Public Health England

Guidance

Laser radiation: safety advice

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1. Lasers

Lasers are now widely used during the course of our daily lives. They can be found at home, in the workplace and they are used for many different applications. Lasers are a valuable scientific tool in material, pharmaceutical and forensic research.They play an important role

in the areas of medicine and industry, as well being used for entertainment purposes since the mid-1960s.

At home, lasers can be found in many modern appliances such as in computers, laser printers, DVD and Blu-Ray® players. In these appliances the consumer would have no access to the laser in normal use.

Lasers are also used in domestic products where the laser can be 'seen' such as medical devices, and even toys. Laser pointers or pens have also found their way into the home and are often described as 'toys'. However, some of these 'toy laser pens' have been found to be more powerful than is acceptable for unrestricted use and have the potential to cause eye damage and other harm.

The misuse of lasers, predominately laser pointers or pens, reported in the press has highlighted concerns over the safety of these devices from a number of perspectives.

This guide provides:

- basic information on the properties of laser radiation
- the different laser classes
- a summary of Public Health England's (PHE's) position on the safety of laser pointers

The advice from PHE takes account of the current British Standard for laser safety, and the technically equivalent European and International Standards.

PHE's predecessor organisations were involved in the initial development of these Standards and PHE continues to work with the technical standards committees responsible for maintaining these documents.

PHE provides advice to the Department for Business, Energy and Industrial Strategy (BEIS) and Trading Standards concerning the safety of hand-held laser pointers and the optical hazards posed by the use of these products.

2. Laser radiation

Lasers produce radiation with unique properties. It is these properties that distinguish laser radiation from the optical radiation produced by more familiar sources such as the sun or the common household electric light bulb.

When the radiation emitted by a source can be detected by the eye and produces a sensation of vision, it is referred to as light. Lighting devices such as the compact fluorescent, LED or incandescent electric light bulbs produce optical radiation comprising of many different wavelengths. Their light is perceived as white light, and the bulb emits fairly equally in all directions.

The optical radiation produced for lighting is said to be highly divergent, that is the light spreads out rapidly as the observer moves away from the bulb. It is this property which allows the illumination of large areas using a single light bulb. In contrast a laser produces

optical radiation over a very narrow wavelength band, so narrow that the laser is referred to as a monochromatic or single wavelength source.

If the laser emits in the visible region then the radiation is perceived as a single colour. The wavelength of light is usually measured in nanometres, or one-thousand-millionth of a metre and is abbreviated to ‘nm’.

The laser also usually produces a very narrow beam which diverges, or spreads out, very little with increasing distance from the source. This low divergence property means that the laser output is highly directional, forming a pencil-like beam that will still appear as a small spot when shone against a surface, even at distances of 100 m or more.

A consequence of this is that high power devices can present a hazard over considerable distances, often many kilometres. However, there are exceptions to these general points: some lasers produce optical radiation over a wide wavelength spectrum and some produce widely divergent beams.

When considering the safety implications of the laser beam an important parameter is the power (in Watts) or energy (in Joules) in the beam divided by the cross-sectional area (in m^2) of the beam. This is called the irradiance and is usually quoted in watts per square metre or W m^{-2} or radiant exposure usually quoted in J m^{-2}.

3. Laser pointers or laser pens

Laser pointers have been used as presentational aids by professional trainers for many years, with no reported incidents in the UK. They are usually portable, low powered, battery operated, hand held laser devices.

Commonly available laser pointers generally emit red coloured light (wavelengths between 630 and 670 nm), green coloured light (532 nm) or blue coloured light (about 445 nm).

The response of the human eye is wavelength dependent and peaks at around 555 nm, the response decreasing as either end of the visible spectrum is approached (400 nm to 780 nm). As a result, if laser pointers are compared at 3 different wavelengths (670 nm, 635 nm and 532 nm) but at the same radiant power, the brightness as perceived by the eye will be approximately in the ratios 1 : 10 : 30.

