PREFACE

Charles Sturt University is committed to the provision of a safe and healthy working environment, in regards to laser usage, for its staff, students and visitors. As a consequence of this the University encourages all members of the University community to regard accident prevention and working safely as a collective and individual responsibility.

The Vice Chancellor has ultimate responsibility for the implementation and review of the University Laser Safety policy, and delegation of laser management responsibilities. In fulfilling the objectives of this policy, management is committed to regular consultation with the Radiation Safety Committee to ensure that the policy operates effectively and that radiation hygiene issues are regularly reviewed.

5.1 INTRODUCTION

Charles Sturt University has staff who use laser apparatus for both teaching and research. As such, users of lasers are encouraged to comply with the relevant standard (AS2211.1-2004 Laser Safety – Equipment classification, requirements and User's Guide) and any other relevant codes of practice. The objective of this safety program is:

A. To protect persons from laser radiation in the wavelength range 100 nm to 1 nm* by indicating safe working levels of laser radiation and by introducing a system of classification (as per the standard) of lasers and laser products according to their degree of hazard. *In the standard, the wavelength range λ_1 to λ_2 means $\lambda_1 \leq \lambda \leq \lambda_2$

B. To lay down requirements for the user to establish procedures and provide information so that appropriate precautions can be taken.

C. To ensure adequate warning to individuals of hazards associated with accessible radiation from laser products through signs, labels and instruction.

D. To reduce the possibility of injury by minimising unnecessary accessible radiation, to give improved control of the laser radiation hazards though protective features, and to provide safe usage of laser products by specifying user control measures.

5.1.1 Responsibilities

The University has a designated responsibility as defined in the University OH&S Policy "Occupational Health, Safety and Welfare Objectives and Responsibilities" which can be found at the following website address:
http://www.csu.edu.au/adminman/hum/OCC02.rtf

This policy also applies to lasers. Within the guidelines of the Standard and International Codes of Practice it is primarily the principal supervisor or researcher who will be responsible for laser safety. This includes all relevant documentation and institutional procedures.

5.1.2 Safety and Compliance with Requirements

Hazards from laser radiation are dependent on the general class of the lasers(s) being used. See Section 5.2: Laser Classification for detail. Laser beams striking human tissues directly or reflected onto the tissue may be capable of inflicting varying degrees of damage. The principal concern is with damage to the retina of the eye, since the eye is capable of increasing light intensity many thousands of times by its focusing power. Skin damage is also possible with increasing laser intensity.

The factors that can contribute to tissue injury and influence the degree of damage from laser beam exposures include:

a) Wavelength of laser radiation.
b) Tissue spectral absorption, reflection and transmission.
c) Strength of irradiance of incident laser beam.
d) Size of irradiated area.
e) Exposure duration.
f) Pupil size.
g) Location of retinal injury.
h) Laser pulse characteristics.

Because of the medical/biological damage (See Section 5.3: The Effects of Laser Radiation on Biological Tissue) that may occur due to exposure to laser radiation, and the difficulty of assessment of this damage, the Standard and both National and International Codes of Practice require medical assessments. These assessment forms can be found in Section 5.4: Medical Surveillance for Laser Users. With this concern, all University laser users shall be registered with the Radiation Safety Committee of the University. Registration shall proceed before any planned laser usage. Current users shall also register; this is to ensure that all users are medically observed. To register use form <u>Laser 1</u>. This form can be found in Section 5.5: Registration Forms for Users. In Addition, those users who are or will be working with Class 3B and 4 Lasers must have an opthalmic examination before starting work and at three yearly intervals, or at the conclusion of the project.

As an addendum to the registration of the users, all laser equipment will be inventoried by the University. Completion of form <u>Laser 2</u> is required. This form can be found in Section 5.5: Registration Forms for Users.

Since there is a large variety of lasers and lasers operations, the University will not develop a comprehensive Laser Safety Manual. Instead there is a set of guidelines in Section 5.6 Laser Safety SOP Guidelines that can be used in the development of Standard Operating Procedures to cover safety in laboratories specific to the operations/equipment being used including the Personal Protective Equipment required. The SOPs developed by each laboratory shall be presented to the Radiation Safety Committee for approval. Details on required Personal Protective Equipment can be found in Section 5.7: Personal Protective Equipment. The University requires areas to comply with placarding requirements for laser laboratories and encourages all users to ensure that their facility is signposted as per the requirements of the standard. Details of the placarding requirements can be found in Section 5.8: Laser Warning Signs.

The Human Resources Coordinator (Environment, Health and Safety) and members of the Radiation Safety Committee are available for consultation and discussion of problems or procedures.

5.1.3 Laser Pointer Safety Guidelines to be included in First Year Orientation Booklet/Information Pack

The hazards of laser pointers are limited to the eye, the largest concern being potential damage to the retina. For most laser pointers, the likely effects from exposure to viewing the direct beam are afterimage, flash blindness and glare.

<u>To reduce potential hazards</u>:

- Never look directly into the laser beam;
- Never point a laser beam at a person;
- Do not aim the laser at reflective surfaces;
- Never view a laser pointer using an optical instrument, such as binoculars or a microscope;

Further Information relating to the **Charles Sturt University's Laser Safety Policy** can be located at the **Radiation Safety Committee** Website:

http://www.csu.edu.au/acad_sec/committees/radiation/index.html

5.2 LASER CLASSIFICATION

The classification provided here is as is described in the Australian Standard and International Literature (viz., IRPA).

Because of the wide ranges possible for the wavelength, energy content and pulse characteristics of a laser beam, the hazards arising in their use vary widely. It is impossible to regard lasers as a single group to which common safety limits can apply.

To ensure all lasers manufactured prior to 2004 are easily identified both the 2004 and 1997 standards are included for reference.

Description of Laser Class (AS2211.1-2004)

Class 1 laser product any laser product which does not permit human access to laser radiation in excess of the accessible emission limits of Class 1 for applicable wavelengths and emission durations.

Class 1M laser product any laser product in the wavelength range from 302,5 nm to 4 000 nm which does not permit human access to laser radiation in excess of the accessible emission limits of Class 1 for applicable wavelengths and emission durations however, evaluated with smaller measurement apertures or at a greater distance from the apparent source than those used for Class 1 laser products. The output of a Class 1M product is therefore potentially hazardous when viewed using an optical instrument.

Class 2 laser product any laser product which does not permit human access to laser radiation in excess of the accessible emission limits of Class 2 for applicable wavelengths and emission durations.

