LONDON METROPOLITAN UNIVERSITY

H&S Standard: Management and Use of Lasers

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Contents

1. Introduction

The word laser is an acronym for Light Amplification by the Stimulated Emission of Radiation.

The ‘light’ produced by a laser, a form of non-ionising optical radiation, has a unique combination of spatial coherence (all the waves are in phase) monochromaticity (i.e. have just one colour or a narrow bandwidth) and usually high collimation (i.e. low angular divergence such that the beam does not ‘spread out’ significantly with distance). This combination of characteristics distinguishes laser radiation from all other light sources.

Lasers come in various shapes and forms. They have many uses in teaching, research, manufacturing, medicine, dentistry, shop checkouts and most commonly at work in the office. Lasers emit radiation as narrow concentrated beams of light, not necessarily visible to the human eye. The optical and skin hazards presented by lasers vary markedly according to the wavelength and power of the output. The hazards of lasers are often associated with the ability of the laser to damage eyesight or burn skin, but quite often the radiation or optical hazards are not the ones that present the greatest risk, with associated risks from electrical supplies, cryogenic liquids or chemical dyes being more hazardous.

There is a legal requirement to identify risks and take appropriate action to eliminate or control those risks (optical and non-optical). We all have a responsibility under the *Health & Safety at Work etc. Act 1974* (also referred to as HSWA, the HSW Act, the 1974 Act or HASAWA) to ensure that work with lasers is carried out safely.

The Regulations include the requirement to assess and control the hazards from light emitted from all artificial sources in all its forms such as ultraviolet, infrared and laser beams. The assessment of non-optical hazards is dealt with by a few different regulations, which may be appropriate; for example, PPE Regulations, Workplace Regulations, Electricity at Work, and CoSHH.

2. Laser Safety Officer

Schools need the advice and assistance of a Laser Safety Officer (LSO) to implement the requirements of **BS EN 60825** when Class 3 and Class 4 lasers are being used. In particular, the LSO will need to ensure that arrangements are in place for:

- The training of new staff/students.
- Identification of lasers and users of equipment.
- Provision of a measuring service (where appropriate).
- Inspection of all new laser facilities; and
- The routine auditing of laser facilities.

The LSO is responsible for ensuring that:

- all lasers except for low power Class 1 devices (and excluding laser printers, DVDs, Class 2 laser pointers etc.) are identified on a register.
- all lasers are labelled in accordance with Appendix E and laser designated areas clearly identified.
- Scheme(s) of work are drawn up, where necessary, for the safe operation of lasers. These will normally be required for all Class 3B and Class 4 lasers when not totally enclosed.
- personnel intending to work with Class 3R, Class 3B and Class 4 lasers, and others who may be working with modified Class 1M or Class 2M devices, will need to be identified and receive training in the safe use of lasers.
- laser safety eyewear is provided and worn (when appropriate) by all people working with Class 3B and Class 4 lasers **when the beam is not totally enclosed,** and that training is given in the use and maintenance of this eyewear.
- undergraduates working with lasers should use the minimum power laser practicable and follow a written scheme of work.
- all lasers in the department are used in accordance with this guidance; and routine surveys are undertaken to ensure compliance with this guidance.

A summary of the requirements placed on manufacturers and users by **BS EN 60825** is given in Appendix B together with a survey form/checklist for new laser installations. More detailed information can be obtained by referring to the standards directly.

If a survey reveals non-compliance with **BS EN 60825** and a potentially dangerous situation, **the laser should not be used** until the situation has been remedied by the adoption of additional control measures.

3. Hazard Classification for Lasers

Lasers produce electromagnetic radiation at wavelengths extending from 100 nm in the ultraviolet, through the visible (400-700 nm), and the near infrared (700-1400 nm), to the far infrared (1400 nm-1 mm). Thus, the light emitted can be either visible or invisible. Lasers can be operated in several different modes. Some lasers produce a continuous output and are known as continuous wave or CW lasers. The power outputs of CW lasers are usually expressed in terms of watts (W). Others operate in a pulsed mode producing short bursts of radiation. The power of the laser output can vary from less than 1 mW to many watts in some CW devices. The energy output of pulsed lasers is generally expressed in joules (J) per pulse.

Due to the wide ranges possible for the wavelength, energy content and pulse characteristics of laser beams, the hazards arising from their use varies widely. It is impossible to regard lasers as a single group to which common safety limits can apply.

A system of laser classification is used to indicate the level of laser beam hazard and maximum **Accessible Emission Levels** (AELs) have been determined for each class of laser. The previous classification system, which was based on five classes (1, 2, 3A, 3B & 4), has been replaced with a system of seven classes (1, 1M, 2, 2M, 3R, 3B & 4) and these are described below.

3.1 Class 1

Lasers that are safe under reasonably foreseeable conditions of operation, either because of the inherently low emission of the laser itself, or because of its engineering design such that it **is totally enclosed and human access to higher levels is not possible under normal operation**.
Note: If access panels of a totally enclosed system are removed for servicing etc. then the laser product is no longer Class 1 and the precautions applicable to the embedded laser must be applied until the panels are replaced.

3.2 Class 1M

Laser products emitting in the wavelength range 302.5 nm to 4000 nm, whose total output is in excess of that normally permitted for Class 1 laser products but because of their diverging beams or very low power density do not pose a hazard in normal use and comply with the measurement conditions for a Class 1M product. However, they may be hazardous to the eyes under certain conditions if gathering optics are used with them, i.e.

