Science and Technology Facilities Council

Working with Lasers

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Contents

1 Purpose 1
2 Scope 1
3 Legislation and guidance 1
4 Duties and Responsibilities 4
4.1 Directors 4
4.2 Line Managers and Supervisors 4
4.3 Overall Laser Responsible Officers 5
4.4 Laser Responsible Officers 6
4.5 Laser Nominated Persons 8

Appendices

A 1. Beam hazards associated with laser use 10
A 2. Non-beam hazards associated with laser use 13
A 3. Classes of laser 18
A 4. Matters to be considered in an optical radiation specific risk assessment 21
A 5. Exposure Limit Values Directive 2006/25/EC (The UK regulations do not contain numerical values for the limits, but instead refer to the annexes to the Directive) 22
A 6. Summary of control measures for normal laser operation 23
A 7. Laser control measures: normal operation 25
A 8. Laser control measures: additional requirements for specific high risk laser activities 36
A 9. Laser control measures: designated laser areas 44
A 10. Labels and signs HSE Signs and Symbols Regulations Signs and Symbols Regulations 48
A 11. Selection and use of laser safety eyewear 49
A 12. Medical examinations, health surveillance, accident and Incident reporting 50
A 13. Additional guidance on risk assessment for laser use 52
A 14. Laser safety documentation 53
A 15. Laser safety checklist 57
A 16. Definitions 60
A 17. Training 65
A 18. Bibliography of laser safety references 67
A 19. Document retention policy 68

Working with Lasers

1. Purpose

Lasers emit beams of non-ionising radiation at wavelengths spanning the ultraviolet to the far infrared. The skin and eyes are at risk of injury: thermal burns from visible or infrared laser beams or photochemical injuries from ultraviolet and short wavelength visible laser beams.

For lasers in the visible or near infrared part of the spectrum there is a particular risk of injury to the retina of the eye, resulting in permanent visual impairment. The output of lasers, particularly those that are pulsed, can be so high that not only the main beam but also weak reflections and diffusely scattered radiation may be hazardous.

Lasers are flexible research tools that have widespread application across all disciplines. For lasers whose output presents a significant risk of harm, this flexibility and breadth of use combined with continuing evolution (e.g. higher output from physically smaller devices) creates unique challenges to the control of laser hazards.

There is no single solution that is universally applicable to the management of risks associated with high output lasers. The diversity and innovative nature of laser applications in the research environment generally dictates a flexible approach based on detailed risk assessment to establish effective engineering controls supported, as appropriate, by robust administrative arrangements.

As a last resort reliance on laser protective eyewear may be necessary to address residual risks, but should be minimised so far as reasonably practicable.

2. Scope

2.1 This code is applicable to all staff, contractors, users and tenants working with lasers at STFC sites.

2.2 This code applies to all lasers and laser products except those considered to present no risk (see section 4).

2.3 This code deals principally with the beam hazards of using lasers (see Appendix 1); it refers to but does not deal with associated (non-beam) hazards of laser use, including electrical, chemical and secondary radiation hazards. These hazards are described in more detail in Appendix 2, and details of safety precautions relating to these hazards can be found in the relevant SHE safety codes.

3. Legislation and guidance

The STFC is required to comply with the Control of Artificial Optical Radiation at Work Regulations 2010. Control of Artificial Optical Radiation at Work Regulations 2010

3.1 Risk assessment

STFC has a legal duty to make a suitable and sufficient assessment of the risks associated with the work (see SHE Code 6 Risk management). SC06-Risk-management.
However, where the work involves the use of hazardous lasers, the assessment must include an exposure assessment and must address matters specified in the Control of Artificial Optical Radiation at Work Regulations 2010. Further guidance is given in Appendix 4 of this code.

3.2 Risk management

STFC has a duty to ensure that any risks identified in the risk assessment are either eliminated or, where this is not reasonably practicable, reduced to as low a level as is reasonably practicable.

3.3 Exposure limitation

STFC has a duty to ensure that exposures of staff do not exceed the exposure limit values specified in annex II of Directive 2006/25/EC Artificial Optical Radiation 2006/25/EC . These values are legally binding exposure limits.

3.4 Action plan

Where the risk assessment shows that staff are exposed above the exposure limit values, STFC has a duty to implement an action plan to reduce exposures below the limits. Matters that must be taken into account in the action plan are specified in the regulations (reproduced in Appendix 6) and broadly follow the accepted hierarchy of controls.

3.5 Designation of areas

If there are areas where the exposure limit values could be exceeded (i.e. where there are open beams of class 3R, class 3B or class 4) STFC is required to demarcate the area, restrict access and post warning signs.

3.6 Information and training

Where staff are working with potentially hazardous lasers, STFC is required to provide suitable and sufficient information and training.

3.7 Health surveillance and medical examination

Where the risk assessment identifies a risk of adverse health effects to the skin, STFC is required to place those who may be affected under health surveillance. This situation is most likely to arise where there is potential for exposure to scatter from an ultraviolet laser beam. However, for some categories of employee at particular risk, adverse reactions could also be triggered by other wavelengths.

STFC must provide employees with a medical examination:

3.7.1 If they have been exposed in excess of an exposure limit value
3.7.2 If they suffer an identifiable adverse health effect to the skin that could be attributed to exposure.
3.7.3 Any medical examination must include advice on whether ongoing health surveillance would be appropriate.

3.8 Guidance

This code takes account of accepted good practice as given in the Non-binding guide to good practice for implementing Directive 2006/25/EC 'Artificial Optical Radiation' Good practice guide and PD IEC TR 60825-14: 2004 Safety of laser products – Part 14: A user's guide. Where relevant, the manufacturer's requirements contained in BS EN 60825-1:2014 Safety of laser products – Part 1: Equipment classification and requirements have also been considered.

4. Duties and Responsibilities

4.1 Directors shall:

4.1.1 Establish a structure of responsible persons, as described below, to manage safety when working with lasers. These appointments can be made within a single department, several departments or across a whole site.

Appointments

4.1.2 Delegate the implementation of laser safety responsibilities in one of the following ways, dependent on the size and complexity of laser activities, recording their names in SHE Directory where the geographic/equipment scope of the appointments should be defined:

4.1.3 Appoint in writing a single person to take on the duties of overall laser responsible officer (OLRO).

4.1.4 Appoint more than one OLRO provided that the duties of each do not overlap. Such an option might be useful, for example, if there are several major groupings of laser activities.

4.1.5 Combine the duties of the OLRO with those of a laser responsible officer (LRO). This option might be appropriate if there is only one small laser activity.

4.2 Line managers and supervisors shall:

4.2.1 Ensure that the requirements of this code are met with regard to laser work for which they are responsible.

Appointments

4.2.2 In conjunction with the OLRO, appoint in writing one or more laser responsible officers (LROs) and deputies as appropriate, to provide day-to-day supervision of all activities that involve high hazard lasers (see Appendix 16). Where low hazard lasers are also in use they will also supervise this work. Where more than one LRO is appointed, their duties must not overlap. Line managers and supervisors may take on the role of LRO. The appointments should be recorded in SHE Directory where the geographic/equipment scope of the appointments should be defined.

Control of laser work

4.2.3 Ensure that a risk assessment addressing the matters in Appendix 4 is completed for each laser setup that could give rise to exposures in excess of an exposure limit value (generally those involving class 3R, class 3B and class 4 lasers).

4.2.4 Where it is reasonably foreseeable that employees at particular risk are present in the workplace, ensure that this is addressed in the risk assessment.

4.2.5 Ensure that the risk assessment includes an assessment of possible and likely exposures, and comparison with relevant exposure limit values.

4.2.6 Ensure that laser work does not proceed unless risks identified in the risk assessment have been either completely eliminated or reduced so far as is reasonably practicable using the standard hierarchy of controls.

4.2.7 Ensure that wherever reasonably practicable local enclosure is used to manage the hazards presented by beams from high hazard lasers.

4.2.8 Ensure that where it is necessary to carry out open beam work with high hazard lasers, the reasons for this are documented

4.2.9 Where a risk assessment shows that staff may be exposed above an exposure limit value, ensure that an action plan is drawn up, recorded and implemented to ensure that this does not happen.

Control of changes to laser work

4.2.10 Ensure that before significant changes are made to laser activities (e.g. additional high hazard lasers, major reorganisation of laser layouts etc.):

- the OLRO is consulted;
- adequate facilities are available for safe use;
- the necessary documentation is drafted or updated and submitted to the OLRO.

Training for users of low hazard and/or low risk lasers

4.2.11 Ensure that persons working with low hazard and/or low risk lasers, for which no LRO is responsible, receive sufficient training in the safe use of lasers (See Appendix 17).

4.3 Overall Laser Responsible Officers shall:

4.3.1 Implement this code within the scope of their letter of appointment. This includes the following duties, which may be undertaken with the assistance of a laser protection adviser.

Advice

4.3.2 Advise and liaise with the director, line managers and supervisors on laser safety matters.

4.3.3 Advise line managers and supervisors on the appointment of LROs, particularly with regard to the scope of their approved activities.

4.3.4 Advise and support LROs in the discharging of their laser safety responsibilities.

Incidents and accidents

4.3.5 Assist the director, line managers and supervisors in the investigation of any laser-related safety incidents.

4.3.6 Establish procedures to ensure that in the event of an apparent or suspected laser injury to the eye, a medical examination by a qualified and suitably experienced ophthalmologist is carried out within 24 hours.

Arrangements

4.3.7 Ensure that arrangements are in place for:

- training LROs and LNPs (Appendix 17);
- laser classification (if appropriate);
- Inspection of new laser facilities;
- Regular audits of laser areas.

Control of changes in laser use

4.3.8 Review and provide input to proposals for the acquisition or major reorganisation of high hazard laser equipment.

4.3.9 Review laser safety implementation before and after commissioning of new or significantly changed high hazard laser equipment, checking that appropriate engineering controls and working practices have been implemented and that laser safety documentation as set out in Appendix 14 has been updated accordingly.

Relaxations of the Code

4.3.10 Approve, if appropriate, discretionary relaxations from requirements of this code provided justification is made in writing by the LRO and approved by the responsible Line Manager or Supervisor. The justification should detail how risks will be controlled.

Inspections

4.3.11 Undertake/arrange regular (every 18 months) inspection/audit of high hazard laser activities as set out in Appendix 8.

4.3.12 Distribute the reports of inspections and audits as appropriate e.g. to director, safety committees, line managers or supervisors, LROs, SHE group etc.

4.3.13 Monitor the recommendations/findings, from any inspections and audits against deadlines for completion.

4.4 Laser Responsible Officers shall:

4.4.1 Take on specified duties and responsibilities for the day-to-day implementation of this code for the laser area and/or activity for which they have been appointed.

Arrangements

4.4.2 Review and approve new or revised risk assessments and standing orders for laser work in areas for which they have responsibility.

4.4.3 Ensure that high hazard laser beams are fully enclosed unless this is not reasonably practicable.

Appointments and training

4.4.4 Where appropriate and in consultation with line managers / supervisors, appoint laser nominated persons (LNPs) to undertake specific tasks, setting out in writing, prior to commencement of their work, the constraints on their activities. LNPs may be given specific titles (e.g. target area operator, visiting laser user) if this helps clarify their role and recording their names in SHE directory where the geographic/equipment scope of the appointments should be defined.

4.4.5 Ensure that prior to commencing their duties, LNPs attend training as specified in Appendix 17.

4.4.6 Provide on the job training to all LNPs before they begin laser work, including a review of standing orders. This training should include:

- the technical and organisational measures in place to manage risks associated with the use of lasers exposure limit values
- significant findings from the risk assessment(s) relating to work with lasers in the area
- safe working practices to minimise the risk of adverse effects from work with lasers in the work area
- proper use of personal protective equipment, where appropriate

4.4.7 Approve the proposed work of LNPs and the laser/experimental arrangements and activities prior to commencement of their work.

4.4.8 Ensure that LNPs are suitably supervised when carrying out their work and where appropriate rescind their appointment in the event of cases of breaches in safe practice.

4.4.9 Ensure that all those working with high hazard lasers are aware of the procedures for real or suspected eye injuries (see Appendix 12).

Establishing safe working with high hazard lasers

4.4.10 Identify both the beam hazards (Appendix 1) and the non-beam hazards (Appendix 2) and, for work with high and low hazard lasers, produce an optical radiation-specific risk assessment (see Appendix 4) and standing orders for each work area or activity (Appendix 14).

4.4.11 Review and approve new or revised risk assessments and standing orders for laser work in areas for which they have responsibility.

