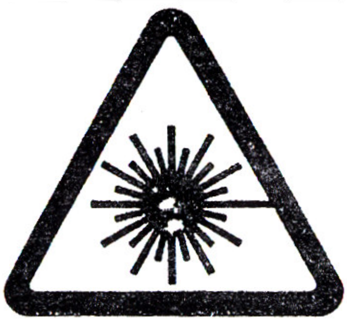

Safety in Universities:
Notes of Guidance

Part 2:1 – *Lasers*

Revised 1992

CVCP

CVCP Laser Safety Guidelines

The first edition of this document was prepared on behalf of the Committee of Vice Chancellors and Principals by a Working Party of the Association of University Radiation Protection Officers (AURPO), whose members were:

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The revision necessary for the second edition was undertaken by W T Baker, with the assistance of E A Cox, CChem, FRSC, Radiation Consultant.

The revision necessary for the preparation of this third edition was undertaken by T J Moseley, BSc, of the University of Sheffield who is the AURPO representative on BSI Technical Committee EEL/28 (Laser Equipment).

These Notes of Guidance are not intended to apply to the exposure of patients intentionally exposed to laser radiation for therapeutic, diagnostic or other purposes, under the direct supervision of suitably qualified personnel. Applications of this nature are covered by a DHSS publication – 'Guidance on the Safe Use of Lasers in Medical Practice'. Personnel actually *using* lasers for such purposes on University premises should, however, take cognisance of the requirements of both CVCP's publication, and the DHSS guidance, and prepare suitable local rules accordingly.

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In this document 'must' is used to indicate that the level of compliance required is equivalent to legislative requirements, and 'should' to indicate a level of compliance representing good working practice.

CVCP Laser Safety Guidelines

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FOREWORD

The first edition of this document was issued by the Committee of Vice-Chancellors and Principals in 1978. A second revised edition was issued in 1987. Since that date the British Standard on laser safety has been updated on two occasions culminating in the current issue BS EN 60825:1992, which is now a ‘Euronorm’.

The CVCPs Working Group on Health & Safety considered that it was important that the changes brought about by the new British Standard should be incorporated in an updated version of these Guidance Notes and this third revised edition is the result. We are indebted to Mr T J Moseley (University of Sheffield) for his work in preparing this handbook and we commend it to all universities.

We should also like to draw your attention to the continued relevance of the video entitled ‘Laser Safety in Higher Education’ which was produced by the University of Southampton for this Committee in 1986. It avoided detailed mention of some of the finer points of the British Standard and concentrated on the basic philosophy of laser safety and the main laser classification. These have not changed and the video remains valid today. It is recommended that it should be used in conjunction with the guidance given in this booklet as part of the training that should be given to all laser workers.

Professor R N Franklin
Vice-Chancellor
City University

Thomas Burgner
Secretary
Committee of Vice-Chancellors and Principals

October 1992

CVCP Laser Safety Guidelines

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CVCP Laser Safety Guidelines

PREFACE

These guidance notes are designed to assist those responsible for the use of lasers in universities to ensure that this work is carried out in a safe manner and in accordance with BS EN 60825:1992.

This latest British Standard has replaced BS 7192:1989. It is a ‘euronorm’ based upon the International Electrotechnical Commission’s IEC 825:1984 and its Amendment 1:1990. It was accepted by the European Committee for Electrotechnical Standardisation (CENELEC) for adoption by all European countries in EC and EFTA by 1 March 1992. All the changes brought about by Amendment 1 are indicated by two sidelines in the margin of the new standard.

At present there are no statutory regulations governing the use of lasers but the most up-to-date British Standard and ‘in-house’ guidance notes, like these, are the yardsticks by which the Health and Safety Executive will judge our compliance with the general provisions of the Health and Safety at Work, etc Act 1974. However, in the pipeline is the Physical Agents Directive of the European Community which will give rise to European regulations in this field and it is hoped that these will essentially endorse the guidance given in BS EN 60825 without being too restrictive.

In order to warn the user of the potential hazard posed by a particular laser, various laser classification systems have been developed and refined over the years. This process is continuing and further refinement of BS EN 60825 can be expected in the future. This booklet is largely based upon the current requirements of BS EN 60825 and a summary of its laser classification system is presented in Table 1. One exception is the labelling requirements (Appendix III). Here we have stood by our own specifications which have always been more practical than those recommended by the British Standard. Thankfully the forthcoming Amendment 2 will allow greater flexibility with regards labelling specifications and our recommendations should comply with this.

Although the British Standard does not recognise the concept of ‘Totally Enclosed Systems’ for lasers which are Class 1 by engineering design, the author feels that this concept has proven value and that it is important that there should be a clear distinction between Class 1 lasers that are inherently safe because of their low power, and those Class 1 lasers that are reliant upon engineering features for their safety. The labelling, which it is recommended should be adopted, will provide adequate warning of the potential hazard which could exist if the engineering safeguards are downgraded or defeated, e.g. during maintenance, servicing and alignment procedures which require removal of part of the enclosure. It is important to ensure that confusion does not arise with commercial equipment which might be supplied labelled either in accordance with the European or some other standard. This is but one reason for ensuring that all the procedures detailed in these Guidance Notes are strictly adhered to.

TABLE 1

Class and Description	Reason for Classification	Sections of this Document which are applicable
Class 1 SAFE	Either: (i) the output is so low that the laser is 'INHERENTLY SAFE', or (ii) because the laser is part of a 'Totally enclosed system' and is 'SAFE BY ENGINEERING DESIGN'. In either case the relevant MPE cannot be exceeded.	1, 2, 4.1 & 6 1, 2, 3, 4.2, 4.6, 4.7, 5, 6 & 7
Class 2 LOW POWER Visible CW & Pulsed lasers	In the case of CW lasers eye protection is normally afforded by the natural aversion responses including the blink reflex. Hazard can be controlled by relatively simple procedures	1, 2, 3, 4.3, 4.6, 4.7, 6 & 7
Class 3A LOW-MEDIUM POWER LASERS Class 3B*	An extension of Class 2, where protection is still afforded by the natural aversion responses, but direct intrabeam viewing with optical aids may be hazardous. This must be controlled. As for Class 3A but there is a slight hazard from viewing the direct beam. Power limited to 5mW. NB visible only.	1, 2, 3, 4.4, 4.6, 4.7, 6 & 7
Class 3B** MEDIUM POWER LASERS	Hazard from direct beam viewing and from specular reflections. More detailed control measures are necessary.	1, 2, 3, 4.5, 4.6, 4.7, 5, 6 & 7
Class 4 HIGH POWER LASERS	Not only a hazard from direct viewing and from specular reflections but possible from diffuse reflections also. Their use requires extreme caution.	1, 2, 3, 4.5, 4.6, 4.7, 5, 6 & 7

NOTES:

(a) The boundaries of each class are defined by derived Accessible Emission Limits (AELs) and further details are given in Appendix II.
(b) Particular care is needed to distinguish between lasers which are Class 1 by virtue of their low power and those which are Class 1 because they have been engineered to form a *totally enclosed system.*
(c) MPE = Maximum Permissible Exposure, which is the level of laser radiation to which, under normal circumstances, persons may be exposed without suffering adverse effects. (Appendix I).
(d) CW = continuous wave, ie. continuous emission of beam.
(e) Visible = electromagnetic radiation in the range of 400-700nm.

CVCP Laser Safety Guidelines

You will notice that there has been considerable rationalisation of the opening three sections of the Guidance notes in order to make them more pertinent to laser users. The Administrative Procedures (Section 2) are essentially the same, but with the prospect of safety auditing coming to the fore, more emphasis is being placed on the duties of the Departmental Laser Supervisor and in fact a new appendix has been devoted to this (Appendix IV).

The guidance which is given in Sections 1, 2 and 3 is applicable to all classes of lasers. However, people who only use Class 1 low power lasers or equipment which contains Class 1 laser products such as laser printers or CD ROM players will not need to be troubled by this document. People who work with a Class 1 Totally Enclosed System in which they have access to the laser beam must be familiar with the precautions that are necessary when working with the higher classification laser that the system contains (See Section 4).

Class 2, Class 3A and Class 3B* together encompass the largest single group of lasers used in universities, i.e. He-Ne lasers with power outputs less than 5mW. 3B* is a new sub-class of 3B which is confined to visible lasers with less than 5mW continuous wave output but for which there is no power density limitation. Essentially this small relatively low powered subgroup of Class 3B is treated like Class 3A for which there is now no requirement for key control, emission warning, remote interlock connector or beam shutter/attenuator. There is also now no requirement to wear safety eyewear with any of these Classes of laser. Full details of the current requirements and advised treatment of these lasers are given in Sections 4.3 and 4.4.

For Class 3B** and Class 4, Medium and High Power Lasers there have been no changes regarding the requirements for laser eye examinations (see Section 5) and these Notes still envisage the setting-up and maintenance of Laser Designated Areas as the fundamental step in controlling the hazard (see Section 4.5). It is recognised however that people working in, and indeed visiting, such areas may still be at risk and the adoption of other precautions (see Section 3) must be taken into consideration.

Undergraduate work, and lecture demonstrations undertaken with lasers, should be restricted to lasers of Classes 1, 2, 3A and 3B* wherever practicable. Nevertheless, there will be special circumstances where higher powered lasers can be used with the express approval of the Laser Safety Officer and the Departmental Laser Supervisor. Section 6 is devoted to this topic.

If work is undertaken outdoors it is obviously more difficult to establish Laser Designated Areas, and at the same time the possibility of innocent parties becoming involved increases dramatically. This is so even if the work is undertaken on sites owned by or under the control of the university, and is an even greater problem if this is not the case. Guidance on the procedures which should be followed for work with lasers out-of-doors is given in Sections 4.6 and 4.7.

The use of lasers for purposes of entertainment or display, be they lasers in the students' union disco, in the campus theatre, or those used on open days and the like for various public demonstrations, needs yet further consideration. As a minimum it is considered necessary to observe the standards laid down in Guidance Note PM 19 issued by the Health and Safety Executive under the title ‘Use of Lasers For Display Purposes’. Details of this are given in Section 7.

CVCP Laser Safety Guidelines

1. INTRODUCTION TO LASERS

1.1 *Laser Characteristics and Biological Hazards*

1.1.1 The word laser is an acronym for *Light Amplification* by the *Stimulated Emission of Radiation*. The light produced by a laser has a unique combination of spatial coherence (all the waves are in 'step' or in 'phase'); monochromaticity (i.e. have just one 'colour' or a very narrow 'bandwidth'); and, usually, high collimation (i.e. 'low angular divergence' such that the beam does not 'spread out' significantly with distance). This combination of characteristics distinguishes laser radiation from all other light sources.

