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Association of University Radiation Protection Officers

GUIDANCE ON THE SAFE USE OF LASERS IN EDUCATION AND RESEARCH

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Prepared by Trevor Moseley, University of Sheffield
and Gus Zabierek, University of Birmingham

FOREWORD

This document represents general guidance on good practice. It is intended to aid in the identification of the hazards associated with work with lasers, to assist in assessing the risk and to outline appropriate control measures in a university environment. The guidance is not mandatory and each Institution is responsible for detailing their own management structures and arrangements, appropriate to local circumstances.

This guidance draws from, and should be used together with, the applicable British Standard document(s) in the BS EN 60825 series of documents and associated amendments. This revision, which replaces the previous CVCP guidance, has been produced following a review of the guidance available and changes made to the laser classification system. NB - the document does not provide detailed guidance on all aspects of the use of lasers and the advice and assistance of a Laser Safety Adviser should be sought for work with high-powered lasers.

Important changes made to BS EN60825-1:1994 in 2000 include:

- New laser classes - 1M, 2M and 3R (Table 1 shows how these fit in);
- New measurement conditions for classification, which are of particular benefit to high divergence laser sources;
- Overhaul of MPE levels especially values for ultra-short pulses and shorter-wavelength visible radiation under long exposure conditions (retinal photochemical damage);
- Improved treatment of extended source viewing; and
- New wording of laser warning signs

TABLE 1

CLASS	MEANING	Old Classification	New Classification	Reason for Change
Class 1	Normally Safe	**1**	**1** **1M**	1M - diverging/low power density devices that could be hazardous if beam focussed
Class 2	Eye protected by aversion response (visible only)	**2**	**2** **2M**	2M - diverging/low power density devices that could be hazardous if beam focussed
Class 3	Eye hazard	**3A & 3B***	**3R**	Low eye hazard, power density restriction removed
		3B**	**3B**	No significant change
Class 4	Eye and skin hazard	**4**	**4**	No significant change

It is intended to review and update this document on a regular basis and to publish it on the AURPO web site at:-

http://www.aurpo.org

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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. We all have a responsibility under the Health & Safety at Work etc Act 1974 to ensure that work with lasers is carried out safely[1]. Users have a duty to protect both themselves and others from the potential hazards involved, particularly when working with the more powerful lasers.

The safety of laser products is covered by the British Standards Institute (BSi), BS EN 60825 series of documents. The BS standard is a `euronorm' based upon the corresponding International Electrotechnical Commission's IEC 60825 document. The 60825 standard encompasses a range of standards for manufacturers on lasers, fibre optic systems, laser guards, components and user's guide etc. Of particular importance for users is the Technical Report PD IEC TR 60825-14:2004 which is a new detailed user's guide that incorporates a risk assessment approach to laser safety.

Many Institutions have internet access to British Standards Online and have licence subscriptions allowing standards to be downloaded. Each institution should at least have access to Technical Report PD IEC TR 60825-14:2004 or its current version.

The previous classification system, which was based on five classes (1, 2, 3A, 3B & 4), has been replaced with a new system of seven classes (1, 1M, 2, 2M, 3R, 3B & 4). It should be noted however that most of the changes relate to the lower classes of laser and that there has been minimal changes to the requirements for Class 3B and Class 4 lasers.

[1] To date there has been no specific UK legislation regarding optical radiation and lasers are dealt with generally. Within the EU, the Optical Radiation Directive was published in the Official Journal of the European Communities on 27 April 2006 (Ref: L114) under the title of "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)" Laser optical radiation is dealt with in Annex II of the Directive and Institutions should have access to this as a reference.

2. LASER SAFETY POLICY and ADMINISTRATIVE ARRANGEMENTS

The lowest power laser suitable for the purpose should be used and lasers should be operated so that individuals are not exposed to levels in excess of the "Maximum Permissible Exposure Levels" given in the current BS EN document. These levels can often be established by calculation. In some cases appropriate measurements using specific detectors/instrumentation may be necessary; if this is the case then a suitably qualified person will be required to undertake the measurements. Written procedures for the safe operation of lasers should be drawn up and applied.

Each Institution should have their own local arrangements and management structure defined with the Vice-Chancellor having overall responsibility for ensuring the effective management of all health and safety matters including laser safety. All personnel involved in laser work have a role to play in ensuring the health and safety of themselves and others who may be affected by their work. Some key personnel have special responsibilities related to laser safety and these are described below.

A useful guide to the levels of competency required in laser safety is given in PD CLC/TR 50448:2005. This guide provides information and guidance to employers and employees using lasers. It outlines procedures for the management of laser safety and defines levels of competence for both those who have responsibilities for laser safety and those who work with laser equipment.

2.1 Laser Safety Adviser (LSA) /Laser Safety Officer (LSO)

The Institution will need the advice and assistance of a Laser Safety Adviser to implement the requirements of BS EN 60825 when Class 3 and Class 4 lasers are being used. This role may be taken by the Radiation Protection Adviser, if suitably trained, or other competent person within the organisation, or assistance could be obtained as and when required from an external expert. Whatever the arrangements for expert advice the institution will need to appoint an in-house Laser Safety Officer to perform executive duties on behalf of the Vice-Chancellor to ensure that the university procedures relating to laser safety are followed. 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.

2.2 Departmental Laser Safety Officers (DLSO)

In departments where Class 3B and Class 4 lasers are used the Head of Department in consultation with the Laser Safety Adviser/Officer should appoint a suitably qualified member of staff as Departmental Laser Safety Officer who will be responsible for ensuring that all lasers used in the department are identified and used in compliance with the institution's local rules. A system should be in place so that the DLSO is aware of lasers being acquired, prior to them arriving on the premises, to ensure that adequate facilities are available for their safe use.

2.2.1 Duties of the Departmental Laser Safety Officer

A guide to the duties of a DLSO is given below. In some small institutions these could well be looked on as the duties of the LSO as well. The DLSO should ensure that:-

- all lasers except for low power Class 1 devices (and excluding laser printers, DVDs, Class 2 laser pointers etc) are identified;
- all lasers are labelled in accordance with Appendix 10 and laser designated areas clearly identified;
- schemes of work are drawn up, where necessary, for the safe operation of lasers (see example in Appendix 5). These will normally be required for all Class 3B and Class 4 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 are 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 7 together with a survey form/checklist for new laser installations. Further, 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.

2.3 Responsibilities of Research Supervisor/Principal Investigator

The day-to-day health and safety management of individual research projects is normally the responsibility of the research supervisor. All work involving hazardous lasers must be covered by risk assessments and where appropriate by written schemes of work and protocols. There should also be procedures to ensure that lasers are made safe prior to disposal and dealt with appropriately if they contain hazardous materials. The research supervisor should also ensure that their laser workers are effectively trained in the operating techniques required and that inexperienced staff are adequately supervised.

2.4 Responsibilities of Laser Users

Laser users also have responsibilities:-

- to observe the Local Rules and Schemes of Work applicable to the lasers that will be used and to follow the guidance of supervisors and the Departmental Laser Safety Officer;
- not to leave a laser experiment running unattended unless a risk assessment has established that it is safe to do so;
- for their own safety and that of others who may be affected by their acts or omissions; and

- when working with Class 3B or Class 4 lasers and there is the possibility of stray laser beams that could damage the eyesight, the appropriate laser eyewear **MUST BE WORN**.