4.4.12 Based on the results of the risk assessment:

- Implement controls for normal laser operation (Appendix 7).
- Implement additional controls for specific high hazard laser activities (Appendix 8).
- Ensure that so far as reasonably practicable risks are managed through use of enclosures or other equally effective engineering controls.

- Where required, establish a designated laser area (Appendix 9).
- Where required, ensure the correct labelling of designated laser areas and lasers.
- Where required, ensure availability of appropriate laser safety eyewear and its proper storage and maintenance (Appendix 11).

Changes in laser work

4.4.13 Before implementing major changes in a designated laser area or making significant changes to laser activities (e.g. additional high hazard lasers, major reorganisation of laser layouts etc.), consult and obtain advice from the OLRO.

4.4.14 After completion of the changes, complete and submit to the OLRO the new/revised risk assessment and standing orders prior to first operation.

4.4.15 Ensure that devices with the capability to emit laser radiation, including OEM lasers (i.e. devices that are supplied unclassified and without safety features for the purpose of incorporation into another piece of equipment) are classified or have had their classification confirmed to EN 60825-1, preferably by an EU-based manufacturer or agent, prior to their first use on site. Until such confirmation is obtained a device with the capability to emit laser radiation should be treated as Class 4. For OEM lasers that are incorporated into equipment, the completed unit should be classified to BS EN 60825-1:2014.

For laser pointers see also A7.2.6.

Documentation

4.4.16 Prepare full laser safety documentation as appropriate to the class of laser (Appendix 14).

4.4.17 Keep all laser safety documentation up to date, review the documents at least annually and forward copies of reissued documents to the line manager or supervisor and OLRO.

4.4.18 Maintain lists of laser nominated persons.

4.4.19 Ensure that risk assessments and standing orders for each area are made readily available to users of the area.

4.4.20 For LNPs about to undertake laser work, ensure that the methods, procedures and aims are first agreed in writing and that signatures to this agreement are obtained from the LRO and LNP.

4.4.21 Where required, approve Permits to Work for laser equipment.

4.5 Laser Nominated Persons (staff, tenant, user or contractor) shall:

4.5.1 Be aware of the significant findings of the risk assessment(s) for laser work they are involved with and be familiar with the control measures implemented to control those risks.

4.5.2 Ensure that high hazard laser beams are fully enclosed unless this is not reasonably practicable.

4.5.3 Be familiar with and abide by the Standing Orders for the area in which they work, and follow the prescribed procedures for the equipment that they are using.

4.5.4 Work within the constraints placed upon their activities by the LRO.

4.5.5 Undertake training as requested by the LRO.

4.5.6 Not defeat interlocks, remove enclosures or otherwise disable / bypass engineering controls, safety features, or warning devices without the prior written approval of the LRO. High hazard lasers must not be operated under these conditions unless all risks have been fully assessed and the identified mitigating actions implemented.

4.5.7 Where it is necessary to temporarily remove enclosures for the purposes of setting up, alignment, or other adjustment, ensure that they are replaced as soon as it is practicable to do so.

4.5.8 Not make any significant changes to laser beam paths, beam wavelengths or safety devices, nor introduce new lasers to the laboratory without the authorisation of the LRO.

4.5.9 Inform their line manager / supervisor or occupational health of any pre-existing eye condition they may have, since this could affect the risk assessment. Occupational Health should hold sensitive personal medical information.

4.5.10 Be conversant with and follow the procedures for real or suspected eye injuries (see Appendix 12)

4.5.11 Where a risk assessment has identified a requirement for the use of laser protective eyewear or other PPE:

- check that the PPE used is of the correct specification
- wear PPE when required
- check the condition of PPE before each use
- return PPE to correct storage after each use
- keep issued PPE in a clean and serviceable condition
- report any damage or loss to the LRO

Appendix 1 Beam hazards associated with laser use

Over the wavelength range that different lasers operate, the skin is a strong absorber, thereby protecting all the organs of the body except for the eyes.

A1.1 Injury mechanisms

There are a number of tissue damage mechanisms for laser radiation, including thermal, photochemical thermos-acoustic transients and non-linear effects. For supra-threshold exposures, the predominant injury mechanism is determined principally by a combination of laser wavelength and exposure / pulse duration.
In general, photochemical mechanisms dominate in the ultraviolet region where thresholds for photochemical damage are generally lower than for thermal injury. For wavelengths between about 400 nm and 550 nm, both photochemical and thermal mechanisms occur with the dominant mechanism dependent on the timescale of exposure. At longer wavelengths mechanisms are predominantly thermal.
As noted above, the injury mechanism also depends on the exposure duration. The predominant injury mechanisms for different exposure / pulse durations are summarised below.

Timescale	**Mechanism**
>10 s	photochemical
10 µs – 10 s	thermal
1 ns – 10 µs	microcavitation around melanin granules leading to pressure wave
50 fs – 1 ns	shock waves resulting from localised self-focussing
<50 fs	non-linear effects, particularly low density plasma generation

A1.2 Ocular injuries

The site of injury is determined by the spectral transmission of ocular tissues. Broadly the dependence on wavelength is as follows:

	Wavelength range	**Primary tissue at risk of damage**
Ultraviolet	180 nm - 315 nm	Cornea
Ultraviolet A	315 – 400 nm	Lens
Visible Near Infra-red	400 nm - 1.4 µm	Retina, but cornea /lens also needs to be considered (not included in ELV / MPE)
Infrared B	1.4 µm – 3 µm	Cornea and lens
Infra-red C	3 µm - 1 mm	Cornea

Retinal eye damage from laser radiation can occur at very low power or energy levels due to the point source nature of most laser sources, which results in a very small image of the source being formed on the retina. As essentially, all the power / energy entering the posterior eye will be focussed onto this small spot, which typically has a diameter of 10 - 20 μm, the resulting retinal irradiance or radiant exposure may be very high. Even allowing for intraocular scattering and corneal aberrations, it can be estimated that the retinal irradiance will be around 200,000 times higher than the irradiance incident on the cornea. Immediately behind the photoreceptor layer is the retinal pigment epithelium, which is very rich in melanin and absorbs strongly throughout the visible and into the near infrared. The result of these two effects (focussing to a small spot and strong absorption) is that the retina is extremely sensitive to laser radiation at wavelengths between 400 nm and 1400 nm.

In a research laboratory there may be lasers operating at different wavelengths, fixed and variable, from the UV through the visible and IR. What may seem to be a steady beam may be a pulsed laser operating at a high pulse repetition rate with peak powers in the individual pulses that are more than a million times the average power of the beam.

Apparently weak blue or red beams may be operating at wavelengths at the extreme of the visual response range of the eye where its sensitivity is several thousand times below its peak sensitivity (green light). UVA and blue light transmission through the ocular media decreases with cumulative exposure, which is broadly related to age: UV does not penetrate to the retina in adults and consequently does not elicit a visual response. The long wavelength end of the visible spectrum is defined as 700 nm by convention. However, longer wavelengths still penetrate to the retina, but the response of photoreceptors decreases rapidly above 700 nm: most people can perceive wavelengths up to at least 850 nm if there are enough photons. This is a major safety concern as people perceive very intense beams at wavelengths between 700 nm and 850 nm as a dull red glow and are consequently misled into believing the beam power to be very low. Longer wavelengths in the near infrared will not elicit any visual response at all.

The exposure limit value (ELV) and the maximum permissible exposure (MPE) represent slightly different definitions of the safe level of exposure to laser radiation. Exposure limit values are legal limits on exposure that must be complied with. Maximum permissible exposures are used in the derivation of accessible emission limits for each laser class.; both vary with wavelength range and duration of exposure, reflecting the underlying damage mechanisms discussed above. These different processes make the determination of safe radiation levels for pulsed lasers a complicated task that requires a detailed study of the ELV / MPE tables.

A1.3 Injuries to the skin

Skin hazards from exposure to laser radiation are simpler to assess than those for the eye as the complications arising from imaging of the source in the visible and near infrared spectral regions do not apply. Injuries are generally superficial, although the depth of penetration is wavelength-dependent, being maximal in the visible and near infrared and decreasing in both the ultraviolet and mid/far infrared. Ultraviolet radiation produces photochemical injuries, which can include erythema, oedema and blistering. As for other photochemical effects, exposures are generally cumulative adverse reactions may have delayed onset. As a result, it is important to consider exposure to scattered radiation as well as direct beam exposures. In addition, exposure can give risk to long-term adverse effects including skin ageing and an increased risk of skin cancer; neither the exposure limit values nor the maximum permissible exposures are intended to protect against these long-term effects.

Laser damage mechanisms for skin tissue are similar to those for the eye in terms of the effect of wavelength and exposure duration. As noted above, the eye is particularly sensitive to injury in the retinal hazard region (400 nm – 1400 nm). For shorter (ultraviolet) and longer (mid- and far-infrared) wavelengths the sensitivities of the eye and skin are similar and the limits are identical. Hence if eye protection is required outside the retinal hazard region, then skin protection will also be required.

Appendix 2 Non-beam hazards associated with laser use

In addition to the direct laser radiation hazard, a laser can present other hazards, all of which need to be considered in a risk assessment of laser use. The tables that follow list some of the more common of these non-beam or associated hazards together with some typical situations where they arise and typical control measures.

A 2.1 Hazards arising from the laser source

Hazard	Typical hazardous situation	Typical control measures
High voltage	Many lasers utilise high voltages, and pulsed lasers frequently employ capacitors to store electric charge. Laser head and power supply exposed during servicing.	Containment of high voltages in normal use. 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.
Fire and Explosion	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.	Safe design conforming to relevant standards Routine electrical testing For fire: access to a fire extinguisher; smoke alarm; training. For explosion protection during maintenance activities: gloves and face shield; training.
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 can also be harmful.	Use of acoustic barriers / enclosures Use of ear protectors where excessive noise levels cannot be eliminated by other means.
Collateral radiation	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, particularly during servicing. Low frequency magnetic	Proper screening combined with access restricted to service engineers. Subject to specific regulatory requirements: Control of Artificial Optical Radiation at Work Regulations 2010 (see STFC code 22) Control of Electromagnetic Fields at Work Regulations 2016 (see STFC code 23)

	fields from switched mode power supplies and pulsed lasers may present a hazard to those dependent on active medical devices. X-rays can be produced by high-voltage thermionic valves within the laser power supply.	
Mechanical	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.	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.
Chemical	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. These chemicals often have limited life and require frequent replacement resulting in a requirement for safe handling procedures. 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.	Proper storage, handling and disposal precautions should be adopted. Ensure quality of pipework, inspection regimes and requirements for secondary containment. Training and use of gloves and other PPE.

A 2.2 Hazards arising from the laser process

Hazard	Typical hazardous situation	Typical control measures
Fume	Release of hazardous particulate and gaseous by-products into the atmosphere through the interaction of the laser beam with the target material.	General precautions include: Fume extraction and filtration. Face mask and gloves worn during cleaning operations.
Hazardous substances	Cleaning solutions and also other materials used in conjunction with the laser (e.g., zinc selenide lenses) may be hazardous.	Use proper storage and implement handling and disposal precautions.
Fire and	The laser emission from high-	Control flammable materials and

explosion	power (Class 4) lasers can ignite target and other materials. These effects may be enhanced in oxygen-rich and other unusual atmospheres. Laser emission from even lower-class lasers, especially when focussed to very small spot sizes, can cause explosions in combustible gases or in high concentrations of airborne dust.	beam path. Provide a fire extinguisher in the laser area.
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. Subject to specific regulatory requirements: Ionising Radiations Regulations 2017 (see STFC code 29) Control of Artificial Optical Radiation at Work Regulations 2010 (see STFC code 22) Control of Electromagnetic Fields at Work Regulations 2016 (see STFC code 23)
Mechanical	Beam delivery arms and robotic systems that move under remote control can cause serious injury. Large work-pieces can present manual handling problems such as cuts, strain, and crush injuries.	Guard traps and add warning signs. Restrict access to moving parts.

A 2.3 Hazards arising from the laser environment

Hazard	Typical hazardous situation	Typical control measures
Temperature and humidity	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	Provide air conditioning and humidity control of the local environment. Install a gas purge in beam delivery line.

	uncomfortable. Condensation on optical components can affect beam transmission through the system.	
Mechanical shock and vibration	Misalignment of the optical path, generating hazardous errant beams.	Install a vibration isolation system on the legs of optical tables holding optical components. Construct a floating foundation for large laser machines.
Atmospheric affects	Laser ignition of solvent vapour, dust, and inflammable gases present in the environment.	Enclose beam and process zone and add a gas purge. Install gas sensors to detect presence of inflammable gases and vapours.
EM and RF interference	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.	Screen equipment and filter supply and data cables.
Power supply interruption or fluctuation	Interruption or fluctuation of the electrical supply can affect the operation of the laser's safety system.	Install a voltage regulation system and back-up supply.
Computer software problems	Serious and unpredictable hazards arising without warning caused by errors in computer programming of software control.	Use only approved protocols for software control of safety functions.
Ergonomic and human-factor considerations	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	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.

	performed; influence on human performance of the equipment that has to be used); organisational aspects ("safety culture" 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).	

