UNIVERSITY OF STRATHCLYDE
LASER EYE STRIKE
EMERGENCY INSTRUCTIONS

In the event of an incident involving a laser eye strike please proceed as follows:

- Switch off laser.
- Reassure the casualty then call for assistance.
- Summon assistance from Security Control on Ext 2222 (emergency number) or alternatively Ext 3333.
- All security wardens are qualified first aiders.
- Please state clearly:
  - Name, department, location and extension number
  - Brief details of the injury- LASER EYE STRIKE.
  - Medical attention will be (see full instructions / contact details on “Grab Sheets”).
  - Transport will be required.
- Stay with the casualty and reassure until help arrives.
- Complete laser details to be sent with casualty or take “Grab Pack” details to hospital. (See Appendix 4).
- The security warden will take charge.
- The casualty should be accompanied to the hospital ensuring all the relevant details of the laser involved in the incident are available for the medical staff.
- The incident should be reported to the appropriate Departmental Radiation Protection Supervisor (or Laser Safety Officer), Head of Department and Safety Services as soon as possible (Ext 2726).

Contact Numbers

| During Office Hours (0900 to 1700 hours, Mon - Fri) | Security Control – Ext 2222
Radiation Protection Officer (RPO) – Ext 4673 or 2726 |
<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>Outside Normal Working Hours (Evenings and Week-ends)</td>
<td>Security Control – Ext 2222 ask them to notify Head of Safety Services, Radiation Protection Officer and the Radiation Protection Adviser.</td>
</tr>
</tbody>
</table>

In every event –

Contingency plans giving details of the action to be taken in the event of an incident or accident should be incorporated into Departmental Safety Arrangements/Regulations and/or the individual risk assessment and safe system of work.
## CONTENTS

**GENERAL - PART 1**

1. **Introduction** 6
   1.1 University Policy  
   1.2 Safety Statement  
   1.3 Aim and Scope of this Guidance Document  
   1.4 Background  
   1.5 Terminology

2. **Legislation** 8
   2.1 General legal requirements  
   2.2 Non-ionising radiation legal requirements  
   2.3 Exposure standards  
   2.4 Other relevant legislation  
   2.5 Risk assessments  
   2.6 Safe systems of work

3. **Roles and Responsibilities** 9
   3.1 University Management of Radiation Safety  
   3.2 University Advice and Support  
   3.3 Heads of Departments / Directors of Service  
   3.4 Principal Investigators  
   3.5 Department Radiation Protection Supervisor / Laser Safety Officer  
     3.5.1 General duties of DRPS / LSO  
   3.6 Employees and students responsibilities and duties

4. **Non-Ionising Radiation Workers** 11
   4.1 Postgraduate and undergraduate students  
   4.2 New and expectant mothers

5. **Others** 12
   5.1 Visitors  
   5.2 Contractors  
     5.2.1 Contractors associated with projects  
     5.2.2 Contractors not associated with projects  
   5.3 Other University Staff

6. **Departmental Local Rules** 13

7. **Training** 13
   7.1 Safety Services  
   7.2 Departmental Training

8. **Purchase and Design of NIR Sources and Equipment** 14
   8.1 CE Marking

9. **Laboratory and Workshop Facilities** 15

10. **Monitoring and Auditing** 15
SPECIFIC - PART 2

11. Optical Radiation
   11.1 Development of legislation and exposure standards
   11.2 Exposure limits

12. Lasers
   12.1 Sources and types of lasers
   12.2 Laser fundamentals
   12.3 Classification of lasers
   12.4 Laser hazards
       12.4.1 Biological effects
       12.4.2 Non-beam hazards
   12.5 Current guidelines and exposure limits
   12.6 DRPS (Lasers) / Laser Safety Officers (LSO)
       12.6.1 Appointment
       12.6.2 General duties
       12.6.3 Training
   12.7 Laser workers
       12.7.1 General duties
       12.7.2 Training
   12.8 Laser controlled areas
   12.9 Laser hazard analysis and control
   12.10 Laser risk assessment
   12.11 Control measures: lasers
       12.11.1 Engineering
       12.11.2 Administrative
       12.11.3 Personal protective equipment

13. Ultraviolet Radiation
   13.1 Sources of ultraviolet radiation
   13.2 Ultraviolet radiation health effects
       13.2.1 Ultraviolet skin hazards
       13.2.2 Ultraviolet eye hazards
   13.3 Legislation, guidelines and exposure limits
   13.4 Control measures: UV - artificial sources
       13.4.1 Engineering
       13.4.2 Administrative
       13.4.3 Personal protective equipment
   13.5 External UV solar exposure and outside workers
       13.5.1 Control measures: UV solar exposure

14. Visible Light Hazards
   14.1 Blue light hazard

15. Infrared Radiation
   15.1 Infrared radiation hazards

16. Light Emitting Diodes

17. Electromagnetic Field Radiation
   17.1 Factors affecting exposure to RF / MW radiation
   17.2 Potential bio-effects of exposure to RF/MF radiation
       17.2.1 Direct effects on people
       17.2.2 Indirect effects on people
       17.2.3 Effects on the environment
   17.3 Exposure guidelines and future legislation
   17.4 Identifying EMF radiation hazards
17.5 Control measures: EMF radiation
17.6 Other RF/MW Sources
   17.6.1 Antennae and Antenna Arrays
   17.6.2 Mobile phones
   17.6.3 Microwave sources
   17.6.4 Power supplies
   17.6.5 EMF radiation from leaking sources

18. References, Guidance and Further Reading

Appendices
1: Occupational H&S Responsibility & Management Structure 43
2: Example of Draft Local Rules for Work with Lasers 44
3: Emergency Instructions for a Laser Eye Strike 45
4: Example of a ‘Grab Pack’ Template Sheet 46
5: Examples of Laser Warning Labels 47
6: Summary of Laser Classes and Control Measures 49
7: Example Laser Risk Assessment Template Form 51
8: Common Non-Beam Laser Hazards and Control Measures 56
9: Additional Laser Control Measures - High Risk Laser Activities 58
10: Working With Optical Fibre Systems 60
11: Selection and Use of Laser Safety Eyewear 61
12: Laser Safety Checklist 63
13: Examples of Non-Ionising Warning Signage 65
14: Definitions of Technical Laser and Other NIR Terms 66

Figures
1: Electromagnetic Spectrum 7
2: Laser Classes and Hazard Level 18
3: Structure of the Eye and Penetration of Different Wavelengths 20
4: Structure of the Skin and Penetration of Different Wavelengths 20
5: Additional Non-Hazards to be Considered 21

Tables
1: Approximate Wavelengths and Frequency Ranges of NIR 7
2: Summary of Laser Classes and the Required Control Measures 18
3: Possible Effects of Wavelengths on the Eyes and Skin 20
4: Potential Health Effects of UV Exposure on the Skin 29
5: Potential Health Effects of UV Exposure on the Eye 29
6: Time to Exceed ICNIRP Exposure Limits for Typical UVR Sources 30
7: The Visible Light Spectrum Range 32
1.0 Introduction

1.1 University Policy

It is the Health and Safety Policy of the University of Strathclyde to ensure, so far as is reasonably practicable, the health, safety and welfare of all its employees at work, of students while they are engaged in activities under the supervision of the University and of members of the general public who have access to University property.

1.2 Safety Statement

The University of Strathclyde expects a high level of professionalism from all persons who are authorised to work with Non-Ionising Radiation (NIR). The University ensures that there is a secure framework for Departments on which to base radiation safety management which still allows the greatest latitude for all research workers.

1.3 Aim and Scope of this Guidance Document

This document is intended to serve as a guide to departments and individuals using or having responsibility for work with non-ionising sources of equipment. It aims to support the University’s Local Rule for Work with Non-Ionising Radiation, ensure compliance with current legislation and encourage good practice to be followed in order to protect individuals from non-ionising radiation exposure. It describes the roles and responsibilities of various groups and individuals; the University’s safety management structure, operating procedures, standards and practices for the safe use and management of non-ionising radiation within the University. This document has been written to provide guidance and advice to staff and students who may be exposed to sources of NIR during their work at Strathclyde University or during placement schemes. It is recognised that not all aspects of this guidance will apply to all types of non-ionising work and users should ensure that they refer to all relevant sections in line with their particular work requirements.

The University’s Local Rule for Non-Ionising Radiations details the key management actions that departments must comply with when working with non-ionising radiation sources of equipment.

Non-ionising electromagnetic radiation is the term used to describe the part of the electromagnetic spectrum covering the main regions of optical and electromagnetic field (radio waves) radiation. From a non-ionising radiation viewpoint, lasers, ultraviolet, infra red and microwave sources generally present the greater hazard than that of other NIR sources.

There are numerous applications from both artificial and solar sources of NIR within the University. The primary sources of NIR within the University include:

**Optical Radiation**
- Incoherent sources of light emitting in the visible part of the spectrum;
- Lasers (coherent source);
- Ultraviolet (UV) sources;
- Infrared (IR) sources;
- Light Emitting Diodes (LED’s);

**Electromagnetic Field (EMF) radiation**
- Radiofrequency including microwaves; and
- Extremely low frequency sources.
All members of staff working with any of the above must make themselves aware of the requirements contained within the University Local Rule for NIR.

1.4 **Background**

Non-ionising radiation is grouped into the region of the electromagnetic spectrum that has a wavelength greater than 100nm or frequencies less than $3 \times 10^{15}$ Hz (See Figure 1). It is termed ‘non-ionising’ as the photon energy is insufficient to ionise (change atomic structure) of matter. However, over exposure to sources of NIR may cause biological damage. Potential damage is dependent on numerous factors relating primarily to the source of NIR and the environment it is used in. The two main regions of the non-ionising spectrum: optical and radiowaves are categorised in terms of the photon wavelength or frequency. Generally optical radiation is classed by wavelength, and radiowaves classed by frequency. NIR is further subdivided into a number of wavelengths and frequency ranges as described in Table 1.

**Figure 1:** Electromagnetic spectrum.

![Electromagnetic spectrum](Image: © Health Protection Agency (Non-Binding Guide to the Artificial Optical Radiation Directive, 2009).)

**Table 1:** Approximate wavelengths and frequency ranges of NIR

<table>
<thead>
<tr>
<th>Type of NIR</th>
<th>Wavelength / Frequency range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Optical radiation</strong></td>
<td></td>
</tr>
<tr>
<td>Ultraviolet (UV)</td>
<td>100 - 400 nm</td>
</tr>
<tr>
<td>Visible (light)</td>
<td>380 - 740 nm</td>
</tr>
<tr>
<td>Infrared (IR)</td>
<td>750 nm- 1mm</td>
</tr>
<tr>
<td><strong>Radiowaves</strong></td>
<td></td>
</tr>
<tr>
<td>Radiofrequency radiation (RF) including</td>
<td></td>
</tr>
<tr>
<td>Microwaves</td>
<td>300 Hz to 300GHz</td>
</tr>
<tr>
<td>Extremely low frequency (ELF) fields</td>
<td>$\leq 300$ Hz</td>
</tr>
</tbody>
</table>

1.5 **Terminology**

Please refer to Appendix 16 for a description of common laser and other NIR terms.
2.0 Legislation

2.1 General Legal Requirements
The Health and Safety at Work etc. Act 1974 (HASWA) and the Management of Health and Safety at Work Regulations 1999 (MHSWR) set out requirements for employers to provide a safe place of work, safe systems of work and to carry out risk assessments covering all work activities. The University (acting as the employer) must do all that is reasonably practicable to secure the health, safety and welfare of employees at work in addition to ensuring the safety to non-university employees. One primary objective of the MHSWR is to focus attention on the importance of employers in identifying preventative measures and to implement management systems for the planning, control, monitoring and review of work procedures.

2.2 Non-Ionising Legal Requirements
In addition to the above general health and safety legislation, the Control of Artificial Optical Radiation at Work Regulations 2010 applies in the UK and future legislation for EMF is expected to come into force in October 2013. Both of these regulations stem from European Union Physical Agents Directives.

2.3 Exposure Standards
The International Commission of Non-Ionising Radiation Protection (ICNIRP) has produced a set of guidelines relating to exposure of optical radiation and electromagnetic fields. The Radiation Protection Division of Public Health England (formerly the Health Protection Agency) has produced a set of guidelines specific to the UK regulatory framework in line with the international standards set by ICNIRP. The PHE guidance includes recommended exposure limits for humans to non-ionising radiation over the range of frequencies and wavelengths likely to be encountered. Situations where exposure standards apply will be where the intended radiation can interact with people and the environment. The aim of both sets of guidelines and standards is to express safety limits in numbers, which can be verified in order to safeguard people. The guidelines take into account, and assess the biological effects from exposure to NIR and address the basic restrictions required.

2.4 Other Relevant Legislation
Other legislation may also apply when working with sources of non-ionising radiation. Many of these are covered by other University Local Rules, for example, Local Rules for working with:

- Ionising Radiation
- Control of Substances Hazardous to Health (CoSHH)
- Electrical Safety
- Provision and Use of Work Equipment Regulations (PUWER)
- Contractor Local Rules for Safe Practice
- Manual Handling

Where work with NIR sources e.g. high power lasers could result in the generation of x-rays or the activation or generation of radioactive materials, the Local Rules and Guidance for Work with Ionising Radiation will apply and consultation should be made with Safety Services in the first instance.

You will find additional useful guidance documents on specific subjects in the References Section (Section 19) of this document.
2.5 **Risk Assessments**

It is part of University policy that prior to work commencing, risk assessments should be carried out for all work involving non-ionising radiation. In some circumstances, Departments may wish to forward their risk assessments for review by the University RPA. For example, if a department is new to working with lasers, or if the work being proposed is particularly high risk or unusual.

The purpose of a risk assessment is to make sure that no one is injured or becomes ill as a result of work activities undertaken. The process involves finding out what aspects of the work activity could cause harm to people, then deciding if enough has been done to reduce the likelihood and severity of that harm, taking into account existing precautions. Where it is decided that further measures are required, then it should be ensured that these are implemented and remain effective. The significant findings of the risk assessment should then be recorded and provided to those who could be affected.

The risk assessment should be carried out by someone who has the required knowledge, experience and training to do so. In most cases, Heads of Department will delegate this function to the Principal Investigator (PI); Academic Supervisor, Trade Supervisor or Line Manager who is responsible for the work. The assessment will address all potential hazards, identify the person(s) who may be harmed (staff, students or any other persons susceptible to access the hazard) and any control measures in place to reduce either the likelihood or the severity of the hazard. The outcome of the risk assessment is to develop a hierarchy of control measures and a Safe System of Work to ensure that the residual risk is reduced to an acceptable level. The risk assessment should be recorded and reviewed on a regular basis or if any significant changes are made.

2.6 **Safe Systems of Work**

A Safe System of Work (SSW) is a formal, written agreement between line management and staff defining how to perform a task safely.

The SSW:
- states identified risks (from the risk assessment step);
- lists necessary risk / management controls;
- provides instruction to staff working on the task.

A SSW may relate to one very specific task or to a wide area of work where hazards and risks are common to many tasks. The SSW relates to specific staff working on specific tasks and is in operation for an agreed period of time until revision. A SSW may need to be reviewed before its revision date in line with the risk assessment if the task is significantly changed.

3.0 **Roles and Responsibilities**

3.1 **University Management of Radiation Safety**

The University Executive Team authorises the Local Rule for NIR as the framework for NIR safety management within the University as part of its commitment to the University’s Occupational Health and Safety Policy. The University Court has responsibility for health and safety as do the Heads of Departments/Heads of Schools/Directors of Services for ensuring this framework is implemented. (Refer also to Appendix 1).
3.2 University Advice and Support
Safety Services provides competent advice through the employment of a Radiation Protection Officer (RPO) and the appointment of a Radiation Protection Adviser (RPA).

3.3 Heads of Department / Heads of School / Directors of Services
In accordance with the University’s Occupational Health and Safety Policy it is the responsibility of the Head of Department to ensure that the requirements of the Local Rule for Non-Ionising Radiation is implemented within their Department. Whilst the Head of Department retains responsibility to ensure adequate arrangements are in place, they will usually delegate the function of overseeing the management of the requirements of these Local Rules to other Departmental staff members by formally appointing them as a DRPS / LSO for NIR.

3.4 Principal Investigators
It is likely that Principal Investigators (Academic Supervisor), Trade Supervisors, and Line Managers will be responsible for undertaking the process of risk assessment with assistance from the DRPS / LSO. These personnel also have responsibilities in respect of health and safety for any staff, students or visitors that are under their direction or management.

3.5 Department Radiation Protection Supervisors / Laser Safety Officers
There are a wide variety of NIR sources in the University and as such there may be a requirement to have various personnel designated to help manage certain or all NIR aspects at departmental level. In some departments this individual may be the same person that is responsible for both ionising and non-ionising radiation safety management at departmental level or it may be an individual appointed in relation to one particular area of NIR safety management.

The Head of Department is required to appoint, in writing on form RP2, suitable personnel as Departmental Radiation Protection Supervisors (DRPS) and Deputy DRPS (where appropriate) to assist locally with the implementation of the Local Rule at Departmental level. Personnel with responsibilities for NIR sources are categorised as either DRPS (Lasers) or DRPS (other non-ionising sources). DRPS (Lasers) may also be termed as Laser Safety Officers (LSO) as this is a standard title commonly used in laser safety management.

Prior and during their appointment, the DRPS / LSO must receive appropriate training for their work and should be part of their Department's Safety Committee.

3.5.1 General Duties of DRPS/LSO:
- Co-ordinate NIR safety management procedures at department level.
- Prepare and issue Departmental Local Rules for NIR sources and work. These can be separate or part of Departmental Regulations.
- Liaise with the Radiation Protection Officer, RPA and other external bodies in relation to NIR safety.
- Receive and record all new risk assessments.
- Act as a point of contact for departmental NIR queries and for new NIR workers.
- Retain an up-to-date inventory of NIR sources.
- Co-ordinate with Safety Services on University NIR training requirements. They may also be involved with NIR training at departmental level along with Principal Investigators, Academic Supervisors, Trade Supervisors or Line Managers.
- Co-ordinate departmental safety audits with Safety Services.
- Co-ordinate with the work of contractors or service engineers involved with NIR sources or NIR facilities.
• Liaise with the Head of Department to ensure they are kept informed of all NIR issues.

Heads of Department retain legal responsibility for all health and safety issues at departmental level; the PI also retains a high level of responsibility; whilst the DRPS/LSO role is purely a functional one to assist the HOD in the management of this area of safety.

3.6 Employees’ and Students Responsibilities and Duties

University employees have a legal responsibility, further emphasised by the University’s Occupational Health and Safety Policy and the Local Rule, to ensure they comply with the information and instruction supplied by the University to safeguard their health and safety and that of others. For the purposes of health and safety management, University students also fall into this category.

Generally these duties include:

• Co-operating with the University to enable it (as the employer) to meet its’ legal obligations for example by following established procedure to minimise the risk of exposure;
• Make full and proper use of control measures including personal protective equipment and report defects;
• Ensure equipment is used in accordance with its recommended use and instructions;
• Report any incident, accident or faulty equipment to the appropriate person;
• Attend health surveillance programmes where a need is identified (University Occupational Health Adviser/Physician);
• Not to knowingly put others at risk through their acts, failures or omissions.

4.0 Non-Ionising Radiation Workers

All workers using non-ionising radiation sources must be given suitable training; instruction and supervision on the SSW and the risk assessment by the supervisor of the project prior to work commencing (refer also to section 7.2). Specific University safety training courses are available online (e.g. laser safety) and are mandatory for new workers carrying out certain NIR activities (see section 7.1 also). Some departments also run their own basic laser safety training courses, which have been approved by Safety Services.

4.1 Postgraduate and Undergraduate Students

All students have a duty to follow the information, instruction and training that is provided in connection with a risk assessment and a safe system of work for all work with NIR sources.

New postgraduates must receive suitable induction, training and supervision. The supervisor must be satisfied that they are competent before permitting them to work unsupervised. Completed training should be recorded by updating the relevant training record. Postgraduates should assist their supervisors in the production of risk assessments and the SSW, however, the Principal Investigator / Trade Supervisor will still remain responsible for the work.

