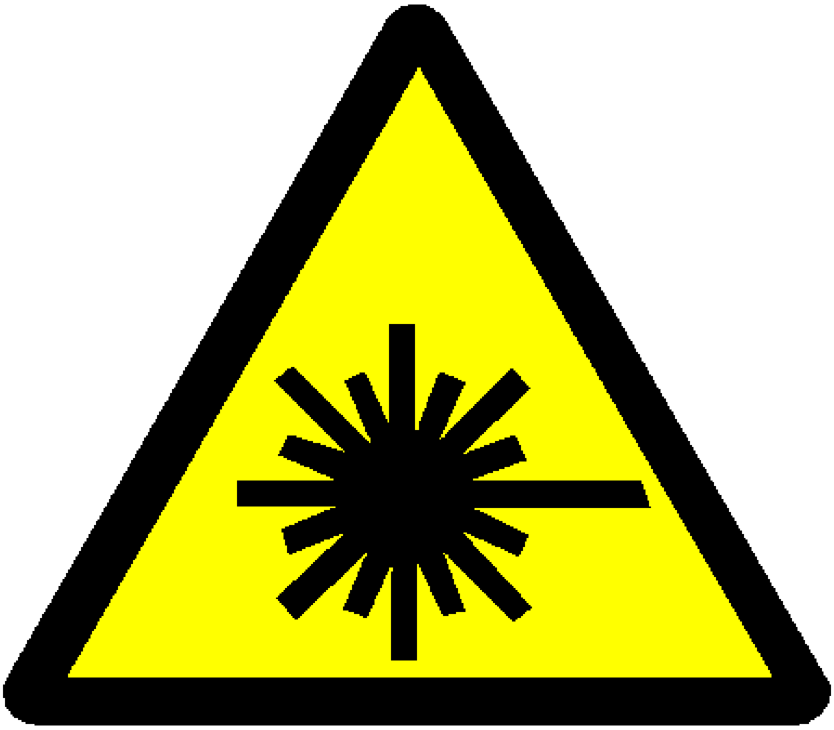
Health and Safety Services

University of Reading

Safety Guide 21

The safe use of lasers



The safe use of lasers

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Summary

This Guide is concerned with the safe use of lasers and laser-based equipment in the University. It incorporates information on the scheme used to classify lasers; gives guidance on risk assessment for laser applications; and gives guidance on the need for registration of certain types of equipment and certain types of work with lasers. Figure 1 below summarises the key responsibilities.

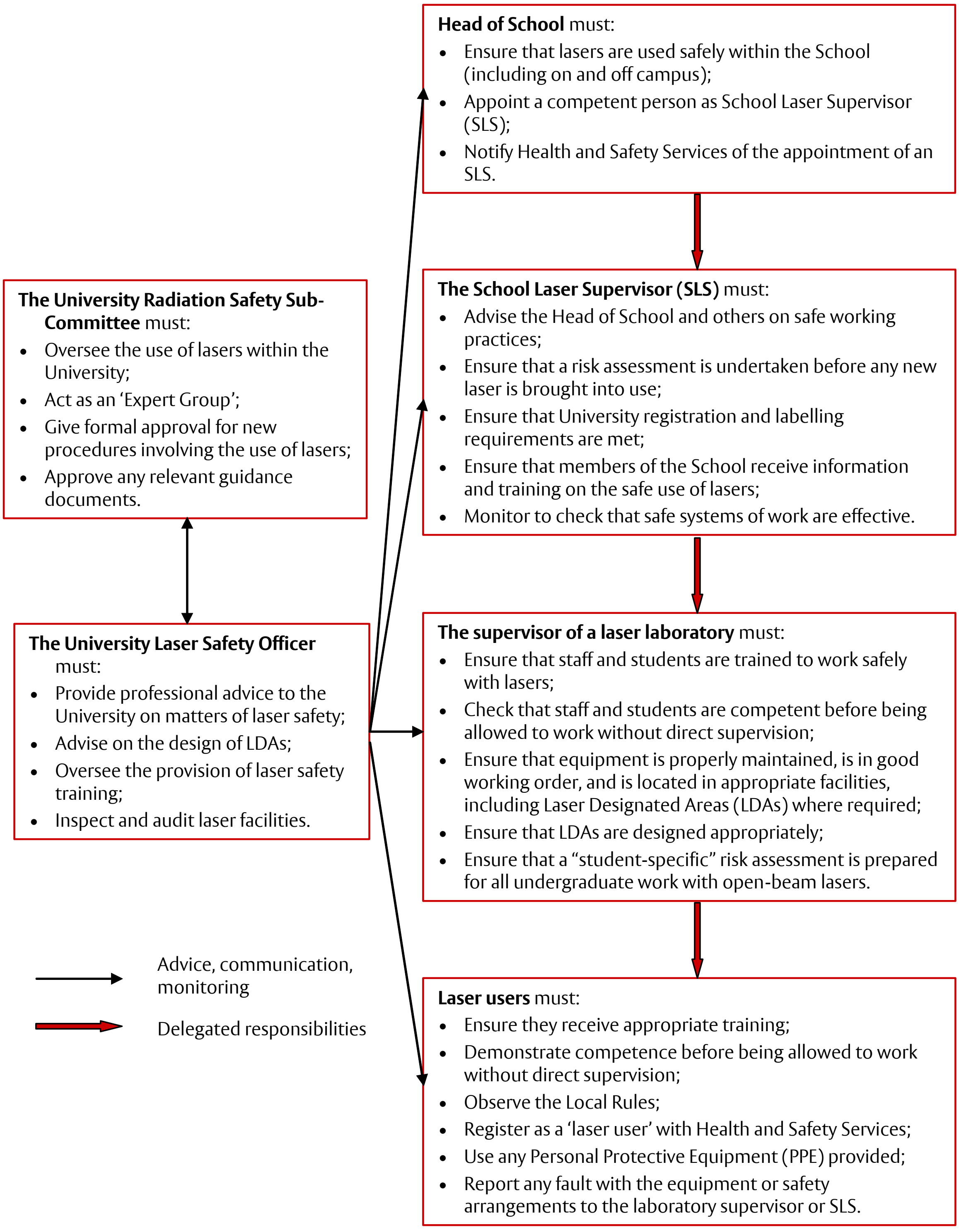

Figure 1

1. Scope

This Guide sets out what managers, staff, students and tenants have to do to ensure that all those who work with lasers, either with "open beams" or where the laser is embedded in a scientific or other instrument, may do so in a safe manner.

It applies to the use of **all** lasers other than "Class 1" (inherently safe lasers where the output power is such that anyone exposed to the laser beam is not placed at risk). It therefore applies to all work with higher class "open beam" lasers where the totality of the beam is not completely enclosed and where a laser beam could be accessible to the operator. It also applies to situations where a member of the University undertakes adjustment or servicing of an "embedded" Class 3 or Class 4 laser in equipment. It does **not** apply to such equipment where there is no possibility of any person being able to access the beam of the laser, even during service or maintenance.

