PRIFYSGOL BANGOR UNIVERSITY

GUIDANCE NOTE – OHSU G27 (JULY 2005) (technically amended Nov 2014)

GUIDANCE NOTES ON LASER SAFETY

INTRODUCTION

Work with lasers at the University is very diverse and is also in many cases at the forefront of research activities that are ever developing and changing. Lasers are used not only in analytical apparatus in the biological sciences but also in other advanced technologies such as opto-electronics and nanotechnology.

All lasers are potentially hazardous. The actual degree of the hazard is however related to the laser's characteristics and use. This Guidance Note seeks to advise on the University's policy and controls on the safe use of all lasers in order to prevent any harm occurring or any person from being exposed to risk.

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SECTION 1: POLICY

1. RESPONSIBILITIES

i. The Vice-Chancellor, as Chief Executive Officer of the University, has overall responsibility for administration and implementation of the University's Health and Safety Policies, as determined by the University Council.

ii. The Head of School/ Department is responsible for ensuring the safe use and operation of all lasers within his/her School or Department and for ensuring the laser is registered with Health and Safety Services as appropriate.

iii. The University shall appoint a suitably qualified and / or experienced Laser Safety Officer (LSO) and he/she will be responsible for advising the University on all safety matters concerned with the use of lasers and for carrying out such duties as are required.

iv. The Radiation Health and Safety Sub-Committee has been charged with reviewing and revising this document and with overseeing its implementation. The Sub-Committee shall consider and act upon reports received from Health and Safety Services, the LSO and individual Schools/Departments, where necessary.

SECTION 2: DUTIES AND GUIDANCE

1. SCHOOL/DEPARTMENT DUTIES

i. The Head of each School/Department, that undertakes laser work, where required shall appoint a Laser Protection Supervisor (LPS).

ii. All Laser Workers at the University are subject to and shall follow the procedures established by this Guidance Note, appropriate risk assessments and by Local Rules produced by the School/Department.

iii. Any University Laser Worker undertaking laser work in any establishment other than the University must conform to the Local Rules in force at that establishment and must ensure that a suitable and sufficient risk assessment has been completed and subsequently approved by the appropriate School/Departmental LPS.

iv. Any person, not being a member of staff or a student of the University, who wishes to undertake laser work on University premises must at all times conform to this Guidance Note and appropriate Local Rules. The appropriate LPS must approve all such work.

v. Members of staff and students wishing to work with Class 3B / 4 lasers - with the exception of undergraduates participating only in supervised teaching/demonstration activities - must be registered as Laser Workers. The Register of Laser Workers is compiled by the LPS and it is the duty of the LPS to ensure that the LSO is provided with a copy of the School/Department Register and informed immediately of any additions to, or deletions from, the Register so that a central Register of all Laser Workers is kept. All Laser Workers will be required to sign a declaration that they have read the Local Rules. Registration must always be completed before work with lasers is commenced.

vi. All Laser Workers must be made aware of their responsibilities both to themselves and to others in the laboratory who may be affected by their activities, for the safe performance of their work. All Laser Workers must be informed of the requirements of this Guidance Note and Local Rules.

vii. The Head of School/Department must ensure that people unfamiliar with lasers and their associated hazards are never allowed to operate and/or maintain them. New Laser Workers must be given appropriate instruction and be made aware of this Guidance Note, the Risk Assessment, Local Rules and of the operational advice supplied by the manufacturer. It is recommended that a formal training session is provided by the LSO or

through the appropriate LPS for all work with Lasers of Class 3B / 4. Suitable instruction and training shall also be provided by the School/Department for all workers of lasers of a Class below 3B.

viii. The Head of School/Department must ensure that maintenance and alignment operations on lasers are undertaken by a competent person and are suitably risk assessed to ensure that no significant risk prevails.

ix. All safe systems of work and/or Local Rules must be based on the hierarchy of control; ie avoidance of the risk, reduction of the level of risk, reduce exposure to the risk, introduction of a suitable safe system of work, training and only as a last resort, the use of suitable personal protective equipment (PPE).

x. The Head of School/Department must ensure that Supervisors of undergraduate laboratories which use lasers must submit and agree a safe system of work with the appropriate LPS prior to commencing work with lasers and ensure that all students and laboratory staff are aware of this safe system of work. In all cases, it should be the aim of all Schools/Department to use the minimum power laser practicable for the teaching activity.

2. CLASSIFICATION OF LASERS

Class 1 lasers are products where the irradiance (measured in watts per metre square) of the accessible laser beam (the accessible emission) does not exceed the Maximum Permissible Exposure (MPE) value. Therefore, for Class 1 laser products the output power is below the level at which it is believed eye damage will occur. Exposure to the beam of a Class 1 laser will not result in eye injury and may therefore be considered safe. However, some Class 1 laser products may contain laser systems of a higher Class but there are adequate engineering control measures to ensure that access to the beam is not reasonably likely. Examples of such products include laser printers and compact disc players. Anyone who dismantles a Class 1 laser product that contains a higher Class laser system is potentially at risk of exposure to a hazardous laser beam.