Undergraduate students must be informed of any risks associated with NIR sources / experiments and of the control measures implemented. The control measures and level of supervision required for undergraduate students will be dependent on the activities being undertaken and the outcome of the risk assessment. Fourth year undergraduate students completing their final year thesis, must undergo a
comprehensive induction and competence assessment prior to starting any work involving NIR.

4.2 New and Expectant Mothers

Unlike activities involving ionising radiation, such as working with radioactive material or x-ray generating equipment, non-ionising radiation is generally not considered to pose any greater risk to new and expectant mothers. Many scientific studies have now been carried out and, taken as a whole; these do not show any link between miscarriages or birth defects and working with VDUs.

5.0 Others

5.1 Visitors

Many departments permit visitors to participate in research, teaching and work in connection with the University. It is necessary that they abide by the information that is provided and work to the arrangements set out in the safe system of work. It is the responsibility of the Head of Department and the responsible department risk assessor (often a combination of the Principal Investigator, DRPS / LSO and Departmental Safety Convenor in such cases) to decide if the individual would require to be provided with specific training in relation to the activity. All visitors must be properly inducted regarding work in that particular environment and within the department, before commencing work with NIR sources.

If a visitor is only here for a very short period <30 days it is reasonable to expect they will be supervised at all times no matter how experienced they are. If they are to work alone they must be put through a recorded induction programme which will include emergency / contingency arrangements. The risk assessment will also need to be reviewed to ensure that it takes account of the visitor and that all safety issues have been adequately and sufficiently addressed. Their work may also need to be covered by a contract of appointment or letter of visitor status through and departments should ensure Human Resources, Finance Office and Research & Knowledge Exchange Services are informed and notified as appropriate to ensure visitors are covered by insurance.

5.2 Contractors

All contractors (and their employees) must be informed and/or be familiar with the hazards and risks associated with departmental locations, equipment or activities involving, using or producing non-ionising radiation. The University has produced a guidance document and a Local Rule for Engaging External Service Providers for departments engaging external service providers. The aim of these documents is to ensure that a satisfactory exchange of information on risks and control measures occurs between all parties concerned prior to work commencing. In most occasions, the DRPS/LSO (acting in the capacity as a University Supervising Officer) should be approached in the first instance to ensure adequate information is exchanged between relevant parties.

5.2.1 Contractors associated with projects

Departments must ensure where persons are coming into service equipment, align lasers etc. that they have requested sufficient information and been provided sufficient transfer of information as outlined in the above documents. Departments must be satisfied that contractors (and others) have been made aware of any hazards/risk and that the work will be undertaken in a safe manner.
5.2.2 Contractors not associated with projects.
These contractors should not be permitted into areas where NIR sources are in use. In these cases access arrangements must be made through the DRPS/LSO and Departmental Safety Convener. Contractors can be asked to leave if they do not follow the correct procedures or if they have not had their access approved by appropriate departmental personnel.

5.3 Other University staff
The risk assessment for the project will address any risks to other persons, including cleaners, security and maintenance staff etc. All control measures must be implemented and maintained throughout the project. Departments are responsible for ensuring appropriate and sufficient information is communicated to those staff that may be indirectly or inadvertently affected by the NIR work activity.

6.0 Departmental Local Rules
The University Local Rule for Non-Ionising Radiations is generic for the University and outlines key management actions and the basic control measures to prevent or minimise exposure. Departments must produce their own project and application specific Local Rules for the work undertaken to give guidance to researchers and these must be read and understood by all identified personnel. Refer to Appendix 2 for an example.

Department Local Rules should cover all the local safety management arrangements. They should be updated on a regular basis and reviewed following any significant changes.

A typical content for local rules would cover:

- DRPS / LSO contact details and identify the area of NIR they specifically cover, e.g. lasers or other NIR sources.
- Department procedures for initiating work, ordering equipment, allocating designated areas.
- Guidance on their expected working standards.
- Specific mention of Departments system for approving risk assessments and their assorted skills; contingency arrangements;
- Training – expected to be provided by Supervisors/DRPS/LSO/DSC to staff and students. This should be a standardised induction, and practical competence based assessment before the person works with any non-ionising radiation;
- Instruction relating to contractors/visitors.

The Departmental Local Rules may be included as part of the Department Health and Safety Arrangements/Regulations or exist as a separate standalone document.

7.0 Training

7.1 Safety Services Training
Safety Services provide online courses for laser awareness training. Some similar courses have been approved and are carried out by particular University Departments. Courses for other NIR sources can be customised where required or to meet a particular Department’s needs. Course details can be found on the Safety Services website or by contacting Safety Services directly.

Typical courses can include:—
• Laser Safety Management – suitable for all new LPS / NIRPS.
• Basic Laser Safety Awareness – available online
• NIR – safety awareness class

7.2 Departmental Training

Departments must ensure all NIR workers have received adequate and appropriate training prior to commencing work with NIR sources.

The following topics must be addressed:

• a basic introduction to NIR protection
• safety and personal protection requirements
• any legal and administrative requirements
• departmental procedures and protocols (e.g. Departmental Local Rules)
• practical training and
• emergency procedures

It is the department’s responsibility to ensure that the NIR worker is competent to begin work. It is recommended that departments retain a record of all departmental training carried out for workers.

8.0 Purchase and Design of NIR Sources and Equipment

There are certain legal requirements that both manufacturers and users need to adhere to. Manufacturers and suppliers of new equipment must comply with supply law and ensure that machinery is safe when supplied. The equipment should in most cases be CE marked (although there are some exceptions), and be supplied with a Declaration of Conformity or Incorporation (if applicable) and a user manual written in English.

Supply law which may affect NIR equipment sources includes:

• The Supply of Machinery (Safety) Regulations 1998 (as amended)
• The Electrical Equipment (Safety) Regulations 1994 (as amended)
• The Electromagnetic Compatibility Regulations 1992

User law on the other hand e.g. the Provision and Use of Work Equipment Regulations 1998 requires that employers provide the right kind of safe equipment for use at work, and ensure that it is correctly used and maintained in a safe condition. Employers, as users, are also expected to ensure that they are satisfied that the equipment complies with the relevant supply law.

When departments purchase or are gifted sources of NIR equipment, (new or old), they must ensure it is CE marked, meets current standards (e.g. BS, ISO or Best Industry Practice) and if being purchased, follows the University Purchasing procedures.

If equipment is second hand, departments must ensure it is brought up to correct standards. Consideration should be given to labelling, contamination (in particular activation products) electrics, interlock standards, information supplied or available for the product. If in doubt, please consult with Safety Services.

Where departments are designing a new piece of equipment as a prototype (or are adapting an existing piece of equipment), it must consider all the safety controls, the end users and the eventual working environment for the equipment. The University does not currently manufacture any finished products. Where departments adapt
and develop collaborations with external companies, they may wish to consult Research & Knowledge Exchange Services for advice in the first instance.

8.1 CE Marking

The letters “CE” are the abbreviation of French phrase “Conformité Européenne” which literally means "European Conformity". CE Marking on a product is a manufacturer’s declaration that the product complies with the essential requirements of the relevant European health, safety and environmental protection legislation. However, CE marking is only a claim by the manufacturer that the machinery is safe and that they have met the relevant supply law. It remains the duty of the user to also check that it is, in fact safe, before use. Note of caution: the CE marking can be misused and may refer to China Export. The CE marking logo is specific, and simple precautions can be taken during the procurement process to avoid any confusion in this area.

9.0 Laboratory and Workshop Facilities

Laboratories and workshops in the University must be appropriately designed to house and use NIR sources and equipment as safely as possible. Depending on the equipment and work activities being carried out the following aspects will need to be considered at an early stage:

- **Site and location plans**
- **Ventilation, noise, humidity and air conditioning**. Air conditioning must provide sufficient air changes taking into account the equipment in use, the occupancy, the size and location of the room and the work activities undertaken.
- **Lighting** – it is strongly advisable to have adjustable light level settings to allow lights to be dimmed. Lighting must be adequate for work to be performed.
- **Ergonomics** – the suitability of the work equipment to the person using it, workstation design and size of room.
- **Specialist requirements and proximity needs** for example, water cooling requirements, shielding, interlocks etc.
- **Electricity** – suitable positioning and numbers of electrical points, means of suspending cables, positioning of electrical isolating switches etc.

10.0 Monitoring and Auditing

Safety Services have been charged by Court to audit all laser installations and other specified non-ionising equipment, sources or facilities within the University as part of a rolling programme. Audits are carried out in conjunction with the University’s Radiation Protection Advisers. Prior to such audit visits, departments may be asked to submit an inventory of all laser products or applicable non-ionising equipment held or in use in their departments at that time. Refer also to appendices 8, 9 and 14.
11.0 Optical Radiation

Electromagnetic radiation in the wavelength range between approximately 100nm and 1mm is widely termed ‘optical radiation’.

Optical radiation from artificial sources is used in a wide variety of industrial, consumer, scientific and medical applications, and in most instances the visible light or infrared and ultraviolet energy is not hazardous. However, there are certain sources of optical radiation that are potentially very hazardous such as intense visible, ultraviolet and infrared sources. These may be very hazardous to the eye and skin depending on the source strength and environment. There are however numerous common sources, such as artificial lamps used in many consumer and office appliances and light emitting diodes (LEDs) that emit a relatively narrow band optical radiation, that are designed for visual comfort and are not hazardous to the eye or skin.

11.1 Development of Legislation and Exposure Standards

The Control of Artificial Optical Radiation Regulations 2010 (AOR) aim to protect workers from the risks to health from hazardous sources of artificial optical radiation (AOR). The Regulations are aimed at employers who artificially produce ultraviolet, infrared and visible radiation either coherently (laser radiation) or not. The Regulations require due consideration when assessing processes emitting optical radiation, either deliberately, or as a by-product and the requirements to protect staff and others from experiencing adverse health effects to the eyes (e.g. corneal damage, cataracts and blindness) and skin (e.g. reddening/burning, blistering and skin cancer).

The AOR Regulations are based on a European Directive (Directive 2006/25/EC) which lays down exposure limit values, which, if exceeded, will constitute a regulatory offence. These exposure limits are based on the recommendations of the International Commission on Non-Ionising Radiation Protection - Optical Publications.

The University has produced a simple set of AOR guidelines to aid departments in ensuring that they are carrying out the necessary steps to comply with these new Regulations. There is also HSE guidance for employers and a non-binding guide by the Public Health England which can assist the risk assessment process and the implementation of these Regulations.

11.2 Exposure Limits

Exposure limits are highly dependent on the part of the optical spectrum under consideration as biological effects are closely related to the wavelength of the optical source. Variation is particularly significant for the eyes where the wavelength determines the level of penetration and therefore the severity of the hazard. Exposure guidelines have been developed taking into account the biological variables, the effect of eye movements, the actual mechanisms of injury, and the reversibility of damage. The impact of exposure limits varies with wavelength, source intensity and exposure duration.
12.0 Lasers

Lasers are a special form of optical radiation that encompass the ultra violet, visible and infra red wavelength regions of the electro-magnetic spectrum. The difference between lasers and other forms of optical radiation are that they produce a coherent beam of monochromatic radiation that has low divergence. As a result, the inherently high irradiance (power per unit area irradiated) of the laser can be maintained over considerable distances and focussed to a very small area. The concentration of low divergent emitted radiation gives lasers different physical properties to other optical radiation.

12.1 Sources and Types of Lasers within the University

In the University research environment, the potential for hazardous exposure to laser radiation may be high in certain departments as a result of the flexibility in arrangements of the laser components.

Within the University, laser applications will include:

- Lasers for student experiments;
- Laser particle sizing equipment;
- Interferometers;
- Raman spectrometers;
- Numerous research applications;
- Laser pointers.

The optical radiation hazards associated with laser radiation vary greatly from the small lasers used for alignment to the high-powered pulsed ruby and neodymium (Nd:YAG) lasers.

12.2 Laser Fundamentals

A LASER (Light Amplification by Stimulated Emission of Radiation) is a device that produces a beam of monochromatic light in which all the waves are in phase or are coherent. A laser contains four primary components:

1. Active medium — solid crystal or gases
2. Excitation mechanism
3. Feedback mechanism, usually an optical cavity with highly and/or partially reflecting mirrors

12.3 Classification of Lasers

To distinguish between different operational lasers, they are classified according to the risks and severity of damage they can do. All laser products should be correctly classified and satisfy the relevant class in accordance with the provisions of BS EN 60825-1. The classification system uses the concept of an Accessible Emission Limit (AEL), which is the maximum value of accessible laser radiation that an individual is likely to be exposed to during the operation of a laser. The AEL is derived from the Maximum Permissible Exposure (MPE) for the particular wavelength, source and pulse characteristics. This exposure level is the maximum level of irradiation which the eye or skin can be exposed to without injury occurring and is the function of the laser emission wavelength and exposure duration. Therefore, each laser is classed depending on the AEL.
Where a laser product is incorporated into other equipment, then classification applies at the highest level of integration of that equipment. This responsibility usually rests with the manufacturer. If the laser product is modified in a way which changes its class then it must be re-classified to account for this modification.

Lasers can be classed as either; 1, 1M, 2, 2M, 3R, 3B or 4, with Class 4 lasers presenting the greatest hazard. Appendix 6 gives a brief summary of each laser class, the radiation hazards associated with each class and a brief description of the basic protection measures required. It should be noted that, although a laser product may have a particular manufacturer’s classification; it may be possible that the laser installation in which the laser is incorporated can be re-classified. This may be due to the addition or removal of engineering controls, which alter the AEL.

**Figure 2:** Laser classes and hazard level.

**Table 2:** Summary of laser classes and the required control measures for each.

<table>
<thead>
<tr>
<th>Class</th>
<th>Class 1M</th>
<th>Class 2</th>
<th>Class 2M</th>
<th>Class 3R</th>
<th>Class 3B</th>
<th>Class 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description of hazard class</strong></td>
<td>Safe under reasonably foreseeable conditions</td>
<td>Safe for naked eye; may be hazardous if the user employs optics</td>
<td>Safe for short exposures; eye protection is afforded by aversion response</td>
<td>Safe for naked eye for short exposures; may be hazardous if the user employs optics</td>
<td>Risk of injury is relatively low, but may be dangerous for improper use by untrained persons</td>
<td>Direct viewing is hazardous; hazardous for eye and skin; fire hazard</td>
</tr>
<tr>
<td><strong>Controlled area</strong></td>
<td>Not required</td>
<td>Localised or enclosed</td>
<td>Not required</td>
<td>Localised or enclosed</td>
<td>Enclosed and interlock protected</td>
<td>Enclosed and interlock protected</td>
</tr>
<tr>
<td><strong>Key control</strong></td>
<td>Not required</td>
<td>Not required</td>
<td>Not required</td>
<td>Not required</td>
<td>Not required</td>
<td>required</td>
</tr>
<tr>
<td><strong>Training</strong></td>
<td>Follow manufacturer instruction for safe use</td>
<td>Recommended</td>
<td>Follow manufacturer instruction for safe use</td>
<td>Recommended</td>
<td>Required</td>
<td>Required</td>
</tr>
<tr>
<td><strong>PPE</strong></td>
<td>Not required</td>
<td>Not required</td>
<td>Not required</td>
<td>Not required</td>
<td>May be required – subject to the findings of the risk assessment</td>
<td>required</td>
</tr>
<tr>
<td><strong>Protective measures</strong></td>
<td>Not necessary under normal use</td>
<td>Prevent use of magnifying, focusing or collimating optics</td>
<td>Do not stare into the beam</td>
<td>Do not stare into the beam. Prevent use of magnifying, focusing or collimating optics</td>
<td>Prevent direct eye exposure</td>
<td>Prevent eye and skin exposure to the beam. Guard against unintentional reflections</td>
</tr>
</tbody>
</table>

**Table 2 Image:** © Public Health England (Non-Binding Guide to the Artificial Optical Radiation Directive, 2009)
The University Local Rule applies to any class of laser where it is possible to access the beam. However, it does not apply to Class 1 laser products contained within equipment such as CD Rom players, laser printers, bar code readers, etc (on the understanding that the equipment is not altered, modified or changed in any way). It is important that departments make a clear distinction between Class 1 lasers that are inherently safe because of their low power and those Class 1 lasers that are reliant upon engineering features for their safety. If there is any doubt or ambiguity as to whether or not the Local Rule applies, please contact Safety Services.

12.4 Laser Hazards

Adverse health effects of exposure to laser radiation are possible across the entire optical spectrum, from 100nm in the UV region of the electro-magnetic spectrum to 10000μm in the far infrared region. Laser hazards can be grouped into:

(i) Beam hazards to the eye and skin;
(ii) Non-beam hazards.

The radiation hazards from a laser beam can severely damage the eye and skin. However, injuries from other laser associated hazards such as slip, trip and fall, electrical shock and chemical exposure are far more likely.

12.4.1 Biological Effects

The eye and skin are the organs most susceptible to damage by direct laser radiation. The type, injury, organ affected, organ thresholds, and damage mechanisms vary significantly with the laser wavelength. The biological effects induced with optical radiation are essentially the same for both coherent and incoherent sources for any given wavelength, exposure site and area, and duration (see diagrams in Appendix 15). Laser radiation is treated as a special case as few optical sources can produce the radiant intensities and irradiances achieved by lasers.

Laser biological effects are the result of one or more competing biophysical interaction mechanisms — thermal, acoustic, optical and photochemical. Eye damage depends upon the structure of the eye which is susceptible to damage and the structure which absorbs the greatest radiant energy per volume or tissue. Retinal damage is most probable when the laser wavelength is within the visible and near infrared regions (400nm — 1400nm) as at such wavelengths the laser radiation is sharply focused onto the retina. Corneal damage occurs when the laser wavelength is in the short UV (UV A & B) region and Mid infrared (IR B) and lens damage occurs at wavelengths in the far UV (UV C) and Far infrared (IR C) as shown in Figure 3.

The risk of skin injury is considered secondary to the risk of eye damage, as skin injuries will usually heal. The damage mechanism to the skin may be thermal or photochemical and the levels of intensity and duration of exposure are comparable to the levels considered hazardous to the cornea.

The hazards and associated biological effects arising from the use of lasers vary due to the range of operational wavelengths, laser power, pulse duration and pulse characteristics of the laser beam. It must be noted that biological effects not only occur as a result of primary beam exposure but also as a result of secondary reflections and scattering.
**Figure 3:** Structure of the eye and penetration of different wavelengths

![Eye Diagram](image)


**Figure 4:** Structure of the skin and penetration of different wavelengths

![Skin Diagram](image)


**Table 3:** Possible effects of wavelengths on the eyes and skin

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Eye</th>
<th>Skin</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 – 280</td>
<td>UVC</td>
<td>Photokeratitis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Photoconjunctivitis</td>
</tr>
<tr>
<td>280 – 315</td>
<td>UVB</td>
<td>Photokeratitis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Photoconjunctivitis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cataracts</td>
</tr>
<tr>
<td>315 – 400</td>
<td>UVA</td>
<td>Photokeratitis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Photoconjunctivitis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cataracts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Photoretinal damage</td>
</tr>
<tr>
<td>380 – 780</td>
<td>Visible</td>
<td>Photoretinal damage (Blue Light Hazard)</td>
</tr>
<tr>
<td>780 – 1400</td>
<td>IRA</td>
<td>Cataracts</td>
</tr>
<tr>
<td>1400 – 3000</td>
<td>IRB</td>
<td>Retinal burn</td>
</tr>
<tr>
<td>3000 – 10^6</td>
<td>IRC</td>
<td>Corneal burn</td>
</tr>
</tbody>
</table>

**Image:** © Health Protection Agency (Non-Binding Guide to the Artificial Optical Radiation Directive, 2009).
12.4.2 Non-Beam Hazards

There are also associated hazards out with the direct biological effects. These are classed as 'non-beam hazards' and are not affected by the laser classification and power (unlike the biological effects) so may be present with even Class 1 laser products (see also Appendix 10).

**Figure 5:** Additional non-hazards to be considered

![Image: © Public Health England (Lasers at Work, 2003).](image)

(i) Electrical Hazards

The high voltage electrical supply required by high power lasers present a potentially lethal hazard. The electrical supply to power a laser is the dominant hazard typically due to high voltages, high power and large inductors. Consideration should also be given if handling capacitor banks used with some pulsed lasers as electrical charge can be stored even when disconnected from the mains power. Numerous casualties as a result of electrocution have occurred in both industrial and research establishments.

