February 2006

UNIVERSITY OF SURREY
CODE OF PRACTICE FOR WORKING SAFELY WITH LASERS

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1. SUMMARY

Lasers present a radiation hazard and can cause damage to the eyes and skin, the use of lasers can generate a set of additional significant hazards.

2. SCOPE

The aim of this document is to outline the elements of good laser practice and it applies to all lasers and their use in the University.

3. RISKS

Lasers produce electromagnetic radiation that is coherent, monochromatic and has low angular divergence, and this laser "light" can cause damage to the eye or burns to the skin and can also present a fire or explosion hazard. The magnitude of the damage is dependent on the power output of the laser which also determines the classification of the laser. Further information of classification of lasers and the optical and biological effects of lasers is given in this guidance.
The direct hazard of laser radiation is not the only risk associated with lasers. These are complex pieces of equipment that for instance require a high voltage supply, can use highly toxic chemicals as the lasing medium, may be supplied with specialist gases and may need cooling. These supplies and the complex connections and processes involved introduce significant non-beam hazards.

4. CONTENT

This Code of Practice sets out the standards that must be achieved for all lasers. Herein, you will be informed of your responsibilities and those of other laser workers, the Laser Supervisor (LS), Laser Safety Officer (LSO) and the Laser Safety Adviser (LSA). You will find the documentation required and compulsory training available in order to get started as a laser user. The enclosed outlines what equipment and who needs to be registered and with whom. Risk methodology for lasers is provided.

For your convenience the main implications of the laser standards and details of the new laser classes are included in this document. Also included are the contingency plans to be used in the event of an accident and these are also displayed at each laser laboratory. Further, there 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.

A brief summary of the biological effects of laser radiation is given.

5. GLOSSARY OF ABBREVIATIONS

LSA Laser Safety Adviser

LSO Laser Safety Office – there is one for each school where lasers are used

LS Laser Supervisor

SOP Safe Operating Procedure

AEL Accessible Exposure Limits

LED Light Emitting Diode

MPE Maximum Permissible Exposure

NOHD Nominal Ocular Hazard Distance

OD Optical Density

6. RISK CONTROL STANDARD

If a School or Service Department has lasers then it must have

- a Laser Safety Officer, and
- a Laser Supervisor for each Laser suite within that School.

All lasers, other than Class 1 must be registered with the Laser Safety Adviser in the H&S Office and used in accordance with this Code of Practice. All registered lasers and their use must be risk assessed by the Laser Supervisor in line with the guidance contained in this document. All risk assessments must be checked against the requirements of BS EN 60825 as outlined in **Appendix 4**

Before any work with lasers, all laser users must have received appropriate instruction and guidance, and must have confirmed that they have understood the contents of this code of practice and other written guidance given to them. Further all lasers users must be registered with the Health and Safety Office prior to starting work, as outlined in **Appendix 1**

All lasers workers must attend induction training in the safe use of lasers and are required to attend refresher training every two years.

Each laser suite containing Class 3B or 4 lasers must have local rules that are documented. These local rules must include

- Engineering controls that apply to each Class 3B or 4 laser in the suite
- The nature and management of personal protective equipment available
- The management structure in the School
- The administrative controls that must be followed
- Any special procedures that must be followed
- A copy of the University's standing instructions on contingency plan and Quality standard for PPE

The Laser Safety Officer must understand the requirements of, and ensure compliance in their School with, this Code of Practice.

All lasers must be labelled appropriately as detailed in **Appendix 11**

Operating instructions/procedures (SOPs) must be drawn up and implemented for the safe operation of all Class 3B and Class 4 lasers that are not totally enclosed and for other lasers where there is a hazard to people if the laser is not operated appropriately.

Laser safety goggles must be provided, maintained in accordance with the Quality requirements and worn as required by risk assessment, SOPs and local rules by all users working with Class 3B and 4 lasers where the beam is not totally enclosed.

Undergraduates working with lasers should be provided with the lowest power laser practicable and are required to follow a written scheme of supervised work.

Written instructions must be issued to staff or contractors (and to their managers) who have approval to enter a laser suite for specific purposes such as cleaning, waste collection and maintenance or servicing work.