Class 1M lasers are products which produce either a highly divergent beam or a large diameter beam. Therefore, only a small part of the whole laser beam can enter the eye. However, these laser products can be harmful to the eye if the beam is viewed using magnifying optical instruments. Some of the lasers used for fibre-optic communication systems are Class 1M laser products.

Class 2 lasers are limited to a maximum output power of 1 milliwatt (abbreviated to mW) or one thousandth of a watt and the beam must have a wavelength between 400 and 700 nm. A person receiving an eye exposure from a Class 2 laser beam, either accidentally or as a result of someone else's deliberate action (misuse) will be protected from injury by their own natural aversion response. This is a natural involuntary response causing the individual to blink and avert their head terminating the eye exposure. Repeated, deliberate exposure to the laser beam may not be safe. Some laser pointers and barcode scanners are Class 2 lasers.

Class 2M lasers are products which produce either a highly divergent beam or a large diameter beam. Therefore, only a small part of the whole laser beam can enter the eye and this is limited to 1 mW, similar to a Class 2 laser product. However, these products can be harmful to the eye if the beam is viewed using magnifying optical instruments or for long periods of time. Some lasers used for civil engineering applications, such as level and orientation instruments are Class 2M laser products.

Class 3R lasers are higher powered devices than Class 1 and Class 2 and may have a maximum output power of 5 mW or 5 times the Accessible Emission Limit (AEL) for a Class 1 product. The laser beams from these products exceed the maximum permissible exposure for

accidental viewing and can potentially cause eye injuries, but the actual risk of injury following a short, accidental exposure, is still small.

Class 3B lasers may have an output power of up to 500 mW (half a watt). Class 3B lasers may have sufficient power to cause an eye injury, both from the direct beam and from reflections. The higher the output power of the device the greater the risk of injury. Class 3B lasers are therefore considered hazardous to the eye. However, the extent and severity of any eye injury arising from an exposure to the laser beam of a Class 3B laser will depend upon several factors including the radiant power entering the eye and the duration of the exposure.

Class 4 lasers have an output power greater than 500 mW (half a watt). There is no upper restriction on output power. Class 4 lasers are capable of causing injury to both the eye and skin and will also present a fire hazard if sufficiently high output powers are used.

3. REGISTRATION

i. All lasers and laser systems must conform both to the requirements of this Guidance Note and publications by the British Standards Institute (BSi). An up-to-date Register of all lasers, of Class 3B / 4 type at the University will be maintained by the LSO. The LPS is responsible for notifying the LSO of all Class 3B / 4 lasers within his/her School or Department and of the subsequent disposal of Class 3B / 4 lasers. The Registration / Disposal form is attached as Appendix 1 of this Guidance Note. All new lasers, except low power Class 1 lasers, must also be registered with the LPS so that safety matters may be discussed before the laser is brought into use.

ii. All lasers must be appropriately labelled so that everybody concerned is immediately aware of the class of the laser and any basic precautions which are necessary. Details of labels required are at Appendix 6 of this Guidance Note.

iii. Use of Class 3B / 4 lasers will be restricted to Laser Designated Areas, i.e. laboratories or other clearly defined areas which are set aside for the purpose, and where hazards can be effectively controlled. Such areas must be clearly identified using the appropriate laser warning sign. The sign must be used at the entrance to all Laser Designated Areas and should be readily identifiable from any angle of approach. Entry to such areas will be restricted to authorised personnel only and appropriate fire fighting equipment should be provided. Local Rules shall be posted in the area and the LSO shall be notified of the Laser Designated Area classification.

iv. Work with lasers of Classes 1, 2 and 3R (i.e. lasers with a power output below 5 mW) will not normally require the setting up of Laser Designated Areas. Wherever possible lasers within these classes should be used for student experimental work and lecture demonstrations.

4. LASER SAFETY OFFICER (LSO)

i. The LSO advises on the use of lasers in the University and performs executive duties to ensure that the University procedures relating to laser safety are followed and are compliant with legislative requirements, this Guidance Note and good practice in the Sector.

ii. The LSO is responsible for ensuring that new LPSs have received appropriate training and instruction, maintaining the central Register of lasers and Laser Workers, the registration of Laser Workers, the inspection of all new Laser Designated Areas and periodic auditing of laser facilities and controls.

iii. The LSO reports to Health and Safety Services.

5. LASER PROTECTION SUPERVISOR (LPS)

i. In Schools and Departments where Class 3B / 4 lasers are used the Head of School/Department, in consultation with the LSO, should appoint a suitably qualified and/or experienced member of staff as LPS. The LPS will be responsible for assisting the Head of School/Department in ensuring that all appropriate lasers used in the School/Department are registered and used in compliance with this Guidance Note and good practice and that suitable and sufficient risk assessments are undertaken.

ii. The LPS has a duty, to the Head of School/Department, to supervise the general day-to-day control of use of lasers, the laser safety standards within the School/Department. The LPS shall also undertake to monitor and advise upon the School/Department's level of compliance with this University Guidance Note, appropriate Local Rules on the Safe Use of lasers and other appropriate control measures. To achieve these requirements the LPS should ensure that:

- All Class 3B / 4 lasers are Registered by the School/Department with the LSO.
- All lasers are labelled in accordance with Appendix 6.
- Safe Systems of Work are drawn up, where necessary, for the safe operation of lasers and all Risk Assessments are completed and suitable.
- Personnel intending to work with Class 3B / 4 lasers or who may be working with modified Class 1M or Class 2M devices are registered with the LSO as Laser Workers.
- All registered Laser Workers receive appropriate training in the safe use of lasers at the School/Department.
- Undergraduates working with lasers should use the minimum power laser practicable and follow a written scheme of work.
- All lasers in the School/Department are used in accordance with the University's Guidance Note and Local Rules.

