University of St. Andrews

Local Rules for Work with Lasers

(*2006*)

Contents **Page Number**

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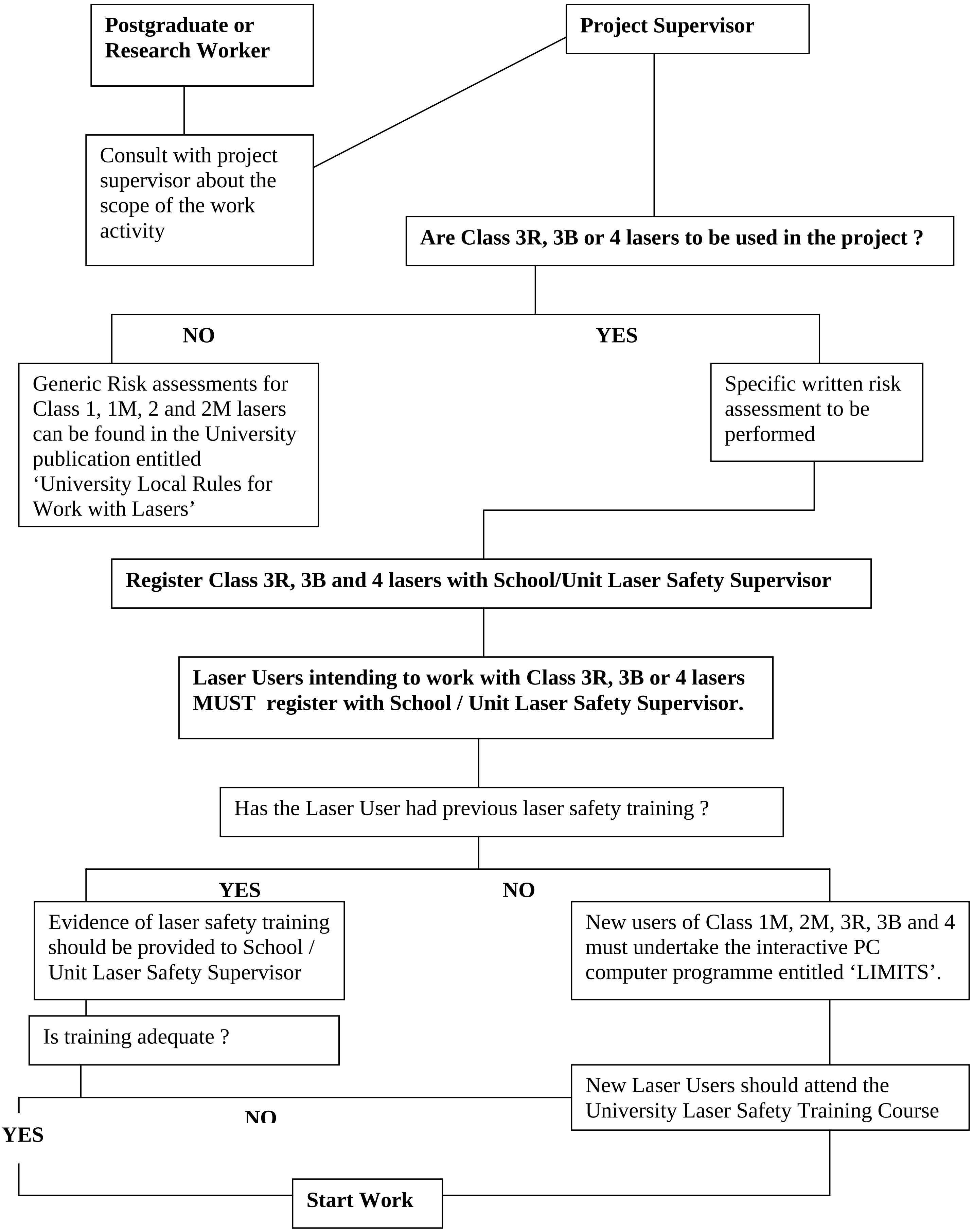
Guidelines for Commencing Work with Lasers



1. **Introduction**

Coherent light sources (i.e. lasers) and high powered light emitting diodes (LEDs) can generate significant quantities of power over small areas and at significant distances from the light source. As a consequence there are potential risks associated with the use of such equipment. These include the risk of fire, thermal injuries to the eyes and skin as well as photochemical reactions in the eye and skin.

There is no specific legislation for laser safety, however, the Management of Health and Safety at Work Regulations 1999 require that all work with a significant risk of injury (which will include work with lasers and LEDs) must be risk assessed and appropriate control measures implemented to eliminate or minimise the risk of injury. The British Standard BS TR 60825 - Part 14 gives details on laser safety good practice and the following guidance is based on this document.

1.1 Biological Effects of Lasers

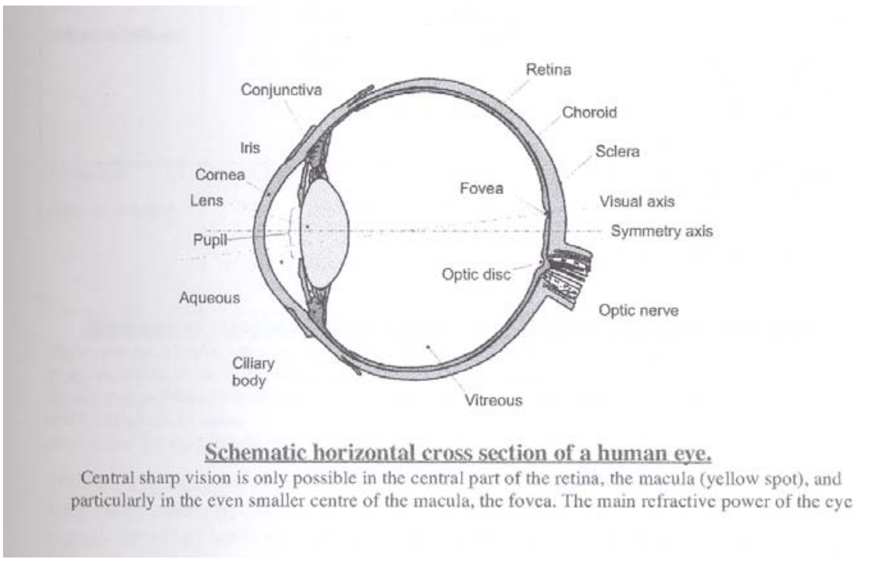
The two major effects on biological tissue of lasers are thermal injuries and photochemical type injuries.

