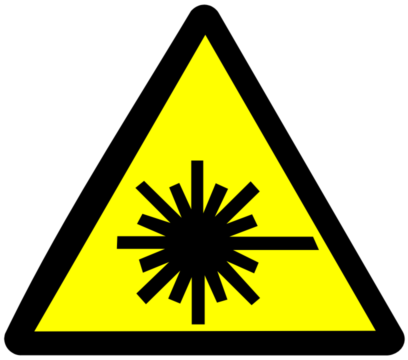
UNIVERSITY OF SHEFFIELD

LOCAL RULES
FOR LASER SAFETY



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1. INTRODUCTION

We all have a responsibility under the Health & Safety at Work Act 1974 to ensure that work with lasers is carried out safely. Users have a duty to protect both themselves and others from the potential hazards involved, particularly when working with the more powerful lasers. Quite often it is not the laser itself that presents the greatest potential hazards but the associated risks from electrical supplies, cryogenic liquids or chemical dyes.

In this document you will find forms for registering users (Appendix 1) and equipment (Appendix 2). Section 3 (Getting Started) will tell you what and who needs to be registered.

The safety of laser products is covered by BS EN 60825. This BS is a `euronorm' based upon the International Electrotechnical Commission's IEC 60825. Under the 60825 umbrella are a range of standards for manufacturer's and users on lasers, fibre optic systems, laser guards, components etc. Of particular importance for user's are: BS EN 60825-1:2007 'Equipment Classification and Requirements' and, the Technical Report PD IEC TR 60825-14:2004 which is a detailed user's guide that incorporates a risk assessment approach to laser safety. You are advised to refer to these documents for further guidance on classification, determining MPEs (maximum permissible exposure levels), evaluating risk, control measures, interlock systems, calculations and biophysical considerations. Also of importance are the standards relating to laser safety eyewear, namely BS EN 207 and BS EN 208.

The University is licensed to access and download full text British Standards online. To gain access to this facility you need to be set-up to use the University's 'MUSE' portal. Access instructions are then as follows:-

1. Log into **MUSE**
2. Select '**Library**' from index tabs (top left hand side)
3. At right hand side under **Library eResources** select '**Subject Databases**'
4. Select '**Alphabetical Table**' then '**B**' and then '**British Standards Online**'
5. Click on **Bsi Online logo** and at BSi Online page look to top left-hand side for the search box.
6. Enter **60825** in the search box and you will find all BS and IEC laser related standards.

You will currently find details of 20 standards the first 12 of which are current. For your convenience the main implications of the laser standards and details of the new laser classes are included in this document. Also included in your Local Rules are details of two laser accidents at other universities. These are examples of what can go wrong when people do not follow the correct procedures and are careless. (see Appendix 5). A brief summary of the biological effects of laser radiation is given in appendix 10.

2. LASER CLASSIFICATION

2.1 Lasers

LASER stands for light amplification by the stimulated emission of radiation but is defined in BS EN 60825 as 'any device that can be made to produce or amplify electromagnetic radiation in the wavelength range from 180nm to 1mm primarily by the process of controlled stimulated emission'.

The higher the class of laser the greater the optical hazard it presents. The classification is based upon the measured radiation through a given aperture at a set distance (see section 9 of BS EN 60825-1:2007), and AELs (accessible emission levels) have been set for each class of laser (see Tables 4-9, p43-48 BS EN 60825-1: 2007). In the descriptions below the lasers cover the full wavelength range unless a restriction is stated.

2.2 Class 1 Lasers

These are normally safe either because of their inherently low power or because they are a totally enclosed system where access to higher levels of laser radiation is not possible during 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.

2.3 Class 1M Lasers

These are laser products, emitting in the wavelength range 302.5nm to 4000nm, 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:-

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.

