This Information Sheet provides guidance regarding the arrangements that Colleges / Professional Services must put in place to ensure the safe use of lasers. The document should be read in conjunction with the University's Safe Use of Lasers Policy Standard, developed to ensure compliance with the Artificial Optical Radiation at Work Regulations.

WHAT ARE LASERS?

A laser is a man-made, high intensity optical radiation light source. Lasers produce an intense monochromatic, narrow beam of light by emitting light through a process of optical amplification based on the stimulated emission of electromagnetic radiation. Laser wavelengths span the ultraviolet to the far infrared in a continuous or pulsed wave. The term "laser" is an acronym for *"light amplification by stimulated emission of radiation".*

ARE LASERS RADIATION?

Lasers are a form of non-ionising radiation, a type of electromagnetic radiation with insufficient energy to ionize atoms or molecules ie completely remove an electron from an atom or molecule.

RISKS FROM LASERS

In general the greatest risk is to the eye with the more powerful the laser Class, the closer to the beam, and the longer the laser stays in the same eye area, the greater the chance of eye damage.

Whilst laser eye injuries are rare, all laser beams should be treated as potentially hazardous as the coherence and low divergence of the light means the eye can focus it into an extremely small spot on the retina, resulting very quickly in localised burning and permanent damage. Certain laser Classes can cause cataracts or even boiling of the vitreous humour, the fluid in the eyeball. Infrared and ultraviolet lasers are particularly hazardous, as the body's "blink reflex", which can protect an eye from excessively bright light, works only if the light is visible.

In addition, some lasers, because of their thermal properties can cause tissue damage (ie skin burns) as well as creating the potential for fire, explosion and noxious or hazardous fumes and vapours if used for welding or cutting. Indirect effects also require consideration. For example, the dazzle effect temporarily affecting vision and potential for surrounding surfaces to reflect the laser.

LEGISLATION: ARTIFICIAL LIGHT SOURCES

The Control of Artificial Optical Radiation at Work Regulations came into effect on 27th April 2010. The Regulations require employers to protect the eyes and skin of workers exposed to hazardous sources of artificial optical radiation. The use of lasers falls under the remit of these Regulations.

UNIVERSITY RESPONSIBILITIES

The University will appoint a suitable qualified and / or experienced Laser Safety Officer (LSO) who will advise the University on all safety matters concerned with the use of lasers. The LSO will be supported locally by the relevant Project Supervisor and, in some cases, dependent on the number of lasers operated by a College / Service a local Laser Protection Supervisor (LPS).

GENERAL COLLEGE / PROFESSIONAL SERVICE REPONSIBILITIES

Colleges and Services have the following core obligations under the Control of Artificial Optical Radiation at Work Regulations to ensure no harm occurs because of the use of lasers. Full details of responsibilities are available in the *Safe Use of Lasers Policy Standard*:

- Identify and establish Class of lasers operated within their area of control.
- Assess the risk to operators and others posed by these.
- Put in place appropriate controls to reduce the risk of harm eg engineering controls, Risk Assessments, Local Rules.
- Provide appropriate information, instruction and training to affected persons as required.
- Ensure lasers inspected and maintained by a competent person as necessary.

<u>NOTE:</u> ADDITIONAL REQUIREMENTS APPLY IF OPERATING CLASS 3R, 3B OR 4 LASERS

THE ACCESSIBLE EMISSION LIMIT (AEL)

The AEL is the maximum level of laser radiation a laser can emit and be accessible at any time after manufacture. The AEL depends on the wavelength, exposure duration, viewing conditions and specifies the maximum output within each Class of laser. Examples of the AEL for a He-Ne laser emitting a narrow beam in continuous wave (CW) mode at 633nm are as follows:

Class 1 and 1M	0.39 mW
Class 1C	Should have engineering controls to prevent leakage of laser radiation in excess of the AEL of Class 1
Class 2 and 2M	1 mW
Class 3R	5 mW
Class 3B	500 mW

These limits also apply to other narrow beam CW lasers operating in the wavelength range 400-700nm except for Class 1 and 1M devices where there are further restrictions for wavelengths <500nm. See BS EN 60825-1: 2014 for full details.