7. WHO DOES WHAT AT THE UNIVERSITY

The Vice-Chancellor has overall responsibility for ensuring the effective management of all health and safety matters including laser safety in the University.

Radiation Protection Adviser/Laser Safety Adviser (RPA/LSA)

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/LSA is responsible for training of new staff/students, ensuring registration of lasers and users of equipment, ensuring that there is provision of a measuring service (where appropriate), inspection of all new laser facilities and routine auditing of laser facilities.

Head of School or Service Department

The Head of School or Service Department where lasers are used must appoint, in consultation with the Laser Safety Adviser:

- a Laser Supervisor for each Laser Suite, and
- a Laser Safety Officer for the School.

Laser Safety Officers (LSO)

The LSO supports the Head of School by ensuring that this code of Practice is implemented within the School. The LSO should ensure that:-

1. all lasers except for low power Class 1 devices are registered with Health and Safety Office - **Form LR1 – Appendix 7** (Full registration details only required for Class 3 and Class 4 devices **Form LR2 – Appendix8**)

   The procurement of all lasers must be approved by the LSO and the prior risk assessment agreed with the LS intending to use the laser. The LSO must advise the LSA of the approval to purchase a new laser. The laser list must be updated accordingly with copy to the LSA.

2. all lasers are labelled appropriately - see **Appendix 11.**
3. operating procedures (SOPs) are drawn up, where necessary, for the safe operation of lasers. Required for all Class 3B and Class 4 when not totally enclosed and that all risk assessments made by the LS are suitable and sufficient.
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 the Health and Safety Office.**(Form LR3 (P) – Appendix 9)**
5. all registered laser workers receive training in the safe use of lasers, a certificate will be issued and refresher training will be required every two years.
6. laser safety goggles are provided and worn (when appropriate) by all people working with Class 3B and Class 4 lasers where the beam is not totally enclosed.
7. undergraduates working with lasers should use the minimum power laser practicable and follow a written scheme of supervised work

Laser Supervisor (LS)

The Laser Supervisor should be a Research Supervisor or Principle Investigator for the laser suite. The health and safety management of individual research projects is normally delegated to the LS who has a responsibility to ensure that all work is covered by risk assessments and where appropriate by written protocols. They should also ensure that their laser workers are effectively trained in the operating techniques required and that inexperienced members of staff are adequately supervised.

The procurement of new lasers must be advised to the LSO with full justification for requirement of new laser, and requirement for that class of laser. This must be accompanied by a prior risk assessment for the intended use. Only once the LSO has approved the procurement and informed the LSA can the laser be imported.

Laser Supervisors must register all their lasers (except for Class1) with the LSA who must update their records at the point of registration. The updated Laser register must be sent to the LSA in the H&S Office.

The disposal of any laser when no longer required must be made via the School Safety Adviser and the University Waste Administrator, and must be noted to the LSO and LSA.