2.4 Class 2 Lasers

These are laser products that only emit visible radiation in the wavelength range 400nm to 700nm and whose output is less than the appropriate AEL. They are safe for accidental viewing as protection is afforded by the aversion and blink responses. There is no hazard to the skin.

2.5 Class 2M Lasers

These are laser products that only emit visible radiation in the wavelength range 400nm to 700nm, 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:-

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.

2.6 Class 3R Lasers

These are laser products, emitting in the wavelength range 302.5nm to 1mm, that present a relatively low risk of eye damage as their output is restricted to no more than 5 times the AEL for visible Class 2 lasers or no more than 5 times the AEL for Class 1 devices at other wavelengths. Direct eye exposure should be prevented.

2.7 Class 3B Lasers

These are laser products that are hazardous to the eye for direct intrabeam viewing and from specular reflections but diffuse reflections are normally safe. They may be hazardous to the skin at some wavelengths at the upper limit of the class. Output levels must be less than the appropriate AEL for Class 3B devices.

2.8 Class 4 Lasers

These are high power devices that exceed the AELs for Class 3B devices and are hazardous to the eyes and skin from direct viewing and from specular reflections. Diffuse reflections may also be hazardous. They can also have sufficient energy to ignite materials and produce hazardous fumes. Their use requires extreme caution.

2.9 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 60825-1:2007 for full details.

3. MAXIMUM PERMISSIBLE EXPOSURE LEVELS (MPEs)

MPEs reflect the state of our knowledge in relation to the hazard posed by laser radiation to different biological tissues. It is obviously important to know what levels of laser radiation are considered to be safe and MPEs represent the maximum level to which eye or skin can be exposed without suffering short or long-term damage. With the use of appropriate safety factors MPEs have been established for two different scenarios:-

- direct ocular exposure - intrabeam viewing
- exposure of the skin.

MPEs vary according to the wavelength, exposure time, tissue at risk and, for visible and near infra-red radiation, the size of the retinal image. For detailed information on MPEs and tables of values see Annex A, p56-62 of BS EN 60825-1:2007 or p49-52 of PD IEC TR 60825-14:2004.

Examples of MPEs for a CW He-Ne laser operating at 633nm are

- intrabeam viewing - 1 $mW.cm^{-2}$
- skin exposure - 200$mW.cm^{-2}$

4. GETTING STARTED

4.1 Registration of Personnel - Use Form RPS/L/1 (Appendix 1)

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 register with Safety Services via their Departmental Laser Safety Officer (DLSO). The DLSO will need to establish if people who are only going to use Class 1M or 2M devices are going to be modifying them and therefore require training and full registration. Registered users will then be issued with the appropriate safety information and informed of the arrangements for eye examinations if applicable. The DLSO should ensure that they receive copies of any relevant schemes of work.

4.2 Registration of Lasers - Use form RPS/L/2 (Appendix 2)

The use of lasers, except for low power Class 1 devices and embedded laser products such as those used in laser printers or CD players, needs to be registered with Safety Services. Class 3R, 3B and 4 devices must all be registered individually whereas just the use of other lower powered devices needs to be registered. Safety Services will then check the registered lasers to see that they are labelled in accordance with the guidance notes, operated in accordance with the guidance notes and if necessary they will help with the drawing up of schemes of work to cover their use.

4.2.1 Schemes of work (**Appendix 3**) are required if you are using Class 3B or Class 4 lasers and the beam paths are not totally enclosed. They need to spell out the precautions that will be taken to ensure containment of the laser beam inside the experimental area and protection of the operatives.

4.3 Laser Safety Training

All people who will be working with any Class 3 or Class 4 laser or people who may be modifying and working on Class 1M or Class 2M devices need to attend Laser Safety training prior to the commencement of such work. This training should be repeated as necessary particularly for employees with responsibility for supervising and training others. Records of training will be kept by Safety Services. It is advised that departments keep their own records as well.