Safety guidelines:
1. Do not wear rings, watches when working with electrical equipment.
2. Do not handle electrical equipment when hands or feet are wet or when standing on a wet floor.
3. When working with high voltages, regard all floors as conductive and grounded.
4. Use shock prevention shields, power supply enclosure and shielded leads.
5. Be familiar with electrocution rescue procedures and emergency first aid procedures.

Refer to the University's [Local Rule for Electrical Safety](#) for further information.
(ii) Chemical and Fume Hazards
Many gases and dyes used as the active medium can be toxic, carcinogenic, and corrosive or pose a fire hazard. All chemicals used and handled in the University must be accompanied by an appropriate Control of Substances Hazardous to Health (COSHH) risk assessment. Proper ventilation is required to extract the gases produced by lasers or targets. Cryogenic fluids are required to cool certain lasers and adequate ventilation must also be provided. Condensation of oxygen in liquid nitrogen presents a serious explosion hazard if the liquid oxygen comes in contact with organic material. Compressed gases contained in pressurised cylinders present serious health and safety hazards. Cryogenic fluids are potentially explosive when ice collects in valves or connectors in addition to the hazardous materials produced by the laser striking and interacting with certain target materials. Refer to the University's Local Rule for CoSHH for further information.

(iii) Noise
The discharge of capacitor banks within the laser power supply can generate noise levels high enough to cause ear damage. Ultrasonic emissions and repetitive noise from pulsed lasers may also be present. Refer to the University’s Guidance on Occupational Hygiene Services.

(iv) Mechanical
Mechanical hazards exist from the bulk of the laser equipment itself including gas cylinders and the box incorporating the laser. Cables and water-circulation hoses pose a trip hazard. Refer to the University’s Local Rule for Manual Handling.

(v) Fire
Emission from a Class 4 laser can ignite target materials and also cause explosions in combustible gases. Such effects are enhanced with oxygen rich environments. Refer to the University’s Guidance on Fire Safety.

12.5 Current Guidelines and Exposure Limits
As mentioned earlier in Section 11.1, laser safety now falls under the Control of Artificial Optical Radiation at Work Regulations 2010. The European Normalised British Standards, BS EN 60825: Part 1 2007 and PD IEC/TR 60825: Part 14 2004 (Safety of Laser Product. A user’s guide) may also be used for demonstrating good practice. The Association of University Radiation Protection Officers (AURPO) has also published a guidance note on the safe use of lasers in education and research, which draws on the applicable British Standard documents in the BS EN 60825 series of documents and associated amendments and can be used as a source of reference.

12.6 DRPS (Lasers) or Laser Safety Officer (LSO)

12.6.1 Appointment
A DRPS (Lasers), or Laser Safety Officer (LSO) must be appointed to the department by the Head of Department in writing. The DRPS/LSO shall take administrative (and possibly supervisory) responsibility on behalf of the Head of Department for day-to-day matters of laser safety. However, the actual legal responsibility for ensuring laser safety within the department rests with the Head of Department and the Principal Investigator (PI) responsible for each laser installation and associated applications.
12.6.2 General Duties
The duties should be those necessary to ensure the continuing safe use of lasers and shall include:

- Being aware of and maintaining records for all laser products;
- Responsibilities for monitoring compliance with the Departments procedures;
- Reporting known or suspected accidents;
- Ensuring that local rules are available to laser workers;
- Maintaining appropriate records (e.g. training, maintenance, risk assessment);
- Liaising with Safety Services over departmental local rules, SSW and training.

12.6.3 Training
All new DRPS must receive suitable and appropriate training to allow them to undertake their appointed duties. This normally requires the DRPS / LSO to attend a suitable externally run training course as soon as possible and, preferably, prior to appointment. Contact the Safety Services website for details of suitable courses and further information.

12.7 Laser Workers
12.7.1 General Duties
All laser workers have responsibilities and duties, which include:

- Compliance with standards prescribed by the department;
- Familiarity and understanding of the local rules;
- Not operating a Class 3 or 4 laser unless authorised by the DRPS / LSO; and
- Reporting known or suspected accidents to the DRPS/LSO;
- Reporting any defect to the laser system or its safety controls (e.g. interlocks)

12.7.2 Training
Every laser worker must receive suitable and sufficient laser safety training commensurate with the Class of the laser to be used. They should be made aware of the hazards to which they may be exposed to during work with the laser equipment and are aware of all procedures to follow. Laser users should complete the online laser training course unless their department offers an approved substitute course. Training should be commensurate with the type of hazard associated with the work and should include:

- The departments policy for safe laser use;
- The risks of harm from normal operation and laser misuse;
- The meaning of displayed warning signs;
- The correct use and operation of the laser equipment, controls in place and the Personal Protection Equipment provided (where applicable);
- Safe systems of work and local rules.

The Head of Department will decide on the training requirements for new members and operators in conjunction with the DRPS/LSO. The DRPS/LSO must be satisfied that the training provided is adequate and the new person is competent to carry out the proposed work.

All records of training must be retained and stored with the DRPS/LSO for periodic review and auditing purposes.
12.8 Laser Controlled Areas

A Laser Controlled Area (LCA) may be designated to limit access to the laser laboratory area. The area must be clearly delineated with appropriate warning signs and legends outlining the restricted area i.e. the laser starburst with the additional legend ‘Laser Controlled Area’. All warning signs must comply with the Health and Safety (Safety Signs and Signals) Regulations 1996 (see Appendix 16 for some examples of NIR signage).

A laser controlled area will only be designated if the risk assessment shows that there is a reasonably foreseeable risk of harm arising from the use of laser equipment.

12.9 Laser Hazard Analysis and Control

The laser hazard and safety procedures required for any application vary with the:

(i) Laser hazard classification;
(ii) Laser power;
(iii) Laser wavelength(s);
(iv) Environment where the laser is used; and
(v) Personnel operating, or within the vicinity, of the laser beam.

The control measures required vary widely depending on the laser equipment in use, the working environment, the task or processes performed and the personnel working with the lasers. Within a research establishment there is often changing personnel and facilities involved with various experiments that requires new configurations of the laser system and laboratory.

12.10 Laser Risk Assessment

Performing a risk assessment is only one component of a comprehensive laser safety program that must also include training, inventory tracking, University policy and administration. The laser classification scheme is based on the maximum level of radiation that is accessible under normal conditions of operation but a more detailed consideration of potential risk and severity of risk are required for each department, environment and operation. Individual departments must carry out a risk assessment that outlines all potential hazards, existing and additional control measures required. If required, these can be forwarded to Safety Services for review. See Appendix 7 for an example risk assessment template form.

The first step of the risk assessment will be to make an assessment of laser exposure by carrying out Maximum Permissible Exposure (MPE) and Nominal Ocular Hazard Distance (NOHD) calculations. The MPE is the maximum limit for human exposure to laser radiation and is expressed in terms of irradiance or radiant exposure at the body surface and are complex functions of emission wavelength and exposure duration. The NOHD is the distance from the laser at which the maximum level of irradiance (power density) or radiant power (energy density) within which the laser beam is equal to the MPE.
Such assessments will determine the boundary of the laser hazard zone and specify the level of protection required. The next step in the risk assessment should assess the level of human exposure, taking into account all reasonably foreseeable configurations of the direct beam emission and all reasonably foreseeable reflections or deflections of the direct emission. The main parameters that need to be assessed are as follows:

- emission wavelength(s)
- beam dimensions of laser output;
- beam divergence;
- beam profile (power or energy distribution across the beam);
- maximum foreseeable exposure duration;
- minimum reasonably foreseeable exposure distance;
- apparent source size

and for continuous (CW) emission

- beam power;

in addition, for pulsed emission;

- peak power or pulse energy;
- pulse duration;
- pulse repetition frequency;
- pulse shape and pulse distribution with time.

12.11 Control Measures: Lasers

Following on from the risk assessment, the first stage of planning to control exposure is to establish a hierarchy of control measures to reduce all associated hazards to a tolerable level. The order in which these are approached and implemented is extremely important. The order is as follows:

- Engineering controls;
- Administrative; and
- Personnel protective equipment.

The first control measure to be considered is the feasibility of using a laser of lower Class. The next stage will be to eliminate any laser hazard altogether i.e. enclose the beam or switch off any potential exposures through the use of interlocks etc. If this is not possible or engineering controls require support, then administrative procedures (e.g. key control) are required. Personnel Protective Equipment (PPE) should only be used as the last resort where a combination of engineering and administrative controls cannot reasonably provide a sufficient level of protection.

The reduction of risk to a tolerable level is a repetitive process. Risk assessments will be required at numerous stages throughout the hazard identification process and decision process regarding the control of the laser application. See Appendix 11 for additional control measures for high risk lasers.
12.11.1 Engineering Controls

a) Key Controls and Laser Access
It is the discretion of each department to decide who has access to the laser laboratories and laser products. All personnel authorised must have undergone suitable awareness and instructional training in the risks and operation of the laser products. All training must be recorded and reviewed. Access and use of laser equipment by unauthorised personnel must be prevented by any reasonable means.

<table>
<thead>
<tr>
<th>Enclosing the hazard</th>
<th>Human access to a laser hazard must be prevented as far is reasonably practicable by use of barriers, local enclosures and beam tubes, and by ensuring that access to the laser area is limited to those persons who are working with the laser equipment.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interlocks</td>
<td>Access to a protective enclosure must be controlled by an interlocking system. There are various types and designs of interlock (e.g. door, shutter) with the main requirement to prevent access to the beam (either by de-energising the laser or by stopping the beam at source (shutter) on activation of the interlocks). <strong>Interlocks should not be tampered with or defeated.</strong> If it is found damaged or inoperable report it to the DRPS/LSO.</td>
</tr>
<tr>
<td>Emergency stop button</td>
<td>Required for all Class 3R, 3B or 4 lasers.</td>
</tr>
</tbody>
</table>

12.11.2 Administrative Controls
Administration is the second stage in the hierarchy of controls. Appropriate administration controls will depend on the Class of the laser and the existing engineering controls.

a) Warning Signs and Notices
Appropriate warning signs and notices must be placed outside laboratory doors, and where appropriate, to indicate the presence of laser radiation. Warning lights (if the risk assessment outlines that they are required) shall accompany warning signs to outline the system status and so to avoid any un-necessary activation of door interlocks. Signs shall be of the form of the laser starburst with appropriate accompanying legends. All warning signs and lights must comply with the Health and Safety (Safety Signs) and Signals Regulations 1996.

b) Labelling
Labels on laser products are requirements of the BS EN 60825-1:2007 Safety of Laser Products Part 1: ‘Equipment, Classification and for laser products’. They must be permanently fixed, legible and clearly visible during operation, maintenance or service and be placed so that they can be easily read. All lasers above Class 1 must display the laser starburst and an accompanying explanatory legend (see Appendix 5 for label examples). The manufacturer must supply safety information about the laser product including details of power and operational wavelengths. All labels must be in UK British Standard notation.
c) Written Safety Instructions

Each department must produce a working document outlining the department’s policy for laser work. Departmental local rules can either be incorporated within Departmental Health and Safety Arrangements/Regulations or they may be prepared as a separate stand alone document, which should be cross-referenced within the Departmental Health and Safety Arrangements/Regulations. The departmental local rules should outline all administrative controls, procedures, use and display of warning signs, instructions and prohibitions required for a safe laser working environment. It is also advisable for the departmental local rules to include:

- Description and purpose of the equipment (including operational powers and wavelength(s));
- Name and contact number of the DRPS/LSO or responsible person;
- Name of personnel permitted to work with laser equipment;
- Contingency plans (refer to Appendices 3 and 4);
- Information on key storage and entry into the laser controlled areas.
- It is essential that each operator (lecturer, researcher or student) reads and fully understands the contents of the local rules. An example of departmental local rules is given in Appendix 2.

d) Key control

When the operation of a laser requires a key (power supply, interlock panel or directly on laser), management of the key is an effective administrative control which prevents misuse of the laser by unauthorised personnel. The control of the key may vary according to the hazard posed by the laser. Each department must develop procedures to ensure that the management of laser keys is adequate.

12.11.3 Personnel Protective Equipment

Personal Protective Equipment (PPE) such as laser protective eyewear must only be used if all other controls are not sufficient to reduce the hazard to a tolerable level and the risk assessment identifies that further protection is required. Such equipment should only be used where it is not reasonably practicable to ensure adequate protection by other means. Refer also to Appendix 13 for details on selection and use of laser safety eyewear.

13.0 Ultraviolet Radiation

Ultra Violet Radiation (UVR) is defined as having a wavelength between 100nm and 400nm. The UV spectrum is generally divided into three sections, which are referred to as bands:

- UVA (wavelength range from 315 to 400nm, bordering visible wavelength)
- UVB (wavelength range from 280 to 315nm)
- UVC (wavelength range from 100 to 280nm)


The direct potential radiation hazards to health arise from UV radiation with wavelength greater than 180 nm (since UV radiation of lower wavelength is strongly absorbed in air and common materials). The naked eye is unable to view any of the UVC and UVB bands and the far UVA band is only partially visible. Therefore, the intensity of UVR cannot be judged on the quantity of visible light or apparent brightness that one can see. The main organs likely to be adversely affected as a result of excessive exposure are the skin and eyes.
Every Head of Department should ensure that all artificial UV sources emitting between 180 and 400 nm are appropriately identified and each identified source has an appropriate risk assessment. This must detail the control measures, which are necessary under the various conditions in which the equipment is used.

13.1 Sources of UVR

The most widely recognised source of non-artificial UV radiation is the sun. There are various artificial UV radiation sources that are common in industry, research, teaching, medical and general sources. The principal artificial sources of inadvertent UV radiation exposure include:

- electric arc-welding where adventitious UV is generated
- UV lamps
- industrial photo-processes
- UVA sources for non-destructive testing
- contamination testing
- spectrophotometres
- germicidal lamps used for sterilisation (emit hazardous UVC radiation at 254nm) and disinfection
- Transilluminators (particularly hazardous as radiation is emitted upwards and researchers are normally looking down at them)
- photocuring of inks and plastics.

Lasers can also be sources of UV radiation but are referred to separately in Section 12 of this document.

13.2 Ultraviolet Radiation Health Effects

UV radiation affects a number of organs and systems throughout the body but the critical organs are the eye and skin (See Figures 3 and 4). The severity and nature of biological damage is dependent on the wavelength and energy of the UV radiation absorbed. The energy carried by photons increases as its wavelength shortens. The most significant adverse health effects of exposure to UV radiation have been reported at wavelengths below 315nm, known collectively as actinic ultraviolet. This region covers the UVB/C part of the spectrum from 200-310nm range.

The lower the MPE level, the more hazardous the radiation. For example, transilluminators (297nm (UVB)) and germicidal lamps (254nm (UVC)) operate at very hazardous wavelengths. MPE associated with these artificial optical sources is expected to be low thus will require the use of effective control measures to protect workers from potential over-exposure.

13.2.1 Ultraviolet Skin Hazards

Erythema (reddening of the skin, heat and discomfort) is the most commonly observed skin effect after exposure to UV radiation. Erythema is a photochemical response of the skin normally resulting from overexposure to wavelengths in the UVC and UVB bands (180-315nm). Delayed biological effects on the skin are skin aging and can lead to an increased risk in developing skin cancer. However, this type of exposure is hard to quantify or eliminate, as most individuals will receive substantial exposure from the sun during normal outdoor activities over a human lifetime. Skin protection from UV is best achieved through the use of clothing, gloves and face shields. The use of UV skin blocks (creams and lotions) is considered inadequate for protection against the high irradiance of man-made UV radiation sources.
### Table 4: Potential health effects of UV exposure on the skin:

<table>
<thead>
<tr>
<th>Early effects</th>
<th>Delayed effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>• darkening of existing skin pigment (melanin) by UVA.</td>
<td>• skin ageing</td>
</tr>
<tr>
<td>• erythema - reddening of skin (sunburn) UVB at 297nm (more than thousand times more effective than UVA)</td>
<td>• skin cancer from all wavelengths of UV</td>
</tr>
<tr>
<td>• increase in pigmentation (production of new melanin granules) - UVB most effective.</td>
<td></td>
</tr>
<tr>
<td>• changes in cell growth - can result in scaling.</td>
<td></td>
</tr>
</tbody>
</table>

### 13.2.2 Ultraviolet Eye Hazards

Various components of the human eye are susceptible to damage from UVR. The UV wavelength is the determining factors as to which part(s) of the eye absorb the radiation incurring any biological effects.

The cornea is like the skin in that it can be ‘sunburned’ causing the cells of the cornea to be damaged. The medical term for this is keratonyjunctivitis but it is most commonly referred to as ‘welder’s flash’ or ‘snowblindness’. Within 6-12 hours following UV exposure, the individual may feel the sensation of a foreign body in the eye, which will normally recede 2 days after exposure due to the re-growing of the corneal cells.

In severe cases, the cornea may be permanently damaged. Exposure to UVB and UVC present the greatest risk to the cornea.

Over exposure to UVA can affect the lens tissue of the eye. The lens may become cloudy which then may lead to the formation of certain forms of cataracts.

Eye protection will be required when the risk assessment shows that control of UV exposure cannot be afforded by any alternative method. Polycarbonate safety glasses or a face shield can normally protect the eyes against exposure to UV wavelengths.

### Table 5: Potential health effects of UV exposure on the eye:

| Early effects | • conjunctivitis and keratitis. |
| Delayed effects | • possible cataract formation from UVA |
13.3 Legislation, Guidelines and Exposure Limits

This falls within the AOR Regulations as detailed under Section 11.1.

The International Commission on Non-Ionising Radiation Protection (ICNIRP) has also previously produced guidance on maximal limits of exposure to UVR in the spectral region between 180nm and 400nm ICNIRP UVR Exposure Limits. The exposure limits are derived from the existing biological database and includes safety margins for each identified effect. The purpose of the guidelines is to deal with the basic principles in protecting the workers and general public from the potentially adverse effect of ultraviolet radiation.

The exposure limit values for exposure of the eye or skin can be used to evaluate potentially hazardous exposures from UVR e.g. from arcs, gas and vapour discharges, fluorescent lamps, incandescent sources and solar radiation. The limits do not apply to UV lasers. The exposure limits should be considered absolute limits for the eye and ‘advisory’ limits for the skin because of the wide range of susceptibility to skin injury depending on skin type.

One of the difficulties with regulating, and especially of enforcing the dose limits is that for the majority of population, the major contributor of UVR exposure is from the sun.

Table 6 below gives some examples where the exposure limits are exceeded for a number of artificial sources.

Table 6: Time to exceed ICNIRP exposure limits for some typical UVR sources (guidance only, actual time will depend on the source properties)

<table>
<thead>
<tr>
<th>Category</th>
<th>Time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluorescent lighting</td>
<td>unlimited</td>
</tr>
<tr>
<td>Quartz halogen lamp</td>
<td>Approximately 10</td>
</tr>
<tr>
<td>Germicidal (UVC) lamp</td>
<td>3</td>
</tr>
<tr>
<td>Arc welding</td>
<td>1 (depending on the metal, shielding, gas and arc current)</td>
</tr>
</tbody>
</table>

13.4 Control Measures: UV (Artificial Sources)

UV, like other radiation sources, presents an external hazard that can be controlled by a combination of:

- time - minimise your time of exposure
- distance - maximise your distance from the source
- shielding - utilise effective shielding materials

For artificial sources used in various forms within the University, hazards are controlled by applying a hierarchy of control measures. Firstly by applying engineering controls, if at all possible, then using administrative controls, and finally, if the hazard still poses a risk, by using personal protective equipment.

13.4.1 Engineering controls include:

- Containment of source;
- Sealed housings with non-UVR transmitting inspection windows;
- Use of interlock enclosures;
- Elimination of reflected UVR.
- Effective screening
13.4.2 Administrative controls include:

- Hazard awareness — risk assessments;
- Training of all operators using UVR sources;
- Written instructions — produced for each department that should include:
  - Operating procedures, source hazard and contingency arrangements;
  - Limitation of access;
  - Hazard warning signs and lights when the equipment is energised;
  - Distance as a safety factor;
  - Limitation of exposure time;
  - Maintenance on only de-energised equipment.

