**Lasers Management and Control Policy**

Aberdeenshire council will demonstrate that, in regard of managing the risks associated with Lasers it will:

* Identify and assess sources of risk
* Prepare a control system for preventing, reducing or controlling the risk
* Implement and manage and monitor precautions
* Maintain suitable and sufficient records of the precautions implemented and will carry this out for each Aberdeenshire Council premises within the Council’s control.
* Appoint a person to be responsible for the management and maintenance of the control system and measures adopted.

The Manager of the establishment has the day to day responsibility for the implementation of these procedures to ensure, so far as is reasonably practicable, the safety of employees and others at council premises

Management has a statutory duty to ensure that compliance is active, continuous and effectively policed.

The Council must be able to demonstrate it has:

* Identified all the relevant factors
* Instituted the appropriate corrective or preventive actions and
* Is monitoring the effective implementation of the required solutions.

# LASERS

**CHARACTERISTICS OF LASER RADIATION**

**1. Radiometric quantities and units and terminology**

The physical (radiometric) terms and units used in the optical region of the electromagnetic spectrum are standardized by the *Systeme International d’Unites* (SI). The International Commission on Illumination (Commission Internationale de l’Eclairage, CIE) together with the International Electro technical Commission (IEC) publishes a standardised vocabulary of lighting terminology that includes definitions of radiometric and photo metric terms, quantities, and units (CIE 1989) which are used in this document. There are only a few terms, quantities, and units in widespread use when specifying exposure limits for the health protection of workers.

**2. Types of lasers**

There are a number of methods to group or categorise lasers depending upon wavelength, pulse characteristics, active medium or pumping process. Lasers may be pulsed or continuous-wave (CW) depending upon the duration of excitation of the active medium by pumping. The duration of a pulse may vary from femto seconds (10-15 s) or pico seconds (10-12s) to larger fractions of a second. If the laser emits pulses of duration less than 1 nanosecond (10-9s), it will normally be a ‘mode-locked’ laser. If the laser emits pulses of the order of several nanoseconds (ns) to several 100 ns it is referred to as a ‘q-switched’ laser. If the emission of an optically pumped laser follows the normal pulse emission of a flash lamp, then the laser is normally referred to as a ‘long-pulse’ or ‘normal-pulse’ laser. For safety purposes, lasers which emit continuously for periods greater than 0.25s are referred to as ‘CW lasers’. Lasers which emit groups or ‘trains’ of pulses are referred to as ‘repetitively pulsed’ and the frequency of pulses is referred to as the ‘pulse repetition frequency’ (PRF). By contrast with conventional light sources, the laser is coherent, normally collimated and monochromatic.

**SOURCES OF OCCUPATIONAL EXPOSURE TO LASER RADIATION**

**1. Industrial and scientific laser applications**

1.1 Industrial laser use

Industrial lasers typically are used for cutting, welding or other type of material processing. These systems contain high power lasers, but are operated in a controlled environment.

1.2 Scientific laser applications

These types of applications are the hardest to categorise – almost any possible exposure wavelength or condition can occur. These applications are the hardest to control and most complaints about ‘overly restrictive’ controls are received from scientists. However, scientists are also the most likely to be injured in laser accidents.

**2. Medical and surgical laser applications**

In medicine, lasers were first used in ophthalmology for retinal photo-coagulation purposes and secondly in general surgery. They are a first class tool in microsurgery, including neuro surgery. Diagnostic and therapeutic laser techniques are presently being investigated in most medical fields, such as diagnostic transillumination of tissue, gynaecological and gastro-enterological surgery, dermatology, and aesthetic (cosmetic) surgery.

1. **Laser optical fibre communications**

During operation, laser energy is confined to the optical fibre. Maintenance and service procedures may allow access to laser levels that may be hazardous.

1. **Display and entertainment lasers**

These lasers typically emit many watts of visible light. They are potentially very dangerous if system safety system fails during operation.

**HAZARD EVALUATION AND LASER DEVICE CLASSIFICATION**

**1. General concepts of hazard evaluation and risk assessment**

Four aspects of the use of lasers need to be taken into account in the evaluation of possible hazards, the assessment of risk of injury and in the application of control measures:

(a) The capability of the laser or laser system to injure personnel determines its ‘hazard classification’. This includes consideration of human access to the main exit port or any subsidiary port of the laser beam. Certain hazard controls are built into commercially manufactured lasers or laser systems (IEC 1984, 1990). The concept of *risk* is included in the scheme of ‘hazard’ classes.