- With a diverging beam if optics are placed within 100mm of the source to concentrate/collimate the beam.
- With a large diameter collimated beam viewed with binoculars or a telescope.

3.3 Class 2

Lasers that only emit visible radiation in the wavelength range from 400 nm to 700 nm and whose output is less than the appropriate AEL. They are safe for accidental viewing as eye protection is afforded by aversion responses, including the blink reflex. This reaction may be expected to provide adequate protection under reasonably foreseeable conditions of operation including the use of optical instruments for intra-beam viewing.

3.4 Class 2M

Laser products that only emit visible radiation in the wavelength range 400 nm to 700 nm, whose total output is in excess of that normally permitted for Class 2 laser products but because of their diverging beams or very low power density are safe for accidental viewing during normal use and comply with the measurement conditions for a Class 2M product. However, they may be hazardous to the eyes under certain conditions if gathering optics are used with them, i.e.

With a diverging beam if optics are placed within 100mm of the source to concentrate/collimate the beam.
With a large diameter collimated beam viewed with binoculars or a telescope.

3.5 Class 3R

Lasers that emit in the wavelength range from 180 nm to 1 mm where direct intra-beam viewing is potentially hazardous but the risk is lower than for Class 3B lasers, and fewer manufacturing requirements and control measures for the user apply. The AEL is restricted to no more than five times the AEL of Class 2 for visible wavelengths and no more than five times the AEL of Class 1 for other wavelengths.

3.6 Class 3B

Class 3B lasers are normally hazardous when direct intra-beam exposure occurs (i.e. within the **Nominal Ocular Hazard Distance** (NOHD), which is the distance within which the beam irradiance or radiant exposure will exceed the appropriate MPE). Viewing diffused reflections is normally safe. Output levels must be less than the appropriate AELs for Class 3B devices.

3.7 Class 4

High power lasers that exceed the AELs for Class 3B products that are also capable of producing hazardous diffused reflections. They may cause skin injuries, could also constitute a fire hazard, and could cause hazardous fumes to be produced as well as being a hazard to the eyes. Their use requires extreme caution.

3.8 Example AELs

The AELs for He-Ne lasers emitting a narrow beam in CW mode at 633nm are as follows:

- Class 1 and 1M 0.39 mW
- Class 2 and 2M 1 mW
- Class 3R 5 mW
- Class 3B 500 mW

These limits will also apply to other narrow beam CW lasers operating in the wavelength range 400-700 nm except for Class 1 and 1M devices where there are further restrictions for wavelengths <500 nm. **Refer to BS EN 60825-1 for full details**. ***Note****: Maximum output from Class 1M and Class 2M devices can take them well into Class 3B if the output is collimated.*

4. Maximum Permissible Exposures

The main criterion for assessing the optical safety of a given situation is the **Maximum Permissible Exposure** (MPE). The MPE is that level of laser radiation to which, under normal circumstances, persons may be exposed without suffering adverse effects.

The MPE levels represent the maximum level to which eye or skin can be exposed without consequential injury immediately or after a long time and are related to the wavelength of the radiation, the pulse duration or exposure time, tissue at risk and, for visible and near infra-red radiation in the range 400 nm to 1400 nm, the size of the retinal image. MPE levels are specified in *Safety of Laser Products-Part 14: A user's guide*, PD IEC/TR 60825-14.

Planned ocular exposure to laser radiation should not exceed the MPE for the intended exposure duration. However, for visible laser beams, sub-damage threshold effects, such as distraction, dazzle, glare, and afterimages, also should be considered. Software packages are available that can be used to assess the hazards of a given situation.

These packages can be used to calculate the MPE and the **Nominal Ocular Hazard Distance** (NOHD). However, a word of caution, the output of these expert systems is only as good as the detail and accuracy of the data input and users still need to have a good understanding of the BS requirements.

5. Precautions for specific classes of laser

Class 1 laser products/systems do not require any special precautions or formal control measures. The exception is where such a system consists of a totally enclosed Class 3B/4 laser and access is required for the purpose of servicing or alignment. In this case, it should be included on the laser inventory and there should be a **Scheme of Work** for that activity.

Class 1M and 2M products can be hazardous if the output is viewed with optical instruments (i.e. eye loupe). Modification of these products needs to be carefully assessed, reclassification may be necessary and the appropriate control measures detailed.

For **Class 2** laser products, protection is based on exposure being limited by the **natural aversion response** (0.25 sec). Simple measures such as information to users not to deliberately aim the beam at people, stare into the beam and terminate the beam at the end of its useful path will be sufficient.

For **Class 3R** products, the control measures will include:

- terminating the beam at the end of its useful path.
- avoiding beam paths at eye level and where practicable enclose the beam.
- instruction and training to an appropriate level.
- taking care to prevent unintentional specular reflections.
- where non-visible wavelengths are used an emission indicator device is to be used to indicate the laser is energised.

For **Class 3B or 4** lasers, each laser laboratory or experiment, as appropriate, **should have its own Laser Scheme of Work** based upon the findings from a risk assessment.

The name of the local Laser Safety Officer and the permitted authorised users, the extent of any laser designated area and reference to specific protocols that are to be used should be included in the scheme of work. Safety Form no. 44 provides a template for a scheme of work to be developed.

All the above control measures indicated for Class 3R lasers should be used as well as remote interlocks, safety interlocks, key control, beam stop/shutter and the full list of user precautions detailed in Appendix B.