3. HAZARD CLASSIFICATION FOR LASERS

Lasers produce electromagnetic radiation at wavelengths extending from 100 nm in the ultra-violet, 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 a number of 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 1mW to many watts in some CW devices. The energy output of pulsed lasers is generally expressed in joules (J) per pulse.

Because of 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 new 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. **NB** 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.

a) With a diverging beam if optics are placed within 100mm of the source to concentrate/collimate the beam.

b) 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 intrabeam 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.

a) With a diverging beam if optics are placed within 100mm of the source to concentrate/collimate the beam.

b) With a large diameter collimated beam viewed with binoculars or a telescope.

3.5 Class 3R: Lasers that emit in the wavelength range from 302.5 nm to 1 mm where direct intrabeam 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: Lasers that are normally hazardous when direct intrabeam exposure occurs (i.e. within the Nominal Ocular Hazard Distance, which is the distance within which the beam irradiance or radiant exposure will exceed the appropriate MPE). Viewing diffuse 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 diffuse 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.**

NB: IEC 60825-1 Amendment 2, which includes the new classification system, was published in January 2001 effective from 1st January 2001. However, manufacturers could still use the previous classification scheme until the 1st January 2004. There are no major differences between schemes to the classification of both Class 3B and 4 lasers systems. Details of the previous classification system used can be found in the CVCP *Notes of Guidance, Part 2:1 Lasers* Revised 1992.

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 -700nm except for Class 1 and 1M devices where there are further restrictions for wavelengths <500nm. See BS EN 60825-1 for full details.

***NB** Maximum output from Class 1M and Class 2M devices can take them well into Class 3B if the output is collimated.*

3.9 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 BS EN 60825 in particular in - Safety of Laser Products – Part 14: A user's guide, PD IEC TR 60825-14:2004

Planned ocular exposure to laser light should not exceed the MPE. Software packages are available that can be used to assess the hazards of a given situation (See Appendix 12). These packages can be used to calculate the MPE, the Nominal Ocular Hazard Distance (NOHD) and Optical Density required for protective eyewear etc. 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.

4. GENERAL SAFETY PROCEDURES

4.1 Identification of Lasers/ Laser Inventory

As a general rule, all Class 3R, 3B and Class 4 devices should be identified and a laser inventory for each department maintained – see example inventory proforma in Appendix 1. 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 IM, 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 LSA/LSO should keep a copy of each departmental list. Departments will maintain these lists and notify the LSA/LSO of changes. Before the operation of any new laser or significant modifications the LSA/LSO should be consulted.

4.2 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. Institutions may chose, for operational reasons, to have some form of registration system – an example registration form is given in Appendix 2. 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 CD players, should be identified. Persons who could or are going to modify Class 1M or 2M devices should also be identified, as they will require instruction/training.

4.3 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. Appropriate refresher training should also be provided to ensure that people are kept up to date with the latest British Standard requirements. An example of a training record form for authorised laser users is given in Appendix 13.

4.4 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 by the use of neutral density filters or beam expanders.

It is important to introduce students to good safety practice and a written scheme of work/local rules 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 will be treated as laser workers and be subject to the normal registration and training process. They should also be given close supervision if working with high-powered lasers.

4.5 Labelling of Lasers

Inherently safe lasers in Class 1 do not need warning labels but lasers which are Class 1 by engineering design and contain an embedded laser of higher power should be labelled as 'Class 1'. Supplementary information describing the laser product as a 'Totally Enclosed System' with details of the embedded laser clearly displayed may be of value in situation where access to the embedded product is routinely required. (NB this is not a BS requirement but is thought to be useful additional information). 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 10.

Where lasers and laser systems are not adequately labelled (some American systems have very small labels that are hard to read and do not comply with our BS), they will need to be relabelled. Institutions should note that for mains powered equipment the labelling of lasers in future will have to comply with European Standards and any institution obtaining a laser directly from the US will assume the responsibilities of the importer and supplier.

4.6 Designation of Laser Areas

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 10. 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.

4.7 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 non-reflective 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 fire fighting 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.

4.8 Experimental set-up

Before starting to use your laser there are a number of basic risk reduction measures that should be considered.

- Can a lower powered laser be used?
- Can output power of 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 - 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.
- Laser should be securely fixed 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 - use 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.
- And don't forget to have the laser pointing away from the laboratory entrance!

5. PRECAUTIONS FOR SPECIFIC CLASSES OF LASER

5.1 **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.

5.2 **Class 1M and 2M** products can be hazardous if the output is collimated or viewed with optical instruments. Modification of these products needs to be carefully assessed, reclassification may be necessary and the appropriate control measures detailed.

5.3 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.

5.4 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.

5.5 For **Class 3B or 4** lasers, each laser laboratory or experiment, as appropriate, should have its own Laser Scheme of Work based upon the conclusions of 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. (See example schemes of work with planning procedure in Appendix 5).

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 7. 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.

A summary of warnings and protective control measures from BS EN 60825 for all classes of laser is given in Appendix 7.

6. 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. In general terms, the skin can tolerate a great deal more exposure to laser beam energy than can the eye. 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. See Appendix 11 for further information. 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.

Special considerations apply to the use of lasers for medical and dental work, and lasers for display purposes. Such work must be very carefully planned and controlled and specialist guidance followed.

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.

6. Stages in a Risk Assessment

There are basically 5 stages to a risk assessment:

1. identify the hazards, i.e. the potential for harm;
2. assess risk from these hazards and who is at risk;
3. determine and implement the necessary control measures;
4. assess residual risk – repeating stage 3 if necessary; and
5. record the findings.

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

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.

6.2 Assessing Risk

The people who may be at risk need to be identified. These may include cleaning, service personnel, other 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.

6.3 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, MPE, 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 parameters 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.

6.3.1 Laser alignment

About sixty percent 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 - 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.

6.4 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;
- **fumes** - 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 high-powered lasers can present a burning hazard, possible oxygen depletion hazard and possibly an explosion hazard from over-pressure of gases in a closed system;
- **fire and explosion** - high-powered (class 4) lasers can ignite materials and even relatively low-powered lasers (>35 mW) 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.

Other hazards may also arise from the environment in which the laser is used - adverse temperature and humidity, low light-level conditions, mechanical shock and vibration, interruptions to the power supply, computer software problems and ergonomic problems caused by poor design of the layout of equipment. Issues such as cleaners or maintenance staff inadvertently disturbing equipment or unsupervised access must also be addressed.

6.5 Laser accidents

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 - pay particular attention 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.

6.6 Assessing residual risk and recording the results

In most circumstances after introducing control measures one should be able to assess the residual risk as being low. One then needs to produce a standard operating procedure and make it available to all users so that they are aware of all protective measures they should be taking and the procedures they should be following. (See example risk assessment in Appendix 4)

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.

7. PERSONAL PROTECTION

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

Protection by safety eyewear is afforded by incorporating optical filters to reduce the level of eye exposure for a specified wavelength and power or pulse energy, to below the limiting MPE. The required Optical Density (OD), which is the logarithm (to the base 10) of the ratio of maximum reasonably foreseeable exposure to the MPE, needs to be determined. Eyewear providing a smaller level of OD than required will not offer sufficient protection. When choosing protective eyewear, 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*.