(b) The environment in which the laser is used.

(c) The level of training of the personnel who operate the laser or who may be exposed to its beam.

(d) The intended use of the laser

The practical means for evaluating laser radiation hazards and assessing risk of exposure is to first determine the hazard classification of each laser system. The hazard class indicates the laser’s relative hazard potential and may also incorporate an assessment of risk of exposure to potentially hazardous levels of laser radiation. Appropriate controls are specified for each class. The use of the classification system will, in most cases, preclude any requirement for radiometric measurements and a detailed risk assessment by the user.

In the standardised laser classification scheme, aspect (a) (the potential hazard of the laser or laser system) is defined. Aspects (b) and (c) vary with each use and cannot be readily included in a general classification scheme. In total hazard evaluation and risk assessment procedures, all four aspects must be considered, although in most cases aspects (a) and (d) are sufficient to determine the control measures applicable.

**2. Classification of laser devices**

The hazard and risk classification scheme give below is based on the output parameters and accessible levels of radiation. This classification takes largely into account that of the IEC (1984) the US Food and Drug Administration (FDA 1989) and that used by ANSI (1986). The laser device classification normally will appear on many commercial laser products manufactured subsequent to the adoption of these standards. This classification should be used unless the laser is modified so as to change its output power or energy significantly. The classes are:

1. laser systems that are not hazardous (without known biological hazards);

2. laser systems (visible only) that are normally not hazardous by virtue of normal aversion responses (low-risk);

3. laser system where intrabeam viewing of the direct beam and specular reflections may be hazardous (moderate-risk), sometimes divided into two subcategories a and b, where Class 3a represents a low risk (similar to Class 2) and is hazardous only if the beam is re-collected or focused by an optical instrument;

4. laser system where even diffuse reflections may be hazardous and where the beam produces a fire hazard or serious skin hazard

The basis of the hazard and risk classification scheme is the ability of the primary laser beam or reflected beam to cause biological damage to the eye or skin.

A Class 2 laser or low-power system does not produce an immediate hazard when accidentally viewed directly, but must have a cautionary label affixed to the external surface of the device to advise against staring into the beam. Similar controls are required for a Class 3a laser.

The moderate-risk Class 3b category (or medium-power system) requires control measures to prevent viewing of the direct beam.

Class 4 high-risk (or high power) systems require the use of controls that prevent exposure to the eye and skin to the direct and diffusely reflected beam. In addition to the possibility of eye damage, exposure to optical radiation from such devices could constitute a serious skin hazard.

**3. Laser output parameters required for hazard classification**

Accessible emission limits (AELs) have been established for each class of laser below Class 4; i.e. a laser product is in a given class only if the emitted laser radiation is below the AEL for its class. There are no AELs (i.e. upper limits) for Class 4. The following parameters are required for the classification of the different types of lasers:

1. Essentially all lasers; wavelength(s) or wavelength range

2. Continuous-wave (CW) or repetitively pulsed lasers; average power output is also required and, in some cases, a determination of the exposure duration depending upon the application

3. Pulsed lasers; total energy per pulse (or peak power), pulse duration, pulse repetition frequency, and emergent beam radiant exposure

4. Extended-source laser devices, such as injection laser diodes and those lasers having a permanent diffuser within the output optics; all of the above parameters, the laser source radiance or integrated radiance, and the maximum viewing angular subtence,

**4. Definitions of laser device hazard classes**

**Class 1** – laser devices with no known radiation hazard

A Class 1 laser device is defined as any laser, or laser system containing such a laser, that cannot emit laser radiation levels in excess of the AEL for Class 1 (see below) for the classification duration. The classification duration is the longest daily exposure duration expected. The exemption from hazard controls applies strictly to emitted laser radiation hazards and not to other potential hazards.

The AEL for Class 1 is defined by a ‘worst-case’ analysis of a laser’s potential for producing injury. In this ‘worst-case’ risk assessment it is necessary to consider not only the laser output irradiance or radiant exposure, but also whether a hazard would exist if the total laser output were concentrated within the defining aperture for the applicable exposure limit. For instance, the unfocused beam of a CW, CO2 laser of 10.6µm would normally not be hazardous if the beam irradiance were less than 1kWm-2, however, if the output power were 10W and the beam could be focused by a mirror at some location to a spot 1mm in diameter, a serious hazard could exist. The aELs for class 1 must be defined in two different ways, depending on whether the laser itself is considered an ‘extended source’ (an unusual case), or a ‘point source’ (the normal case).