Thermal injuries occur when the tissue is heated to above 60^{o}C causing cell death and if heated sufficiently causes carbonisation of the tissue. This type of injury is non-cumulative in nature, thus either a very high powered laser or a long exposure period to a low powered laser is required to cause such an injury. This type of injury is more common with the non-visible wavelengths as the eye aversion response is not present.

Photochemical injuries are caused by the light inducing chemical reactions in the biological tissue. This type of injury is strongly wavelength dependent and depends on the accumulated radiant exposure (J m^{-2}). This means that the effects of exposure are cumulative over time.

1.2 Laser Induced Injuries to the Eye.

The eye is made up of many parts each with different sensitivities to the various wavelengths of light produced by lasers (see Figure 1).



Schematic horizontal cross section of a human eye.
Central sharp vision is only possible in the central part of the retina, the macula (yellow spot), and particularly in the even smaller centre of the macula, the fovea. The main refractive power of the eye

Figure 1
(From: Laboratory Laser Safety Training Course - Provided by Dr. Mike Green, Pro Laser Consultants)

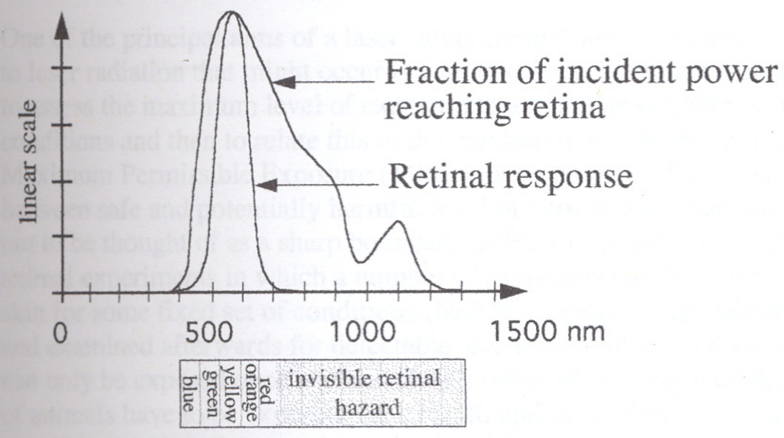
Damage to the eye by laser radiation can be permanent as specific regions of the eye cannot be regenerated e.g. the lens and retina.

The damage caused to the eye is dependent on the wavelength of the light, the length of time exposed to the beam, and the type of laser (i.e. pulsed lasers have very high powered pulses of light over very short periods). Table 1 gives examples of the types of injury lasers can cause to the eye:

Wavelength Range	**Tissue Affected**	**Short Pulse Injury**	**Long Exposure (over several seconds or more) from Continuous Wave (CW) Lasers and Repetitively Pulsed Lasers**
Ultraviolet (180 nm to 400nm)	Cornea and lens	Thermal damage dominates. Denaturation (clouding) of cornea and at 280nm - 400 nm lens. ***Short Pulses*** - Photoablation of corneal tissue with high power pulses	Photochemical damage dominates. Photokeratitis (‘arc-eye’ or ‘snow blindness’) of the cornea. Photochemical cataract (at 280nm to 400nm).
Visible and Near Infra-Red	Retina	Thermal damage dominates. Burn (protein degradation) with severe vision loss when damage in the foveal region of the eye. ***Short Pulses*** - Photochemical damage i.e. rupture of tissue, bleeding into the inner eye.	400 - 550 nm (Blue to Green) - Photochemical damage for exposure for more than several seconds. Visible exposure for thermal damage limited to one second by aversion response to bright light. Eye movement reduces hazard for longer durations
Far Infra-ed	Cornea and Lens	Thermal damage dominates. Denaturation (clouding) of the cornea and (at 1.4 - 1.9μm) lens. ***Short Pulses*** - Photoablation of corneal tissue with high powered pulses	Exposure for thermal damage normally limited to a few seconds by reaction to pain due to heating of the cornea. Long term infra-red cataract (1.4 - 3 μm)

Table 1 - Summary of Principle Ocular Injuries for Ultraviolet, Visible and Infra-Red Radiation
(From: Laboratory Laser Safety Training Course - Provided by Dr. Mike Green, Pro Laser Consultants)

Laser radiation in the near infra-red region (700nm - 1400nm) is not sensed by the eye either as light or as pain. The damage caused by this region of the electromagnetic spectrum can be very serious as the fraction of the power reaching the retina is high (see Figure 2) without the worker being aware of this. Many of the diode and solid state lasers (e.g. Nd:YAG) lasers are in this wavelength range thus workers should be aware of their hazards.



The eye-transmitting wavelength band and the limited range of retinal response

Figure 2
(From: Laboratory Laser Safety Training Course - Provided by Dr. Mike Green, Pro Laser Consultants)

1.3 Laser Induced Injuries to the Skin

Laser beams can have many effects on the skin depending on the wavelength and power of the laser. Table 2 summarizes the effects of lasers on the skin.

Wavelength	Effects on the Skin	
Ultraviolet UV-C (180-280 nm) Ultraviolet UV-B (280-315 nm)	Erythema (Sunburn) Accelerated skin ageing Increased skin pigmentation	
Ultraviolet UV-A (315-400 nm)	Skin Darkening Photosensitive Reactions	Erythema (Sunburn)
Visible (400 - 780 nm)	Skin Darkening Photosensitive Reactions	Erythema (Sunburn)
Infra-Red IR-A (780 - 1400 nm) Infra-Red IR-B (1400 - 3000 nm) Infra-Red IR-C (3 µm - 1 mm)		Erythema (Sunburn)

Table 2 - Summary of laser beam hazards to the skin
(Courtesy of the Health Protection Agency)

2. Policy Statement

It is the policy of the University to, so far as reasonably practicable, ensure the health safety and welfare of staff / students at the University and of those who may be affected by this work.

Thus, it is the policy of this University that all work with lasers is carried out in such a manner as to prevent undue risk to those performing the work or put others at risk due to their actions or omissions.

This document will describe the arrangements the University has put in place to manage laser safety.

Work with lasers should only be carried out if a suitable assessment of the risks of the work are identified and that appropriate control measures are implemented to eliminate or minimise the risks of the hazards. This guidance will provide practical information on how risk assessments on work with lasers can be performed and the actions which should be taken to minimise these risks.