The Guide also covers University procedures for the registration of relevant lasers, and includes guidance on risk assessment for the use of lasers or laser-based equipment.

Guidance:

See Section 3 for information on laser classification.

Lasers come in various shapes and forms. Within the University they are used primarily in teaching and research, but they will also be found in work equipment such as level devices, CD players, pointers and pens. Lasers emit radiation as narrow concentrated beams of light, not necessarily visible to the human eye. The hazards of lasers are associated with the ability of the laser to damage eyesight or burn skin, but there may be other risks from electrical supplies, cryogenic liquids or chemical dyes.

2. Responsibilities

2.1. Duties on Heads of School

Heads of Schools that use lasers (other than Class 1 lasers or inherently safe devices where there is no possibility of access to the beam) must ensure that lasers are used safely within the School (including on and off campus). They must:

- Appoint a School Laser Supervisor (SLS) to advise them on the safe use of lasers and laser-based equipment in their School;
- Ensure that the SLS receives a copy of the *Duties of a School Laser Supervisor* (see Appendix 1);
- Inform the University Laser Safety Officer (ULSO) in writing of the appointment of an SLS;
- Ensure that the SLS is provided with training relevant to his/her duties.

Guidance:

An "Area Health and Safety Personnel Appointment Form" is circulated by Health and Safety Services (H&SS) to Heads of Schools/Departments prior to the start of the Autumn Term for the purpose of identifying current appointments.

2.2. The University Laser Safety Officer (ULSO)

The University Laser Safety Officer (ULSO) is appointed by the University to advise on all safety matters concerned with the use of lasers. For convenience the University Radiation Safety Officer acts as ULSO. The duties are as specified in Appendix 2 to this Guide.

Guidance:

The University Radiation Safety Officer is a member of H&SS. He/she may be contacted on tel. extension 8887.

2.3. Duties of the School Laser Supervisor (SLS)

A detailed list of duties of an SLS is given in Appendix 1 to this Guide. In summary, the SLS is responsible for ensuring that:

- A comprehensive risk assessment is undertaken before any new laser is brought into use;
- All relevant lasers are registered on the University database of lasers;
- Members of the School/Department are correctly advised on matters of laser safety and that they have appropriate safe working procedures to follow;
- Members of the School/Department receive adequate information and training with respect to laser safety matters;
- There is adequate monitoring to check that precautions are suitable and effective, including equipment maintenance, staff and student training, and risk assessments.

The SLS must ensure that he/ she is fully familiar with all relevant statutory provisions; the requirements of any non-statutory provisions (for example, relevant parts of the IEC BS/EN 60825 Standard on laser safety); the University's Health & Safety Policy; and any Local Rules regarding laser safety.

2.4. Duties of supervisors of laser laboratories and laser based equipment

The designated supervisor of a laser laboratory or an individual item of laser-based equipment must ensure that:

- Every user of the laboratory or laser-based equipment is:
  - provided with comprehensive instructions and/ or a copy of the Local Rules (as appropriate);
  - properly trained, and (if appropriate) registered as a laser user;
  - provided with any necessary personal protective equipment, which must be maintained in good working order;
  - competent before he/ she is allowed to work in the laboratory without direct supervision.
- All lasers within the laboratory are properly maintained in good working order, and that equipment is properly serviced and adjusted by properly trained personnel. This would normally be undertaken by a service engineer who is a representative of the manufacturer or an appointed service agent. Where, for any reason, such operations are undertaken by University personnel, the laboratory supervisor must ensure that only named individuals (who can demonstrate their training and competence in the necessary tasks) are permitted to undertake the work.

2.5. Duties of laser users/ users of laser-based equipment

All individuals who intend to use lasers (or equipment to which this guidance applies), must:

- Attend the Laser Safety training course, given by Health and Safety Services, or (if their use of lasers is likely to be limited in time such that attendance at the course is impossible) – must view the Laser Safety video and be instructed on the safe use of lasers by the SLS or his/her appointed deputy;
- Demonstrate their competence in the use of the equipment to the laboratory supervisor before being allowed to work without direct supervision;
- Register as a “Laser User” with Health and Safety Services for each relevant item of laser equipment they intend to use (see Section 7 – University Procedures);
- Use any personal protective equipment (PPE) that is provided for use in the laboratory;
- Report any defect in such PPE to the laboratory supervisor;
- Comply with any Local Rules that have been formulated for the use of any laser or item of equipment to which this guidance applies;
- Report any fault with the equipment to the laboratory supervisor: they must not attempt to correct the fault, or undertake adjustments to the equipment unless they have been properly trained and are regarded as competent to undertake the work.

3. Laser hazard classification

Lasers and laser products (i.e. any device which contains a laser, for example a CD player) are classified according to the hazard they present to the user. The hazard depends on the output power of the laser and its characteristics (*i.e.* continuous output or pulsed output) and on the wavelength of radiation emitted. A laser or laser product is regarded as "safe" if the maximum permissible exposure (**MPE**) at the characteristic wavelength of the laser is not exceeded. NB the hazard depends on the wavelength of the emitted energy as well as the energy density, see Section 6 and Appendices 3 and 4.

The **classification scheme** is defined in the standard BS EN 60825-1: 2007 (Edition 2), and is based on the amount of radiation "accessible" to the user – the **Accessible Emission Limit (AEL)**. This value defines the maximum power of each class of laser. There are currently seven classes of laser, which are described below:

- **Class 1**

Class 1 lasers/ laser products are regarded as "inherently safe", either because the output of the laser is low and incapable of causing damage, and/or because the beam is totally enclosed and never accessible to the user during normal use of the device. The latter situation is regarded as "*being made safe by engineering means*". Readers should however note that the laser in such a laser product may be of a much higher hazard class, and if access panels of the instrument are removed *e.g.* for servicing or adjustment, **then the precautions applicable to the embedded laser must be applied during such operations.** A typical Class 1 CW laser operating at 633 nm would have an AEL of 0.39 mW.

- **Class 1M**

Class 1M laser products emit radiation in the wavelength range 302.5 – 4000 nm, and have a low power density such that during normal operating conditions, a user would never be exposed to hazardous levels of radiation. This is, for example, because a divergent beam is emitted from the laser device. However the total output power of the laser may be so high that it would otherwise fall into class 3; it follows therefore if optical devices are used to concentrate the beam, the level of radiation may reach hazardous levels. NB this may include hazards to the skin as well as to the eye because the wavelength range includes the infra-red. The AEL of a class 1M laser is the same as for a class 1 laser.