Details of safety precautions relating to particular hazards can be found in the relevant SHE Safety Codes. https://staff.she.stfc.ac.uk/Pages/Codes

Appendix 3 Classes of laser

Lasers are classified on the basis of their accessible emission to give the user a simple guide to beam hazard. It is the manufacturer's responsibility to classify the laser, but a user who significantly modifies a laser takes on the role of manufacturer including the responsibility to reclassify (or confirm the original classification). Where original equipment manufacturer (OEM) lasers are purchased for integration into a laser system, it will be the integrators responsibility to classify the final product. Where laser products are purchased from outside the European Union, the purchaser will become an importer and may have responsibilities for classification and 'CE' marking.

For each laser class there are accessible emission limits (AEL), generally expressed in Watts or Joules measured through one or more specified apertures placed at a specified positions. The accessible emission limits are related to the maximum permissible exposures such that the laser class gives an indication of the beam hazard. Full details of assessment procedures are given in BS EN 60825-1:2014. It should be noted that it is often possible to classify a laser product without making any measurements. Should it be necessary to make measurements in order to classify a product then further guidance is available in PD IEC/TR 60825-13:2006 Safety of laser products – Part 13: Measurements for classification of laser products.

A3.1 Class 1

Class 1 laser products are safe in normal use under reasonably foreseeable conditions. There are two types of class 1 laser products:

A3.1.1 Inherently class 1 or exempt

The laser output is safe because the output of the laser source is too low to cause harm, even if magnifiers or other such optical devices are used to modify the laser beam or assist viewing. Such devices may be either assigned to class 1, or referred to as an exempt laser product. This code places no requirements on the use of inherent class 1 / exempt lasers.

A3.1.2 Class 1 laser products containing an embedded laser of higher class

A class 1 laser product containing an embedded laser of higher class are safe because of engineering design. In general, this means that the laser radiation is totally enclosed, preventing it becoming accessible to the user in normal operation.
In this Code the term 'class 1 embedded' is restricted to products that are Class 1 but contain a Class 3B or Class 4 laser that is not accessible during the service operations specified by the manufacturer.
The use of class 1 (embedded) laser products in general is dealt with in this code because: (i) a degree of preventative maintenance and care may be required to preserve its safety; and (ii) the laser hazard may be exposed during servicing of the product.
However, this code places no requirements on the use of class 1 (embedded) laser products that are intended for use as consumer products, including desk top laser printers, and photocopiers, CD and DVD players and recorders provided they are serviced off site.

A3.2 Class 1M

Class 1M laser products have a total output that exceeds the accessible emission limit for class 1, but is emitted into a well-collimated beam with a diameter that exceeds the diameter of the limiting aperture for that wavelength and is outside the retinal hazard region. Hence, they are safe for 'naked eye' viewing (i.e. without the use of viewing aids) by virtue of the fact that the power or energy passing through the limiting aperture will be below the MPE.
The applicability of class 1M is restricted to laser wavelengths in the range 302.5 nm to 4 µm. This is deemed to be the reasonably foreseeable transmission range of optical viewing aids and corresponds approximately to the transmission window of fused quartz.

Class 1M lasers products are regarded as low risk in this code.

A3.3 Class 1C

Class 1C is applicable when the laser radiation is intended to be applied in contact with the intended target, either skin or non-ocular tissue and has safeguards that prevent leakage of laser radiation in excess of the AEL of class 1. The laser product can be assigned to class 1C only if it also complies with a set of safety requirements for class 1C laser products that can be found in an applicable IEC vertical standard.

A3.4 Class 2

Class 2 laser products emit low levels of visible radiation (i.e. in the wavelength range 400 nm to 700 nm) and are safe in normal use by virtue of the natural aversion response of the eye to bright light, which is deemed to limit the duration of exposure to 0.25 s. Nevertheless, they may present a severe dazzle hazard that must be considered in an optical radiation-specific risk assessment. For a continuous wave (CW) laser the class 2 AEL is 1 mW.

Class 2 laser products are regarded as low risk in this Code.

A3.5 Class 2M

Class 2M laser products have a total output that exceeds the accessible emission limit for class 2, but that is emitted into well-collimated beams of visible radiation (i.e. in the wavelength range 400 nm to 700 nm) of diameter greater than the pupil size of the eye (7 mm maximum); thus are safe for 'naked eye' viewing. That is without the use of viewing aids), by virtue of the natural aversion response of the eye to bright light, which is considered to limit exposure to 0.25 s, and the fact that the eye will only collect a fraction of the total laser output. They are safe in normal use if:

- the observer does not stare into the beam; and
- lenses and/or mirrors are not used to reduce the laser beam diameter and then re-collimate the beam; and
- Telescopic optical devices are not used to assist viewing. Control of such viewing aids and optical arrangements is generally sufficient to ensure safety.

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<u>Class 2M lasers products are regarded as low risk in this code. Nevertheless, they present a severe dazzle hazard that must be considered in an optical radiation-specific risk assessment.</u>

A3.6 Class 3R

The emission from class 3R laser products exceeds the exposure limit value / maximum permissible exposure for an accidental exposure and must therefore be considered unsafe for direct viewing of the laser beam, whether in aided or unaided viewing. Nevertheless, the risk of injury is regarded as low due to the safety margins used in the derivations of exposure limit values and maximum permissible exposures.
The AEL for class 3R is 5 times greater than for class 1 or, for visible beam lasers, 5 times greater than for class 2.
The applicability of Class 3R is restricted to laser wavelengths greater than 302.5 nm, since for shorter wavelength ultraviolet the 5 times excess is deemed too great a factor for the exposure to be low risk.
Unlike class 1M and class 2M, where unaided viewing is considered safe, eye exposure to the beam from a class 3R laser carries a small risk of injury and would be a breach of the Control of Artificial Optical Radiation at Work Regulations 2010.

<u>Class 3R lasers products are regarded as low hazard in this code.</u>

A3.7 Class 3B

Class 3B laser products are medium power devices for which ocular exposure to either the direct beam or a specular reflection would carry a high risk of injury; ocular exposure to a diffuse reflection is normally safe, subject to certain conditions (i.e. a minimum viewing distance of 130 mm and a maximum viewing time of 10 seconds). For a CW laser in the visible or infrared wavelength range the Class 3B AEL is 500 mW.

<u>Class 3B laser products are regarded as high hazard in this code.</u>

A3.8 Class 4

Class 4 laser products are high power devices for which exposure to the direct beam, specular and diffuse reflections is generally hazardous. They may also cause skin burns and may present a fire hazard. There is no AEL for Class 4.

<u>Class 4 laser products are regarded as high hazard in this code.</u>

Appendix 4 Matters to be considered in an optical radiation-specific risk assessment

Regulation 3 of the Control of Artificial Optical Radiation at Work Regulations 2010 Control of Artificial Optical Radiation at Work Regulations places a duty on employers to carry out a risk assessment for any work with optical radiation sources (including lasers) that present a risk of adverse effects on the eyes or skin of employees.
The requirements of this regulation are much more specific than the general requirements for risk assessment under regulation 3 of the Management of Health and Safety at Work Regulations 1999.

In particular, there is a requirement to carry out an exposure assessment as part of the risk assessment. In addition, the assessment must include consideration of the following matters:

- the level, wavelength and duration of exposure
- the exposure limit values
- the effects of exposure on employees or groups of employees whose health is at particular risk from exposure
- any possible effects on the health and safety of employee resulting from interaction between artificial optical radiation and photosensitising chemical substances
- any indirect effects of exposure on the health and safety of employees such as temporary blinding, explosion or fire
- the availability of alternative equipment designed to reduce levels of exposure
- appropriate information obtained from health surveillance, including where possible published information
- multiple sources of exposure
- any class 3B or 4 laser that is classified in accordance with the relevant IEC standard that is in use by the employer and any artificial optical radiation source that is capable of presenting the same level of hazard
- information provided by manufacturers of artificial optical radiation sources and associated work equipment in accordance with the relevant European Union Directives.

The risk assessment must be reviewed regularly if:

- there is reason to suspect that it is no longer valid
- there has been a significant change in the work to which the assessment relates

The employer must record:

- the significant findings of the risk assessment
- the measures that have been taken and which the employer intends to take to:
    - eliminate or reduce risks
    - provide information and training.

Appendix 5 Exposure limit values (ELVs)

ELVs are tabulated in Annex II of Directive 2006/25/EC Directive 2006/25/EC (the UK regulations do not contain numerical values for the limits, but instead refer to the annexes to the Directive).

Appendix 6 Summary of control measures for normal laser operation

Risk →	NO RISK	LOW RISK				HIGH RISK		
Class →	1		2	3R	1M and 2M	Class 3B	Class 4	
Requirement ↓	Intrinsic	Embedded						Reference Clause ↓
LRO needs to be appointed						√	√	4.2.2
Registration	-	√	-	√	√	√	√	A14.3
Standing Orders	-	-	-	√	-	√	√	4.4.1; A7.4.2.3
Generic (MHSW 99) risk assessment		√	√		√			A14.1
Optical radiation-specific risk assessment	-	-	-	√	-	√	√	A4
Training for normal use	-	-	-	√	√	√	√	A17
Restricted use of viewing aids	-	-	-	-	√	-	-	A7.2.3
Conform to basic beam path design principles	-	-	-	√	√	√	√	A7.4.3.18 & .19
Conform to restricted beam path design principles	-	-	-	-	-	√	√	A7.4.3.19
Control of specular reflections	-	-	√*	√	√*	√	√	A8.3.1 A9.1.7
Use of key control	-	√	-	-	-	√	√	A8.1.5
Service and maintenance restrictions	-	√	-	-	-	√	√	A8.2
Restricted to	-	-	-	-	-	√	√	A7.4

interlocked Designated Laser Area								
Isolation of non-laser activities in normal operation	-	-	-	-	-	√	√	A15.5
Restricted multiple wavelength operation	-	-	-	-	-	√	√	A12
Medical examination required in the event of accidental exposure	-	-	-	√	-	√	√	A10.1.1
Laser Safety Eyewear to be provided (if identified in risk assessment)	-	-	-	-	-	√	√	A11
Protective clothing to be provided (if identified in risk assessment)	-	-	-	-	-	-	√	A2.1

* visible beam lasers only

Appendix 7 Laser control measures: normal operation

A7.1 General

A7.1.1 All lasers except for ‘no risk’ laser products (see definitions in section 4) are to be labelled in accordance with appendix 10.

A7.1.2 Laser equipment in use must be properly maintained and serviced.

A7.1.3 Lasers must be made safe prior to disposal and dealt with appropriately if they contain hazardous materials.

A7.2 Low risk lasers

A7.2.1 Risk assessment

Low risk lasers (see definitions in section 4) can be used anywhere on site provided that their use is subject to a general risk assessment (which should include risk of dazzle for visible laser beams), and the person responsible for their use implements the default control measures set out below. Otherwise, an optical radiation-specific risk assessment (see appendix 4) must be undertaken before use.

A7.2.2 Engineering controls

It is not necessary to implement any additional engineering controls for low risk lasers; it should be noted that these products may well incorporate engineering controls that are required to achieve the manufacturer’s classification and these must not be overridden or defeated.

A7.2.3 Administrative controls

Class 1 (embedded) and class 1C lasers

A7.2.3.1 Class 1 (embedded) and class 1C lasers must be operated according to the manufacturer’s instructions.

A7.2.3.2 If a key switch is provided, this must be withdrawn and stored in a safe place when the product is not in use.

N.B. Additional measures apply for service activities (see Appendix 8).

Class 1M and 2M lasers

The use of binoculars and telescopes must be strictly controlled within the extended nominal ocular hazard distance of class 1M and 2M lasers. Primarily this means that the beams from class 1M and class 2M lasers should not be directed into areas where other people may be present if it is possible that those people may be using telescopes or binoculars. A typical example might be the use of lasers in an area rich in wildlife, where bird watchers or similar may be present. If the extended nominal ocular hazard distance does not extend outside an area that is under STFC control then it may be feasible to prohibit the use of viewing aids.

A7.24 For class 2M lasers consideration must be given to the risk of dazzle or distraction. The beam should be terminated at a suitably diffuse surface unless this is not reasonably practicable given the application of the laser.