Class 2M laser product any laser product in the wavelength range from 400 nm to 700 nm which does not permit human access to laser radiation in excess of the accessible emission limits of Class 2 for applicable wavelengths and emission durations however, evaluated with smaller measurement apertures or at a greater distance from the apparent source than those used for Class 2 laser products. The output of a Class 2M product is therefore potentially hazardous when viewed using an optical instrument.

Class 3R and Class 3B laser products any laser product which permits human access to laser radiation in excess of the accessible emission limits of Class 1 and Class 2 as applicable, but which does not permit human access to laser radiation in excess of the accessible emission limits of Classes 3R and 3B (respectively) for any emission duration and wavelength.

Class laser product any laser product which permits human access to laser radiation in excess of the accessible emission limits of Class 3B.

Description of Laser Class (AS2211.1-1997)

Class 1: Laser products which are safe under reasonably foreseeable conditions of operation.

NOTE: The upper limits for Class 1 laser products are given in Table 1(see Australian Standard AS2211.1-1997 and AS2211.1-2004) and are derived from the most limiting MPE values, with allowance made for the possible concentration of energy by optical instruments.

Class 2: Laser products which emit visible radiation in the wavelength range from 400 to 700 nm. Eye protection is normally afforded by aversion responses including the blink reflex.

Class 3A: Laser products which emit higher levels of radiation and require more stringent precautions than those necessary for Class 2 laser products. They differ from Class 2 laser products in that they emit more power in a beam of larger cross-section, so that when the output is directly viewed, the power of the beam entering the eye does not exceed that of a Class 2 laser product (the pupil diameter is assumed to be 7 mm). However, if the beam is viewed through larger diameter collecting optics (e.g. binoculars) then the hazard is usually increased. For CW output in the visible wavelength range (400 nm to 700 nm), the output power is limited to 5 mW and the maximum irradiance is $25 \text{ W} * \text{m}^{-2}$.

Class 3B (Restricted): Laser products which operate at the same power levels as Class 3A laser products, but have higher levels ($\leq 50 \text{ W} * \text{m}^{-2}$) of irradiance (power density). They may be used in daylight conditions, where the pupil diameter will be not greater than 5 mm, under the same controls as for Class 3A laser products. Where used in conditions of lesser illuminance, (in general this is less than approximately 10 lux), the appropriate safety controls are those specified for Class 3B laser products.

Class 3B: Laser products which emit either invisible or visible radiation and direct viewing is hazardous to the eye. Class 3B laser products are capable of causing eye injury either because their output is invisible and therefore aversion responses are not activated, or because the beam power is such that damage is done in a time shorter than the blink reflex (0.25 s). Higher power laser products in this class may also cause skin burns. However, with laser wavelengths other than those in the ultraviolet region, the pain produced by rapid heating of the skin will usually evoke an aversion response sufficient to avoid such burns.

Class 4: High power laser products with output powers exceeding the AELs specified in Table 4 (See Australian Standard AS2211.1-1997) for Class 3B. All Class 4 laser products are capable of producing hazardous diffuse reflections. They may cause skin injuries and could also constitute a fire hazard. Their use requires extreme caution.

5.3 THE EFFECTS OF LASER RADIATION ON BIOLOGICAL TISSUE (Extract from AS2211.1-2004 Laser Safety – Equipment classification, requirements and User's Guide)

5.3.1 General

Laser radiation is distinguished from most other known types of radiation by its beam collimation. This, for lasers with an initial high energy content, can result in excessive amounts of energy being transmitted to biological tissues. The primary event in any type of laser radiation damage to a biological system is the absorption of radiation by that system. Without absorption, damage cannot occur. Absorption occurs at an atomic or molecular level and is a wavelength specific process. Thus, it is the wavelength that determines which tissue a particular laser is liable to damage. The mechanism by which laser radiation induces damage is similar for all biological systems and may involve interactions of heat, thermo-acoustic transients and photochemical processes. The degree to which any of these mechanisms is responsible for damage may be related to certain physical parameters of the irradiating source, the most important of which are wavelength, pulse duration, image size, irradiance, and radiant exposure.

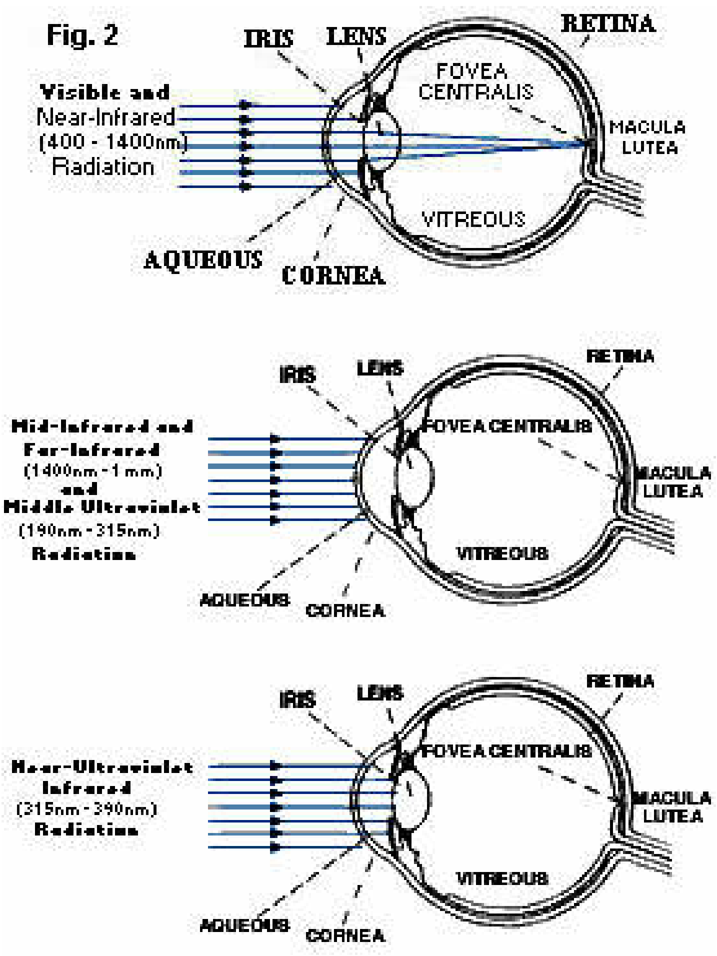
In general terms, in suprathreshold exposures the predominating mechanism is broadly related to the pulse duration of the exposure. Thus, in order of increasing pulse duration, the predominant effects in the time domains are as follows:

a) Nanosecond and sub-nanosecond exposures, thermo-acoustic transients.
b) From 100 ms to several seconds, thermal effects.
c) For times in excess of 100 s, photochemical processes.