For most lasers, the AEL for Class 1 is the product of a x b, where a is the intrabeam (point-source) exposure limit for the eye for the exposure duration T max and b is the circular area of the defining aperture.

For extended-source lasers, (e.g. laser arrays, laser diodes and diffused-output lasers that emit in the spectral range 400-1,400nm), the AEL for Class 1 is determined by a power or energy output such that the source radiance would not exceed the extended-source exposure limit, if the source were viewed at the minimum viewing distance of 10cm. An optical viewing system does not increase the hazard for extended sources. This AEL is seldom necessary to apply, and the point-source AELs can be applied to provide a conservative analysis.

**Class 2** – low-risk, low-power visible laser devices which do not represent a hazard for momentary viewing, and are defined as follows:

(a) visible continuous-wave laser devices that can emit a power exceeding the AEL for Class 1 for the classification duration (0.4 µW for T max greater than 0.25 second) bur not exceeding 1mW;

[NOTE: In some standards, some Class 2 lasers may be placed into a subcategory, Class 2a (which are not hazardous for viewing durations greater than 1,000 s)]

(b) visible scanning laser systems and repetitively pulsed laser devices that can emit a power exceeding the appropriate AEL for Class 1, but not exceeding the AEL for Class 1 for a 0.25 second exposure, are Class 2.

Any laser device in a low-risk classification by virtue of enclosure must have warning labels indicating higher-risk class ‘when access panels are removed’. These labels may be covered by a separate enclosure which must be removed before the main access panels can be removed.

**Class 3a** – low-risk, medium-power laser devices are visible continuous-wave lasers, operating in a power range of 1-5mW, which have an irradiance in the emergency beam of 25 Wm-2 or less. In some standards the class applies to non-visible lasers having an emission with less than five times the AEL for Class 1 which do not exceed the occupational exposure limit (EL) due to a large exit beam diameter.

**Class 3b** – moderate-risk, medium-power laser devices are defined as:

(a) UVR, IRB and IRC laser devices (ultraviolet radiation, infrared B and C radiation) that can emit a radiant power in excess of the AEL for the lower classes but cannot emit:

- an average radiant power in excess of 0.5W for T max greater than 0.25 second; or

- a radiant exposure of 100 Jm-2 within an exposure duration of 0.25 second or less;

(b) visible and IRA (near infrared) continuous-wave or repetitively-pulsed laser devices that exceed the limits for lower classes but cannot emit an average radiant power of 0.5 W for T max greater than 0.25 second;

(c) visible and IRA pulsed laser devices that exceed the limits for lower classes but cannot emit a radiant exposure that exceeds either 100 Jm-2 or that required to produce a hazardous diffuse reflection from a perfect diffuser.

**Class 4** – high-risk, high-power laser devices that can emit in access of AELs for Class 3b laser devices.

**5. Classification of multi-wavelength and multiple-source lasers**

The classification of laser devices that can potentially emit at numerous wavelengths should be based on the most hazardous possible wavelength combination. Usually the risk from one wavelength far outweighs the contribution of other wavelengths. Multiple sources are considered independent if separated by the appropriate limiting angle for an extended source.

**6. Detailed risk assessment**

Classification is the initial step in hazard analysis and risk assessment. However, it is not sufficient merely to classify the laser in terms of its power or energy output. The place and way that a laser is used, as well as the people who may operate it or be in the exposure zone, must also be considered. The additional safety measures that such environmental and personnel factors may require must be taken into account, and are discussed below.

**7. Environment**

Environmental factors require careful consideration after the laser device has been classified, as their importance in the total hazard evaluation and risk assessment depends on the laser classification. The decision to employ additional hazard controls not ordinarily required for moderate-risk and high-risk laser devices may depend largely on environmental considerations. The probability of exposure of personnel to hazardous laser radiation must be considered separately, since it is influenced by the laser’s use: indoors, as in a machine shop, a classroom, a research laboratory, or a factory production line; or, outdoors, as at a highway construction site, on the open sea, on a military laser range, in the atmosphere above occupied areas, or in a pipeline construction trench. Other environmental hazards should also be considered.