1.1.2 Lasers produce electromagnetic radiation at wavelengths extending from l80nm in the ultra-violet, through the visible (400-700nm), and the near infra-red (700-l400nm), to the far infra red (l400nm-lmm). Outputs at wavelengths shorter than the ultra violet, i.e. into the X-ray region, are theoretically possible. Devices which produce coherent electromagnetic radiation at wavelengths beyond the infra-red have been known for many years, but are called *Masers* (*Microwave Amplification* by the *Stimulated Emission of Radiation*). We are not concerned with these here.

1.1.3 Some lasers can only be operated in a pulsed mode to produce short bursts of coherent radiation. The duration of an individual pulse can vary from tens of femtoseconds to several milliseconds with repetition rates from a few Hz to many MHz, or as essentially 'single shot' devices. Other lasers can be made to produce a continuous output and are known as continuous wave or CW lasers. To complicate matters, some CW lasers can have a pulse output superimposed on to their continuous output. The energy output of pulsed lasers is generally expressed in joules (J) per pulse; the power output of CW lasers in watts (W). Sometimes, however, the output of pulsed lasers is expressed in terms of 'peak power' (pulse energy in joules divided by pulse duration in seconds) for which the unit 'watt' is also used, e.g. a 1 joule 1 nanosecond rectangular pulse is equivalent to 10^9 watts peak power.

1.1.4 The actual energy or power output of the vast majority of practical lasers can be, and often is, quite modest. Many of the helium neon CW lasers in common use have power outputs ranging from several hundred microwatts to a few tens of milliwatts. However, the spectral brightness (the brightness for a given wavelength in $W.m^{-2}sr^{-1}nm^{-1}$ even for these lasers is many orders of magnitude greater than any other known conventional non-laser light source. This intense beam can give rise to biological hazards even for 'low-power' lasers. With high power lasers, the hazards are much greater.

1.1.5 Harm from laser radiation results from the absorption of energy from the incident beam by the biological tissue which is irradiated. The ability or otherwise of the irradiated tissue to dissipate the heat resulting from such absorption of energy will depend on many factors. These include the surface area of the irradiated site, and the total amount of energy concerned and the rate at which it is absorbed. If the tissue cannot adequately deal with the dissipation of the absorbed energy, biological damage will result. In practice it is necessary to give consideration as to whether the incident beam is CW or pulsed; its wavelength; the way in which such radiation is transmitted, scattered and absorbed by the materials though which it passes; the area of the beam at the irradiation site; and the power or energy density which is encountered there. In the case of the eye, current knowledge suggests that, for long term exposure in excess of about 100s, photochemical effects predominate; for shorter durations and for pulses down to 100µs thermal effects are most likely; whilst for pulses of a nanosecond or less, ionisation and thermo-acoustic shock are the most likely causes of damage.

1.1.6 The narrow, almost parallel beam of coherent monochromatic radiation, which is a characteristic of most lasers means that, in the absence of absorbers, the power delivery by the beam does not diminish significantly with distance. In addition, if such a beam is focused by a lens down to a spot, the power density ($W.m^{-2}$) will be increased very significantly indeed. The increase which is experienced is largely determined by the diameter (actually the aperture) of the lens (which will govern the amount of light collected), the focal length of the lens and the distance to the image. The human eye has evolved as a complex direct extension of the brain to respond to visible light. It contains an aperture in front of the lens – the pupil – which can have a diameter as large as 7mm. The human lens has a focal length of 17mm. The ‘gain’ of such a system for visible light may be as high as 10^5. The power density at the retina arising from even low power laser light incident upon the cornea will usually be enough to cause a rapid rise in temperature. If this is high enough (usually only a few degrees of centigrade above normal) it will denature the proteins which make up the light sensitive elements of the eye. This in turn can lead to irreversible damage to that part of the eye; to general impairment of vision; and even to the person concerned being legally registered as blind if the central part of the visual field is damaged. If the collecting power or diameter of the lens of the eye is effectively increased by the use of telescopes, binoculars, etc, the damage potential may be even greater.

1.1.7 In the above case, the nearly parallel beam of radiation is focussed to a spot. This is one example, and a very important one, which is known as ‘intrabeam viewing’. This term is actually applied to all viewing conditions whereby the eye is exposed to laser radiation except those cases where it is known for certain that the situation gives rise to ‘extended source viewing’. This distinction is made to cater for those situations when viewing a source such as a diffuse reflection of a laser beam or a laser diode array. Under these conditions the eye may be capable of resolving an image of the source, and hence the energy distribution on the retina would be quite different from that which would be encountered by intrabeam viewing and the formation of spot images. In practice, pulsed lasers (and indeed other factors) complicate this relatively simple distinction and reference should be made to one of the standard texts for a more detailed explanation.

1.1.8 Because of the ability of the eye to focus visible radiation – and some near infra-red – on to the retina; because of the possible irreversible nature of the injury which might result; and because of the extreme importance of vision; the eye is recognised as being the critical organ for damage by lasers. Indeed even for those lasers which emit ultra-violet or infra-red radiation of wavelengths which cannot be focussed by the eye, the eye is still the critical organ owing to the damage which even these radiations can cause to the cornea, the lens, and other anterior structures of the eye. In some ways such damage can be more insidious and the hazard more difficult to control, simply because ultra-violet and infra-red radiations are totally invisible. The skin can, of course, also be damaged by laser radiation of any wavelength. There is, however, no focusing effect to complicate the situation, and a small area of damage to the skin is not likely to have anywhere near the same serious consequences as damage to the eye. Nevertheless, due consideration must be given under appropriate circumstances to providing protection for the skin.

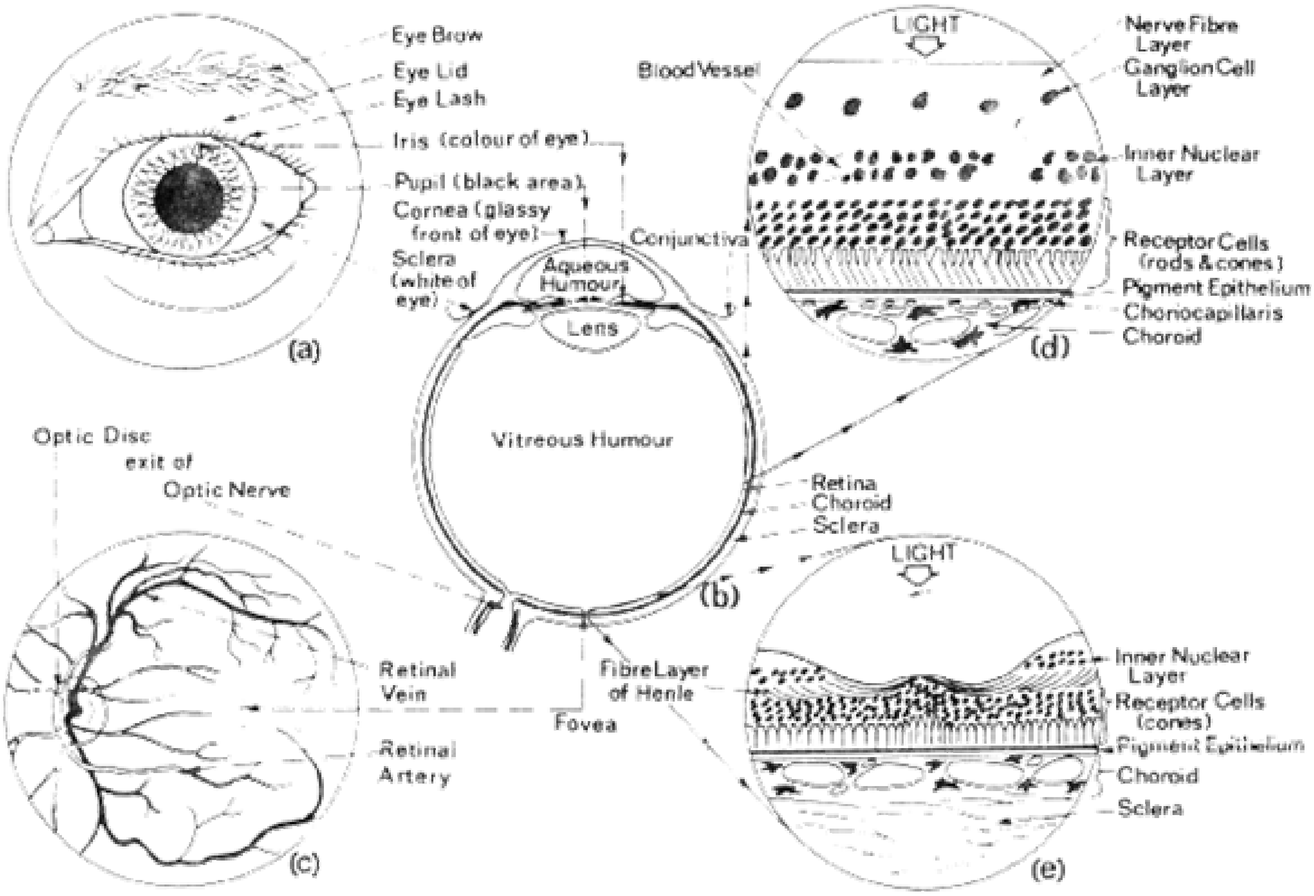

Figure 1. *Anatomy of the eye*

1.1.9 Diagrams giving details of the essential anatomy of the eye and of the absorption properties of the eye with regard to different wavelengths are given in **figures 1** and **2**. These are reproduced by kind permission of the British Standards Institute. Reference should be made to BS EN 60825 for a more detailed exposition.