- **Class 2**

This class only applies to devices which emit in the visible region (400 – 700 nm), and which are regarded as "safe" both for skin exposure, and for "accidental viewing". Eye protection is provided by the natural aversion responses (including the blink response), whereby the viewer automatically avoids looking at a bright source of light. The AEL of a class 2 laser is therefore such that the maximum permitted exposure is not exceeded in the time that it takes for the aversion response to operate: this is conventionally taken as 0.25 seconds. The AEL for a narrow beam CW laser operating at 633 nm is 1 mW.

- **Class 2M**

These are also visible lasers which have a total output greater than a class 2 laser, but where, because there is either a divergent beam or a low power density (because the beam is of a large diameter - cf. class 1M), the MPE is not exceeded in 0.25 seconds in normal use of the laser (i.e. the AEL is the same as a Class 2 laser). As with Class 1M, if optical devices are used to concentrate the beam, the level of radiation may be hazardous to the eye.

- **Class 3R (**medium power**)**

Lasers with an output in the range 302.5 nm to 1 mm [N.B. – this includes the visible range] where direct intrabeam viewing of the beam is hazardous to the eye (i.e. exposure >the MPE for the eye), and where the AEL is restricted to no more than 5x the AEL of a class 2 laser (for visible wavelengths) or Class 1 laser (for other wavelengths.). Thus, the AEL for a class 3R laser emitting at 633 nm (visible wavelength) is 5 mW.

- **Class 3B (**medium – high power)

Lasers with an output such that direct viewing, or viewing of specular reflections, is hazardous, but viewing of diffuse reflections is normally safe. The output limit for a CW Class 3B laser is 500 mW at 633 nm.

- **Class 4** (high power)

High power lasers with an output greater than the 3B limit. Normally, any exposure, even to diffuse reflections, can be hazardous. Depending on the wavelength, they can cause skin burns, eye/ retinal damage, and may constitute a fire hazard.

Full details of the laser classes, plus information on the required labelling, is given in Appendix 3.

4. Maximum permitted exposure

As noted above, the MPE is the level of laser radiation to which, under normal circumstances, persons may be exposed without suffering adverse effects. The SLS and the designated supervisor of a laser laboratory or an individual item of laser-based equipment are responsible for ensuring that the MPE is not exceeded.

The MPE depends on the duration of the exposure and the characteristics of the laser radiation *i.e.* on the wavelength, and on whether it is continuous wave (CW) or pulsed. The eye is the most sensitive organ in the body as far as "visible" electromagnetic radiation is concerned, whereas skin is much less affected by such an exposure. The MPE for the eye is therefore much lower than for the skin for radiation in the visible wavelength range. In addition, because the sensitivity of the eye differs at different wavelengths, the MPE is also wavelength-dependent within the visible region.

Guidance:

1. For pulses of very short duration, the repetition frequency will determine the total amount of energy delivered during the exposure, *e.g.*, for pulses of 10^{-13} second duration and repetition frequency of 1 KHz, a 1 second exposure would deliver 1000 x the energy contained in a single pulse.

2. The eye is most sensitive to green light i.e. the wavelength region 520 – 570 nm. For eye exposure, it is assumed that the pupil diameter is 7 mm, and for skin exposure, the area of skin irradiated is 3.5 mm diameter.

MPE levels are given in PD 60825 Part 14 (see Tables 5, 6 and 7 in ref. 4). Exposure Levels are normally quoted in units of W m^{-2} for CW lasers, and J m^{-2} for pulsed lasers. Users of open beam lasers must avoid exposures which may be greater than the MPE, which may require calculation of the maximum possible duration of exposure as part of the risk assessment – see below.

5. Risk assessment

A risk assessment must be undertaken **before** any new laser is brought into use (except Class 1 lasers). Note that this includes "Class 1 laser products" that incorporate a laser of higher classification [Class 3 or Class 4]. However, if no access to the beam is possible for University personnel, the assessment can record "zero exposure during normal use", but it must be made clear in the Local Rules or instructions for the equipment that undertaking alignments (etc) or servicing is not permitted by University staff.

The risk assessment must identify and take account of **all** hazards, including "non-beam" hazards – see Section 6.

The risk assessment process for the use of lasers follows the same principles as for any other risk assessment:

1. Identify the hazards i.e. the potential for causing harm;
2. Identify those at risk of being exposed to the hazards;
3. Identify the potential for exposure to the hazards;

4. Identify the magnitude of harm that could be realised if exposure occurred (Magnitude = probability of occurrence x consequence of exposure);
5. Identify and implement the control measures which are required to minimise the harm;
6. Assess the residual risk - repeating stage 4 if necessary;
7. Record the findings;
8. Review the assessment at regular intervals – usually every 12 months, or if circumstances change, or any information comes to light that suggests the original assessment is no longer valid.

Guidance:
A change of circumstances could include a change in personnel. New information could become available *e.g.* via the scientific literature or from the manufacturer, or as the result of an accident or incident that was not taken into account in the original assessment.

Form RA2-L (available via the "Forms" page of the Health & Safety Services website) should be used to record the risk assessment. A completed example is given in Appendix 5. The risk assessment should be reviewed by the nominated supervisor of the laser being assessed. If necessary, the SLS should be asked for assistance with the assessment. A copy of the completed risk assessment should be kept centrally with the School health and safety records, and should be included in the annual return of risk assessments to Health & Safety Services. The information contained in the risk assessment is also used when the laser is registered with Health and Safety Services – see Section 7.

6. Associated non-beam hazards

Other hazards that may be present in the laser laboratory must be included in the risk assessment. Some of these may be directly connected with the operation of the laser itself, for example, the provision of high voltage power supplies operating at potentials of several kV, where others may be only indirectly connected to the laser operation – for example, the presence of cables to ancillary equipment trailing across the floor.

6.1. Electrical hazards

Electrical equipment safety is described in Safety Guide 11. The two most important aspects are the:
- Use of high voltage power supplies; and
- Avoidance of trailing leads and adapters, which are particularly hazardous should a leak of cooling water occur. Water connections should not be made vertically above electrical connections.

6.2. Mechanical and physical hazards

Some of the equipment associated with high power lasers is very heavy, and crushing accidents have been reported when units were inadequately secured. The hazards associated with pumps and motors must be given adequate consideration *e.g.* guarding, venting of exhausts, etc. The use of cryogenic coolants may cause cold burns or asphyxiation due to liquid nitrogen boiling off in an unventilated space, or fire risk if flowing hydrogen is used etc.

6.3. Other radiation hazards

Adventitious x-radiation may be generated by high voltage rectifiers. Equipment operating at more than 5 kV is covered by the Ionising Radiations Regulations (see Safety Guide 20: X-rays).

Where appropriate, precautions must be taken against exposure to UV radiation (see Safety Guide 22).