6. LASER WORKERS

i. All Laser Workers at the University have a duty to observe this Guidance Note, Risk Assessments and local Safe Systems of Work or Local Rules and Procedures applicable to the lasers that will be used and to follow the guidance of Supervisors and the School/Departmental LPS.

ii. Laser Workers should not leave a laser experiment running unattended unless a Risk Assessment has established that it is safe to do so. Laser Workers also have responsibilities for their own safety and that of others who may be affected by their acts or omissions.

iii. All Laser Workers are required to attend training as required and stipulated by the LSO, the University, the LPS and/or Head of Department.

iv. When working with Class 3B / 4 lasers and where there is the possibility of stray laser beams that could damage the eyesight, the appropriate laser goggles/glasses must be worn unless the risk assessment indicates that there is no significant risk from the work activity and there is no significant benefit from wearing such eye protection.

7. RISK ASSESSMENTS

i. Risk Assessments form an essential part of controlling the dangers associated with the use of lasers. The control of hazards arising from the installation, operation, maintenance, service and disposal of laser equipment should be based on an assessment of the risk.

This Section should be read in conjunction with the Risk Assessment Policy Standard 2009. All Risk Assessments must be produced in association with the relevant LPS and completed assessments must be forwarded to the LSO for his/her information.

Where practicable, an assessment of the risk associated with a particular laser process should be undertaken prior to purchase of the laser; this will ensure that the potential risks and hazards are quantified, the safety implications are known and the necessary control measures are implemented.

Risk Assessments must consider every foreseeable injurious situation that could arise in the use of laser equipment and in environments where lasers are used. Particular care should be taken to fully assess the risks during alignment and maintenance operations as well as reasonable foreseeable misuse or failure; such as burning or decay of a mirror or specular reflection.

ii. All Risk Assessments will take the form of a staged approach:

Stage 1: Identify the Hazard

Hazard = Anything that has the potential to cause harm

It is important to consider the full range of possible hazards and the circumstances in which they might arise, taking into account the type of laser equipment (its Class, how a hazardous exposure could occur and the kind of injury that may result) and the task or process being performed. At this stage it is important to look flexibly at the assessment and to consider other associated hazards, such as electricity, hazardous fumes and particles being generated by the laser process and room access.

It is imperative that each laser type, each laser activity and set-up and each differing operation or process is assessed separately whenever there is a discernable risk of harm to an individual.

Stage 2: Identify who may be harmed?

Once you have identified the hazards it is important to identify who may be harmed and when. Consider those who may be in the area or room when the laser is in operation, being aligned, being maintained and particularly consider when a person may be potentially exposed to the greatest potential danger. For example, the person operating an enclosed Class 4 laser is not exposed to any great danger as the laser radiation is enclosed and exposure cannot reasonably occur but when that same item of equipment is maintained or is re-aligned then there is a greater potential of injury for that person performing such operations and other in the area and who are within the lasers wavelength and range.

Stage 3: Evaluate the Risk from the Hazard

Risk = the chance, great or small, of someone being harmed from the hazard and the consequence of such harm

Two factors that make up the risk, namely the likelihood and the severity of an injury, can be considered separately for each hazardous situation previously identified.

The assessment of risk will, for example, take into account the frequency of potential exposure to a hazard (laser), the severity of any harm that may result from exposure and the consequences of injury to the eye or skin, the duration of laser radiation exposure and the laser wavelength and power.

After assessing the potential risks from the hazard consider whether those control measures that have been put in place are suitable, as well as how easy and likely it is for such control measures to be circumnavigated or to fail, or whether additional controls are required in order to reduce or eliminate the risk.

When evaluating the risk it important to think of all situations where exposure could occur and to consider what could go wrong and how such situations can be avoided or prevented. It is equally important to note that Personal Protective Equipment (PPE) is only acceptable where no other control measure, such as complete enclosure of the laser radiation, can be used and where the PPE offers a suitable level of protection.

Control measures as indicated in Section 2. 9 of this Guidance Note should be considered alongside those further described within British Standards Institute (BSi) publications.

Once the risk has been identified and quantified and the control measures have been implemented the whole assessment should again be considered to confirm that what could be done to prevent harm from occurring has been done.

Stage 4: Record your findings

Always record your risk assessment and always keep it in your research/project file and posted in the area for inspection and reference. Ensure that the LPS is satisfied with the suitability of the assessment before commencing with the laser work.

Stage 5: Review the assessment

From time to time all Risk Assessments should be reviewed to ensure that they are still suitable and cover adequately the level of risk posed by the hazards; and indeed that all hazards have been identified.