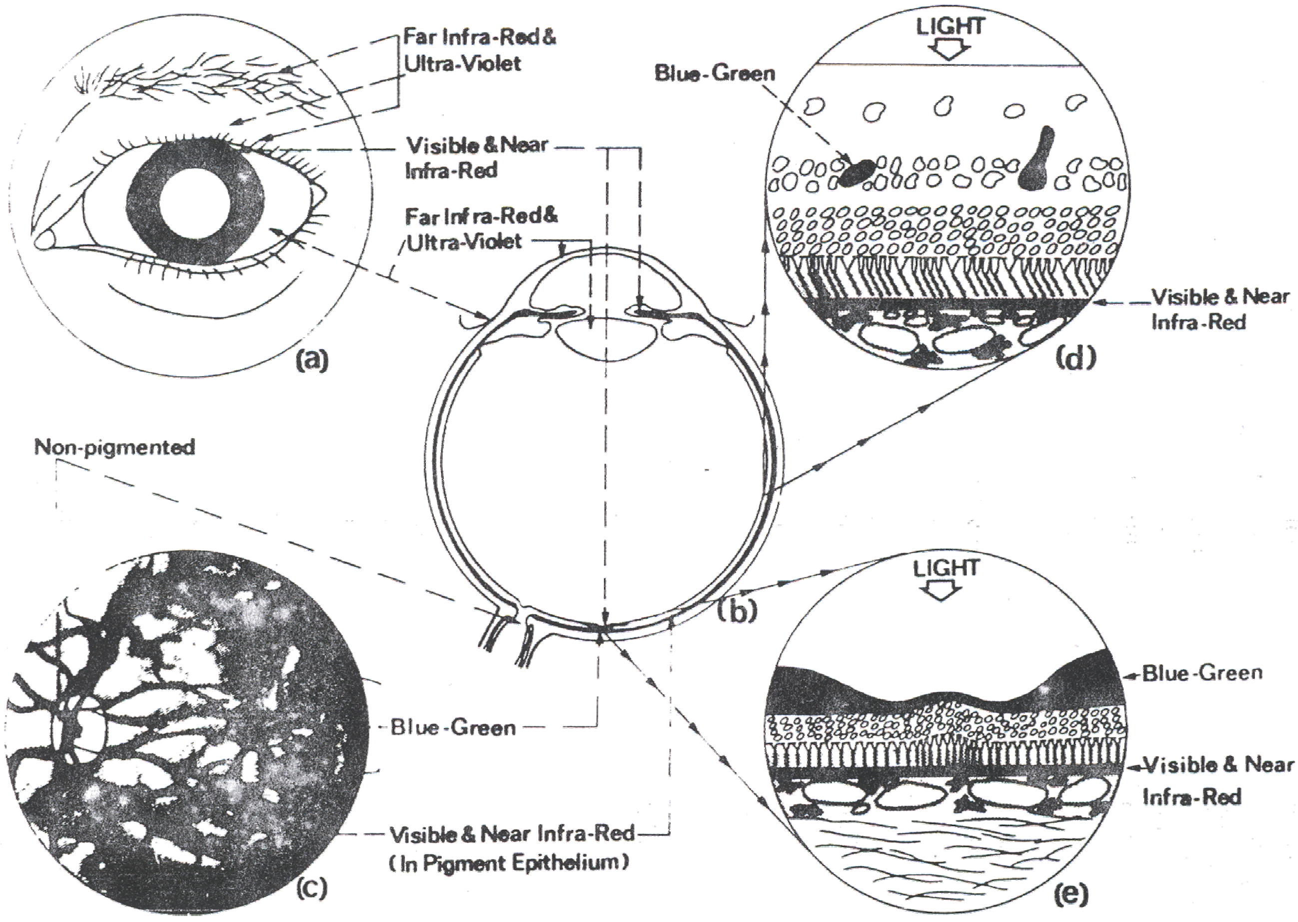

Figure 2. *Absorption properties of the eye with respect to radiations of different wavelengths*

1.1.10 In the case of acute damage to the eye, it is quite likely that the small retinal 'burn' resulting from a slight overexposure would go unnoticed by the person concerned, particularly if this was outside the central 'foveal' region of the retina, where vision is most acute. A large overexposure, especially in the foveal region, could lead to more immediate and extensive damage, including the possibility of complete blindness.

1.1.11 Though little is known about chronic damage to the eye from long-term exposure to lasers and other bright light sources, there is a growing volume of evidence to suggest that this might occur at levels not much greater than those encountered in everyday life. It is thought that this possibly comes about by virtue of photochemical changes in the lens and in the eye's light receptors. The 'premature ageing' of the eye resulting from chronic exposure would appear to be wavelength dependent, and it is believed to be significantly enhanced in the 'blue light' region of the visible spectrum, and in the longer wavelength region of the ultra-violet.

1.1.12 Experiments have been conducted to establish, under the wide variety of exposure conditions which are possible, the thresholds at which damage to the eye commences. Whilst there is no doubt whatsoever that damage to the eye does occur above certain threshold energy levels, there is still some doubt about the levels that can be viewed without chronic photochemical damage occurring. The situation is complicated still further by the many variables already mentioned in 1.1.5, which it is known have to be taken into account in endeavouring to establish the effect from a given incident beam. Under these circumstances, a cautious approach is desirable.

1.2 *Protection from the Direct Hazards of Laser Radiation*

1.2.1 Maximum Permissible Exposure Levels (MPEs), based on the biological data collected to date and modified by suitably safety factors, are those levels of laser radiation to which, in normal circumstances, persons may be exposed without suffering adverse effects. A guide to maximum permissible exposure levels taken from BS EN 60825 is given in Appendix I.

1.2.2 It is important to realise that under intrabeam viewing conditions the levels of exposure which should not be exceeded at the surface of the eye (the cornea), for visible radiation, are very low indeed, for CW lasers being as low as 10^{-2}W.m^{-2} (equivalent to 10^{-8}W for 1mm^{2} beam) for long viewing periods. For visible pulsed lasers, the level can be as low as 5×10^{-3}J.m^{-2} (equivalent to 5×10^{-9}J.mm^{-1} per pulse). It is obvious that *nearly all lasers* will give rise to energy or power densities in their direct beam which are greater than the MPEs recommended for the cornea. In many cases, reflected, refracted or scattered radiation will also exceed these levels.

1.2.3 The prime purpose of any laser safety programme is to ensure that people are not exposed to laser radiation in excess of the MPEs. This aim is achieved in practice by the adoption of a suitable combination of measures from three main safety elements. These are known as 'engineering controls'; 'administrative controls'; and 'personal protective equipment'.

1.2.4 Engineering controls embrace all those safety features which are actually built, or 'engineered', into the design of the laser and its associated plant and equipment, and which, where possible, do not depend on human intervention for their safe operation. For example when the laser is firmly bolted down so that the beam cannot be accidentally knocked out of alignment; the beam paths are all enclosed, or boxed-in, so that people cannot be accidentally exposed to the beam; 'fail-safe' interlocks are provided to prevent unauthorised access to areas of potential danger; these are all engineering controls. Attention must always be given to the adoption of such controls as a first priority, for, in theory at least, it ought to be possible to make any operation completely safe by such measures.

1.2.5 In practice consideration also has to be given to the use of appropriate administrative controls as well, since it is seldom reasonably practicable to be able to deal with the problem solely by engineering controls. Thus it is usually necessary to ensure all equipment is properly labelled so that all concerned can be aware of the type and class of laser which they are dealing with. Local rules are prepared and circulated as necessary, defining all those things that need to be done in order to achieve safe operation. Attention is devoted to the provision of adequate training and instruction. Thought is given to what needs to be done so that non-standard operations such as alignment, servicing and maintenance can be performed safely. These are all examples of administrative controls.

1.2.6 Ideally an appropriate combination of engineering and administrative controls should provide all that is necessary in order to achieve safe operation, and this must certainly be the aim of all those concerned. Unfortunately there might still be occasions when in spite of the efforts which have been made there is still a possibility of persons being exposed to radiation in excess of the MPEs. If there is no way of avoiding this then thought must be given to the use of appropriate personal protective equipment. This means that specially approved laser safety goggles, or other approved eyewear, specifically designed and selected to give adequate protection against the wavelengths and intensities which will be encountered, may have to be provided, and in some circumstances fire resistant protective clothing and gloves may be needed. It must be stressed that the use of personal protective equipment should only be considered when all other avenues of control have been considered first and there is no other reasonably practicable way of protecting the individuals concerned.

1.2.7 The priority which is afforded a particular control element will depend on a number of factors, though perhaps the most important of these is what is 'reasonably practicable'. Obviously if engineering controls are going to cost so much that they are out of all proportion to the risk and the value of the exercise, then greater emphasis would have to be put on the adoption of appropriate administrative controls. This might also be the case if the provision of engineering controls would take much longer than the actual time needed to complete the laser operation or experiment. Again, work outdoors may well demand a different mix of the elements than work indoors. The risk associated with a particular laser is also another major consideration, and it is attempts to rationalise this aspect of the problem that have led to the concept of laser classification.

1.2.8 These Notes set out to establish in later Sections the actual degree of control which those responsible for laser safety should seek to achieve for each Class of laser. The degree of freedom that is exercised in achieving a solution in practice must always result from an active consideration of the problem in line with the requirements of these Notes and such other documents as may be appropriate, and must not arise by general default and failure to honour ones obligations. Professional advice must always be sought whenever there is any doubt.

1.3 *Protection from the Indirect hazards Associated with Lasers*

1.3.1 Care must always be taken when working with lasers not to concentrate on the obvious risk to the exclusion of the more conventional hazards to which persons might well be subjected at the same time. Almost all lasers need for example electrical power supplies to make them work. An electric shock from these have been known to result in death – something the laser radiation itself is most unlikely ever to do! There are many other hazards which can be encountered, and these may include the following:

(i) electrical hazards from directly associated equipment, particularly from high voltage power supplies and, those arising from capacitor banks used with pulsed lasers. These probably constitute the most dangerous and likeliest cause of accidents with lasers;

(ii) electrical hazards from indirectly associated power supplies to all the ancillary equipment used with lasers. Incorrectly used trailing leads and adaptors are a particular problem;

(iii) water supplies of any kind, and particularly those used for cooling purposes, can lead to problems in their own right, but when associated with potential electrical risks can compound these greatly;

(iv) mechanical hazards from motors, pumps, associated belt and gear drives, and the electrical, mechanical and pneumatic systems, etc employed in driving cutting and welding heads and associated *x-y* tables and similar devices;

(v) intense conventional light sources used to pump lasers – these can often include hazardous sources of ultra-violet;

(vi) toxic chemicals used either in the lasers themselves, or which are used in associated equipment or apparatus. In this connection it must be noted that many of the chemicals used in dye-lasers may be potentially carcinogenic and must be handled in a fume cupboard using protective clothing and disposed of accordingly;

(vii) toxic by-products formed under the influence of laser radiation, such as those resulting from the irradiation of a great variety of chemicals, or vaporised target materials arising from laser cutting, drilling or welding operations;

(viii) explosion or implosion hazards associated with high voltage electrical supplies, evacuated tubes and systems, some types of lasers themselves, materials used in or with lasers including cryogenic coolants and particularly liquid oxygen, and, materials irradiated by lasers;

(ix) fire;

(x) the hazards associated with the use of cryogenic coolants such as liquid nitrogen, oxygen and helium;

(xi) the formation of ozone, and oxides of nitrogen;

(xii) *X*-rays generated by high voltage rectifiers and possibly the lasers themselves.