All of these damage mechanisms have been shown to operate in the retina, and are reflected in the breakpoints or changes of slope in the safe exposure levels described in this Standard.

5.3.2 Beam Hazards

The human body is vulnerable to the output of certain lasers, and under certain circumstances, exposure can result in damage to the eye and skin. Research relating to injury thresholds of the eye and skin has been carried out in order to understand the biological hazards of laser radiation. It is now widely accepted that the human eye is almost always more vulnerable to injury than human skin. The Cornea (the clear, outer front surface of the eye's optics), unlike the skin, does not have an external layer of dead cells to protect it from the environment. In the far-ultraviolet and far-infrared regions of the optical spectrum, the cornea absorbs the laser energy and may be damaged. Figure 2 illustrates the absorption characteristics of the eye for different laser wavelength regions. At certain wavelengths in the near-ultraviolet region and the near-infrared region, the lens of the eye may be vulnerable to injury. Of greatest concern, however, is laser exposure in the retinal hazard region of the optical spectrum, approximately 400 nm (violet light) to 1400 nm (near-infrared) and including the entire visible portion of the optical spectrum. Within this spectral region collimated laser rays are brought to focus on a very tiny spot on the retina.



In order for the worst case exposure to occur, an individual's eye must be focused at a distance and a direct beam or specular (mirror like) reflection must enter the eye. The light entering the eye from a collimated beam in the retinal hazard region is concentrated by a factor of 100,000 times when it strikes the retina. Therefore, a visible, 10 milliwatt/cm2 laser beam would result in a 1000 watt/cm2 exposure to the retina, which is more than enough power density (irradiance) to cause damage. If the eye is not focussed at a distance or if the beam is reflected from a diffuse surface (not mirror like), much higher levels of laser radiation would be necessary to cause injury. Likewise, since this ocular focussing effect does not apply to the skin, the skin is far less vulnerable to injury from these wavelengths.

5.3.3 Thermo-acoustic Effects

Thermo-acoustic transients may occur with short pulsed high-peak-power (i.e. Q-switched or mode-locked) lasers. Energy is delivered to the biological target in a very short time and hence a high irradiance is produced. The target tissues experience such a rapid deposition of energy that heat dissipation processes are overwhelmed, and local intracellular temperatures are raised to such a degree as to convert the liquid components to gas virtually instantaneously. The gaseous volume/pressure increases result in physical damage to cellular structures. In most cases, these phase changes are so rapid that they are explosive and the cells rupture. The pressure transients so produced result in an annular blast zone around the burn centre. Similar pressure transients may result from thermal expansion and both may also result in shearing damage to tissues remote from the absorbing layers by bulk physical displacement.

5.3.4 Thermal Effects

When sufficient radiation energy has been absorbed by a system its component molecules experience an increased vibration, and this is an increase in heat content. Much laser damage is due to the heating of the absorbing tissue or tissues. This thermal damage is usually confined to a limited area extending either side of the laser energy absorbing site, and centred on the irradiating beam. Cells within this area show burn characteristics, and tissue damage primarily results from denaturation of protein. As indicated above, the occurrence of secondary damage mechanisms in laser impacts can be related to the duration of the tissue heating reaction which is directly related to the pulse duration of the laser.

If a CW or long pulse laser system is directed onto a tissue, then because of conduction, the area of the system experiencing a raised temperature is progressively increased. This spreading thermal front results in an increasing damage zone as more and more cells are raised above their thermal tolerance. The beam image size is also of great importance, as the degree of peripheral spread due to conduction is a function of the size as well as the temperature of the initial area of tissue heating. This type of thermal lesion is commonly seen on exposure to CW or long pulsed lasers.

5.3.5 Photochemical Effects

Photochemical processes involve molecular absorption of energy and subsequent chemical reaction. This process arises through the absorption of light of particular photon energies (i.e. particular wavelengths). Rather than releasing the energy, however, the affected tissue molecules undergo a chemical reaction unique to their excited state. Some biological tissues such as the skin, the lens of the eye and, in particular, the retina may show irreversible changes induced by photochemical reaction during prolonged exposures to low or moderate levels of light. These changes may result in damage to tissue if the duration of irradiation is excessive, or if short exposures are repeated over prolonged periods. Some of the photochemical reactions initiated by laser exposure may be abnormal, or may be exaggerations of normal processes.

5.3.6 Hazards to the Eye

In the wavelength range from 400 nm to 1400 nm, the greatest hazard is retinal damage. The cornea, aqueous humour, lens and vitreous humour are transparent for radiation of these wavelengths.

In the case of a well collimated beam, the hazard to the retina does not diminish rapidly with increasing distance between the source of radiation and the eye. The worst case retinal image is a diffraction-limited spot of around 10 pm diameter. In this case, assuming thermal equilibrium, the retinal zone of hazard is dependent upon the minimum angular subtense amin.

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In the case of an extended source, the hazard to the retina is approximately (over a limited range of distances) independent of the distance between the source and the eye, because the retinal irradiance only depends on the source's radiance and on the optical characteristics of the eye.

In the case of a point-type, diverging-beam source, the hazard increases with decreasing distance between the apparent source of the beam and the eye. The reason is that, with decreasing distance, the collected power increases, whereas the size of the retinal image can be assumed to remain diffraction-limited (due to the accommodation capabilities of the eye). The greatest hazard occurs at the shortest accommodation distance. With further reduced distance, the hazard to the retina is also reduced, as there is a rapid growth of the retinal image and a corresponding reduction of the irradiance, even though more power may be collected. (Note that this is not the case for corneal or lens hazards.)

For the purpose of this document, the shortest accommodation distance of the human eye is set to 100 mm at all wavelengths from 400 nm to 1400 nm. This was chosen as a compromise, because the majority of adults cannot accommodate their eyes to distances less than 100 mm. A 100 mm distance is used for the measurement of irradiance in the case of intrabeam viewing.

For wavelengths less than 400 nm or more than the greatest hazard is damage to the lens or the cornea. Depending on the wavelength, optical radiation is absorbed preferentially or exclusively by the cornea or the lens (see Table Bl). For diverging-beam sources (extended or point-type) of these wavelengths, short distances between the source and the eye should be avoided.