In addition to periodic and planned reviews of the Risk Assessment is particularly important that the assessment is reviewed whenever an incident or potential incident has occurred and when new or revised information on the dangers or risks is produced. A risk Assessment is a living document and should be continually and regularly reviewed and amended to ensure its suitability and to ensure the safety of all affected by it.

The above guidance on Risk Assessment is based partly on guidance contained within the BSi publication PD IEC TR 60825-14:2004 Safety of Laser Products: A User's Guide and is produced in accordance with BSi copyright requirements. Further and more detailed guidance is provided by this BSi publication, a copy of which is held by the LSO.

8. HARMFUL EFFECTS

Lasers emit beams of non-ionising radiation, at wavelengths spanning the ultraviolet to the far infrared. The laser output can be continuous wave, or pulsed. The eyes and skin are at risk of injury. The main beam hazards are to the eyes.

	Wavelength	**Potential Damage**
Ultraviolet	200nm - 400nm	Corneal or lens (302-315nm)
Visible Near Infra-red	400nm - 1.4µm	Retinal
Medium & Far Infra-red	1.4µm - 1mm	Corneal or lens

For lasers in the visible or near infrared part of the spectrum there is a particular risk of damage to the retina of the eye and permanent visual impairment is possible. Retinal eye damage can occur at very low power levels (including weak reflections and diffusely scattered radiation) due to the focusing effect of the lens of the eye and the coherence of laser radiation.

Visible emissions from lasers can cause disturbing and potentially dangerous dazzle effect at exposure levels that are well below the MPE (Section 2.8) and which therefore cause no direct physiological injury. This is especially so with laser classes below 3B (including laser pointers and

low-power alignment lasers) and therefore such lasers should never be directed, whether intentionally or unintentionally, at a person's eye.

Temporary visual affects may produce disturbing after-images and induce reactions such as watering eyes and a headache; persistent rubbing of the eyes in response to a perceived injury can also result in painful corneal abrasions.

There are other hazards associated with laser use that can cause harm; including electrical, chemical and secondary radiation hazards.

9. CONTROLS

i. The eye is recognised as being the critical organ for damage by lasers, due to its ability to focus the laser beam to a spot on the retina. This can produce irreversible damage to that part of the eye, leading to general impairment of vision. For this reason, wherever possible, a high standard of general illumination must be provided within the Laser Designated Area, so that the pupil of the eye will remain as small as possible thus minimising the risk of laser radiation entering the eye. The general illumination may be enhanced by painting all walls, ceilings and other fittings within the area with a light coloured matt paint. Gloss painted surfaces, glass fronted cupboards and other reflecting surfaces should be avoided in order to minimise specular reflections.

ii. Safe working conditions for the laser must be achieved by use of both appropriate engineering controls and administrative/management procedures (e.g. fail-safe interlocks, screens, automatic or interlocked shutters, systems of work etc.). If the required standards are not reached by these alone then personal protective equipment (eye protection in particular) will be required. Eye protection must be specifically designed for laser use and selected in accordance with the recommendations in BS EN 60825, taking into consideration both the wavelength and power levels being used.

iii. The safety of all laser work and demonstrations should be Risk Assessed by or with the LPS who should then draw up or approve a scheme of work. These should be displayed in a prominent position so that it can be clearly seen by all persons carrying out the work

iv. Ventilation is important especially with higher-powered lasers if cryogens are used, or if toxic fumes are produced that need to be extracted and in this case it is important that the extraction is very close to the source. Facilities may also be needed for the handling of toxic chemicals that are associated with some dye lasers. These should be considered by the risk assessment.

v. The laboratory should be equipped with appropriate fire fighting equipment. Electrical supplies, switch and control gear should be sited in order to:

- enable the laser to be shut down 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;
- provide sufficient and adequate power supplies for all ancillary equipment and apparatus so that the use of trailing leads is minimised.

vi. Before starting to use lasers there are a number of basic risk reduction measures that should be considered.

- Can a lower powered laser be used?
- Can output power of laser be restricted if full power is not needed?
- Can intra-beam viewing be prevented by engineering design?
- Can laser be used in a screened off area - limiting potential for others to be affected?
- Can work be carried out in a total enclosure?

- 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. Laser should be securely fixed to avoid displacement and unintended beam paths.
- If practicable align powerful lasers with low-power devices that are safe for accidental viewing, or reduce the power of the laser by turning it down or introducing neutral density filters. The aim should be to get the output power <1mW, NB some kW lasers will only be able to be turned down to a few watts. Alternatively remote viewing techniques can be used.
- Eliminate chance of stray reflections - use coated optical components or shroud them so that only the intended beam can be refracted or reflected. Keep optical bench free from clutter and remove jewellery, wrist watches etc.
- Always point lasers away from the laboratory entrance.

10. MEASUREMENTS

Accessible Emission Level (AEL)

The AEL is defined as the radiation level produced in regions accessible to the user, which must not be exceeded for a given class of laser.

Examples of the AEL for a He-Ne laser emitting a narrow beam in CW mode at 633nm are as follows:

- Class 1 and 1M 0.39 mW
- Class 2 and 2M 1 mW
- Class 3R 5 mW
- Class 3B 500 mW

These limits will 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 60825-1:1994 for full details.