All these, and any other related hazards, must be properly assessed and dealt with at the planning and construction stage, and must not be left until after operation has commenced. Professional safety advice must be sought whenever necessary.

2. ADMINISTRATIVE PROCEDURES

2.1 The governing body of the university is the Controlling Authority responsible for the implementation of the provisions of these Notes of Guidance and must set up an administrative organisation for the control of laser operation within the university in accordance with the following recommendations.

2.2 A committee must be charged by the Governing Body to ensure the implementation of these Notes of Guidance and any other provisions which may be recommended from time-to-time. All universities should already have appropriate committee structures to honour their obligations regarding general safety, radiation protection, and related matters and it would appear appropriate for the committee required here to be incorporated within this structure.

2.3 The Governing Body should make arrangements for the medical examination of laser workers in accordance with the requirements of Section 5. The Governing Body should formally nominate such persons or organisations who may be considered necessary in order to implement these requirements.

2.4 The Governing Body must appoint a Laser Safety Officer (LSO) with responsibility for advising the university on all safety matters attendant upon the use of lasers and for carrying out such duties as required by the committee. The LSO must be responsible for the instruction of staff, the provision of measuring equipment where appropriate, and the registration of lasers at the university.

2.5 The Head of Department must be responsible to the Governing Body, in consultation with the committee, for safe operation of all lasers within his Department/Laboratory.

2.6 The head of any department where lasers are used must appoint a Departmental Laser Supervisor (DLS) who must be responsible for the supervision of laser operations within the department in accordance with these Notes of Guidance and safety rules issued by the committee.

2.7 The committee must ensure that local rules are issued on behalf of the Governing Body detailing the safety procedures which must be observed whenever university personnel intend to operate lasers of any kind. These rules must give details of the names of persons appointed to posts of special responsibility, and other duties. Any person to whom responsibility is allocated must be given a clear written statement of his duties, and must acknowledge its receipt. A list of such persons shall be maintained by the Laser Safety Officer. **A guide to the duties expected of a DLS are given in Appendix IV.**

2.8 Any individual working with, or intending to work with, lasers must be made aware of his responsibility both to himself, and to others who may be affected by his activities, for the safe performance of his work, and must have his attention drawn to the requirements of these Notes of Guidance.

NB: *In the above requirements the titles of Laser Safety Officer and Departmental Laser Supervisor have been used for convenience. It is the functions that these individuals undertake which is important and if arrangements already exist whereby the functions are performed by people recognised by other titles this is in order.*

3. GENERAL SAFETY PROCEDURES

3.1 All lasers and laser systems currently in use and those planned for future use must conform to the requirements of these Notes of Guidance and to the British Standard, or to appropriate local rules produced to ensure levels of safety at least as good and effective as those demanded by these two documents. Forward planning is essential and adequate financial provision for safety requirements must be made in grant applications. The head of department must instruct his Departmental Laser Supervisor to take such steps as are necessary to ensure that this is so. The advice of the Laser Safety Officer must be sought in any case of doubt, or as required by these Notes of Guidance.

3.2 Frequent use is made in these Notes of words such as ‘appropriate’. This is primarily in recognition of the fact that widely different standards can, and indeed should, apply to lasers from different classes. Details relating to each specific class are given in Section 4. ‘Appropriate’ also recognises that in many practical situations, cognisance will have to be taken of what is ‘reasonably practicable’ in the accepted Health and Safety understanding of that term. It is not possible to give adequate guidance on this topic in these Notes. Whenever it is considered necessary to interpret ‘appropriate’ in this way, the advice of the Laser Safety Officer must be sought.

3.3 The provision and use of appropriate warning signs and labels in accordance with the requirements of these Notes of Guidance, and as set out in Appendix III, is essential in order to ensure that all parties are adequately informed of the risks and of the steps that they must take in order to avoid them.

3.4 In the first instance thought should always be given to the adoption of appropriate engineering controls in order to achieve safe working conditions; then to appropriate administrative controls; and finally if it is not practicable to attain the required standard by an appropriate combination of these two elements, to the use of personal protective equipment with particular emphasis on eye protection.

3.5 Though specific guidance relating to each class of laser is given in Section 4 there are some general matters which can be usefully considered now. These are that it is safer to:

(i) use a low power laser rather than a high power one. If, taking all other considerations into account, a choice exists, then this should be exercised in favour of the low power device;

(ii) prevent intrabeam viewing by engineering design, or at least forbid it;

(iii) operate lasers in areas separate from other work activities. This will limit the number of people who have access to the area and hence reduce significantly those in need of training and instruction;

(iv) provide total enclosures so that human access to potentially hazardous direct beams, and potentially hazardous specular and diffuse reflections, is not possible;

(v) keep the beam path from the laser to any equipment as short and direct as possible, with a minimum of optical reflection, and to terminate the beam in a suitable energy absorbing non reflective beam-stop;

(vi) securely fix the laser so that it cannot be knocked out of alignment and hence give rise to unexpected beam paths and reflections. This is equally true of other components used within the system;

(vii) carry out alignment procedures, and such other adjustments and alterations which may give rise to unexpected beam paths or reflections, with the laser switched off. This is true for 'visible' lasers and is perhaps even more so for those that emit 'invisible' radiation in the infrared and ultra-violet. Where practicable conventional light sources should be employed for such operations; or, the laser output should be reduced as much as possible either by the adjustment of the power supply or by the use of suitable attenuating or polarising filters; or, another laser of the lowest possible output should be used;

(viii) eliminate the chance of stray reflections. Consideration should be given to the use of appropriately coated optical components. Select components which will not shatter' or craze under the influence of the laser beam; to the removal of unwanted apparatus, furniture and equipment from the laser area and the elimination of reflective surfaces from items which have to remain; to the removal of personal jewellery, wristwatches, etc, and to the covering of shiny buttons, belt buckles, etc, with a suitable laboratory coat or coverall;

(ix) ensure that lasers are not left running unattended. This is not so important if they are in Designated Laser Areas (see Section 4.5.5) or in a total enclosure (see Section 4.2);

(x) ensure the design of pulsed lasers is such that they cannot fire spontaneously. One may need to consider the introduction of a 'count-down' procedure prior to firing, and turning ones head away and to closing ones eyes immediately prior to firing;

(xi) ensure that whenever mechanical or electrical safety interlocks are required that they are of an approved and appropriate fail-safe design, and that they are properly installed and used;

NB: *It should be noted that it is a requirement of BS EN 60825 that all access panels shall have safety interlocks: if they are intended* *to be removed during maintenance or operation, and if this removal gives human access to laser radiation from the embedded laser which is above the following levels:*

a) for Classes 1-3A where access is gained to laser radiation equivalent to Class 3B or greater;*

b) for Class 3B or above where access is gained to laser radiation equivalent to Class 3B** or greater.*

(xii) when key controls are fitted to lasers ensure that their use is properly managed and controlled. **Keys that are left in switches and just used as on-off switches are worse than useless**;

and finally,

(xiii) ensure when personal protective equipment is considered to be necessary, that it has been properly approved and chosen for the task. Clothing and gloves must be suitably heat and fire resistant and otherwise suitable for the work concerned. Protective goggles must be designed for use with lasers, and comply with the Protection of Eyes Regulations, 1974, Certificate of Approval No 2 (General). Specific regulations for laser protective eyewear are being developed in a draft European Standard prEN207 which is based upon the German DIN 58215. The points which are considered relevant to the choice and use of protective eyewear are detailed in Section 10.8 of the British Standard. This and any other relevant literature, including that provided by eyewear manufacturers and suppliers, **must be consulted if there is any doubt whatsoever as to what is required**. Some of the features which must be considered are the wavelengths or wavelength at which they will be used; the optical density required to provide the necessary attenuation; the power levels they can intercept without shattering, bleaching, or burning; their closeness of fit and comfort; and their ability to cope with the need for prescription lenses and to provide adequate peripheral vision. Only the correct goggles for the particular laser(s) in use must be allowed in the area concerned. All goggles must be clearly and indelibly labelled and identified as being suitable for use with a particular type of laser and the optical density and wavelength must be specified. The possibility of deterioration of the goggles with time or as a result of mechanical damage, or after exposure to intense beams must not be overlooked, and appropriate inspection and/or testing procedures should be instituted.

N.B: *The wearing of protective eye wear must not prevent the user from seeing any warning lights that may have been installed for his guidance. Suitably coloured and/or flashing lights must be used, perhaps in conjunction with audible signals, to ensure that he can still receive the necessary messages.*

3.6 It is recognised that lasers will be constructed and developed in university departments. These must be registered with the Laser Safety Officer at an early stage and special care adopted throughout the commissioning and testing, in order to ensure that they are correctly classified (see Appendix II), and operated.

3.7 Attention also needs to be drawn to the growing use of laser diodes for alignment purposes, scanning, holography and numerous other applications. These very small inexpensive devices can be quite powerful and, with a collimated focusable beam, just as hazardous as a conventional laser. They therefore need to be treated with the same respect.

3.8 Due to the difficulty of making meaningful estimates or measurements of laser beam intensities under the variety of working conditions which are encountered in practice, reference must be made to Appendix A of the British Standard, where a number of examples of laser safety calculations are presented. It is hoped that these, used in conjunction with the information provided by the manufacturer, will in many cases render it unnecessary for radiometric measurements to be made, and enable a laser classification and the relevant safeguards to be established. However, in some cases this may not be possible and then the help and advice of the Laser Safety Officer should be sought.

4. PRECAUTIONS RELATING TO SPECIFIC CLASSES OF LASERS

4.1 *Use of Class 1 Low Power Lasers on University Premises*

4.1.1 It is important to note that this refers solely to those lasers whose outputs are so low that the relevant MPE cannot be exceeded under any viewing conditions. No formal control measures need to be taken regarding the use of these lasers.

4.2 *Use of Class I Totally Enclosed Laser Systems on University Premises*

4.2.1 It is important to note that this refers to those laser systems where the relevant MPE cannot be exceeded by virtue of their engineering design. The design of the total enclosure must be such that the system can be used in complete safety with regard to allied hazards and the enclosure must be such that it is not possible for personnel to gain access, or to be able to insert any part of their bodies into the beam or be exposed to reflected radiation levels in excess of the MPE, during normal operation.

4.2.2 A register must be kept of all such laser systems except for CD ROM players, laser printers and similar devices not serviced by the operator. All registered systems must be labelled in accordance with the details given in Appendix III.