A7.25 If it is necessary to mount any optics in the beam from a class 1M or class 2M laser, then an assessment must be made to determine if those optics will increase the hazard, either by focussing the beam or by producing a collimated beam of smaller diameter. Any optics with a diameter that is smaller than that of the limiting aperture may be ignored.

Lasers that have been classified as 1M or 2M under BS EN 60825-1:2007 (edition 2) or BS EN 60825-2:2004 + A2:2010 *Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCS)* because they emit a highly divergent output, should not be used in conjunction with magnifying lenses, viewing loupes, or microscopes. Similarly, the assessment of optics placed in the beam path must include collimating optical components. Any optics with a diameter that is smaller than that of the limiting aperture AND that are placed more than 100 mm from the laser aperture may be ignored.

If there is a specific experimental need to use instruments containing magnifying optics in an area where class 1M or class 2M lasers are in operation, then this will need to be subject to an optical radiation-specific risk assessment that should inform the selection of effective control measures. Options for control measures include:

(i) using the instrument in conjunction with a camera rather than direct viewing;
(ii) equipping viewing aids with filters that block at the laser wavelength; or
(iii) fitting an interlocked shutter or turning mirror arrangement that prevents the laser beam entering the viewing aid when the laser is on.

Class 1 and class 2 lasers

Where class 1 and class 2 lasers have a total output that exceeds the accessible emission limit for class 1 or class 2, but that is emitted into a highly divergent beam, AND there is a need to mount optics in the beam path, then an assessment is required to determine if those optics will produce a hazardous beam either by collimation or focussing of the emitted beam. Any optics with a diameter that is smaller than that of the limiting aperture and that are placed more than 100 mm from the laser aperture may be ignored.

Where class 2 lasers are in use, consideration should be given to control of risks arising from distraction and dazzle. The beam should be terminated at a suitably diffuse surface unless this is not reasonably practicable given the application of the laser.

Laser pointers

A7.2.6 Laser pointers that are substantially overpowered and incorrectly classified are now in widespread circulation (overpowered laser pointers are available in a wide range of wavelengths). As an additional check, the maximum output (e.g. with new batteries) of laser pointers brought onto site should be measured and their use prohibited unless the output is below the AEL for Class 2 (i.e. ≤ 1 mW) for hand held general use and, exceptionally, below the AEL for Class 3R (i.e. ≤ 5 mW) for specialist use. If checking the output of green laser pointers, which are often diode pumped frequency doubled Nd:YAG lasers, it should be noted that often the fundamental output (1064 nm) and the pumping wavelength (around 810 nm) are substantial contributors to total output and in some cases greatly exceed that of the useful wavelength (532 nm),

A7.3 Low hazard lasers

A7.3.1 Risk assessment

As ocular exposure to the beam from a low hazard laser would exceed the exposure limit value, it is potentially hazardous and should be subject to an optical radiation-specific risk assessment (see appendix 4).

A7.3.2 Engineering controls

Unless it is not reasonably practicable for the application the laser and all associated optics should be securely mounted with the beam path maintained in the horizontal plane.
If the beams are not fully enclosed, then optical tables must be fitted with edge protection unless this is not reasonably practicable for the application.

A7.3.3 Administrative controls

The beams from class 3R lasers must not be directed into areas where other people unconnected with the work may be present.

The beam should be terminated at a suitably diffuse surface unless this is not reasonably practicable given the application of the laser.

A7.4 High hazard lasers

A7.4.1 Risk assessment

All work with high hazard lasers must be subject to one or more optical radiation-specific risk assessments.
If there is a need to carry out alignment of exposed beams or any other atypical activity then this must be subject to a separate optical radiation-specific risk assessment.
Risk assessments must address the matters specified in appendix 4.
In addition, an optical radiation risk assessment for a high hazard laser should:

- consider significant changes in hazard along the beam path (losses in complex beam paths often result in considerable changes in hazard – similarly, optics that diverge or converge the beam may change the hazard)
- consider potential for access to beams and the power or energy in the beam at this point
- inform the selection of reasonably practicable control measures
- record if there are technical reasons why an otherwise desirable control is not reasonably practicable (for example, the necessity to carry out alignments with high power beams due to thermal effects in optics)
- explain the reasons why existing controls (eg enclosures) may have to be temporarily removed or overridden, the new controls that are implemented in their place and why these will be effective
- identify any actions required to keep controls effective
- identify any reasonably foreseeable accidents

The risk assessment must address any deviations from implementing the control measures set out below.

A7.4.2 General

A7.4.2.1 High hazard lasers (see definitions in section 3) must only be operated inside designated laser areas (see appendix 9).

A7.4.2.2 Before starting work involving high hazard lasers a number of basic risk reduction measures must be considered:

- Is it necessary to use a laser at all?
- Can a lower powered laser be used?
- Can the output power of the laser be restricted if full power is not needed?
- Can work be carried out in a total enclosure?
- Can eye or skin exposure be prevented by engineering design?
- Can the laser be used in a screened off area - limiting potential for others to be affected?

A7.4.2.3 All work involving high hazard lasers must be covered by risk assessments and standing orders.

A7.4.2.4 Laser nominated persons must be suitably trained in the operating techniques required and inexperienced staff must be adequately supervised.

A7.4.3 Engineering controls

Design of enclosures

A7.4.3.1 High hazard beams should be fully enclosed wherever reasonably practicable. Although it is not acceptable to routinely work with exposed high hazard beams, there will often be times when it is necessary to work with open beams for the purposes of setting up or alignment (see appendix 8). For situations where it is not reasonably practicable to effectively enclose beams during routine operation then alternative engineered solutions must be considered.

A7.4.3.2 Wherever practicable, setups should be engineered so that they are effectively class 1 laser products. Providing STFC is not making equipment available to third parties as part of a commercial arrangement, there is no legal requirement to conform to BS EN 60825 1:2014, but it provides a useful guide to good practice in the selection of effective engineering solutions.

A7.4.3.3 A variety of solutions are available for enclosure of high hazard beams. Removable sections of enclosures should be fixed so that tools are required for their removal. A selection of common approaches are discussed below:

A7.4.3.4 Beam tubes are useful where beam paths are relatively isolated and are frequently used for enclosing beams between pumping lasers and amplifiers or oscillators. They can also be useful for enclosing beams between optics. In this context, it is often helpful to place a turret around each optic and place the beam tube into mounts on each turret – these mounts can incorporate shutters that are displaced by mounting the tube.

A7.4.3.5 As an alternative to beam tubes for enclosure of well-separated beam paths, sectional tunnels that can be placed over both beam paths and optics and secured to the optical table.

A7.4.3.6 For more complex optical arrangements box-type enclosures are often perceived to provide greater flexibility; these enclosures should always incorporate a top as well as sides. There is often equipment associated with optical setups, such as power supplies and measuring instruments. It is important that this equipment remains outside any enclosure so that it can be accessed and adjusted without having to remove or displace panels. This means that there will normally need to be a means of routing cables through the enclosure and this can be achieved by using a baffle arrangement, whereby there is a route for cables, but no direct path for errant beams to leave the enclosure.

A7.4.3.7 Each panel of the enclosure should be appropriately labelled to indicate the nature of the hazard inside (see clause 7.10 of BS EN 60825-1:2014 and appendix 10).

A7.4.3.8 The interlocking of removable sections of an enclosure is not a general requirement. The decision on whether to interlock a section should be based on the foreseeable reasons for access and particularly on whether it is required in the presence or absence of a high hazard beam. For example, access to a high hazard beam might be required for alignment or adjustment, whereas the placement and retrieval of samples would not normally require access to the beam.

A7.4.3.9 Where access is required in the presence of a high hazard beam (for example for alignment or adjustment) then the removable section constitutes a service panel. In this situation, any interlock would have to be routinely overridden, which would defeat the purpose of fitting it. Instead, the section/panel should be secured with fixings such that removal or displacement requires the use of a tool or tools (clause 6.2.2 of BS EN 60825-1:2014). Where alignment or adjustment is carried out with a low hazard beam, then interlocking may be appropriate (see paragraph A7.5.2.11 below).

A7.4.3.10 Where access is required in the absence of a high hazard beam (for example, for placement or retrieval of samples) the removable section constitutes a panel for operation or maintenance (see clause 6.3.1 of BS EN 60825-1:2014) and should be interlocked. However, the interlock does not necessarily need to power down the laser and could instead operate a shutter. If occasional access is required with the high hazard beam present, then an interlock override should be provided, In this case, the use of the override must activate a visual or audible warning and the act of replacing the removable sections must reset the override.

A7.4.3.11 Where access is required for beam alignment at reduced power, consideration should be given to an interlock that automatically reduces the power of accessible beams, either by means of a signal to the laser controller to reduce output, or by introducing an attenuator in the upstream beam path.

A7.4.3.12 For complex beam paths, optical losses within the system often mean that upstream beams are considerably more hazardous than those downstream, which may not even be hazardous at all. Hence, when designing enclosures for complex beam paths, consideration should be given to segregating low and high power zones. Consideration should also be given to dividing enclosures so that stable beam paths are separated from those that require regular alignment. Enclosures do not necessarily need to be entirely light tight, but should prevent access to primary beams, reasonably foreseeable errant beams and any potentially hazardous scatter.

A7.4.3.13 The material used to construct any enclosure needs to be selected with care. The first consideration is the purpose of the enclosure. Often this will be to simply prevent access to the beam. If this is the case then the material needs to be physically robust, but does not need to be able to attenuate or withstand exposure to the beam. However, if there is a reasonably foreseeable risk of either the primary or an errant beam striking the enclosure then the material should be opaque at that wavelength and should be able to withstand the predicted exposure. For class 4 lasers the material must be fire resistant and the potential for a high average power laser beam to penetrate an otherwise opaque material by melting or vaporising it must be considered. Strictly, in order to satisfy the requirements for class 1 the enclosure should be able to withstand exposure without human intervention. However, as STFC will not generally have a legal requirement to conform to BS EN 60825-1, it may be acceptable to take a slightly more relaxed approach based on risk assessment: this would be consistent with the approach recommended in BS EN 60825 4:2006+A2:2011. *Safety of laser products – Part 4: Laser guards*. This standard also includes a useful annex (annex F) that includes charts showing burn-through times for a selection of materials when exposed to some typical laser beams. It is by no means exhaustive, but is a helpful guide nevertheless.

A7.4.3.14 The exposure limit values for ultraviolet laser radiation are cumulative and consequently consideration needs to be given not just to preventing exposure to primary and errant beams, but also to general scatter. Hence where ultraviolet lasers are enclosed it is important to use materials that will substantially attenuate or preferably block any scatter.

A7.4.3.15 It is important to document the approach taken when enclosing laser beams. This should include the rationale for the general design, decisions on interlocking or otherwise of panels and decisions on the choice of materials used to fabricate the enclosure.

A7.4.3.16 Where enclosures have to be temporarily opened or removed to permit work on high hazard beams, alternative engineered solutions must be provided. These may include beam stops and side shields provided around beam paths. These should be robust, securely mounted in position and, unless it is not reasonably practicable, continuous. Beam stops and enclosures for this purpose need to be robust and firmly located in position. Beam stops must have a heat dissipating capacity sufficient for the output of the laser.

7.4.4 Design of beam paths

A7.4.3.17 High hazard laser beam paths must take account of the beam path design principles:

Hazardous beam path design principles

i. Main and hazardous secondary beams must be enclosed unless this is not reasonably practicable for the application
ii. Lasers and optics that define the beam path must be securely mounted
iii. Beam paths must be in a single horizontal plane unless this is not reasonably practicable for the application (particular care is needed to avoid changes in level)
iv. Upwardly directed vertical beams must be avoided unless this is impracticable for the application
v. Where possible beam paths must be as short as reasonably practicable with a minimum number of directional changes
vi. All primary and all hazardous secondary and errant beams must be terminated at the end of their useful paths
vii. Open beam paths must be clear of surfaces producing hazardous reflections
viii. Open beam paths must not cross walkways

Permitted deviations from beam path principles

A7.4.3.18 Deviations from the hazardous beam path design principles are only permitted if it can be shown through an optical radiation-specific risk assessment that risks are adequately controlled.

A7.4.3.19 The risk assessment must include an exposure assessment that must include reasonably foreseeable accidental exposures. The risk assessment should also include all measures taken and a note of why adherence to the beam path design principles are not feasible in this case.

A7.4.3.20 Where complete beam enclosure is not reasonably practicable then a combination of local enclosure (in particular around sources of scattered radiation such as laser dye cells and sources of multiple beams such as prisms and filter stacks) and peripheral enclosure (skirts around optical tables) should be employed where possible. Where beams are unable to be enclosed across walkways, alternative engineering controls should be considered (such as electronic beam interrupt systems. Documented laser risk assessments should specifically record reasoning where full enclosure is not possible.