TABLE B1
SUMMARY OF PATHOLOGICAL EFFECTS ASSOCIATED WITH EXCESSIVE EXPOSURE TO LIGHT

CIE Spectral region*	Eye	Skin
Ultraviolet C (100 nm to 280 nm)	Photokeratosis	Erythema (sunburn)
Ultraviolet B (280 to 315 nm)		Accelerated skin ageing process increased pigmentation
Ultraviolet A (315 nm to 400 nm)	Photochemical cataract	Pigment darkening Photosensitive reactions
Visible (400 nm to 780 nm)	Photochemical and thermal retinal damage	
Infrared burn A (780 nm to 1400 nm)	Cataract, retinal burn	skin burn
Infrared burn B (1.4 µm to 3.0 µm)	Aqueous flare, cataract corneal burn	
Infrared C (3.0 µm to 1 mm)	Corneal burn only	

* The spectral regions defined by the CIE are useful in describing biological effects and may not agree perfectly with spectral breakpoints in the MPE tables.

Visible and near infrared lasers are a special hazard to the eye because the properties necessary for the eye to be an effective transducer of light result in high radiant exposure being presented to highly pigmented tissues. The increase in irradiance from the cornea to the retina is approximately the ratio of the pupil area to that of the retinal image. This increase arises because the light which has entered the pupil is focused to a 'point' on the retina. The pupil is a variable aperture but the diameter may be as large as 7 mm when maximally dilated in the young eye. The retinal image corresponding to such a pupil may be between 10 1μm and 20 μm in diameter. The increase in irradiance between the cornea and the retina is between 2 x 10^5 and 5 x 10^5. If an increase of 5 x 10^5 is assumed, a 50 W. m^{-2} beam on the cornea becomes 2.5 x 10^7 W. beam on the retina. In this Standard, a 7 mm pupil is considered as a limiting aperture as this is a worst-case condition, and is derived from figures obtained from the young eye, where pupillary diameters of this order have been measured.

If an intense beam of laser light is brought to a focus on the retina, only a small fraction of the light (up to 5%) will be absorbed by the visual pigments in the rods and cones. Most of the light will be absorbed by the pigment called melanin contained in the pigment epithelium (in the macular region, some energy in the 400 nm to 500 nm range will be absorbed by the macular pigment). The absorbed energy will cause local heating and will burn both the pigment epithelium and the adjacent light sensitive rods and cones. This burn or lesion may result in a loss of vision.

Depending on the magnitude of the exposure, such a loss of vision may or may not be permanent. A visual decrement will usually be noted subjectively by an exposed individual only when the central or foveal region of the macula is involved. The fovea, the pit in the centre of the macular, is the most important part of the retina as it is responsible for sharpest vision. It is this portion of the retina that is used to look directly at something. The visual angle subtended by the fovea is approximately equal to that subtended by the moon. If this region is damaged, the decrement may appear initially as a blurred white spot obscuring the central area of vision, however, within two or more weeks, it may change to a black spot. Ultimately, the victim may cease to be aware of this blind spot during normal vision. However, it can be revealed immediately on looking at an empty visual scene such as a blank sheet of white paper. Peripheral lesions will only be registered subjectively when gross retinal damage has occurred. Small peripheral lesions will pass unnoticed and may not even be detected during a systematic eye examination.

Blue laser light (400 nm to 500 nm) has been singled out as a wavelength region of concern because this may produce retinal photochemical damage. Above 500 nm, photochemical effects are minimal.

Ultraviolet light of wavelengths greater than 300 nm may reach the retinas of aphakes (people without lenses, e.g. who have had their ocular lenses removed because of cataract). Unless adequately screened by the replacement corrective devices offering appropriate spectral protection (spectacle, contact or intraocular lens), such people have an increased risk of retinal photochemical damage from lasers in the range 300 nm to 400 nm. The transmittance of such devices should be known for the specific wavelength of any laser to which they may be exposed.

Certain compounds may lower the light threshold for biological effects in the eye (and on the skin). These are referred to as photosensitising drugs. They presently include medications such as phenothiazines, sulfonylureas, psoralens, chloroquine; many antibiotics such as sulfonamides, griseofulvin and tetracyclines; some cosmetics, perfumes and medicated shampoos which may contain photosensitizing agents such as scents (e.g. the essential oils bergamot and cedar), dyes (e.g. rose bengal or eosin), or coal tar derivatives; and foodstuffs (e.g members of the Umbelliferae family, or cyclamates).*

Loss of colour vision discrimination may accompany retinal damage following light exposure. This is usually a differential loss of sensitivity to blue light. A test particularly suitable for distinguishing colour vision losses, and blue losses in particular, is the Famsworth D15 test. The test consists of 15 movable colour samples placed in a box with a fixed reference sample. The patient's arrangement of the colour is plotted on a circular diagram. Major errors give rise to lines which cross the circle.

Skin hazards In general terms, the skin can tolerate a great deal more exposure to laser beam energy than the eye can tolerate.

The biological effect of excessive irradiation of skin by lasers operating in the visible (400 nm to 700 nm) and infra-red (700 nm to 1060 nm) spectral regions may vary from a mild erythema to severe blisters. An ashen charring is prevalent in tissues of high surface absorption following exposure to very short-pulsed, high-peak power lasers. This may not be followed by erythema.

If the irradiance is extremely high, pigmentation, ulceration, and scarring of the skin and damage of underlying organs may occur. Latent or cumulative effects of laser radiation have not been found prevalent. However, some limited research has suggested that under special conditions, small regions of human tissue may be sensitised by repeating local exposures with the result that the exposure level for minimal reaction is changed and the reactions in the tissues are more severe for such low level exposure.

Exposure to moderate levels of ultraviolet radiation (200-400 nm) can lead to photochemical injury processes for which the biological repair mechanisms are slow (of order several hours to days). The most common of these is ultraviolet erythema, generally known as sunburn. The potential for injury varies between individuals, and depends upon many factors, including the particular wavelength, the total radiant exposure, and the recovery and repair periods involved. Repeated short-term exposures to ultraviolet radiation at levels below the corresponding short-term MPE should therefore be assessed on a total daily exposure basis. Furthermore, if a person receives significant ultraviolet exposure in the course of laser use, together with additional ultraviolet exposure from other sources (e.g. solar radiation, sunlamps, arc welders), these should be considered in assessing the need for appropriate skin and eye protection. A desirable objective is that the total daily exposure from all such radiations should be less than the MPE. As an indication, the MPE for ultraviolet exposure is set a little below the level that produces 'just perceptible erythema' in untanned skin, and corresponds to approximately four minutes exposure to bright sunlight.

If the irradiance of the laser is extremely high, ultraviolet radiation can cause acute skin burns, scarring and ulceration.