MAXIMUM PERMISSIBLE EXPOSURE LEVELS (MPES)

MPEs should be calculated for all Class 3R, 3B / 4 laser work as part of the Risk Assessment. The Project Supervisor and LSO can assist, using calculations and examples provided by the *BSi publication PD IEC TR 60825-14:2004 Safety of Laser Products: A User's Guide.*

MPEs represent the maximum level of laser radiation human tissue can be exposed without suffering injury or damage. MPEs reflect the current knowledge in relation to the hazard posed by laser radiation to different biological tissues. MPEs exist for two different scenarios:

- Direct ocular exposure - intrabeam viewing
- Exposure of the skin

MPEs vary according to wavelength, exposure time, tissue at risk and, for visible and near infra-red radiation, the size of the retinal image. Example MPEs for a CW He-Ne laser operating at 633nm are:

- Intrabeam viewing - 1 mW.cm-2
- Skin exposure - 200mW.cm-2

LASER CLASSIFICATIONS

Lasers are grouped into several Classes depending on the potential for the beam to cause harm. The hazard and hence 'Laser Classification' depends on the wavelength, power, energy and pulse characteristics. The Class can help determine what safety controls are required when using the laser. The Table on the following page provides further details.

Class	Power	Basis for Classification	Basic Controls
Class 1: Laser Inherently Safe visible/non visible		Output below level it is believed eye damage occurs. Safe under reasonably foreseeable operation, including long-term direct intrabeam viewing, even if using optical aids	Protective controls not required for normal use. (NOTE: Special precautions may be needed for service work on embedded lasers)
Class 1: Laser Product safe as long as not modified		Contains a higher class laser but access to the beam is controlled by engineering means eg laser printer	As Class 1 above
Class 1C: Laser Product		Designed explicitly for contact application to the skin or non-ocular tissue eg hair removal products	During operation, the ocular hazard is prevented by engineering means. The accessible emission is stopped or reduced to below Class 1 when the applicator is removed from skin / tissue contact
Class 1M: Safe Without Viewing Aids		Large diameter beam so only a small part of the whole beam can enter the eye. As Class 1, safe for the naked eye under reasonably foreseeable operation. However, harm can occur if beam viewed using magnifying optics	**PREVENT** direct viewing with magnifying optics
Class 2: Low Power visible only (Wavelength: 400-700nm)	Maximum Output: 1mW	Person exposed to beam, either accidentally or as a result of deliberate action (misuse) will be protected by natural aversion response (ie blink). Repeated, deliberate exposure to the laser beam may not be safe.	**DO NOT** stare into the beam. **DO NOT** direct the beam at other people in public areas
Class 2M: Safe Without Viewing Aids visible only (Wavelength: 400-700nm)	Large diameter beam	Only a small part of the whole laser beam can enter the eye(and this is limited to 1mW, similar to a Class 2 laser. Products can be harmful to the eye if viewed using magnifying optics	**DO NOT** stare into the beam. **DO NOT** direct the beam at other people in public areas Terminate beam at end of useful path with non-specular beam stop. **PREVENT** direct viewing with magnifying optics
Class 3R: Low/Medium Power visible / non-visible	Maximum Output: 5mW *(5 x AEL for a Class 1)*	Beams exceed the MPE for accidental viewing and can potentially cause eye injuries. Practically risk in most cases is low for short and unintentional exposure due to natural aversion behaviour to bright lights for visible radiation (ie blink) and by response to heating of the cornea for far infrared radiation (watering)	**PREVENT** direct eye exposure to the beam. **DO NOT** direct the beam at other people or into public areas ***See 'Controls specific for Class 3R, 3B, 4 Lasers'***
Class 3B: Medium/High Power visible / non-visible	Output: Up to 500mW (half a watt)	Sufficient power to cause eye injury, both from the direct beam and reflections. The higher the radiant power of the device the greater the risk of injury Products near upper limit for the Class may produce minor skin injuries or pose a risk of igniting flammable materials	Products require: access to area where laser operated, key control, emission indicators, beam shutters, removal of reflecting surfaces that could be struck by errant beam, beam enclosures (if possible) ***See 'Controls specific for Class 3R, 3B, 4 Lasers'***
Class 4: High Power visible / non-visible	Output: More than 500mW	Can cause eye and skin injury from direct exposure. Specular and diffuse reflections hazardous. Beams present a fire hazard. **TREAT WITH CAUTION**	In addition to 3R, 3B above, the laser must be installed in a total enclosure with interlock.

RISK ASSESSMENTS: KEY POINTS

Risk Assessments should be produced by the relevant Project Supervisor, with Assessments for Class 3R, 3B and 4 laser activities also forwarded to the University LSO for review.

It is essential Risk Assessments cover the laser's 'life cycle' from installation, operation, maintenance, servicing and disposal. Each laser type, laser activity / operation and set-up may also require a separate Risk Assessment if there is a discernible risk to an individual.