A7.4.3.21 In general, deviations should only be permitted if alterative engineering controls (e.g. a pressure pad or intruder-type beam interrupt in the case of beams crossing walk-ways) are implemented.

A7.4.3.22 Administrative controls (e.g. the use of retractable tape or chain in the case of beams crossing walk-ways) may only be considered to temporarily replace engineering controls if it can be demonstrated that the power or energy in a beam does not exceed that for a low hazard laser.

Beam release

A7.4.3.23 If the master laser control panel of the laser cannot be located less than 2m away and in line of sight from where persons could receive a hazardous exposure from the beam, then a clear system of communication must be established between the laser operator and any person in the hazard zone, giving adequate warning of each activation of the laser hazard.

A7.4.3.24 The following considerations must be made in regard to the transfer of high hazard laser beams between rooms:

a) Persons in the room receiving the laser beam must have sole and overriding control to prevent the emergence of the laser hazard. The means of preventing the emergence of the laser hazard must be clearly visible from within the room and an indication must be provided on the status of the laser with regard to emission of laser radiation.
b) Persons in the room containing the laser must have a reliable means of terminating the beam path within the room.

Control of access

Lasers inside a designated laser area (DLA) must be linked into the external interlock chain provided within the DLA, either using the remote interlock connector on the laser or an external safety shutter, such that:

i. The laser emission is rapidly terminated when a break occurs in the external interlock chain. For pulsed systems, if termination is achieved by removal of the energy source, this must be accompanied by the dumping of any residual energy which could give rise to further laser pulses;

ii. Resetting the external interlock chain must not cause automatic emission of hazardous levels of laser radiation. A manual operation must be required for reinstatement of the laser emission.

iii. If an external safety shutter on the laser it must be:
   - located either within the protective housing or, if external, as close to the laser aperture as reasonably practicable and in fixed location to it;
   - of a robust, fail-safe design and construction;
   - fast acting;
   - providing a clear visual indication of when it is in its closed position. This indication must be derived from the location of the interlocked beam stop and not from some control signal or interruption in the external interlock chain;
   - provided with an approved means of connection to the external interlock chain.

A7.4.3.25 Where lasers within a designated laser area (DLA) are operated with all high hazard beams fully enclosed at all times (i.e. in a class 1 (embedded) configuration), there is no requirement for a room interlock system to be provided or for the laser to be connected to one where it is provided.

A7.4.3.26 Where lasers within a designated laser area are predominantly operated with all high hazard beams fully enclosed, but occasionally operated with the enclosure open or removed for the purposes or alignment or adjustment, then the room interlock system may be adapted to provide an override facility. This should operate such that the room interlock system can be overridden when the high hazard beams are enclosed and enabled when the enclosure is open or removed. The override should be key (rather than code) operated where possible and its status should be clearly indicated.

A7.4.4 Administrative controls

Unauthorised use

A7.4.4.1 If access to the laser is uncontrolled then the key must be withdrawn from the switch when the laser is not in use and stored in a safe place.

Unintended reflections

A7.4.4.2 Watches, rings and other items of jewellery that might specularly reflect a laser beam must be removed or covered.

A7.4.4.3 Other items with shiny surfaces must be kept away from open beam paths. Optical benches must be kept free from clutter (N.B. Many surfaces which appear visually dull will be highly specularly reflecting for infrared radiation).

A7.4.4.4 The individual who adjusts or introduces an optical component into a beam path is responsible for identifying and terminating each and every stray beam coming from that component.

A7.4.4.5 The placement of additional optics should be planned to minimise the possibility of stray reflections.

A7.4.5 Personal Protective Equipment

A7.4.5.1 Laser safety eyewear must be provided and worn if, after applying all other reasonably practicable control measures, there remains an unacceptable risk to the eyes. (See appendix 11 for details of selection and use of laser safety eyewear).

A7.4.5.2 If the high hazard laser beam is only present occasionally then controls should be introduced (e.g. deployment of engineering means to isolate the laser hazard; initiate a pre-warning to replace eyewear) to allow the removal of laser safety eyewear in the laser area when it is safe to do so.

A7.4.5.3 Laser protective eyewear should not be worn routinely where there is no laser hazard.

A7.4.5.4 The risk of skin exposure must be assessed when working with class 4 lasers and appropriate measures taken. In general, if it is appropriate to use eye protection with class 4 lasers then it will also be appropriate to use skin protection.

A7.4.5.5 The effects of UV exposure are cumulative and so skin protection should be provided if there is a risk of exposure to scattered radiation.

A7.5 Diode Lasers (General)

Laser diodes can easily be mistaken for other forms of light emitting diodes and simple testing techniques can cause them to produce a light output that is harmful to the eyes. The following additional control measures apply:

A 7.5.1 Laser diodes not incorporated in equipment must be kept in a container labelled with classification and registration particulars, and locked way;

A7.5.2 Before laser diodes are incorporated into equipment, any energy storing components therein must first be discharged;

A7.5.3 Before disposal of laser diodes, the LRO must ensure that they are made non-operational.

Appendix 8 Laser control measures: additional requirements for specific high risk laser activities

A8.1 Open beam work

A8.1.1 All open beam work with high hazard lasers must be subject to a separate optical radiation-specific risk assessment, which must include an assessment of all reasonably foreseeable accidental eye exposures.

A8.1.2 All alignment and adjustment work with high hazard beams must be covered by a detailed written alignment procedures that documents the precautions to be implemented.

A8.1.3 The following initial safety checks for open beam work should be considered for inclusion in the standing orders for work with temporarily unenclosed high hazard laser beams.

Before releasing high hazard 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 side shields, 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 authorized people are in the area.
- Check that all required controls have been implemented, including, were appropriate, that everyone in the area is wearing suitable laser safety eyewear.
- Give prior warning that the laser beam is about to be launched.

A8.1.4 Alignment of open high hazard beams is the most common cause of laser eye injuries. Unless there are justified reasons for not doing so (which must be approved by the OLRO), the following rules should be included in the standing orders.

- Only suitably trained and authorised laser nominated persons may carry out alignment. All other persons must be excluded from the room during this procedure.
- The competence of the individual carrying out the alignment work should be formally assessed and recorded before permitting them to carry out the work unsupervised.
- Watches, bracelets and other reflective jewellery must be removed or covered.
- Appropriate laser safety eyewear must be worn if the risk assessment shows that it is required.
- All alignments must be performed at the lowest possible beam power or energy consistent with technical requirements. This may be achieved by a variety of means, including reducing the output of the laser, attenuation of the beam close to the laser aperture, or dumping part of the beam using a beam splitter. The power or energy in the beam must be compared with the relevant exposure limit value as part of the risk assessment for the process (see A8.1.1).

- If it is not possible to reduce the power or energy in the beam to below the exposure limit value, then consideration must be given to the use of a separate low power alignment beam introduced into the beam path for the initial alignment.
- Each and every optical element in the beam path must be analysed for stray reflections/errant beams and suitable beam blocks installed to terminate them. (The blocks must be securely mounted and suitable to withstand the power or energy being blocked.)
- Access to the DLA must be restricted, with effective arrangements in place to prevent unauthorized personnel from entering the area whilst there are exposed hazardous beams.
- 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.
- If alignment with a higher power beam is essential, the risk assessment must be used to identify appropriate controls and these must all be in place before commencing the work. If the risk assessment identifies a need for staff to use laser protective eyewear, then this must be worn throughout the process. With eyewear in place, it may be difficult to visualise beams. The table below gives examples of suitable visualisation techniques.

Wavelength range	Techniques for beam position detection during alignment
Visible only	Introduce an attenuator to reduce accessible emission preferably to class 2 and in any event no more than class 3R. Protective eyewear will not be required. Alternatively, if attenuation of the beam is not reasonably practicable, wear laser alignment eyewear.
UV and/or Visible	Attenuate the beam and use a CCD camera Use fluorescent card (suitable cards are commercially available or alternatively, impregnate paper with dye, mark target with highlighter ink): fluorescence at shifted wavelength can be seen through UV protective eyewear, which can be transparent at visible wavelengths.
Infrared only	Options include: ➢ 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 ➢ for near infrared, phosphorescent or scintillation viewing cards ➢ if beam powers have to be high the use of up-conversion fluorescent viewing cards can be considered, but as these lack sensitivity their use is not recommended unless high beam

	powers are necessary anyway ➢ .for far infrared, thermochromic materials, which change colour when heated ➢ heat sensitive fax/chart recorder paper ➢ fluorescent-coated blocks illuminated with UV lamps
Single Pulse lasers	Use black coated or lithographic paper; the coating is ablated by the more powerful pulsed lasers.
Any wavelengths	Use a collinear low power visible CW laser for principal alignment. Introduce variable (iris) diaphragms to aid alignment.
'All' visible wavelengths	Where multiple visible wavelengths are present, PPE may not be a viable option, but alternative approaches should have been explored anyway as PPE should always be the last resort.

A8.1.5 Where the alignment technique requires one person controlling release of the laser hazard (e.g. by blocking and unblocking the laser beam); whilst another (or others) view the beam. The latter 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.

A8.1.6 Where the alignment requires the simultaneous presence of open beam Class 3B and/or 4 laser beams for which there is no suitable eye protection available with sufficient visible transmission. Such situations occur, for example, with (i) 'white light' laser beams and (ii) generally where there are at discrete wavelengths at both ends of the visible spectrum), the following steps must be taken:

- Consider complete enclosure, using cameras and motorized controllers for beam alignment.
- If open beam work is inevitable, then use an optical filter in the beam path to select only a single or narrow wavelength range (e.g. for 'white light' laser beams consider the use of an acousto-optic tuneable filter).
- 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.

A8.2 Maintenance and service of laser equipment

A8.2.1 **Maintenance of laser equipment**

The following precautions should be considered for inclusion in the standing orders.

- Before commencing the maintenance, the manual for the laser system should be consulted, to identify the recommended procedure.

- In the case of anything other than routine maintenance, and/or when the laser manual does not give a procedure, the advice of the equipment supplier should be sought. Some procedures may go beyond the competence of the laser user.
- The risks associated with the procedure should be assessed, the control measures reviewed, and the conclusions recorded. In the case of some regular maintenance procedures there may be an existing protocol that is suitable and sufficient.
- Maintenance of class 1, 1C, 1M, 2, 2M and 3R lasers should not give access to class 3B or class 4 laser radiation. Maintenance of a class 3B laser should not give access to class 4 laser radiation.

A8.2.2 **Servicing carried out in-house**

Servicing may be carried out in-house. However, servicing may permit access to hazardous laser beams and significant non-beam hazards. For instance, introducing the pump laser into a frequency mixing crystal, can lead to an increased risk of laser radiation exposure. Consequently, servicing operations should only be performed in-house where:

- an optical radiation-specific risk assessment for the activity has been completed
- staff are suitably qualified and competent to undertake the work
- where relevant the manufacturer’s service procedures are available and have been consulted by those involved in the work
- a written procedure detailing how the work will be undertaken safely is available
- all necessary controls identified in the risk assessment have been implemented.

A8.2.3 **Service using external contractors**

Contractors must supply suitable and sufficient risk assessments and method statements for approval before work can proceed. Key considerations in assessing these documents include:

- does the risk assessment address the matters required of an optical radiation-specific risk assessment (see appendix 4)?
- has the risk assessment identified reasonably foreseeable accident scenarios?
- does the risk assessment include an assessment of foreseeable exposure including those that might result from identified accident scenarios?
- does the risk assessment identify suitable controls?
- are these controls reflected in the method statement (these should be specific activities with no freedom of choice, only specific instructions)?
- is the method of alignment clear and unambiguous?
- does the procedure require the service engineer to wear laser safety eyewear? If so, what is the specification and under what circumstances should it be worn? Does the engineer have eyewear of the appropriate specification available?

- are others (e.g. spectators) within the vicinity at risk?
- if the engineer is to work alone, have they provided details of a rescue plan to allow STFC staff to safely render assistance in the event of an accident or emergency?

N.B. The host organization retains a duty of care for all work on site even if waivers are given by the contractor.