5.4 MEDICAL SURVEILLANCE FOR LASER USERS

As part of the University's concern and responsibility, the University will organise an opthalmological examination for the user of laser classes 3B and 4 prior to commencement of work. An opthalmological examination may be organised for users of the other classes of laser if requested or considered necessary. In line with the Standard, there will also be an examination at the termination of employment or laser operations, and at any other time that is deemed appropriate. These examinations shall be paid for by the particular school or section employing the person at the University.

The University will follow the guidelines as described by the Australian Standard. The Standard describes the requirement and types of examinations to be conducted:

General. The term medical surveillance in the context of this Standard refers to the specific examination of laser workers whose work involves a significant risk of exposure to laser radiation in excess of the MPE (Maximum Permissible Exposure). These eye examinations and, where appropriate, skin examinations should be carried out when required, on the following occasions:

(a) On placement, to determine if an individual meets job standards, or is at risk, and to establish a baseline for medico-legal and epidemiological purposes. There are few, if any, contraindications for people being prevented from using or working with lasers. For anyone at increased risk of laser damage, eye examinations more frequent than specified below may be prudent.

(b) On termination, for medico-legal and epidemiological purposes.

(c) Following any apparent or suspected laser radiation in excess of the maximum permitted exposure.

(d) Following any serious injury to, or illness of the eye.

Pre-placement or periodic examinations of the skin are not as useful as eye examinations and are generally not considered essential or cost-effective. Persons will generally be aware of any damage to the skin, which is not always true for damage to the eye. However, skin examinations should always be carried out after any laser accident.

5.4.1 Eye Examination of Laser Workers at Commencement and Termination of Employment

Eye examination should be done on laser workers with Class 4 or Class 3B or Class 2M and Class 3R, except Class 3B (Restricted), lasers at the times of commencement and termination from the position. Tests in Items (a) to (e), described below, should be performed on all such persons; attached is a medical form that the opthalmologist should use to record the test information for the university (please print out this form and present to medical examiner to be completed and returned to the University. If ocular history and general health show no problems, and distance visual acuity is better than or equal to 6/6, and Amsler grid response and colour vision are normal, no further examination is required. The following tests should be done on laser workers:

a) *Ocular history* Review the patient's past eye history and family eye history. Note any current eye complaints which the patient now has about his/her eyes

b) *General health* - The patient's general health status should be inquired about with a special emphasis upon diseases which can give ocular problems. History of medications use should also be included, with special emphasis upon the long-term use of photosensitizing drugs.

c) *Visual acuity* - This should be tested and recorded in Snellen figures for 6 m to better than 6/6.

d) *Amsler grid* - This chart resembles a piece of graph paper and shows disturbances in the central IS' retina by distortions in the grid as described by the patient.

e) *Colour vision* - Loss of colour vision discrimination may accompany retinal damage following light exposure.

f) This is assessed using the Farnsworth D15 test. The test should be presented separately to each eye.

Any deviations from acceptable performance in the above tests require further examination by an optometrist or an ophthalmologist, in which case the additional tests described below are recommended.

Additional tests are as follows:

i) *Refraction* This is done to measure the patient's refractive error and corrected visual acuity. This need only be done on persons whose visual acuity, as determined in test (c), is less than 6/6.

ii) *External ocular examination* The examination should include brows, lids, lashes, conjunctiva, sclera, cornea, iris and pupil reactions.

iii) *Examination by slit lamp* The cornea, aqueous humour, iris and pupil should be examined with the slit lamp.

The angle of the anterior chamber should be checked to determine if it is safe to dilate the pupils. If so, the pupils are dilated by instillation of a mydriatic in each eye and the remainder of the examination is carried out with the eye under this medication.

The lens is then examined with the slit lamp.

Position and description of any abnormalities should be recorded.

iv) *Examination of the ocular fundus with an ophthalmoscope*
In the recording of this portion of the examinations, the points to be considered are as follows:

A) Presence or absence of opacities in the media.
B) Sharpness of outline of the optic nerve.
C) Colour of the optic nerve.
D) Size of the physiological cup, if present.
E) Ratio of the size of the retinal veins to that of the retinal arteries.
F) Presence or absence of a well-defined macula and the presence or absence of a foveolar reflex.
G) Any retinal pathology that can be seen with a direct ophthalmoscope. Even small deviations from normal should be described and carefully localized.

v) *Other examinations* Further examinations may be deemed necessary by the examiner.

Charles Sturt University - Laser Worker Survey

Eye Examination to be Completed by Opthalmologist

(from AS 2211.1-1997)

Opthalmologist : ____

Location/Address : ____

Date : ________________________

Name (Block Letters):

Designation Location DOB

	YES	NO
1. Occular History Normal?	☐	☐

If No, describe ____

____

2. General Health Normal ?	☐	☐

If No, describe ____

____

Any photosensitising drug medications ?	☐	☐

If Yes, describe ____

____

3. Visual Acuity (with spectacles if worn) R L

Write denominator of Snellen fraction e.g. 60 if visual acuity is 6/60 M M

4. Amsler grid normal ?	☐	☐

If No, describe ____

____

5. Colour Vision (Farnsworth D15 test) normal?	☐	☐

If No, describe ____

____

6. Refraction (only use if visual acuity in item 3 is less than 6/6)
Visual acuity (Snellen denominator)
Refraction R L

7. External Occular examination normal?	☐	☐

If No, describe ____

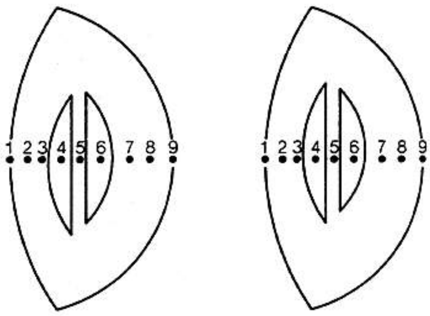
____

8. **Slit Lamp**

(Code 1 if abnormal, blank if normal)

Describe any abnormality	RE	LE
8.1. Cornea	☐	☐
8.2. Aqueous	☐	☐
8.3. Iris & Pupil	☐	☐
8.4. Van Herick a/c	☐	☐

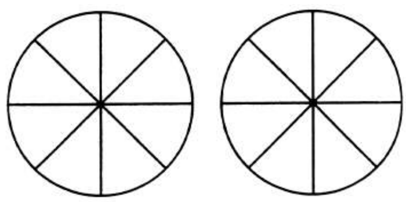
9. **Lens** (draw extent & depth of opacities) Depth of opacities



Depth of Opacities	RE	LE
1.1. Subcapsular	☐	☐
1.2. Anterior cortex	☐	☐
1.3. Mid nuclear	☐	☐
1.4. Posterior nuclear	☐	☐
1.5. Posterior cortical	☐	☐
1.6. Post subcapsular	☐	☐
1.7. Capsular or extracapsular opacities	☐	☐