13.4.3 Personal Protective Equipment controls include:

- Adequate UV protection of skin and eyes.

Note: the MPE value for transilluminators generally equates to an exposure time of less than 1 minute per day for unprotected skin. When using a transilluminator, areas that are often forgotten are the neck / upper chest below a face visor; and, underneath the wrist area of the forearms. It is important that these areas are adequately protected.

13.5 External UV Solar Exposure and Outside Workers

Exposure to ultraviolet (UV) radiation from the sun (non-artificial source) can cause skin damage including sunburn, blistering, skin ageing and in the long term can lead to skin cancer.

UV radiation should be considered an occupational hazard for staff or students who regularly work outdoors (either in the UK or abroad), including gardeners and field trip researchers.

Particular care is required for outside workers that have:

- fair or freckled skin that doesn’t tan, or goes red or burns before it tans;
- red or fair hair and light coloured eyes;
- a large number of moles.

13.5.1 Control Measures: UV Solar Exposure

Whilst there is no legal obligation for the University to provide sun cream or sunglasses for outdoor workers, there are a number of control measures that should be encouraged to protect outdoor workers from external UV exposure.

Where possible, outside work should be scheduled to minimise exposure, especially when solar UV radiation is at its highest (around 4 or 5 hours either side of solar noon).

Workers should be given sun protection advice as part of their routine health and safety training and be advised of personnel protection measures including:

- Keeping covered up (for example keeping a top on) during the summer months.
- Wearing a hat with a brim or a flap that covers the ears and the back of the neck,
- Staying in the shade whenever possible, during your breaks and especially at lunch time.
- Wearing sunglasses and a high factor sunscreen on any exposed skin.
- Drink plenty of water to avoid dehydration.
- To regularly check their skin for any unusual moles or spots and to see a doctor promptly if any moles or spots change shape, size or colour, or start to itch or bleed.

14.0 **Visible Light Hazards**

The visible region of the electromagnetic spectrum, which is visible to the human eye ranges from about 380 to 740nm.

**Table 7: The visible light spectrum range**

<table>
<thead>
<tr>
<th>Colour</th>
<th>Wavelength (nm)</th>
<th>Frequency Interval (THz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>625 - 740</td>
<td>480 to 405</td>
</tr>
<tr>
<td>Orange</td>
<td>590 - 625</td>
<td>510 to 480</td>
</tr>
<tr>
<td>Yellow</td>
<td>565 - 590</td>
<td>530 to 510</td>
</tr>
<tr>
<td>Green</td>
<td>520 - 565</td>
<td>580 to 530</td>
</tr>
<tr>
<td>Cyan</td>
<td>500 - 520</td>
<td>600 to 580</td>
</tr>
<tr>
<td>Blue</td>
<td>435 - 500</td>
<td>700 to 600</td>
</tr>
<tr>
<td>Violet</td>
<td>380 - 435</td>
<td>790 to 700</td>
</tr>
</tbody>
</table>

All visible light entering the human eye is focused upon the sensitive cells of the retina (foveal region). Any very bright light will cause a human aversion response (blink, squint or turn the head away). The mechanism of the aversion response will generally protect the eye but it should never be trusted as a control measure.

Any sufficiently bright light source viewed for an extended period will over time degrade both day and night time vision. Appropriate protective filters must be worn for any visible light source that requires extended viewing. For prolonged viewing of plasma arcs, flash lamps etc. protective goggles must be worn.

A risk assessment will outline if further control measures are required. Contact Safety Services for further information.

14.1 **Blue Light Hazard**

Prolonged exposure to bright blue light can cause the eyes to lose sensitivity to blue light, i.e. blue objects would begin to appear grey. Annex D of BS EN 60825: Part 1 2007, Biophysical Considerations gives a good description of the photochemical effects of laser radiation on biological tissue. The photochemical reaction with tissue is believed to be responsible for damage at low levels of exposure. By this mechanism, some biological tissues such as the skin, the lens of the eye, and in particular, the retina may show irreversible changes induced by prolonged exposure to moderate levels of ultraviolet radiation and short wavelength light. Such photochemically induced changes may result in damage to a system if the duration of exposure is excessive, or if shorter exposures are repeated over prolonged periods.
15.0 Infrared (IR) Radiation

Infrared radiation is defined as the section of the electromagnetic spectrum that extends from the long wavelength, or red end of the visible-light range to the microwave range. Invisible to the eye, it can be detected as a sensation of warmth on the skin. The infrared range is usually divided into three main regions: near infrared (nearest the visible spectrum), middle infrared, and far infrared (nearest to the microwave end), although the definitions distinguishing the infrared spectral regions can vary quite significantly in the literature.

- Near Infrared (also known as IR A) in the 750nm to 1400nm range
- Mid Infrared (also known as IR B) in the 1400nm to 3000nm range
- Far Infrared (also known as IR C) in the 3000nm to 1mm range

15.1 Infrared Radiation Hazards

The potential biological hazards (see section 12.4.1) are a function of the:

- Exposure time;
- The irradiance value (a function of both the image size and source power); and
- The environment (conditions of exposure).

The evaluation of IR hazards can be difficult but reduction of eye exposure is relatively easy through the use of appropriate eye protection. The viewing of high irradiance IR sources should be limited by the use of appropriate filters. Goggles and safety glasses may be required if the risk assessment outlines that exposure could be problematic. Contact Safety Services for further information.

16.0 Light Emitting Diodes (LED’s)

Both visible and infrared laser diode and light emitting diodes (LED’s) are widely used in displays and in many entertainment systems, signal lamps and optical fibre communication. While the higher power laser diodes have routinely been considered to be ‘eye hazards’, traditional LED’s have been regarded as safe. However, with the recent development of higher power LED’s, there has been a need and effort to develop LED safety standards.

Based upon current exposure limits, most LED’s (particularly surface-emitting LED’s) pose no clear hazard to the eye. Current surface-emitting LED’s produce exposure levels at the retina, which is significantly less than the levels that are known to cause retinal damage. All LED’s require assessment.
17.0 Electromagnetic Field Radiation

Electromagnetic fields (EMF) cover frequencies in the range of 3 kilohertz (kHz) up to 300 megahertz (MHz) for radio frequency (RF) radiation and 300 MHz - 300 gigahertz (GHz) for microwave (MW) radiation. RF and MW radiation are non-ionising in that there is insufficient energy to ionise atoms. Use of RF/MW radiation includes: radar transmitters, imaging systems, radio transmission systems, mobile phones, processing and cooking of foods, heat sealers, induction heaters, flow solder machines, communications transmitters, ion implant equipment, microwave drying equipment, broadcasting antennas, magnetron / wave guides, particle accelerators, superconducting spectrometers and isotope separation units.

University employees and students may be exposed to high magnetic fields if they work near electrical systems that use large amounts of electric power (for example, large electric motors, generators, or the power supply or electric cables of a building). High magnetic and electric fields may also be present in numerous research applications within various departments of the University including those using Nuclear Magnetic Resonance (NMR) equipment.

Electromagnetic radiation from the above sources, may, under certain conditions, give rise to health hazards.

17.1 Factors Affecting Exposure to RF/MW Radiation

The hazards from exposure to RF/MW radiation are related to the following parameters:

- Frequency of the source
- Power density and the point of exposure
- Accessibility to the radiation field
- If the exposure is in the near or far field
- Orientation of the human body to the radiation field

Radiofrequency fields penetrate the body to an extent that decreases with increasing frequency. The magnitudes of the fields need to be determined within the various parts of the body that are exposed.

17.2 Potential Bio-Effects of Exposure to Microwave/RF Radiation

The potential hazards of RF radiation can be defined in terms of the direct and indirect effects on people and the effects on the environment.

17.2.1 Direct Effects on People

The photon energy of RF radiation is too small to ionise molecules so chemical, cellular and DNA damage will not result. The epidemiological evidence currently available does not suggest that RF exposure causes cancer.
a) Thermal Effects
The main demonstrable effect on the human body above about 100kHz is the thermal effect i.e. the transfer of electromagnetic field energy to the body and the heating of the human body due to the absorption of energy. Polar molecules (e.g. water molecules) are most liable to influence of impinging electromagnetic fields. A gain in energy from the field in the form of heat causes an increase in the temperature of the tissue concerned. In the healthy human body, the thermoregulatory system will cope with the absorbed heat until it reaches the point at which it cannot maintain the body temperature satisfactorily. People with impaired thermo-regulatory systems, may not be so tolerant to the heating limits set out in the standards.

The energy absorbed and depth of penetration in human tissues is dependent on the frequency of the RF radiation and the orientation of the subject relative to the field. The absorption of RF energy can result in a non-uniform distribution of heat resulting from a complex mixture of structures. From the thermal transfer point of view, parts of the body with poor blood supply, such as the lens of the eyes or the testes, which do not have a direct blood supply for thermal regulation, are considered more susceptible to heat effects than other areas of the body. At resonance frequency, the absorption of RF energy is at a maximum.

b) Burns and Shocks
Electrically conducting materials such as spectacle frames or medically implanted metal objects (screws, valves and plates) may become hot when exposed to strong EMF or RF fields, leading to damage of the surrounding tissue. Burns can occur when the EMF induced current enters the body through contact between a small area of the body (such as a finger) and an electrical conductor.

Low frequency RF radiation, up to about 100MHz may interact with the body through electrical charges induced on ungrounded or poorly grounded metallic objects such as vehicles, wires or fences. When a person comes into contact, usually via the hands with such an object, a current can pass to ground through the body causing shocks and sometimes burns. The current depends on the total charge which in turn depends on the frequency and field strength as well as the geometry and capacitance of the object and the person's impedance to ground.

c) The ‘Athermal’ Effect
‘Athermal’ is the term used to describe any effect, which is thought to arise by mechanisms other than that involving the production of heat in the body. This includes agitation, vibration and resonance noise type effects that may occur at the cellular level.
17.2.2 Indirect Effects on People

It is possible that some sources of EMF radiation could interfere with the proper operation of some implantable medical devices such as pacemakers and implantable cardioverter defibrillators (ICDs). The significance of such interference may depend on the type of device or pacemaker fitted and the distance and exposure time to the equipment. Individuals fitted with such medical devices should avoid close or prolonged contact with electrical devices or devices that have strong magnetic fields. Devices for which close and prolonged exposure can interfere with a pacemaker include:

- Cell phones
- Portable media players
- Appliances, such as microwave ovens or cookers
- High-tension wires
- Metal detectors
- Industrial welders
- Electrical generators

Such devices may disrupt the electrical signalling of the pacemaker and stop it from working properly, sometimes without the individual initially being aware of this. It is therefore important to ensure appropriate warning notices (see example in Appendix 15) are clearly displayed for areas where this may be an issue and ensure all personnel are informed of the hazards and control measures that must be followed.

17.2.3 Effects on the Environment

EMF radiation has been linked to the potential ignition of flammable vapours and electro-explosive devices as well as possible interference with other sources of electrical equipment.

17.3 Exposure Guidelines and Future Legislation

In order to provide guidelines for RF safety, it is necessary to try and define safety limits, which will reflect those findings of researchers in the field of RF safety that have been accepted by governments or standards bodies. Although standards try to set exposure limits in such a way that they have a direct proportionality to the actual exposure effects experienced, the exposure and Specific Absorption Rate (SAR) distribution is very much affected by the frequency, field polarisation and the specific characteristics of the human bodies involved.

Current national guidelines on limiting exposure to electromagnetic fields (0-300GHz) have previously been published. These guidelines are based on an assessment of the possible effects on human health derived from studies of exposed human populations, biological information, and from dosimetric data. The purpose of the guidelines are to:

1. Control the exposure of people to EMF fields including microwave/RF; and to
2. Prevent the ignition of flammable vapours and electro-exposure devices by RF energy.

In controlling human exposure to EMF radiation, there are two readily identifiable forms of safety standards reflecting whether the potential hazard relates to:

1. Adventitious (unwanted) radiation in the form of leakage from RE sources.
2. Intended radiation from an antenna, machine or application.
Guidelines for EMF exposure are given for members of the public as well as for occupational exposure.

The recommendation provides two values for the limitation of EMF exposure: the basic restrictions and the reference levels. The basic restrictions are derived with regard to the frequency, as potential biological effects are frequency dependent. For the 50 Hz region (1Hz to 10MHz) the basic restriction provides a limitation on the current density induced in the body to prevent effects on the nervous system functions. The basic relevant restriction is given as $2 \text{ mAm}^2$.

The reference levels are obtained from the basic restrictions by mathematical modelling and by extrapolation of laboratory experiments. The current density cannot be easily determined and thus prevent direct measurement of the basic restriction. The reference levels can be measured relatively easily and therefore provide an important means of ensuring that the EMF field strength is acceptable. The reference level for a member of the public at 50 Hz is $100 \mu T$ (microTesla).

The European Union (EU) Physical Agents (Electromagnetic Fields) Directive 2004/40/EC, which is designed to protect the health and safety of workers exposed to electromagnetic fields is due to be implemented into UK law in Oct 2013.

This new Directive will put the internationally accepted ICNIRP Guidelines for EMF which are currently used in the UK, to assess risk from exposure to electromagnetic fields onto a legal footing.

Employer duties from this Directive include:

- The requirement to conduct a risk assessment and if necessary measure the levels of electric and magnetic field strengths to which workers may be exposed to.
- Consider any indirect effects, such as interference with medical electronic devices (e.g. cardiac pacemakers) within the risk assessment.
- The need to eliminate or reduce as low as reasonably possible the risk of exposure; and where risk cannot be eliminated ensure control measures are devised to reduce the risk of exposure below ELV (Exposure Limit Value).
- If the relevant action values are exceeded, the employer is required to assess whether the exposure limit values could be exceeded.
- Provide the risk assessment to those responsible for health surveillance.
- Provide appropriate information and training to employees / workers.
- Where appropriate, initiate health surveillance and maintain records of results.
- Performing investigations and medical examinations where an employee is ‘detected’ as having been exposed.

17.4 Identifying EMF Radiation Hazards

Safety Services, in conjunction with the University RPA, can work with individual departments to identify and assess the RF/MW hazards in your work area. In some cases, RF and MW surveys may be required.
17.5 Control Measures: EMF Radiation

In view of the potential hazards of exposure to EMF radiation a number of control measures should be considered including the following:

- It must be ensured as far as reasonably practicable that where equipment likely to generate a strong EMF radiation is purchased or borrowed, that the supplier provides details of the likely EMF output characteristics and recommended control measures. Such data should already be provided if the equipment is CE-marked, but nevertheless it may be prudent to test the equipment locally to confirm its EMF output.
- The immediate vicinity of unmanned, high-power sources of EMF radiation (e.g. radio-transmitters) shall be suitably fenced off to prevent unauthorised access.
- Equipment generating strong EMF radiation shall be positioned as far away as reasonably practicable from areas normally occupied by staff and others.
- There shall be no unnecessary metal objects near any radiating EMF device. The presence of such objects may result in high-intensity fields in certain locations.
- Shielding or screening of equipment shall be carried out as necessary to reduce EMF radiation exposure.
- Equipment generating high-power microwaves shall not be tested without an appropriate load connected to its output. The power generated should never be allowed to radiate freely into occupied areas.

Safety procedures to be followed by operators of equipment generating strong EMF radiation shall include the following requirements:

- Replacement components, in particular, waveguides, gaskets, flanges, etc., must be such that the equipment's EMF radiation characteristics remain acceptable.
- Testing of an EMF-radiating device either before or after completion of repair work must be carried out and should normally be carried out after protective shields, waveguides and other components have been put back in their designated locations as far as reasonably practicable.
- Adjustments of voltages, replacement or dismantling of EMF-radiation-generating components or refitting waveguides should be undertaken by people trained, competent and authorised to undertake such tasks.
- Maintenance staff and operators of EMF radiation generating devices shall be suitably aware of the potential hazards of EMF radiation.
- Managers responsible for new or existing EMF-radiating-equipment subjected to modification/maintenance should ensure that EMF surveys with appropriate test equipment are carried out.
- Suitable warning signs indicating the presence of EMF radiation should be posted as appropriate where exposure above Action Values may occur.
- Warning signs, prohibiting individuals with pacemakers, metallic implants or other similar devices (which could heat up and cause burns) from entering areas where EMFs exist should be posted at all entrances.
- EMF-generating equipment may present additional hazards such as X-ray emission and electrical dangers which will have to be evaluated separately (see Local Rule specific to these additional hazards).
17.6 Other RF/MW Sources

17.6.1 Antennae and Antenna Arrays

Operation of radio, television, microwave and other related communication systems, using electromagnetic radiation and carrier-current systems require prior review and approval by the University. Safety Services must be contacted before a new transmission antenna is placed in or around the campus.

17.6.2 Mobile Phones

The numbers and usage of mobile phones have increased exponentially in recent years and concerns whether the technology is safe have also arisen. As yet there is no definitive scientific evidence to suggest that the technology is unsafe.

Every mobile phone is rated according to the levels of electromagnetic radiation (radiowaves) that it emits. This SAR (specific absorption rate) value reflects the maximum amount of energy absorbed by the body when the phone is being used. The higher the phone's SAR, the more radiation the body will absorb. The SAR rating for mobile phones can be found:

- With the mobile phone instructions;
- on the manufacturer's website or
- at www.sarvalues.com or www.mobile-phones-uk.org.uk

In Europe, the EU has adopted the recommendations made by the International Commission on Non-Ionising Radiation Protection. These recommend a SAR limit of 2W/kg (watts per kilogram). All mobile phones on sale in the UK and the rest of Europe comply with this limit. However, standards vary around the world. For example, in the USA the limit is set slightly lower than Europe, at 1.6 W/kg.

General points:

- Mobile phones are low power devices operating at about 900 MHz and 1000 MHz.
- The present limit for radiowaves is 100 mW absorbed in 10g of tissue (time averaged over 6 minutes) gives < 1°C rise in tissue.
- Typical mobile phone emits < 2 mW.
- Radiowaves of this frequency do not have enough energy to disrupt DNA directly.
- Other effects – not enough evidence to decide.
- There is evidence to suggest that they can disrupt sensitive electronic equipment.
17.6.3 Microwave Sources

There are a number of microwave ovens used as heating sources around the University. Although microwave ovens are a familiar sight in most homes, they are still potentially hazardous and should be treated with respect. Typical microwave ovens operate at between 500 – 1000 W @ 2.45 GHz and radiation of this type can produce rapid heating of soft tissue. The following common sense rules should therefore be followed:

- Manufacturer’s instructions on use and maintenance should be followed.
- Microwave ovens must be kept clean, with seals regularly checked and the equipment electrically tested at suitable periods (i.e. PAT tested).
- Door shields are present to prevent radiation from escaping the enclosure – never operate the equipment with the door opened.
- Do not operate the oven with metallic objects inside.
- Be aware of the possibility of superheating liquids and the risk of explosions for example if microwave ovens are used to melt agar.
- Do not operate the oven when empty – this can damage the magnetron.

It is unusual for a commercial microwave oven to leak, but misuse, damage, and interlock failures can cause ovens to leak. Any microwave oven suspected of leaking should be removed from use and surveyed for leakage with a suitable and calibrated microwave leakage detector.

17.6.4 Power Supplies

Many high voltage power supplies operate in the microwave or radiofrequency regions. If damaged, or not properly shielded, these sources can leak, producing unintended RF / MW radiation exposure. Most of the time, the leakage from these sources is minimal and does not pose any significant hazard. However, if you have an indication of microwave / RF radiation leakages (RF interference with other equipment) please contact Safety Services.