Laser Users

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

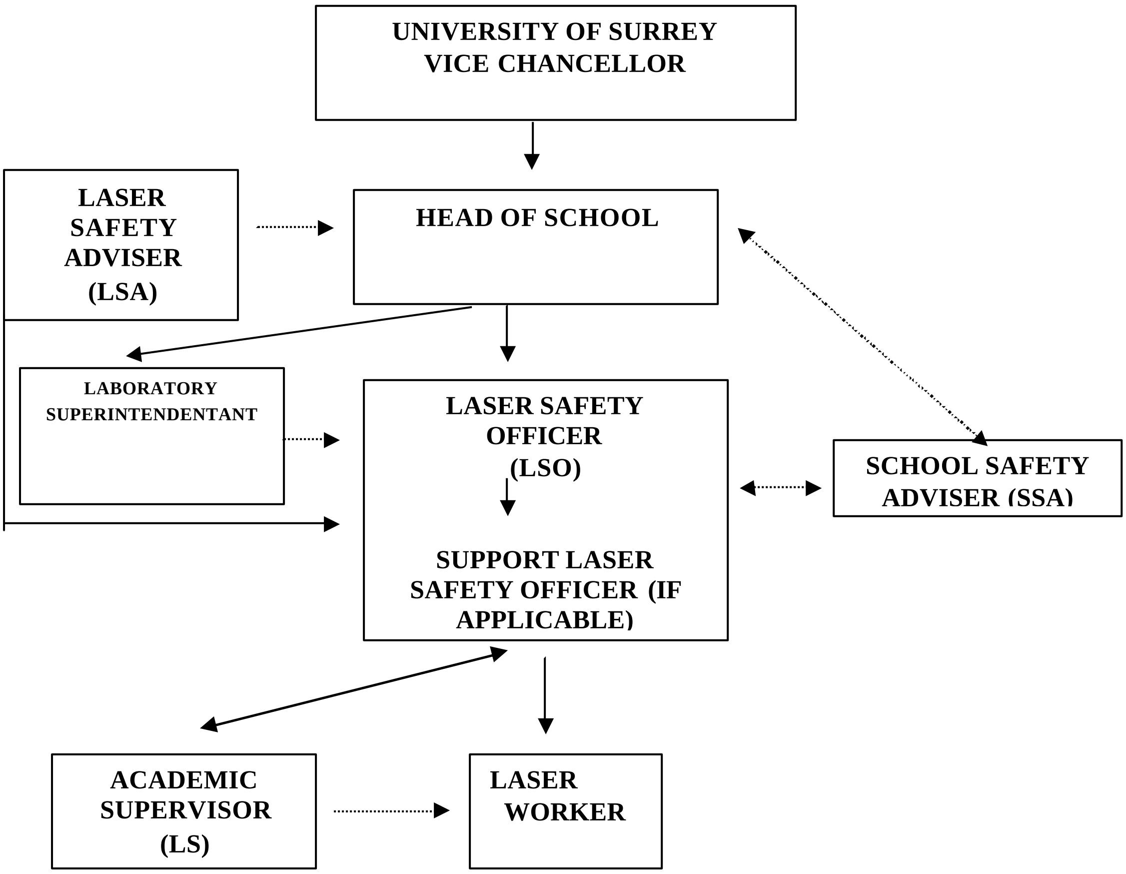
Students involved in project work and working with Class 3B or 4 lasers will be treated as laser workers and should be registered as such. They should also be given close supervision if working with high-powered lasers.

The must observe these Guidance Notes, any SOPs applicable to the lasers that will be used, and to follow the guidance of supervisors and the 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.

When working with Class 3B or 4 lasers and there is the possibility of stray laser beams that could damage the eyes, the <u>appropriate</u> laser goggles **MUST BE WORN** .

8. ORGANISATION FOR LASER SAFETY



REPORTING LINE TO MANAGEMENT

LASER WORKERS MEETING/LIAISON WITH LSO

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HAZARDOUS SUBSTANCES AND EQUIPMENT COMMITTEE - ATTENDED BY LSA, HEAD OF HEALTH AND SAFETY, AND SCHOOL SAFETY ADVISERS

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UNIVERSITY HEALTH AND SAFETY EXECUTIVE COMMITTEE ATTENDED BY HEAD OF HEALTH AND SAFETY AND PRO VICE CHANCELLOR FOR HEALTH AND SAFETY

↓

UNIVERSITY OF SURREY EXECUTIVE BOARD

APPENDIX 1. GETTING STARTED

Procurement of new lasers.

Any worker wishing to purchase or import a new laser to the University must make application to the LSO for approval to do so. This application must be accompanied by a prior risk assessment for the intended use and location, and both the requirement for a new laser and that class of laser.

Registration of Personnel - Use Form LR3(P) (Appendix 9)

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 the LSA in the Health and Safety Office via their Laser Safety Officer (LSO). The LSO 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, training by both the LS and as arranged by the LSA. The LSO should ensure that they receive copies of any relevant schemes of work.

Registration of Lasers - Use Form LR1 for Classes 2,2M, 3M – Appendix 7, and Form LR2 for Classes 3R, 3B and 4 – Appendix 8.