A8.2.3.1 Before permitting an external laser service engineer to conduct service work on site the responsible LRO must:

- be satisfied that the person conducting the servicing is competent.
- establish the boundaries of the hazard area and, where appropriate, ensure the provision of appropriate PPE (laser safety eyewear etc.) for those in the area, and the means by which other personnel will be excluded.
- review the hazards to be exposed and the procedures to be followed during servicing activities. This review should place particular emphasis on beam control and termination (e.g. large area beam stops), beam visualisation techniques for alignment, and the transfer of control, especially where servicing takes place at a point remote from the equipment controls.
- review emergency procedures, including how the equipment would be isolated if there is a risk of injury from electrical or mechanical hazards, or how a fire would be extinguished if there are open class 4 laser beams. This may involve the presence of an STFC employee (perhaps the LRO) during the servicing, and the safety of that employee must then also be considered.
- review isolation procedures (e.g. Lock-Out-Tag-Out (LOTO)) for times when the service engineer may wish to leave the area.
- review the safety of the proposed service activity (i.e. are the measures proposed in the risk assessment and method statement adequate?)

A8.2.3.2 The LRO must issue a Permit to Work before work is allowed to proceed.

The LRO must impose a system of work for handing over the equipment to a service engineer and accepting it back when the work is completed. This handover arrangement should be formally documented, including an assurance from the engineer that all interlocks and other safety systems have been fully restored and the equipment is in a safe condition.

A8.2.3.3 After completion of the work the LRO must check:

- that the equipment has been restored to normal operation and is safe to use.
- that overrides and tools have been removed and protective covers replaced.
- that temporary warning signs have been taken down.
- that the log book for the equipment records the servicing operation, what was done and any consequent changes to the performance of the laser product.

A8.2.4 **Temporary set-ups**

Subject to a risk assessment evaluation the following relaxations to the control measures may be applied to laser enclosures erected for service activities. Such temporary set-ups may also be used for maintenance and trials/demonstrations involving high hazard and class 1(embedded) laser products.

A8.2.4.1 High hazard lasers may be operated outside a DLA provided either that all beams are fully enclosed or that a temporary laser hazard area is established with screens, coupled with laser warning signs and lights.

A8.2.4.2 Warning signs and lights may be used in place of interlocks to control access to the laser hazard area.

A8.3 Outdoor Laser Use

A8.3.1 Risk assessment

A8.3.1.1 An optical radiation-specific risk assessment must be made before class 1M , class 2M, class 3B or class 4 lasers are used outdoors.

A8.3.1.2 The risk assessment must include an estimate of:

- The ENOHD for the ‘raw’ laser beam.
- The potential of visible laser beams to dazzle or distract spectators and those working at heights or driving vehicles (e.g. motor vehicles, aircraft – both would be offences under the Laser Misuse (Vehicles) Act 2018).
- The potential for eye or skin injury from high hazard laser beams, including specular reflections.
- The potential injury from diffuse reflections from class 4 laser beams, including back reflections in the case of beams propagating through fog and rain.

A8.3.2 Approval

The OLRO must be provided with the following documentation/information:

- a suitable and sufficient optical radiation-specific risk assessment.
- a statement on the purpose and duration of the outdoor work.
- a description of the means of defining and enforcing the boundaries of the hazard control area (i.e. the area within which the class 1AEL or MPE, as appropriate, can be exceeded) for spectators and other persons present.
- the means by which the laser will be fixed in position and the beam manipulated, and any limitations placed upon the pointing of the laser beam.
- the means of protecting people within the hazard area
- the arrangements for the management of laser safety during initial setup.

A8.3.2.1 The OLRO and director must approve the risk assessment before outdoor laser work is allowed to commence.

A8.3.2.2 For laser displays and shows, guidance can be found in IEC 60825 Part 3 and the PLASA Guidance for the Safety of Display Lasers. If applicable the requirements of the PLASA guidance must be complied with and any statutory notifications must be made.

A8.4 Working with optical fibre systems

Guidance on fibre optic laser work can be found in BS EN 60825-2:2004 + A2:2010 *Safety of laser products - Part 2:Safety of optical fibre communication systems* though the standard strictly only applies to optical fibre communications systems. Nevertheless, many of the principles can be applied to other optical fibre systems. Moreover, there is increasing use of equipment from the fibre communications industry in research applications due to the ready availability of high power systems emitting at useful wavelengths.

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. BS EN 60825-2 introduces the concept of hazard levels to quantify the level of hazard that could become accessible for reasonably foreseeable events. Effectively, the hazard level assigned to any part of a fibre system is the maximum class of laser radiation that would become accessible should the foreseeable event occur. It essentially provides a means of identifying the potential hazard from a closed class 1 system; the concept of hazard levels and associated labelling requirements can be usefully applied to research laser systems.
BS EN 60825-2 requires that connectors, splice boxes and other parts that could emit radiation when opened should be labelled with a laser starburst pictogram, together with the hazard level and an associated standard warning phrase. It recommends the use of labels, sleeves, tags and tapes to effect this labelling.
The standard also introduces the concept of unrestricted, restricted and controlled locations in relation to hazard levels:

- unrestricted – the hazard level should not exceed 2M
- restricted – the hazard level should not exceed 3R
- controlled – the hazard level should not exceed 3B (for optical fibre communications systems automatic power reduction is implemented to prevent hazard levels exceeding 3B so this limit could be re-interpreted to 4 for a research environment)
-

Other aspects of BS EN 60825-2 dealing with automatic power reduction and restart conditions may be more difficult to implement in a research environment.

Good practice (all lasers)

A8.4.1 Do not stare with unprotected eyes or with any unapproved collimating device at the fibre ends or connector faces.

A8.4.2 Use only approved filtered or attenuating viewing aids

A8.4.3 Do not cleave ribbon fibres or use ribbon splicers without first assessing the hazard of exposure to multiple laser outputs.

A8.4.4 Do cover the output ends of fibres, either individually or collectively, when they are not in use.

A8.4.5 Do, when using optical test cords, connect the optical power source last and disconnect it first.

A8.4.6 Do dispose of fibre off-cuts (sharps) in an approved container.

High hazard lasers

A8.4.7 Before connecting High hazard 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. It would be good practice to label them with the hazard level.

Appendix 9. Laser control measures: designated laser areas

A9.1 Containment of the laser hazard

A9.1.1 The designated laser area (DLA) must present a robust physical boundary capable of adequately containing the laser radiation generated within it, thereby protecting those outside the boundary from hazardous exposure to laser radiation.

A9.1.2 Any parts of the DLA boundary through which it is reasonably foreseeable that class 3B or class 4 laser radiation could pass (e.g. gaps in doors, windows), and which could then reasonably present a laser hazard to a person outside the DLA must be covered during laser use.

A9.1.3 Illuminated warning signs must be displayed at every point of entry to the DLA.

A9.1.4 The warning signs should take the form of clearly visible lights or a monitor screen giving the status of the laser(s) inside. STFC currently operates two versions of warning signs; one of these formats must be adopted.

a. If coloured lights are used, then they can either conform to a ‘traffic light system’ of red/amber/green e.g.
   - (i) A red colour; implying ‘restricted access: laser ON’ i.e. that a high hazard laser within the DLA is energised and the beam has been released;
   - (ii) An Amber colour; implying ‘restricted access: laser ON’ but that the high hazard laser within the DLA exists only within a small, specific zone within the DLA (such as the focal point of a beamline).
   - (iii) A green colour; implying ‘SAFE to enter’. This is the default colour to show that the monitor and/or lights are active and that no laser protective eyewear is required.

b. Alternatively, a red colour lamp stating ‘Laser On’ implying that a high hazard laser within the DLA is energised and the beam has, or has the potential to be, released. If the lamp is not lit, it implies that it is ‘SAFE to enter’.

A9.1.5 If practicable the laser laboratory should have a high level of illumination.

A9.1.6 Windows should be kept to a minimum and may need to be covered or protected. Preferably, the covering should be a rigid fixed panel.

A9.1.7 Walls, ceilings and fittings should be painted with a light coloured matt paint to enhance illumination and minimise specular reflections. Reflecting surfaces such as the use of glass-fronted cupboards should be avoided.

A9.2 Access

A9.2.1 Lasers inside a designated laser area (DLA) must be linked into the external interlock chain provided within the DLA, either using the remote interlock connector on the laser or an external safety shutter (see A7.4 Control of Access).

A9.2.2 Where lasers within a designated laser area (DLA) are operated with all high hazard beams fully enclosed at all times, including during service (or servicing takes place off-site), there is no requirement for a room interlock system to be provided or for the laser to be connected to one where it is provided.

A9.2.3 Where lasers within a designated laser area are predominantly operated with all high hazard beams fully enclosed, but occasionally operated with the enclosure open or removed for the purposes or alignment or adjustment, then the room interlock system may be adapted to provide an override facility. This should operate such that the room interlock system can be overridden when the high hazard beams are enclosed and enabled when the enclosure is open or removed. The override should be key (rather than code) operated where possible and its status should be clearly indicated.

A9.2.4 Where the use of overrides is absolutely essential on technical grounds there must be a detailed written justification that demonstrates why the override is required. In general, if access into and out of an area is necessary when enclosures may be removed or open, then the room interlock system can be used to control beam hazards through the use of one or more shutters.

A9.2.5 If their use is justified, interlock overrides at access doors are only permitted under the following circumstances:

- Overrides that can be operated only from within the DLA must be located near the door. Controls must be installed to prevent the escape of hazardous levels of laser radiation when the door is opened.
- Overrides that can be operated from outside the DLA must be of a coded or key operated type with access restricted to authorised personnel. Secondary screening (e.g. labyrinth) within the DLA must ensure that the laser hazard zone does not extend outside the door when it is opened. Exceptionally, where space does not permit a labyrinth entrance, then during activities (e.g. beam alignment) when a beam could emerge through the open door:
  - (i) a warning light should be placed adjacent to the door to indicate the laser hazard status;
  - (ii) a prominent temporary warning sign should be placed near or on the outside of the door during alignment;
  - (iii) the door should be locked but with a key for emergency access (e.g. a knob to lock the door on the inside and a key behind a break glass cover on the outside).

A9.2.6 Access doors, both those at the DLA boundary and any within the DLA that divide laser hazard areas from one another or that separate laser hazard from hazard-free areas, should be self-closing.

A9.3 Layout

A9.3.1 The layout of the facility should take account of the need to undertake alignment and other adjustment work.

A9.3.2 High hazard laser beams that are likely to be exposed during alignment or adjustment should point away from and not towards the DLA entrance.

A9.3.3 If more than one high hazard laser is operated within the same DLA, consideration will need to be given to how alignment or other open beam work can temporarily be carried out on one system without putting the operators of other systems at risk. The risk assessment for the open beam work must consider the risks to others who may be in the DLA and should lead to the selection of effective control measures. Options that should be considered include:

- whether it is reasonably practicable to carry out open beam work with non-hazardous or low hazard beams
- where it is essential to carry out open beam work with high hazard beams, there is a legal requirement to demarcate the area, restrict access and display warning signs
- where it is essential to carry out open beam work with high hazard beams, it may be feasible to temporarily prevent access to the entire DLA by those not involved in the work with the open beams. It would not be acceptable to require all working in the area to wear laser protective eyewear
- where it is essential to carry out open beam work with high hazard beams, the use of curtains or temporary screens together with appropriate warning signals may be used to temporarily restrict access to the immediate vicinity of the installation with open beams
- the positioning of curtains and screens must be arranged so that it is not necessary for those not involved in the open beam work to move through an area in order to gain access to their own work area. It should be possible to independently access each potential hazard area from a ‘safe area’
- curtains/screens and warning signs together with local supervision should normally be sufficient to restrict access to the hazardous area, but consideration could be given to supplementing these measures with pressure pads or light beams to detect intrusion into the area and terminate the laser beam
- the standing orders must include specific requirements for the open beam work including any arrangements for restriction of access and any procedures to be followed for work within the hazardous area, including the specification for any laser protective eyewear that is required.
- See also appendix 11 for information on additional marking of laser safety eyewear to avoid wrong selection.
- If there is likely to be a requirement for entry or exit from the hazard area during open beam work the arrangements for this must also be detailed in the standing orders

A9.3.4 SHE Group must be consulted about the provision of suitable fire fighting equipment and adequate means of escape from the DLA.

A9.3.5 Any areas within the DLA in which non-laser (or low hazard / low risk laser) activities take place, such as computer work, clean rooms or sample preparation rooms, must be partitioned off from those where high hazard open beams may be in use. It should not be necessary to pass through the hazard area in order to enter or exit these areas. The use of chairs in a DLA, if essential, must be restricted to screened off areas where there are no hazardous beams.