4.4 Eye Examinations

Initial and routine eye examinations for laser workers are no longer required although if a new laser worker with concerns about their eyesight requests one, this can be arranged, via Safety Services, in the Department of Ophthalmology at the Royal Hallamshire Hospital.

If there should ever be a case of suspected eye damage from lasers then Safety Services should be informed immediately and an eye examination must be carried out within 24 hours at the Royal Hallamshire Hospital. If there has been serious eye damage then referral will be made to Moorfields Eye Hospital in London.

4.5 Protective Equipment

If you are working with Class 3B or Class 4 lasers and the laser beam is not totally enclosed then you will probably need to wear laser safety goggles. These may also be considered necessary for work with some Class 3R lasers (invisible wavelengths). It is important that ones with the correct optical density for the laser you are using are worn. However, there is no need to buy high optical density laser goggles for use with some low power lasers (e.g. 5-10mW He-Ne). Quite often acceptable goggles can be made from coloured perspex, with an optical density of 2-3, for very low cost. Remember however that these simple homemade devices can only be for your own use and not for selling on, unless they are CE marked and in compliance with the Personal Protective Equipment Regulations 2002.

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 should always be worn when working with invisible lasers. The goggles chosen need to conform with the appropriate standard: BS EN 207:1999 for total eye protection, and BS EN 208:1999 for alignment goggles.

If working with Class 4 lasers, and some Class 3B devices operating at UV wavelengths, you will have to consider the need for skin protection. The hands and forearms are the areas most at risk and should therefore be covered.

4.6 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 should be registered with Safety Services. They should also be given close supervision if working with high-powered lasers.

4.7 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 - Totally Enclosed System' with details of the embedded laser clearly displayed (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 6. 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), labels can be supplied by Safety Services.

4.8 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.

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 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;
- 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.

4.9 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 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, wrist watches etc.
- And don't forget to have the laser pointing away from the laboratory entrance!

5. EVALUATING RISKS

It is important that an adequate risk assessment is carried out of every laser installation and associated equipment. The classification of the laser identifies the optical hazard and it is important that all other associated hazards are identified and dealt with. Written evidence of a risk assessment will be expected by the HSE when they carry out an inspection. Examples of risk assessments can be found at - http://www.shef.ac.uk/safety/riskass/index.html and in Appendix 4.

5.1 Stages in a Risk Assessment

There are basically 5 stages to a risk assessment:

Stage 1: identify potentially dangerous situations

Stage 2: assess risk from these hazards and who is at risk

Stage 3: determine and implement the necessary protective measures

Stage 4: assess residual risk - repeating stage 3 if necessary

Stage 5: record your findings

5.2 Identifying non-optical hazards

The manufacturer's safety guidance material should help in identifying most of the associated hazards. The main non-optical hazards to look out for are as follows:-

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

noxious 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 (>35mW) can cause explosions in combustible gases and dusts

mechanical hazards - from gas cylinders, trailing cables and water hoses, cuts from sharp objects, handling difficulties with large work pieces.

noise - from discharging capacitor banks, from some pulsed lasers and from some air-cooled lasers

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. Could cleaners inadvertently disturb equipment? Is unsupervised access allowed to the laboratory?

5.3 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.

5.4 Protective Control Measures

In dealing with any hazard one should look first to containing the hazard if reasonably practicable by: **engineering controls**; then by the application of **administrative controls** and then finally by the use of **personal protective equipment**.

- **engineering controls** - features incorporated by the manufacturer or added by the user to prevent or minimise human access[1] to hazardous levels of laser radiation. They include: beam enclosures, beam tubes, protective barriers and guards, interlocked access panels etc.
- **administrative controls** - include display of warning signs, local rules, schemes of work and written procedures.
- **personal protective equipment** - protective eyewear should be appropriate for the power and wavelength of the laser used and the wavelength and optical density (or scale number for CE marked eyewear) should be clearly marked. For work with visible lasers, alignment goggles are recommended that permit the safe accidental viewing of the laser light. High OD goggles should always be used when working with invisible laser beams. Visible light transmission and the ability to see warning lights are important considerations when choosing safety eyewear. If protective clothing is needed it may need to be fireproof.