Laser pointers emitting light with the laser wavelength which is closer to the eye’s peak response are therefore capable of producing the adequate visual stimulus, such as aversion response, at lower radiant powers.

Laser pointers come in all shapes and sizes today, although most are pen shaped. Originally marketed for professional use, today this style is often marketed as ‘toy’ laser pens and they often come with interchangeable effects heads.

Devices intended for the toy or novelty market can be of different shapes, for example a toy sword. Laser pointers which are larger in size and more importantly have a high power output are very common and inexpensive today. The size of the batteries used in a laser pointer may

give some clue to the radiant power. However some laser pointers powered by AAA batteries are still powerful enough to cause life changing eye injuries.

4. Laser safety standards

Laser pointers sold in the UK should be classified in accordance with the current British Standard [1] on laser safety. This document specifies requirements for the manufacturers of laser products to ensure that the risk of accidental exposure is minimised through the use of engineering control features and product labelling, and by specifying minimum requirements for the supply of product information to allow for their safe use.

A user's guide to the Standard also contains advice to the user of laser products in terms of procedural controls and class-specific training requirements [2]. In the USA, there is a Federal Performance Standard for Laser Products [3] which has similar requirements, but there are differences between these 2 documents.

If product mislabelling is suspected, or there is doubt over the classification of a product then measurements should be carried out in accordance with the requirements of the British Standard to determine the actual laser class to which the device should be assigned. There is no simple test available to the general public to determine the radiant power of a laser product. A visual inspection of the laser product or its laser output will not provide any indication of the appropriate class for the device.

The British Standard sets out 8 classes of laser products, these are:

- Class 1
- Class 1C
- Class 1M
- Class 2
- Class 2M
- Class 3R
- Class 3B
- Class 4

The classification scheme for lasers indicates the potential risk of adverse health effects, where the higher the class number, the greater the laser radiation hazard posed by the laser. In practice, the risk also depends upon the conditions of use, exposure time and the environment. However, potential risks may or may not actually lead to adverse health effects, so with the help of classification, users may select appropriate control measures to minimize the risks.

Class 4 lasers are high power devices, usually needing a mains power supply. Class 4 lasers are used for specific applications in research, medicine and industry. They are also used in as well as the entertainment industry. Historically Class 4 lasers required a mains power supply. However today handheld battery powered Class 4 laser pointers are common.

Class 4 lasers are not designed to be used as laser pointers.; it is recommended that a laser pointer should be no greater than a Class 2 laser product. Devices intended for use by consumers should not be Class 3B or Class 4 laser products.

The classification system uses the concept of an Accessible Emission Limit (AEL). An AEL is the maximum value of accessible laser radiation to which an individual could be exposed during the operation of a laser and is dependent on the laser class.

The AEL values are in turn based on Maximum Permissible Exposure (MPE) levels. An MPE is a level of laser exposure which it is believed an individual could be exposed to without incurring an injury. An MPE may therefore be considered as a maximum safe level of exposure. MPE levels are specified for both the eye and skin as a function of the wavelength of the laser radiation and the duration of exposure. These MPE values are internationally agreed.

A laser is assigned to a particular class when the measured emission level exceeds the AEL for all lower laser classes but does not exceed the AEL for the class assigned. For example, a laser will be assigned as a Class 3R laser product when the maximum measured accessible emission level exceeds Class 1, Class 1M, Class 2 and Class 2M AEL values but does not exceed the Class 3R AEL.

Once a laser has been assigned to a particular class there are other requirements prescribed in the British Standard which should be met. These include product labelling and customer information, and may include specific engineering control features to be incorporated in the laser product depending upon the class assigned. A summary of the laser classes is given below.

5. Laser classes

The following laser classification scheme is taken from BS EN 60825-1 [2].