Areas need to be defined and warning signs used.

The Scheme of Work should be displayed in a prominent position or readily available within a laboratory folder.

6. General safety procedures

6.1 Identification of Lasers/ Laser Inventory

As a general rule, all Class 3R, 3B and Class 4 devices should be identified, and a laser inventory maintained. There may be occasions when this is not practicable because the laser products are in fact just electrical components. In circumstances like this it should be the use of particular types of laser device that should be recorded. It may be useful to also note the use of Class 1M, Class 2M and Class 2 products but it is not necessary to record the use of low powered Class 1 devices, Class 2 laser pointers or the use of embedded lasers in products such as DVD players and laser printers. The LSO should keep a copy of each departmental list. Before the operation of any new laser or significant modifications the LSO should be consulted.

6.2 Record/Registration of Users of Lasers

In order to make people aware of the hazards of lasers and to ensure that safe systems of work are being practiced management arrangements should be in place to identify users of lasers. Risk assessments should also identify users of lasers and a list/record must be kept up to date in departments. All people intending to work with any class of laser, except for inherently safe Class 1 or Class 2 devices or embedded laser products such as those in laser printers or DVD players, should be identified via a Laser User Registration form. Persons who could or are going to modify Class 1M or 2M devices should also be identified, as they will require instruction/training.

6.3 Training

Initial training will be a basic instruction in laser hazards, risks, and their control. Class 3R, Class 3B and Class 4 laser workers should attend training before commencing any laser work and should also be familiar with the schemes of work/protocols provided. A record of attendance should be made. Training in the use of individual lasers is the **responsibility of the Research Supervisor** and a record of this training must also be made and kept on file. Appropriate refresher training should also be provided to ensure that people are kept up to date with benchmarking and the latest regulatory requirements.

PD CLC/TR 50448:2005 ***Guide to levels of competence required in laser safety*** details that laser workers should be sufficiently competent in the operation and use of the equipment and should understand

- the general nature of laser radiation.
- the health hazards, the tissues of the body at risk, and the severity of harm which can result.
- the different laser classes and the meaning of the warning labels appropriate to the classes.

- the proper use of hazard control procedures and where appropriate the need for personal protective equipment.
- the need for any necessary additional precautions when undertaking non-routine activities; and be conversant with this procedure and any local safe operating procedures governing laser use, including emergency action and accident reporting procedures.

6.4 Undergraduate Work

If reasonably practicable, undergraduate work should be restricted to Class 1/1M, 2/2M or visible 3R lasers, especially for class experiments. Sometimes it is possible to downgrade a higher-powered laser using neutral density filters or beam expanders.

It is important to introduce students to good safety practice and a written Scheme of Work should be drawn up and posted in the laboratory. In addition, clear written instructions should be provided for each student experiment.

Students involved in project work and working with Class 3B or Class 4 lasers **should** be treated as laser workers and be subject to the normal registration and training process. The risk assessment should take into account the inexperience of the users and additional close supervision is likely to be necessary.

6.5 Labelling of Lasers

Lasers that are safe within reasonably foreseeable conditions of operation in Class 1 do not need warning labels. Supplementary information describing the laser product as a ‘Totally Enclosed System' with details of the embedded laser clearly displayed is required in situations where access to the embedded product is routinely required. All other laser products should carry the appropriate warning labels in accordance with **BS EN 60825-1**. Recently manufactured lasers should all conform to this Standard. For full details of labels required see Appendix E.

Where lasers and laser systems are not adequately labelled, they will need to be relabelled. Users should note that for mains powered equipment the labelling of lasers will have to comply with European Standards and any user obtaining a laser directly from the U.S. and elsewhere overseas will assume the responsibilities of the importer and supplier.

6.6 Designation of Laser Areas

A “laser-controlled area” is an area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from the laser radiation hazards. Access to a laser-controlled area should be restricted to all except authorised persons when the laser is turned on and there is the possibility of exposure. Class 3B and 4 lasers should be operated in a laser controlled area if engineering controls have not entirely eliminated the risks; in this case an interlock system should be fitted (or other means of protecting unauthorised people, e.g. by controlling access by swipe card or key access).

The points of access to areas in which Class 3B and Class 4 lasers are used must be

marked with appropriate warning signs - see Appendix E. There may also be experiments where open beam work with modified Class 1M/Class 2M or Class 3R lasers are used that will also warrant the display of appropriate warning signs.

6.7 Laboratory Design

The following considerations relate mainly to the use of Class 4 lasers, but some may be appropriate for Class 3B devices as well, or as general specifications for a laser laboratory.
If practicable the laser laboratory should have a high level of illumination that will minimise pupil size and reduce the risk of stray laser light reaching the retina. Windows should be kept to a minimum and may need to be covered or protected by blinds. These should be nonreflective and may need to be fireproof where higher-powered lasers are used.

Walls, ceilings, and fittings should be painted with a light-coloured matt paint to enhance illumination and minimise specular reflections. Reflecting surfaces such as the use of glass-fronted cupboards should be avoided.
Ventilation is important especially with higher-powered lasers if cryogens are used, or if toxic fumes are produced that need to be extracted and, in this case,, it is important that the extraction is very close to the source. Facilities may also be needed for the handling of toxic chemicals that are associated with some dye lasers.