Types of opacities	RE	LE
1.7. Epicapsular stars, pigment spots	☐	☐
1.8. PXF	☐	☐
1.9. Cortical wedges or spokes	☐	☐
1.10. Cortical clubs	☐	☐
1.11. Cortical dots	☐	☐
1.12. Cortical flakes	☐	☐
1.13. Central fluid clefts and vacuoles	☐	☐
1.14. Cortical Plaques	☐	☐
1.15. Posterior saucer	☐	☐
1.16. Posterior rosette	☐	☐
1.17. Polychromatic lustre	☐	☐
1.18. Diffuse nuclear sclerosis	☐	☐

Position of opacities



	RE	LE
1.19. Nuclear wedges	☐	☐
1.20. Sutural opacities	☐	☐
1.21. Nuclear needles	☐	☐
1.22. Nuclear flakes	☐	☐

1.23. Other ☐ ☐

	Yes	No
10. Opthalmoscopy normal ?	☐	☐

If No, describe any abnormality - photograph if necessary

11. Other examinations

____

____

____

____

____

____

Summary and Comment

____

____

____

____

____

____

5.5 LASER USER REGISTRATION FORMS

(Please print out the following form, complete and send to the Executive Officer of the Radiation Safety Committee)

For registration of lasers, users are required to use the following form **"Laser 1": User Registration Form**. (For the registration of Laser Equipment, please use form **"Laser 2": Apparatus Registration Form**, which can be found in the Appendices).

This form is for the University to register users and to continue surveillance of users, procedures and to arrange medical examinations.

CHARLES STURT UNIVERSITY

Charles Sturt University
Radiation Safety Committee

Form
Laser 1
Version 1.0

USER REGISTRATION FORM

Name: ……………………………………………………………….……………………

Title (Mr, Mrs, Ms, Dr): ………………………………………………………………

Staff/Student Number: ………………..…………………………………………..

School/Centre/Department: ……………………………………………………………

Supervisor's Name (if applicable): ……………………………………………….

Starting date: …………………………………………………………………………

Termination date: …………………………………………………………………….

Please complete all of the following questions (tick the appropriate box):

Classes of Laser to be used:

(Please update whenever conditions change [viz., class of laser].)

I have read and I have understood the Department's S.O.P(s) for the laser(s) to be used ? Yes ☐ No ☐

I have seen and am cognizant with the relevant sections of AS 2211.1-2004 (Laser Safety) and the relevant ARPANSA Guidelines? Yes ☐ No ☐

I know the location of the Department's Laser S.O.P(s)? Yes ☐ No ☐

In the presence of my supervisor or the Laser Safety officer or his delegate:

I have demonstrated my knowledge and operation or use of the laser safety/protection equipment? Yes ☐ No ☐

I know how to operate the laser safely? Yes ☐ No ☐

Eye/Medical History

Please Tick the appropriate box.

Is your Occular history Normal ? Yes ☐ No ☐
If No describe (eg., glaucoma, retinal abnormalities, etc.)

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Is there any genetic or abnormal
occular conditions in your family history? Yes ☐ No ☐
If Yes describe :

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

General health normal? Yes ☐ No ☐
If No describe :

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Any Photosensitising medication(s) ? Yes ☐ No ☐

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Applicants Signature : ………………………………………. **Date**: …………………

Supervisor's Signature (if applicable) : …………………………………………………

Laser Safety Officer/Radiation Safety Committee Signature: ……………………………..

Date: ………………………. Comments: ………………………………………………..

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Page 2

CHARLES STURT UNIVERSITY	Title: **Laser Safety Program** **Part Vb: Registration Form for Apparatus**	
	Version: 1.0 3 May 2001	**Approved:** Council 3 May 2001 Vide CNL01/57
	Administered: Human Resources	**Next Review:** May 2003

APPARATUS REGISTRATION FORM

(Please print out the following form, complete and return to the Radiation Safety Committee)

(For registration of laser users, please use Form Laser 1)*. *For the inventory register and record of equipment in use by the University, please use *Form Laser 2* ***below.***

CHARLES STURT UNIVERSITY	***Charles Sturt University*** Radiation Safety Committee	Form **Laser 2** Version 1.0

LASER APPARATUS REGISTRATION FORM

Name of School/Centre : ……………………………………………………………………………….

Date: …………….

Item Description	Brand / Country of Manufacture (If Known)	Supplier	Purpose	Owner/ User	Location Bld/Room	Power Output	Laser Frequency	Class of Laser	Lab/Field Usage
Laser Pointer *Example*	Laserex/Australia	Laserex Australia P/L	Teaching Aid	P.Maxwell	229/149	3.0mW	670 nm	llla	No

5.6 LASER SAFETY STANDARD OPERATING PROCEDURE (SOP) GUIDELINES

The following guidelines are to be used to develop a departmental or local area set of Laser Safety Procedures or Standard Operating Procedures. Not all of the following points will be applicable, but all should be considered in the development of the procedures.

5.6.1 Basic Guidance

a) The written SOP must discuss beam alignment and normal operation (check manufacturer's recommendations) for each laser system. It is advisable to include non-beam hazard management and servicing in the SOP.

b) To insure the SOP is read and used, the document should not be too lengthy.

c) The primary intent of the SOP is to institutionalize good safety practices.

d) The Australian Standard (AS2211.1) and other Codes of Practice have information which may be useful in developing the SOP.

e) The Human Resources Coordinator (Environment, Health and Safety) and members of the Radiation Safety Committee will be happy to review and comment on the draft SOP.

f) No one may undertake any work which involves lasers or laser systems without the person being trained (preferably attend a Laser Safety Course and annual refresher courses), the work approved, and registration of both the user and the equipment with the Radiation Safety Committee.

g) If the work involves chemicals then the full application of the NSW Hazardous Substances Regulation and the Code of Practice are to be applied and reference is to be made in the SOP.

h) The appointed Unit Laser Supervisor will refer all new laser workers to the University Health Service and the Radiation Safety Committee for the necessary medical screening. Undergraduates who work with low powered lasers (classes 1, 2, 3A & Class 1M will be regarded, for medical screening purposes only, as visitors. This will mean that they may use low powered lasers in the above classes under the close supervision of a competent person without first having an eye test (medical examination).

In addition they must continue to work to a written protocol, there is no intention of reduce any of the other safeguards required.

i) New users must be familiar with the Australian Standard AS2211.1-2004 and any relevant ARPANSA Codes of Practice.