Staff and students have a responsibility to take care of their own health and safety with respect to laser safety and that their acts or omissions do not endanger the health and safety of others. Workers also have a responsibility to comply with any instructions provided by management regarding laser safety matters.

3 Management and Organisation of Laser Safety

The management of laser safety within the University is given in Appendix 1.

3.1 The Radiations Hazards Sub-Committee

This is a Sub-Committee of the University Health and Safety Committee and is responsible for determining laser safety policy for the University. These policies must be complied with in Schools/Units.

The Radiations Hazards Sub-Committee is responsible for ensuring University policies are being complied with and it does this by performing laser safety audits.

This Sub-Committee oversees the work of the University Radiation Protection Service which carries out the day-to-day work of the Sub-Committee.

Membership of this Sub-Committee is given in Appendix 2.

3.2 The University Laser Safety Adviser

The University Laser safety Adviser provides specialist advice on laser safety to the Radiations Hazards Sub-Committee, management (senior management, Heads of Schools/Units and School/Unit Laser safety Advisers) and to laser workers on request. The remit of the University Laser Safety Adviser is given in Appendix 3.

3.3 Laser Safety Responsibilities of the Head of School

The Head of School / Unit must ensure that University laser safety policies are implemented and being complied with.

The Head of School/Unit should ensure that an appropriate annual inspection of laser safety is carried out.

The Head of Schools/Units where lasers are used should appoint a School/Unit Laser Safety Supervisor. The person appointed should have suitable experience, knowledge about the physics of lasers and the biological effects of the lasers.

3.4 School / Unit Laser Safety Supervisor

The remit of this post includes:

- Advise the Head of School/Unit on matters relating to laser safety.
- Provide laser safety advice to Heads of Research Groups, Research Staff/Students, Teaching Lab Personnel and other Laser Workers within the School.
- Make available appropriate training in laser safety to University Laser Workers based within the School/Unit.
- Make available for consultation current Codes of Practice, Guidelines and other literature.
- Assist (the University Laser Safety Adviser and University Safety Office) in the reporting and investigation of suspected laser accidents and near misses and ensure that appropriate medical advice has been sought after such incidents.
- Carry-out annual laser safety audits in conjunction with University Laser Safety Adviser on behalf of the Radiation Hazards Cub-committee and report findings/actions to Heads of Research Groups, Head of School/Unit and Radiation Hazards Cub-committee.
- Ensure that all work involving lasers (Class 1M, 2M, 3R, 3B and 4) within the School/Unit is risk assessed.
- Ensure that all lasers (Class 1M, 2M, 3R, 3B and 4) and all Laser Workers are registered with the School/Unit.
- Maintain records of School/Unit; Registered Laser Users, Lasers and Risk Assessments.
- Provide laser safety input to School/Unit Safety Committee meetings.

3.5 Laser Users

Each ‘Laser User’ has a responsibility for their own safety while using lasers and should not put others at risk by their acts or omissions when using lasers.

All users of laser which pose a significant risk should be registered with the School/Unit and undergo appropriate laser safety training. This means all users of Class 1M, 2M, 3R, 3B and 4 lasers. Where the laser is totally enclosed and the beam inaccessible, then the equipment is classed as Class 1 equipment even though it may contain a Class 4 laser (see section 4). Where access to a Class 4 laser in Class 1 equipment may be envisaged in the presence of a laser user, for example during servicing or realigning, the laser user should undergo specific training and must be registered with the School/Unit.

It is, also, the responsibility of workers to:

- Register as a Laser User with the School Laser Safety Supervisor using the form in Appendix 4;
- Ensure the laser(s) they intend to use are registered with the School Laser Safety Supervisor;
- Attend, as soon as practicable, a viewing of the latest version of the laser safety video (this should be carried out before work with Class 3R or above lasers starts);
- Read the University Local Rules for Work with Lasers;
- Attend the laser safety training session organised by the School of Physics and Astronomy;
- Acquaint themselves with the School/Unit precautions and procedures for managing laser safety;
- Comply with relevant laser safety instructions issued by the University and by the School/unit.

3.6 Registration of Lasers

All lasers being used within a School/Unit should be registered with the School/Unit Laser Safety Supervisor. This should be done using the form in Appendix 5.

Where a laser has been decommissioned or removed from the University, the School/Unit Laser Safety Laser Supervisor should be notified as soon as reasonably practicable.

3.7 Laser Safety Training

All users (including staff, students, visiting research staff etc) of Class 1M, 2M, 3R, 3B and 4 lasers **must** attend the University annual laser safety training course which is organised by the University Laser Safety Adviser and held in the School of Physics and Astronomy. If a new worker (staff, student, visiting research worker etc) arrives at a time prior to being able to attend this course, these workers **must** undergo the PC based interactive training exercise entitled 'LIMITS' **before starting their work at this University**. Workers who have undertaken this PC based interactive programme **must** also attend the annual training course at the earliest opportunity.

The School/Unit Laser Safety Supervisor should be notified, who will also notify the University Laser Safety Adviser, of all visiting research workers who intend to use Class 1M, 2M, 3R, 3B or 4 lasers. The University Laser Safety Adviser will then decide on the level of training the visiting researcher should receive.

All workers should discuss the work they propose to undertake with their School/Unit Laser Safety Supervisor prior to the work starting.

4. Definitions

There are many terms used in laser safety. This section will define some of these terms.

Accessible Emission Limit (AEL) - This the power of a laser beam at the point of exit from the laser equipment.

Irradiance - is the power of a laser beam given in watts per square metre (usually for Continuous Wave type lasers)

Light Emitting Diodes (LEDs) - It is very important to note that LEDs are included in the British Standard classifying lasers.

Maximum Permissible Exposure (MPE) - This is the maximum level of energy that an organ can be exposed to without causing harm. It is usually about 10 times lower than the amount that causes harm in 50% of a population (ED_{50}).

The calculation of the MPE is complicated as it depends on the type of laser (continuous wave or pulsed laser), if pulsed, on the pulse frequency, the wavelength, time of exposure, organ being exposed (skin or eye usually). There are tables available to determine the MPE in different situations.

The MPE determines acute effects and does not relate to chronic long term effects (e.g. cataracts). The MPE, also, does not take into account the severity of injury (e.g. may be just reddening of the skin or may carbonise skin).

A 1 mW laser beam through an aperture of 7mm (the size of a dilated eye pupil) has a MPE of 25 Wm^{-2}.