Maximum Permissible Exposure Levels (MPEs)

The Maximum Permissible Exposure Level (MPE) is defined as the maximum level of laser radiation to which human tissue can be exposed without suffering consequential injury or damage.

MPEs reflect the current state of knowledge in relation to the hazard posed by laser radiation to different biological tissues. It is obviously important to know what levels of laser radiation are considered to be safe and MPEs represent the maximum level to which eye or skin can be exposed without suffering short or long-term damage. With the use of appropriate safety factors MPEs have been established for two different scenarios:

- direct ocular exposure - intrabeam viewing
- exposure of the skin

MPEs vary according to the wavelength, exposure time, tissue at risk and, for visible and near infra-red radiation, the size of the retinal image.

Examples of MPEs for a CW He-Ne laser operating at 633nm are:

- intrabeam viewing - 1 mW.cm-2
- skin exposure - 200mW.cm-2

The establishment of a MPE should be made in cooperation with the LSO or the LPS using calculations and examples provided by BSi PD IEC TR 60825-14:2004. The MPE must be established for all Class 3B / 4 lasers as part of the Risk Assessment process.

11. GENERAL INFORMATION

i) General Controls

Where an initial risk assessment has shown that an unacceptable level of risk does exist then protective control measures must be introduced or the work discontinued in that form.

As with all risk assessments a hierarchy of control measures should be considered starting with the substitution of the laser with a laser of a lower classification; the use of hazardous lasers should therefore be justified prior to purchase and use.

Where the use of a hazardous laser is justified control measures should come under three headings, covering engineering controls, administrative controls and personal protective equipment.

- Engineering Controls

Engineering controls include features included into the laser equipment and around the laser beam by the manufacturer or the user; in particular the fixing of protective barriers, interlocks, emergency stops, laser stops and guards to prevent access to the laser. Engineering controls, in terms of local exhaust ventilation, may also be required to extract any hazardous gases given off during the laser process.

- Administrative Controls

Administrative controls cover policy and procedural issues, such as local rules, and the use and display of illuminated warning signs, training and instructions, the assignment of responsibilities to individuals and prohibitions and audit arrangements.

- Personal Protective Equipment (PPE)

PPE is that protection worn by laser workers and primarily, in terms of laser use, relates to eye protection. However, PPE may also relate to respiratory protection, the wearing of lab coats and gloves and even ear defenders where excessive noise is anticipated

ii) Laser Equipment Servicing

There is a significant potential increased risk during servicing operations of lasers, due to possible removal of guards and barriers, the disabling of protective measures, and the close vicinity of the laser worker due to his/her service operation.

- In-house Servicing

Before servicing operations are undertaken a thorough risk assessment should be undertaken. A record of all servicing operations should also be kept and details of any changes to the laser operation should be recorded; and where appropriate the general operating risk assessment and local rules should be reviewed in light of any changes.

Servicing of any laser may require the setting-up of a temporary Laser Controlled Area. All persons undertaking service operations must be competent to undertake the task.

- Visiting Service Engineer

If an outside company is engaged to conduct the servicing of the laser equipment then a permit-to-work procedure should be established so that a laser is handed over to the service engineer and is handed back fully restored to normal operation when the work is complete.

In some cases temporary Laser Controlled Areas should be established. Servicing of lasers by an outside company should be considered as part of the general laser risk assessment.

iii) Accident and Incident Report and Investigation

In the event of an actual or potential hazardous exposure to a laser or the failure or possible failure of a control feature an Accident/Incident Report must be completed and an investigation must be undertaken. All work on that laser apparatus should stop until such time as the accident/incident is explained and control measures reviewed. All accidents should be reported to Health and Safety Services immediately and all incidents and details of remedial actions should be reported within 7 days of the incident.

iv) Medical Attention and Surveillance

Where an accident occurs and a person is exposed to laser radiation medical attention should be sought as necessary. In the event of an apparent or suspected injury to the eye a medical examination by a qualified ophthalmologist should be carried out as soon as possible and within 24 hours. A summary of the laser beam characteristics should be provided to the medical staff.

In all events a full investigation (as outlined above) should be undertaken to ascertain the cause of the accident and what actions are required, what was the possible exposure and to prevent a further incident.

The University does not undertake or require routine medical surveillance of Laser Workers as such measures are seen as having little or no value as part of a health surveillance programme.

12. IMPLEMENTATION

This document, with the exception of the appointment of a Laser Safety Officer, shall be implemented at Bangor University from 1st August 2005. Section 2, Sub-Section 4, Laser Safety Officer shall be implemented from the 1st September 2005.

This document shall firstly be reviewed by the Radiation Health and Safety Sub-Committee and any Laser Users Group that is established by the 1st September 2007 and thereafter as is required by legislation, good practice or as a result of any incident.

PRIFYSGOL BANGOR UNIVERSITY

REGISTRATION / DISPOSAL OF LASER EQUIPMENT HELD AT BANGOR UNIVERSITY (Class 3B / 4)

Department/School: .....

Location of Laser: .....

Laser Type & Class:[1] .....

Manufacturer & Serial No: .....

Power/Energy/Wavelength: .....

Laser Usage & Activities: .....

.....

.....

.....

Print Name: .....

Signed & Date: .....