6.4. Chemical hazards

Some types of laser rely on the input of energy (for example, from a Xenon flash tube or from another laser) into a chemical dye solution. The chemicals used are often toxic and some may be carcinogenic. The chemical hazards may well outweigh the laser hazards, and the Control of Substances Hazardous to Health (COSHH) Regulations will apply – see Safety Guide 28. In addition, if the chemical dyes are dissolved in flammable solvents, the Dangerous Substances and Explosive Atmospheres (DSEAR) Regulations may well apply – see Safety Guide 24.

In all cases the University Good Chemical Laboratory Practice (GCLP) must be observed (Reference 6), and a COSHH assessment made for all chemicals used in association with lasers. Any control measures identified by the COSHH assessment must be adopted, including the adoption of less hazardous materials/techniques. Many of the substances used in dye lasers are potential carcinogens, and exposure must be prevented or minimised.

Guidance:

1. Typical dyes used in chemical lasers include Rhodamine 6G; fluorescein; coumarin; stilbene, umbelliferone; tetracene and malachite green - the majority of these are hazardous in some way.

2. Toxic by-products such as ozone or oxides of nitrogen may be formed by laser irradiation, or as a byproduct of the action of the laser on a target material. A COSHH assessment may dictate the provision of local exhaust ventilation (LEV).

7. University procedures

7.1. Registration and labelling

All lasers (with the exception of Class 1 lasers) must be registered with the Health & Safety Services database before they are used. On registration a University Laser Number [ULN] will be issued: the supervisor of the particular laser must attach a self-adhesive label to the instrument to clearly show this number. The laser should also carry appropriate warning labels (the laser “starburst” symbol, accompanied by the words “*Caution: Laser Radiation: Do not stare into the beam*” for Class 1 or Class 2 lasers; “*Danger: Laser Radiation: Do not stare into the beam*” for higher power (Class 3R or 3B) lasers.

Class 3B and Class 4 lasers **must** be used in a laser designated area (LDA) if there is any possibility of laser radiation being emitted from the machine into the laboratory (“open beam work”). The entrance to the LDA must be suitably marked and signed. Warning signs / notices should comply with the Health and Safety (Safety Signs and Signals) Regulations, and include information on the class of laser and warnings to avoid exposure to the beam and to reflections of the beam - see Section 7.2 below, and Appendix 3.

A commercially-produced laser should carry a manufacturers’ label indicating the class of laser, the maximum output power and the wavelength of the emitted radiation. If the laser was manufactured or purchased from outside the EU, users need to be aware that the labels may not comply with or follow the BS EN classification scheme, and it may be necessary to undertake power output measurements in order to properly classify the laser. In addition, lasers produced before the current classification scheme should have labels corresponding to the former scheme – it is not necessary to reclassify any laser which is already on the database, but any newly-acquired laser (even “old” equipment which has been donated) will have to be re-classified before it can be entered onto the database.

If the laser is “home produced” in the laboratory, such BS EN-compliant labels must be fixed to the device before the laser is used.

Any change of location for the laser must be notified to Health & Safety Services so that the database can be kept up to date.

7.2. Laser Designated Areas (LDAs)

The setting up of an appropriate LDA is an essential step in controlling the hazard from lasers of Classes 3B and 4. The features mentioned here are only guidelines, as the requirements for *e.g.* a high energy pulsed laser operating in the UV are very different from those of a CW laser operating in the visible at a few mW. The purpose of the LDA is to minimise the risk to persons working with the laser and to provide protection for all persons outside the LDA. Each LDA should be designated for a particular laser application.

7.2.1. Laboratory design

Any windows in the room must be covered in opaque material such as a blackout blind or curtain, so that any stray reflections are not emitted via a window into the immediate environment of the laboratory. Reflecting surfaces should be avoided: light coloured matt paint should be used for walls, ceilings and fittings and glass-fronted cupboards should be avoided.

There should be an illuminated warning sign at the entrance to the LDA to indicate when the laser is operating. If there is no lobby to the LDA, there should be a means of linking opening the door of the LDA to the operation of a beam shutter, such that the beam is shut off when the door is opened. If there is a lobby, the door from the lobby into the laboratory should be arranged so that if both doors are opened together, then there is not a straight line path from the interior of the lab via the lobby to the external environment of the laboratory. The illuminated sign should if possible be linked to the laser in such a way that not only does the sign become illuminated when the laser is operating, but also so that if one or more of the bulbs in the sign fail, then a beam shutter will operate and prevent laser light from being emitted from the laser.

Electrical supplies, switch and control gear should be sited in order to:

- Enable the laser to be shut down rapidly by the operator;
- Enable the laser to be made safe in an emergency from outside the laser area if reasonably practicable;
- Prevent accidental firing of the laser;
- Provide an indication of the state of readiness of the laser;
- Enable personnel to stand in a safe place.

A comprehensive risk assessment can be useful at the planning stage *e.g.* to assist the design of a laser laboratory in terms of positioning of a laser, provision of screens and PPE; location of power supplies, etc.

7.3. The Radiation Safety Sub Committee (RSSC)

The Radiation Safety Sub Committee has been established to oversee all aspect of the use of radiation sources at the University. Its remit includes oversight of the use of lasers. The subcommittee is composed of all the School Radiation Protection Supervisors (SRPSs) and the School Laser Supervisors plus nominated representatives of those campus Unions that have involvement with sources of radiation. Meetings are held once per term. In respect of lasers, the sub-committee acts as an “Expert Group”, and as a means of discussing the use of lasers in the different Schools. If appropriate, the RSSC will give formal approval for new procedures involving the use of lasers (for example, new proposals for undergraduate work with lasers, including project work), and to approve any guidance documents such as Safety Guides or Safety Notes before publication.

8. Undergraduate experiments & demonstrations (except Class 1)

A “student-specific” risk assessment should be undertaken for all undergraduate work with open-beam lasers. For new proposals, this assessment will be submitted to the Radiation Safety Sub-Committee for approval, which must be given before the work can begin.

Every opportunity should be taken to introduce students to good laser safety practice. The following precautions must be adopted:

- The least hazardous laser must be used *i.e.* lowest power and a visible beam;
- A written System of Work which has been approved by the SLS must be displayed where it can be seen by those performing the experiment;
- Clear written instructions must be provided, and students informed of the hazards and potential injuries should they be disobeyed;
- A supervisory member of staff should be present in the laboratory, or in lower risk situations be readily available, in accordance with the risk assessment;
- Lasers must not be accessible to students except when used in approved experimental work.

9. Use of open beam lasers on University premises out of doors

A laser, except where incorporated in a device such as a printer or compact disc player, must not be used in the open until all interested parties have been consulted, and formal written permission has been granted by the SLS. The SLS should consult with the ULSO when necessary.

Problems of public relations as well as safety may arise if the public has access to any area outdoors where lasers are being used. Normally the laser beam must be terminated within the experimental area. When the beam is pointed upwards the person(s) in charge of the experiment may need to consult with the appropriate Aviation Authorities.