Safety 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 (see clause 12). Exceptions to this are:

- when engineering and administrative controls are such as to eliminate potential exposure in excess of the applicable MPE;
- 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.

Eye protection supplied must provide adequate attenuation at the appropriate wavelength and comply with the requirements of BS EN 207 and 208. BS EN 207 relates to normal use of eyewear and is the specification for *Filters and Equipment used for Personal Eye-Protection Against Laser Radiation*. BS EN 208 relates to maintenance and adjustment work and is the specification for *Personal Eye-Protection Used for Adjustment Work on Lasers and Laser Systems*. As a general rule alignment goggles that still allow the user to see where the beam is are recommended for visible lasers, whereas high optical density goggles must always be worn when working with invisible lasers.

Personal protective equipment should be personal, i.e., it should be appropriately cleaned between users, or each user has their own.

When working with Class 4 lasers (and some Class 3B devices emitting in the UV) skin protection may also be required and face masks/respirators may be needed where fume and dusts are a hazard.

Special attention has to be given to the resistance and stability against laser radiation when choosing eyewear or protective clothing for protection against Class 4 lasers.

8. MEDICAL SUPERVISION, EMERGENCY EYE EXAMINATIONS and ACCIDENTAL EXPOSURES

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.

What is of more importance is having 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 which deals with eye injuries needs to be identified. 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 9.

In the unlikely 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 Laser Safety Adviser and School/Departmental Laser Safety Officer will carry out a detailed investigation of the accident/incident.

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

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

9. 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 8 is an example of the instructions that should be provided.

10. CONTROLLING THE RADIATION SAFETY OF DISPLAY LASER INSTALLATIONS

Most lasers that are used in entertainment and public exhibition work emit beams that are powerful enough to cause significant eye injury. In cases where the radiant beam powers exceed 0.5 Watt, exposed people may receive skin burns.

Guidance on laser displays and shows can be found in IEC 60825 Part 3 and the Health and Safety Executive has also published guidance on this topic in Guidance Note HS(G)95.

Organisers of events at which lasers are used for display should:

- ensure that a general risk assessment has been carried out to identify relevant hazards and appropriate control measures are in place, in advance of any display;
- ensure that requirements of HS(G)95 are complied with and that any statutory notifications are made;
- comply with any arrangements and conditions set out by the University.

Where the relevant precautions above are not implemented for a particular class of laser, a justification needs to be made in the appropriate documentation/protocol for the display.

It should be noted that deliberate scanning of an audience with laser beams should not be permitted unless a rigorous assessment of the likely exposure, and any foreseeable fault conditions, show that the applicable MPE will not be exceeded. When the radiant power of a visible laser beam exceeds about 10mW, the MPE for the eye will generally be exceeded even when the beam is scanned.

11. 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*.

IEC 60825-3 *Safety of laser products, Part 3: Guidance for laser displays and shows.*

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

British Standard EN 207: 1999 EN 207: 1999 *Filters and Equipment used for Personal Eye-Protection Against Laser Radiation*.

British Standard EN 208: 1994 *Personal Eye-Protection Used for Adjustment Work on Lasers and Laser Systems*.

CVCP Safety in Universities Notes of Guidance Part 2:1 Lasers, 1992 Edition.

The radiation safety of lasers used for display purposes - Health & Safety Executive publication HS(G)95 1996 **ISBN** 0 7176 0691

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)"
or
http://europa.eu.int/eurlex/lex/LexUriServ/site/en/oj/2006/l_114/l_11420060427en00380059.pdf

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
http://www.laserinstitute.org/store/LSAFPUB/301

NB *Other useful web references are given in Appendix 12.*

Appendix 1

LASER INVENTORY PROFORMA

Location	Manufacturer and Model	Type	Wavelength	Power Output (for CW) or Pulse Power, duration and repetition rate	Laser Class

Note: Do not include office based Class 1 laser products or equipment containing them i.e. Compact Disc/DVD players, laser printers etc.

School/Department: ………………………………………………………………….

Laser Supervisor/Officer: …………………………………………………………………..

Date: …………………………………………………………………...

Appendix 2

University of xxxxxxxxxxxx

REGISTRATION FORM FOR LASER USERS

Surname:			
Prename(s):			
Title (Mr, Ms, Dr etc)		Status (Lecturer, RA, Technician, RS etc)	
email:		Supervisor:	
Department:			
Lasers to be used:			
Experiments to be performed:			
Labs to be used:			

Appendix 3

EXAMPLE - USE OF CLASS 1M, 2M, 2 and 3R LASERS HAZARD & RISK ASSESSMENT

School/Dept		Assessment Number	
Assessor		Date of Assessment	

Without the use of magnifying optics 1M devices do not pose an eye hazard, neither do 2M or Class 2 devices as long as you do not stare into the beam (eye protection is normally afforded by the aversion responses). An eye hazard is possible if there is: exposure in excess of more than 0.25 seconds from Class 2/2M lasers; exposure to modified Class 1M/2M; or if Class 3R lasers are viewed directly. Risk of eye injury is low. There is no skin or fire hazard.

1	**LOCATION AND DESCRIPTION OF THE WORK ACTIVITY**	

2 **LASER SPECIFICATION**

Model:	
Maximum Power:	
Wavelength Range:	

3 **HAZARDS – NON-OPTICAL and OPTICAL (1M/2M)**

Detail the significant risks and the control measures necessary for any non-optical hazard identified, and any optical hazard from 1M/2M devices	**Hazard/Risk**	**Control Measure**

4 **CONTROL MEASURES**

Avoid eye level and do not expose users or others to the beam.
NB Modified 1M/2M devices may need to be reassessed as a higher classified laser.

	**Follow the manufacturer's safety instructions.** **Take care when operating the laser system.** **Keep the laser 'on' only when necessary.** **Restrict unauthorised use.** **Terminate the beam at the end of its useful path.**
	**Do not point at or towards persons deliberately.** **Do not point at mirrored surfaces that may cause unplanned reflections.** **Never look into the laser aperture.** **Never look directly or stare into the beam/beam aperture when on.** **Never allow unauthorised use.** **Do not use direct optical viewing aids.**

5	**CONTACT**	NAME		PHONE	

Appendix 4

USE OF CLASS 3B & 4 LASERS – HAZARD & RISK ASSESSMENT

Class 3B and Class 4 lasers are capable of causing eye injury to anyone who looks directly into the beam or its specular reflections. In addition, diffuse reflections of a high-power (Class 4) laser beam can produce permanent eye damage. High-power laser beams (Class 4) 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. Thus, each proposed experiment or operation involving a laser must be evaluated to determine the hazards involved and the appropriate safety measures and controls required.