17.6.5 EMF Radiation from Leaking Sources

For waveguides, co-axial cables, generators, sealers and ovens, the most important aspect of controlling microwave / RF radiation hazards is a careful physical inspection of the source. Leaking sources will normally show misalignment of doors or plates, missing bolts, or physical damage to plane surfaces. Sources that are suspected of leaking should be repaired and surveyed by appropriate instrumentation.
### 18.0 Key Management Actions

Implementation of this Local Rule will be monitored as part of Safety Services Audit Programme, therefore the following key action points must be fulfilled where non-ionising radiation risks are present in a department:

<table>
<thead>
<tr>
<th>Subject</th>
<th>Summary of the Key Actions Required by Departments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Roles &amp; responsibilities</td>
<td>Heads of Department must:</td>
</tr>
<tr>
<td></td>
<td>1. appoint in writing (RP2 Form), a responsible person (or persons as appropriate) to the role of Departmental Radiation Protection Supervisor (DRPS) to assist the HOD / Director in meeting both legislative and university requirements in relation to work with non-ionising radiation</td>
</tr>
<tr>
<td></td>
<td>2. ensure that appropriate health and safety management arrangements are put in place and implemented (where applicable) for the various aspects relating to non-ionising radiation work (see point 5 below)</td>
</tr>
<tr>
<td></td>
<td>3. ensure that these arrangements are regularly reviewed and updated where necessary</td>
</tr>
<tr>
<td></td>
<td>4. ensure that recommendations issued by the RPA/LPA/ Safety Services following safety audit visits or if advised outwith are acted and implemented on as soon as possible</td>
</tr>
<tr>
<td></td>
<td>5. ensure that any notifications and/or investigations required are carried out when requested (or as appropriate) and in line with any specified time period</td>
</tr>
<tr>
<td>2 Identifying non-ionising radiation hazards</td>
<td>Departments must:</td>
</tr>
<tr>
<td></td>
<td>6. identify work activities and equipment which may present a non-ionising radiation risk</td>
</tr>
<tr>
<td></td>
<td>7. carry out a risk assessment for such activities</td>
</tr>
<tr>
<td></td>
<td>8. maintain an up-to-date inventory of non-ionising radiation-sources and equipment</td>
</tr>
<tr>
<td>3 Evaluating non-ionising radiation risks</td>
<td>Departments must:</td>
</tr>
<tr>
<td></td>
<td>9. work with the University in meeting all legal requirements and specifically those covered by the Control of Artificial Optical Radiation at Work Regulations 2010</td>
</tr>
<tr>
<td></td>
<td>10. consult and seek additional advice where necessary with a RPA/LPA and supporting occupational health and safety staff</td>
</tr>
<tr>
<td></td>
<td>11. ensure that all high risks areas and locations are suitably identified and appropriately designated (if required)</td>
</tr>
<tr>
<td></td>
<td>12. consult with Safety Services and RPA/LPA on all new proposed non-ionising radiation facilities, locations, projects or activities which may require advice on design features and engineering controls</td>
</tr>
<tr>
<td></td>
<td>13. ensure all lasers and laser containing equipment (except class 1) are appropriately identified by its class</td>
</tr>
<tr>
<td></td>
<td>14. ensure that where new or second-hand NIR equipment is being brought into the department, that it meets acceptable standards in terms of labelling and safety control</td>
</tr>
<tr>
<td></td>
<td>15. ensure that any NIR sources being built as prototypes or being adapted meet acceptable standards in terms of labelling and safety control</td>
</tr>
<tr>
<td>4 Risk assessments</td>
<td>Departments must:</td>
</tr>
<tr>
<td></td>
<td>16. ensure risk assessments are carried out for all new work</td>
</tr>
<tr>
<td></td>
<td>17. ensure laser risk assessments consider both beam and</td>
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<td></td>
<td></td>
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<td>---</td>
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</tr>
<tr>
<td>18</td>
<td>ensure risk assessments are reviewed regularly or where significant changes have occurred</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5</th>
<th>Dept. management arrangements</th>
<th>Departments must:</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>ensure no high risk non-ionising radiation sources or equipment is brought into or removed from departmental or University premises without appropriate notification / authorisation with the DRPS</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>ensure suitable Local Rules are available for any areas designated as Laser Controlled Areas (LCA)</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>ensure high risk non-ionising radiation sources / equipment, are maintained in good condition and that regular testing and checking of engineering controls, design features, safety features and warning devices are carried out and documented</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>provide suitable and appropriate PPE (e.g. laser protective eyewear) where deemed necessary from the risk assessment</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>ensure PPE is maintained in good working condition, and is stored and used correctly</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>ensure suitable and appropriate arrangements are in place for maintenance and security staff, visitors, non-ionising radiation workers going to visit other establishments or coming from other establishments and for contractors and servicing engineers.in terms of access to areas, risk assessments, induction and training</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>6</th>
<th>Information, Instruction, Supervision and Training</th>
<th>Departments must:</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>ensure DRPSs receive appropriate and suitable training, time and support for their roles as DRPS (see 4.6.1 for further details)</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>provide all non-ionising radiation workers with relevant information, instruction, supervision and training in relation to the risks and work activities involving non-ionising radiation</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>retain a record and details of the training provided to non-ionising radiation workers</td>
<td></td>
</tr>
</tbody>
</table>
19.0 References, Guidance and Further Reading

General
- The Health and Safety At Work etc Act 1974 HSMO ISBN 0 10 543774 3
- The Management of Health and Safety at Work Regulations 1999 (No. 3242) ISBN 0 11 085625 2
- The Control of Artificial Optical Radiation Regulations 2010
- Guidance for Employers on the Control of Artificial Optical Radiation at Work Regulations (AOR) 2010
- Physical Agents (Artificial Optical Radiation) Directive 2006/25/EC
- Physical Agents (Electromagnetic Fields) Directive 2004/40/EC
- The Supply of Machinery (Safety) Regulations 2008
- The Electrical Equipment (Safety) Regulations 1994 (as amended)
- The Electromagnetic Compatibility Regulations 2006
- The Provision and Use of Work Equipment Regulations 1998
- Simple guide to the Provision and Use of Work Equipment Regulations 1998, INDG291
- Safe use of work equipment, Provision and use of Work Equipment Regulations, 1998, ACOP L22
- International Commission on Non-ionizing Radiation Protection (ICNIRP) (www.icnirp.de) - Various Publications and guidelines on Optical and EMF radiation
- Health and Safety Executive website (non-ionising radiation index)
- European Committee for Electrotechnical Standardization (CENELEC)
- International Electrotechnical Commission (IEC)
- European Coordination Committee of the Radiological, Electromedical and Healthcare IT Industry (COCIR)
- Public Health England - Various information sheets on non-ionising radiation
- International Commission on Illumination (ICE): Division 6: Photobiology and Photochemistry
- Buying new machinery INDG271

Lasers
- British Standard EN 207: 1999. Filters and Equipment used for Personal Eye-Protection Against Laser Radiation
- Public Health England - FAQs about lasers

Ultraviolet (UV) Radiation
NRPB (now part of the Health Protection Agency) publications:


External Exposure in Relation to Outside Workers

HSE documents and website:

- [Working in the sun](http://www.hse.gov.uk/healthtopics/sun.htm)
- [Sun Protection](http://www.hse.gov.uk/healthtopics/sun.htm)
- [Keep your top on: Health risks from working in the sun INDG147](http://www.hse.gov.uk/healthtopics/sun.htm)
- [Sun protection: advice for employers of outdoor workers INDG337](http://www.hse.gov.uk/healthtopics/sun.htm)

The following website also provides useful information:

- [SunSmart: the UK’s national skin cancer prevention campaign](http://www.sunsafe.org.uk/)

Electromagnetic Radiation

- [Public Health England - Electromagnetic Fields](http://www.hpa.org.uk/healthTopics/)
- ICNIRP Factsheet - Limits of exposure to static magnetic fields, 2009
- ICNIRP Guidelines for Limiting Exposure to time-varying Electric, Magnetic, and Electromagnetic Fields (up to 300GHz)
- National grid information site on EMFs: [www.emfs.info](http://www.emfs.info)
- The Energy Networks Association website: [www.energynetworks.org](http://www.energynetworks.org)

NRPB (now part of the Public Health England) publications:

Appendix 1

Occupational Health & Safety Responsibility and Management Structure

OHS Management Responsibility

- Court
- Executive Team
- Faculty / Professional Services
- Departments/ Schools

Key Responsibilities

- Principal
- Chief Operating Officer
- Chief Financial Officer / Deans
- Directors / Heads of Dept/ Heads of School
- Managers / Principal Investigators / Academic Supervisors
- All staff / students
Appendix 2
Draft Example of Local Rules for work with an [insert] Laser

<table>
<thead>
<tr>
<th>DRPS (Lasers) / Laser Safety Officer (LSO)</th>
<th>Name</th>
<th>Contact details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser Protection Advisor</td>
<td>Name</td>
<td>Contact details</td>
</tr>
<tr>
<td>Issued under the authority of University department</td>
<td>Name</td>
<td>Signature</td>
</tr>
<tr>
<td>Version</td>
<td>Version number</td>
<td>Date</td>
</tr>
</tbody>
</table>

Scope
These Local Rules cover the use of the insert laser located in insert. They cover the normal use and user maintenance service operations.

Description
It is often useful to describe the laser and the laser product. This may include the classification, type of laser system, wavelength etc.

Authorised users
Only persons who are adequately trained (state how) and authorised as listed in the appendix to these local rules may work with the laser/ carry out maintenance on the laser.

Laser controlled area
Describe the area and the conditions under which one exists. Warning signs to indicate the extent of the area could be described here.

Procedures
The intention here is not to reproduce the operating manual, but to identify potential safety critical operations that need to be carried out. Examples include connecting interlocks, shutter checks etc.

Protection measures
These may be identified in the ‘Procedures’ section, but specifically here would be a description of any control measures, especially administrative, personnel or PPE, which are required to be actioned. It may include ‘how’ the user ensures that the protection measure is adequate for the task to be completed.

Summary of hazards
It is useful to summarise the nature of the hazards associated with the laser product — and these may extend beyond the laser beam itself. It can also help to describe the risk and how this is managed e.g. restrict entry.

Contingency plan
Essential — the adverse incident procedure.

Appendix+
List of authorised users

User declaration
It may be useful for a high flow of students to have a declaration that authorised users sign to say that they have understood the contents.
UNIVERSITY OF STRATHCLYDE

LASER EYE STRIKE

EMERGENCY INSTRUCTIONS

In the event of an incident involving a laser eye strike please proceed as follows:

- Reassure the casualty then call for assistance.
- Summons assistance from security control on Ext 2222 (emergency number) (or alternatively Ext 3333, if unable to get through to Ext. 2222).
- All security wardens are qualified first aiders
- Please state clearly
  - Name, department, location and extension number
  - Brief details of the injury - LASER EYE STRIKE
  - Medical attention will be required (see full instructions / contact details on “Grab Sheets”)
  - Transport will be required
- Stay with the casualty and reassure until help arrives
- Switch off laser
- Complete laser details to be sent with casualty or take “Grab Pack” details to hospital. (Appendix 4)
- The security warden will take charge
- The casualty should be accompanied to the hospital ensuring all the relevant details of the laser involved in the incident are available for the medical staff.
- The incident should be reported to the DRPS (Lasers) / LSO and the Safety Office (Ext 2726)
[Insert Laser Name] Laser
[Insert Laser Location]

GRAB PACK

Security Services: 2222 or 3333

The injured person should be taken to:

Accident and Emergency Dept.
Glasgow Royal Infirmary
84 Castle Street
Glasgow, G4 0SF
0141 211 5608 / 4484 / 4314

If the deemed necessary, then the Accident and Emergency Doctor may make a referral request for the person to be taken to the Ophthalmology Acute Referral Centre (ARC) at Gartnavel General Hospital:

Ophthalmology Acute Referral Centre
Gartnavel General Hospital:
1053 Great Western Road,
Glasgow, Lanarkshire, G12 0YN
0141 211 3000

The Accident and Emergency Doctor may also seek specialist medical advice from:

Moorfields Eye Hospital
NHS Foundation Trust, London,
162 City Road, London
EC1V 2PD
020 7253 3411

**Laser Eye Strike Details**

In order to assist the eye care specialist / hospital, someone assisting the casualty, should complete the following laser details, which must then accompany the casualty to hospital.

(Please write clearly and state units where applicable)

<table>
<thead>
<tr>
<th>Casualty Name</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Eye</td>
<td>Left</td>
</tr>
<tr>
<td></td>
<td>Both</td>
</tr>
<tr>
<td></td>
<td>Right</td>
</tr>
<tr>
<td>Full beam or specular reflection</td>
<td></td>
</tr>
<tr>
<td>Laser Type/material</td>
<td></td>
</tr>
<tr>
<td>Laser Wavelength</td>
<td></td>
</tr>
<tr>
<td>Pulsed/CW</td>
<td></td>
</tr>
<tr>
<td>Maximum Power/Energy</td>
<td></td>
</tr>
<tr>
<td>Pulse Length</td>
<td></td>
</tr>
<tr>
<td>Repetition Rate</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 5
Examples of Laser Warning Labels

Class 1 (by engineering design)
No hazard warning label.
Explanatory label bearing the words:

CLASS 1 LASER PRODUCT
A TOTALLY ENCLOSED LASER SYSTEM CONTAINING A CLASS [insert] LASER

In addition each access panel or protective housing shall bear the following words,

CAUTION - CLASS [insert] LASER RADIATION WHEN OPEN

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

Class 1M
No hazard warning label.
Explanatory label bearing the words:

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

NB – ‘Optical Instruments’ can be supplemented with either ‘Binoculars or telescopes’ (for a large diameter collimated beam) or ‘Magnifiers’ (for a highly divergent beam).

Class 2
Label with hazard warning symbol.
Explanatory label bearing the words:

LASER RADIATION DO NOT STARE INTO BEAM
CLASS 2 LASER PRODUCT

Class 2M
Label with hazard warning symbol.
Explanatory label bearing the words:

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

NB – ‘Optical Instruments’ can be supplemented with either ‘Binoculars or telescopes’ (for a large diameter collimated beam) or ‘Magnifiers’ (for a highly divergent beam).

Class 3R
Label with hazard warning symbol.
For $\lambda$, 400nm-1400nm ONLY
Explanatory label bearing the words:

LASER RADIATION AVOID DIRECT EYE EXPOSURE
CLASS 3R LASER PRODUCT
Appendix 5

Examples of Laser Warning Labels

Note: For other λ, replace ‘AVOID DIRECT EYE EXPOSURE’ with ‘AVOID EXPOSURE TO BEAM’

Class 3B

Label with hazard warning symbol. 
Explanatory label bearing the words:

![LASER RADIATION AVOID EXPOSURE TO BEAM CLASS 3B LASER PRODUCT]

CLASS 3B LASER PRODUCT

CLASS 4

Label with hazard warning symbol. 
Explanatory label bearing the words:

![LASER RADIATION AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION CLASS 4 LASER PRODUCT]

CLASS 4 LASER PRODUCT

Aperture labels for Class 3R, Class 3B & Class 4 Lasers

Each Class 3R, Class 3B and Class 4 laser product shall display a label close to where the beam is emitted bearing the words ‘LASER APERTURE’ or ‘AVOID EXPOSURE – LASER RADIATION IS EMITTED FROM THIS APERTURE’. This label can take the form of an arrow if it conveys more meaning.

![LASER APERTURE]

Radiation Output and Standards Information

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

- Maximum output
- Emitted wavelength
- Whether laser is visible, invisible or both
- Pulse duration (if appropriate)
- Name and publication date of classification standard

It may be useful to also put details of the type of laser and the lasing medium onto the labels, although this is not a BS requirement.
### Appendix 6

## Examples of Laser Classes and Required Control Measures

<table>
<thead>
<tr>
<th>Laser Class</th>
<th>Radiation hazard</th>
<th>Protection requirements</th>
</tr>
</thead>
</table>
| 1           | Normally safe under reasonably foreseeable conditions due to low emission of the laser itself or by engineering design. | • Avoid staring into the beam  
• Ensure that the conditions for Class 1 operation are maintained  
• During servicing, protection requirements for a higher Class apply. |
| 1M          | Laser products that exceed the permitted emission levels for Class 1 lasers. Harmful effects to the unaided eye are not possible under direct viewing. Ocular exposure can be exceeded by using:  
- Magnifying viewing instruments e.g. telescopes;  
- Microscopes;  
- If the spatial distribution is altered by optical components or instruments | • Avoid all magnifying aids  
• Avoid placing optical devices in the emitted beam to concentrate the laser beam intensity  
• Ensure the beam is terminated at a suitable non-specular surface |
| 2           | Laser products emitting low-levels of visible radiation with exposure safe to the skin and eye protection afforded by the natural aversion response (blink or closing of the eye). | • Avoid staring directly into the beam  
• Avoid mis-directing of the laser at other people |
| 2M          | Laser products, which exceed the permitted emission levels for Class 2 lasers. Harmful effects to the unaided eye are not possible under direct viewing. Ocular exposure can be exceeded by using:  
- Magnifying viewing instruments e.g. telescopes;  
- Microscopes;  
- If the spatial distribution is altered by optical components or instruments;  
- The use of large diameter collimated beams | • Avoid magnifying aids  
• Avoid placing optical devices in the emitted beam  
• Ensure the beam is terminated at a suitable non-specular surface |
| 3R          | Laser products with emission levels greater than 5 times that of Class 1 products. The MPE may be exceeded but the risk of injury is low. | • Prevent direct eye exposure to the beam  
• Avoid directing the beam into areas where other people may be present.  
• Prevent all eye exposure to the beam  
• Guard against all unintentional beam |
<table>
<thead>
<tr>
<th>Laser Class</th>
<th>Description</th>
<th>Control Measures</th>
</tr>
</thead>
</table>
| 3B          | Laser products with emission levels which can be harmful to the unaided eyes. If emission is outside the wavelength range 400 to 1400nm then these products may be harmful to the skin. | - Prevent all eye exposure to the beam  
- Guard against all unintentional beam reflections  
- Use in an enclosed area  
- For emission wavelengths between 180 and 400nm and 1400nm and 1mm, provide personal protective equipment and avoid skin exposure  
- Ensure the beam is terminated at a suitable non-specular surface |
| 4           | High power lasers that exceed the AELs for Class 3B products that are also capable of producing hazardous diffuse reflections. They may cause skin injuries, could also constitute a fire hazard and could cause hazardous fumes to be produced as well as being a hazard to the eyes. Their use requires extreme caution (see Appendix 11 also). | - Prevent all eye exposure to the beam  
- Guard against all unintentional beam reflections  
- Use in an enclosed area  
- Provide personal protective equipment and avoid skin exposure  
- Ensure the beam is terminated at a suitable non-specular surface |
<table>
<thead>
<tr>
<th>Background Information</th>
<th>Date:</th>
<th>Name of Assessor:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Describe the product and application</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Describe the Laser</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Describe the Beam Delivery System</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Describe the Laser Process</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Describe the Environment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Who uses the product or could affect its operation?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circle the part(s) of the life cycle of interest</td>
<td>Planning, Design, Manufacture, Testing, Transport, Installation, Commissioning, Normal Operation, Maintenance, Servicing, Modification, Decommissioning, Disposal</td>
<td></td>
</tr>
</tbody>
</table>
## Laser Risk Assessment Template

<table>
<thead>
<tr>
<th>Assessment Number:</th>
<th>Assessment Date:</th>
<th>Activity/Facility Assessed:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessed by:</td>
<td>Review Date:</td>
<td>Location:</td>
</tr>
</tbody>
</table>

### STEP 1

<table>
<thead>
<tr>
<th>List significant hazards</th>
<th>List groups of people who are at risk</th>
<th>List existing controls</th>
<th>Are these controls OK?</th>
<th>What is the risk factor from these hazards?</th>
<th>Actions Required? Yes or No. (If yes – complete Actions Required table)</th>
</tr>
</thead>
</table>

### The Laser:

### Beam Delivery:

### The Laser Process:

### Environment & People:

<table>
<thead>
<tr>
<th>Persons at risk</th>
<th>Risk</th>
<th>Life Cycle</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staff</td>
<td>S</td>
<td>High</td>
<td>Set-up</td>
</tr>
<tr>
<td>Contractor</td>
<td>C</td>
<td>Medium</td>
<td>Normal Operation</td>
</tr>
<tr>
<td>Visitor</td>
<td>V</td>
<td>Low</td>
<td>Maintenance</td>
</tr>
<tr>
<td>Public</td>
<td>P</td>
<td></td>
<td>Service</td>
</tr>
<tr>
<td>Other</td>
<td>O</td>
<td></td>
<td>Other</td>
</tr>
</tbody>
</table>
## Laser Risk Assessment Template