5.1 Class 1

Class 1 laser products are safe under reasonably foreseeable conditions of operation, including long-term direct intrabeam viewing, even when using optical viewing instruments, for example eye loupes or binoculars. For Class 1 laser products the radiant power of the accessible laser beam (the accessible emission) is always below or equal to the Maximum Permissible Exposure value. Therefore, for Class 1 laser products the output power is below the level at which it is believed eye damage will occur. Exposure to the beam of a Class 1 laser will not result in eye injury. Class 1 lasers may therefore be considered safe.

However, Class 1 laser products may contain laser systems of a higher class but there are adequate engineering control measures to ensure that access to the beam is not reasonably likely during normal use. Examples of such products include laser printers and compact disc players. Users of Class 1 laser products are generally exempt from optical radiation hazard controls during normal operation.

5.2 Class 1C

Class 1C laser products are products which are designed explicitly for contact application to the skin or non-ocular tissue. Examples of such products include home use hair removal products. The irradiance or radiant exposure levels may exceed the skin MPE as necessary for the intended treatment procedure. During operation, the ocular hazard is prevented by

engineering means, meaning the accessible emission is stopped or reduced to below the AEL of Class 1 when the applicator is removed from contact with the skin or non-ocular tissue.

5.3 Class 1M

Class 1M laser products are usually products that produce beams with a large diameter. Therefore, only a small part of the whole laser beam can enter the eye. As for a Class 1 laser product, they are safe for the naked eye under reasonably foreseeable conditions of operation. However, these laser products can be harmful to the eye if the beam is viewed using magnifying optical instruments.

Some of the lasers used for fibre-optic communication systems are Class 1M laser products, and these are likely to be beams that spread out quickly from a small point of emission, as from the end of a fibre optic cable.

5.4 Class 2

Class 2 lasers are limited to a maximum output power of 1 milliwatt or one-thousandth of a watt (abbreviated to mW) and the beam must have a wavelength between 400 and 700 nm. A person receiving an eye exposure from a Class 2 laser beam, either accidentally or as a result of someone else's deliberate action (misuse) will be protected from injury by their own natural aversion response. This is a natural involuntary response which causes the individual to blink and avert their head thereby terminating the eye exposure. Repeated, deliberate exposure to the laser beam may not be safe. Some laser pointers and barcode scanners are Class 2 laser products.

5.5 Class 2M

Class 2M laser products are products which produce beams with a large diameter beam in the wavelength range 400 to 700 nm. Therefore, only a small part of the whole laser beam can enter the eye and this is limited to 1 mW, similar to a Class 2 laser product. However, these products can be harmful to the eye if the beam is viewed using magnifying optical instruments.

5.6 Class 3R

Class 3R laser products are higher powered devices than Class 1 and Class 2 and may have a maximum output power of 5 mW or 5 times the AEL for a Class 1 laser product. The laser beams from these products exceed the MPE for accidental viewing and can potentially cause eye injuries, but practically the risk of injury in most cases is relatively low for short and unintentional exposure. The risk is limited because of natural aversion behaviour for exposure to bright light for the case of visible radiation and by the response to heating of the cornea for far infrared radiation.

Examples of Class 3R laser products include some laser pointers and some alignment products used for home improvement work.

5.7 Class 3B

Class 3B laser products may have an output power of up to 500 mW (half a watt). Class 3B laser products may have sufficient power to cause an eye injury, both from the direct beam and from reflections. The higher the radiant power of the device the greater the risk of injury. Class 3B laser products are therefore considered hazardous to the eye. However, the extent and severity of any eye injury arising from an exposure to the laser beam of a Class 3B laser product will depend upon several factors including the radiant power entering the eye and the duration of the exposure.

Class 3B laser products which approach the upper limit for the Class may produce minor skin injuries or even pose a risk of igniting flammable materials. Examples of Class 3B products include lasers used for physiotherapy treatments and many research lasers.

Class 3B lasers are not suitable for general use by consumers.

5.8 Class 4

Class 4 laser products have an output power greater than 500 mW (half a watt). There is no upper restriction on output power. Class 4 laser products are capable of causing injury to both the eye and skin from direct exposure and reflections also may be hazardous. Class 4 laser beams also present a fire hazard. Lasers used for many laser displays, laser surgery and cutting metals may be Class 4 products.