The laser beam controls normally required are indicated by the laser classification. They should be implemented unless a risk assessment justifying the adoption of alternative protective control measures indicates otherwise. A summary of protective control measures is given in Appendix 7. Whenever deviating from the norm it is important to record your justification of the control measures adopted.

5.5 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 report 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 is routinely reviewed.

[1] human access – see definition 3.37, p13 in BS EN 60825-1:2007 - any reasonable access by part of the body either inside or outside of a protective housing with or without the use of a tool.

6. RESPONSIBILITIES

The Vice-Chancellor has overall responsibility for ensuring the effective management of all health and safety matters including laser safety in the University. A detailed breakdown of the organisation and arrangements for health and safety management can be found in the University's Health and Safety Code of Practice.

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.

6.1 Radiation Protection Adviser/Laser Safety Officer (LSO)

The University's Radiation Protection Adviser also advises on the use of lasers in the University and performs executive duties to ensure that the University procedures relating to laser safety are followed. The RPA/LSO is responsible for training of new staff/students, registration of lasers and users of equipment, provision of a measuring service (where appropriate), inspection of all new laser facilities and routine auditing of laser facilities.

6.2 Departmental Laser Safety Officers

In departments where Class 3B and Class 4 lasers are used the Head of Department in consultation with the Radiation Protection Adviser 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 registered and used in compliance with these local rules.

6.2.1 Duties of the Departmental Laser Safety Officer

The DLSO is responsible for the day-to-day safe operation of lasers in the department in accordance with the University's Health & Safety Code of Practice and Local Rules on the Safe Use of Lasers at the University of Sheffield. The DLSO should ensure that:-

1. all lasers except for low power Class 1 devices (and excluding laser printers, DVDs etc) are registered with Safety Services. (NB Full registration details only required for Class 3 and Class 4 devices see Section 3.1 of Local Rules.)
2. all lasers are labelled in accordance with Appendix 6.
3. schemes of work are drawn up, where necessary, for the safe operation of lasers (see example in Appendix 3). These will normally be required for all Class 3B and Class 4 when not totally enclosed.
4. personnel intending to work with Class 3R lasers and above or who may be working with modified Class 1M or Class 2M devices are registered with Safety Services.
5. all registered laser workers receive training in the safe use of lasers.
6. laser safety goggles are provided and worn (when appropriate) by all people working with Class 3B and Class 4 lasers when the beam is not totally enclosed.

7. undergraduates working with lasers should use the minimum power laser practicable and follow a written scheme of work (see Section 4.6 of Local Rules).

8. all lasers in the department are used in accordance with the University's Local Rules.

A summary of the requirements placed on manufacturers and users by BS EN 60825 is given in Appendix 8 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.

6.3 Responsibilities of Research Supervisor/Principal Investigator

The health and safety management of individual research projects is normally delegated to the research supervisor who has a responsibility to ensure that all work is covered by risk assessments and where appropriate by written schemes of work and protocols. They should also ensure that their laser workers are effectively trained in the operating techniques required and that inexperienced staff are adequately supervised.

6.4 Responsibilities of Laser Users

To observe these 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.

Users should not leave a laser experiment running unattended unless a risk assessment has established that it is safe to do so.

Users have responsibilities for their own safety and that of others who may be affected by their acts or omissions.

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 goggles **MUST BE WORN**.

Appendix 1

(RPS/L1/2008)

University of Sheffield

REGISTRATION FORM FOR LASER USERS

Surname:		Prename(s):	
Email:		Date of Birth:	
Title (Mr, Ms, Dr etc)		Status (Lecturer, RA, Technician, etc)	
Department:		Supervisor:	
Lasers to be used:			
(*indicate power or class of laser*)			
Experiments to be performed:			
Labs to be used:			

Date form Submitted	

Please give a copy of this registration form to :-

Your Departmental Laser Safety Officer, and,

then send the form to: Trevor Moseley, Safety Services, 40 Victoria St.