5.6.2 Beam Alignments (Address these safety areas in the SOP)

a) **SECURITY** - Secure the lab and (to avoid distractions) mark the door with the following sign: "**NOTICE - Laser Alignment in Progress - DO NOT ENTER - EYE PROTECTION REQUIRED**."

b) **PREPARATION** - Locate all equipment and materials needed to perform the alignment prior to beginning the procedure.

c) **BEAM CHARACTERISTICS** - Is the beam visible or invisible? Is special equipment needed to view the beam? If the beam is pulsed, can you fire a single pulse at a time to limit the exposure hazard?

d) **BEAM VIEWING** - Intrabeam viewing is prohibited on the campus and a remote viewing camera should be used if intrabeam viewing is required to align the beam. Only diffuse reflections should be viewed directly. Use a low power alignment laser (Class 2 or 3a) or if none is available, always use the lowest beam power which will allow viewing of an image with protective eyewear.

e) **PERSONAL PROTECTIVE EQUIPMENT** - Use laser protective eyewear with a low enough Optical Density to allow viewing of the diffuse reflection (contact Human Resources Coordinator (Environment, Health and Safety) and members of the Radiation Safety Committee if you need information on alignment eyewear). Use skin covers (labcoat, gloves, and UV face shield) to protect users from UV laser beam scatter.

f) **PERSONNEL** - Whenever possible, the "buddy" system must be used during alignments. If another person is not available to be in the room, let someone else know where you are and check in with them on a regular basis.

g) **EXPOSURE PRECAUTIONS** - Keep the optical table clear of objects which may cause unwanted specular reflections. Always close the laser shutter while adjusting optics or when entering the beam path. After making adjustments, assure the optics are secured prior to opening the shutter.

h) **REPLACE BEAM CONTROLS** - Insure all beam blocks, enclosures, and beam barriers are replaced when the alignment is complete.

i) **CHECK DOOR SIGNS** - Verify that the "**NOTICE - Laser Alignment in Progress - DO NOT ENTER - EYE PROTECTION REQUIRED**" sign is removed from the room entrance and that the regular Australian Standard laser warning sign is in place and correct.

5.6.3 Normal Operation of the Laser (Address these safety areas in the SOP)

a) **SECURITY** - Do not rely upon a closed door as adequate security. Always use key locks or activate the door interlocks (if required by the Australian Standard - class 3b, 4 2M, & 3R are to be interlocked) on the laser facility.

b) The entrance to laser areas should be posted with standard laser warning signs, as per the entrance recommendations.

c) **OPERATIONAL PREPARATIONS** - Indicate the location of the Laser Safety Guidelines posting. Indicate the equipment needed to perform the (laboratory specific) experiment.

d) **PERSONAL PROTECTIVE EQUIPMENT** - Have the appropriate (laboratory specific) safety equipment on hand. Specify what is needed and its use.

e) **START-UP PROCEDURE** - Insert key, turn on water, turn on power supply, close shutter, activate laser, etc. as specific to the laboratory.

f) **EXPERIMENTAL PROCEDURE** - Specific to the laboratory.

g) **EMERGENCY PROCEDURE** - Location of "PANIC" shut-down switch. Location of emergency procedure posting. Location of fire extinguisher, safety shower, etc.

h) **SHUT-DOWN PROCEDURE** - Specific to the laboratory.

i) **STORAGE** - Remove and store laser activation key, deactivate interlocks (if applicable) and secure door to laser facility.

5.6.4 Non-Beam Hazards to Address

a) **TOXICITY OF LASING MEDIA** - Toxic laser dyes should be handled with labcoat, safety glasses, and gloves. Dyes should be mixed in a properly functioning fume hood and transported in sealed, leakproof containers. Dye pumps should sit in a secondary containment tray. Concentrated halogen gases (greater than 5%) should be used and stored in a properly functioning gas cabinet.

b) **ELECTRICAL HAZARDS** - Only properly trained and approved personnel should work on high voltage systems. The "buddy" system should always be used when working on electrical systems and laboratory staff should be trained in CPR as a safety precaution.

c) **COMPRESSED GASES** - Staff should be trained in the safe management of cylinders and the hazards associated with the specific compressed gases being used.

d) **FIRE PROTECTION** - Attention should be given to protection against fires and explosions. Flammable solvents are often used for laser dyes and to clean optical components. Fire extinguishers should be well marked and staff should know how to use extinguishers and the fire alarm system.

e) **HOUSEKEEPING** - Poor housekeeping (on and off the bench) can create physical hazards. Staff may trip over cables that have not been secured and injuries may result from sharp tools that are not properly stored.

5.6.5 Safety Associated with Servicing of the Laser

a) Only approved and properly trained personnel should service laser systems. Vendor service staff are required to follow the vendor's laser safety policy. If University staff are assisting the service staff, the University staff must follow campus laser safety policy (eye protection, etc.).

b) If University staff are to perform the service, a written service procedure with safe practice information must be available for reference (often the manufacturer will supply this information). All enclosures, interlocks, and safety devices (shutters, etc.) must be replaced and verified operational prior to returning the laser to service.

c) Safety interlocks shall not be permanently disabled without the consent of the Human Resources Coordinator (Environment, Health and Safety) and members of the Radiation Safety Committee.

5.7 PERSONAL PROTECTIVE EQUIPMENT

5.7.1 Eye Protection for Laser Use

In general, whilst in laboratories, eye wear must be worn at all times. With lasers in the workplace, it is of greater importance to use eye protection specific to the hazards that may occur or be present. With lasers, the power, class and type (viz., wavelength) is of great importance to the selection of the right eye protection.
With the higher classes of laser, there is no second chance - one exposure may be enough to produce blindness.

General
Information on eye protectors suitable for use with particular lasers and operations is given in **BS EN 207**, **BS EN 208, AS2211-2004 & AS/NZS1336-1997**.
(no single type of eyewear will provide protection against all wavelengths or levels of power of laser radiation)
The following should be considered, when specifying suitable protective eyewear:

(a) Wavelength(s) of operation.
(b) Radiant exposure or irradiance.
(c) Maximum permissible exposure (MPE).
(d) Optical density of eyewear at laser output wavelength.
(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 legislation.

Eye protection which is designed to provide adequate protection against specific laser radiations should be used in all hazard areas where Class 3B, Class 4, Class 2M or Class 3R lasers are in use. This requirement does not apply to Class 3B laser products with not more than five times the AEL of Class 2 in the wavelength range from 400 nm to 700 nm.

Additional exceptions to this are as follows:

i. When engineering and administrative controls are such as to eliminate potential exposure in excess of the applicable MPE.

ii. 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.