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 Health and Safety Office. Class 3R, 3B and 4 devices must all be registered individually whereas just the use of other lower powered devices needs to be registered. The LSA 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 will ensure that a suitable and sufficient SOP has been drawn up (usually by the LS) to cover their use.

SOPs are essential 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.

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 every two years particularly for employees with responsibility for supervising and training others. Records of training are kept by LSA, and it is advised that departments keep their own records as well. Training is usually provided by an external trainer, but in the intervening times between courses, provision of a training session is given in the Health and Safety Office once a month to cover safe working practice, laser classification, AELs, PMEs and Risk Evaluation and Assessment.

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 the Health and Safety Office and the Occupational Health Department.

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. 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

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/protocol 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 as such. They should also be given close supervision if working with high-powered lasers.

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 11**. 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 should be obtained and your LSO will advise.

Laboratory Design

The following considerations relate mainly to the use of Class4 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.

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 (N. B 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!

APPENDIX 2. RISK EVALUATION AND ASSESSMENT

It is important that an adequate risk assessment is carried out of every laser installation and associated equipment in each laser suite. 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.

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

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?

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.

Protective Control Measures

In dealing with any hazard one should look first to containing the hazard if reasonably practicable by:

- **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 THE LAST RESORT and, where unavoidable, 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.

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. It should be noted that with the changing nature of experimental work it is important that the risk assessment is routinely reviewed.

* Note also the **Laboratory Design** and **Experimental set-up** in the Getting Starting section of the Code of Practice for further basic risk reduction measures that should be considered

APPENDIX 3. CONTINGENCY PLANS

Any laser incident or accident must be reported to the Laser Safety Officer and the School Safety Adviser who will report to the Health and Safety Office. A University Accident Form must be completed and sent to the Health and Safety Office.

For Ocular injury Accident

Following an incident/accident any equipment must be isolated pending investigation. If ocular exposure has occurred, a full investigation into the cause and nature of the exposure must be undertaken and recorded in full.

If there is suspected injury to the eye, the injured person should see a specialist ophthalmologist at the Royal Surrey County Hospital within 24 hours. The injured person should not drive.

The Laser Safety Officer must report any injury to the Occupational Health Department to ensure follow up for the injured person.

If an opthalmologist is not available at the RSCH, the injured person should be sent within 24 hours to Moorfields Eye Hospital where the medics are experienced in dealing with laser eye injuries.

Details of the laser beam should accompany the casualty to hospital. These should include type of laser system, classification, wavelength, power/energy per pulse and pulse duration.

Royal Surrey County Hospital
Accident and Emergency Department open 24 hours a day
Address: Egerton Road, Guildford, GU1
Telephone Number: 01483 571122

Moorfields Eye Hospital
Accident and Emergency Department open 24 hours a day
Address: 162 City Road, London EC1V 12PD
Telephone: 0207253 4696
Location and directions to A&E department available at
www.moorfields.org.uk/Locations/CityRoad

APPENDIX 4: Legislation and standards for Lasers

The safety of laser products is covered by BS EN60825:1994 (incorporating amendments 1,2 and 3) This BS is a `euronorm' based upon the International Electrotechnical Commission's IEC 60825-1. The 60825 standard encompasses a range of standards for manufacturer's and users on lasers, fibre optic systems, safety eyewear, laser guards, components etc. Of particular importance for user's 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. You are advised to refer to this document for further guidance on determining MPEs (maximum permissible exposure levels), evaluating risk, control measures, interlock systems, calculations and biophysical considerations. There is also software available in the Safety Office for these purposes

All the British Standards on laser safety are available online and your LSO and LS will direct you to the relevant website.

APPENDIX 5: LASER CLASSIFICATION

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'. This definition now incorporates semi-conductor devices and **LED**s (**light emitting diodes**).

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 60825-1:1994), and **AEL**s (**accessible emission levels**) have been set for each class of laser (see Tables 1-4, p36-39 BS EN 60825-1: 1994). In the descriptions below the lasers cover the full wavelength range unless a restriction is stated.

Class 1 Lasers

The AEL is less than or equal to the MPE

These are normally safe to both skin and eyes 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. However 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.