4.2.3 In order to qualify as a ‘Totally Enclosed System’, commercial and home-made systems must have the following features:

(i) interlocks must be provided such that it is not possible, during normal operations, to remove any part of the enclosure and by so doing expose oneself or others to radiation in excess of the Accessible Emission Limits for a Class 1 Laser recommended in this document;

(ii) the laser(s) and its enclosure must be designed on a ‘fail-safe’ basis so that adjustment. alterations and failures of any part of the system will not invalidate the requirements relating to the levels of exposure outside the enclosure, or result in the system becoming unsafe in other respects;

(iii) the lasers within the enclosure must be clearly identified and labelled in accordance with the requirements for the appropriate Class given in Appendix III;

(iv) an electrical isolation switch for the whole of the system must be provided. This must be clearly labelled and sited in a conspicuous and convenient position.

4.2.4 If the above conditions have been met, then for normal operation most of the protective measures outlined in Sections 3 and 4 of these Guidance Notes are not relevant. However, if it is intended that personnel should have access to the enclosure and then be able to defeat the interlocks, etc, for maintenance/alignment purposes, then the system must be treated according to the highest class of laser it contains and the appropriate sections of these Guidance Notes strictly adhered to.

4.3 *Use of Class 2 Lasers on University Premises*

4.3.1 A register must be kept of all such lasers, which must be labelled in accordance with the details given in Appendix III.

4.3.2 Protection in this class is based on the consideration that a brief exposure which might occur accidentally, and, which would be limited by the natural aversion response to bright lights, to a period of not more than about 0.25 seconds, would not be hazardous. Even so, the laser beam must never be deliberately aimed at people, or indeed, stared at, as it is quite possible to overcome the aversion response and continuous viewing is hazardous.

4.3.3 The only control measures required are that the laser beam should be terminated at the end of its useful path by a suitable beam stop and that open laser beam paths at eye-level should be avoided.

4.4 *Use of Class 3A and Class 3B* Lasers on University Premises*

4.4.1 A register must be kept of all such lasers, which must be labelled in accordance with the details given in Appendix III.

4.4.2 Protection in these classes is not always provided by the natural aversion response and additional precautions are required. The power density can be increased by the use of optical viewing aids, such as microscopes, binoculars, etc and the use of these must be controlled by the Departmental Laser Supervisor or Laser Safety Officer and suitable filters fitted where necessary, so that the MPEs at the eye piece are not exceeded. With Class 3B* lasers the power density is already high enough for the laser to be hazardous from direct viewing of the beam and this must be avoided.

4.4.3 Control measures which are required are as follows:

(i) the laser beam must be terminated at the end of its useful path by a suitable beam stop;

(ii) open laser beam paths at eye-level should be avoided and should be enclosed (e.g. within a tube) where practicable;

(iii) instruction and training should be given to all operatives (see Section 2);

(iv) laser warning signs should be displayed at the entrance to areas where these classes of lasers are used (see Appendix Ill).

4.5 *Use of Class 3B** and Class 4 Lasers on University Premises*

4.5.1 A register must be kept of all such lasers, which must be labelled in accordance with the details given in Appendix III.

4.5.2 Class 3B** lasers present a hazard to the eye if the direct beam, or specular reflections are viewed without the protection afforded by features of the engineering design, by suitable administrative procedures, or by the use of appropriate protective eyewear.

4.5.3 Class 4 lasers present an even greater hazard to the eye and, in addition, the viewing of even diffuse reflections can be hazardous. This class of laser can be a hazard to the skin, and can also constitute a serious fire hazard. It must be recognised that this class embraces all lasers with power outputs in excess of 0.5 watts. In practice this is a very wide range indeed, and it is clear that, for safety considerations, not all lasers in this class can be treated alike.

4.5.4 All Class 3B** and Class 4 lasers must incorporate the following safety features:

(i) A ‘captive-key’ control switch. One must not be able to remove the key except when the switch is in the off position. The key must be removed when the laser is not in use and kept in a safe place. Keys must never be issued to unauthorised persons.

(ii) A beam shutter or attenuator. This must be properly maintained and should operate automatically to prevent the inadvertent exposure of persons to hazardous laser radiation.

(iii) A remote interlock connector. This can operate warning lights outside the laser area and also act to shutdown the laser on opening the door to the laboratory. This may be considered a necessary safety precaution if work involving open beam paths is being conducted especially if high powered pulse lasers are being used. There is a provision in the British Standard for a momentary override of the remote interlock connector to enable entry into the laboratory by authorised personnel. This override should be sited inside the laboratory and only used by the person in charge if it is safe to do so.

(iv) An audible and/or visible warning device(s). This should signal when the laser is energised or, for pulsed lasers, when the capacitor banks are being charged or have not been positively discharged. The warning device shall be fail-safe and any visual signal should be of a wavelength that can be seen through the normal protective eyewear.

4.5.5 The actual precautions needed for each Class 3B** or Class 4 laser installation should be carefully planned in advance by the Departmental Laser Supervisor in conjunction with the Laser Safety Officer. Nevertheless, lasers of either of those classes must only be used in laboratories, or such other clearly defined areas which can be set aside for this purpose, and where the hazards can be effectively controlled. These will be called *Designated Laser Areas (DLA)*. The committee may also wish to consider the inclusion of some lower class lasers and Totally Enclosed Systems, in such areas.

4.5.6 DLAs must be clearly identified by a suitable warning notice (see Appendix III). Consideration should also be given to utilising the remote interlock connector to provide a visual signal at the entrance to the area to indicate the lasers state of readiness to emit laser radiation.

4.5.7 Entry to a DLA should be limited to authorised personnel only and a suitable mandatory notice supplementary to the one in Section 4.5.6 should make this clear.

4.5.8 Each DLA should be purpose designed for the particular laser application in order to minimise the risk of any personal injury not only from the laser itself but also from associated electrical, mechanical, chemical and other hazards. The following design aspects therefore need to be carefully considered:

(i) the laser beam must be terminated at the end of its useful path by a suitable non-reflecting beam stop or target. This must be capable of absorbing the energy concerned and have the fire resistant characteristics necessary for that particular laser;

(ii) beam paths should be kept well below eye-level and enclosed (e.g. within a tube or boxed-in) whenever practicable. Boxing-in and screens should be opaque to the laser wavelengths involved and should be designed to prevent hazardous specular and diffuse reflections. Where necessary they should be painted with matt black paint and be constructed of fire-resistant material. When complete the assembly should eliminate as far as reasonably practicable the possibility of any part of the body being accidentally placed in a hazardous area;

(iii) if it is not reasonably practicable to ‘box-in’ the laser beam then consideration must be given to the total exclusion of laser beam leakage from the area. Careful siting of the laser within the area will help to eliminate the possibility of leakage through doors and windows, but 'blacking-out' may still be necessary;

(iv) where possible, only one laser should be used in any one Designated Area at any one time. If this is not possible, consideration should be given to the use of suitable opaque screens for separation.

(v) the provision, wherever possible, of a high standard of general illumination within the area, so that the pupil of the eye remains as small as possible;

(vi) the painting whenever possible, of walls, ceilings and fittings within the Designated Laser Area with a light coloured matt paint to enhance the general illumination and reduce specular reflections;

(vii) the removal of all unnecessary equipment from the Designated Laser Area especially from the laser bench itself;

(viii) the minimisation and if possible, the elimination, of reflecting surfaces. Glass fronted cupboards and gloss painted items of electrical and other equipment are obvious examples;

(ix) the provision, where necessary, of adequate ventilation to prevent the build-up of toxic gases or vapours either from the contents of the lasers themselves, or from materials irradiated by the lasers. The use of materials such as liquid oxygen, present a further hazard which must not be ignored;

(x) the provision, where necessary, of adequate facilities for the dispensing and handling of toxic chemicals, such as, for example, those used in dye lasers some of which may well be carcinogenic. Thought must also be given to the manner in which toxic wastes will be dealt with and removed from the premises;

(xi) the provision of adequate and appropriate fire-fighting equipment;

(xii) the siting of approved electrical supplies with identified switch and control gear designed:

a) to prevent accidental firing of the lasers;
b) to provide an indication of the state of readiness of equipment such as associated capacitor banks;
c) to enable personnel to stand in a safe place;
d) to incorporate all relevant electrical safety features;
e) to enable the laser to be shut down by a person standing next to the laser;
f) to enable the equipment to be isolated and made safe from outside the designated Laser Area in the event of fire or other emergency; and
g) to provide sufficient and adequate power supplies for all the ancillary equipment and apparatus, and to restrict the use of trailing

leads (which must in any case be adequately secured) to an absolute minimum.

4.5.9 Even with all the design features listed above incorporated into the laser system and the designated laser area and with carefully thought out administrative controls, there will probably still be times when access is required to open beams during alignment and maintenance procedures. At times like this the appropriate eye protection in accordance with Section 3.5(viii) must be used.

4.6 *Use of all Classes of Lasers on University Premises Out of Doors*

4.6.1 The use of lasers of any class on university premises out of doors necessitates special precautions to deal with the problems of public safety and public relations which such work poses, particularly when the public have access to the area. It is important to realise that the range of the laser could be very significant, and there is a need to appreciate the concepts of nominal ocular hazard distance' and 'nominal ocular hazard area', as explained in Para 12.2 of BS EN 60825. In particular the laser beam must normally be terminated completely within the experimental area, which must be positively defined and clearly indicated. In those cases where the laser beam is directed in an upward direction, the need for consultation with the appropriate Civil Aviation Authorities should be considered.

4.6.2 Any person intending to use a laser out of doors must submit details of his intentions to his Departmental Laser Supervisor, who will then be responsible, after seeking the advice of the Laser Safety Officer, for advising on what detailed action is necessary. Under no circumstances must a laser be used out in the open until all interested parties have been consulted and formal written permission has been granted. Some additional guidance will be found in Paragraph 12.6 of BS EN 60825.

4.7 *Use of all Classes of Lasers, other than Class 1 Low Power Lasers, off University Premises*

4.7.1 Apart from the not unimportant problem of public relations, the use of lasers either indoors or outdoors on premises not owned or controlled by the university will inevitably raise questions relating to responsibility, liability and insurance. In these circumstances, the opinion of the university's legal advisers must be sought before embarking upon such a project, and it may also be advisable to seek the assistance of the local representatives of the Health and Safety Executive and/or the National Radiological Protection Board. If suitable assurances can be obtained, the person must then:

(i) inform the Head of Department and obtain his formal permission for the project, and then inform the Departmental Laser Supervisor and the Laser Safety Officer, and action any advice which they may give;

(ii) follow carefully any Regulations, Codes of Practice, Notes of Guidance, or other instructions regarding the use of lasers which might apply specifically to the premises concerned, or, in the absence of any such documents, work in accordance with those sections of this document which may be relevant.