As a starting point, before using lasers consider the following basic risk reduction measures:

1. Can a lower powered laser be used?
2. Can output power of laser be restricted if full power is not needed?
3. Can Engineering Controls prevent intra-beam viewing?
4. Can laser be used in a screened off area - limiting potential risks to others?
5. Can work be in a total enclosure?
6. Beam paths should be as short as possible, optical reflections should be minimised and the beam terminated with an energy absorbing non-reflective beam stop.
7. Laser should be securely fixed to avoid displacement and unintended beam paths.
8. If practicable, align powerful lasers with low-power devices that are safe for accidental viewing, or reduce the laser's power by turning it down or introducing neutral density filters to get the output power <1mW. Alternatively use remote viewing techniques.
9. Eliminate stray reflections; use coated optical components or shroud them so only the intended beam can be refracted or reflected. Keep bench free of clutter, remove jewellery etc.
10. Always point lasers away from the laboratory entrance.

Further guidance on Risk Assessments is available on the HSS Website and in the *BSi publication PD IEC TR 60825-14:2004*. In summary:

HAZARD: Anything with the potential to cause harm
Establish when exposure could occur and resultant harm ○ Hazards arising during the laser operation ○ Associated hazards in the general working environment ○ Other associated hazards eg electricity, fire, hazardous fumes and particles ○ Specific risks during alignment and maintenance operations ○ Reasonable foreseeable misuse or failure eg burning, mirror decay, specular reflection

HARM: What could be harmed
○ Personnel: – Laser operator – Others in the work area eg reflections – Specific risks for persons carrying out laser alignment and maintenance – Laser operators with individual needs ○ Other assets: – Fire, electrical risks, smoke / fumes triggering fire detectors

RISK EVAULATION: What is the likelihood of harm and severity if harm occurred

Consider:

- Frequency of potential exposure to laser hazard
- Duration of laser exposure and the Class of laser
- Severity of any harm eg eye / skin injury, reversible / irreversible, fire, fumes, electrical
- If existing control measures suitable. Do they follow the hierarchy of control measures:
  - Engineering Controls
  - Administrative controls
  - Personal Protective Equipment
- Can control measures be easily overridden or fail
- Are additional controls required to reduce or eliminate the risk
- Specific controls if operating Class 3R, 3B, 4 lasers eg MPEs, Training

FOLLOW UP

When you have assessed the risk always:

- Record the Risk Assessment. Ensure the Supervisor is satisfied (and LSO if required). Keep a copy with the Research / Project File and on display in the laser area
- Communicate the Risk Assessment to all persons affected by the activities
- Keep the Risk Assessment and associated documents (eg Local Rules) under review to check controls in place and working
- **REMEMBER:** Communicate / display revised documents. File old versions

GENERAL CONTROLS

1. **Risk Assessments, Local Rules, Safety Operating Procedures**

   All laser activities (including teaching) must be Risk Assessed with the relevant Project Supervisor and the University LSO if working with Class 3R, 3B and 4 Lasers. It is essential the Risk Assessment covers the 'life cycle' of the laser taking into account not only operator risks but also others that could be affected.

   In some cases supporting Local Rules, Safe Operating Procedures will be needed.

   NOTE: Alignment and maintenance work may require specific Risk Assessments due to potential for engineering controls to be temporarily disabled.

   Always communicate relevant documents (and subsequent amendments) to all persons affected **and** make available in the laser operating area.

2. Specific requirements if operating Class 3R, 3B or 4 Lasers

Colleges / Services must implement the following if operating Class 3R, 3B, 4 lasers:

a) Establish and sign Class 3B / 4 'Designated Areas' as required.

b) Ensure all Risk Assessments, Local Rules, Safe Operating Procedures etc are approved by the LSO before work starts (includes teaching activities).

c) Register lasers as required with the LSO.

d) Ensure any person before working with a Class 3B / 4 laser (Laser Workers):

   i. Receives appropriate training from the Project Supervisor.

   ii. Signs the 'Declaration' stating they have read the Local Rules etc.

   iii. Is 'Registered' as a Laser Worker with the LSO.

e) Inform the LSO of any changes in Laser Workers and / or lasers.

f) Maintain local records eg Risk Assessments, Local Rules, Safe Operating Procedures, maintenance, Declarations and details of registered Laser Workers and lasers.

3. Training and Information

Any person operating, or affected by laser activities must receive appropriate information, training or instruction (example content below) from the relevant Project Supervisor. The LSO will provide training to LPSs if appointed:

i. Risks associated with laser operations.

ii. Local Rules, Laser Policy, Risk Assessment and Safe Operating Procedures.

iii. Responsibilities to themselves and others affected by their activities.

iv. The action to take if they are exposed to a laser beam.

v. The use of Personal Protective Equipment.

vi. Specific requirements if working with Class 3R, 3B or 4 lasers.