The laboratory should be equipped with appropriate firefighting equipment. Electrical supplies, switch and control gear should be sited in order to:

- enable the laser to be shut down by a person standing next to the laser.
- enable the laser to be made safe in an emergency from outside the laser area if reasonably practicable.
- prevent accidental firing of a laser.
- provide an indication of the state of readiness of the laser.
- enable personnel to stand in a safe place.
- provide sufficient and adequate power supplies for all ancillary equipment and apparatus so that the use of trailing leads is minimised.

6.8 Experimental set-up

- Before starting to use the laser equipment, there are a few basic risk reduction measures that should be considered.
- Can a lower powered laser be used?
- Can the output power of the laser be restricted if full power is not needed?
- Can intra-beam viewing be prevented by engineering design?
- Can the laser be used in a screened off area, thereby limiting potential for others to be affected?
- Can work be carried out in a total enclosure?
- Beam paths should be as short as possible, optical reflections should be minimised and the beam terminated with an energy absorbing non-reflective beam stop.

- The laser and optical components should be securely fixed to the bench to avoid displacement and unintended beam paths.
- If practicable, align powerful lasers with low-power devices that are safe for accidental viewing, or reduce the power of the laser by turning it down or introducing neutral density filters. The aim should be to get the output power <1mW, NB some kW lasers will only be able to be turned down to a few watts. Alternatively, remote-viewing techniques can be used.
- Eliminate chance of stray reflections by using coated optical components or shroud them so that only the intended beam can be refracted or reflected. Keep optical bench free from clutter and remove jewellery, wristwatches etc.
- **NEVER** have the laser pointing towards the laboratory entrance

7. Hazard/risk assessment

Excessive exposure to laser radiation will result in biological damage. The main areas at risk are the eye and the skin. Visible and near infra-red lasers are a special hazard to the eye because the very properties necessary for the eye to be an effective transducer of light result in high radiant exposure being presented to highly pigmented tissues. The biological effect of irradiation of skin by lasers operating in the visible (400 nm to 700 nm) and infrared (greater than 700 nm) spectral regions may vary from a mild erythema to severe blisters. This topic is covered in depth in **Annex C** of **PD IEC/TR 60825-14:2004**. When carrying out a risk assessment for the optical hazard, it is important to know of the effects of laser radiation on biological tissue

Before the appropriate controls can be selected and implemented, laser hazards must be identified and evaluated together with non-beam hazards that may be present. The laser's capability of injuring personnel and the environment and the way in which the laser or lasers are to be used needs consideration. A risk assessment **must be** carried out to establish the significant risks and whether suitable and effective controls exist.

7.1 Stages in Risk Assessment

There are basically 5 stages to a risk assessment:

- Identify the hazards, i.e. the potential for harm.
- Identify who is at risk and Assess risk from these hazards.
- Determine and implement the necessary control measures.
- Assess residual risk – repeating stage 3 if necessary; and
- Record the findings.

Class 3B and Class 4 lasers are capable of causing significant eye injury to anyone who looks directly into the beam or its specular reflections. Diffuse reflections of a high-power laser beam can also cause permanent eye damage. High-power laser beams can burn exposed skin, ignite flammable materials, and heat materials releasing hazardous fumes, gases, or debris. Equipment and optical apparatus required to produce, and control laser energy may also introduce additional hazards associated with high voltage, high pressure, cryogenics, noise, other forms of radiation, flammable materials, and toxic fluids.
Each proposed experiment or operation involving a laser must be evaluated to

determine the hazards involved and the appropriate safety measures and controls required.

To assist in identifying hazards and risk control measures, a proforma has been developed for Class 1M, 2/2M and 3R lasers and Class 3B & 4 laser systems.

7.2 Assessing Risk

The people who may be at risk need to be identified. These may include cleaning, service personnel, contractors, visitors, and the public as well as trained operatives. Risk can be assessed by using quantitative measures that combine the likelihood of occurrence with the severity of injury; however, in laser safety it is usually more **important to eliminate the risk** of injury by adopting appropriate control measures in all situations where there is the possibility of MPEs being exceeded.

8. Laser Controls – optical hazards

The simplest rule to follow to avoid eye injury is not to look directly into a laser beam or its specular reflection, regardless of the laser's power or classification or the laser eyewear being worn. A Maximum Permissible Exposure should be calculated for laser sources present in a laser system based on the radiated wavelength(s), output power(s) or energy(ies), and, if appropriate, the pulse duration and pulse repetition rate. MPEs apply to a specific combination of these parameters and will usually change if any of the parameter's changes. Engineering and administrative controls should be used to keep exposures below the MPE whenever practicable. **Skin protection and laser eyewear should be used only where engineering and administrative controls are impractical.**

8.1 Laser alignment

A vast majority of laser accidents in research settings occur during the alignment process. Laser alignment guidelines to help prevent accidents should include:

- Restricted access, unauthorised personnel must be excluded from the room or area.
- The wearing of laser protective eyewear when appropriate.
- The training and instruction of Class 3B/4 laser users.
- Instructions to remove watches and reflective jewellery before any alignment activities begin.
- The lowest possible/practical power must be used during alignments.
- The use of a He-Ne or CW diode alignment laser, when possible, for a preliminary alignment.
- Identifying individual responsibilities. For example, the individual who moves or places an optical component on an optical table is responsible for identifying and terminating each and every stray beam coming from that component.
- Identifying when the beam is directed out of the horizontal plane.
- Checks on the stability and rigidity of all optical mounts, beam blocks and stray beam shields.
- Use of beam paths at a safe height, below eye level when standing or sitting

and not at a level that tempts one to bend down and look at the beam.