A9.3.6 As stated in A9.3.5, there should normally be a safe route to and from any work area where there is no laser hazard. Exceptionally there may be one or more small rooms or areas off a DLA with no other access route. In these cases, the additional rooms must form part of the DLA and should be subject to the same restrictions when a high hazard laser beam is exposed. However, additional controls are required to ensure that nobody working in such an area is inadvertently overlooked prior to generating a hazardous exposed beam:

i. warning signals must be installed in each area to give warning when a hazardous situation is about to be created (this should include an audible warning) and a distinguishable warning when the hazardous situation exists
ii. a means of terminating hazardous emission must be provided in each area
iii. the standing orders must require a search to be made of all areas prior to releasing a hazardous beam

A9.3.7 If, in addition to emergency stop buttons, emergency laser-off buttons are provided in the DLA, they must be colour coded with a clearly visible black on yellow laser hazard triangle on a red background. Operation of an emergency laser-off button must immediately terminate accessible laser radiation from high hazard lasers in the DLA. This could be achieved, for example, by breaking the laser external interlock circuit or closure of laser safety shutters positioned in the proximity of the laser apertures, as described in A7.5.2.25.

A9.4 Administrative controls

A9.4.1 Standing orders must be readily available within the DLA.

A9.4.2 Visitors

- Visitors may enter a DLA provided there are no open hazardous beams. This could be either because:
  - all beams are fully enclosed
  - beams have been attenuated to non-hazardous levels
  - there are no beams present
- If there are genuine reasons for a visitor to enter a DLA whilst hazardous open beams are present (for example as part of training in a particular procedure), they should be subject to the same controls as anyone routinely working in the area.
- A maximum numbers of visitors should be established and consideration given to the need for additional persons to be present to help supervise the visitors.

Appendix 10 Labels and signs

All health and safety signs and symbols used must comply with the HSE Signs and Symbols Regulations 1996. Signs and Symbols Regulations

Appendix 11. Selection and use of laser safety eyewear

- 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.**
- It should be noted that for **wavelengths outside the retinal hazard region** (400 nm – 1400 nm) the exposure limit values are the same for the eye and the skin and so **if laser protective eyewear is required then skin protection will also be required.**
- Laser Protective Eyewear is available from a number of laser component suppliers and is usually expensive. However, if it is required then it is worth taking time to source eyewear that will be comfortable to wear and will provide the best possible vision; uncomfortable eyewear with a restricted field of view is unsuitable for the regular laser user.
- It should be noted that in order to be suitable personal protective equipment as defined in the Personal Protective Equipment at Work Regulations 1992 (as amended), laser protective eyewear must comply with the requirements of the Personal Protective Equipment Regulations 2002. PPE Regulations 2002. In practice this means that it must conform to one or both of the two harmonised laser protective eyewear standards: BS EN 207 and BS EN 208.
- In order to be correctly specified, eyewear must be selected using the procedures in annex B of the relevant standard. It is likely that eyewear will also be marked with optical density for use in countries outside the European Union: these markings cannot be used to specify eyewear used in the UK.

Laser safety eyewear for general use must conform to BS EN 207 *Personal eye protection equipment – Filters and eye protectors against laser radiation (laser eye-protectors)*.

Appendix 12. Medical examinations, health surveillance, accident and incident reporting

A12.1 Incident reporting

Significant occurrences in the eyes possibly relating to laser damage include: pain or discomfort, blurring of vision, loss of ability to read small print, or any unusual appearance or sensation, such as persistent ‘after-images’ following exposure to high intensity light in the visible range.

A12.1.1 The procedure for accidents must be included in the standing orders for the laser activity.

A12.1.2 Any incident that results in exposure to laser radiation must be immediately reported to management (see SHE Safety Code 5 Incident Reporting and Investigation).

A12.1.3 STFC occupational health will arrange for a medical examination if:

- there is reason to believe any person has been exposed in excess of an exposure limit value
- for eye exposures this examination should be carried out within 24 hours of the exposure
- any person is found through health surveillance to have an identifiable disease or adverse health effect to the skin, which in the opinion of a medical professional could be the result of exposure to artificial optical radiation

A12.1.4 STFC occupational health must ensure that a doctor or suitably qualified person:

- Informs the person of the results of the examination
- provides advice on whether ongoing health surveillance is appropriate
- provide ongoing health surveillance if, in the opinion of the medical examiner, this is appropriate
- ensure it is kept informed about the outcome of any ongoing health surveillance that is carried out

- The OLRO for the area in which the incident occurred must review the risk assessment

A12.1.6 In the event of a failure of a protective measure that could have led to an incident, laser emission must be terminated until a full assessment of the failure has been made and corrective action taken. The incident must be reported to the LRO and management notified as per local procedures (see SHE Safety Code 5 Incident Reporting and Investigation).

A12.1.7 In the unlikely event of an eye injury caused by an individual staring down the beam of a lower powered laser the emergency arrangements for high hazard lasers must be followed (A12.1.2 and A12.1.3).

A12.2 Health surveillance

Occupational health must arrange health surveillance if a risk assessment indicates that there is a risk of adverse health effects to the skin of any employee as a result of exposure to artificial optical radiation. This is most likely to arise from exposure to ultraviolet radiation.

A12.3 Return to work

Anyone returning from absence due to injury or disease of the eyes must notify occupational health before resuming work with lasers.

Appendix 13. Additional guidance on risk assessment for laser use

The requirements for conducting and documenting risk assessments are described in section 3.2 of STFC Safety Code 6 Risk Management. SC06-Risk-management.Contractors may use their own format for risk assessments but they must meet the standards laid out in this code.

An optical radiation-specific risk assessment is required for all high hazard and low hazard laser work, and for use of low risk category lasers on those exceptional occasions where the requirements of this code as set out in Appendix 7 cannot be met.

The laser radiation hazard is unique: with its long range, the ease with which the hazard path can be redirected, its speed of impact and immediacy of injury and the severity of the injury to the eyes. Also unique is the wide range of control measures available to deal with the risk.

Appendix 14. Laser safety documentation

The following table summarises laser safety documentation that may be required for different classes of laser:

Class	1C, 1M, 2 & 2M (coll)	3R	3B & 4	Embedded
Generic risk assessment	√			√
Optical radiation-specific risk assessment		√	√	
Standing orders		√	√	√
Laser registration form	√	√	√	√
Equipment maintenance and service documents			√	√
Permit to Work on laser equipment			√	√
Letter of appointment of OLRO, LRO, LNP etc	√	√	√	√
Training records	√	√	√	√

A14.1 Risk Assessments
Generic risk assessments (meeting the requirements of the Management of Health and Safety at Work Regulations 1999) are required for all class 1 (embedded), class 1C, class 1M, class 2 and class 2M lasers.

Optical radiation-specific risk assessments (meeting the requirements of the Control of Artificial Optical Radiation at Work Regulations 2010) are required for all class 3R, class 3B, and class 4 lasers. Details are provided in Appendix 4.

A14.2 Standing Orders

14.2.1 Standing Orders are required for all class 3R, class 3B and class 4 laser products. The Orders must include the following information:

- A signature and date of issue.
- A brief description of the area and/or equipment to which they apply.
- An laser-centric overview of the area, highlighting any important instructions (e.g. 'the use of personal protective equipment during normal operation is always required'):
- The type, maximum and typical power or energy, wavelength and classification of lasers involved.
- Identification of laser hazard area(s).
- Basic engineering and administrative controls.
- Need and form of PPE.
- Non-beam hazards.
- Contact details of the LRO and deputies.
- A table of beam and non-beam hazards, listing the source of the hazard and reference to any relevant SHE safety codes.

- <u>Emergency procedures</u>, identifying isolation valves and switches, E-stops, etc., procedure for summoning assistance (with names and numbers), making safe prior to evacuation of the building.
- <u>Laser accident procedures,</u> identifying the most appropriate ophthalmic Accident and Emergency Department which deals with eye injuries.
- <u>Procedures for normal operations</u>. Include checks of engineering controls, the use of PPE, if required, and, together with general descriptions of what is involved in normal operation, a note of any departures from the guidance in this code, any restrictions in the use of lasers and any operations that do not conform to the manufacturer's requirements or guidance, or that are otherwise non-standard. Normal shut-down procedure should be described. See Appendices 5 and 6.
- <u>Procedures for alignment.</u> Procedures for alignment should be covered; see Appendix 8.
- <u>Procedures for other maintenance and service activities</u>. Requirements for safety checks (interlocks etc.) should be included under 'maintenance'. Servicing procedures should address the establishment of temporary hazard areas and use of external service engineers; see Appendix 8.

14.2.2 Standing Orders must link with the risk assessment i.e. where a control is specified in the RA it should appear in the Standing Orders and *visa versa*.

A14.3 Registration form

With the exception of class 1 consumer products, all class 1 (embedded), class 1C, class 1M, class 2M, class 3R, class 3B and class 4 devices should be identified and a laser inventory maintained. There may be occasions when this is not practicable because the laser products are in fact just electrical components. In circumstances like this it should be the use of particular types of laser device that should be recorded. It is not necessary to note the use of intrinsic class 1 devices, class 2 laser pointers or the use of embedded lasers in consumer products such as DVD players and laser printers.

The registration document must include the following information:

- The identification of the laser product e.g. the name of the makers of the equipment, serial or asset numbers. Where appropriate, the name can be used to refer to a facility comprising several integrated laser units;
- The location of the laser product (e.g. building and room number).
- The type of laser equipment (e.g. Q-switched diode pumped Nd:YAG).
- The laser output (e.g. wavelength(s) plus maximum average and peak power, pulse energy and duration).
- The beam size and beam divergence
- The assigned class of the laser equipment (for class 1 (embedded) laser equipment, note 'embedded' under 'type of laser equipment' and list the embedded laser characteristics under 'laser output'.

- A note of any engineering features appropriate to the class of the laser product that have been removed, overridden or otherwise not used.
- A note of any limitations imposed in the use of the product.
- The person named as responsible for the laser.

A14.4 Safety systems test and maintenance report

A test and maintenance report should be maintained identifying all the enclosures, interlocks and other engineering controls for laser systems, indicating that they have been tested and actions taken. These should be dated and signed and a note made of the due date for the next test.

A14.5 DLA test and maintenance report

A test and maintenance report should be maintained identifying all the safety interlocks and guards and any other engineering safety controls for the DLA, indicating that they have been tested and actions taken. These should be dated and signed and a note made of the due date for the next test.

A14.6 Equipment maintenance and service reports

For equipment that needs to be kept properly serviced and maintained for safety reasons, separate maintenance and service records need to be kept. The maintenance record should follow the recommendations of the user manual and should simply note the date that maintenance was carried out, what was done, any actions taken and by whom, together with the due date for the next test. The external service engineer should complete the service record provided by the manufacturer after each visit.

A14.7 Permit to Work

The Permit to Work must address all hazards including laser radiation. With regard to the assessment the laser radiation hazard must include consideration of the following:

a. The use of screens, coupled with laser warning signs and lights to define a temporary laser hazard area;
b. Control of access to the laser hazard area;
c. The introduction of a system of work for handing over the equipment (if applicable) and accepting it back when the work is completed;
d. (For service activities) a check to ensure that tools have been removed, interlocks returned to normal operation and covers replaced.

A14.8 Letters of appointment to laser safety positions

A14.8.1 Persons appointed under the terms of this code must be competent to carry out the duties assigned to them. This means that, with respect to these duties, they must be judged to have sufficient:

- Appreciation of the way in which laser radiation propagates in free space, the effect of optical components on this propagation, and the manner in which laser radiation can be reflected, refracted, scattered, transmitted and/or absorbed;
- Experience of work in connection with lasers;
- Training in the relevant operating procedures;
- Awareness of the hazards to the eyes and skin that may arise during use, and

- Knowledge of this code and experience in the use of appropriate hazard control procedures and in the use of personal protective equipment.

Formal or on-the-job training prior to appointment may be necessary, but is not a prerequisite for persons with adequate experience.

A14.8.2 Letters of appointment must clearly define the scope of duties and must be dated. The recipient must be requested to acknowledge their acceptance clearly in writing.

A14.9 Training records

The requirements for this documentation are specified in SHE Safety Code 10 Provision of Safety, Health and Environmental (SHE) Training.

Appendix 15. Laser Safety Checklist

The checklist below was developed for use by the LRO to help identify shortcomings in laser safety and areas of deviation from this code that need to be addressed in the risk assessment. It can also be used by the OLRO during routine inspections of laser areas. **However, it does NOT claim to be comprehensive, nor is it designed as a checklist for compliance to the code.**

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)? **YES/NO**
   Points to consider:
   Laser products need to bear signs conforming to BS EN 60825-1.
   If commercial laser products have been modified their classification should be checked.

2. Is the use of optical viewing permitted within the laser area? **YES/NO**
   If YES, please summarise the precautions taken to preventing hazardous levels of laser exposure.
   State if Class 1M and 2M lasers are in use.

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

4. Are there normally Class 3B and Class 4 open beam paths in the laser area? **YES/NO**
   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.
   b. All beam path components that generate errant beams are locally enclosed.
   c. All beam paths are properly terminated.
   d. All unprotected open horizontal laser beams lie above or below normal eye level.
   e. All lasers and optical components on the beam line are securely mounted.
   f. Shiny surfaces (including jewellery) are not permitted around laser beam paths.
   g. Laser beam paths do not cross walkways.
   h. All upwardly directed beams are shielded to prevent human exposure.
   i. Laser sources and beam paths are kept under the control of competent persons
   j. Information of the current laser hazard is clearly displayed at each and every point of access to the laser area.
   k. Low level lighting is provided for ‘lights-out’ operations

l. Persons at risk of exposure to the laser radiation have received adequate laser safety training and instruction.
m. A safe method of beam alignment is provided.
n. A visible or audible warning of the potential laser hazard is provided.
o. Unauthorised persons are prevented from gaining access to the laser area.
p. Precautions are in place to safeguard visitors entering the laser area.
q. Multiple wavelengths.
r. Laser safety eyewear is provided.

If NO to any of the above, please summarise precautions that are taken to control these activities:

5 Do all 3B and 4 laser operations take place within a Designated Laser Area?

YES/NO

If YES, please indicate which of the following control measures below are in place:

a. The DLA presents a robust physical boundary that isolates laser radiation from personnel outside the area.
b. The DLA boundary (including windows) is opaque at the laser wavelengths and without gaps.
c. Points of entry from hazard-free to laser hazard areas within the DLA (e.g. a door or opening from a room for changing or data collection) carry current laser hazard information.
d. All hazards are clearly identified at all access points to the DLA.
e. Where different laser wavelengths are accessible in the DLA at different times, accurate status information is displayed at all access points.
f. The laser hazard cannot extend beyond the DLA if a door into the DLA is opened.
g. The laser hazard is automatically terminated if an unauthorised person enters the DLA.
h. The laser hazards from separate laser experiments within the DLA are isolated and information of the current laser hazard within a sub-divided area is clearly displayed at points of access.
i. Independent non-laser activities are prohibited within the DLA.
j. Prior warning is provided if laser hazards are introduced from outside the DLA.
k. Laser beams entering the DLA from other (adjacent) areas are under sole and overriding control from within the DLA.
l. Temporary restrictions are imposed for servicing and other non-routine activities within the DLA

If NO to any of the above, please summarise precautions taken to control these activities:

YES/NO

6 Is laser safety eyewear provided?

If YES, please which of the following control measures below are in place:

a. Laser safety eyewear provides sufficient protection for each accessible hazardous laser wavelength (including wavelengths that could be generated by non-linear effects)

b. Laser eyewear is properly stored and maintained in good condition.
c. The eyewear clearly identifies the laser/area within the DLA it is suitable for.
d. Lighting levels are appropriate for the visual transmission of the eyewear.
e. The colours of warning signs and lights are effective when viewed through the eyewear.

If NO to any of the above, please provide a brief justification:

7 Are there non-beam hazards associated with laser use (including during servicing and maintenance)? **YES/NO**

If YES, are control measures in place to address the following hazards:

a. Fire hazard (with Class 4 laser beams).
b. Laser generated fume hazard.
c. Electrical hazards.
d. Explosion hazard.
e. Secondary and collateral radiation.
f. High-pressure gas hazard.
g. Trip hazards and sharp corners at head height.
h. Other non-beam hazards.

Appendix 16 Definitions

Accessible Emission Limit (AEL)
The radiation level to which human access is possible, which must not be exceeded for a given class of laser. It is generally expressed as the total power or pulse energy output of the laser through a limiting aperture.

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.

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 1C laser products
Laser product designed explicitly for contact application to the skin or other non-ocular tissue and has safeguards that prevent leakage of laser radiation in excess of the AEL of class 1. The laser product can be assigned to class 1C only if it also complies with a set of safety requirements for class 1C laser products that can be found in an applicable IEC vertical standard.

Class 1 (embedded) lasers
Laser products that contain a class 3B or class 4 laser but which, because of engineering features limiting accessible emissions, have been assigned as class 1. However, if these lasers are to be aligned, modified or serviced on site then additional precautions need to be taken as laid out in Appendix 8.

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. The output laser beam is reasonably collimated and has a large diameter, such that harmful exposure can occur under viewing with a telescope or binoculars.

Class 2 laser products
Laser products emitting low levels of visible radiation (i.e. in the wavelength range 400 nm to 700 nm) 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 400 nm to 700 nm) 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. The output laser beam is reasonably collimated and has a large diameter, such that harmful exposure can occur under 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 do not normally 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 400 nm to 700 nm) 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.

Continuous wave (CW)
The description used for a laser which produces a constant, as opposed to a pulsed laser output.

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.

Diffuse reflection
The scattering of laser radiation from a rough surface.

Employee at particular risk
Any employee or group of employees whose health is at particular risk from exposure to artificial optical radiation.

Exposure limit value
Statutory limits on the exposure of employees (see 2006/25/EC). They represent the maximum levels to which the eye or skin can be exposed without risk of injury.
Almost identical to the maximum permissible exposure values in BS EN 60825-1:2007, but different to those in BS EN 60825-1:2014. As legal limits on exposure the exposure limit values take precedence over the maximum permissible exposures.

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.

Hazard level
The classification of fibre optic output at locations where interruption of the fibre might reasonably be foreseen, as described in BS EN 60825-2 'Safety of laser products: Part 2- Safety of optical fibre communication systems'. Hazard levels use the same nomenclature and warnings as is used for laser classes.

High hazard lasers
Class 3B and 4 laser products.

Human access
Capability for part of the human body to meet hazardous laser radiation.

Inherently safe
Safe by virtue of its inherently low emission of laser radiation. This contrasts with the emission from a Class 1 (embedded) laser product which is safe by engineering design.

Intra-beam viewing
The exposure of the eye to all or part of a laser beam, either directly or after specular reflection.

Irradiance
The radiant power incident on an element of a surface divided by the area of that element (Wcm^{-2}). For normal incidence irradiation, this term is equal to the beam intensity at the surface.

Laser
(As defined in EN 60825-1) a device that can be made to produce or amplify electromagnetic radiation in the wavelength range from 180 nm to 1 mm primarily by the process of stimulated emission. ELV/MPE values do not exist for wavelengths outside this.

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 nominated person (LNP)
A competent person appointed to carry out specified laser work.

Laser product
Any product or assembly of components that constitutes, incorporates or is intended to incorporate a laser or laser system.

Laser protection adviser (LPA)
A competent person, knowledgeable and experienced in laser safety matters, who is called upon to assist the OLRO in the performance of his or her duties. The LPA may be an employee or an external consultant.

Laser responsible officer (LRO)
A competent person appointed to take on specified duties and supervisory responsibilities in respect to a laser area or activity.

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

Low hazard lasers
Class 3R laser products

Low risk lasers
Class 1M, class 2, class 2M, class 1C and class 1 (embedded) laser products (including alignment lasers).

Maximum permissible exposure (MPE)
That level of laser radiation to which, in normal circumstances, persons may be exposed without suffering adverse effects. MPE values for eyes and skin exposures represent the maximum levels to which the eye or skin can be exposed without consequential injury. They vary with the wavelength of the radiation, the pulse duration or exposure time, the tissue at risk and, for visible and near-infrared radiation, the size of retinal image. The values are specified in BS EN 60825-1:2014 and forming the basis from which accessible emission limits for each laser class are defined. Similar to ELVs, but not identical.

Maintenance
Adjustments or procedures specified in the user information provided by the manufacturer/supplier with the laser product, which are performed by the user for the purposes of assuring the intended performance of the product. It may require access within the laser enclosure, but should not exposure the user to hazardous laser beams.

No risk lasers
Inherently class 1 or exempt laser products, and class 1 consumer products containing embedded lasers of higher class (e.g. laser printer, photocopier, compact disc or DVD player or recorder)

Nominal ocular hazard distance (NOHD)
The shortest distance (generally measured from the position of the laser source) at and beyond which a laser beam is safe for unaided viewing as the beam remains below the appropriate corneal ELV or MPE

Overall laser responsible officer (OLRO)
A competent person appointed by the authority of the director or equivalent, to oversee the control of laser radiation hazards and to be responsible for the implementation of this code with respect to a defined area of laser installations and/or equipment.

Personal protective equipment (PPE)
Protection that is worn or carried. This includes laser safety eyewear and protective clothing, such as gloves. Viewing windows and screens are not PPE.

Protective housing
Those portions of a laser product (including a product incorporating an embedded laser) that are designed to prevent human access to laser radiation in excess of the AEL prescribed for the product. (The laser product manufacturer generally installs the protective housing.)

Pulsed laser
(As defined in EN 60825-1) a laser that delivers its radiation output in the form of pulses with duration less than 0.25s, either singly or a train of pulses.

Pulse repetition frequency (PRF)
The number of pulses per second emitted by a pulsed laser.

Radiance
The radiant power per unit area of a radiating surface per unit solid angle of emission ($Wsr^{-1}m^{-2}$).

Radiant exposure
The radiant energy incident on an element of a surface divided by the area of that element (Jm^{-2}).

Specular reflection
Reflection from a shiny surface, such as a mirror.

Standing orders (SO)
A set of formal written instructions that address all hazards and procedures for a specified location or piece of laser equipment.

Appendix 17. Training

Role	Initial Training	Refresher	Frequency	Comments
LRO/OLRO	LRO/OLRO Initial training (1 day) and LNP Basic Laser Course (1/2 day)	LRO/OLRO Refresher training (½ day)	3 years	Training to be consistent with TR 50448 'Guide to levels of competence required in laser safety' plus a review of current laser safety standards.
Courses Available:	Contact your local SHE group			
LNP	**high hazard** laser users (class 3B and 4) and low hazard laser users: Basic Laser Course (½ day) or **Operation of High hazard Lasers, Low Risk** and **No Risk** laser users (): as a minimum a verbal briefing from LRO appropriate to level and range of duties being undertaken and /or the Basic Laser Awareness course (on-line)	**high hazard** laser users (class 3B and 4) and low hazard laser users: Basic Laser Course (½ day) or **Operation of High hazard lasers, Low Risk** and **No Risk** laser users (): as a minimum a verbal briefing from LRO appropriate to level and range of duties being undertaken and /or the Basic Laser Awareness course (on-line) Where operation of = remote	3 years	Training to be consistent with TR 50448 'Guide to levels of competence required in laser safety' for laser users. Training must cover: • exposure limit values • why and how to detect adverse health effects to the eyes or skin • circumstances under which employees are entitled to health surveillance • proper use of personal protective equipment Training should be supplemented with local training that must cover: • the control measures in place in the area • the significant findings of the risk assessment,

	Where operation of = remote operation outside the DLA.	operation outside the DLA.		including the results of any measurements • safe working practices
Courses Available:	Contact your local SHE group			
Users of Low Risk lasers	Verbal briefing from LRO	Verbal briefing from LRO	3 years	Training should cover the effect of laser radiation on the eye and the importance of preventing direct eye exposure.
Courses Available:	None specific to Low Risk laser use			

Formal or on-the-job training for any of the above positions prior to appointment may be necessary, but is not a prerequisite for persons with adequate experience.

Appendix 18 Bibliography of laser safety references

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EN 60825-2: 2004 + A2:2010. Safety of laser products. Part 2: Safety of optical fibre communications systems.
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EN 207: 2017. Filters and Equipment used for Personal Eye-Protection Against Laser Radiation
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PLASA Guidance for the Safety of Display Lasers
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Optical Radiation Directive, published in the Official Journal of the European Communities on 27 April 2006 (Ref: L114) "Directive 2006/25/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (artificial optical radiation)"
Laser Safety Management. Kenneth Barat. CRC, Taylor & Francis, 2006 ISBN: 0 824 72307 4 http://www.laserinstitute.org/PDF/pubs/pub209toc.pdf
Non-binding guide to good practice for implementing Directive 2006/25/EC 'Artificial Optical Radiation', June 2010.

Appendix 19 Document Retention Policy

Records Established	Minimum Retention Period	Responsible Record Keeper	Location of Records	Comments / Justifications
Risk Assessments /Local Rules	Current + 5 Years	Line Management	Evotix Assure	SHE Group Maintain Evotix Assure Facility
Local Rules	Current + 5 Years	Line Management	Local Record Systems	
Appointments:				
Overall Laser Responsible Officer	Most Recent	Director	SHE Directory	Appointment Letter
Laser Responsible Officer	Most Recent	Line managers	SHE Directory	Appointment Letter
Laser Nominated Person	Most Recent	LRO	SHE Directory	Appointment Letter