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 satisfy the measurement conditions for a Class 1M product. However they may be hazardous to the eyes under certain conditions if gathering optics (magnifying products) 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.

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 (for exposures less than 0.25 seconds). There is no hazard to the skin.

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 satisfy the measurement conditions for a Class 2M product. However they may be hazardous to the eyes under certain conditions if gathering optics (magnifying products) 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.

Class 3R Lasers

These are laser products, emitting in the wavelength range 302.5nm to 1mm, that present only a 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.(5 x 1 mW = 5mW) Direct eye exposure should be prevented. Safe to skin.

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 unless you are close to the beam (<13 cm away). 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. Maximum power is 500 mW.

Class 4 Lasers

These are high power devices that exceed the AELs for Class 3B devices and are always hazardous to the eyes and skin from direct viewing and from specular reflections. Diffusesly reflected beams should be assumed harmful to the eyes and skin unless proven otherwise by risk assessment. Both direct and scattered beams have sufficient energy to ignite materials and produce hazardous fumes. Their use requires extreme caution.

Example AELs

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

- Class 1 and 1M0. 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 60825-1:1994 for full details.

APPENDIX 6: 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 MPEs and tables of values - p48-64 of BS EN 60825-1:1994or p49-52 of PD IEC TR 60825-14:2004.

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

- intrabeam viewing - $0.1 mW.cm^{-2}$
- skin exposure - $200 mW.cm^{-2}$

APPENDIX 7: LASER REGISTRATION FORM (2, 2M, 3R) Form LR1

University of Surrey
LASER REGISTRATION FORM Classes 2, 2M, 3R

School:	
Laboratory:	
Responsible Person (Laser Superviser)	
Make, model and Serial Number	
Laser Details: Class:	Lasing medium: Wavelength range: Mode of operation: Maximum Power/ Or pulse energy: Beam Diameter: Beam Divergence:
Brief Description of Use: (Attach Risk Assessment)	
Signature:	Date:
Registration and Risk Assessment Approved Signature of LSO:	Date:

FOR SAFETY OFFICE USE	
LASER CLASS	**Date Inspected**
Signature LSA:	

APPENDIX 8: LASER REGISTRATION FORM (3B AND 4) Form LR2

LASER REGISTRATION FORM FOR USE OF CLASS 3B AND 4 LASERS INCLUDING FULL RISK ASSESSMENT - FORM LR2

THIS DOCUMENT IS AVAILABLE:

1. ON THE HEALTH &SAFETY OFFICE WEBSITE
2. FROM YOUR SCHOOL LASER SAFETY OFFICER
3. FROM THE LASER SAFETY ADVISER IN THE HEALTH & SAFETY OFFICE

APPENDIX 9: PERSONAL REGISTRATION FORM Form LR3(P)

UNIVERSITY OF SURREY RADIATION PROTECTION SERVICE
LASERS - PERSONAL REGISTRATION FORM

All prospective users of lasers except undergraduate students working in set laboratory classes must complete this form before work starts. Users include employees, students and visitors carrying out experimental work under contract or otherwise.

1. PERSONAL DETAILS

Surname:	Other Names:	Title:
School or Department:	University Library No:	Date of Birth:
Phone or Extension No:	Staff/UG/PG/Visitor:	

2. WORK DETAILS

Description of Work and/or Project Title:	
Start Date:	Finish Date:

3. PREVIOUS LASER EXPERIENCE

Establishment and Address:	Description of Work:	Period:

4. CONDITIONS APPLYING TO REGISTRATION

I have read and understood the |University Guidance for Working Safely with Lasers and I have undertaken mandatory training provided by the Laser Safety Adviser, and Laser Supervisor. I agree to comply with the Guidance, Local Rules and Special Operating Procedures that may apply to work areas that I enter.

Signature:_______________________________________Date: ________________

Laser supervisor signature________________________Date: ________________

Laser Safety Officer signature ____________________ Date: _________________

5. Laser Safety Officer will retain a copy of this form and send a copy to the Laser Safety Adviser.
Comments :

APPENDIX 10: WHO DOES WHAT IN LASER SAFETY AT THE UNIVERSITY OF SURREY FORM LR4

This checklist is intended as a guide to actions required by users and the laser safety community. The list is not intended to be definitive but ensures compliance with the Guidance notes, and there may be further actions required by the users, supervisers, and officers in compliance with School Safety strategies. The final column is for safety office audit purposes only.