8.2 Control of Non-optical hazards

Many hazards (other than from laser radiation) that can be found in the laser area must be adequately assessed and the risks controlled. The manufacturer's safety guidance material should help in identifying most of the associated hazards. The main non-optical hazards include
:

- electrical – high voltages and capacitors used with pulsed lasers can present a serious hazard particularly during servicing.
- collateral radiation – this could include x-rays, UV, RF, visible and IR radiation.
- fume – can be released from the action of high-power lasers used in materials processing and surgery.
- hazardous substances – substances used in dye and excimer lasers can be toxic and carcinogenic, cleaning solutions may also be hazardous.
- cryogenic liquids – used with certain high-powered lasers can present a burning hazard, possible oxygen depletion hazard and possibly an explosion hazard from overpressure of gases in a closed system.
- fire and explosion – high-powered (class 4) lasers can ignite materials and even relatively low-powered lasers (>35mW) can cause explosions in combustible gases and dusts.
- mechanical hazards – from gas cylinders, trailing cables and water hoses, cuts from sharp objects, handling difficulties with large work pieces.
- noise – from discharging capacitor banks, from some pulsed lasers and from some air-cooled lasers.

9. Laser accidents

Accidents should be reported to the Laser Safety Officer and the Health & Safety Office at the earliest opportunity. Refer to Appendix D for more information. Some common unsafe practices that are causes of preventable laser accidents are:

- Lack of pre-planning and failure to follow safety protocols.
- Misaligned optics and upwardly directed beams –attention must be paid to periscopes, and reflections from windows and beam splitters/combiners.
- Available eye protection not used, particularly during alignment procedures.
- Wearing the wrong eyewear.
- Bypassing of door interlocks and laser housing interlocks.
- Insertion of reflective materials into beam paths.
- Lack of protection from non-beam hazards.
- Improper methods of handling high voltage.
- Operating unfamiliar equipment.

10. Residual-risk assessment and recording the results

In most circumstances after introducing control measures one should be able to assess the residual risk as being low. Written Systems of Work must then be produced and made available to all laser users so that they are aware of all protective measures they should be taking and the procedures they should be following. A laser safety risk assessment form is available on the Health & Safety intranet page.

It should be noted that with the changing nature of experimental work it is important that the risk assessment and operating procedures are routinely reviewed and, most importantly, reviewed prior to any significant change.

.11. Personal protection

Whenever there is a risk of laser exposure to levels above the specified MPEs, personal eye protection is one of the most common and important elements of personal laser protection. **Personal eye-protection should be regarded as a last line of defence against exposure to laser radiation**; it can be adopted only after a full safety evaluation has been carried out and other means of affording protection have been considered and rejected. Its use should not be regarded as a convenient alternative to proper engineering controls or thorough hazard assessments.

Laser eye protection must be CE Marked and appropriate for the laser wavelength, and optical density. Requirements apply within Europe covering the specification, marking, and testing of laser eye-protection, using protective effect rather than optical density. Scale numbers which take into account maximum spectral transmittance and resistance to laser radiation are used. These are detailed in **BS EN 207: 2009** *Personal eye-protection equipment - Filters and eye protectors against laser radiation (laser eye-protectors)* and **BS EN 208: 2009** *Personal eye protection – Eye-protectors for adjustment work on lasers and laser systems (laser adjustment eye-protectors)*. Annex B of both BS EN 207 and BS EN 208 give recommendations for the selection of personal eye-protection depending on the type of laser radiation and the operating conditions.

When choosing personal eye-protection, it is important to consider not only the ability of the eyewear to attenuate the incident radiation but also to have a damage threshold high enough to withstand the maximum possible exposure long enough for avoiding action to be taken, and to take into account comfort and visual light transmission (mean percentage of visible spectrum that is not filtered by the eyewear). Special consideration needs to be made when selecting eyewear for femtosecond and picosecond pulsed lasers. Information on specifying eye protection is given in **PD IEC /TR 60825-14**: *A user's guide*.
Laser protective eyewear should never be relied on to provide protection against deliberate exposure to a laser beam but should be regarded as a means of providing some protection against accidental exposure.
Eye protection which is designed to provide adequate protection against specific laser wavelengths should be used in all hazard areas where Class 3R laser products emitting energy outside of the 400 nm to 700 nm wavelength range, Class 3B or Class 4 lasers are in use.

Exceptions to this are:

1. when engineering and administrative controls are such as to eliminate potential exposure in excess of the applicable MPE.
2. when, due to the unusual operating requirements, the use of eye protection is not practicable.

Such operating procedures should only be undertaken with the approval of the Laser Safety Supervisor/Officer.

When working with Class 4 lasers (and some Class 3B devices emitting in the UV) skin protection may also be required.
Personal protective equipment should be personal, i.e., it should be appropriately maintained and cleaned between users, or each user has their own. There are basic duties concerning the provision and use of personal protective equipment (PPE) and the requirements of the Personal Protective Equipment at Work Regulations 1992.

12. Emergency Eye Exams and Accidental Exposures

Routine eye examinations for laser users are not recommended as a part of a safety programme. The value of routine examinations for Class 3B/4 laser users has been reviewed and it is generally accepted that routine examinations are of little value and that the only reason for these may for medical legal reasons.