Additional guidance, for example on laser products used for surveying, alignment and levelling, is given in Reference 5.

10. Use of lasers off-campus

The AURPO Guide (Reference 1B - Section 4.7) should be studied and followed (but it is not necessary to obtain the opinion of the University's legal advisers in any but exceptional circumstances). Laser users/ supervisors should also be aware of the need to ensure the safety of third parties *e.g.* employees or students of a host employer or institution.

No (registered) laser may be taken away from the University *e.g*. for a lecture, a demonstration, or for research purposes, without the permission of the Head of School. The SLS should be consulted before the first occasion on which a particular use off-campus is intended. The operator concerned will be held directly responsible for ensuring that all safety requirements are met and must, if requested, obey the instructions of the host institution's LSO and Departmental Laser Supervisor.

Full information regarding the lecture, demonstrations or research for which a registered laser is to leave the University must be sent to the University Insurance Officer (extension 8309) in advance, so that appropriate insurance arrangements can be made. This information should include any contracted arrangements, conditions applicable etc.

Lasers of Classes 3B and 4 must be operated only in Laser Designated Areas (LDAs). Research laboratories may contain appropriate Areas, but it is unlikely that this will be the case for non-laboratory situations, such as general lecture theatres. It is therefore recommended that such lasers are **not** used for lecture theatre or classroom demonstrations.

In all cases of uncertainty users must consult the SLS in advance.

11. Lasers temporarily brought into the University

If a laser is brought into the University and is to be used for a period of less than four weeks it need not be registered with Health and Safety Services and need not be given a ULN.

When any laser that is not University property is brought onto University premises the insurance position must be clarified with the University Insurance Officer (extension 8309), and written arrangements regarding the use must be made.

The SLS must be informed in advance of what is intended, and will permit the temporary use only if he/she believes that it complies with the School's local rules. Appreciable hazards would not be expected for lasers up to and including Class 3R, but a suitable LDA is necessary for Class 3B and Class 4 lasers. Discussion with the LSO of the organisation owning the laser will probably be necessary to determine how responsibility is to be apportioned. If any responsibility rests with the University of Reading, the approval of the Head of School **must** be obtained.

Written arrangements must be made when the laser is to be used by persons who are not employees of the University.

12. Use of lasers for entertainment and display purposes

Normally, University owned research lasers must not be used for purposes for which they are not intended or designed *i.e.*for entertainment or display purposes.

When lasers for display purposes are supplied, installed and operated by an outside body the hire contract must be drawn up to ensure that the division of responsibilities is clearly understood. Such lasers are generally Class 3B or 4, and the usual concept of the Laser Designated Area can no longer be applied. Appropriate steps must be taken so that no person is exposed to laser radiation at a level in excess of the Maximum Permissible Exposure (MPE).

13. Laser pens and pointers

Class 1 and Class 2 Laser pens and pointers may be used in teaching and demonstrations without prior registration; the only restriction in use is that the beam must not be directed towards anyone.

The advice of the URSO must be sought before purchase for pointers or devices labelled as "3R". Such devices are subject to the relevant requirements described in this guide, and should be registered with Health & Safety Services. Anyone proposing to acquire a Class 3R device must justify why it is needed when completing the registration form.

Those labelled as Class 3B or Class 4 items **must not be used**.

Items not bearing appropriate classification labels **must not** be used.

"Recreational" use of laser pens and pointers is strictly prohibited.

Safety Note 9 gives more detail on the use of laser pens and pointers. This is available via the Health & Safety Services website.

Further advice and information

References in the text

1A: *Safety in Universities: Notes of Guidance. Part 2:1 Lasers.* Committee of Vice Chancellors and Principals, London 1992. ISBN 0948890 19 7.

1B: *Guidance on the safe use of lasers in education and research.* Association of University Radiation Protection Officers, 2007.

2. Health & Safety at Work (etc.) Act, 1974.
3. *Management of Health and Safety at Work Regulations 1999.* Approved Code of Practice and Guidance L21 HSE Books 2000 ISBN 0 7176 2488 9.
4. "The Safety of Laser Products – Guide for Users" IEC PD 60825 part 14. BSI, London 2004.
5. "The Safety of Laser Products –Part 1, Equipment Classification and requirements". BSI, London, 2007.
6. *Good Chemical Laboratory Practice* – leaflet issued by Health & Safety Services.

Appendix 1 Duties of a School Laser Supervisor

The School Laser Supervisor (SLS) must ensure that:

- A comprehensive risk assessment is undertaken before any new laser is brought into use, and that no unregistered lasers are brought into the department;
- All relevant lasers are registered on the University database of lasers (held by Health & Safety Services), and are labelled with the registration number issued by the ULSO;
- Any change of location of a registered laser is notified to the ULSO;
- When a laser is permanently taken out of use (scrapped), the ULSO is notified so that the database can be kept up to date.

The SLS is responsible for:

- Providing advice to members of the School/Department on matters of laser safety and in particular advising the Head of School on the formulation and revision of its safety policy and procedures regarding laser safety;
- Acting with the delegated authority of the Head of School/Department in matters of urgency and referring promptly to the Head of School or University Laser Safety Officer any laser safety problems which cannot be resolved locally on a time scale commensurate with the risk;
- Liaising with the University, University Laser Safety Officer, the Head of Health & Safety Services and other central Officers and Advisers as necessary;
- Attending (*ex officio*) meetings of the Area Health & Safety Committee and the University Radiation Safety Sub Committee when required;
- Conducting or co-ordinating systematic inspections and accident investigations (together with Safety Representatives of the recognised Trade Unions having employees working in the area/department), to identify unsafe or unhealthy conditions or work practices which may lead to excessive exposure to laser radiation, and monitoring that preventative action is recommended and pursued;
- Ensuring that any accidents and/ or unplanned incidents involving lasers are reported to Health & Safety Services, and promptly investigated;
- Disseminating laser safety information and reports to appropriate members of School/Departmental staff and students;
- Ensuring that new members of the area/department receive adequate information with respect to laser safety matters on induction, and that all persons wishing to use lasers (or laser-based equipment to which this guidance applies) have attended the Health & Safety Services safety training course on the use of lasers;
- Identifying members of the area/department for:
    - laser safety training events;
    - or (if attendance is not possible because of time restrictions) ensure that each user has received laser safety training and seen the video "*Laser Safety in Higher Education*".
    - occupational health medical surveillance; and
    - liaison with other internal or external laser safety specialists.
- Monitoring in the area/department that:
    - adequate precautions are taken regarding any laser hazards;
    - adequate precautions are taken regarding any changes to be made;
    - plant, equipment and processes are being maintained as required by any relevant statutory provisions;
    - staff and students are suitably informed, instructed and trained;
    - adequate records of lasers are being maintained where appropriate, i.e. as required by relevant statutory provisions or by University or area/departmental health and safety policy;
    - safe working practices and procedures, together with any necessary risk assessments for project work (especially for postgraduate students), are complied with;

  - the need for personal protective equipment (PPE) has been included in the risk assessment, and that suitable and sufficient PPE (Safety Guide 27) is available and used when appropriate;
  - systems are set-up and maintained to check that laser safety facilities such as monitors, shielding, beam stops, interlocks, etc are provided where necessary and maintained in a readily usable condition; and
  - other laser safety aspects that legislation or university/area/departmental policy may dictate are catered for.
- Co-ordinating the implementation of advice from the University Laser Safety Officer.
- Periodically reviewing laser safety procedures within the area/department.
- Such other laser safety duties that may be assigned by the Head of Department.