ACTION	**LS**	**LSO**	**LSA**	**LASER USER**	**SAFETY AUDIT**
Advise LSO of new laser or modification to existing one	**X**				
Advise LSA of new laser or modification to existing one		**X**			
Complete registration forms LR1or LR2 along with risk assessment, SOP and Safety Rules and send copies to LSO	**X**				
Complete personal registration form LR3(P) and send to LSO with copy to LSA				**X**	
Retain Risk assessment form for the information of all users and to be available for HSE inspection	**X**				
Arrangement for Safety Training			**X**		
Risk assessment and laser class checked BEFORE any work commences – must be signed off		**X**	**X**		
Advice on eye protection		**X**			
Read and understand Guidance notes, SOP and local rules				**X**	
Advice supervisor and occupational health on any eye defects other that short sight				**X**	

APPENDIX 11: 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. The signs shall incorporate the following information:

1) hazard warning symbol (detailed 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 Fig 15 p66 of BS EN 60825-1.

Where the size of the laser product does not permit the affixing of a reasonably sized label then 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(E) - 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.

Details of wording required on explanatory labels is given below.

Class 1(E)

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 ? 400nm-1400nm ONLY.

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

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

Class 3B

Label with hazard warning symbol.

Explanatory label bearing the words:-

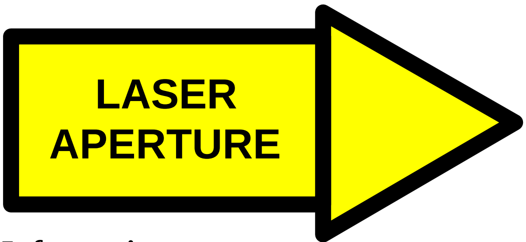
Class 4

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.

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

APPENDIX 12: 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 may be necessary especially 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 from near the beam path, 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.

APPENDIX13: 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 access to Class 3B or4 lasers
4	Emission indicator -	an audible or visible indicator should be provided by the manufacturer for each Class 3R laser (400-700nm) and each Class 3B and Class 4 laser system
5	Beam stop or attenuator/shutter -	should be provided by 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 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
14	Door/Area signs -	required for Class 3B and Class 4 lasers indoors and also for Class 1M, 2M and 3R if used outdoors

***** Note: When engineers come into the University to install, maintain or repair any lasers, it is essential that the LSO/LS obtain their risk assessment, have a protocol for hand over procedure and exclude all workers from area unless involved in the maintenance procedure**

<u>BUT BEAR IN MIND THAT THE UNIVERSITY AS THE EMPLOYER IS RESPONSIBLE FOR HANDLING ANY INCIDENT/ACCIDENT IF IT OCCURS.</u>

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:		**?:**		**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

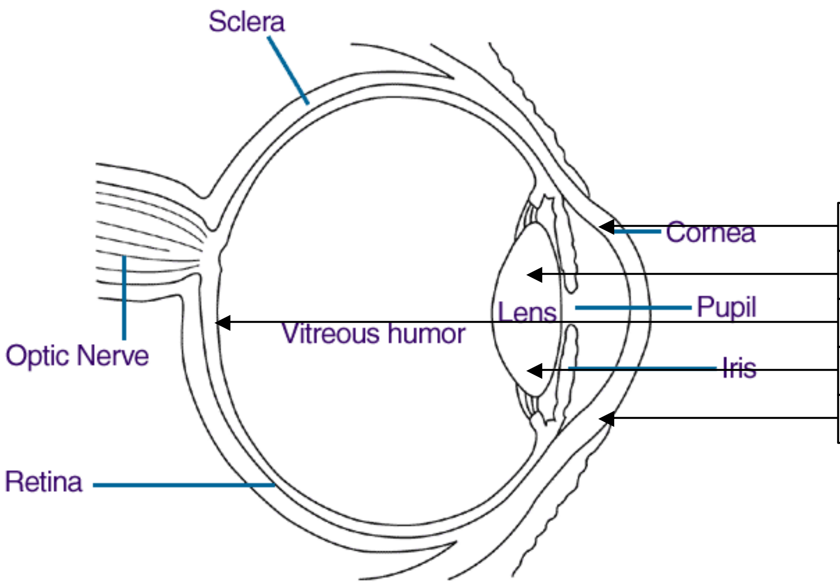
Laser installation: satisfactory/ not satisfactory

Additional control measures required:...
....
....
....