It is very important to have procedures in place if there has been an apparent or suspected ocular exposure. A medical examination by a qualified specialist needs to be carried out as soon as possible. In the event of an accident or incident involving suspected injury to the eye(s), an emergency examination should be carried out as soon as possible and within 24 hours. The most appropriate Accident and Emergency Department that deals with eye injuries needs has been identified as *Moorfields Eye Hospital*. The injured party should be taken to this place.

Suitable arrangements should be in place to ensure that all persons working with Class 3B/4 lasers are aware of the action to take in the event of an accident/incident. Each Class 3B/4 laser should have a card or proforma that can be taken with the casualty to Hospital. An example of such a card and the information that will be required in the event of an accident/incident is given in Appendix D.

In the event of an eye injury caused by an individual staring down the beam of a lower powered laser the emergency arrangements for Class 3B/4 lasers should be followed.

Where an emergency eye examination is required, the Safety Liaison Officer and local Laser Safety Officer will carry out a detailed investigation of the accident/incident.
In the event of a skin injury, i.e. thermal burn, this can be treated, as would any other burn.

All accidents and incidents, whether involving an emergency examination or not, must be reported **promptly** to the Health & Safety Office using the appropriate current local Accident/Incident Report Form.

Depending on whether an injury has been sustained there may be a requirement for the Health & Safety Office to notify the Health and Safety Executive (HSE) under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR).

13. Laser Pointers

Small lasers are commonly available, and some are used for presentation purposes as pointers. These laser pointers are normally classified at a level above Class 1 and therefore in some circumstances can cause harm, particularly by staring into the beam. In the past they were only available in red wavelengths and had output powers up to and sometimes over 5mW. Nowadays devices are available emitting green wavelengths where the eye is more sensitive and lower powers are all that is needed so that laser pointers should now be Class 2 devices (output < 1mW). Normally the eye's natural aversion response, including the blink reflex, affords protection to short duration accidental exposure. Where laser pointers are used instructions on their safe use should be readily available; Appendix C is an example of the instructions that should be provided.

14. Monitoring

The Laser Safety Officer will conduct an annual audit of lasers in their Schools/Departments using the Laser Safety Audit Checklist. Principal Investigators/Researchers in charge of lasers are expected to conduct an annual self-audit using the Laser Safety Audit Checklist and retain a copy of the completed checklist, findings and actions taken on file.

15 References

- **BS EN 60825-1** *Safety of laser products, Part 1: Equipment classification and requirements.*
- **BS EN 60825-2** *Safety of laser products, Part 2: Safety of optical fibre communications systems.*
- **PD IEC/TR 60825-14:2004** *Safety of laser products, Part 14: A user's guide.*
- **PD CLC/TR 50448:2005** *Guide to levels of competence required in laser safety. ISBN 0 580 46730 9*
- **BS EN 207: 1999** *Personal eye-protection equipment - Filters and eye-protectors against laser radiation (laser eye-protectors)*
- **BS EN 208: 2009** *Personal eye-protection – Eye-protectors for adjustment work on lasers and laser systems (laser adjustment eye-protectors)*
- CVCP Safety in Universities Notes of Guidance Part 2:1 Lasers, 1992 Edition.
- The International Commission on Non-Ionising Radiation Protection (ICNRP) publications. http://www.icnirp.org/pubOptical.htm
- Optical Radiation Directive, published in the Official Journal of the European Communities on 27 April 2006 (Ref: L114) *"Directive **2006/25/EC** on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (artificial optical radiation)"*
- Control of Artificial Optical Radiation at Work Regulations 2010 (AOR)
- European Commission's publication *A non-binding guide to the Artificial Optical Radiation Directive 2006/25/EC*
- *Laser Safety Management*. Kenneth Barat. CRC, Taylor & Francis, 2006 ISBN: 0 824 72307 4

- http://www.laserinstitute.org/PDF/pubs/pub209toc.pdf
- *Laser Safety*. Roy Henderson & Karl Schulmeister. Institute of Physics Publishing, 2003. ISBN: 0 750 30859 1

16. Appendix A: Summary of warnings and protective control measures

Class	Protective Control Measures
1	No protective control measures for normal use (NB special precautions may be needed for service work on embedded laser products).
1M	No protective control measures for normal use (NB special precautions may be needed for service work on embedded laser products).
2	Do not stare into beam. Do not direct the beam at other people or into public areas.
2M	Do not stare into beam Do not direct the beam at other people or into public areas. Terminate beam at end of useful path with a non-specular beam stop. Prevent direct viewing with magnifying optics. (NB fitting external optics that decrease beam divergence may affect classification) + see footnote [1]
3R	Prevent direct eye exposure to the beam. Do not direct the beam at other people or into public areas. + see footnote
3B and 4	Class 3B and Class 4 laser products should not be used without first carrying out a risk assessment to determine the protective control measures necessary to ensure safe operation. Where reasonably practicable engineering means should be used reduce the laser class to a totally enclosed Class 1 laser product. The use of any Class 3B or Class 4 lasers without an interlocked enclosure will require a written Scheme of Work. Even with an enclosure written procedures will be necessary if the user is involved in any alignment procedures that require over-riding of interlocks. Class 3B and Class 4 laser products require the control of access to the area where the laser is operated by the use of a remote interlock, the use of key control, emission indicators, beam shutters, removal of reflecting surfaces that could be struck by an errant beam, beam enclosures wherever practical, the use of eye protection and protective clothing as appropriate, training of staff and the appointment of a Laser Safety Officer.