Appendix 2

(RPS/L2/2005)

University of Sheffield

LASER REGISTRATION FORM

Department:			
Labs used:			
Responsible Person:			
Make, Model &s/n			
Lasing medium: (e.g. He-Ne)			
Mode of operation: ….. (e.g. CW or pulsed)			
Pulse Duration:		Pulse Rep Frequency:	
Wavelengths Used:			
Max Output Power/ or Pulse energy			
Beam Diameter (mm):			
Beam Divergence: (specify mR or deg, full or half angle)			
Brief description of use:			
Identified Hazards (see section 5.2 of Local Rules)			
Risk Assessment Performed ?			
What goggles are available ?			
Signature:			
Date:			

FOR OFFICE USE			
CLASS OF LASER	**SCHEME OF WORK**	**RISK ASSESSMENT**	**DATE INSPECTED**

Appendix 3 - EXAMPLE SCHEME OF WORK

Laser Scheme of Work | **Class 4 3W 635nm Diode Laser (CW) in K117 Dept of Surgery, RHH**

Experiments:	Photodynamic therapy in vitro and using mice.
Person responsible:	Prof N Brown
Authorised operatives:	Prof N Brown Dr SL Hankin

General Precautions

1. Only the above named personnel are permitted to use this laser. They must be familiar with the manufacturer's and the University'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.

Laser Safety Officer .... Date ....

Appendix 4: EXAMPLE RISK ASSESSMENT

General Risk Assessment: Polariser Laboratory (MRI)

- Laboratory access restricted to authorized operators only when laser is in use
- Maintenance and cleaning staff admitted only under supervision when all lasers and HV supplies are turned off.

Hazard	Potential Risk	Precautions	Residual Risk
Optical hazard from laser. (Totally enclosed CLASS 4 - 100W IR)	Serious damage to eyes and skin when access panels removed	Laser and optics contained in an interlocked system. However, access can be gained to the assembly for changing optical cell and when changing He-3 cylinder. Used by trained operatives only. Laser goggles provided must be worn until a satisfactory light tightness test has been performed.	Low
High Voltage supplies	Danger of death from electrocution. Damage to equipment	HV supplies turned off when not in use. Never leave unconnected.	Low
Asphyxiation from Nitrogen	Suffocation if large amounts of air become displaced from the room	Air extraction system is continually in use giving 5 changes/hour. Subject to annual inspection. Volume of liquid nitrogen in room kept to a minimum and oxygen deficiency sensor fitted.	Low
Trip hazard from trailing cables and air pipes	Damage to individuals through falling, and striking head/limbs on steel benches or frame	All cables to run under walkway ramps. All walkways to be kept clear	Low
Heater	Fire-risk, burns to personnel.	The heater is protected by an air-flow interlock device. If the air flow is cut off then the heater (and laser are cut off). Hazard warning notice displayed	Low