5. MEDICAL SUPERVISION

5.1 The main concern here is with the eyesight of laser workers. Many establishments used to carry out routine pre, interim and post employment ophthalmic examinations for all laser workers using Class 3B and Class 4 lasers. However, these have proved to be of little value and occupy the time of skilled ophthalmological staff who could be more usefully employed dealing with patients with real problems.

5.2 Routine ophthalmic examinations are therefore not recommended as part of a safety programme. If universities consider that they need to continue with them for medical-legal reasons then they should be carried out by a qualified specialist and be restricted to workers using Class 3B** and Class 4 laser products.

5.3 What is recommended is that prior arrangements should be made for ophthalmic examinations to be undertaken in the event of an accident or incident involving suspected injury to the eye. These emergency examinations should be carried out by a qualified specialist as soon as possible and within 24 hours. The Laser Safety Officer and Departmental Laser Supervisor must also carry out a detailed investigation of the accident/incident. It is recommended that a copy of this report together with the results of the ophthalmological examination should be referred to a central agency[*] and the necessary steps should be taken to prevent recurrence of similar accidents.

N.B. *A serious injury (3 days off work) would have to be reported to the HSE under 'The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1985'.*

[*] Professorial Unit, Moorfields Eye Hospital, City Road, London EC1V 2PD.

6. UNDERGRADUATE EXPERIMENTS AND LECTURE DEMONSTRATIONS

6.1 Where possible, every attempt should be made to use the least hazardous lasers for student experimental work and lecture demonstrations. Lasers falling within Classes 1 (both Low Power and Totally Enclosed Systems), 2, 3A and 3B* of this document should therefore be used in preference to those from Classes 3B** and 4. It is recognised that lasers from these latter classes may be necessary for a limited number of special teaching projects, and, if this is the case the full provisions of Sections 3 and 4 must be applied.

6.2 Work with lasers of Classes 1, 2, 3A and 3B will not normally require the setting up of Laser Designated Areas (Section 4.5.5) and it will usually be sufficient to follow the guidance given in Sections 3, 4.1, 4.2, 4.3 and 4.4. Due regard must be paid, however, to the conditions which prevail in teaching laboratories and lecture theatres; to the relative inexperience of the students; and to the desirability of introducing the students to good laser safety practice as part of their educational programme.

6.3 It is suggested, therefore, that the following additional special conditions should be satisfied for work under this heading:

(i) All experiments and demonstrations should be subject to an ‘Approved Scheme of Work’.

(ii) The safety of an experiment or demonstration should be assessed by the Departmental Laser Supervisor and the Lecturer in charge. They should be responsible for drawing up the ‘Approved Scheme of Work’ in writing, and for obtaining the approval of the Laser Safety Officer for this. A copy of the ‘Scheme’ should then be displayed in a position where it can be clearly seen by persons carrying out the work or performing the demonstration.

(iii) Where specular reflections cannot be avoided during demonstrations, screens must be positioned to prevent exposure of any student or demonstrator to radiation in excess of the Maximum Permissible Exposure Levels.

(iv) Clear written instructions should be provided for each student experiment, and the participants informed of the risks of exposure to laser beams if the instructions are not followed.

(v) The Member of Staff responsible should either visit the experiment at reasonable intervals or be present in the laboratory where the laser is in use.

(vi) Lasers must not be accessible to students at any time other than when they are being used in approved experimental work.

7. USE OF LASERS FOR ENTERTAINMENT AND OTHER DISPLAY PURPOSES

7.1 In recent years there has been a significant increase in the use of lasers for entertainment and display purposes, particularly in ‘Disco’ type situations. Such use can be spectacular and effective – it can also be most unsafe. The ‘lasers’ used for such displays are often Class 4 devices identical to those used in university research. The conditions which prevail in a dance hall are, however, very different from those in a laboratory. At the same time the very large number of participants will not be primarily concerned with laser safety and indeed the circumstances will often moderate their natural caution and replace it with incautious bravado.

7.2 In recognition of the special care which is needed to ensure such displays are conducted in a safe manner, the Health and Safety Executive has published a separate Guidance Note (PM 19) on the ‘Use of Lasers for Display Purposes’. In the light of BS EN 60825 this has recently been revised and updated. It is stressed that ‘for the purpose of this guidance, “display” includes all entertainment, theatrical, stage and set applications, advertising promotions and illuminations’. It is also important to recognise that the conditions must also apply to the ‘setting-up’ and installation of the equipment, and to any adjustments, servicing or maintenance which may be necessary. For any such use on university premises Guidance note PM 19 must be adhered to. The committee responsible for lasers set up under Section 2 may well wish to consider whether it should also apply to other applications such as the use of lasers on ‘open days’, and other public demonstrations.

7.3 In general, lasers used for display purposes will be supplied, installed and operated by a specialist supplier. If this is the case many of the responsibilities resulting from PM 19 will fall upon this supplier and the operator who comes with the equipment. The university, its staff and its students, do however have responsibilities for the general safety of all concerned and for ensuring that the terms of any licence which might apply to the premises are observed. Appropriate thought must be given to these matters and the hire contract suitably drawn up to ensure that the division of responsibilities is clearly understood.

7.4 If lasers belonging to the university are contemplated for such use not only will the university have to assume full responsibility for the observance of PM 19, but it must also give appropriate consideration to the suitability of the laser for such use and to the relevant skill and experience of the people who install and operate it.

7.5 It must be stressed that commercial considerations and the pressures of ‘one night stands’ must not be allowed to influence adversely the safety standards which are so important if people are not to be injured from such displays.

7.6 In brief the requirements of PM 19 are that persons must be prevented from being exposed to laser radiation at levels in excess of the MPEs by adequate separation, i.e. hazardous direct and reflected beams have to be kept specified distances away from all people who might otherwise be exposed. This means that some pre-planning of the event is essential. PM 19 requires that details of the entertainment or display including drawings, calculations and measurements, are submitted to the person responsible for the venue, in advance, setting out how the safety of those attending the event will be secured. A degree of cooperation is required between both parties in order to ensure that this is done, and that the agreed procedures are properly implemented.

APPENDIX I

A Guide to Maximum Permissible Exposure Levels

When working with lasers it is obviously essential to have available information relating to those levels of power or energy density which are known to be safe when incident upon the eye or skin. Experimental data can provide the basis of such information though clearly this has to be modified by appropriate 'safety factors' which are of necessity somewhat subjective. Nevertheless, meaningful and helpful levels of Maximum Permissible Exposure (MPE) have been established, though it must be recognised that these should be used as guides in the control of exposures and should not be regarded as precisely defined lines between safe and dangerous levels.

It will be appreciated that the MPEs are particularly dependent upon wavelength and exposure time, and are also affected by other variables. This is true for CW and single-shot' pulse lasers working at a single wavelength, and the position becomes vastly more complex for repetitively pulsed lasers, which may or may not have a uniform pulse repetition frequency, and of course to simultaneous exposure to outputs of different wavelength and pulse duration. Self mode locking – where pulses of highpeak power can be superimposed on the output of a CW laser – also requires special attention.

Detailed advice is given in Section 13 of BS EN 60825 and the topic is kept under constant review. This source of information must be referred to in all but the most straightforward of cases.

Readers should note that in addition to the above, help can also be obtained from the National Radiological Protection Board at the addresses given below.

With the above in mind the MPEs:

- i) for Direct Ocular Exposure or 'Intrabeam Viewing';
- ii) for viewing an 'Extended Source' Laser or a Laser Beam by Diffuse Reflection and;
- iii) for Exposure of the Skin

have been reproduced from BS EN 60825 and are given for general guidance in Tables I, II and III. It is suggested however that in practice it may not always be necessary to determine the MPEs particularly frequently, as the adoption of the laser classification and the appropriate safeguards detailed in these Notes of Guidance, should go a long way to ensure that these levels are not exceeded.

National Radiological Protection Board

Northern Centre: Hospital Lane, Cookridge, Leeds LS16 6RW
– Tel: Leeds (0532) 679041

Southern Centre: Chilton, Didcot, Oxon OX11 0RQ
– Tel: Abingdon (0235) 831600

Scottish Centre: 155 Hardgate Road, Glasgow G51 4LS
– Tel: Glasgow (041) 440 2201

CVCP Laser Safety Guidelines

Table I: Maximum permissible exposure (MPE) at the cornea for direct ocular exposure to laser radiation (intrabeam viewing)

Wavelength λ (nm) \ Exposure time t(s)	$<10^{-9}$	10^{-9} to 10^{-7}	10^{-7} to 10^{-6}	10^{-6} to 1.8×10^{-5}	1.8×10^{-5} to 5×10^{-5}	5×10^{-5} to 10	10 to 10^3	10^3 to 10^4	10^4 to 3×10^4
180 to 302.5	3×10^{10} W.m^{-2}	30J.m^{-2}							
302.5 to 315		C_1J.m^{-2} ($t < T_1$) / C_2J.m^{-2} ($t > T_1$)					C_2J.m^{-2}		
315 to 400		C_1J.m^{-2}					10^4J.m^{-2}	10W.m^{-2}	
400 to 550	5×10^6W.m^{-2}	5×10^{-3}J.m^{-2}			$18 t^{0.75}$ J.m^{-2}		100J.m^{-2}		10^{-2}W.m^{-2}
550 to 700							$18 t^{0.75}$ J.m^{-2} ($t < T_2$) / $C_3 \times 10^2$J.m^{-2} ($t > T_2$)		$C_3 \times 10^{-2}$W.m^{-2}
700 to 1050	$5 \times C_4 \times 10^6$W.m^{-2}	$5 \times 10^{-3} \times C_4$J.m^{-2}			$18 \times C_4 t^{0.75}$ J.m^{-2}			$3.2 \times C_4$W.m^{-2}	
1050 to 1400	5×10^7W.m^{-2}	5×10^{-2}J.m^{-2}				$90 \times t^{0.75}$ J.m^{-2}		16W.m^{-2}	
1400 to 1530	10^{11}W.m^{-2}	100J.m^{-2}	$5600 \times t^{0.25}$ J.m^{-2}				1000W.m^{-2}		
1530 to 1550		1.0×10^4J.m^{-2}		$5600 \times t^{0.25}$ J.m^{-2}					
1550 to 10^6		100J.m^{-2}	$5600 \times t^{0.25}$ J.m^{-2}						

See Notes in Appendix II

Diameter of limiting apertures shall be for:

1 mm	200	$< \lambda <$	400 nm
7 mm	400	$< \lambda <$	1400 nm
1 mm	1400	$< \lambda <$	10^5 nm
11 mm	10^5	$< \lambda <$	10^6 nm