School/Dept		Assessment Number	
Assessor		Date of Assessment	

1	**LOCATION OF THE ACTIVITY**	

2 **LASER IDENTIFICATION AND SPECIFICATIONS**
Complete the following chart, list all lasers, including low power alignment lasers:

	Laser 1	Laser 2	Laser 3	Laser 4
Type:				
Manufacturer:				
Model:				
Serial #				
Maximum Power				
Maximum Pulse Energy				
Wavelength Range				
Wavelength Used				
Power Used				
Pulse Energy Used				
Pulse Length				
Pulse Repetition Rate				
Beam Diameters (x,y)				
Beam Shape (e.g. ellipse, box, circular)				
Beam Divergence (x,y)				
LASER CLASSIFICATION				

3	**DESCRIPTION OF ACTIVITY OR RESEARCH PROJECT** *Provide a brief description of the laser set up, its purpose and operational parameters.*	
	DURATION OF ACTIVITY/PROJECT *Is the work ongoing or for a limited period?*	

4	**IDENTIFICATION OF NON-BEAM HAZARDS**
	Electrical Hazards *Most lasers contain high-voltage power supplies and often large capacitors/capacitor banks that store lethal amounts of electrical energy.* **Are any special precautions/procedures required? Yes / No**
	Laser Dyes *Laser dyes are often toxic and/or carcinogenic chemicals dissolved in flammable solvents* **Are laser dyes used? Yes / No** Give details, if yes.
	Compressed and Toxic Gases *Hazardous gases may be used in laser applications, i.e., excimer lasers (fluorine, hydrogen chloride).* **Are compressed gases and/or toxic gases used? Yes / No** Give details, if yes.
	Cryogenic Fluids *Cryogenic fluids can create hazardous situations. Adequate ventilation must be provided.* **Are cryogenic fluids used? Yes / No** Give details, if yes.
	Fumes/Vapours/Laser Generated Air Contaminants from Beam / Target interaction *When laser beams are sufficiently energised to heat up a target, the target may vaporise, creating hazardous fumes or vapours that may need to be captured or exhausted.* **Is there a potential for fumes/vapours/Laser Generated Air Contaminants? Yes / No** Give details, if yes.
	UV and Visible Radiation/ Plasma Emissions *UV and visible radiation may be generated by laser discharge tubes, pump lamps or plasmas. The levels produced may be an eye and skin hazard.* **Is there a potential for significant UV/visible radiation? Yes / No**
	Explosion Hazards *High-pressure arc lamps, filament lamps, and capacitors may explode if they fail during operation. Laser targets and some optical components also may shatter if heat cannot be dissipated quickly enough.* **Is there an explosion hazard? Yes / No** Give details, if yes.
	Ionising Radiation (X-rays) *X-rays can be produced from two main sources, high voltage vacuum tubes of laser power supplies such as rectifiers, thyratrons, and electric discharge lasers. Any power supplies that require more than 15 kV may produce x-rays.* **Is there an ionising radiation hazard? Yes / No**
	Other hazards not identified above. Please specify

RISK ASSESSMENT and CONTROL MEASURES

5	**PERSONS WHO MAY BE AT RISK**	**Specified Authorised Laser Users** **Project Supervisors** **Others**

6	**MEASURES TO REDUCE LEVEL OF RISK (LASER BEAM HAZARD)**		
	Are open or partially enclosed beams used during the following?	1. Initial setting up and beam alignment; 2. Addition of new optical elements/lasers; 3. Day to day operation 4. Maintenance	**YES / NO / n/a** **YES / NO / n/a** **YES / NO / n/a** **YES / NO / n/a**
	Are there protocols/procedures to control risks from the optical (and if applicable, skin) hazard?	1. Initial setting up and beam alignment; 2. Addition of new optical elements/lasers; 3. Day to day operation 4. Maintenance	**YES / NO / n/a** **YES / NO / n/a** **YES / NO / n/a** **YES / NO / n/a**
	List the operating protocols with references/dates/location. ALL OPEN BEAM WORK MUST HAVE AN APPROPRIATE PROTOCOL/OPERATING PROCEDURE		

7	**INSTRUCTION/TRAINING** Authorised laser users must receive appropriate training and instruction
	Specify the instruction and training arrangements.
	A list of authorised laser users is to be displayed

8	**PROTECTIVE EYEWEAR**
	Detail how OD was determined.

Number available	Location	Manufacturer	Optical Density	Wavelength

9	ASSESSMENT OF RISK (ASSOCIATED HAZARDS identified in Section 4)	
Detail the significant risks and the control measures necessary (i.e. by reference to protocols/procedures or safety manual). For hazardous substances, specify the location of the appropriate COSHH assessments.	**Hazard/Risk**	**Control Measure**

10 MONITORING

Performance of control measures,
It is the individual responsibility of each laser operator to follow the guidelines on laser safety. Where control measures have failed or have been suspect then laser users should report these. Supervisors should monitor that users are complying with procedures as should the School and University Laser Safety Officers by carrying out periodic checks.

11 REVIEW

Enter the date or circumstances for review of assessment (maximum of 3 years or the length of the particular project if shorter.)
Where new lasers or components are introduced then these changes need to be assessed; protocols may need to be modified. A review would also be required where a new laser worker starts ensuring that they are informed of the relevant risks and protocols.

12 EMERGENCY ACTION

TO CONTROL HAZARDS	To stabilise situation e.g. turn off power source, etc.
Turn off power.	
TO PROTECT PERSONNEL	Evacuation, protection for personnel, Special First Aid
Once power has been turned off the laser does not present an optical hazard to personnel in the area.	
TO RENDER SITE OF EMERGENCY SAFE	Power , ventilation
Turn off power.	

13	EMERGENCY CONTACT	NAME	.	PHONE	

Appendix 5

Example 1 - SCHEME OF WORK WITH PROCEDURE

Name of School
Laboratory/Room/Activity

These guidelines have been prepared by..

Before commencing work with Class 3B/4 lasers, you must read this document, and sign the sheet at the end to confirm this, and your agreement to abide by the protocols contained herein.

Purpose and Structure of this document

The principal aim of this document is to outline the elements of *good laser practice* as they apply specifically to experiments currently being undertaken in the above laboratory. General aspects of laser safety are covered in sections of the manuals accompanying the lasers.

The document is structured as follows: at the top level (this sheet) an overall description is made of laser research activity in this laboratory. The user is then referred to a number of accompanying documents under two headings: Laser types in use and Safety Protocols.

Description of Activity:

.......*Description of the activity/experiment and its purpose*.............................

Four types of situation have been identified which require separate safety protocols, where appropriate:

- setting up;
- adding new elements;
- day-to-day operation of the experiment; and
- maintenance/servicing of the laser system.

Separate sections dealing with each of these are to be included where appropriate.

Lasers in use

.... *Reference to completed Hazard/Risk Assessment proforma* ....

As a general rule all Class 3B/4 laser emissions are capable of causing severe eye damage if viewed directly, or as a specular (i.e., mirror-like) reflection. Control measures (careful planning, beam pipes, blocking of reflections, safety eyewear) must be taken to avoid this!

Authorised users of the above lasers are (*to be named*):

Supervisor(s): ....
Student(s): ....
Postdoctoral fellow(s): ....
Other(s): ....

There should be reference to this guidance in particular the ***General Overview on Laser Hazard/Risk Assessment*** **and** ***Maximum Permissible Exposure Calculations.***

Laser safety protocol: Setting up

Definition
Setting up applies to the initial installation of a new experiment, and to major changes such as the addition of a new type of laser system, or, for example, a complete change of beam paths.