4. Illumination

The eye is the main organ for laser damage as it can focus the beam to a spot on the retina, potentially causing irreversible damage. Where possible, provide good general illumination in Laser Designated Areas to keep the pupil as small as possible minimising the risk of laser radiation entering the eye. Methods include painting all walls, ceilings and other fittings within the area with a light coloured matt paint. To minimise specular reflections **AVOID** gloss painted surfaces, glass fronted cupboards and other reflecting surfaces.

5. Engineering Controls

Encompass features designed into the laser equipment and around the laser beam by the manufacturer or the user; in particular the fixing of protective barriers, fail-safe interlocks, emergency stops, laser stops and guards to prevent access to the laser. Position controls to:

- Enable shut down of the laser in an emergency.
- Prevent accidental firing of a laser.
- Provide an indication of the state of readiness of the laser.
- Enable personnel to stand in a safe place.

Local exhaust ventilation may be required to extract any hazardous gases given off during the laser process. Facilities to handle toxic chemicals from some dye lasers may also be needed.

6. Administrative Controls

- For Class 3B and 4 Lasers:
  - Establish a ‘Designated Laser Controlled’ Area.
  - Restrict access eg SALTO, documented system key issue to ensure use is limited to trained, authorised persons only.
  - Enclose beams if practicable. Keep open beams above/below eye level.
- Display relevant information ie:
  - Local Rules, Risk Assessments, Safe Operating Procedures, required PPE.
  - Laser warning signs and in Class 3B and 4 laser areas a ‘Designated Laser Area’.
  - Relevant staff details ie LPS, Project Supervisor, Laser Safety Officer.
- Training to cover:
  - Hazards including the bio-effects upon eyes and skin.
  - Controls. Risk Assessments. Safe Operating Procedures.
  - The need for PPE – when to wear it and what to wear.
  - The action to take if accidental exposure occurs.
  - Accident and Incident Reporting Procedures.

7. Personal Protective Equipment (PPE)

Individuals wear PPE to protect against a hazard. In respect of lasers this is usually eye protection, although other PPE may require ie skin protection (particularly for UV), face masks for respiratory protection, gloves for cryogenics/chemicals and even ear defenders (if excessive noise is expected) may be needed.

Always confirm PPE is suitable for the hazards posed by the Class of laser and laser activity (ie power and wavelength). For example, BS EN 207 eyewear is for general use, and BS EN 208 eyewear is specific for laser alignment.

Cover the correct use of PPE in any training and instruction. Include a check of PPE in any Inspections to ensure it is available and remains in good condition.

8. Laser Equipment Maintenance and Servicing

Risks may increase during maintenance and servicing due to the removal of guards and barriers, disabling of protective measures and the close vicinity of those undertaking the work.

- Anyone servicing / maintaining lasers must be competent to undertake the task.
- A thorough Risk Assessment should be prepared before work, and which, in some cases may require the setting up of a temporary Laser Designated Area.
- Records, including changes to the laser operation must be kept.
- Changes in laser operation may also necessitate a review of the General Operating Risk Assessment, Local Rules etc.
- If an outside company is appointed to carry out the work a Permit to Work should be established so the laser is handed over to the Engineer and handed back fully restored to normal operation when the work is complete.

9. Emergency Arrangements

The laboratory should be equipped with appropriate fire-fighting equipment. Emergency Arrangements detailing the action to take in a fire or if First Aid is needed should be displayed as well as included in any training and information given.

Persons exposed to laser radiation should go to hospital with the incident investigated (see below) to establish the cause, level of exposure and determine actions needed to prevent a recurrence.

10. Accident and Incident Report & Investigation

If exposure / near exposure to a laser, or a failure / potential failure of a control feature occurs all work on the laser must stop until the event is investigated and control measures reviewed. The University Accident & Incident Reporting Procedure must be followed at all times.

11. Records

Records must be kept to evidence the laser is operated and maintained as per the requirements of the Safe Use of Lasers Policy. For example, Risk Assessments, Local Rules, Safe Operating Procedures, checks of safety critical devices, laser maintenance, training, Laser Worker Declarations and Registrations and the information formally registered with the LSO.

12. Monitoring

Recorded, checks of all safety critical devices eg safety interlocks, access controls, time delays should be carried out every 3 months to confirm their efficacy.