[1] Classes 1M, 2M and 3R may also require training of staff, care with beam paths and specular reflections - see **BS EN 60825-1** and **PD IEC/TR 60825-14** for more details.
Special attention should also be given to other non-optical hazards such as risk of electric shock, hazardous chemicals, cryogenic liquids and flying debris from targets to name but a few.

17. Appendix B: Summary of BS EN 60825-1 Manufacturer's and User Requirements

Remote interlock	Connection provided by the manufacturer for door or enclosure interlock for Class 3B and Class 4 lasers
Safety interlocks	Required for access panels on Class3R, 3B and 4 laser systems
Key control	A key or similar device is required to control unauthorised operation of Class 3B and Class 4 lasers
Emission indicator	An audible or visible indicator should be provided by the manufacturer for each Class 3R laser (except wavelengths 400-700nm) and each Class 3B and Class 4 laser system
Beam stop or attenuator/shutter	Should be provided by the manufacturer for each Class 3B or Class 4 laser system
Beam termination	The user should ensure that all beam paths are terminated at the end of their useful path. (does not apply to class 1 devices)
Beam level	Avoid eye level
Beam enclosure	To guard against specular reflections from Class 3R, Class 3B and Class 4 lasers. It can mean anything from screening the experimental area or piping the beam up to a total enclosure.
Eye protection	Required for open beam work with invisible beam Class 3R and all Class 3B and Class 4 devices.
Protective clothing	Mainly required for Class 4 lasers but be careful with Class 3B UV lasers as well, may need fire resistant material for some lasers
Eye examinations	Only required after an accident but may be important to people with poor eyesight working with Class 3B or Class 4 lasers
Training	Required for people working with any Class 3 or Class 4 laser and any modified Class 1M or Class 2M devices.
Laser labels	Required for all lasers except low power Class 1 (though need not be directly affixed if the size of the laser product does not permit this)
Door/Area signs	Required for Class 3B and Class 4 lasers indoors and for Class 1M, 2M and 3R if used outdoors

18 Appendix C: The safe use of Laser Pointers

Small lasers are commonly available, and some are used for presentation purposes as pointers. In the past laser pointers were only available in red wavelengths and had output powers up to and sometimes over 5mW. Nowadays devices are available emitting green wavelengths, where the eye is more sensitive and lower powers are all that is needed, so that laser pointers now only need to be Class 2 devices (output < 1mW).

Note:
Class 1 laser products are normally safe.
Class 2 and Class 3R products are not hazardous under certain conditions; however, they can cause harm to the eyes particularly if the beam is stared into. Class 3B laser pointers must not be used.
Normally the eye's natural aversion response affords protection to short duration accidental exposure to Class 2. Class 1 or Class 2 laser pointers are the recommended choice where a laser pointer is necessary and are the only type that should now be purchased.

Laser pointers should only be used as a pointing device and securely stored when not in use. Persons who use laser pointers should ensure that they are aware of potential hazards and they should comply with the basic instructions below.

Instructions for use

When operating laser pointers, users must ensure that they use them in a safe manner and do not expose themselves or others to the beam. Laser pointers are not to be modified in any way.

Do:

- Follow the manufacturer's safety instructions.
- Take care when operating the laser pointer.
- Keep the ‘on’ button depressed only when necessary.

Do NOT:

- Do not keep the 'on' button depressed when not pointing at the screen.
- Do not point at or towards the audience.
- Do not point at mirrored surfaces.
- Never look into the laser aperture.
- **Never look directly or stare into the beam/beam aperture when on.**
- Never allow unauthorised use, especially by children.

19. Appendix D: Emergency Procedure for Exposure to Class 3B or 4 Laser

Report to Moorfields Eye Hospital **at 162 City Road, London EC1V 2PD (Tel: 020 7253 3411) as soon as possible and within 24 hours of the incident.**

Do not drive yourself; get a friend or colleague to take you.

Out of hours: Contact local Security or Emergency Services (Ext: 3333)

a) State Building and Department
b) Location and nature of incident/accident
c) Request assistance to take the casualty to **Moorfields Eye Hospital**
d) Take the card below to the Hospital

EMERGENCY OPHTHALMIC EXAMINATION LASER EXPOSURE
REPORT TO: Accident and Emergency Department, **Moorfields Eye Hospital** 162 City Road, London EC1V 2PD Tel: **020 7253 3411**
LASER DETAILS: **a) Type**: Continuous Wave / Pulsed* **b) Wavelength**: ……nm **c) Power Output** (CW): …… **or Pulse Energy, Duration, and Rate** (pulsed): …… **d) Laser Classification**: …… **e) Department** …….. **EXPOSURE DETAILS:** **i. Circumstances of accident/injury:** …… **ii. Time/Date of Injury** …… **iii. Eye affected:** Left / Right / Both **iv. Were protective goggles being worn? (***Please Circle*) Yes / No **REPORT ACCIDENT/INCIDENT to the Health & Safety Office**

All accidents and incidents, whether involving an emergency examination or not, must be reported **promptly** to the Health & Safety Office using the current Accident/Incident Report Form.