The SLS must ensure that training records are kept of laser safety training received by individuals, plus a copy of the worker registration form where a worker is required to register as a laser user.

Appendix 2 Duties of the University Laser Safety Officer

The University Laser Safety Officer (ULSO) is responsible to the Head of Health & Safety. For convenience, the function is undertaken by the University Radiation Safety Officer (URSO), and in respect of laser safety, the duties include:

- Providing professional advice to the University on matters of laser safety;
- Liaising with School Laser Supervisors and members of the University Health & Safety Committee in implementing the University Health & Safety Policy regarding laser safety;
- Co-operating with specialists inside and outside the University on laser safety matters;
- Advising officers in charge of the design and construction of new buildings and the modification of existing buildings on matters affecting laser safety;
- Advising on:
    - implications of any new relevant statutory provisions or standards;
    - restriction of exposure and maintenance of engineering controls and other equipment provided for such restriction;
    - control of access to laser-designated areas (LDAs);
    - drawing up of written local rules and written systems of work;
    - selection of School Laser Supervisors;
    - risk assessment and appropriate contingency arrangements; and
    - prior examination of any plans for new plant or new premises or modifications to existing plant or premises from a laser safety aspect.
- Overseeing and co-ordinating the provision of central laser safety training;
- Undertaking or assisting with periodic inspections of University premises where a laser safety input is required;
- Auditing departmental laser safety arrangements;
- Liaising with the relevant inspectorate (HSE) and co-ordinating any visit or inspections;
- Such other laser safety duties that may be assigned by the University.

Appendix 3 Laser classification

CLASS	PROPERTIES	LABELS	NOTES
Class 1	Inherently safe, Accessible Emission Limit (AEL) 700 μJ in the visible region for exposure times from 18μ s to 10 s. Registration with H&SS not needed.	No University requirement for additional labelling [manufacturer label only].	
[Class 1 Device containing higher class laser – formerly 1E]	Totally enclosed systems inherently safe because of engineering design, or engineering design such that any routine exposure restricted to Class 1 AEL. Typically applies to scientific instruments such as cell counters. Must register with H&SS if maintained or adjusted by University staff.	If maintained by manufacturer's service engineer: no University requirement for additional labelling [manufacturer label only]. If maintained by University staff: "LASER PRODUCT CLASS 1. A TOTALLY ENCLOSED LASER SYSTEM CONTAINING A CLASS (x) LASER" Adjacent to, but not on, removable panels etc: "CAUTION - LASER RADIATION WHEN OPEN AND INTERLOCK OVER-RIDDEN" (Label R5) ULN	Ideally, a system of work should be in place that defines that all maintenance and adjustment operations are to be undertaken by the manufacturer's authorised service engineer. University staff should not be present if the system is operated without guards during such operations. **If maintained or adjusted by University staff**, the system must be reclassified during maintenance etc, when the beam is accessible through the over-riding of interlocks. Instructions regarding such circumstances must be given to the personnel concerned. The system must be designed on a fail-safe basis; lasers within the enclosure must be clearly identified and labelled, and a clearly labelled and conspicuously sited electrical isolation switch must be provided.

The following requirements apply to "Open Beam" work with any laser, i.e., where a laser beam is emitted from a device, and which could be accessed by the user. If the beam is totally enclosed at all times, and cannot be accessed by the user, the device can be regarded as a "Class 1 device, and is considered safe (as above).

Low to medium power lasers

CLASS	PROPERTIES	LABELS	NOTES
Class 1M SAFE WITHOUT VIEWING AIDS	For lasers emitting in the wavelength range 302.5 – 4000 nm. Beams highly divergent or large diameter.	"CLASS 1M LASER". "SAFE WITHOUT VIEWING AIDS". "DO NOT USE OPTICAL AIDS WITHIN THE LASER BEAM".	The use of optical viewing aids e.g. microscopes, must be controlled or filters must be fitted so that Maximum Permissible Exposure levels (MPEs) at the eyepiece are not exceeded.
Class 2 (Visible only) LOW POWER	Normally protected by blink reflex. CW power < 1mW. Must register with H&SS.	"LASER PRODUCT CLASS 2" (Label R6). "DO NOT STARE INTO BEAM" ULN	Applies to some laser pointers The User must never stare at the beam, nor aim the laser at other persons
Class 2M (Visible only) SAFE WITHOUT VIEWING AIDS	Normally protected by blink reflex. Direct viewing with optical aids may be hazardous. Beams either large diameter or highly divergent. Must register with H&SS.	"LASER PRODUCT CLASS 2M". "DO NOT STARE INTO BEAM". "USE OF OPTICAL INSTRUMENTS REQUIRES LASER SUPERVISOR'S APPROVAL". ULN.	The use of optical viewing aids e.g. microscopes, must be controlled or filters must be fitted so that Maximum Permissible Exposure levels (MPEs) at the eyepiece are not exceeded
Class 3R - LOW/ MEDIUM POWER 302.5 nm – 1mm	Direct viewing may be hazardous. Up to 5 x AEL for Class 1 or Class 2 (*e.g.* CW power in the visible region <5 mW). Must register with H&SS.	"LASER PRODUCT CLASS 3R" "DO NOT STARE INTO BEAM". "USE OF OPTICAL INSTRUMENTS REQUIRES LASER SUPERVISOR'S APPROVAL". ULN.	The use of optical viewing aids, e.g.,microscopes, must be controlled or filters must be fitted so that Maximum Permissible Exposure levels (MPEs) at the eyepiece are not exceeded Protective eyewear may be needed if beam is exposed