Project Supervisor : EJR van Beek

Appendix 5

EXAMPLES OF LASER ACCIDENTS

1. At a Midlands University in the UK in 1999

Late one afternoon a postgraduate student was aligning two lasers at different wavelengths that had been set up in a relatively new configuration. The beam from a dye laser (720nm, 10 mJ, 10 ns pulse at 10 Hz) was passed through a dichroic mirror coated for high reflection at 266 nm in order to combine it with the beam from a fourth harmonic Nd:YAG laser (266 nm, 50 mJ, 10 ns pulse at 10 Hz). This configuration resulted in a partial reflection from the rear of this mirror (approximately 5% of the dye laser) in an upward direction. Temporarily forgetting the presence of the stray beam, the person on leaning over the top of the apparatus received a single pulse of light from the dye laser reflection. This immediately left a large blind spot in the person's central vision in one eye. The person was not wearing protective eyewear as it was claimed they could not see that the beams they were aligning were coincident (*but both were at invisible wavelengths so they could only see the fluorescence*). The experiment was shut down and the person was accompanied to the local hospital Eye Unit. On examination the person was informed that there was a small burn on the fovea and that he would be referred to a consultant as a matter of urgency. As to the absence of beam enclosures (drainpipes had been used previously), because of the orientation of the experiment being changed these had not been re-incorporated at this stage. The source of the reflection had allegedly been identified prior to the injury and this had been listed as an action to do by the injured person. There was some concern with regard to the examination and advice received from the local hospital Eye Unit. It was concluded that the most appropriate action was to get the injured person to the Moorfields Eye Hospital, Accident and Emergency Unit (London) as soon as possible (the afternoon after the incident) to obtain a second examination. It was confirmed that the fovea had been damaged leading to a blind spot and peripheral blurring in the left eye. As a consequence the following may be of use to others:

a). Risk assessments need to be scrutinised, monitored and audited so that it can be shown that they are suitable and sufficient. Essentially three elements related to the optical hazard need to be covered (i.e. initial set up/alignment, normal operation/tweaking and the introduction of new components) and protocols detailing precautions need to be in place. Appropriate justification of procedures outside of conventional guidance need to be documented. Associated hazards need to be dealt with also.

b). The importance of following procedures, such as eliminating stray beams/reflections and enclosing exposed beams as far as reasonably practicable needs to be strongly re-emphasised. Human factors need to be taken into account especially where there may be hazardous open beam work; in this case an eagerness to get results may have been a contributory factor.

c). Procedures in the event of an injury or suspected injury need to be in place and effective. In most laser eye injuries there is not a lot that can be done to rectify damage; it is essential that competent examinations are carried out as soon as possible and within 24 hours of the injury. Referral to Moorfields Eye Hospital in London should be made in the event of a serious laser eye injury. Thus in light of the number of injuries recently in the UK research institutions, emergency procedures in place need to be checked as to whether they are appropriate (all Class 3B/Class 4 laser users and their supervisors need to be aware of what to do*). (Arrangements with Dept of Ophthalmology, RHH last checked Oct 2004. - see also Para 4.4)*

2. At Los Alamos National Laboratory, California USA, 2004

On 14th July 2004 an undergraduate student was injured whilst working with a Nd:YAG laser in the Chemistry Division. The work involved the use of two lasers one to analyse particles (L1) and one to generate and suspend particles in a target chamber (L2). On the day in question the Principle Investigator (PI) was using L1 in flash-lamp mode to illuminate the suspended particles. After firing and shutting down L2 the PI removed the beam stop from behind the target chamber and looked inside whilst L1's flash lamps continued to operate. When the student bent down to look too she immediately saw a flash and a reddish-brown spot in her left eye - a hole had been burnt in her retina.

An investigation followed and PI claimed that he was operating L1 with the Q-switched trigger cable disconnected from the pulse generator, however the investigating team confirmed that the laser could not lase under those conditions.

The accident investigation team found the following failures of management and procedures:-

- Neither the PI nor the student were wearing laser eye protection and there were no engineered safety measures in place.
- The PI did not recheck beam alignment or laser condition or check for beam reflections on July 13 or 14.
- The PI prepared an insufficiently detailed risk assessment/scheme of work and had not updated it to reflect experimental changes.
- The student had not received proper pre-job training and had been asked to sign up to the scheme of work after the accident.
- Line managers responsible for the area had not monitored PIs safety practices
- The Line Manager and Laser Safety Officer had signed off PIs risk assessment/scheme of work without noting the lack of detail.
- Management did not ensure that PI followed the Local Rules
- No PI training in relation to mentoring students

As a result of this incident the Los Alamos Lab was required to review its procedures, improve safety management and improve training of mentors and students to ensure that this type of incident would hopefully not occur again.