Note: For repetitively pulsed laser radiation, use rules in Sub-clause 13.3 of BN EN 60825

Table II: Maximum permissible exposure (MPE) at the cornea for viewing an extended source laser beam by diffuse reflection

Wavelength λ (nm) \ Exposure time t(s)	$<10^{-9}$	10^{-9} to 10^{-7}	10^{-7} to 10^{-6}	10^{-6} to 10	10 to 10^{3}	10^{-3} to 10^{4}	10^{4} to 3×10^{4}
180 to 302.5	3×10^{10} W.m^{-2}	30J.m^{-2}					
302.5 to 315		C_1J.m^{-2} $t < T_1$ C_2J.m^{-2} $t > T_1$			C_2J.m^{-2}		
315 to 400		C_1J.m^{-2}			10^{4}J.m^{-2}	10W.m^{-2}	
400 to 550	10^{11}W.m^{-2} sr^{-1}	$10^{5} \times t^{0.33}$J.m^{-2} sr^{-1}			2.1×10^{5}J.m^{-2} sr^{-1}		21W.m^{-2} sr^{-1}
550 to 700					$t < T_2$ $3.8 \times 10^{4} \times t^{0.75}$J.m^{-2} sr^{-1} $2.1 \times C_3 \times 10^{5}$J.m^{-2} sr^{-1} $t > T_2$		$21 \times C_3$ W.m^{-2} sr^{-1}
700 to 1050	$10^{11} \times C_4$W.m^{-2} sr^{-1}	$10^{5} \times C_4 \times t^{0.33}$J.m^{-2} sr^{-1}			$3.8 \times 10^{4} \times C_4 t^{0.75}$J.m^{-2} sr^{-1}	$6.4 \times 10^{3} \times C_4$W.m^{-2} sr^{-1}	
1050 to 1400	5×10^{11}W.m^{-2} sr^{-1}	$5 \times 10^{5} \times t^{0.33}$J.m^{-2} sr^{-1}			$1.9 \times 10^{5} \times t^{0.75}$J.m^{-2} sr^{-1}	3.2×10^{4}W.m^{-2} sr^{-1}	
1400 to 1530	10^{11}W.m^{-2}	100J.m^{-2}	$5600 \times t^{0.25}$J.m^{-2}		1000 W.m^{-2}		
1530 to 1550		1.0×10^{4}J.m^{-2}		$5600 \times t^{0.25}$ J.m^{-2}			
1550 to 10^{6}		100J.m^{-2}	$5600 \times t^{0.25}$J.m^{-2}				

See Notes in Appendix II

Table III: Maximum permissible exposure (MPE) of skin to laser radiation*

Wavelength λ (nm) \ Exposure time t(s)	$<10^{-9}$	10^{-9} to 10^{-7}	10^{-7} to 10	10 to 10^{-3}	10^{3} to 3×10^{4}
180 to 302.5	3×10^{10}W.m^{-2}	30J.m^{-2}			
302.5 to 315		C_1J.m^{-2} $t < T_1$ C_2J.m^{-2} $t > T_1$		C_2J.m^{-2}	
315 to 400		C_1J.m^{-2}		10^{4}J.m^{-2}	10W.m^{-2}
400 to 1400	2×10^{11}W.m^{-2}	200J.m^{-2}	$1.1 \times 10^{4} \times t^{0.25}$J.m^{-2}	2000W.m^{-2}	
1400 to 10^{6}	10^{11}W.m^{-2}	100J.m^{-2}	$5600 \times t^{0.25}$J.m^{-2}	1000W.m^{-2}	

See Notes in Appendix II

*Limiting aperture = 1 mm for $\lambda < 10^{5}$ nm and 11 mm for $\lambda > 10^{5}$ nm

APPENDIX II

A Guide to Accessible Emission Limits and Laser Classification

Accessible Emission Limits (AELs) are specified in BS EN 60825:1992 for the different classes of laser according to the hazard posed by particular wavelengths of laser radiation.

A summary of laser classification is given in the preface to this booklet and full details of how lasers are classified according to AELs are given in Section 9 of BS EN 60825:1992 and in Tables I to IV of that document which are reproduced here by kind permission of British Standards Institute.

An additional Table, Table V, has been produced which gives examples of the AELs for He-Ne lasers with a wavelength of 633nm.

Notes to Tables of AELs and MPEs

1. For Class 1 laser products there are dual limits in the wavelength range from 400-1400nm and a laser product is classified as Class 1 if it complies with either the AEL for radiant power (W) or the AEL for radiance ($W.m^{-2}sr^{-1}$). There is also a reduced time basis of 100s for classification of some Class 3A lasers and the procedures for determining the AELs of repetitively pulsed or modulated lasers have been revised.

2. There is only limited evidence about effects for exposures of less than 10^{-9}s. The AELs and MPEs for these exposure times have been derived by maintaining the irradiance, radiance, or radiant exposure applying at 10^{-9}s.

3. Correction factors C_1 to C_4 and breakpoints T_1 and T_2 used in the tables in Appendix I and II are defined in the following expressions:

Parameter	Spectral Region
$C_1 = 5.6\times10^3\, t^{0.25}$	302.5 to 400 nm
$T_1 = 10^{0.8(\lambda-295)}\times10^{-15}$ s	302.5 to 315 nm
$C_2 = 10^{0.2(\lambda-295)}$	302.5 to 315 nm
$T_2 = 10\times10^{0.02(\lambda-550)}$ s	550 to 700 nm
$C_3 = 10^{0.015(\lambda-550)}$	550 to 700 nm
$C_4 = 10^{(\lambda-700)/500}$	700 to 1050 nm

4. The wavelength range λ_1 to λ_2 means $\lambda_1 \le \lambda < \lambda_2$ (e.g. 180 to 302.5 means $180 \le \lambda < 302.5$).

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Table I: Accessible emission limits for Class 1 laser products

Wavelength λ (nm) \ Emission duration t (s)	$<10^{-9}$	10^{-9} to 10^{-7}	10^{-7} to 10^{-6}	10^{-6} to 1.8×10^{-5}	1.8×10^{-5} to 5×10^{-5}	5×10^{-5} to 10	10 to 10^{3}	10^{3} to 10^{4}	10^{4} to 3×10^{4}
180 to 302.5	2.4×10^{4}W	2.4×10^{-5}J							
302.5 to 315		$7.9 \times 10^{-7} C_1$J ($t < T_1$) / $7.9 \times 10^{-7} C_2$J ($t > T_1$)					$7.9 \times 10^{-7} C_2$J		
315 to 400		$7.9 \times 10^{-7} C_1$J					7.9×10^{-3}J	7.9×10^{-6}W	
400 to 550	200 W	2×10^{-7}J			$7 \times 10^{-4} t^{0.75}$J		3.9×10^{-3}J		3.9×10^{-7}W
or	10^{11}W.m^{-2} sr^{-1}	$10^{5} t^{0.33}$J.m^{-2} sr^{-1}					2.1×10^{5}J.m^{-2} sr^{-1}		21 W.m^{-2} sr^{-1}
550 to 700	200 W	2×10^{-7}J			$7 \times 10^{-4} t^{0.75}$J.($t < T_2$) / $3.9 \times 10^{-3} C_3$J ($t > T_2$)				$3.9 \times 10^{-7} C_3$W
or	10^{11}W.m^{-2} sr^{-1}	$10^{5} t^{0.33}$J.m^{-2} sr^{-1}					($t < T_2$) $3.9 \times 10^{4} t^{0.75}$J.m^{-2} sr^{-1} / 2.1 $10^{5} C_3$J.m^{-2} sr^{-1} ($t > T_2$)		21 C_3W.m^{-2} sr^{-1}
700 to 1050	200 C_4W	$2 \times 10^{-7} C_4$J			$7 \times 10^{-4} t^{0.75} C_4$J			$1.2 \times 10^{-4} C_4$W	
or	$10^{11} C_4$W.m^{-2} sr^{-1}	$10^{5} t^{0.33} C_4$J.m^{-2} sr^{-1}					$3.9 \times 10^{4} t^{0.75} C_4$ J.m^{-2} sr^{-1}	$6.4 \times 10^{3} C_4$W.m^{-2} sr^{-1}	
1050 to 1400	2×10^{3}W	2×10^{-6}J				$3.5 \times 10^{-3} \times t^{0.75}$J		6×10^{-4}W	
or	5×10^{11}W.m^{-2} sr^{-1}	5×10^{5} $t^{0.33}$J.m^{-2} sr^{-1}					$1.9 \times 10^{5} t^{0.75}$ J.m^{-2} sr^{-1}	3.2×10^{4}W.m^{-2} sr^{-1}	
1400 to 1530	8×10^{4}W	8×10^{-5}J	$4.4 \times 10^{-3} t^{0.25}$J				8×10^{-4}W		
1530 to 1550		8×10^{-3}J		$4.4 \times 10^{-3} t^{0.25}$J					
1550 to 10^{5}		8×10^{-5}J	$4.4 \times 10^{-3} t^{0.25}$J						
10^{5} to 10^{6}	10^{7}W	10^{-2}J	$0.56 t^{0.25}$J				0.1 W		

See Notes in Appendix II

Table II: Accessible emission limits for Class 2 laser products

Wavelength λ (nm)	Emission duration t (s)	Class 2 AEL
400 to 700	$t<0.25$ $t \geq 0.25$	Same as Class 1 AEL 10^{-3}W