Protocol/Scheme of Work

Planning:
- The installation or changes should be discussed with a supervisor prior to operation of Class 3B/4 laser systems.
- In the case of a completely new experiment, the School Laser Safety Officer and/or the University Laser Safety Adviser must be consulted and invited to visit the lab.
- The laser beam paths and associated optics should be planned to minimise the possibility of stray reflections.
- Termination of each main laser beam should be planned.
- Provision of suitable laser safety eyewear should be addressed at this stage.

Initial safety checks:
- Before starting the Class 3B/4 lasers, beam paths should be inspected for any objects that should not be there.
- Laser warning signs should be activated, where installed and unauthorised persons excluded and doors closed.
- Alignment may be carried out by one or at most two authorised laser operators. No one else may be present in the room during this procedure and watches, bracelets and other reflective jewellery should be removed.
- Appropriate laser safety eyewear should be worn if practicable. Visible or multi-wavelength alignment may have to be carried out without laser safety eyewear, as it would otherwise be impossible to visualise the laser beam on a card. In this case, extra caution must be exercised by the operator(s).

Initial alignment and suppression of stray reflections:
- Initial laser beam alignment should be performed with a Class 2 or Class 1 alignment laser (e.g., He-Ne or small CW diode laser). Remember that the final beam path may differ slightly due to dispersion (i.e., the beam path may be slightly wavelength-dependent)
- At this stage, each and every optic element in the beam path must be analysed for stray reflections. Initially this can be done by predicting the likely path of specular (i.e., non-diffuse) reflections and the actual reflections of the Class 2/1 alignment laser may also be used to help identify stray reflections.
- Suitable beam blocks, opaque at the appropriate wavelengths, should then be installed when necessary to block all stray reflections.
- 'Beam pipes' should be installed at this stage to cover longer runs of laser beam, and especially any beams that leave the confines of the laser table. It is recognised that there may be some places where beam pipes are inappropriate, e.g. when the distance between optics is very short. Beam pipes should be designed to allow limited access to the beam for alignment checking without removal.

Alignment using Class 3B/4 lasers at low power

- The next stage of alignment using the Class 3B/4 lasers may be carried out only after obtaining the verbal permission of a supervisor.
- Alignment may be carried out by one or at most two authorised laser operators. No one else may be present in the room during this procedure and watches, bracelets and other reflective jewellery should be removed.
- Under no circumstances must direct viewing of the laser beam be attempted even if the beam has been attenuated. The use of a video camera for remote viewing should be considered.
- All optics should be checked for damage, and the stability of optics mounts verified prior to operation of laser.
- This next stage in alignment should be carried out using the lowest possible laser energy (e.g. operating a Nd:YAG laser on fixed-Q) at which it is possible to visualise the laser beam in an appropriate fashion. The method of visualisation is dependent on the wavelength: for UV or visible light, the beam can be viewed on a fluorescent card. An invisible infrared beam may be visualised using LCD heat sensitive paper or possibly using burn paper or a laser power meter.
- In the case of UV or IR beams, appropriate laser safety eyewear should be worn during the alignment procedure at all times when the laser pulse energy exceeds the MPE: note that it should not block the wavelength-shifted visible fluorescence (UV) or the heat effect on LCD paper or burn paper (IR), which can then be used to visualise the beam.
- Visible or multi-wavelength alignment may have to be carried out without laser safety eyewear, as it would otherwise be impossible to visualise the laser beam on a card. In this case extra caution must be exercised by the operator(s) after appropriate consideration of alternatives and assessment of risks. The laser(s) should be operated below the MPE if possible and in any case at the lowest practicable pulse energy. Blocking of possible stray reflections must be double-checked prior to carrying out this stage.
- Alignment of each laser beam to variable diameter apertures (iris diaphragms) should be employed where possible to minimise the necessity for multi-wavelength alignment.
- Further alignment at full power may be carried out in accordance with the protocol outlined under ‘day-to-day operation’.

Laser safety protocol: Adding new elements

Definition

Adding new elements applies to the introduction of any new optic such as a lens or filter into the beam path of a Class 3B/4 laser.

Protocol/Scheme of work

Planning:

- The placement of additional optics should be planned to minimise the possibility of stray reflections.
- Beam blocks should be devised to terminate any unavoidable stray reflections.

Initial safety checks:

- Before starting the Class 3B/4 lasers, beam paths should be inspected for any objects that should not be there and beam pipes should be replaced if necessary.

- Laser warning signs should be activated, unauthorised persons excluded and laboratory doors closed.
- Alignment may be carried out by one or at most two authorised laser operators. No one else may be present in the room during this procedure and watches, bracelets and other reflective jewellery should be removed.
- Appropriate laser safety eyewear should be worn if practicable. Visible or multi-wavelength alignment may have to be carried out without laser safety eyewear, as it may otherwise be impossible to visualise the laser beam on a card. In this case extra caution must be exercised by the operator(s).
- All optics should be checked for damage, and stability of optics mounts verified.

Initial alignment and suppression of stray reflections:

- Once a new optic is in place, initial alignment should be performed with a Class 1/2 alignment laser (e.g., He-Ne or small CW diode laser). For simple optics it may be judged sufficient to proceed to the next step without using a Class 1/2 alignment laser.
- The new optic element in the beam path must be analysed for stray reflections. This can be done by predicting the likely path of specular (i.e., non-diffuse) reflections. The actual reflections of the Class 1/2 alignment laser may also be used to help identify stray reflections.
- Suitable beam blocks, opaque at the appropriate wavelengths, must then be installed to block all these stray reflections.
- Any effect 'downstream' of the new optic should be checked. 'Beam pipes' should be re-installed at this stage.

Alignment using Class 3B/4 lasers at low power:

- This may now be carried out in accordance with the procedure outlined under 'setting up' with the exception that explicit permission of a supervisor is not deemed necessary for addition of a simple optical element. (Anything more complex should be taken as 'setting up' and the protocol followed accordingly.)

Laser safety protocol: Day-to-day running

Definition

Day-to-day running applies to the operation of Class 3B/4 lasers under all circumstances except setting up or addition of a new optic element. It includes initial, minor realignment of laser beams at the beginning of an experimental run and 'tweaking' of alignments during an actual experiment.

Protocol/Scheme of work

Initial safety checks:

- Before starting the Class 3B/4 lasers, beam paths should be inspected for any objects that should not be there, and beam pipes should be replaced if necessary.
- Laser warning signs should be activated, unauthorised persons excluded, and laboratory doors closed.
- Alignment may be carried out by one or at the most two authorised laser operators. No one else may be present in the room during this procedure and watches, bracelets and other reflective jewellery should be removed.

- Appropriate laser safety eyewear should be worn if practicable. Visible or multi-wavelength alignment may have to be carried out without laser safety eyewear, as it would otherwise be impossible to visualise the laser beam on a card. In this case extra caution must be exercised by the operator(s).
- All optics should be checked for damage, and stability of optics mounts verified.

