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)
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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.