<table>
<thead>
<tr>
<th>Significant Hazards Identified</th>
<th>Actions Required (eg Control Measures to be introduced)</th>
<th>Date for Action</th>
<th>Completed By (Name and Date)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>The Laser:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Beam Delivery:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>The Laser Process:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Environment &amp; People:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 4 Examples of Hazards

<table>
<thead>
<tr>
<th>People</th>
<th>Noise</th>
<th>Fumes</th>
<th>Radiation hazards</th>
<th>Hot objects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor instruction, training</td>
<td>Fire</td>
<td>Moving parts of machinery</td>
<td>X Rays/EMI</td>
<td>Ozone</td>
</tr>
<tr>
<td>Inadequate systems or procedures</td>
<td>Lifting of heavy objects</td>
<td>Pressure systems</td>
<td>Compressed gases</td>
<td>Trailing leads</td>
</tr>
<tr>
<td>Unsuitable workstation/equipment</td>
<td>Electricity</td>
<td>Falling objects</td>
<td>Inadequate optics mounts</td>
<td>Optical fibre breakage</td>
</tr>
<tr>
<td>Poor lighting</td>
<td>Chemicals/substances</td>
<td>Explosion</td>
<td>Optical component failure</td>
<td>Errant beams</td>
</tr>
<tr>
<td>Slip, trip hazards</td>
<td>Dust</td>
<td>Bio-hazards</td>
<td>Confined spaces</td>
<td></td>
</tr>
</tbody>
</table>
# Appendix 8

## Common Non-beam Laser Hazards and Control Measures

### Hazards arising from the Laser source

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Typical hazardous situation</th>
<th>Typical control measure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High voltage</strong></td>
<td>Laser head and power supply exposed during servicing. Many lasers utilise high voltages, and pulsed lasers frequently employ capacitors to store electric charge.</td>
<td>Proper screening of exposed HV. Restricted access to qualified persons. Use of earthing stick to ensure the removal of stored energy prior to commencement of servicing work.</td>
</tr>
<tr>
<td><strong>Fire and Explosion</strong></td>
<td>Laser equipment can present a fire hazard by virtue of the flammable components, plastic parts etc. contained within it, which can overheat or catch fire in the event of a fault within the equipment. High-pressure flash lamps, capacitors and other internal components can explode.</td>
<td>For fire: provision of a fire extinguisher; smoke alarm; training. For explosion protection during maintenance activities: gloves and face shield; training.</td>
</tr>
<tr>
<td><strong>Noise</strong></td>
<td>The discharge of capacitor banks within the laser power supply can generate noise levels high enough to cause ear damage. Ultrasonic emissions and repetitive noise from pulsed lasers can also be harmful.</td>
<td>Use of ear protectors where excessive noise levels cannot be eliminated.</td>
</tr>
<tr>
<td><strong>Collateral radiation</strong></td>
<td>Ultraviolet, visible and infrared emission can be produced from gas laser discharge tubes. Microwave and radio frequency radiation is produced in RF-excited lasers, and can be emitted by the equipment if not properly shielded during servicing. X-rays can be produced by high-voltage thermionic valves within the laser power supply.</td>
<td>Proper screening combined with access restricted to service engineers.</td>
</tr>
<tr>
<td><strong>Mechanical</strong></td>
<td>Unloading and positioning of laser power supplies and ancillary items such as gas cylinders. Trailing cables and water-circulation tubing can present a trip hazard.</td>
<td>Provide attachment points for use of lifting equipment by qualified persons. Training and use of gloves. Properly secure equipment. Cover cables in ducting or under a raised walkway.</td>
</tr>
<tr>
<td><strong>Chemical</strong></td>
<td>The material used as the active medium in many lasers (especially laser dyes and the gases used in excimer lasers) can be toxic and carcinogenic. The solvents used in many dye lasers have the ability to carry their solutes through the skin into the body. They may also be highly volatile and should not be inhaled.</td>
<td>Proper storage, handling and disposal precautions should be adopted. Training and use of gloves and other PPE.</td>
</tr>
</tbody>
</table>

### Hazards arising from the Laser process

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Typical hazardous situation</th>
<th>Typical control measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fume</strong></td>
<td>Release of hazardous particulate and gaseous by-products into the atmosphere through the interaction of the laser beam with the target material during laser materials processing and laser surgery.</td>
<td>General precautions include: Fume extraction and filtration. Face mask and gloves worn during cleaning operations.</td>
</tr>
<tr>
<td><strong>Hazardous substances</strong></td>
<td>Cleaning solutions and also other materials used in conjunction with the laser (e.g., zinc selenide lenses) may be hazardous.</td>
<td>Use proper storage and implement handling and disposal precautions</td>
</tr>
<tr>
<td><strong>Fire and explosion</strong></td>
<td>The laser emission from high-power (Class 4) lasers can ignite target materials. These effects are enhanced in the oxygen-rich environment utilised in some laser processing applications. Laser emission from even lower-class lasers, especially when concentrated over very small areas, can cause explosions in combustible gases or in high concentrations of airborne dust. Improperly terminated Class 4 laser radiation.</td>
<td>Control flammable materials and beam path. Provide a fire extinguisher in the laser area.</td>
</tr>
</tbody>
</table>
### Secondary radiation
- X-ray, UV and blue light emitted by the plasma that can be generated by interaction of the laser beam (particularly those containing short, high power pulses) with target materials. Such emissions can include x-rays, ultraviolet radiation (UV), visible light, infrared radiation (IR), microwave radiation and radio-frequency (RF) radiation.
- Enclose target area and monitor hazard. Wear PPE for exposure to UV and blue light.

### Mechanical
- Beam delivery arms and robotic systems that move under remote control can cause serious injury. Large work-pieces (such as sheet metal) can present manual handling problems such as cuts, strain, and crush injuries.
- Guard traps and add warning signs. Restrict access to moving parts.

### Hazards arising from the Laser environment

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Typical hazardous situation</th>
<th>Typical control measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature and humidity</strong></td>
<td>Excessive high or low ambient temperatures, or high levels of ambient humidity, can affect the performance of the laser equipment, including its in-built safety features, can compromise safe operation and make the wearing of safety eyewear uncomfortable. Condensation on optical components can affect beam transmission through the system.</td>
<td>Provide air conditioning and humidity control of the local environment. Install a gas purge in beam delivery line.</td>
</tr>
<tr>
<td><strong>Mechanical shock and vibration</strong></td>
<td>Misalignment of the optical path, generating hazardous errant beams.</td>
<td>Install a vibration isolation system on the legs of optical tables holding optical components. Construct a floating foundation for large laser machines.</td>
</tr>
<tr>
<td><strong>Atmospheric affects</strong></td>
<td>Laser ignition of solvent vapour, dust, and inflammable gases present in the environment.</td>
<td>Enclose beam and process zone and add a gas purge. Install gas sensors to detect presence of inflammable gases and vapours.</td>
</tr>
<tr>
<td><strong>EM and RF interference</strong></td>
<td>Compromised operation of control circuits caused by interference to laser equipment resulting from exposure to EM radiation and high voltage pulses conducted down supply or data cables.</td>
<td>Screen equipment and filter supply and data cables.</td>
</tr>
<tr>
<td><strong>Power supply interruption or fluctuation</strong></td>
<td>Interruption or fluctuation of the electrical supply can affect the operation of the laser's safety system.</td>
<td>Install a voltage regulation system and back-up supply.</td>
</tr>
<tr>
<td><strong>Computer software problems</strong></td>
<td>Serious and unpredictable hazards arising without warning caused by errors in computer programming of software control.</td>
<td>Use only approved protocols for software control of safety functions.</td>
</tr>
<tr>
<td><strong>Ergonomic and human-factor considerations</strong></td>
<td>Poor arrangement of the physical layout of the laser and its associated equipment. Lack of space resulting in a cluttered environment. Complex or difficult operating procedures. Human factors, including: personal aspects (mental and physical attributes of the individual, including work ability, perception of workplace risks, age and experience, and attitude to safety); job aspects (tasks or functions to be performed; influence on human performance of the equipment that has to be used); organisational aspects (&quot;safety culture&quot; of the organisation, including the framework within which an individual has to work and the influences and pressures (real or imagined) that the individual may be under).</td>
<td>Improve layout, reduce clutter and review the ergonomics of repetitive or sustained tasks. Training to improve human factors since these play some part in the majority of work-related accidents</td>
</tr>
</tbody>
</table>
Appendix 9

Additional Laser Control Measures for High Risk Laser Activities

Open Beam Work
The following initial safety checks for open beam work should be considered for inclusion in the Safe System of Work for work with unenclosed High Risk laser beams.

Before releasing High Risk laser beams:
- Beam paths should be inspected for any objects that should not be there and any beam line components that may have been displaced or misaligned.
- Any screens/enclosures or beam stops that have been removed should be replaced.
- All optics should be checked for damage, and the stability of optics mounts verified prior to operation of laser.
- Check that only authorised people are in the area.
- Check that everyone in the area is wearing appropriate laser safety eyewear.
- Give prior warning that the laser beam is about to be launched.

Beam alignment of open beam paths is the most common cause of laser eye injuries. The following guidelines should be considered for inclusion in the Safe Systems of Work.
- Only suitably trained and authorised individuals may carry out alignment.
- Alignment should be carried out with one or at most two authorised laser operators. All other persons should be excluded from the room during this procedure.
- Watches, bracelets and other reflective jewellery should be removed.
- Appropriate laser safety eyewear to be worn.
- Initial alignment should be at the lowest possible power, preferably Class 2 or Class 1, by attenuating the laser or by use of an alignment laser.
- Analyse each and every optical element in the beam path for stray reflections and install suitable beam blocks. (The blocks must be stable, preferably locked to the table.)
- Restricted access, unauthorised personnel must be excluded from the room or area.
- Under no circumstances must direct viewing of the laser beam be attempted even if the beam has been attenuated. The use of a video camera for remote viewing should be considered.
- Alignment with a higher power beam should be carried out using laser safety eyewear. The table below gives examples of suitable techniques.

<table>
<thead>
<tr>
<th>Wavelength range</th>
<th>Techniques for beam position detection with the operator using laser safety eyewear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visible only</td>
<td>Introduce an attenuator to reduce accessible emission to Class 3R or below. Protective eyewear can then be removed. Alternatively wear laser alignment eyewear.</td>
</tr>
<tr>
<td>UV and/or Visible</td>
<td>Use fluorescent card (e.g. impregnate paper with dye, mark target with highlighter ink): fluorescence at shifted wavelength can be seen through protective eyewear. Attenuate the beam and use a charge coupled device (CCD) camera</td>
</tr>
</tbody>
</table>
| Infrared only    | Options include:  
- liquid crystal paper, which changes colour when heated  
- heat sensitive fax/chart recorder paper  
- fluorescent-coated blocks illuminated with UV lamps  
- for near infrared, phosphor or scintillation cards  
- attenuate the beam and use a CCD camera  
- simple detector in conjunction with an aperture (or a position sensitive centroid or quadrant detector) to locate the centre of the beam. |
## Additional Laser Control Measures for High Risk Laser Activities

<table>
<thead>
<tr>
<th>Laser Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Pulse lasers</td>
<td>Use black coated or lithographic paper; the coating is ablated by the more powerful pulsed lasers.</td>
</tr>
<tr>
<td>Any wavelengths</td>
<td>Use a collinear low power visible cw laser for principal alignment. Introduce variable (iris) diaphragms to aid alignment.</td>
</tr>
<tr>
<td>‘All’ visible wavelengths</td>
<td>Multi-wavelength alignment may have to be carried out without laser safety eyewear, as it would otherwise be impossible to visualise the laser beam on a card.</td>
</tr>
</tbody>
</table>

Where the alignment technique involves two people, the one viewing the position of the laser beam and the other blocking and unblocking the laser beam, the person viewing the beam should be provided with a fail-safe engineered means (e.g. a key control or a hand held button on a flying lead operating a simple external shutter) to prevent unintentional activation of the laser hazard.

Where the alignment requires the simultaneous presence of open beam Class 3B and/or 4 laser beams at several visible wavelengths for which there is no suitable eye protection available with sufficient visible transmission, the following steps must be taken:

- Consider complete enclosure, using cameras and motorised controllers for beam alignment.
- If open beam work is inevitable, expose the minimum number of wavelengths simultaneously and use eyewear that protects against the most powerful beam(s) exposed.
- Implement strict administrative control of reflecting surfaces and use optical mounts that prevent excessive angular adjustment, especially in the vertical plane.
- All optical mounts and tools (screwdrivers etc) should have matt surfaces.
- The operator(s) when making adjustments must exercise extra caution.
Guidance on fibre optic laser work can be found in IEC 60825 Part 2. ‘Safety of optical fibre communication systems’ though the standard strictly only applies to extended Class 1 communications systems.

Optical fibres carrying laser radiation normally provide a complete enclosure of the radiation, and so prevent access to it. However, if a fibre is disconnected or a fibre break occurs, hazardous levels of laser exposure can be present. IEC 60825 Part 2 introduces the concept of Hazard Levels, corresponding exactly to the classification scheme for lasers. This scheme is particularly useful for dealing with servicing of extended optical communication systems that may be driven by Class 3B or 4 lasers but are essentially closed Class 1 systems in normal operation.

**Good practice (all lasers)**
- Do not stare with unprotected eyes or with any unapproved collimating device at the fibre ends or connector faces.
- Fibre end(s) must be individually or collectively covered when not being used.
- Do not cleave ribbon fibres as an unseparated ribbon, or use ribbon splicers, without first assessing the hazard of exposure to multiple laser outputs.
- When using optical test cords, connect the optical power source last and disconnect it first.
- Dispose of fibre off-cuts (sharps) into a suitable and approved “sharps” waste bin container.

**High Risk lasers**
- Before connecting high risk laser test equipment assess the potential hazard at other points of access to the optical fibre system and either block the open ends or take appropriate action to prevent access.
- Optical fibre in mixed service conduits must be protected and clearly distinguished from electrical and other service cabling.
Laser Protective Eyewear is not a substitute for other precautions; indeed, it is only to be used if, after applying all reasonably practicable control measures, adequate protection for the eyes has not been achieved.

Laser Protective Eyewear is available from a number of laser component suppliers and can be expensive. However, it is generally a key item of safety and economies should not be made in this area; uncomfortable eyewear with a restricted field of view is unsuitable for the regular laser user.

Laser safety eyewear is marked to show the wavelength(s) for which it provides protection and the level of protection. Laser protective eyewear is given a scale number with a prefix ‘L’. Adjustment eyewear is also available for visible cw laser radiation in which the filters attenuate the laser radiation to a safe level for 0.25 s exposure. In this way, visible laser beams can safely be viewed during adjustment work. The scale number for adjustment eyewear is given the prefix ‘R’.

**Mandatory requirements**
The eyewear must be:

- CE marked;
- marked as providing the necessary level of protection for the assessed maximum exposure at the appropriate wavelength(s);
- held in appropriate receptacles providing clear type identification, protection from dust and scratching and separated according to type of eyewear if more than one specification is available; located near the entrance to the Laser Controlled Area;
- Inspected regularly and replaced or repaired if: the filters are excessively marked or damaged or display an anomalous colouration; the mechanical integrity of the frames is suspect; or elastic tape is used and has become worn.

**Selection of protective eyewear**
When choosing appropriate eyewear each of the following must be considered:

- the wavelength of operation;
- the reasonably foreseeable worst-case effective exposure (beam power or pulse energy, and beam diameter);
- visible light transmission, and the ability to see warning lights or other indicators through the filters;
- general design, comfort, ventilation, peripheral vision, and provision for spectacle correction (either by using goggle-style protectors which fit over normal spectacles, or protective spectacles which incorporate the wearer's own optical correction);
- use of the eyewear, whether for occasional casual use or for working for long periods, perhaps in restricted spaces where the eyewear may be knocked.
Identifying the correct eyewear
Where several types of laser safety eyewear are available for different lasers in the LCA, effective action must be taken to reduce the likelihood of incorrect selection of eyewear occurring. This could include:

- paint a distinctive mark on the eyewear, using a colour code to readily identify the eyewear;
- make it part of the procedures for the DRPS (Lasers) / LSO to ensure that only the eyewear appropriate to the laser(s) in use is available in the area;
- inappropriate eyewear for the work in laser progress is locked away.

Hygiene
If the eyewear is to be worn by more than one person, then an antiseptic spray and/or medical wipes, lens cleaner and tissues should be provided in the vicinity of where the eyewear is stored. In addition, the use of anti-fogging sprays and basic lens cleaning fluids should be considered.
The checklist below aims to help identify shortcomings in laser safety and areas of deviation from these Local Rules that need to be addressed in the risk assessment for laser safety management. It can also be used during routine inspections of laser areas.

Name: ................................................. Dept. & Section: .................................................
Building and Room No: ................................................. Ext. No: .................................................
Building and room(s) to which this assessment applies: .................................................

1. Do all the laser sources have the appropriate classification and warning label(s)?
   Points to consider:
   a) Laser products need to bear signs conforming to BS EN 60825-1 and
   b) If commercial laser products have been modified their classification should be checked.

   Yes  No

2. Is the use of optical viewing permitted within the laser area?
   If YES, please summarise the precautions taken to preventing hazardous levels of laser exposure. State if Class 1M and 2M lasers are in use.

   Yes  No

3. Are dazzle-susceptible activities (e.g. vehicle driving, working at heights) permitted within in the laser area?
   If YES, please summarise the precautions taken to control these activities and/or visible laser beams. (If no visible-beam lasers, state ‘None’)

   Yes  No

4. Are there normally Class 3B and Class 4 open beam paths in the laser area?
   If YES, please indicate which of the following control measures below are in place:
   
   a. All beam paths are enclosed as much as is reasonably practicable.
      Yes  No  N/A
   b. All beam path components that generate errant beams are locally enclosed.
      Yes  No  N/A
   c. All beam paths are properly terminated.
      Yes  No  N/A
   d. All unprotected open horizontal laser beams lie above or below normal eye level.
      Yes  No  N/A
   e. All lasers and optical components on the beam line are securely mounted.
      Yes  No  N/A
   f. Shiny surfaces (including jewellery) are not permitted around laser beam paths.
      Yes  No  N/A
   g. Laser beam paths do not cross walkways.
      Yes  No  N/A
   h. All upwardly directed beams are shielded to prevent human exposure.
      Yes  No  N/A
   i. Laser sources and beam paths are kept under the control of competent persons
      Yes  No  N/A
   j. Information of the current laser hazard is clearly displayed at each and every point of access to the laser area.
      Yes  No  N/A
   k. Low level lighting is provided for ‘lights-out’ operations
      Yes  No  N/A
   l. Persons at risk of exposure to the laser radiation have received adequate laser safety training and instruction.
      Yes  No  N/A
   m. A safe method of beam alignment is provided.
      Yes  No  N/A
   n. A visible or audible warning of the potential laser hazard is provided.
      Yes  No  N/A
   o. Unauthorised persons are prevented from gaining access to the laser area.
      Yes  No  N/A
   p. Precautions are in place to safeguard visitors entering the laser area.
      Yes  No  N/A
   q. Multiple wavelengths.
      Yes  No  N/A
   r. Laser safety eyewear is provided.
      Yes  No  N/A

If NO to any of the above, please summarise precautions that are taken to control these activities:
## Appendix 1
### Laser Safety Checklist