Check using Class 3B/4 lasers at low power:

- Before turning on full power, the beam path of each laser should be verified in turn, using the lowest possible pulse energy and visualising the beam in an appropriate fashion (e.g., on fluorescent card or using video camera).
- Under no circumstances must direct viewing of the laser beam be attempted even if the beam has been attenuated. There must be no exceptions to this rule.

Minor realignment ('tweaking') with lasers running at full power:

- During an experimental run, it will sometimes be necessary to re-optimise the alignment to recover lost signal. Of necessity, this can only be carried out at full power, with all lasers on. Extra caution should therefore be exercised.
- All beam guards/pipes and blocks for stray reflections should remain in place during this procedure. Beam pipes should be designed to allow limited access to the beam for alignment checking without removal.
- It is especially important to wear appropriate laser safety eyewear when visualising laser beams at full power. As before, in a visible or multi-wavelength experiment this may not be practicable, and extra caution should therefore be exercised.
- It may be possible (and indeed, preferable) to apply minor 'tweaks' to the alignment using the experimental signal as a guide. In this case it is not necessary to visualise the laser beams.
- If it is necessary to visualise the laser beams, e.g. to optimise beam overlap, this may be done by an appropriate safe method e.g. by fluorescent card or by remote viewing using a video camera. If practicable the output power should be restricted e.g. by the use of iris diaphragms.

Laser safety protocol: Maintenance

Definition

Maintenance applies to adjustments or procedures specified in the user information provided by the manufacturer/supplier with the laser product, which are performed by the user for the purposes of assuring the intended performance of the product. It may require access within the laser enclosure. Any entry into the laser system enclosure potentially exposes the laser worker to additional non-optical hazards, for instance those associated with high voltages, and toxic chemicals, in addition to accessing high energy laser beams that are normally enclosed. The activities can be very diverse, and specific protocols will need to be prepared for each laser, this document provides some general guidelines on the planning of *Maintenance*.

NB Manufacturer's type servicing is outside the scope of this document

Protocol/Scheme of work

Planning:

- Before commencing the maintenance, the manual for the laser system should be consulted, to identify the recommended procedure.

- In the case of anything other than routine maintenance, and/or when the laser manual does not give a procedure, the advice of a laser technician should be sought. Some procedures should only be conducted by an experienced laser technician.
- The risks associated with the procedure should be assessed, the control measures reviewed, and the conclusions recorded. In the case of some regular maintenance procedures (such as changing the dye solution in a dye laser), reference to an existing protocol may well suffice.
- Maintenance involving the alignment of a laser beam inside a laser enclosure, for instance introducing the pump laser into a dye laser, can lead to an increased laser radiation exposure risk, since part of the beam path of a normally enclosed, and potentially very high power beam is likely to be open. The protocol for Setting Up should be consulted.

A SIGNATURE SHEET WILL ACT AS A LIST OF AUTHORISED USERS AND A RECORD THAT PERSONS HAVE BEEN GIVEN INFORMATION AND AGREE TO FOLLOW THE PROCEDURES LAID OUT.

Signature Sheet
This sheet must be signed by all workers before commencing work with Class 3B/4 lasers.
By signing below, you confirm that you have read this document, and you agree to abide by the protocols and guidelines contained herein.

Name (in block letters)	Signature	Date

Appendix 5

EXAMPLE 2 - SCHEME OF WORK (Simple Set-up)

Laser Scheme of Work **Class 4 3 W 635 nm Diode Laser (CW)**
in *Location, Department, Premises*

Experiments: Photodynamic therapy in vitro and vivo.

Person responsible: Prof A N Other

Authorised operatives: Prof A N Other
Dr L Aser

General Precautions

1. Only the above named personnel are permitted to use this laser. They must be familiar with the manufacturer's and the Institution's safety information (*includes these Local Rules).*
2. When not in use the key to the laser (or other means of controlling access) should be kept separately from the laser, to prevent unauthorised use.
3. All beam paths shall be kept as short as possible and enclosed whenever reasonably practicable.
4. The area in which this laser is used should be a designated laser area, and have the appropriate warning notice on the door.

Specific considerations relating to this experiment

The laser should be sited at least 1.1m away from the window, (NOHD is 1.09m) and the blinds should be closed.

Before switching the laser on:

1) The fibre optic head must be securely mounted and pointing vertically down on to a non-reflective surface.

2) The appropriate safety eyewear should be worn that gives at least OD 2.3 (L3) at 635nm. Only those wearing safety eyewear are permitted in the operating area.

3) The 'Laser in Use - Do Not Enter' sign should be posted on the entrance door.

The laser must be aligned using the lowest practicable power setting.

The laser should not be left unattended unless a remote interlock connector linked to the door prevents unauthorised access. (Expected experimental times are 5 min in vitro and 20min irradiation of mice.)

Because of the diverging nature of the beam the eye and skin hazard from these laser experiments is low. The only other hazard identified with this work is from the cabling. All cabling should be tied/taped back away from the operating area to prevent any tripping hazard and damage to the alignment of the fibre optic.

Copies of this scheme of work should be issued to all personnel using the laser, and should also be posted in the laboratory.

Departmental Laser Safety Officer ……………………………………Date ....…………

Appendix 6

SUMMARY OF WARNINGS & 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	Prevent direct viewing with magnifying optics. (NB fitting external optics that decrease beam divergence may affect classification) + *see footnote*
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*
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 laser 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.

+ 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 60825-14:2004 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. It is often the non-optical hazards that pose the greatest risk - one could be blinded in one eye from a powerful laser but electrocution could be fatal. Some non-optical hazards may be present with even Class 1 laser products.

Appendix 7
SUMMARY OF BS EN 60825-1
MANUFACTURER'S AND USER REQUIREMENTS

1	Remote interlock -	connection provided by the manufacturer for door or enclosure interlock for Class 3B and Class 4 lasers
2	Safety interlocks -	required for access panels on Class3R, 3B and 4 laser systems
3	Key control	a key or similar device is required to control unauthorised operation of Class 3B and Class 4 lasers
4	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
5	Beam stop or attenuator/shutter -	should be provided by the manufacturer for each Class 3B or Class 4 laser system
6	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)
7	Beam level -	avoid eye level
8	Beam enclosure -	to guard against specular reflections from Class 3R, Class 3B and Class 4 lasers - can mean anything from screening the experimental area or piping the beam up to a total enclosure.
9	Eye protection -	required for open beam work with invisible beam Class 3R and all Class 3B and Class 4 devices.
10	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
11	Eye examinations -	only required after an accident but may be important to people with poor eyesight working with Class 3B or Class 4 lasers
12	Training -	required for people working with any Class 3 or Class 4 laser and any modified Class 1M or Class 2M devices.
13	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)
14	Door/Area signs -	required for Class 3B and Class 4 lasers indoors and also for Class 1M, 2M and 3R if used outdoors

Laser Survey Form

The following laser survey form takes all the manufacturing and user requirements into account and provides a checklist to see if the laser installation is observing all the requirements recommended by BS EN 60825. Where a box cannot be 'ticked off' the user should be employing some other protective measure justified by a risk assessment.

NB 1(E) indicates a Class 1 totally enclosed system.