If exposure of unprotected personnel to the primary or specularly reflected beam is expected, caluculations or measurements of either irradiance or radiant exposure of the primary or specularly reflected beam, or radiance of an extended source, at that specific exposure location are required. It is important to consider that transmission and reflection properties of materials can vary significantly in the infared and ultraviolet regions when compared to those properties in the visible region of the optical spectrum. For example, plastic curtains which appear very dark or opaque to visible light may be actually highly transparent in the near-infrared; many paints that are of low reflectance in visible light have a much higher reflectance in the near-infrared. Also, dull, non-specular metal surfaces as visualized under visible light are frequently highly specular (mirror-like) for the infrared wavelength of the CO2 laser at 10.6µm.

**7.1 Indoor laser operations**

In general only the laser source itself is considered in evaluating an indoor laser operation if the beam is enclosed or is operated in a controlled area. The following step-by-step procedure is recommended for evaluation of moderate-risk laser devices indoors when this is necessary, since unprotected personnel may potentially be exposed with this particular class of laser devices:

Step 1 Determine the applicable AEL considering the maximum exposure duration from the intended use

Step 2 Determine the hazardous beam path(s)

Step 3 Determine the extent of hazardous specular (mirror-like) reflection as indicated in figure 2. The reflection hazard varies with the degree of focusing of the beam and the nature of the surface.

Step 4 Determine the extent of hazardous diffuse reflections (nominal hazard zone)

Step 5 Determine whether any non-laser hazards exist

**7.2 Outdoor laser operations over extended distances**

The total hazard evaluation of a particular laser device depends on defining the extent of several potentially hazardous conditions. This may be done in a step-by-step manner as follows:

Step 1 Determine the applicable AEL considering the maximum exposure duration from the intended use

Step 2 Estimate the nominal hazardous range of the laser

Step 3 Evaluate potential hazards from specular-surface reflections, such as those from windows and mirrors in vehicles, and hazards from retroflectors

Step 4 Determine whether hazardous diffuse reflections exist (nominal hazard zone), especially if the laser is operating in the 400-1,400nm band

Step 5 Evaluate the stability of the laser platform to determine both the extent of horizontal and vertical range control and which, if any, of the azimuth and elevation constrains need to be placed on the beam traverse

Step 6 Determine the likelihood of people being present in the area of the laser beam

**8. Personnel**

The individuals who may be in the vicinity of a laser and its emitted beam or beams can influence the decision to adopt additional control measures not specifically required for the class of laser being employed. This again depends on the classification of the laser device.

If children or others unable to read or understand warning labels are exposed to potentially hazardous laser radiation, the hazard evaluation is affected and control measures could require appropriate modification.

The type of personnel influences the total risk assessment, especially with the use of moderate-risk, medium-power lasers. The principal means of hazard control for certain lasers or laser systems, such as military laser range-finders and some moderate-risk lasers used in the construction industry, is for the operator to keep the laser beam away from personnel or flat, mirror-like surfaces.

The factors to be taken into account with regard to pesonnel who may be exposed are summarised as follows:

(a) the maturity and general level of training and experience of the laser users (e.g. students, master machinists, soldiers and scientists);

(b) the maturity of onlookers, their awareness that potentially hazardous laser radiation may be present, and their knowledge and ability to apply relevant safety precautions;

(c) the degree of training in laser safety of all individuals involved in laser operation;

(d) the extent to which individuals can be relied on to wear eye protection

(e) the number and location of individuals relative to the primary beam or reflections, and the probability of accidental exposure.

**SAFETY PRECAUTIONS**

**1. Types of control measures**

The purpose of safety precautions and control measures is to reduce the possibility of exposure to hazardous levels of laser radiation and to other associated hazards. Control measures may be grouped into one of three categories: (a) engineering controls, (b) personal protective clothing and equipment, (c) administrative controls. In general, engineering control measures are considered more reliable and therefore preferable. If engineering control measures are not practicable, personal protective equipment (normally eye protectors) should be used. Administrative controls and procedures are additional measures which cannot be used as a substitute for engineering control measures.

**2. Selection of control measures**

It may not be necessary to implement together all of the control measures at a given time or for a specific laser operation. Whenever the application of any one or more control measures reduce the possible exposure to a level below the applicable exposure limit, then the application of additional control measures may become unnecessary for a given laser operation.

**3. Modified laser products**

If a modification by the user of a previously classified laser product affects the intended function or the emergent laser beam power or energy, the person or organisation performing nay such modification is responsible for ensuring the reclassification and re-labelling of the laser product.

**4. Specified environments**

The following guidance relates to safe operation of laser products in:

(a) outdoor and construction environments where administrative controls often provide the only reasonable approach to safe operations;

(b) laboratory and workshop environments where engineering controls may play the greater role;

(c) display and demonstration environments, where pre-planning, delineation and control of access often provide the only reasonably practicable approach to safe operation.

**5. Laser demonstrations, displays and exhibitions**

Only Class 1, Class 2 or Class 3a laser products should be used for demonstration, displays or entertainment in unsupervised areas. The use of lasers of a higher class for such purposes should be permitted only when the laser operation is under the control of an experienced, well-trained operator and when spectators are prevented from exposure to levels exceeding the applicable exposure limits. Where appropriate, licensing of such displays should be based on an assessment of overall laser safety associated with the potential use of the laser.

Each demonstration laser system used for education purposes in schools, etc., should be operated so as not to permit exposure to laser radiation in excess of the applicable exposure limit.

**6. Laboratory and workshop laser installations**

**(i) Class 2 and Class 3a laser products**

Precautions are only required to prevent continuous viewing of the direct beam; a momentary (0.25s) exposure, as would occur in accidental viewing situations, is not considered hazardous. However, the laser beam should not be intentionally aimed at people. The use of optical viewing aids (e.g. binoculars) with Class 3a laser products is potentially hazardous.

**(ii) Class 3b laser products**

Class 3b lasers are potentially hazardous if a direct beam or specular reflection is viewed by the unprotected eye (intrabeam viewing). [[1]](#footnote-1)The following precautions should be taken to avoid direct beam viewing and to control specular reflections.

(a) the laser should be operated only in a controlled area;

(b) care should be exercised to prevent unintentional specular reflections;

(c) the laser beam should be terminated where possible at the end of its useful path by a material that is light-diffusing and of such a colour and reflectivity as to make beam positioning possible while still minimising the reflection hazards;

(d) eye protection is required if there is any possibility of viewing either the direct or specularly reflected beam, or of viewing a diffuse reflection through magnifying optics collecting energy within 20cm;

(e) the entrances to areas should be posted with a standard laser warning sign

**(iii)** **Class 4 laser products**

Class 4 laser products pose potential hazards from both the direct beam or its specular reflections and from diffuse reflections. They also present a potential fire hazard. The following controls should be employed in addition to those of section (ii) to minimise these risks;

(a) beam paths should be enclosed whenever practicable. Access to the laser environment during laser operations should be limited to persons wearing proper laser protective eyewear (and protective clothing in some instances);

(b) class 4 lasers should be enclosed when operated whenever practicable, thus eliminating the need for personnel to be physically present in the laser environment;

(c) good room illumination is important in areas where laser eye protection is worn. Light-coloured and light-diffusing wall surfaces help to achieve this condition;

(d) a sufficient thickness of firebrick or other refractory material should be provided as a backstop for the beam since fire is a principal hazard associated with high-powered lasers (e.g. carbon dioxide, hydrogen fluoride, deuterium fluoride). Caution should be observed with these materials as surface glazing may occur with prolonged exposure and give rise to specular reflection. Adequately cooled non-flat metal targets, such as cones and absorbers, are preferred. Laser cutting and welding, normally do not produce hazardous reflections at a distance except when beam power fails and ablation ceases;

(e) special precautions may be required to reduce unwanted reflections from far-infrared laser radiation, and the beam and target area should be surrounded by a material such as polymethylmethacrylate opaque to the laser wavelength (even dull metal surfaces may become highly specular at the CO2 wavelength of 10.6µm).

**7. Outdoor and construction laser installations**

**(i) Class 2 laser products**

Wherever reasonably practicable, the beam should be terminated at the end of its useful path, and the laser should not be aimed at the eyes of people or routinely operated at head height.

**(ii) Lasers for surveying, alignment and levelling**

Class 1 or Class 2 lasers should be used for surveying, alignment, and levelling applications whenever practicable. There may be situations, however, where high ambient light levels require the use of lasers of higher output power. If Class 3a lasers are used, the requirements of section (iii) should be followed. In those exceptional cases where Class 3b lasers are necessary, the requirements of section (iv) should be followed. In addition, human access should not be permitted to laser radiation in the wavelength range of 400nm to 700nm with a radiant power that exceeds 5mW for any emission duration exceeding 0.38ns, nor should human access be permitted to laser radiation in excess of the accessible emission level (AEL) for Class 1 for any other combination of emission duration and wavelength range.

**(iii) Class 3a laser products used for surveying, alignment and levelling**

The following guidance applies to surveying operations using Class 3a laser products for alignment and levelling:

(a) Only qualified and trained employees approved by a laser safety officer should be assigned to install, adjust and operate the laser equipment

(b) Areas in which these lasers are used should be posted with a laser warning sign.

(c) Wherever practicable, mechanical or electro-optic means should be used to assist in the alignment of the laser

(d) Precautions should be taken to ensure that persons do not look directly into the beam (prolonged intrabeam viewing is hazardous). Direct viewing of a totally collected beam above 2mW through optical instruments (theodolites, etc) may be hazardous and should not be permitted unless specifically approved by a laser safety officer

(e) The laser beam should be terminated at the end of its useful beam path and should in all cases be terminated if the hazardous beam path (to the nominal ocular hazard distance) extends beyond the controlled area

(f) The laser beam path should be located well above or below eye level wherever practicable

(g) Precautions should be taken to ensure that the laser beam is not unconditionally directed at mirror-like (specular) surfaces (most importantly, at flat mirror-like surfaces)

(h) When not in use, the laser should be stored in a location where unauthorised personnel cannot gain access

**(iv) Class 3b and Class 4 laser products**

Class 3b and Class 4 lasers in outdoor and similar environments should be operated only by people adequately trained in their use and approved by the laser safety officer. To minimise possible hazards, the following precautions should be employed in addition to those given in para (iii):

(a) People should be excluded from the beam path at all points where the beam irradiance or radiant exposures exceed the exposure limits unless they are wearing appropriate eye protectors. Engineering controls such as physical barriers, inter-locks limiting in the beam traverse and elevation should be used wherever practicable to augment administrative controls.

(b) The intentional tracking of non-target vehicles or aircraft should be prohibited within the nominal ocular hazard distance

1. The beam paths should, whenever practicable, be cleared of all surfaces capable of producing unintended reflections that are potentially hazardous, or the hazard area should be extended appropriately

**8. Use of built-in engineering controls**

(i) Remote interlock connector

The remote interlock connector installed in a Class 4 laser should be connected to an emergency master disoconnect interlock or to room, door, or fixture interlocks. Door interlocks should be employed when a hazardous level of laser radiation may exist at the doorway

(ii) Key control

When it is not in use each Class 3b or Class 4 laser product should be protected against unauthorised use, by removal of the key of the key control

(iii) Beam stop or attenuator

In addition to the laser operating switch, Class 3b and Class 4 laser products should be provided with a permanently attached beam stop or attenuator mechanism capable of preventing output emission in excess of the appropriate level when the laser product is on stand-by

**9. Warning signs**

The entrances to areas or protective enclosures containing Class 3a, Class 3b, and Class 4 laser products should be posted with appropriate warning signs

**10. Beam paths**

The beam emitted by each Class 3b or Class 4 laser product should be terminated at the end of its useful path by a diffusely reflecting material of appropriate reflectivity and thermal properties or by absorbers.

Open laser beam paths should be located above or below eye level (for standing and seated persons) where practicable.

Laser beams should be enclosed within an appropriate protective enclosure (e.g. within a tube) where practicable.

**11. Specular reflections**

Care should be exercised to prevent the unintentional specular reflection of laser beams from Class 3b or Class 4 laser products. Optical elements such as mirrors, lenses and beam slitters should be rigidly mounted and subject to controlled movements.

**12. Eye protection**

(i) Protective eyewear specifications

The following should be considered when specifying suitable protective eyewear:

(a) wavelength(s) of operation;

(b) maximum expected radiant exposure or irradiance;

(c) applicable exposure limit;

(d) required optical density of eyewear at laser output wavelength, which is normally the logarithm of the radio of (b)/(a);

(e) visible light transmission requirements;

(f) radiant exposure or irradiance at which damage to eyewear occurs;

(g) need for prescription glasses;

(h) comfort and ventilation;

(i) degradation or modification of absorbing media, even if temporary or transient;

(j) strength of materials (resistance to shock);

(k) peripheral vision requirements;

(l) any relevant national requirements;

Eye protection which is designed to provide adequate protection against specific laser radiations should be used in all hazard areas where Class 3b or Class 4 lasers are in use. Exceptions to this are:

(a) when engineering and administrative controls are such as to eliminate potential exposure in excess of the applicable exposure limit;

(b) when, due to the unusual operating requirements, the use of eye protection is not practicable. Such operating procedures should only be undertaken with the approval of the laser safety officer.

(ii) Identification and labelling of laser eye protectors

All laser protective eyewear shall be clearly labelled with information adequate to ensure the proper choice of eyewear with particular lasers

(iii) Required optical density

The optical density (OD) of laser protective eyewear is normally highly wavelength-dependent. Where protective eyewear is required to cover a band of radiation, the minimum value of D within the band shall be quoted. The value of D required to give eye protection can be calculated from the formula:

D = log10 (Ho/EL)

Where Ho is the expected exposure level at the unprotected eye expressed in the same radiometric units as the EL (exposure limit)

(iv) Eyewear selection

Protective eyewear should be comfortable to wear, provide as wide a field-of-view as possible, maintain a reasonably close fit (if the required D is greater than 1.5) while still providing adequate ventilation to avoid problems of misting and to provide adequate visual transmittance. Care should be taken to avoid, as far as is possible, the use of eye protectors employing flat reflecting surfaces which might cause hazardous specular reflections. The frame and any side-pieces should protect against exposures up to 0.03 of that afforded by the lenses.

**13. Protective clothing**

Where personnel may be exposed to levels of laser radiation that exceed the exposure limit for the skin, suitable protective clothing should be provided. This is primarily of importance with UV laser radiation. Class 4 lasers especially are a potential fire hazard, and protective clothing worn should be made from a suitable flame-and heat-resisting material if exposure is expected, although engineering controls should be relied upon rather than resorting to protective clothing.

**TRAINING**

All workers potentially exposed to laser radiation should be informed of any potential hazards and appropriate means of protection. This training should be presented in an understandable manner, and should indicate the consequences if protective measures are not used.

Operation of Class 3b or Class 4 laser systems can represent a hazard not only to the user but also to other people over a considerable distance. Because of this hazard potential, only persons who have received training to an appropriate level should be placed in control of such laser systems. The training which may be given by the manufacturer or supplier of the system, the laser safety officer, or by an approved organisation, should include, but is not limited to:

(a) familiarisation with system operating procedures;

(b) bio-effects of the laser upon the eye and the skin;

(c) the proper use of hazard control procedures, warning signs, etc;

(d) the need, if any, for personal protection;

(e) the consequences, when appropriate, if means of protection are not used;

1. accident-reporting procedures and where medical attention should be sought

**HEALTH SURVEILLANCE**

In the absence of general national regulations, the following recommendations should be taken into consideration

(a) A medical examination by a qualified specialist should be carried out immediately after an apparent or suspected injurious ocular exposure. Such an examination should be supplemented with a full biophysical investigation of the circumstances under which the accident occurred

1. Pre- and post-assignment ophthalmic examinations of workers using Class 3b and Class 4 lasers are recommended. Examinations which emphasise tests of visual function should be considered adequate in any case.

**RESPONSIBILITY OF THE EMPLOYER**

The owner of the device or installation emitting laser radiation has a number of responsibilities. These include:

(a) the radiation safety of employees;

(b) the purchase and provision of laser equipment which meets all appropriate standards when new and during its lifetime of use;

(c) ensuring that the laser equipment meets appropriate radiation safety standards and safety requirements as specified in this document;

(d) acting to reduce the exposure of workers to laser radiation and making the organisational arrangements required to prevent the risks associated with exposure;

(e) establishing and publicising (preferably in writing) a general policy emphasising the importance of prevention, and taking the decisions and the practical steps required to give effect to national regulations and for the implementation of the preventive measures

Responsibility may be delegated by the owner depending on the size of the organisation and the amount of radiation-emitting equipment used. Without prejudice to the responsibility of each employer for the health and safety of the workers in his employment, and with due regard to the necessity for the workers to participate in matters of occupational health and safety, one or more persons may be designed to carry out the role of responsible user and laser safety officer.

**DUTIES OF THE LASER SAFETY OFFICER**

There should be one person designated by the owner or employer as the responsible person for laser safety if Class 3b and Class 4 lasers are in use. If the organisation is sufficiently large, a Laser Safety Committee may exist to establish policy; however, the laser safety officer (LSO) would be the principal executive agent for laser hazard control. In the absence of a Laser Safety Committee, the LSO should have the following duties:

(a) ensuring that an effective safety programme is developed and instituted whenever there is a special hazard due to laser radiation;

(b) ensuring the proper briefing of workers, and to promote the co-operation between employer and workers in the reduction or prevention of laser exposure;

(c) establishing safe operating procedures for laser equipment and ensuring that all staff are made aware of them;

(d) ensuring that assigned laser equipment is maintained and used correctly by competent personnel;

(e) knowing the exposure levels in the vicinity of the equipment under normal conditions of use;

(f) defining areas where exposure in excess of the recommended limits may result, and posting warning signs that clearly indicate the permitted occupancy conditions;

(g) ensuring that appropriate laser radiation surveys and hazard assessments are performed when and as required, and maintaining records of such surveys and assessments;

(h) investigating and reporting laser exposures which may be in excess of the limits recommended;

(i) designating staff as laser workers and arranging for the medical examination and treatment of over-exposed workers in the case of accidental exposure;

(j) recording levels and duration of exposure for persons who have been exposed in excess of the recommended limits;

1. reviewing the precautions listed herein designating the appropriate controls and assuring education and awareness of the potential hazard controls

**DUTIES OF OTHER OCCUPATIONAL SAFETY AND HEALTH SPECIALISTS**

A safety engineer, industrial hygienist, occupational health nurse, health physicist or other health professional may be designated as the LSO, or may be delegated some of the responsibilities of the LSO. In small organisations, the user, LSO and health physicist may be the same person. This person should have direct access to the employer. The extent and nature of the responsibilities will depend on the size of the organisation and the number of devices. In general, the health specialist provides technical support in the planning of the installation and the operation of laser devices. Health specialists should, where necessary, supervise compliance with the regulations and take part in the implementation of preventive measures.

**DUTIES OF THE WORKER (USER)**

Laser users in charge of the day-to-day operation and maintenance of laser-radiation-emitting devices must:

(a) be aware of the hazards associated with operating the specific laser devices assigned to them, and in particular, the importance of any interlock systems and dangers associated with defeating such systems, and adherence to all occupancy restrictions;

(b) be able to recognise malfunctions of the specific devices assigned to them that might result in high laser exposures;

(c) be aware of and trained in normal safe operating practices and the procedures to be followed in the event of malfunction of the devices, or in an emergency situation arising from excessive laser radiation emissions;

(d) use protective equipment provided, as necessary;

1. be willing to undergo reasonable prescribed medical surveillance

### RESPONSIBILITIES OF MANUFACTURERS

Laser equipment manufacturers are responsible for making equipment that conforms to the appropriate standards within the country and for providing information on the hazards of operating and servicing laser equipment, sufficient to alert the owner or employer of the magnitude of the risk and the appropriate precautions that need to be taken. Such information should include classification of the laser product.

## COOPERATION

The following principles should be taken into consideration with regard to co-operation between employers, workers, safety and health committees, manufacturers and so on:

(a) the employer should secure the workers’ co-operation in order to protect their health and to reduce laser exposure, and should establish, by joint agreement, instructions and recommendations for the prevention of such exposure;

(b) employers and workers should co-operate in devising and implementing programmes for the prevention and control of laser radiation exposure, particularly in conjunction with any safety committees for monitoring the working environment;

(c) co-operation should be established between manufacturers and purchasers of equipment with a view to reducing unintended laser radiation emissions of such equipment; and

(d) co-operation in the development of both voluntary and regulatory laser equipment standards should be encouraged

1. Conditions for safe viewing of a diffuse reflection of Class 3b visible lasers are: minimum viewing distance of 13cm between screen and cornea and a maximum viewing time of 10s. Other viewing conditions e.g staring fixedly at a diffuse reflection, are considered unrealistic. [↑](#footnote-ref-1)