Four top scientists faced disciplinary action after the accident, the Principal Investigator was sacked and there was considerable disruption to the work of the laboratory during the course of the investigation and the procedural review.

Both these accidents have similarities. In neither case was safety eyewear being worn. In both cases 2 lasers were being used and the individual was struck in the eye with a pulse from a pulsed laser that they were not expecting. If you are viewing an experimental set-up either:

- *a proper shutdown procedure must be followed before looking down beam-paths, or*
- *safety eyewear must be worn(but not to deliberately look down beam paths!), or*
- *viewing should be via a video camera in a safe location.*

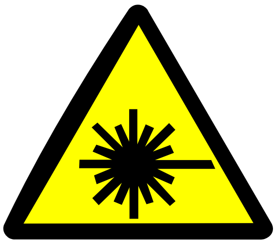
Appendix 6

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 p26 of BS EN 60825-1:2007

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 Fig 2 p27 of BS EN 60825-1:2007.

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:-

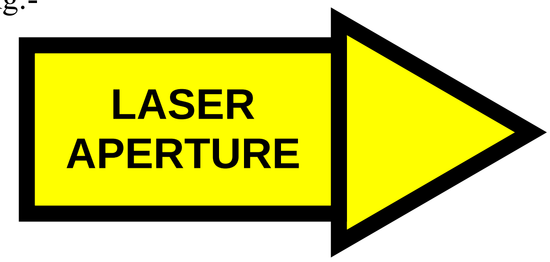
Class 4

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 is visible, invisible or both
- pulse duration (if appropriate)
- name and publication date of classification standard

We have also put on our labels details of the type of laser and the lasing medium, although this is not a BS requirement.

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

Appendix 7

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 -1:2007 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 8

SUMMARY OF BS EN 60825-1:2007 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.

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 9

RESOURCES & LINKS

Information sources

Further information on laser safety can be found from accessing the Health Protection Agency website at:-

http://www.hpa.org.uk/webw/HPAweb&Page&HPAwebAutoListName/Page/1158934607703?p=1158934607703

HPA/NRPB have published guidance on the purchase and use of laser pointers:-

http://www.hpa.org.uk/webw/HPAweb&HPAwebStandard/HPAweb_C/1195733794576?p=1158934607693

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

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://photonics.bfioptilas.co.uk/Laser+Safety&Accessories-17.htm

Lasermet sell an extensive range of laser safety products and laser safety software. They also offer a design and safety consultancy service and were founded by one of the leading laser experts in the UK - Prof Bryan Tozer. A lot of useful information can be found on their site at:-