School/Departmental Laser Protection Supervisor to Complete

Print Name: .....

Signed: ..... Date: .....

Laser Protection Officer to Complete

Date Registered: .....

Print Name: .....

Signed: ..... Date: .....

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[1] Classes – 3B, 4

for office use

REGISTRATION OF LASER WORKERS (Class 3B / 4)

Note: The Laser Protection Supervisor (LPS) is responsible for returning this Form to the Laser Safety Officer (LSO), so that the worker can be added to the Register, **before** work with lasers commences. Registration and authorization relates only to the laser installation listed.

Name	*Title*	*Forename*		*Surname*		
School / Dept.						
Start Date						
Location						
Staff Category	Academic Staff	☐	Research Staff	☐	Technical Staff	☐
	Postgraduate	☐	Other	☐	*Specify*	

LASER WORKER DECLARATION *(MUST be signed before any work with laser commences)*

I have received, read, and undertake to act in accordance with the University Guidance Note for Laser Use and local School / Department laser safety and operating procedures.I have also enclosed a Risk Assessment[2] and project details on my proposed use of lasers.

Print Name	
Signed / Date	

PROJECT SUPERVISOR / LASER PROTECTION SUPERVISOR'S (LPS) DECLARATION

I, the Project Supervisor / LPS, confirm that the person named above has or will receive sufficient and appropriate training in the safe use and hazards of lasers before commencing work and a suitable and sufficient risk assessment has been completed of the installation and activity.

LPS Name	
Signed / Date	

LASER INSTALLATION

Work Involving	*Laser Type*	*Laser Class*
	Description of Laser Installation	

[2] If the work involves the use of a Class 3B / 4 laser, a Risk Assessment and Safe System of Work will be required before commencing work.

for office use

LASER WORKERS: CESSATION OF LASER WORK

School/Department	

The following laser worker(s) will be ceasing laser work (or leaving the University) on the date shown and should be removed from the Register of Laser Workers.

Name	Date

Laser Protection Supervisor's Confirmation

LPS Name	
Signed / Date	

SELF INSPECTION CHECKLIST
LASER USE

Department	
LPS	
Date	
Inspection By	
Others Present	

General		**YES**	**NO**
1	Are all users of Class 3B / 4 lasers and above Registered as Laser Workers (LWs)?		
2	Have all LWs (Class 3B / 4) received instruction on laser safety?		
3	Have all LWs completed or been appraised of applicable risk assessments for their work?		
4	Are Laser Local Rules available in each area in which lasers are used?		
5	Are Specific Rules/Procedures provided for the laser and its safe use?		
6	Has a Risk Assessment been undertaken?		
7	Is the Risk Assessment suitable & sufficient? Has it been reviewed recently?		

Laser Areas		**YES**	**NO**
8	Are all rooms containing laser equipment listed in the School/Department's Laser Register?		
9	Is the information on the Register correct?		
10	Do all rooms in which Class 3B / 4 lasers and above are used have a Laser Warning Sign on the door?		

Laser Equipment		**YES**	**NO**
11	Are all lasers listed in Departmental Laser Register and Central Register?		
12	Is the information in these Registers correct?		
13	Are all lasers correctly labelled?		
14	Is all equipment containing lasers labelled?		
15	Is a beam stop provided for each laser?		
16	Are any laser beam paths at eye-level?		

Laser Designated Areas		**YES**	**NO**
17	Is a written system of work available for access, egress and use of equipment?		
18	Is access restricted to authorised personnel only?		
19	Is the area free from unnecessary equipment & reflecting surfaces?		
20	If more than one laser is used at once are suitable opaque screens used for separation?		
21	Are there remote interlocks for doors?		
22	Is there adequate ventilation to prevent build-up of toxic vapours?		

Class 3B / 4 Lasers		**YES**	**NO**
23	Is the beam path enclosed?		
24	Are suitable Laser Safety Goggles provided if beam is not totally enclosed?		
25	Are special Alignment Goggles provided?		
26	Is necessary protective clothing provided for use with Class 4 lasers?		
27	Key control switches?		
28	Automatic beam shutters or attenuators?		
29	Audible or visible warning device indicating that laser is in use?		

Emergency Planning		**YES**	**NO**
30	Have all potential laser hazards been assessed?		
31	Are contingency plans in existence for emergencies?		

Action Required	

Auditor Signature		**Witnessed By**	
Position		**Position**	

Guidance for Questions	
1	Laser Workers observed in laboratories can be checked against the Laser Worker Register, or copies circulated to relevant Laboratory Heads/Project Supervisors. The University LSO should be informed immediately of any unregistered workers.
2	Assessment of individual competency based on working practices/observed conditions in labs.
3	List to be held by the School/Department or is available from the LSO.
4 5	Are these Rules applicable and suitable?
6 7	Does the risk assessment consider the environment, the area, the people, the equipment and the activity?
8 9	All areas containing lasers of Class 3B / 4 must be designated. Inform LSO of changes.
11 12	Inform LSO of any changes.
13	See Appendix III of CVCP Notes of Guidance.
18	A suitable notice should be displayed which makes this clear.
19	Where possible wall, ceilings and fittings should be painted in a light matt finish to enhance general illumination and reduce specular reflections.
21	Such interlocks can operate warning lights outside the laser area and also act to shutdown the laser on opening the laboratory door. They may be necessary where work involves open beam paths.
22	Arising from the laser itself or from materials irradiated by the laser.
23 24	All protective eyewear must be designed for the wavelengths in use. All eyewear must be clearly labelled and identified as being suitable for use with a particular type of laser, and the optical density and wavelength must be specified.
26	A ‘captive-key’ control switch should be provided. They key must be removed when the laser is not in use, kept in a safe place and only issued to authorised users.
27	These should operate automatically to prevent inadvertent exposure of persons to hazardous laser radiation.
29 30	In addition to hazards from the laser beam itself there are electrical, mechanical, chemical and other hazards associated with the use of lasers.