20. Appendix E: Laser signs and labels

DESIGNATED LASER AREAS

The points of access to areas in which Class 3B or Class 4 laser products are used must be marked with warning signs complying with the Health & Safety (Safety Signs and Signals) Regulations 1996. BS ISO 3864-1:2011, *Graphical symbols. Safety colours and safety signs*. *Design principles for safety signs and safety markings* published September 2011 has replaced BS 5499-1:2002.

The signs shall incorporate the following information:

1. Hazard warning symbol

For the area signs the specifications are quite simple - 50% of the area should be yellow and the width of the black border is 0.06 x the length of the side. A more detailed specification is given for the symbol used in labels; see spec on in BS EN 60825-1

2. Highest class of laser in the area
3. Responsible person with contact details

LASER LABELS

Laser labels are required for all laser products except for low power Class 1 devices. They are designed to give a warning of laser radiation, the class of laser, basic precautions, and the laser's characteristics.
The laser warning uses the same symbol as for the door sign in an appropriate size for the laser to be labelled and should be clearly visible. Supplementary information should be black text on a yellow background in accordance with **BS EN 60825-1**.

Where the size of the laser product does not permit the affixing of a reasonably sized label, a sign should be displayed in close proximity to the laser with all appropriate information on. Information over and above that specified by **BS EN 60825-1** is required for Class 1 products that are Class 1 by engineering design. For these types of laser product, we specify that they are totally enclosed systems and give details of the laser enclosed. The BS requirement is just to describe them on the outside as a Class 1 laser product.

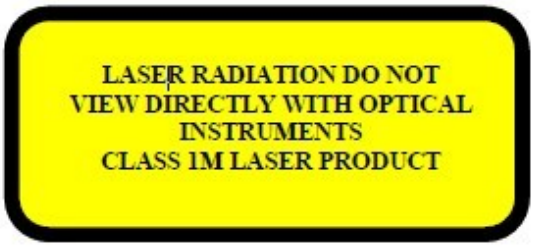
Details of wording required on explanatory labels are given below.

Class 1 (by engineering design)

No hazard warning label. Explanatory label bearing the words:
CLASS 1 LASER PRODUCT - A TOTALLY ENCLOSED LASER SYSTEM CONTAINING A CLASS 1 LASER

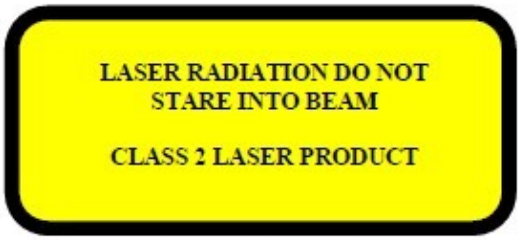
Class 1M

No hazard warning label. Explanatory label bearing the words:



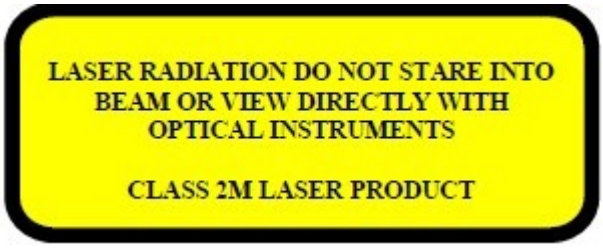
Class 2

Label with hazard warning symbol. Explanatory label bearing the words:



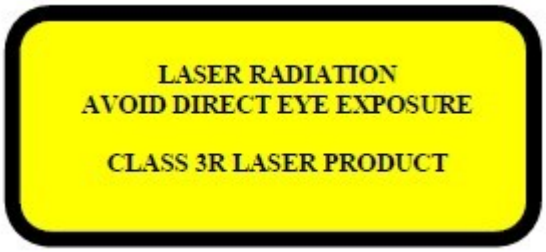
Class 2M

Label with hazard warning symbol. Explanatory label bearing the words:



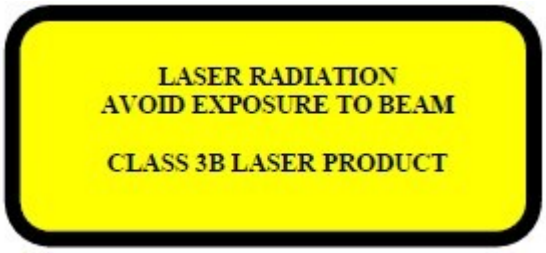
Class 3R

Label with hazard warning symbol. Explanatory label bearing the words: For λ 400 nm – 1400 nm ONLY.



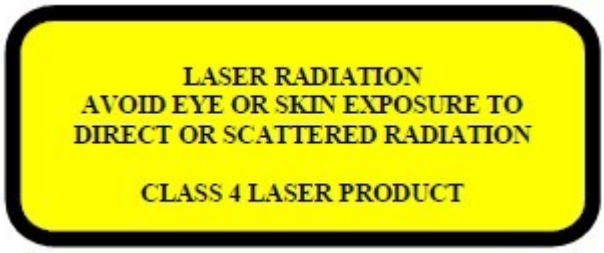
Class 3B

Label with hazard warning symbol. Explanatory label bearing the words:



Class 4

Label with hazard warning symbol. Explanatory label bearing the words:



Aperture Labels for Class 3R, Class 3B & Class 4 lasers

Each Class 3R, Class 3B and Class 4 laser product shall display a label close to where the beam is emitted bearing the words 'LASER APERTURE' or 'AVOID EXPOSURE – LASER RADIATION IS EMITTED FROM THIS APERTURE'. This label can take the form of an arrow if this displays more meaning: