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A7.2.3.2 If a key switch is provided, this must be withdrawn and stored in a safe place when the product is not in use.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