SUMMARY OF WARNINGS & PROTECTIVE CONTROL MEASURES
LASER PROTECTIVE CONTROL MEASURES BY CLASSIFICATION

1	• No protective control measures for normal use (NB special precautions may be needed for service work on embedded laser products.)
1M	• Prevent direct viewing with magnifying optics. (NB fitting external optics that decrease beam divergence may affect classification) + *see footnote*
2	• Do not stare into beam. • Do not direct the beam at other people or into public areas.
2M	• Do not stare into beam. • Do not direct the beam at other people or into public areas. • Terminate beam at end of useful path with a non-specular beam stop. • Prevent direct viewing with magnifying optics. (NB fitting external optics that decrease beam divergence may affect classification) + *see footnote*
3R	• Prevent direct eye exposure to the beam. • Do not direct the beam at other people or into public areas + *see footnote*
3B & 4	• Class 3B and Class 4 laser products should not be used without first carrying out a risk assessment to determine the protective control measures necessary to ensure safe operation. Where reasonably practicable engineering means should be used to reduce the laser class to a totally enclosed Class 1 laser product. • The use of any Class 3B or Class 4 laser without an interlocked enclosure will require a written scheme of work. Even with an enclosure written procedures will be necessary if the user is involved in any alignment procedures that require over-riding of interlocks. • Class 3B and Class 4 laser products require: o the control of access to the area where the laser is operated by the use of a remote interlock; o the use of key control; o emission indicators; o beam shutters; o removal of reflecting surfaces that could be struck by an errant beam; o beam enclosures wherever practical; o the use of eye protection and protective clothing as appropriate; o training of staff.

+ Classes 1M, 2M and 3R may also require training of staff, care with beam paths and specular reflections - see BS EN 60825 -1 and PD IEC TR 60825-14:2004 for more details.

Special attention should also be given to other non-optical hazards such as risk of electric shock, hazardous chemicals, cryogenic liquids and flying debris from targets etc. It is often the non-optical hazards that pose the greatest risk - one could be blinded in one eye from a powerful laser but electrocution could be fatal. Some non-optical hazards could also be present with Class 1 lasers.

LASER SIGNS AND LABELS

- **Designated Laser Areas**

The points of access to areas in which Class 3B or Class 4 laser products are 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**

Laser labels are required for all laser products except for low power Class 1 devices. They are designed to give a warning of laser radiation, the class of laser, basic precautions and the laser's characteristics.

The laser warning uses the same symbol as for the door sign in an appropriate size for the laser to be labelled and should be clearly visible. Supplementary information should be black text on a yellow background in accordance with Fig 15 p66 of BS EN 60825-1.

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

Information over and above that specified by BS EN 60825-1 is required for Class 1 products that are Class 1 by engineering design. For these types of laser product we specify that they are totally enclosed systems and give details of the laser enclosed. 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 given below.

<u>Class 1 (by engineering design)</u>

No hazard warning label. Explanatory label bearing the words:

CLASS 1 LASER PRODUCT

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

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

CAUTION - CLASS .... LASER RADIATION WHEN OPEN

With the appropriate class inserted and then followed by the hazard warning associated with that Class of laser (see warning statements in following labels). *For the area signs the specifications are quite simple -50% of the area should be yellow and the width of the black border is 0.06 x the length of the side. A more detailed specification is given for the symbol used in labels, see BS EN 6082.*

Class 1M

No hazard warning label. Explanatory label bearing the words:

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

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 2

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

LASER RADIATION
DO NOT STARE INTO BEAM
CLASS 2 LASER PRODUCT

Class 2M

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

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

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 label (For λ 400nm-1400nm ONLY) bearing the words:

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

Class 3B

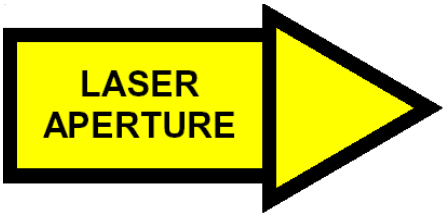
Label with hazard warning symbol. Explanatory label bearing the words:

Class 4

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

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

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



- **Radiation Output and Standards Information**

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

- maximum output
- emitted wavelength
- whether laser is visible, invisible or both
- pulse duration (if appropriate)
- name and publication date of classification standard

We have also included on our labels details of the type of laser and the lasing medium, although this is not a BS requirement. Information to be put on explanatory labels may be combined and LED shall be used to replace the word 'laser' when appropriate.