Identification of eyewear All laser protective eyewear shall be clearly labelled, in accordance with BS EN 207 (referenced in the Aust. Standards), with information adequate to ensure the proper choice of eyewear with particular lasers.

Required optical density The spectral optical density D_λ 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_λ measured within the band shall be quoted. The value of D_λ required to give eye protection can be calculated from the equation:

$$D_\lambda = \log_{10} H_o / \text{MPE}$$

where H_o is the expected unprotected eye exposure level.

Protective eyewear Protective eyewear should be comfortable to wear, provide as wide a field of view as possible, maintain a close fit while still providing adequate ventilation to avoid problems in misting up and provide adequate visual transmittance. Care should be taken to avoid, as far as is possible, the use of flat reflecting surfaces which might cause hazardous specular reflections. It is important that the frame and any sidepieces should give equivalent protection to that afforded by the lens(es).

Special attention has to be given the resistance and stability against laser radiation when choosing eyewear for use with Class 4 laser products.

5.7.2 Skin Protection

If it is necessary to work in close proximity to an exposed high intensity laser, suitable gloves and cover for the forearms should be used. This is most important if the laser is running in the ultra-violet. Very large peak powers with pulsed ultra-violet laser may be particularly dangerous. At the minimum, a natural fibre long sleeved laboratory coat must be worn.

Where personnel may be exposed to levels of radiation that exceed the MPE for the skin, suitable clothing should be provided. Class 4 laser products present a potential fire hazard and protective clothing worn should be made from a suitable flame and heat resistant material.

5.7.3 Respiratory Protection

This is not generally required unless there is a chance of fumes being created or the work involves exposure of laser to chemicals. Engineering controls are the first choice for respiratory protection but if this is inadequate or not used then the appropriate respiratory protection shall be used.

Where there is the risk of fumes being produced or the cryogenic or laser gases may be present in the working atmosphere, then reference to the University's Hazardous Substances Guidelines and Procedures, the NSW Hazardous Substances Regulation, and the Federal Code of Practice and guidelines should be consulted and incorporated into the procedures for the work.

5.8 LASER AREA WARNING SIGNS (As per Australian Standard AS2211.1-1997)

All entrances to areas shall be posted with the following warning signs, of an appropriate size to be easily seen and read.

The Australian Standard recommends signs of type Figure 1 have a base width of 150, 200, 400 or 600mm. Generally the university recommends a Figure 1 type sign have a base width of 200mm.

Figure 1. Laser Warning Sign

The Australian Standard recommends that signs of the type shown in Figure 2, should have a base width of 250 or 400mm. However, the width can be of any size to accommodate the appropriate wording required.

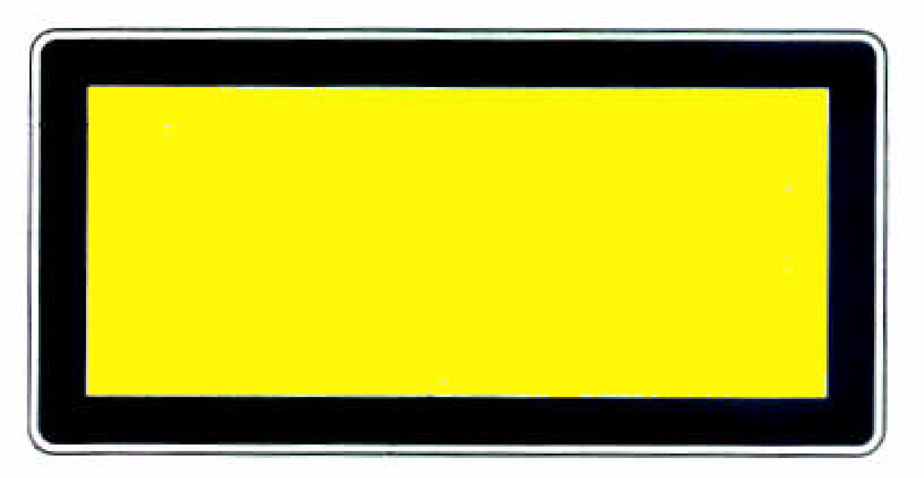


Figure 2. Worded Laser Warning giving specific instructions. See following text for exact wording to be incorporated in sign.

Each Class 1 laser area shall have affixed an explanatory sign bearing the words:

CLASS 1 LASER PRODUCT

Each Class 2 laser area shall have affixed an explanatory label bearing the words listed below:

LASER RADIATION
DO NOT STARE INTO BEAM
CLASS 2 LASER PRODUCT

Each Class 3A area shall have affixed an explanatory label bearing the words listed below:

LASER RADIATION
DO NOT STARE INTO BEAM OR VIEW
DIRECTLY WITH OPTICAL INSTRUMENTS
CLASS 3A LASER PRODUCT

Class **3B** Laser products shall be labelled in accordance with the following:

Each Class 3B, except Class 3B (Restricted), laser area shall have affixed an explanatory label bearing the words listed below:

LASER RADIATION
AVOID EXPOSURE TO BEAM
CLASS 3B LASER PRODUCT

Each Class 3B (Restricted) laser area shall have affixed an explanatory label bearing the words listed below:

LASER RADIATION
AVOID EXPOSURE TO BEAM
DO NOT VIEW WITH OPTICAL INSTRUMENTS
CLASS 3B (RESTRICTED) LASER PRODUCT

Each Class 4 laser area shall have affixed an explanatory label bearing the words listed below:

LASER RADIATION
AVOID EYE OR SKIN EXPOSURE TO
DIRECT OR SCATTERED RADIATION
CLASS 4 LASER PRODUCT

In addition, **Class 3 & 4 laser areas** shall display a sign as shown below:

Where new lasers are purchased with the latest classification e.g. 1M, 2M or 3R then they shall have appropriate signage.

5.9 REFERENCES

1. Australian Standard AS221.1-2004 *Laser Safety: Equipment classification, requirements and user's guide*.

2. Australian Standard AS/NZS1336-1997. *Recommended practices for occupational eye protection*.

3. Australian Standard AS2397-1993. *Guide to the safe use of lasers in the construction industry*.

4. Australian Standard AS/NZS4173-1994. *Guide to the safe use of lasers in health care*.

5. ARPANSA 1999 "Visible light lasers used for surveying, leveling and alignment."

6. ARPANSA 1995 "Code of Practice for the safe use of lasers in schools".

7. ARPANSA 1995 "Code of Practice for the safe use of lasers in the entertainment industry".

8. IRPA/ILO 1993 "The use of lasers in the workplace" OHS Series No.68. Geneva, International Labour Office.