http://www.lasersafety.co.uk/

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.electrooptics.com/

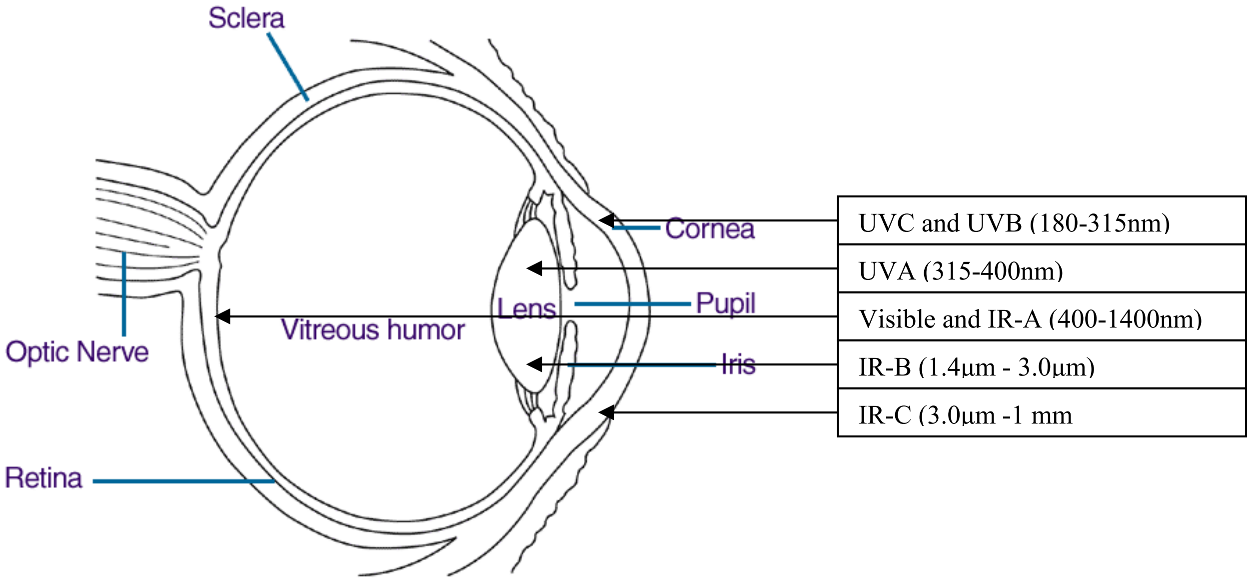
Laser Physics UK market a range of laser safety eyewear, power meters, optical components, safety barriers, curtains and blinds and laser safety software. Details can be found at:-

http://www.laserphysicsuk.com

Appendix 10

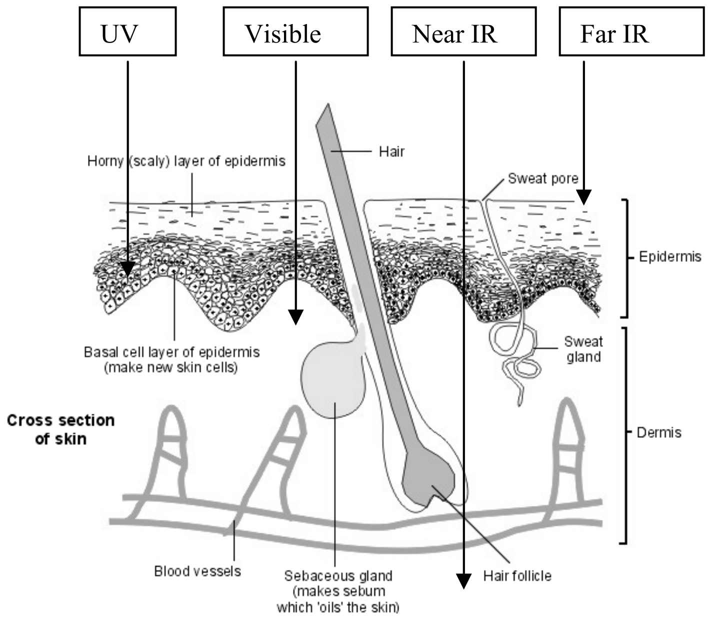
OPTICAL HAZARDS AND BIOLOGICAL EFFECTS OF LASER RADIATION

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>Spectral Region</th><th>Eye</th><th colspan="2">Skin</th></tr>
<tr><td>UV-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>UV-B (280-315nm)</td></tr>
<tr><td>UV-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>IR-A (780-1400nm)</td><td>cataract, retinal burn</td><td rowspan="3"></td></tr>
<tr><td>IR-B (1.4µm- 3.0µm)</td><td>aqueous flare, cataract, corneal burn</td></tr>
<tr><td>IR-C (3.0µm- 1mm)</td><td>corneal burn only</td></tr>
</table>

More detailed information on biological effects can be found in Annex D to BS-EN 60825-1:2007. This is also repeated as Annex C to PD IEC TR 60825-14:2004.

Appendix 11

AUTHORIZED LASER USER TRAINING RECORD FORM

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