Survey performed by: ....

APPENDIX 14: OPTICAL HAZARDS AND BIOLOGICAL EFFECTS OF LASER RADIATION

Penetration of laser radiation into the eye



UVC and UVB (180-315nm)
UVA (315-400nm)
Visible and IR-A (400-1400nm)
IR-B (1.4µm - 3.0µm)
IR-C (3.0µm -1 mm

NB Short pulsed high peak-power lasers are particularly hazardous to the eye, particularly at

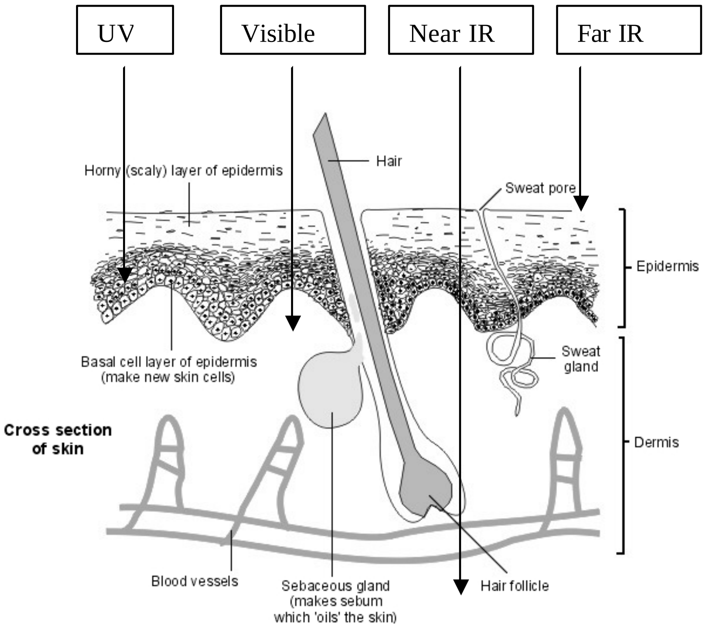
wavelengths that reach the retina, as they deliver a lot of energy in a short period of time that

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



The skin can tolerate a great deal more exposure than the eye and less research has been done on damage mechanisms. In general all lasers can cause surface burns of the skin and with high-powered lasers there would 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.

Summary of biological effects associated with excessive exposure to optical radiation

Spectral Region	Eye	Skin	
UV-C (180-280nm)	Photokeratitis	erythema (sunburn) accelerated skin ageing increased pigmentation	
UV-B (280-315nm)			
UV-A (315-400nm)	Photochemical cataract	pigment darkening photosensitive reactions	Skin burn
Visible (400-780nm)	Photochemical and thermal retinal injury		
IR-A (780-1400nm)	Cataract, retinal burn		
IR-B (1.4µm- 3.0µm)	Aqueous flare, cataract, corneal burn		
IR-C (3.0µm- 1mm)	corneal burn only		

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 15: 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 user 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 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 ware of what to do*)*

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.
- Responsible line managers 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 and the Principal Investigator was sacked.

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 without safety eyewear, or*
- *safety eyewear must be worn, or*
- *viewing should be via a video camera in a safe location.*

APPENDIX 16: USEFUL LINKS

Information sources

Further in formation on laser safety can be found from accessing the Health Protection Agency (HPA) website at:-

http://www.hpa.org/laser/index.htm

HPANRPB have published guidance on the purchase and use of laser pointers:-

http://www.hpa.org/press/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

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 and were founded by one of the leading laser experts in the UK - Prof Brian Tozer. 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