LASER SURVEY FORM		**DEPT:**			
Date:		**LAB:**			
Make:		**Type:**		**Mode:**	
Model & s/n:		**λ:**		**Power:**	

Precautions	**1M**	**2**	**2M**	**3R**	**3B**	**4**	**1(E)**
Remote interlock	n/a	n/a	n/a	n/a			n/a
Safety interlocks	n/a	n/a	n/a				
Key control	n/a	n/a	n/a	n/a			
Emission indicator	n/a	n/a	n/a				
Beam stop/shutter	n/a	n/a	n/a	n/a			n/a
Beam terminator		n/a					n/a
Beam level							n/a
Beam enclosure	n/a	n/a	n/a				
Eye protection	n/a	n/a	n/a				n/a
Protective clothing	n/a	n/a	n/a	n/a			n/a
Eye examinations	n/a	n/a	n/a	n/a			n/a
Training		n/a					
Laser labels							
Door/Area signs	n/a	n/a	n/a	n/a			n/a

Laser installation: satisfactory/ not satisfactory

Additional control measures required: ....

....

....

....

Survey performed by: ....

Appendix 8

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).

NB Class 1 laser products are normally safe.

Class 2 and old Class 3A 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.

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

Further guidance on the purchase and use of laser pointers can be found at:-
http://www.hpa.org.uk/radiation/understand/information_sheets/laser_pointers.htm

Appendix 9

EXAMPLE OF EMERGENCY PROCEDURE
FOR EXPOSURE TO CLASS 3B OR 4 LASER

Report to

Name and address of agreed A&E Centre (Eye Injuries)

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**

- **i. State Building and Department**
- **ii. Location and nature of incident/accident**
- **iii. Request ambulance to take the casualty to the **** (as above)**
- **iv. Take the card or information below to the Hospital**

EMERGENCY OPHTHALMIC EXAMINATION
LASER Exposure

Report to:
Accident and Emergency Department, ******************

Tel: **********************

LASER DETAILS:	
i. Type:	**Continuous Wave / Pulsed***
ii. Wavelength:	**…………………………………nm**
ii. Power Output (CW):	**…………………………………**
or Pulse Energy, Duration, and Rate (pulsed):	**…………………………………**
iv. Laser Classification:	**…………………………………**
Institution Name	**School/Department** **…………………………………**
EXPOSURE DETAILS:	
i. Circumstances of accident/injury:	**……………………………………**
ii. Time/Date of Injury	**……………………………………**
iii. Eye affected:	**Left/Right/Both***
iv. Was protective eyewear being worn?	**Yes/No***
	* delete as appropriate

REPORT ACCIDENT/INCIDENT to local *Health and Safety Office*
Ext ******* during normal hours**

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

The Laser Safety Adviser and School/Departmental Laser Supervisor/Officer must also carry out a detailed investigation of the accident/incident.

Any serious injury or 3 day absence from work has to be reported to the Health and Safety Executive under *'The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995'*.

Appendix 10

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 BS 5378 and the Health & Safety (Safety Signs and Signals) Regulations 1996. 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 p65 of 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 is 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 ..... LASER

In addition each access panel or protective housing shall bear the words:-

CAUTION - CLASS .... LASER RADIATION WHEN OPEN

with the appropriate class inserted and then followed by the hazard warning associated with that class of laser (see warning statements in following labels).

Class 1M

No hazard warning label.

Explanatory label bearing the words:

> **LASER RADIATION**
> **DO NOT VIEW DIRECTLY**
> **WITH OPTICAL INSTRUMENTS**
> **CLASS 1M LASER PRODUCT**

NB-'Optical Instruments' can be supplemented with either 'Binoculars or Telescopes' (for a large diameter collimated beam) or 'Magnifiers' (for a highly diverging beam).

Class 2

Label with hazard warning symbol.

Explanatory label bearing the words:-

> **LASER RADIATION**
> **DO NOT STARE INTO BEAM**
> **CLASS 2 LASER PRODUCT**

Class 2M

Label with hazard warning symbol.

Explanatory label bearing the words:-

> **LASER RADIATION**
> **DO NOT STARE INTO BEAM OR VIEW**
> **DIRECTLY WITH OPTICAL INSTRUMENTS**
> **CLASS 2M LASER PRODUCT**

NB-'Optical Instruments' can be supplemented with either 'Binoculars or Telescopes' (for a large diameter collimated beam) or 'Magnifiers' (for a highly diverging beam).

Class 3R

Label with hazard warning symbol.

Explanatory label bearing the words:-

For λ 400nm-1400nm ONLY.

> **LASER RADIATION**
> **AVOID DIRECT EYE EXPOSURE**
> **CLASS 3R LASER PRODUCT**

NB - For other λ replace 'AVOID DIRECT EYE EXPOSURE' with 'AVOID EXPOSURE TO BEAM'

Class 3B

Label with hazard warning symbol.

Explanatory label bearing the words:-

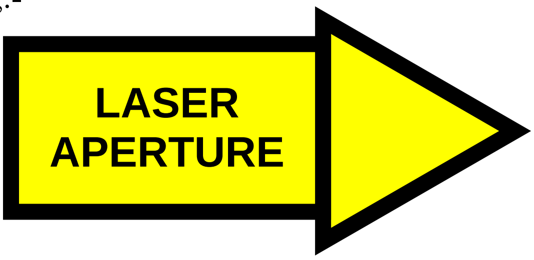
Class 4

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:-



Radiation Output and Standards Information

All laser products, except for low power Class 1 devices, shall be described on an explanatory label with details of :-

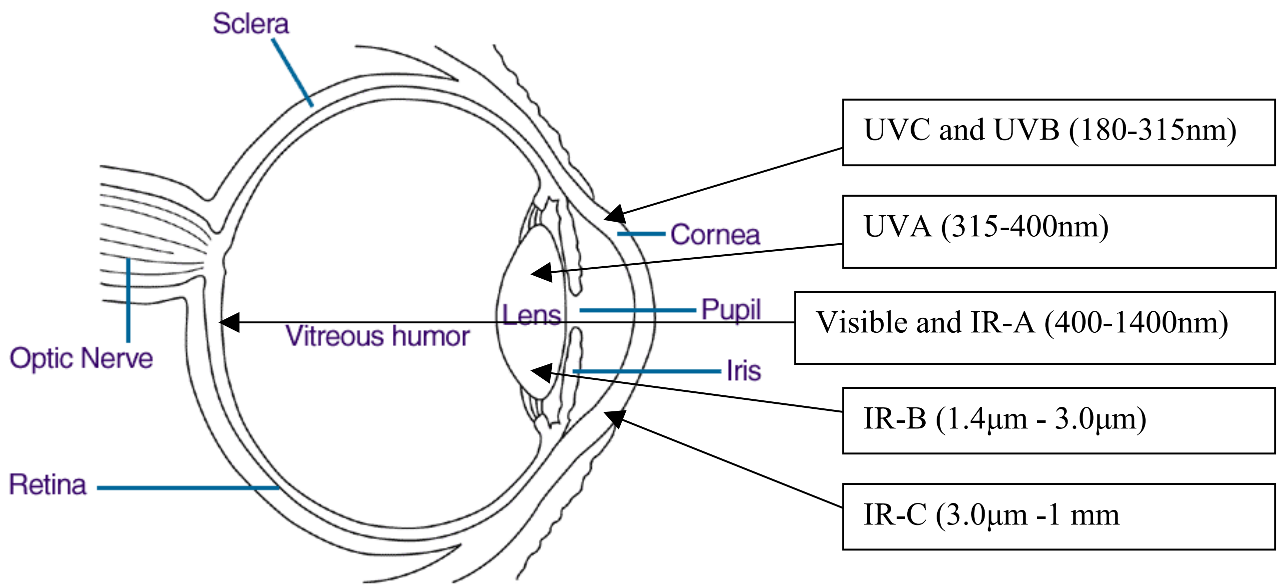
- maximum output
- emitted wavelength
- whether laser beam is visible, invisible or both
- pulse duration (if appropriate)
- name and publication date of classification standard

It may be found useful to also put on the labels details of the type of laser and the lasing medium, although this is not a BS requirement.