You should know the MPE for the lasers you work with. If you do not know this information, you should contact your School/Unit Laser Safety Supervisor.

Nominal Ocular Hazard Distance (NOHD) - This is the point on a divergent light beam where the irradiance/radiant power is equal to the MPE.

Radiant Exposure - Is the power of a laser beam given in Joules per square metre (usually for pulsed lasers).

5. **Classification of Lasers**

Table 3 details the classification of lasers, the meaning of the classification and the warning label which should be attached to the equipment.

Class	Sub-Division	Meaning	Warning Label
Class 1 AEL<MPE	Intrinsic	Safe by virtue of the intrinsic low power of the laser, even with optical instruments	**Class 1 Laser Product**
	Engineering	Embedded laser products safe by virtue of engineering controls e.g. total enclosure, guarding, scan failure mechanism	**Class 1 Laser Product**
Class 1M AEL<MPE	Collimated	Well collimated beam, output in range 302.5 - 4000 nm with large diameter that is safe for unaided viewing but potentially hazardous when a telescope or binoculars are used	**Laser Radiation - Do not view directly with optical instruments (binoculars or telescopes)** **Class 1M Laser Product**
	High Divergence (e.g. LEDs)	Outpur in the 302.5-400nm, Safe for unaided viewing but potentially hazardous when an eye loupe or magnifier is used	**Laser Radiation - Do not view directly with optical instruments (magnifiers)** **Class 1M Laser Product**
Class 2 Maximum Output less than 1 mW		Output in 400-700nm range. Safe for unintended exposure, even with the use of optical instruments by virtue of natural aversion response to bright light	**Laser Radiation -** **Do not stare into the beam** **Class 2 Laser Product**
Class 2M Maximum output of laser equipment less than 1 mW	Collimated	Well collimated beam in the range 400-700nm with large diameter that is safe for unaided viewing by virtue of the natural aversion response to bright light but potentially hazardous when a telescope or binoculars are used.	**Laser Radiation -** **Do not stare into the beam or view directly with optical instruments (binoculars or telescopes)** **Class 2M Product**
	High Divergence (e.g. LEDs)	High divergence source with output in the range of 400-700nm. Safe for unaided viewing by virtue of the natural aversion response to bright light but potentially hazardous when an eye loupe or magnifier is used.	**Laser Radiation -** **Do not stare into the beam or view directly with optical instruments (magnifiers)** **Class 2M Laser Product**
Class 3R Maximum output of laser equipment less than 5 mW	Visible - Near Infrared	Output in range 400-1400nm. Direct intrabeam viewing is potentially hazardous but the risk is lower than for Class 3B	**Laser Radiation -** **Avoid Direct Eye Exposure** **Class 3R Laser Product**
	Other Wavelengths	Output in Ultraviolet (180-400nm) or Infra-red (1400nm - 1 mm). Direct intrabeam viewing is potentially hazardous but the risk is lower than Class 3B	**Laser Radiation -** **Avoid Exposure to Beam** **Class 3R Laser Product**
Class 3B Maximum output of laser equipment less than 500 mW		Medium Power Laser - Direct ocular exposure is hazardous even taking into account aversion responses but diffuse reflections are usually safe.	**Laser Radiation -** **Avoid Exposure to the Beam** **Class 3B Laser Product**
Class 4 Output of laser equipment is 500mW or greater.		High Powered Laser - Direct exposure is hazardous to the eye and diffuse reflections may also be hazardous. Skin and potential fire hazards.	**Laser Radiation -** **Avoid Eye or Skin Exposure to Direct or Scattered Radiation** **Class 4 Laser Product**

Table 3 - Classification of Lasers from BS TR 60825-14 (2004)
(From: Laboratory Laser Safety Training Course - Provided by Dr. Mike Green, Pro Laser Consultants)

The classification of lasers is based on the British Standard BS EN 60825-1 and is derived from the Accessible Emission Limit (AEL) laser power output of a piece of equipment containing the laser, not the laser specifically. This means that equipment where the laser is totally enclosed and thus the AEL is effectively 0 is deemed safe (and thus Class 1) even though a very high powered laser is enclosed in the equipment. If, however, the enclosure is opened (e.g. by a service engineer) such that the beam is exposed, the equipment would now be classified by the power of the laser beam which is exposed. Thus any risk assessment of engineered Class 1 laser equipment must take into account if the containment will be accessed.

6 Risk Assessments

It is a requirement of relevant legislation that a risk assessment be carried out for all work with a significant risk of injury and this will include work with lasers.

Generic risk assessments can be done for low powered Class 1, 1M, 2 and 2M laser equipment but a specific written risk assessment should be produced for Class 3R, 3B and 4 laser equipment.

Risk assessments should be carried out for the procedure not just for work with individual lasers. Thus where work involves multiple lasers and with many non-laser hazards, one risk assessment form should be used. The form which should be used to assess the risks of work with Class 3R, 3B and 4 lasers is given in Appendix 6.

NOTE: It is the duty of the Project Supervisor to undertake specific risk assessments for projects using Class 3R, 3B and 4 lasers and have them approved by the School/Unit Laser Safety Supervisor **before the work starts**. Such risk assessments should be reviewed by the Project Supervisor on an annual basis or when the work significantly changes.

6.1 Generic Risk Assessment for Class 1, 1M, 2 and 2M Lasers

Work with these classes of lasers is considered to be less hazardous than other higher powered lasers. The control measures which should be implemented for these lasers are:

Class 1 - No protective control measures are necessary under normal operation. (This may not be the case for engineered Class 1 laser equipment where the outer casing has been removed). In the case of embedded laser products containing a high powered laser, follow the instructions given on the warning labels and supplied by the manufacturer.

Special written systems of work and other precautions may be needed for on-site servicing of embedded laser products.

Class 1M - Prevent direct viewing of the laser source through magnifying viewing instruments such as binoculars, telescopes, microscopes, optical sights or magnifying lenses unless these incorporate adequate levels of protection (the type of viewing instrument that could be hazardous may be indicated on the warning label or in the user information supplied by the manufacturer).
Prevent the use of any external optics that could decrease the beam divergence or its diameter.

Class 2 - Do not stare into the beam.
Do not direct the beam at other people or into areas where other people unconnected with the laser work might be present.