EXAMPLES OF LASER ACCIDENTS

1. At a Midlands University in the UK in 1999

Late one afternoon a postgraduate student was aligning two lasers at different wavelengths that had been set up in a relatively new configuration. The beam from a dye laser (720nm, 10mJ, 10 ns pulse at 10 Hz) was passed through a dichroic mirror coated for high reflection at 266 nm in order to combine it with the beam from a fourth harmonic Nd:YAG laser (266 nm, 50 mJ, 10 ns pulse at 10 Hz). This configuration resulted in a partial reflection from the rear of this mirror (approximately 5% of the dye laser) in an upward direction. Temporarily forgetting the presence of the stray beam, the person on leaning over the top of the apparatus received a single pulse of light from the dye laser reflection. This immediately left a large blind spot in the person's central vision in one eye. The person was not wearing protective eyewear as it was claimed they could not see that the beams they were aligning were coincident (*but both were at invisible wavelengths so they could only see the fluorescence*).

The experiment was shut down and the person was accompanied to the local hospital Eye Unit. On examination the person was informed that there was a small burn on the fovea and that he would be referred to a consultant as a matter of urgency.

As to the absence of beam enclosures (drainpipes had been used previously), because of the orientation of the experiment being changed these had not been re-incorporated at this stage. The source of the reflection had allegedly been identified prior to the injury and this had been listed as an action to do by the injured person.

There was some concern with regard to the examination and advice received from the local hospital Eye Unit. It was concluded that the most appropriate action was to get the injured person to the Moorfields Eye Hospital, Accident and Emergency Unit (London) as soon as possible (the afternoon after the incident) to obtain a second examination. It was confirmed that the fovea had been damaged leading to a blind spot and peripheral blurring in the left eye. As a consequence the following may be of use to others:

a) Risk Assessments need to be scrutinised, monitored and audited so that it can be shown that they are suitable and sufficient. Essentially three elements related to the optical hazard need to be covered (i.e. initial set up/alignment, normal operation/tweaking and the introduction of new components) and protocols detailing precautions need to be in place. Appropriate justification of procedures outside of conventional guidance need to be documented. Associated hazards need to be dealt with also.

b) The importance of following procedures, such as eliminating stray beams/reflections and enclosing exposed beams as far as reasonably practicable needs to be strongly re-emphasised. Human factors need to be taken into account especially where there may be hazardous open beam work; in this case an eagerness to get results may have been a contributory factor.

c) Procedures in the event of an injury or suspected injury need to be in place and effective. In most laser eye injuries there is not a lot that can be done to rectify damage; it is essential that competent examinations are carried out as soon as possible and within 24 hours of the injury. Referral to Moorfields Eye Hospital in London should be made in the event of a serious laser eye injury. Thus in light of the number of injuries recently in the UK research institutions, emergency procedures in place need to be checked as to whether they are appropriate (all Class 3B/Class 4 laser users and their supervisors need to be aware of what to do*).*

2. At Los Alamos National Laboratory, California USA, 2004

On 14th July 2004 an undergraduate student was injured whilst working with a Nd:YAG laser in the Chemistry Division. The work involved the use of two lasers one to analyse particles (L1) and one to generate and suspend particles in a target chamber (L2). On the day in question the Principle Investigator (PI) was using L1 in flash-lamp mode to illuminate the suspended particles. After firing and shutting down L2 the PI removed the beam stop from behind the target chamber and looked inside whilst L1's flash lamps continued to operate.

When the student bent down to look too she immediately saw a flash and a reddish-brown spot in her left eye - a hole had been burnt in her retina.

An investigation followed and PI claimed that he was operating L1 with the Q-switched trigger cable disconnected from the pulse generator; however the investigating team confirmed that the laser could not lase under those conditions.

The accident investigation team found the following failures of management and procedures:

- Neither the PI nor the student were wearing laser eye protection and there were no engineered safety measures in place.
- The PI did not recheck beam alignment or laser condition or check for beam reflections on July 13 or 14.
- The PI prepared an insufficiently detailed risk assessment/scheme of work and had not updated it to reflect experimental changes.
- The student had not received proper pre-job training and had been asked to sign up to the scheme of work after the accident.
- Line managers responsible for the area had not monitored PIs safety practices
- The Line Manager and Laser Safety Officer had signed off PIs risk assessment/scheme of work without noting the lack of detail.
- Management did not ensure that PI followed the Local Rules.
- No PI training in relation to mentoring students.

As a result of this incident the Los Alamos Lab was required to review its procedures, improve safety management and improve training of mentors and students to ensure that this type of incident would hopefully not occur again.

Four top scientists faced disciplinary action after the accident, the Principal Investigator was sacked and there was considerable disruption to the work of the laboratory during the course of the investigation and the procedural review.

Both these accidents have similarities. In neither case was safety eyewear being worn. In both cases two lasers were being used and the individual was struck in the eye with a pulse from a pulsed laser that they were not expecting. If you are viewing an experimental set-up either:

- *a proper shutdown procedure must be followed before looking down beam-paths, or*
- *safety eyewear must be worn(but not to deliberately look down beam paths), or*
- *viewing should be via a video camera in a safe location.*