Class 4 lasers are not suitable for use by consumers.

6. Use of lasers and training

The British Standard provides advice on the use of lasers for demonstrations, displays and exhibition and states that only Class 1 or Class 2 devices should be used in unsupervised areas unless under the control of experienced well-trained operators.

Laser pointers used by, for example, professional lecturers in the workplace are considered to fall under this category. Minimum training requirements are specified for operators using lasers of a higher class for these purposes due to the risk of eye injury. Such training should include guidance to the user on the risks from the laser beam and advice not to point the beam at anyone.

7. Laser pointers currently available on the market

PHE staff have examined many laser pointers available to the general public in order to assess their laser class and have found a significant proportion of these products to be Class 3B laser products and a few are Class 4. The body's natural aversion responses are unlikely to provide adequate protection from eye injury for Class 3B laser or Class 4 laser 'pointers'.

Incorrectly labelled laser pointers are common. Examples include laser pointers that are marked Class 2 (or output power is marked as less than 1 mW), but are actually Class 3B or even Class 4. A number of eye injuries, especially to children, have occurred from the use of Class 3B and Class 4 laser 'pointers'. The majority of these lasers are bought from the internet rather than on the high street, while some were bought on overseas holidays.

Although the risk of a permanent eye injury from a laser pointer up to Class 3R may be small, an individual receiving even a transient eye exposure from a laser pointer will experience a bright flash, a dazzling effect, which is likely to cause distraction and temporary loss of vision in the affected eye and possibly afterimages. Therefore, these laser beams should not be pointed at people.

The time taken to recover from these effects will vary for different individuals and will also be dependent on the ambient light level at the time of exposure. Medical attention should only be sought if afterimages persist for hours, or if a disturbance in reading vision is apparent.

8. PHE advice

PHE considers the professional use of a Class 1 or Class 2 laser pointer as a training aid in the workplace to be justified, and regards these classes of laser product as being generally adequate for such use. The use of Class 3R laser pointers up to 5 mW may be justified for some applications in the workplace where the user has received adequate training.

PHE advises that the sale of laser products to the general public for use as laser pointers should be restricted to Class 1 or Class 2 devices which should be classified in accordance with the requirements of the current British Standard and should be sold with sufficient accompanying information to enable the user to operate the product in a safe manner. Toys should be Class 1 or of such low output that they do not need to be classified.

PHE advice to the Department for Business, Energy and Industrial Strategy (BEIS) for Trading Standards authorities is that if consumer products containing lasers are restricted to Class 1 or Class 2, eye injuries are unlikely to occur. Class 1M, Class 2M and Class 3R laser products may be acceptable for use by consumers where the manufacturer has concluded that the accessible laser beam is necessary for the intended application and has assessed that the risk of eye injury is very low.

Trading Standards Authorities may use their existing powers under the General Product Safety Regulations 2005[4] to remove laser products intended for consumers of Class 3B and Class 4 (as defined in the British Standard) from the general market. However, it is recognised that consumers also purchase products direct via the Internet and while on overseas holidays, which is difficult to control. In particular, there are some counterfeit versions of wireless slide presenter remote controls containing lasers.

Purchasers need to be aware that they may put themselves and others at risk of serious injury since these devices may emit laser beams of considerably higher radiant powers than marked. Purchasers should also be aware that in general, construction is of poor quality and with normal wear and tear the product may well be capable of causing serious eye injury.

Further guidance is available:

- British Standards Online
- International Commission on Non-ionizing Radiation protection
- Civil Aviation Authority
- International Electrotechnical Commission

- Watch PHE’s video on the dangers of lasers

  Accessible Media Player by Nomensa
  PlayRewindForward
  Mute- Volume Down+ Volume Up100%

  The timeline slider below uses WAI ARIA. Please use the documentation for your screen reader to find out more.

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9. Contact

For enquiries contact laser@phe.gov.uk

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