Class 2M - Do not stare into the beam.
Do not direct the beam at other people or into areas where other people unconnected with the laser work might be present.
Ensure the beam is always terminated at a suitable non-specular (i.e. non-mirror) surface.
Prevent direct viewing of the laser source through magnifying viewing instruments such as binoculars, telescopes, microscopes, optical sights or magnifying lenses unless these incorporate adequate levels of protection (the type of viewing instrument that could be hazardous may be indicated on the warning label or in the user information supplied by the manufacturer).

Prevent the use of any external optics that could decrease the beam divergence or its diameter.

6.2 Work Activity with Class 3R, 3B and 4 Laser Equipment

The first part of the risk assessment is to describe the work activity, giving details of the project. This will give a background to the work and will allow an inspector to assess if suitable lasers have been used for the work. This assessment should be done **before the work starts** by the Project Supervisor and a copy provided to the School/Unit Laser Safety Supervisor.

6.2.1 Hazards Associated with the Work

The hazards of the work activity should be clearly identified. This means identifying:

- The Class of laser being used;
- Whether it is pulsed or continuous wave laser;
- The wavelength of the light from the laser;
- The power output of the laser;
- Diameter of the beam;
- Whether the beam is collimated or divergent.

Working with lasers includes many other hazards which are not associated with the beam. These include:

- Fire (Class 3B and 4 lasers are powerful enough to initiate fires)
- Electricity supply (many lasers use high voltage/high current supplies e.g. a 2kW CO_2 laser will require a 100Amp 3 phase power supply at 40 kW);
- High pressure water supply;
- Chemicals (many dye and excimer lasers use very hazardous substances);
- Mechanical equipment associated with laser work;
- Manual handling operations (many gas lasers are large bulky items which are difficult to lift and carry);
- X-rays / Electromagnetic Interference (High voltage lasers e.g. 5kV CO_2 lasers can generate significant quantities of X-ray ionising radiation)

6.2.2 Who is at Risk

It is very important to identify who is at risk. In general this will be the laser user but you should also consider other workers, for example:

- Other workers in the laboratory;
- Cleaning staff;
- Service engineers (who may open up Class 1 equipment exposing a laser beam greater than Class1);
- The general public if an open air display is performed;
- Those susceptible to particular aspects of the work (e.g. pregnant women may be susceptible to some of the chemicals and manual handling operations).

6.2.3 The Risk of the Work Activity

The risk of an operation is the probability that a hazard will cause harm. Thus, in the assessment, consideration should be given to identify work procedures which increase the probability that a particular hazard will cause harm. The assessment should take into account non-laser beam hazards as well as assessing the laser beam risks.

Examples of factors which may increase the risk of an operation include:

- The use of non-visible wavelengths of light, thus workers will not see the main beam or stray beams;
- Highly complex optical systems which mean that it is difficult to identify where the beam is and where it is going;
- Beams where there is no proper beam stop;
- The use of periscopes thus moving the laser beam upwards towards the eyes of workers;
- Use of open laser beams (thus the potential for stray beams to be generated and injure a worker);
- Alignment of beams by eye increases the risk of an eye injury;
- Poor housekeeping (items which may fall into the laser beam and cause stray beams to be generated);
- Wearing of reflective items by workers e.g. jewellery which may cause stray beams;
- The use of high pressure water systems in close proximity to high voltage/current electrical supplies;
- Working with hazardous substances associated with the laser equipment without any fume extraction system;
- No training in manual handling operations for those having to move large, awkward and possibly heavy laser equipment;
- Using lasers which generate X-rays or electromagnetic interference without appropriate shielding in place.

6.2.4 The control measures which should be implemented

The purpose of a risk assessment is to identify and implement the necessary control measures to eliminate or minimise the risks to workers and to others which may be affected by the work. This section is the most important part of the risk assessment process.

There is a hierarchy of control measures which should be implemented:

- **Eliminate the risks -** Where it is reasonably practicable, the risks of the laser should be eliminated.

- **Substitute the risks -** If it is not possible to eliminate the risks, then can you substitute it with a less hazardous procedure. Examples of substitution include:- can you use a non-coherent light source which is less hazardous, can you substitute any hazardous substance with a less hazardous substance etc.

- **Engineering Controls -** If it is not practicable to eliminate or substitute the hazard, then you should, where reasonably practicable, put in place engineering control measures such that the beam is contained within the necessary work area and cannot escape and injure others. Examples of engineering controls which should be considered include:

    - Fully enclosing the laser equipment such that the beam is never fully exposed (i.e. making the laser equipment Class 1 even though a more powerful laser is enclosed in the equipment);

    - Put in beam stops which are capable of handling the power of the lasers (it is no use using a bit of paper as a beam stop for a very high powered Class 4 laser as this will be set alight by the laser);

    - Enclosing all periscopes to ensure no stray beams are generated upwards towards the workers eyes;

    - Where reasonably practicable, enclosing beam paths in tubing of an appropriate material;

    - Putting appropriate shielding around an optical table to avoid stray beams escaping from the optical table;

    - The use of web-cameras or other devices for the alignment of beams;

    - The use of interlocked doors to rooms with Class 3R or above lasers which either switch off the power to the lasers or put a shutter in the path of the laser beam at its source. This will stop personnel walking into a room being exposed to a laser beam;

    - Putting in place appropriate Residual Current Circuit Breakers (RCCBs) to avoid the potential for electric shock to workers;

    - Ensuring water supplies are well managed when in close proximity to electrical supplies;

    - Where reasonably practicable, all work with hazardous substances is carried out in a Local Exhaust Ventilation system (e.g. a fume cupboard);

    - Other engineering controls which may be appropriate for the laser equipment being used.

Where engineering controls are provided, they must be maintained and serviced at appropriate frequencies to ensure they are working correctly.

- **Procedural Controls -** Where elimination, substitution and engineering controls are not reasonably practicable, then, where reasonably practicable, appropriate procedural controls should be implemented. This is where specific procedures are introduced to minimise the risk of work with lasers. For example, by introducing a written system of work to inform workers what procedures they must follow when working with a particular piece of laser equipment.

- **Personal Protective Equipment (PPE) -** Only as a very last resort should PPE be considered as a control measure to minimise the risks of laser equipment. Eye protection can be afforded by wearing suitable laser safety eyewear but its effectiveness is limited as protection is dependent on the wavelength of the laser and the power of the laser.

  Where none of the above control measures can be implemented, then suitable laser safety eyewear must be supplied and worn by workers. It is vital that workers are aware of the limitations of such eye wear and which type of glasses/goggles should be worn.

