be used in situations where it is unlikely to look directly into the laser beam. This situation, for such users as children, is difficult to ensure. Children, out of their curiosity, will usually try to look directly into the laser beam because of the “funny” visual effects it can cause.

It is also worth noting that the accessible emission limits were defied taking into account healthy people who do not have vision problems, such as hypersensitivity to laser radiation. Thus, children with such problems are particularly vulnerable to any kind of injury caused by exposure to even potentially safe laser radiation.

6 Conclusion

Toys equipped with laser sources can be very attractive for children, expanding their possibilities of playing, but they also pose the risk of eye injury. According to the EN 62115: 2020 standard and the Public Health England Guidance laser toys should be Class 1. The radiation emitted by such products is considered safe even during direct looking into the laser beam for a long time according to the EN 60825-1: 2014. These devices in the case of a visible laser beam characterized by a small diameter (<7 mm) should not emit more than 0.039 mW for radiation in the range of 400–500 nm and not more than 0.39 mW for radiation in the range of 500–700 nm. When the total output power exceeds the above limits, the toys may prove to be of a class greater than one and may be hazardous to children's eyes.

The example of a laser aimer/illuminator presented in this article shows that it is of Class 3R emitting a red beam with a power of 1.7 mW. This is more than four times the value of 0.39 mW considered safe for Class 1. Such radiation may be hazardous, especially during direct looking into the beam for long periods.

It can be clearly stated that the described laser toy does not comply with the applicable standard EN 62115: 2020 and Public Health England Guidance, however they are easily available and still sold as toys in many European states.

Therefore, appropriate legislative measures as well as their appropriate enforcement should be taken by every single European state to prevent children's exposure to hazardous laser radiation.

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