Higher power lasers requiring special precautions

CLASS	PROPERTIES	LABELS	NOTES
Class 3B MEDIUM / HIGH POWER	Hazard from direct viewing and specular reflections. AEL of<500 mW for CW laser. Must register with H&SS. LASER DESIGNATED AREA (LDA) required.	"LASER PRODUCT CLASS 3B". "AVOID EXPOSURE TO BEAM". "LASER APERTURE" or "AVOID EXPOSURE – LASER RADIATION IS EMITTED FROM THIS APERTURE". ULN.	A captive-key control must be fitted. The key must be removed when the laser is not in use, and kept in a safe place by a nominated person. Keys must never be issued to an unauthorised person. Beam shutter or attenuator must be fitted. LDAs must be clearly identified, and entry restricted to authorised personnel.
Class 4	Possible hazard from diffuse reflection CW power in the visible region >0.5 W Eye, skin and fire hazard Must register with H&SS. LASER DESIGNATED AREA (LDA) required.	"LASER PRODUCT CLASS 4". "AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION". "LASER APERTURE" or "AVOID EXPOSURE - LASER RADIATION IS EMITTED FROM THIS APERTURE". ULN.	Written System of Work required. Protective eyewear and other personal protective equipment needed if beam is exposed. A captive-key control must be fitted. The key must be removed when the laser is not in use, and kept in a safe place by a nominated person. Keys must never be issued to an unauthorised person. Beam shutter or attenuator must be fitted. LDAs must be clearly identified, and entry restricted to authorised personnel. Review / recording of risk assessment required whenever changes made to System of Work.

Appendix 4 Technical and legal annex

i) Technical background

The acronym laser stands for **L**ight **A**mplification by the **S**timulated **E**mission of **R**adiation. In this context, the term "Light" includes all electromagnetic radiation in the wavelength band[1] from the far ultraviolet (100 nm upwards) through the visible (400 – 750 nm) to the infra-red (750 nm – 1 mm.) Laser light has high spatial coherence, monochromaticity and, generally, is highly collimated. Some lasers operate in a pulsed mode to produce (very) short bursts of coherent radiation - the pulse duration can be as little as 100 attoseconds (10^{-16} seconds), with a repetition frequency varying from 1kHz upwards. The majority of low power lasers produce a continuous output and are known as continuous wave or CW lasers.

The principle of laser operation is that energy is supplied to a "lasing medium" inside an optical cavity resonator, which in its simplest form consists of two mirrors which are arranged in such a way that "light" is bounced back and forth within the cavity through the lasing medium. One of the mirrors (the output coupler) is normally semi-transparent, and the laser beam would be emitted through this mirror. At each stage, amplification of the light takes place as the input energy is fed into the lasing medium – a process normally referred to as "pumping". The energy may be in the form of electrical energy (in a solid-state or diode laser), or as light of a different wavelength – for example from another laser, or from a Xenon flash tube. (This would normally be used in a pulsed laser, as the flash tube operates in a pulse mode. A continuous laser would normally require a continuous energy input.)

The energy fed into the system is absorbed by the lasing medium, and serves to elevate electrons to a higher energy level in the molecules of the medium (the "excited state"). When the electrons return to the ground state, the energy is emitted as photons of light of a wavelength [energy] controlled by the nature of the lasing medium. This emission is stimulated by the passage of light through the medium in the same direction as the light passing by, which gives rise to a coherent light beam which is tightly collimated with the axis of the optical cavity. The amount of amplification is determined by the number of times the light beam bounces backwards and forwards in the cavity, and the gain (amplification) for each passage through the resonator. This effect is initially exponential, but as the gain increases, a saturation point is reached at which energy input into the excited state is balanced by emission from the excited state back to the ground state. Equilibrium will ultimately be reached when the pump power balances the effect of gain saturation – this would normally be the maximum output of the laser.

Many laser systems are potentially hazardous because the spectral brightness of the laser (in $W\ cm^{-2}\ sr^{-1}\ nm^{-1}$) is many orders of magnitude greater than for any other known light source. Even "low power" lasers have the potential for causing biological damage. Long-term (>100s) over-exposure gives rise to photochemical effects; for shorter exposure and pulses down to 100μs thermal effects are most likely. A temperature rise of a few ^{o}C will denature the proteins that comprise the light sensitive elements of the eye. Very short pulses can cause ionisation and thermo-acoustic shock. Lasers with extremely short pulse durations (10^{-12} seconds or less) are currently being actively studied in the University, and users should be aware that some of the guidance in the Standards (see refs 4-5) may not apply.

There is an increasing number of "non laboratory" uses for lasers which usually (but not always) are based on semiconductor lasers. These are miniature lasers made from small pieces of semiconductor material and are similar to transistors, consisting of a p-n junction. The wavelength and power depend upon the type of materials used. So-called diode lasers are becoming increasingly powerful yet are small and compact. They are used extensively for telecommunications and surveying equipment, and are now found in the "DIY" market as level devices; aiming devices for ultrasonic "tape measures" and infra-red "spot" thermometers. They are also commonly found in laser pointers and

[1] This is the wavelength range referred to as "Optical Radiation" in the Optical Radiation Directive – see Section 4.2.

pens (Section 13). Many of these devices contain "open beam" Class 2 or Class 3R lasers emitting in the visible wavelength region.

It should also be noted that some high power light emitting diodes [LEDs] can produce very intense beams of light, and are at present[2] covered by the requirements of IEC 60825-2 and 60825-12, so for practical purposes can be treated in the same way as lasers.

ii) Applicable legislation, standards and guidance

Current situation
There is at present no specific legislation in the united Kingdom governing the safe use of lasers, but the general provisions of the Health & Safety at Work etc Act 1974 and the risk assessment requirements of the Management of Health and Safety at Work Regulations 1999 (References 2 and 3) apply.

Laser safety standards are covered in the series of documents originating from the International Electrotechnical Commission under the generic title IEC 60825. Some parts of this family have been transposed into British/ European Standards [BS/EN 60825], whereas some parts remain as IEC "Published Documents", for example, PD 60825 part 14 2004 (Reference 4), which gives guidance for users. The parent standard is currently BS EN 60825-1: 2007 Edition 2.

The "old" CVCP *Notes of Guidance* 1992 (Reference 1A) are now out of date, and have been superseded by the AURPO document "*Guidance on the safe use of lasers in education and research*" (Reference 1B). The CVCP document remains useful however as a source of information about the previous hazard classification scheme for lasers. As many old lasers remain in use users should refer to the CVCP document for details on hazard classification of such lasers.

Future developments
The Optical Radiation Directive was published in the Official Journal of the European Union on 27 April 2006 (Reference 4). This Directive covers the use of all artificial forms of optical radiation[3], including lasers, and includes the requirement that it be transposed into national law no later than four years after the Directive was published. The Health & Safety Executive (HSE) must therefore produce and bring into UK law appropriate regulations to comply with the Directive. At the time of writing (June 2008), a first draft of the proposed regulations is still awaited, but this Safety Guide is written with the aim of complying with the spirit of the Directive. Readers should note that a revised edition of this Guide may be required once the detail of the final regulations is known.

[2] Although LEDs were originally included in the "parent" standard IEC 60825-1, they have now (as of June 2007) been removed from the scope of that document.
[3] Optical radiation is defined in the Directive as any electromagnetic radiation in the wavelength range from 100 nm to 1 mm, i.e, far UV to far Infra-red.