  The School/Unit should ensure that laser safety eyewear is well maintained. Guidance on the usage, maintenance and storage of PPE is given in the University publication entitled 'The Selection, Use and Maintenance of Personal Protective Equipment (PPE)' which can be viewed at the following website:
  http://www.st-andrews.ac.uk/services/safety/webpages/ppe/ppe-policy.html
  The protection provided by laser safety eyewear is shown by specific markings on the glasses/goggles - For Example:
  DR 630-720 L5 CE95 ZZ S

  - D protect against continuous wave
  - R protect against giant pulsed waves
  - 630-720 Protect against wavelength range of 630-720 nm
  - L5 Attenuates laser radiation by 10^{-5}
  - CE95 European test marking and date tested
  - ZZ Testing authority
  - S Mechanical strength test (optional marking)

  All laser safety eye protection should be checked by the worker before use for damage and suitability for the work being undertaken. Where such PPE is damaged, it should be taken out of service immediately, reported to the Project Supervisor and replaced as soon as reasonably practicable.

6.3 Monitoring and Review

Risk assessments should be reviewed on a regular basis or when there is a significant change to a project by the Project Supervisor.

6.4 Risk Assessments of Outdoor Laser Demonstrations

There are strict guidelines for such demonstrations. If a group wishes to undertake such work, they should contact the University Laser Safety Adviser for guidance.

7 Contractors

Prior to the work starting, the contractor should liaise with the School/Unit Laser Safety Supervisor over the health and safety arrangements that will be required.

All contractors involved in laser maintenance must produce a System of Work, which should include a risk assessment, prior to the start of the work. The System of Work will identify all the necessary arrangements which need to be implemented to protect the contractor and workers at this University. This is especially important where Class 1 Equipment is opened exposing a laser beam of a rating higher than Class 1.

8 Laser Designated Areas

Rooms where work with Class 3R, 3B and 4 laser equipment is undertaken should be categorised as a 'Laser Designated Area'. Such areas should comply with the following requirements:

- The door should have a sign on it identifying it as a Laser Designated Area, with an appropriate laser warning sign. The sign should also have the name and contact number for the School Laser Safety Supervisor.
- To restrict access to Laser Designated Areas, the doors to Laser Designated Areas should be interlocked to the lasers such that opening the door switches off the power to the laser or puts a shutter in to the beam path close to its source.
- The laser beam should not be able to leave the room e.g. all windows should be 'blacked out'.
- A suitable beam stop must always be in place to stop the beam within the experimental area.
- The provision, where reasonably practicable, of a high level of general illumination within the area so that the pupil of the eye remains as small as possible.
- The walls, ceilings, flooring and fittings should be covered with a matt paint to reduce potential specular reflections of beams.
- The removal of all unnecessary equipment from the area.
- The elimination or minimisation of reflective surfaces from the area e.g. glass fronted cabinets.
- The provision of adequate ventilation (this will depend on the type of hazardous substances being used for the work activity).
- All optical equipment being used with the laser beam should be mounted and fixed on an optical table to reduce accidental movement and hence unexpected direct or reflected beams.
- The provision of adequate fire fighting equipment.
- The provision of seating within the laser area must not give rise to an increased risk as a result of reduced eye level.
- The fitting of appropriate electrical supplies and relevant control equipment designed to:
  - Prevent accidental firing of the laser;
  - Provide an indication of the state of readiness of equipment such as associated capacitor banks;
  - Enable personnel to stand in a safe place;
  - Incorporate all relevant electrical safety features;
  - Enable the laser to be shut down;

- Enable the equipment to be isolated and made safe from outside the Laser Designated Area in the event of a fire or emergency.

9 Emergency Actions

In the event that a person has been exposed to a laser beam directly to the eye, the person should be taken directly to an Ophthalmic Consultant at the Ophthalmic Department, Ninewells Hospital, Dundee. The person (or person accompanying the injured person) should take details of the laser which may have caused the injury (e.g. wavelength of the beam, power output etc) and information on the possible length of time the person may have been exposed to the beam.

After the person has been to Ninewells Hospital, a University Accident Report Form should be completed and signed by the School Safety Co-ordinator. A copy of the accident report form must be sent to the Director of EHSS as some incidents may require the University to report the incident to the Health and Safety Executive (this report is sent by the University Safety Adviser).

A copy of these instructions should be posted in all Laser Designated Areas (see Appendix 7.

10 Inspections

The School / Unit should inspect all facilities where laser equipment is being used on an annual basis. Where the systems do not meet relevant standards, remedial action should be implemented as a matter of urgency.

Laser safety audits and safety tours of areas where laser work is performed will be carried out by representatives of the Radiations Hazards Sub-Committee at regular intervals.

11 Undergraduate Experiments and Lecture Demonstrations with Lasers

Where reasonably practicable, the least hazardous lasers should be used for undergraduate practicals and lecture demonstrations (i.e. Class 1, 1M, 2 and 2M lasers) or if higher powered lasers are used then they should be in totally enclosed systems.

Where such work requires the use of higher powered lasers, then an appropriate risk assessment should be performed and the necessary control measures implemented to eliminate or minimise the risks.

When such assessment is being performed, as well as the standard risks of the work, consideration must be given to the inexperience of undergraduates and that teaching laboratories may not have been designed as Laser Designated Areas (thus there may still be reflective surfaces present).

It is suggested, therefore, that the following special conditions should be observed for undergraduate work or demonstrations with Class 3R, 3B or 4 lasers:

- The safety of the experiment or demonstration should be risk assessed by the lecturer and the School Laser Safety Supervisor;
- Written system of work should be produced for this work;

- A copy of the risk assessment and System of Work should be displayed in a position which can be clearly seen by the persons carrying out the work;
- A copy of the instructions should be given to each student who must be informed of the risks of exposure to laser beams if the instructions are not followed;
- The School Laser Safety Supervisor should visit the experiment at reasonable intervals;
- Lasers must not be accessible to students at any time other than when they are being used in approved experimental work.