<table>
<thead>
<tr>
<th>5 Do all 3B and 4 laser operations take place within a Designated Laser Area?</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>If YES, please indicate which of the following control measures below are in place:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. The LCA presents a robust physical boundary that isolates laser radiation from personnel outside the area.</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>b. The LCA boundary (including windows) is opaque at the laser wavelengths and without gaps.</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>c. Points of entry from hazard-free to laser hazard areas within the LCA (e.g. a door or opening from a room for changing or data collection) carry current laser hazard information.</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>d. All hazards are clearly identified at all access points to the LCA.</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>e. Where different laser wavelengths are accessible in the LCA at different times accurate status information is displayed at all access points.</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>f. The laser hazard cannot extend beyond the LCA if a door into the LCA is opened.</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>g. The laser hazard is automatically terminated if an unauthorised person enters the DLA.</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>h. The laser hazards from separate laser experiments within the LCA are isolated and information of the current laser hazard within a sub-divided area is clearly displayed at points of access.</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>i. Independent non-laser activities are prohibited within the LCA.</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>j. Prior warning is provided if laser hazards are introduced from outside the LCA.</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>k. Laser beams entering the LCA from other (adjacent) areas are under sole and overriding control from within the LCA.</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>l. Temporary restrictions are imposed for servicing and other non-routine activities within the LCA.</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>If NO to any of the above, please summarise precautions taken to control these activities:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>6 Is laser safety eyewear provided?</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>If YES, please identify which of the following control measures below are in place:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Laser safety eyewear provides sufficient protection for each accessible hazardous laser wavelength (including wavelengths that could be generated by non-linear effects)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>b. Laser eyewear is properly stored and maintained in good condition.</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>c. The eyewear clearly identifies the laser/area within the LCA it is suitable for.</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>d. Lighting levels are appropriate for the visual transmission of the eyewear.</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>e. The colours of warning signs and lights are effective when viewed through the eyewear.</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>If NO to any of the above, please provide a brief justification:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>7 Are there non-beam hazards associated with laser use (including during servicing and maintenance)?</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>If YES, are control measures in place to address the following hazards:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Fire hazard (with Class 4 laser beams).</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>b. Laser generated fume hazard.</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>c. Electrical hazards.</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>d. Explosion hazard.</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>e. Secondary and collateral radiation.</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>f. High-pressure gas hazard.</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>g. Trip hazards and sharp corners at head height.</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>h. Other non-beam hazards:</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
Appendix 14
Definitions of Technical Laser and other NIR Terms

Absorb: To transform radiant energy into a different form, with a resultant rise in temperature.
Absorption: Transformation of radiant energy to a different form of energy by the interaction of matter, depending on temperature and wavelength. The reduction in amplitude for a beam of radiation incident in the medium through which it is propagated.
Access Panel: A part of the protective housing or enclosure which provides access to laser radiation when removed or displaced.
Accessible Emission Limit (AEL): The maximum accessible emission level permitted within a particular laser class. It is generally expressed as the total power or pulse energy output of the laser.
Action Value: The Action Value is the frequency-dependent EMF field strength above which formal consideration through risk assessment and EMF surveying must be given to the health and safety of staff and others exposed to EMFs. The frequency-dependent Action Values are established at field strengths equivalent to half the approved power for general public exposure (equivalent to 71% of the field strength).
Active Medium: The material which acts as the light amplifier in a laser. It is typically excited by optical, chemical or electrical means.
Administrative Controls: Safety measures of a non-engineering type such as: key control safety training and warning notices.
AEL: The maximum accessible emission level permitted within a particular laser class.
Aiming Beam: A laser (or other light source) used as a guide light. Used coaxially with infrared or other invisible light may also be a reduced level of the actual laser used for surgery or for other applications.
Alignment aids: Alignment aids should be used whenever routine maintenance requires the alignment of beam path components.
Amplification: The growth of the radiation field in the laser resonator cavity. As the light wave bounces back and forth between the cavity mirrors, it is amplified by stimulated emission on each pass through the active medium.
Amplitude: The maximum value of the electromagnetic wave, measured from the mean to the extreme; simply stated: the height of the wave.
Analogue meter: Displays the power measured as a continuously varying function of the input to the detector.
Angular subtense (α): The visual angle subtended by the apparent source (including diffuse reflections) at the eye of the observer or at the point of measurement.
Aperture: Any opening in a protective housing or other enclosure of a laser product through which laser radiation is emitted.
Aperture stop: An aperture stop is an opening serving to define the area over which radiation is measured.
Apparent source: The real or virtual object that forms the smallest possible retinal image. The concept of an apparent source is used in the extended wavelength region of 302.5nm to 4000nm since focussing by conventional lenses might be possible in this region.
AR Coatings: Antireflection coatings used on optical components to suppress unwanted reflections.
Argon: A gas used as a laser medium. It emits blue/green light primarily at 448 and 515 nm.
Attenuation: The decrease in energy (or power) as a beam passes through an absorbing or scattering medium.
Atom: The smallest part of an element that can take part in a reaction. An atom consists of electrons orbiting a nucleus.
Audit: A systematic critical examination carried out by suitable qualified people to verify that appropriate standards are being set and met.
Autocollimator: A single instrument combining the functions of a telescope and a collimator to detect small angular displacements of a mirror by means of its own collimated light.
Automatic Power Reduction: A feature of an optical fibre communication system by which the accessible power is reduced to a specified level within a specified time, whenever there is an event which could result in human exposure to radiation, e.g. a fibre cable break.
Average Power: The total energy imparted during exposure divided by the exposure duration.
Aversion Response: Movement of the eyelid or the head to avoid an exposure to a noxious stimulant, bright light. It can occur within 0.25 seconds, and it includes the blink reflex time.
Axial-Flow Laser: A laser in which an axial flow of gas is maintained through the tube to replace those gas molecules depleted by the electrical discharge used to excite the gas molecules to the lasing.
Axicon Lens: A conical lens which, when followed by a conventional lens, can focus laser light to a ring shape.
Appendix 14
Definitions of Technical Laser and other NIR Terms

Axis, Optical Axis: The optical centreline for a lens system; the line passing through the centres of curvature of the optical surfaces of a lens.

Beam: A collection of rays that may be parallel, convergent, or divergent.

Beam attenuator: A device to be introduced into the path of a beam which reduces the laser radiation to below a specified level.

Beam Bender: A hardware assembly containing an optical device, such as a mirror, capable of changing the direction of a laser beam; used to repoint the beam, and in "folded," compact laser systems.

Beam divergence: The measure of increasing beam diameter, expressed as a linear angle, with distance of propagation. For beams with non-circular symmetry, beam divergence values in orthogonal planes may be specified.

Beam Expander: A combination of optical elements which will increase the diameter of a laser beam while decreasing beam divergence (spread).

Beam path component: An optical component which lies on a defined beam path such as a beam steering mirror or a focusing lens.

Beam Splitter: An optical device using controlled reflection to produce two beams from a single incident beam.

Beam stop: Any device which terminates a laser beam path.

Brightness: The visual sensation of the luminous intensity of a light source. The brightness of a laser beam is most closely associated with the radiometric concept of radiance.

Cavity: The optical assembly of a laser usually containing two or more highly reflecting mirrors which reflect radiation back into the active medium of the laser.

CEN: Comité Européen de Normalisation (European Committee for Standardisation).

Class 1 Laser products: Laser products that are normally safe under reasonably foreseeable conditions or use, either because the output of the laser source is sufficiently low, or by virtue of their engineering design e.g. total enclosure of the laser output.

Class 1M laser products: Laser products that exceed the permitted accessible emission limits for Class 1 but which are safe for viewing with the unaided eye. This situation can arise under one of two conditions:

Class 1M (high divergence beam): The output laser beam has a high divergence; unaided viewing is safe at normal distances of accommodation but harmful levels of exposure can occur under close viewing with an eye loupe or magnifier.

Class 1M (collimated beam): The output laser beam is reasonably collimated and has a large diameter, such that harmful exposure can occur under distant viewing with a telescope or binoculars.

Class 2 laser products: Laser products emitting low levels of visible radiation (i.e. in the wavelength range 0.4 to 0.7 μm) that are safe by virtue of the natural aversion response to bright light.

Class 2M laser products: Laser products emitting levels of visible radiation (i.e. in the wavelength range 0.4 to 0.7 μm) that exceed the permitted accessible emission limits for Class 2 but which are safe for viewing with the unaided eye by virtue of the natural aversion response to bright light. This situation can arise under one of two conditions:

Class 2M (high divergence beam): The output laser beam has a high divergence; unaided viewing is safe at normal distances of accommodation but harmful levels of exposure can occur under close viewing with an eye loupe or magnifier.

Class 2M (collimated beam): The output laser beam is reasonably collimated and has a large diameter, such that harmful exposure can occur under distant viewing with a telescope or binoculars.

Class 3B laser products: Medium power laser products for which direct ocular exposure is unsafe, but under certain conditions they may be safely viewed via a diffuse reflector. In general these safe conditions are: i) a minimum viewing distance of 130 mm and ii) a maximum viewing time of 10 seconds. These lasers may present a skin hazard.

Class 3R laser products: Laser products for which intra-beam viewing is potentially hazardous but the risk is low. For visible radiation (i.e. in the wavelength range 0.4 to 0.7 μm) the level of accessible emission can exceed the AEL for Class 2 by up to five times; for other wavelengths the level of accessible emission can exceed the AEL for Class 1 by up to five times.

Class 4 laser products: High-power laser products. In addition to the hazard from intra-beam viewing or specular reflections, they are capable of producing hazardous diffuse reflections, may cause skin injuries and could also present a fire hazard. Their use requires extreme caution.

CO₂ Laser: A widely used laser in which the primary lasing medium is carbon dioxide gas. The output wavelength is 10.6 micrometers in the far infrared spectrum. It can be operated in either CW or pulsed.

Coaxial Gas: A shield of inert gas flowing over the target material to prevent plasma oxidation and absorption, blow away debris, and control heat reaction. The gas jet has the same axis as the beam, so the two can be aimed together.
Appendix 14
Definitions of Technical Laser and other NIR Terms

Coherence: Phenomenon in which light waves are “in-step” in both time and space. Correlation (constant phase angle) between the electric field of light at any point in space. Monochromaticity and low divergence are two properties of coherent light.

Collateral Radiation: Any electromagnetic radiation within the wavelength range of between 180 nm and 1 mm, except laser radiation, emitted by a laser product as a result of, or physically necessary for, the operation of the laser.

Collimated Light: Light rays that are parallel. Collimated light is emitted by many lasers. Diverging light may be collimated by a lens or other device.

Collimation: Ability of the laser beam to not spread significantly (low divergence) with distance.

Combiner Mirror: The mirror in a laser which combines two or more wavelengths into a coaxial beam.

Complementary colour: Two pure spectral colours which when mixed produce white light.

Collimated beam: A “parallel” beam of light with a very small angular divergence or convergence. Beam cross-section remains quasi-constant with distance from the source.

Continuous Mode: The duration of laser exposure is controlled by the user (by foot or hand switch).

Continuous Wave (CW): An uninterrupted laser radiation output. The output of a laser which is operated in a continuous manner rather than pulsed mode – i.e. a laser operating with a continuous output period equal to or greater than 0.25 s.

Controlled Area: An area where the activity of those within are subject to control and supervision for the purpose of laser radiation hazard protection.

Convergence: The bending of light rays toward each other, as by a positive (convex) lens.

Corrected Lens: A compound lens that is made measurably free of aberrations through the careful selection of its dimensions and materials.

Cryogenic: Pertaining to very low temperatures.

Crystal: A solid with a regular array of atoms. Sapphire (Ruby Laser) and YAG (Nd:YAG laser) are two crystalline materials used as laser sources.

Current Saturation: The maximum flow of electric current in a conductor; in a laser, the point at which further electrical input will not increase laser output.

Damage threshold: The minimum power or energy density, which if incident on a surface will result in damage.

Defined beam path: An intended path of a laser beam within a laser product.

Degradation Products: The material ejected during material processing as a result of radiation/material interaction causing breakdown.

Delivery System: The optical system that takes laser radiation from the laser output and delivers it to the point where it can interact, e.g. optical fibres, flight tubes.

Depth of Field: The working range of the beam in or near the focal plane of a lens; a function of wavelength, diameter of the unfocused beam, and focal length of the lens.

Depth of Focus: The distance over which the focused laser spot has a constant diameter and thus constant irradiance.

Designated Laser Area (DLA): A room or other enclosed working area designed to contain lasers, such that there is no laser radiation hazard beyond the defined boundary of the area.

Dichroic Filter: Filter that allows selective transmission of colors desired wavelengths.

Diffraction: Deviation of part of a beam, determined by the wave nature of radiation and occurring when the radiation passes the edge of an opaque obstacle.

Diffuse reflection: A diffuse reflection destroys the collimated nature of the beam and occurs when the beam is incident on a non-mirror like surface which is not totally absorbent. The scattering of laser radiation from a rough surface.

Diffuser: An optical device or material that homogenises the output of light causing a very smooth, scattered, even distribution over the area affected. The intensity will obey Lambert’s law.

Digital meter: Displays the power measured as numbers composed of digits.

Divergence: The increase in the diameter of the laser beam with distance from the exit aperture.

Divergent beam: A beam whose cross-section increases with distance from the source.

Drift: All undesirable variations in output (either amplitude or frequency).

Electric Vector: The electric field associated with a light wave which has both direction and amplitude.

Electromagnetic Radiation: Energy produced by vibrating electric and magnetic fields through space at the velocity of light. Electromagnetic radiation can be thought of as waves or streams of photons.

Electromagnetic Spectrum: The range of frequencies and wavelengths over which electromagnetic radiations are propagated. The spectrum ranges from short wavelengths such as gamma rays, x-rays, through visible radiation to longer wavelength radiations of microwaves, television and radiowaves.
Appendix 14

Definitions of Technical Laser and other NIR Terms

**Embedded Laser Product:** A product, which because of engineering features, limits the accessible emissions and has been assigned a class number lower than the inherent capability of the laser incorporated.

**Emergent Beam Diameter:** Diameter of the laser beam at the exit aperture of the system in centimeters (cm).

**Emission:** Act of giving off radiant energy by an atom or molecule.

**Emission duration:** The temporal duration of a pulse, of a train or series of pulses, or of continuous operation, during which human access to laser radiation could occur as a result of operation, maintenance or servicing of a laser product.

**Emission warning device:** Any warning device that gives an audible or visible warning that a laser system is switched on or capacitor banks of a pulsed laser are charged or have been positively discharged.

**Enclosed Laser Device:** System in which, during normal operation, the optical radiation is totally enclosed, e.g. by light proof cabinets, components, total internal reflection or optical fibre cables and connectors.

**End user:** The person/organisation using the optical fibre communication system in the manner the system was designed to be used. The user cannot necessarily control power generated and transmitted within the system.

**Energy:** The product of power (watts) and duration (seconds). One watt second = one Joule.

**Energy Source:** High voltage electricity, radiowaves, flashes of light, or another laser used to excite the laser medium.

**Engineering Control:** Safety measures of a deliberate engineering design which should be used as the fundamental method of reducing exposure to radiation. A physical means of preventing access to radiation.

**Enhanced Pulsing:** Electronic modulation of a laser beam to produce high peak power at the initial stage of the pulse. This allows rapid vaporisation of the material without heating the surrounding area. Such pulses are many times the peak power of the CW mode.

**Errant laser radiation:** Laser radiation which deviates from the beam path. Examples include unwanted secondary reflections from beam path components, deviant radiation from misaligned or damaged components and reflections from a work piece.

**Excimer:** An excited dimer. A system of two similar atoms which, in their excited states, join together and form a molecule in an excited state.

**Excited State:** Atom with an electron in a higher energy level than it normally occupies.

**Extended Nominal Ocular Hazard Distance (ENOHD):** The shortest distance (generally measured from the position of the laser source) at and beyond which a laser beam is safe for aided viewing.

**Extended Source:** A source is considered as extended source when the apparent source subtends a linear angle α greater than α_min (unlike most laser sources). Extended source viewing conditions occur when laser radiation is reflected from a diffusing surface, the image formed by the reflected radiation on the retina of the eye exposed (apparent source) is larger than a certain minimum value.

**Fail Safe:** A failsafe component is one whereby its failure does not increase the likelihood or severity of exposure to the hazard ie it fails in a safe condition. In the failure mode the system is rendered inoperative or non-hazardous.

**Femtoseconds:** $10^{-15}$ seconds. 1 fs = 0.000,000,000,000,001 seconds

**Fibre Optics:** A system of flexible quartz or glass fibres that use total internal reflection (TIR) to pass light through thousands of glancing (total internal) reflections.

**Flashlamp:** A tube typically filled with krypton or xenon. Produces a high intensity white light in short duration pulses.

**Fluorescence:** The emission of light of a particular wavelength resulting from absorption of energy typically from light of shorter wavelengths.

**Flux:** The radiant, or luminous, power of a light beam; the time rate of the flow of radiant energy across a given surface.

**Focal Length:** Distance between the centre of a lens and the point on the optical axis to which parallel rays of light are converged by the laser.

**Focal Point:** That distance from the focusing lens where the laser beam has the smallest diameter.

**Focus:** As a noun, the point where rays of light meet which have been reflected by a mirror or refracted by a lens, giving rise to an image of the source. As a verb, to adjust focal length for the clearest image and smallest spot size.

**Frequency:** The number of light waves (or cycles) passing a fixed point in a given unit of time, or the number of complete vibrations in that period of time. Symbol: f Unit: Hz

**Fumes:** The airborne emission of the material breakdown during radiation / material processing or interaction.

**Gain:** Another term for amplification.
Gas Discharge Laser: A laser containing a gaseous lasing medium in a glass tube in which a constant flow of gas replenishes the molecules depleted by the electricity or chemicals used for excitation.

Gas Laser: A type of laser in which the laser action takes place in a gas medium.

Gated Pulse: A discontinuous burst of laser light, made by timing (gating) a continuous wave output - usually in fractions of a second.

Gaussian Curve: Statistical curve showing a peak with normal even distribution on either side. May either be a sharp peak with steep sides, or a blunt peak with shallower sides. Used to show power distribution in a beam. The concept is important in controlling the geometry of the laser impact.

Giant pulsed: Pulsed lasers having pulse duration < $10^{9}$ seconds.

Ground State: Lowest energy level of an atom.

Half-Power Point: The value on either the leading or trailing edge of a laser pulse at which the power is one-half of its maximum value.

Hazard: Something with the potential to cause harm. The hazard can be to people, property or the environment.

Hazard Level: The potential hazard at any accessible location within an optical fibre communication system. It is based on the level of optical radiation which could become accessible in reasonable foreseeable circumstances, e.g. a fibre cable break. It is closely related to the laser classification procedure in BS EN 60825-1.

Heat Sink: A substance or device used to dissipate or absorb unwanted heat energy.

Helium-Neon Laser (HeNe): A laser in which the active medium is a mixture of helium and neon. Its wavelength is usually in the visible range. Used widely for alignment, recording, printing, and measuring.

Hertz (Hz): Unit of frequency in the International System of Units (SI), abbreviated Hz; replaces cps for cycles per second.

Human access: The ability for any part of the human body to be exposed to hazardous laser radiation as emitted by an aperture or access gained by probe (given limits and definitions). Within a protective housing human access can often be gained from reflecting surfaces inside the product or through openings in the protective housing.

Image: The optical reproduction of an object, produced by a lens or mirror. A typical positive lens converges rays to form a "real" image which can be photographed. A negative lens spreads rays to form a "virtual" image which can't be projected.

Incident Light: A ray of light that falls on the surface of a lens or any other object. The "angle of incidence" is the angle made by the ray with a perpendicular (normal) to the surface.

Infrared Radiation (IR): Invisible electromagnetic radiation with wavelengths which lie within the range of 0.70 to 1000 micrometres. This region is often broken up into IR-A, IR-B, and IR-C.

Integrated Radiance: Product of the exposure duration times the radiance. Also known as pulsed radiance.

Interlock: A mechanical or electrical device to prevent the hazardous operation of a system.

Intensity: The magnitude of radiant energy.

Intrabeam Viewing: The viewing (and measurement) conditions whereby the eye is exposed to all or part of a direct laser beam or a specular reflection. Examples are viewing of collimated beams and of point-type sources.

Intrinsically safe: Safe by virtue of its intrinsically low emission of laser radiation. This contrasts with the emission from a Class 1 Embedded Laser Product which is safe by engineering design.

Ion Laser: A type of laser employing a very high discharge current, passing down a small bore to ionise a noble gas such as argon or krypton.

Ionising Radiation: Radiation of sufficient energy to cause ionisation (produce ions) of substances through which it passes, e.g. gamma radiation and x-rays.

IR: Infrared (IR) region of the spectrum comprising wavelengths in the range 700nm to $10^{6}$nm.

Irradiance: The power of a laser averaged over the area of the beam. W m$^{-2}$

Irradiation: Exposure to radiant energy, such as heat, X rays, or light.

Joule (J): A unit of energy (1 watt-second) used to describe the rate of energy delivery. It is equal to 1 watt-second or 0.239 calorie.