Appendix 5 Example risk assessment

Ref. No.
ULN SS1/Yr. 2006

Laser activity RISK ASSESSMENT FORM (RA2L)

This form must be completed in respect of each registered laser used on University premises.

School / Dept / Unit	Science Studies
A: Laser associated hazards and existing controls	
1. Give brief details of the laser to be used, and its location. Refer to University Laser Number (ULN) where this has already been issued. If this form is used to record a review of a previous assessment, you may refer to that assessment and just note changes.	Class 3B/ 1M solid state CW laser, max. 50 mW at 532 nm [Frequency-doubled Nd:YAG], ref. number ULN SS1/2006. Laser to be set up in incubator room in Microbiology suite. Laser rated as 3B during set up process before beam expanders fitted, when rated as 1M. Class 1 sighting laser (633 nm) to be used as a guide for setting up the green laser/ beam expander.
2. Give a brief summary of the work activity. State whether open beam work is proposed.	Laser to be used to examine the effects of intense green light on the photosynthetic ability of various cyanobacteria and the evolution of oxygen during the period of exposure. Work will involve laser beam directed into cultures of the various organisms held in purpose-designed apparatus [incubation temperature 30^{o}] located in microbial growth room. Possibility of specular reflections from internal and external surfaces of culture tubes during set-up process. Experiments predicted to take up to 3 weeks, with samples (10 μl) taken from the culture tubes at intervals over this period. Samples will be analysed to examine the effects of the laser light on pigment formation as well as oxygen evolution. Evolved oxygen will be continuously measured via gas analyser linked to the culture tube. Alignment of the laser in the correct location with respect to the culture tube occurs in the absence of the beam expander, which has to be adjusted to ensure even illumination of the tube contents. Samples can then be taken without disturbing the alignment of the laser or the beam expander [laser to remain in operation during sampling.]
3. List significant hazards Take into account laser class; beam position in relation to doors & windows; use of optical devices within the beam; beam stops; non-beam hazards such as high voltage, toxic materials, etc Do not forget hazards which may be exacerbated by	Significant hazards are primary and reflected beams during the alignment procedure: beams could be accessed when adjusting the alignment of the primary beam and beam expander with respect to the culture tube after loading with culture to be tested. Apparatus located in a light-shield so that between samples, the apparatus is totally enclosed. Culture tubes have external matt-black coating on the rear surface, and the expanded beam is directed towards this, which therefore acts as a beam stop for light passing through the culture tube. Beam-expanding optics mounted at front of the tube to ensure beam illuminates the whole volume of the culture in the tube. Expansion is such that during operation, the expanded beam is classified as 1M, but reflections from the front of the tube during alignment could be hazardous. Non-beam hazards include biological hazards associated with some of the cultures to be used [some of the cyanobacteria produce toxins] No electrical hazards associated directly with the laser [powered by 3V isolating

poor visibility as a consequence of working in a darkened room – e.g., trip hazards.	transformer], but culture apparatus is mains powered. Use of class 1 sighting laser does not present any hazards.
4. Relevant University or local guidelines or standards. If Local Rules used, please attach a copy to this form.	Tick appropriate box(es) for safety guidelines etc. used : University Safety Guide 21 (Lasers) ☑ British Standard Published Document PD IEC TR 60825-14:2004 – "*The safety of laser products*" ☑ Local Rules - ☑ Location of Local Rules……Office room G5; Microbiology Culture room……………
5. List who might be exposed to the hazards (e.g. staff, students, visitors, consider numbers at risk) Use separate entries for normal operation and operation during beam adjustment or laser servicing, etc.	During normal operation, no exposure expected;. during set-up/ adjustment, only -2 persons [J. Black; G. Brown]. Green laser not regarded as hazardous [1M] during normal operation; Class 3B during set up – persons exposed as above.
6. How might they be harmed? (type(s) of injury or health problem that might result). Please use a separate entry for each type of potential injury that could be caused by exposure to a hazard	Main injury related to laser beam is eye- injury, caused by primary or reflected beam entering the eye of the operator. Could cause permanent eye-injury with partial or total loss of sight in the affected eye. Possible microbiological/ toxic hazards related to particular organisms to be studied – could include infection [unlikely] or toxicity from exposure to toxins produced.
7. List control measures in place to reduce risks Use the information from the checklist on the registration form to compile the list of control measures. Group controls under the headings of "Engineering controls";	Engineering controls: During normal operation, laser / apparatus totally enclosed. Access to hazardous beam(s) only possible during alignment as part of the set-up process. Culture of cyanobacteria enclosed in culture tube; tube fitted with "Quicksample" access port which allows samples to be taken for analysis without disruption of irradiation. Administrative controls: During set-up, notice to be posted on the door to the culture room "No Admittance – Laser-Designated area, Laser Class 3B in operation". After set-up completed, warning notice may be removed.

"Administrative controls" and "personal protective equipment". Note that "engineering controls should fail to safety, for example failure of a bulb in an illuminated sign should be interlocked to a beam shutter. For each control identified above, assess whether this is adequate, is actually used in practice and state whether this is regularly checked, where appropriate. Note that protective eyeware must not be relied upon as a primary control measure.	Microbiological / toxic hazards controlled by adherence to GMLP and training/ experience of the operators Personal Protective Equipment: Laser goggles rated for 75mW exposure at 532 nm to be worn as a precaution during alignment. Standard microbiological PPE – lab coat, non-latex gloves to be worn during set-up, sampling and analysis of samples.

B: Assessing the residual level of risk and further action needed (See Safety Guide 4 pages 10 – 11 for an explanation of the terms in this table)					
7.1 How severe is any injury or health effect likely to be?	Tick one box (**S** =score given in brackets)	Minor (1) ☐	Serious (2) √	Major (3) ☐	Fatal (4) ☐
7.2. How likely is exposure to the hazard?	Tick one box (**P** =score given in brackets)	Very unlikely (1) ☐	Unlikely (2) √	Possible (3) ☐	Likely (4) ☐
7.3. Calculate the risk score by multiplying the 2 scores in Q7.1 & 7.2	Risk Score (S x P) =	Low (1–3) ☐	Medium (4–6) √	High (8–9) ☐	Very High (12–16) ☐
8. Immediate further action to be taken to make the situation safe / reduce risk to health				Action to be taken by whom?	Implementation date
No further action required.					

9. Further action or additional controls needed to reduce risk as low as reasonably practicable	Action to be taken by whom?	Implementation date
Nil		

Name of Assessor (please print)	J. Black	
Signature of Assessor		Date: 25/01/05
Signature of Head of Dept/School/Unit	F. Green	Date: 01/02/05

Date for Review (maximum 12 months from date of this assessment)	