12 Laser Pointer Safety

Laser pointers are now used regularly in lectures and other teaching activities. It has been noted that some of the new pointers, which are readily available in the UK and include red and green devices, are more powerful than the older models and pose a serious risk of eye injury to anyone exposed to the beam. This apparent irregularity of devices being available that may be hazardous arises in part due to American (ANSI) standards being more relaxed than British/European Standards (BS EN). Laser pointers used in areas under the control of the University of St. Andrews must comply with the following University policy based on BS EN standards and CVCP recommendations:

Device Requirements

- Laser Pointers must not exceed **Class 2** (1 mW output power);
- Laser Pointers must be purchased from reputable manufacturers and suppliers;
- Laser Pointers may only be modified under certain circumstances (e.g. output power reduction) and only with the approval of the University Laser Safety Adviser.

Conditions of Use

- Ambient lighting should be kept as high as practicable - blackout conditions should be avoided whenever practicable;
- Laser Pointers must not be directed towards eyes;
- Prior to use, checks should be made that there are no reflective surfaces that could foreseeably redirect the laser beam towards eyes (user and audience);
- Schools / Units are required to take steps to ensure that all relevant persons are made aware of this guidance, including visitors to the University of St. Andrews.

Further Recommendations

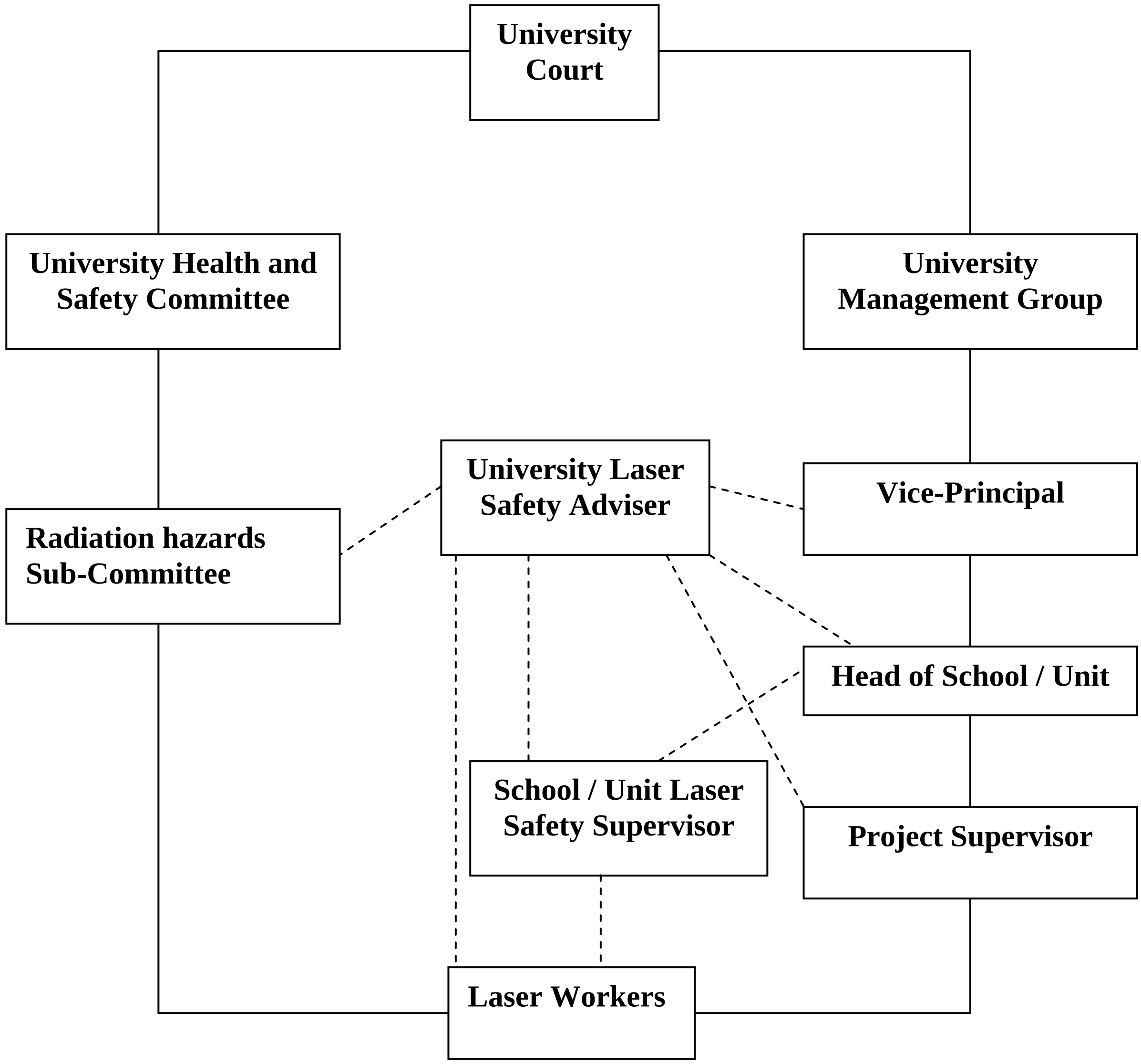
- The use of green or 630nm red waveband laser pointers is recommended. These wavelengths afford greater visibility per unit power;
- If visiting another establishment and intending to use a laser pointer, you should first check the local regulations.

Emergency Actions

In the event of an accidental exposure to the eye of any person, they should be taken to the Ophthalmic Department at Ninewells Hospital, Dundee and the Director of EHSS notified via an Accident Report Form.

Appendix 1

University Management of Laser Safety



Membership of the Radiation Hazards Sub-Committee of the University Health and Safety Committee.

Members

University Radiation Protection Adviser(s) (URPA)

University Laser Safety Adviser

University Safety Adviser

DRPS - Centre for Biomolecular Sciences

DRPS - Bute Medical Building, School of Biology

DRPS - Gatty Marine Laboratory, School of Biology

DRPS - Sir Harold Mitchell Building, School of Biology

DRPS - School of Chemistry (Radioactive sources only)

DRPS - School of Chemistry (X-ray equipment only)

DRPS - School of Geography and Geosciences

DRPS - School of Physics and Astronomy

DRPS - School of Psychology

Convenor - URPA

Secretary - URPA

Appendix 3

Duties of the University Laser Safety Adviser

The University Laser Safety Adviser has the following duties:

1. Advise the University Radiations Hazards Sub-Committee of the University Health and Safety Committee on matters relating to laser safety;

2. Provide laser safety advise to Senior University Management, Heads of Schools/Units, The University Radiation Protection Service, School/Unit Laser Safety Advisers and laser workers;

3. Provide information, instruction and training in laser safety to University laser workers;

4. Investigate all suspected laser accidents and near misses and ensuring that appropriate medical advice has been sought after such incidents;

5. Carry out laser safety audits on behalf of the Radiation Hazards Sub-Committee at appropriate intervals;

6. Ensure that Schools/Units register all Class 3R and above lasers;

7. Ensure that all users of Class 3R and above lasers are registered with the School/Unit and have received appropriate training.