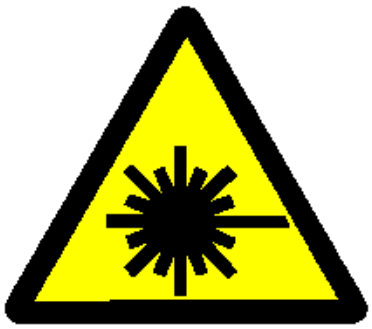
In addition, regular Inspections of the laser area should be performed to ensure controls are being followed and remain pertinent. As part of this process, check PPE provided to protect operators to confirm it is available, is the correct type and remains in good condition.

A Template Laser Inspection Checklist is available on the HSS Website.

LASER SIGNS AND LABELS

- **Designated Laser Areas: Class 3B, 4 Lasers**

The points of access to areas where this Class of laser is used must be marked with warning signs complying with BS 5378 and the Health & Safety (Safety Signs and Signals) Regulations. The signs shall incorporate the following information:



1. The hazard warning symbol
2. Details of the highest class of laser in the area
3. Details of the responsible person with contact details

- **Laser Labels (excluding low power Class 1)**

Except for low power Class 1 lasers, labels are required for all other laser Classes. Labels must warn of laser radiation, the laser Class, basic precautions and the laser's characteristics.

Labels should be clearly visible, using the same symbol as the door sign in an appropriate size for the labelled laser. Supplementary information should be black text on a yellow background in accordance with *BS EN 60825-1 Safety of laser products. Equipment Classification and Requirements.*

Where the laser product does not enable the affixing of a reasonably sized label, a sign should be displayed in close proximity to the laser with all appropriate information included.

Information over and above that specified by BS EN 60825-1 is required for Class 1 products that are 'Class 1 by Engineering Design'. This type of laser should be a totally enclosed system with details of the enclosed laser provided. The BS requirement is just to describe them on the outside as a Class 1 laser product. Details of wording required on explanatory labels are:

Class 1 (by Engineering Design)

No Hazard Warning Symbol BUT
Explanatory Statement Label

CLASS 1 LASER PRODUCT

A TOTALLY ENCLOSED LASER SYSTEM CONTAINING A CLASS ..... LASER

PLUS each access panel or protective housing to state

CAUTION - CLASS .... LASER RADIATION WHEN OPEN

With the appropriate Class inserted, followed by the Hazard Warning associated with that laser Class (see Warning Statements in following labels). For the *Area Sign the specifications are simple - 50% of the area should be yellow and the width of the black border 0.06 x the length.*

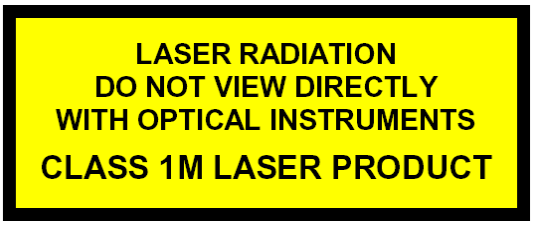
Class 1C

Label with Hazard Warning Symbol
& Explanatory Statement

Class 1M

No Hazard Warning Symbol BUT
Explanatory Statement Label

Note: 'Optical Instruments' can be supplemented with either 'Binoculars or Telescopes' (for large diameter collimated beam) or 'Magnifiers' (for highly diverging beam)



Class 2

Label with Hazard Warning Symbol
& Explanatory Statement

Class 2M

Label with Hazard Warning Symbol
& Explanatory Statement

Note: 'Optical Instruments' can be supplemented with either 'Binoculars or Telescopes' (for a large diameter collimated beam) or 'Magnifiers' (for a highly diverging beam)

Class 3R

Label with Hazard Warning Symbol
& Explanatory Statement (for λ 400nm-1400nm):

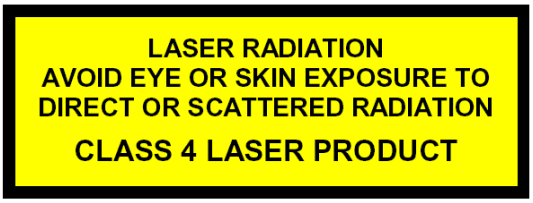
Note: For other λ replace 'AVOID DIRECT EYE EXPOSURE' with 'AVOID EXPOSURE TO BEAM'

Class 3B

Label with Hazard Warning Symbol
& Explanatory Statement:

Class 4

Label with Hazard Warning Symbol
& Explanatory Statement



- **Radiation Output and Standards Information**

All lasers, (except for low power Class 1), should have an Explanatory Label that includes:

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

University labels also include details of the type of laser and the lasing medium, although this is not a BS requirement. Explanatory Label information may be combined, with LED used to replace the word 'laser' when appropriate.