Joule/cm$^{2}$: A unit of radiant exposure used in measuring the amount of energy incident upon a unit area.

Key control: Class 3B and Class 4 laser products should be key operated such that they can be protected against unauthorised use. A key can be other control devices such as magnetic cards, etc.

KTP (Potassium Titanyl Phosphate): A crystal used to change the wavelength of an Nd:YAG laser from 1060 nm (infrared) to 532 nm (green).

Lambertian Surface: An ideal diffuse surface whose emitted or reflected radiance (brightness) is dependent on the viewing angle.
Appendix 14
Definitions of Technical Laser and other NIR Terms

**Laser:** An acronym for light amplification by stimulated emission of radiation. A laser is a cavity, with mirrors at the ends, filled with material such as crystal, glass, liquid, gas or dye. A device which produces an intense beam of light with the unique properties of coherence, collimation and monochromaticity.

**Laser Accessories:** The hardware and options available for lasers, such as secondary gases, Brewster windows, Q-switches, and electronic shutters.

**Laser Associated Hazard:** Hazards arising directly from the operation or installation of the laser or laser system alone.

**Laser Controlled Area (LCA):** An area where the activity of those within are subject to control and supervision for the purpose of laser radiation hazard protection.

**Laser Device:** Either a laser or a laser system.

**Laser Hazard Zone:** The region around the laser and laser beam path within which, under all reasonably foreseeable conditions, a hazardous level of laser radiation may be present.

**Laser Medium (Active Medium):** Material used to emit the laser light and for which the laser is named.

**Laser Oscillation:** The buildup of the coherent wave between laser cavity end mirrors producing standing waves.

**Laser Product:** Any product or assembly of components which constitutes, incorporates or is intended to incorporate a laser or laser system, and which is not sold to another manufacturer for use as a component (or replacement for such component) of an electronic product.

**Laser Protection Adviser (LPA):** A person who gives advice to the employer on laser safety and is generally considered to be an expert. In many situations the LPA will be an external consultant.

**Laser Rod:** A solid-state, rod-shaped lasing medium in which ion excitation is caused by a source of intense light, such as a flashlamp. Various materials are used for the rod, the earliest of which was synthetic ruby crystal.

**Laser Safety Officer (LSO) / Departmental Radiation Protection Supervisor (Lasers):** A person who is knowledgeable in the evaluation and control of laser hazards and has responsibility for the oversight of such.

**Laser System:** A laser in combination with an appropriate laser energy source with or without additional incorporated components.

**Lens:** A curved piece of optically transparent material which depending on its shape is used to either converge or diverge light.

**Light:** The range of electromagnetic radiation frequencies detected by the human eye, or the wavelength range from about 400 to 700 nm (far 'red' to far'violet'). The term is sometimes used loosely to include radiation beyond visible limits.

**Light Emitting Diode (LED):** Any semiconductor junction device which is designed to produce electromagnetic radiation by radiative recombination in a semiconductor in the wavelength region from 180 nm to 1 mm. Radiation is produced primarily by the process of spontaneous emission, although some stimulated emission may be present.

**Light Regulation:** A form of power regulation in which output power is monitored and maintained at a constant level by controlling discharge current.

**Likelihood:** The probability or chance that a hazard will occur.

**Limiting Aperture:** The maximum circular area over which radiance and radiant exposure can be averaged when determining safety hazards.

**Limiting Exposure Duration:** An exposure duration which is specifically limited by the design or intended use(s).

**Limit Value:** The Limit Value is the frequency-dependent EMF field strength above which staff and others should not be exposed. Staff and others exposed to EMFs above this level should be medically assessed by Occupational Health.

**Longitudinal or Axial Mode:** Determines the wavelength bandwidth produced by a given laser system controlled by the distance between the two mirrors of the laser cavity. Individual longitudinal modes are produced by standing waves within a laser cavity.

**Lossy Medium:** A medium which absorbs or scatters radiation passing through it.

**Luminous transmittance / Visible light transmittance (VLT):** The amount of white light transmitted by the filter. Expressed as a percentage.

**Maintenance:** Performance of those adjustments or procedures specified in user information provided by the manufacturer with the laser or laser system, which are to be performed by the user to ensure the intended performance of the product. It does not include operation or service as defined in this glossary.

**Manufacturer:** An organisation or individual who assembles optical devices and other components in order to construct or modify an optical fibre communication system.
Maximum Permissible Exposure (MPE): The level of laser radiation to which a person may be exposed without hazardous effects or adverse biological changes in the eye or skin.

Meniscus Lens: A lens which has one side convex, the other concave.

Metastable State: The state of an atom, just below a higher excited state, which an electron occupies momentarily before destabilising and emitting light. The upper of the two lasing levels.

Micrometre: A unit of length in the International System of Units (SI) equal to one millionth of a metre.

Microsecond: $10^{-6}$ second (1μs, one-millionth of a second).

Millisecond: $10^{-3}$ second (1ms, one-thousandth of a second).

Minimum angular subtense ($\alpha_{\text{min}}$): The value of the angular subtense of the apparent source above which a source is considered an extended source. MPEs and AELs are independent of the source size for angular subtenses less than $\alpha_{\text{min}} = 1.5$ mrad.

Mode: A term used to describe how the power of a laser beam is geometrically distributed across the cross section of the beam. Also used to describe the operating mode of a laser such as continuous or pulsed.

Mode Locked: A method of producing laser pulses in which short pulses are produced and emitted in bursts or a continuous train.

Modulation: The ability to superimpose an external signal on the output beam of the laser as a control.

Monochromatic Light: Theoretically, referring to light comprising of just one colour and or wavelength. (No light is absolutely single frequency since it will have some bandwidth, although lasers provide the narrowest of bandwidths to achieve this).

Multimode: Laser emission at several closely spaced frequencies.

Nanometre (nm): A unit of length in the International System of Units (SI) equal to one billionth of a metre. Abbreviated nm - a measure of length. One nm equals $10^{-9}$ metre, and is the usual measure of light wavelengths. Visible light ranges from about 400 nm in the purple to about 760 nm in the deep red.

Nanosecond: One billionth ($10^{-9}$) of a second. Longer than a picosecond or femtosecond, but shorter than a microsecond. Associated with Q-switched lasers.

Nd:Glass Laser: A solid-state laser of neodymium: glass offering high power in short pulses. A Nd doped glass rod used as a laser medium to produce 1064 nm light.

Nd:YAG Laser: Neodymium:Yttrium Aluminum Garnet. A synthetic crystal used as a laser medium to produce 1064 nm light.

Near Field Imaging: A solid-state laser imaging technique offering control of spot size and hole geometry, adjustable working distance, uniform energy distribution, and a wide range of spot sizes.

Neodymium (Nd): The rare earth element that is the active element in Nd:YAG lasers and Nd:Glass lasers.

Noise: Unwanted minor currents or voltages in an electrical system.

Nominal Ocular Hazard Distance (NOHD): The distance at which the beam irradiance equals the appropriate MPE value. An indication of a ‘safe viewing’ distance for certain criteria. An equivalent term for skin exposure is ‘Hazard Distance’.

Non-Ionising Radiation (NIR): Radiation that does not possess sufficient energy to cause ionisation in biological materials.

Object: The subject matter or figure imaged by, or seen through, an optical system.

Opacity: The condition of being non-transparent.

Open Installation: Any location where lasers are used which will be open to operating personnel during laser operation and may or may not specifically restrict entry to observers.

Operation: The performance of the laser or laser system over the full range of its intended functions (normal operation). It does not include maintenance or services as defined in this glossary.

Optic Disc: The portion of the optic nerve within the eye which is formed by the meeting of all the retinal nerve fibres at the level of the retina.

Optical Cavity (Resonator): Space between the laser mirrors where lasing action occurs.

Optical Density (OD): A logarithmic expression (numerical value) for the attenuation produced by an attenuating medium, such as an eye protection filter. It is dependent on laser wavelength, transmittance of the filter and filter thickness.

Optical Fibre: A filament of quartz or other optical material capable of transmitting light along its length by multiple internal reflection and emitting it at the end.

Optical Fibre Communication System: An engineered assembly for the generation, transference and reception of optical radiation arising from lasers in which the transference is by means of optical fibre for communication and / or control purposes.

Optical Gain: The optical amplification of radiation due to the focussing properties of the eye or other photodetector.
Optical Pumping: The excitation of the lasing medium by the application of light rather than electrical discharge.

Optical Radiation: Part of the electromagnetic spectrum comprising, ultraviolet, visible and infrared radiation (0.35-1.4 nm) that falls in the region of transmittance of the human eye.

Optically Pumped Lasers: A type of laser that derives energy from another light source such as a xenon or krypton flashlamp or other laser source.

Outcome: The result of a hazard being realised. Can also be known as consequence or harm and can range from financial loss, damage, injury or even death.

Output Coupler: Partially reflective mirror in laser cavity which allows emission of laser light.

Output Power: The energy per second measured in watts emitted from the laser in the form of coherent light.

Period: The time for one complete oscillation, wave motion or other regularly repeated process. Symbol: T It is the reciprocal of frequency.

Personal Protective Equipment (PPE): Safety equipment designed to protect the person from non-ionising radiation and other hazards such as gloves, goggles, ear defenders. Necessary when other methods (engineering controls, administrative controls) are not adequate.

Phase: Waves are in phase with each other when all the troughs and peaks coincide and are "locked" together. The result is a reinforced wave in increased amplitude (brightness).

Photocoagulation: Use of the laser beam to heat tissue below vaporisation temperatures with the principal objective being to stop bleeding and coagulate tissue.

Photometer: An instrument which measures luminous intensity.

Photometry: Measurement of the properties of visible radiation, e.g. intensity. Applies only to the region capable of invoking vision in the human eye (approx. 400 to 700nm).

Photon: In quantum theory, the elemental unit of light, having both wave and particle behaviour. It has motion, but no mass or charge. The photon energy (E) is proportional to the EM wave frequency (ν) by the relationship: E=hf; where h is Planck's constant (6.63 x 10^-34 Joule-sec).

Photosensitisers: Chemical substances or medications which increase the sensitivity of the skin or eye to irradiation by optical radiation, usually to UV.

Picosecond: A period of time equal to 10^-12 seconds.

Pigment Epithelium: A layer of cells at the back of the retina containing pigment granules, i.e., a cloud of charged particles surrounding a laser impact.

Plasma Shield: The ability of plasma to stop transmission of laser light.

Pockel's Cell: An electro-optical device used to rotate the plane of polarisation of light by applying an electric field or pulse. Used inside a laser cavity to Q-switch or mode lock to produce a pulsed output.

Point Source: Ideally, a source with infinitesimal dimensions. Practically, a source of radiation whose dimensions are small compared with the viewing distance.

Pointing Errors: Beam movement and divergence, due to instability within the laser or other optical distortion.

Polarisation: The direction of vibration of an electromagnetic wave in the laser beam. Various forms of polarisation include random, linear, vertical, horizontal, elliptical, and circular.

Population Inversion: A state in which a substance has been energised, or excited, so that more atoms or molecules are in a higher excited state than in a lower resting state. This is a necessary prerequisite for laser action and is usually achieved by rapidly supplying energy to the active medium.

Power: The rate of energy delivery expressed in watts (joules per second). Thus: 1 Watt = 1 Joule/1 Sec.

Power Meter: An accessory used to measure laser beam power.

Process Associated Hazard: Hazards arising as a consequence of the particular use or application of a laser or laser product.

Protective enclosure: A physical means for preventing human exposure to laser radiation unless such access is necessary for the intended functions on the installation.

Protective Housing: Those portions of a laser product (including a product incorporating an embedded laser) which are designed to prevent human access to laser radiation in excess of the prescribed AEL (generally installed by a manufacturer).

Pulse: A discontinuous burst of laser, light or energy, as opposed to a continuous beam. A true pulse achieves higher peak powers than that attainable in a CW output.

Pulse duration: The "on" time of a pulsed laser. It may be measured in terms of millisecond, microsecond, or nanosecond as defined by half-peak-power points on the leading and trailing edges of the pulse.

Pulse Mode: Operation of a laser when the beam is intermittently on in fractions of a second.

Pulse Repetition Frequency (PRF): The number of pulses produced per second by a laser.

Pulsed Laser: Laser which delivers energy in the form of a single or train of pulses. Under BS EN 60825-1, the duration of a pulse is less than 0.25s.
Appendix 14

Definitions of Technical Laser and other NIR Terms

**Pump:** To excite the lasing medium.

**Pumping:** Addition of energy (thermal, electrical, or optical) into the atomic population of the laser medium, necessary to produce a state of population inversion.

**Q-Switch:** The laser process in which lasing action is prevented whilst the population inversion increases. The increased energy level is then rapidly released to produce an enhanced energy in a very short pulse.

**Q-Switched Laser:** A laser which stores energy in the laser media to produce extremely short, extremely high intensity bursts of energy.

**Quantum detector (Photodetector):** Detects radiation incident upon it via an element sensitive to the number of photons incident upon it. Examples of photodetectors are photodiodes and photomultiplier tubes.

**Radian:** A unit of angular measure equal to the angle subtended at the center of a circle by a chord whose length is equal to the radius of the circle.

**Radiance Brightness:** The radiant power per unit solid angle and per unit area of a radiating surface.

**Radiant Energy (Q):** Energy in the form of electromagnetic waves usually expressed in units of Joules (watt-seconds).

**Radiant exposure:** Total energy of radiation incident on a surface per unit area (J m²).

**Radiant Flux Radiant Power:** The time rate of flow of radiant energy. Units-watts. (One [1] watt = 1 Joule-per-second). The rate of emission of transmission of radiant energy.

**Radiant Intensity:** The radiant power expressed per unit solid angle about the direction of the light.

**Radiation:** The emission of energy from a source, either as waves (light, sound) or as moving particles (beta rays, alpha rays).

**Radiometry:** Measurement of properties of optical radiation (UV, Visible, IR). Concerned with power content of radiation, e.g. radiant power.

**Rayleigh Scattering:** Scattering of radiation in the course of its passage through a medium containing particles, the sizes of which are small compared with the wavelength of the radiation.

**Reasonably Foreseeable Event:** The occurrence of an event which under given circumstances can be predicted fairly accurately, and the occurrence probability or frequency of which is not low or very low. Examples of reasonably foreseeable events include: fibre cable break, optical connector disconnection, operator error or inattention to safe working practices.

**Reflectance Reflectivity:** The ratio of the reflected radiant power to the incident radiant power.

**Reflection:** The process in which radiation meeting a boundary between two media ‘bounces back’ to stay in the first medium with no change in wavelength.

**Refraction:** The ‘bending’ of light as it passes through a medium.

**Remote interlock connector:** A connector which permits the connection of external controls placed apart from other components of the laser product.

**Repetitively Pulsed Laser:** A laser with multiple pulses of radiant energy occurring in sequence with a PRF > 1 Hz.

**Resonator:** The mirrors (or reflectors) making up the laser cavity including the laser rod or tube. The mirrors reflect light back and forth to build up amplification.

**Risk Factor:** The product of the likelihood of a hazard occurring and the outcome or harm that arises as a result.

**Rotating Lens:** A beam delivery lens designed to move in a circle and thus rotate the laser beam around a circle.

**Ruby:** The first laser type; a crystal of sapphire (aluminum oxide) containing trace amounts of chromium oxide.

**Safe System of Work (SSW):** A formal document defining the procedure to carry out an activity safely.

**Safety interlock:** An automatic device associated with the protective housing of a laser product to prevent human access to Class 3B or Class 4 laser radiation when that portion of the housing is removed.

**Scanning laser radiation:** Laser radiation having a time-varying direction, origin or pattern of propagation with respect to a stationary frame of reference.

**Scattering:** The ‘spreading out’ of a beam of radiation as it passes through matter reducing the energy moving in the original direction.

**Scintillation:** This term is used to describe the rapid changes in irradiance levels in a cross section of a laser beam produced by atmospheric turbulence.

**Secured Enclosure:** An enclosure to which casual access is impeded by an appropriate means (e.g., door secured by lock, magnetically or electrically operated, latch, or by screws).

**Semiconductor Laser:** A type of laser which produces its output from semiconductor materials such as GaAs.
Definitions of Technical Laser and other NIR Terms

Service: The performance of those procedures or adjustments described in the manufacturer’s service instructions, which may affect any aspect of the product’s performance. It does not include maintenance or operation.

Service panel: An access panel that is designed to be removed or displaced for service.

Source: The term “source” means either laser or laser-illuminated reflecting surface, i.e., source of light.

Spectral Response: The response of a device or material to monochromatic light as a function of wavelength.

Specular reflection: A reflection which maintains the collimated and point-source characteristics of the source and occurs when the beam is incident on a mirror like surface.

Spontaneous Emission: Decay of an excited atom to a ground or resting state by the random emission of one photon. The decay is determined by the lifetime of the excited state.

Spot Size: The mathematical measurement of the radius of the laser beam.

Stability: The ability of a laser system to resist changes in its operating characteristics. Temperature, electrical, dimensional, and power stability are included.

Stimulated Emission: When an atom, ion, or molecule capable of lasing is excited to a higher energy level by an electric charge or other means, it will spontaneously emit a photon as it decays to the normal ground state. If that photon passes near another atom of the same energy, the second atom will be stimulated to emit a photon.

Superpulse: Electronic pulsing of the laser driving circuit to produce a pulsed output (250-1000 times per second), with peak powers per pulse higher than the maximum attainable in the continuous wave mode. Average powers of superpulse are always lower than the maximum in continuous wave. Process often used on CO₂ surgical lasers.

Thermal Detector: Detects radiation incident upon it via a temperature sensitive element. Examples of thermal detectors are calorimeters and bolometers.

Thermal Relaxation Time: The time to dissipate the heat absorbed during a laser pulse.

Threshold: The input level at which lasing begins during excitation of the laser medium.

Tool: Denotes a screwdriver, a coin or other object which may be used to operate a screw or similar fixing means.

Transducer: A device which converts a non-electrical parameter, eg light, into electrical signals, the variations in the electrical signals being a function of the input parameter.

Transmission: The passage of radiation through a medium. If not all radiation is absorbed, that which passes through is said to be transmitted. Dependent upon wavelength, polarisation, radiation intensity and transmitting material.

Transmittance: The transmittance of a filter is the amount of light that it allows to pass. Expressed as a percentage.

Tuneable Laser: A laser system that can be “tuned” to emit laser light over a continuous range of wavelengths or frequencies.

Tuneable Dye Laser: A laser whose active medium is a liquid dye, pumped by another laser or flashlamps, to produce various colours of light. The colour of light may be tuned by adjusting optical tuning elements and/or changing the dye used.

Ultraviolet (UV) Radiation: Region of the spectrum comprising wavelengths in the range 100 nm to 400 nm. It can be further subdivided into three regions: UV-A (315 -400 nm), UVB (280 -315 nm) and UV-C (100-280 nm).

Vaporisation: Conversion of a solid or liquid into a vapour.

Vignetting: The loss of light through an optical element when the entire bundle of light rays does not pass through; an image or picture that shades off gradually into the background.

Visible Radiation (light): Region of the spectrum extending from approximately 400 to 700nm, that is to say, any optical radiation capable of directly causing a visual sensation in the human eye. The peak of the human spectral response is about 555 nm.

Watt: A unit of power (equivalent to one Joule per second) used to express laser power.

Watt/cm²: A unit of irradiance used in measuring the amount of power per area of absorbing surface, or per area of CW laser beam.

Wave: An sinusoidal undulation or vibration; a form of movement by which all radiant electromagnetic energy travels.

Wavelength: The distance between the ends of one complete cycle of a wave (length of the light wave) measured from crest to crest, which determines its colour. Symbol: λ.

Window: A piece of glass (or other material) with plane parallel sides which admits light into or through an optical system and excludes dirt and moisture.

X-Ray Laser: A device that uses stimulated emission to produce coherent X rays.

X Rays: Streams of X radiation. X radiation is an energetic form of electromagnetic radiation of wavelength range of 10.11 m to 108 m. X radiation is ionising radiation.
YAG (Yttrium Aluminum Garnet): A widely used solid-state crystal which is composed of yttrium and aluminium oxides which is doped with a small amount of the rare-earth neodymium.

Z-Cavity: A term referring to the shape of the optical layout of the tubes and resonator inside a laser.