Appendix 4

URPS1/L

University of St. Andrews

Registration of Persons as Users of Lasers and Ancillary Equipment

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Note: After completing this form, you should return it to the School/Unit Laser Safety Supervisor

----

Workers Name ....

National Insurance Number ....

Sex Male / Female **Date of Birth** ....

School / Unit ....

Research Status (U/G, P/G, PhD etc) ....

Supervisor's Name ....

Training in Laser Safety ....

....

....

....

I have read and understood the 'University Local Rules for Work with Lasers'

Signature of Worker ....

DO NOT WRITE HERE

Date Registration Received ....

Date that worker informed of the web address to access University Local Rules for Work with Lasers ....

Date Worker Informed of Emergency Procedures ....

Date Worker Viewed Laser Safety Programme ....

Date Worker requested to attend next Laser Safety Training Session ....

Appendix 5

University of St. Andrews

Registration of Laser

Note: After completing this form, you should return it to the School/Unit Laser Safety Supervisor

---

School / Unit ....

Building ....

Room Number ....

Research Supervisor .... **Tel. Ext.** ....

Manufacturer ....

Model Number .... **Serial Number** ....

Type (e.g. He/Ne) .... **CW or Pulsed** ....

Emission Wavelength .... **Maximum Power Output** ....

Class Class 1 ☐ Class 1M ☐ Class 2 ☐ Class 2M ☐

Class 3R ☐ Class 3B ☐ Class 4 ☐

Comments ....

....

Date Tested for Electrical Safety ....

Signature of Research Supervisor ....

To Be Completed by the School/Unit Laser Safety Supervisor

Date Laser Registered ....

Name of School / Unit Laser Safety Supervisor ....

Signature of School / Unit Laser Safety Supervisor ....

Comments from School / Unit Laser Safety Supervisor ....

....

Appendix 6

University of St. Andrews

Risk Assessment for Work Involving Lasers

All work carried out with lasers should comply with the University of St. Andrews publication entitled 'University Local Rules for Work with Lasers'.

Generic risk assessments have been performed for Class 1, 1M, 2 and 2M lasers and these assessments are published in the above University guidance.

NOTE: It is a University requirement that a specific written risk assessment be performed for work involving the use of Class 3R, 3B and 4 lasers. This form should be used for such risk assessments. These assessments should be reviewed where necessary e.g. if there is a significant change in the work.

Location of Work (School / Unit and Room Number)

....

Details of Procedure

Who is at Risk? (Detail those at risk, e.g. workers, visiting researchers, contractors, maintenance staff, cleaners, visitors, others)

....

....

Hazards of Work

Laser Beam Hazards

Eye injury ☐ Skin burns ☐ Fire due to the laser beam ☐ Other Hazards

Non-Laser Beam Hazards

Fire☐ Electricity ☐ Poor lighting ☐ Slips/Trips/Falls☐ Trailing leads☐

Manual Handling Operations ☐ Chemical Hazards ☐ Biohazards ☐ Explosions ☐

Pressure Systems ☐ Compressed Gases ☐ Radiation Hazards (e.g. X-rays, EMI) ☐

Cryogenics ☐ Hot objects ☐ Moving parts of machinery ☐ Confined Spaces ☐

Other Hazards

Details of Laser Class 3R ☐ Pulsed / Continuous wave

Class 3B ☐ Pulsed / Continuous wave

Class 4 ☐ Pulsed / Continuous wave

Wavelength .... Power ....

Risks of Work Activity - e.g. Workers inexperience, use of periscopes, open laser beams, water supply next to high voltage/currents, lone work, unauthorised entry to Laser Designated areas.

Control Measures necessary to eliminate or minimise identified risks
(This section should detail all control measures for laser beam **and** non-laser beam risks **e.g.** training, engineering controls [e.g. work in Laser Designated Areas, door interlocks, enclosing experiments or beams, enclosing periscopes, use of beam stops], use of RCCBs, appropriate tubing for high pressure water systems, written systems of work and as a last resort, Personal Protective Equipment (e.g. eye protection))

Written System of Work For Contractors (Safe systems of work for contractors undertaking repairs/maintenance of lasers)

Signatures

	Name of Worker	Signature of Worker	Laser Safety Training Received		
			When Training Received	Where Training Provided	Detail of laser safety training provided
1.					
2.					
3.					
4.					

Name of Supervisor .... **Signature** .... **Date** ....

School/Unit Laser Safety Supervisor **Signature** .... **Date** ....

(The completed risk assessment should be sent to the School/Unit Laser Safety Supervisor and a copy retained in the work area)

Appendix 7

EMERGENCY PROCEDURES

Accidents Involving Laser Radiation

EMERGENCY PROCEDURES

ACCIDENTS INVOLVING LASER RADIATION

IF EYE DAMAGE IS SUSPECTED, EMERGENCY EXAMINATIONS WILL BE CARRIED OUT AT NINEWELLS HOSPITAL, DUNDEE.

CONTACT: EYE CLINIC (AREA 6A) - hours 09:00-17:00
OPHTHALMIC WARD (WARD 25) - hours 17:00-09:00

TELEPHONE: Ninewells main switchboard 01382 660111
(it is not necassary to phone prior to attending)

EXAMINATIONS SHOULD BE CARRIED OUT AS SOON AS PRACTICABLE AND WITHIN A PERIOD NOT EXCEEDING 24 HOURS.

IF PRIVATE TRANSPORT IS NOT AVAILABLE (DO NOT DRIVE YOURSELF) A TAXI SERVICE SHOULD BE USED.

IN THE EVENT OF AN ACCIDENT OR NEAR ACCIDENT THE FOLLOWING PERSONNEL SHOULD BE NOTIFIED AS SOON AS PRACTICABLE

Head of School:
ext. e-mail:

School Laser Safety Supervisor:
ext. e-mail:

University Laser Safety Advisor: Dr Cameron Rae
ext. 7314 e-mail: cfr

Research Group Supervisor

Note: Accidents and/or near misses must be reported to the Director of Environmental, Health and Safety Services as soon as reasonably practicable.