Information put on explanatory labels may be combined and LED shall be used to replace the word 'laser' when appropriate.

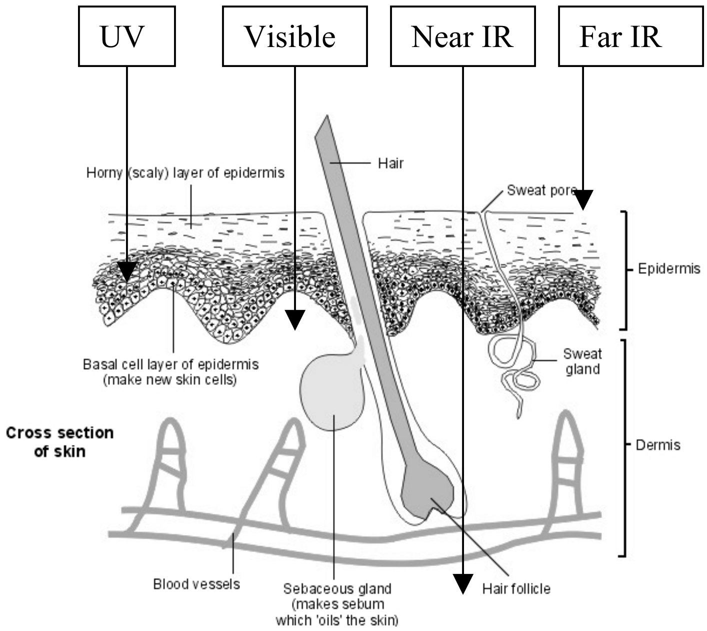
Appendix 11
OPTICAL HAZARDS AND BIOLOGICAL EFFECTS OF LASER RADIATION

Penetration of laser radiation into the eye



NB Short pulsed high peak-power laser beams are particularly hazardous to the eye, especially at wavelengths that reach the retina, as they deliver a lot of energy in a short period of time that can cause irreversible damage. Near infra-red lasers are also particularly hazardous because you can't see the beam but it could be focused on the retina and you would only be aware of it after damage has been caused.

Penetration of laser radiation into the skin



In general, the skin can tolerate a great deal more exposure than the eye and less research has been done on damage mechanisms. All wavelengths of laser output with sufficient power density can cause surface burns of the skin and with high-powered Class 4 lasers there could be no warning of this occurring. Near infra-red lasers are again of particular concern because they are more penetrating and can reach the subcutaneous layer and UV lasers are also of concern because of the long-term risk of developing skin cancer.

Summary of biological effects associated with excessive exposure to optical radiation

<table>
<tr><th>CIE Spectral Region +</th><th>Eye</th><th colspan="2">Skin</th></tr>
<tr><td>Uultra-violet C (180-280nm)</td><td rowspan="2">Photokeratitis</td><td rowspan="2">erythema (sunburn)
accelerated skin ageing
increased pigmentation</td><td rowspan="2"></td></tr>
<tr><td>Ultra-violet B (280-315nm)</td></tr>
<tr><td>Ultra-violet A (315-400nm)</td><td>Photochemical cataract</td><td rowspan="2">pigment darkening

photosensitive reactions</td><td rowspan="5">Skin burn</td></tr>
<tr><td>Visible (400-780nm)</td><td>Photochemical and thermal retinal injury</td></tr>
<tr><td>Infra-red A (780-1400nm)</td><td>cataract, retinal burn</td><td rowspan="3"></td></tr>
<tr><td>Infra-red B (1.4µm- 3.0µm)</td><td>aqueous flare, cataract, corneal burn</td></tr>
<tr><td>Infra-red C (3.0µm- 1mm)</td><td>corneal burn only</td></tr>
</table>

+ *The spectral regions defined by the CIE are shorthand notations useful in describing biological effects and may not agree perfectly with spectral breakpoints in the MPE tables.*

More detailed information on biological effects can be found in Annex B to BS-EN 60825-1:1994. This is also repeated as Annex C to PD IEC TR 60825-14:2004.

Appendix 12
RESOURCES & LINKS

Information sources

Further information on laser safety can be found from accessing the Health Protection Agency website. Look for the broadsheet 'Lasers at Work' which makes a useful poster. See :-
http://www.hpa.org.uk/radiation/laser/index.htm

Guidance on the purchase and use of laser pointers:-
http://www.hpa.org.uk/radiation/understand/information_sheets/laser_pointers.htm

The International Commission on Non-Ionising Radiation Protection (ICNRP) has a useful bibliography of recent publications on optical safety many of which can be freely downloaded.
http://www.icnirp.org/pubOptical.htm

If it is intended to use lasers outdoors one must consult the Civil Aviation Authority (CAA) guidelines:-
http://www.caa.co.uk/docs/33/CAP736.PDF

Health & Safety Executive (HSE) information and guidance on non-ionising radiation :-
http://www.hse.gov.uk/radiation/nonionising/index.htm

Laser Safety Equipment and Software

BFiOptilas market a range of lasers, power meters, optical components, laser safety eyewear, laser guards etc and also offer an advice service. Information on their products can be found at:-
http://www.bfioptilas.com/php_files/index.php

Lasermet sell an extensive range of laser safety products and laser safety software. They also offer a design and safety consultancy service. A lot of useful information can be found on their site at:-
http://www.lasersafety.co.uk/

AG Electro-Optics also market a range of lasers, power meters, optical components, laser safety eyewear, laser guards etc and also offer an advice service. Information on their products can be found at:-
http://www.ageo.co.uk/

Laser Physics UK market a range of laser safety eyewear, power meters, optical components, safety barriers, curtains and blinds and laser safety software. Details can be found at:-
http://www.laserphysicsuk.com

This is not an exhaustive list and members may wish to recommend other entries for this section.

Appendix 13

TRAINING RECORD FORM - AUTHORISED LASER USER

Researcher ……………………………………………………

Room number ……………………………………………………

Lasers used ....……………………………………………….

....……………………………………………….

....……………………………………………….

....……………………………………………….

☐ Attended University training lecture

☐ Registered as University laser user

☐ Read University local rules for laser safety

☐ Familiar with all hazards within the laboratory and the laboratory's risk assessment

☐ Trained in use of lasers named above

☐ Familiar with laser schemes of work

SIGNED

Researcher ………………………… Date ………………………

Supervisor ………………………… Date ………………………

RETURN THIS FORM TO YOUR DLSO