Table III: Accessible emission limits for Class 3A laser products

Wavelength λ (nm) \ Emission duration t (s)	$<10^{-9}$	10^{-9} to 10^{-7}	10^{-7} to 10^{-6}	10^{-6} to 1.8×10^{-5}	1.8×10^{-5} to 5×10^{-5}	5×10^{-5} to 0.25	0.25 to 10	10 to 10^3	10^3 to 3×10^4
180 to 302.5	3×10^{10} W.m^{-2}	30 J.m^{-2}							
302.5 to 315	1.2×10^5 W and 3×10^{10} W.m^{-2}	($t > T_1$) $4 \times C_2 \times 10^{-6}$ J and C_2 J.m^{-2} ($t < T_1$) $4 \times C_1 \times 10^{-6}$ J and C_1 J.m^{-2}						$4 \times C_2 \times 10^{-6}$ J and C_2 J.m^{-2}	
315 to 400		$4 \times C_1 \times 10^{-6}$ J and C_1 J.m^{-2}						4×10^{-2} J and 10^4 J.m^{-2}	4×10^{-5} W and 10 W.m^{-2}
400 to 700	1000W and 5×10^6 W.m^{-2}	10^{-6} J and 5×10^{-3} J.m^{-2}			$3.5 \times 10^{-3} \times t^{0.75}$ J and $18 \times t^{0.75}$ J.m^{-2}		5×10^{-3} W and 25W.m^{-2} (Aversion responses protect for emission > 0.25 s)		
700 to 1050	1000W $\times C_4$ W and $5 \times C_4 \times 10^6$ W.m^{-2}	$10^{-6} \times C_4$ J and $5 \times C_4 \times 10^{-3}$ J.m^{-2}			$3.5 \times 10^{-3} \times C_4 \times t^{0.75}$ J and $18 \times C_4 \times t^{0.75}$ J.m^{-2}				$6 \times 10^{-4} \times C_4$ W and $3.2 \times C_4$ W.m^{-2}
1050 to 1400	10^4 W and 5×10^7 W.m^{-2}	10^{-5} J and 5×10^{-2} J.m^{-2}				$1.8 \times 10^{-2} \times t^{0.75}$ J and $90 \times t^{0.75}$ J.m^{-2}			3×10^{-3} W and 16W.m^{-2}
1400 to 1530	4×10^5 W and 10^{11} W.m^{-2}	4×10^{-4} J and 100J.m^{-2}	$2.2 \times 10^{-2} \times t^{0.25}$ J and $5600 \times t^{0.25}$ J.m^{-2}					4×10^{-3} W and 1000W.m^{-2}	
1530 to 1550		1.0×10^4 J.m^{-2}		$2.2 \times 10^{-2} \times t^{0.25}$ J and $5600 \times t^{0.25}$ J.m^{-2}					
1550 to 4000		4×10^{-4} J and 100J.m^{-2}	$2.2 \times 10^{-2} \times t^{0.25}$ J and $5600 \times t^{0.25}$ J.m^{-2}						
4000 to 10^6	10^{11} W.m^{-2}	100J.m^{-2}	$5600 \times t^{0.25}$ J.m^{-2}					1000W.m^{-2}	

See Notes in Appendix II

Table VI: Accessible emission limits for Class 3B laser products

Wave-length λ(nm) \ Emission duration t (s)	$<10^{-9}$	10^{-9} to 0.25	0.25 to 3×10^4
180 to 302.5	3.8×10^5W	3.8×10^{-4}J	1.5×10^{-3}W
302.5 to 315	$1.25 \times 10^4 C_2$W	$1.25 \times 10^{-5} C_2$J	$5 \times 10^{-5} C_2$W
315 to 400	1.25×10^8W	0.125J	0.5W
400 to 700	3.14×10^{11}W.m^{-2}	$3.14 \times 10^5 t^{0.33}$J.m^{-2} and $<10^5$J.m^{-2}	0.5W
700 to 1050	$3.14 \times 10^{11} C_4$W.m^{-2}	$3.14 \times 10^5 C_4 t^{0.33}$J.m^{-2} and $<10^5$J.m^{-2}	0.5W
1050 to 1400	1.57×10^{12}W.m^{-2}	$1.57 \times 10^6 t^{0.33}$J.m^{-2} and $<10^5$J.m^{-2}	0.5W
1400 to 10^6	10^{14}W.m^{-2}	10^5J.m^{-2}	0.5W

See Notes in Appendix II

Table V: Examples of AELs for He-Ne, CW Laser, λ = 633 nm

Class 1	6.86 μW
Class 2	1 mW
Class 3A	5 mW and <25 W/m² (2.5 mW/cm²)
Class 3B*	5 mW
Class 3B**	500 mW

APPENDIX III

Warning Labels and Notices

1. LABELLING OF LASERS

1.1. General

As all laser safety procedures are based on the classification scheme which has been adopted in these Notes of Guidance, it is of the utmost importance that all lasers are appropriately labelled so that everybody concerned is immediately aware of:

a) The class of laser
b) Any basic precautions which are necessary
c) Where the laser presents a potential hazard, the laser's characteristics

Where the laser does present a potential hazard the class of laser must be indicated in a 'hazard warning label'. All additional information must be contained in 'explanatory labels'. Details relating to the design of both these types of labels are given in para 1.9 of this Appendix.

In practice the user is likely to be confronted by two basic situations:

i.) where the laser has been manufactured and/or supplied in accordance with the requirements of British Standard EN 60825 and has been labelled to satisfy its demands or those of any approved amendments. In such a case the labelling should be perfectly acceptable and in keeping with the requirements of these Notes of Guidance **except** that additional labels are essential for all Class 1 Totally Enclosed Systems as specified in para 1.3 below;

ii.) where the laser has not been manufactured of supplied in accordance with BS EN 60825, which may include 'home-made' lasers and those that have been modified by the user, as well as many lasers from abroad. In all such cases the laser must be labelled in accordance with the following paragraphs as appropriate to its class.

1.2. Labelling of Class 1 Lasers which are Inherently Safe under all Viewing Conditions because of their Low Power

All that is needed for this class of laser is an explanatory label complying with para 1.9.2 and bearing the wording:

LASER PRODUCT CLASS 1

N.B. *No colour combination is now specified by BS EN 60825 for Class lasers.*

1.3. Labelling of Class 1 Lasers which are Only Safe because of their Engineering Design and which are 'Totally Enclosed Laser Systems'

A hazard warning label complying with para 1.9.1 and incorporating the hazard warning symbol detailed in Fig 1 must be affixed to all such lasers and must bear the words:

LASER PRODUCT CLASS 1
A TOTALLY ENCLOSED LASER SYSTEM
CONTAINING A CLASS . . . LASER

The appropriate class must be inserted on all such labels. In addition, any section or service panel of the laser system enclosure which, when removed, would permit possible exposure to laser radiation from a Class 2, 3A, 3B or 4 laser must have fixed to it an explanatory label with the words:

CAUTION – LASER RADIATION WHEN OPEN
AND INTERLOCKS DEFEATED

This shall be visible before and after opening the appropriate section or service panel.

After opening the appropriate section or service panel, hazard warning and explanatory labels containing all the information applicable to the class of laser within the enclosure, must be clearly visible.

N.B. *BS EN 60825 asks for supplementary information to be displayed with the service panel warning label, i.e. outside the enclosure. However, moves are afoot to simplify these service panel labels and this may not be a requirement in the future. Therefore it is recommended that we stay with our current advice.*

1.4. Labelling of Class 2 Lasers

A hazard warning label complying with para 1.9.1 and incorporating the hazard warning symbol detailed in Fig 1 must be affixed to all such lasers and must bear the words:

LASER PRODUCT CLASS 2

In addition an explanatory label complying with para 1.9.2 must be affixed to the laser containing the radiation output information as specified in para 1.8 and the words:

DO NOT STARE INTO BEAM

1.5. Labelling of Class 3A Lasers

A hazard warning label complying with para 1.9.1 and incorporating the hazard warning symbol detailed in Fig 1 must be affixed to all such lasers and must bear the words:

LASER PRODUCT CLASS 3A

In addition an explanatory label complying with para 1.9.2 must be affixed to the laser containing the radiation output information as specified in para 1.8 and the words:

DO NOT STARE INTO BEAM OR VIEW
DIRECTLY WITH OPTICAL INSTRUMENTS

1.6. Labelling of Class 3B Lasers

A hazard warning label complying with para 1.9.1 and incorporating a hazard warning symbol detailed in Fig 1 must be affixed to all such lasers and must bear the words:

LASER PRODUCT CLASS 3B

In addition an explanatory label complying with para 1.9.2 must be affixed to the laser containing the radiation output information specified in para 1.8 and the words:

AVOID EXPOSURE TO BEAM

A further explanatory label, or labels, must be fixed close to the laser output aperture(s) bearing the words:

LASER APERTURE

or

AVOID EXPOSURE –
LASER RADIATION IS EMITTED
FROM THIS APERTURE

This label may take the shape of an arrow (see Fig 7) where this conveys more meaning.

N.B. *This is not a BS EN 60825 specification.*

1.7. Labelling of Class 4 Lasers

A hazard warning label complying with para 1.9.1 and incorporating the hazard warning symbol detailed in Fig 1 must be affixed to all such lasers and must bear the words:

LASER PRODUCT CLASS 4

In addition an explanatory label complying with para 1.9.2 must be affixed to the laser containing the radiation output information specified in para 1.8 and the words:

AVOID EYE OR SKIN EXPOSURE TO
DIRECT OR SCATTERED RADIATION

A further explanatory label, or labels, must be fixed close to the laser output aperture(s) bearing the words:

LASER APERTURE

or

AVOID EXPOSURE –
LASER RADIATION IS EMITTED
FROM THIS APERTURE

This label may take the shape of an arrow (see Fig 7) where this conveys more meaning.

N.B. *This is not a BS EN 60825 specification.*

1.8. Radiation Output and Standards Information

Each laser product, other than the Class 1 Low Power lasers as in para 1.2 above, must have affixed to it an explanatory label complying with para 1.9.2 giving radiation output information, including:

(i) whether the output is visible or invisible radiation, or both,
(ii) the maximum laser radiation output,
(iii) pulse duration (if appropriate),
(iv) the laser medium and principal emitted wavelengths.

These labels may be separate from, or combined with, the specific explanatory labels required for each class listed above. An example is given in Fig 6.

There is also now a requirement for the name and publication date of the standard to which the product was classified to be included on a label, e.g.:

TO BS EN 60825:1992

This will not always be a British Standard and this is essentially part of the manufacturer's requirement to classify his product.

1.9. Notes

1.9.1. Laser hazard warning labels shall be black on a yellow background and may combine the laser hazard symbol (Fig 1) and text. Figures 4 and 5 show examples of laser hazard warning labels.

N.B. *Recommended dimensions are given in BS EN 60825 but these are likely to be supplemented by a forthcoming amendment which is much more practical and permits the use of any legible size that is suited to the size of the laser product as long as the dimensions of the hazard warning label are proportional to the recommended values.*

1.9.2. Except for 'Class 1 laser products' explanatory labels shall be black on a yellow background. Figures 6 and 7 show examples of explanatory labels.

N.B. *Recommended dimensions are again given in BS EN 60825 but will be amended to allow greater flexibility. Legibility will in future be the key factor and labels may be of any size necessary to contain the required lettering and border dimensions g_2 and g_3 shall be 0.06 times the length of the shorter side of the label.*

1.9.3. Except where size or design of the laser product makes labelling impracticable, the labels shall be durably affixed to the laser product in such a position that they are clearly visible and legible during operation, maintenance and servicing of the laser product, according to their purpose.

1.9.4. Where it is not practicable, on account of size or design to affix labels directly to the laser product they shall be displayed adjacent to it in a position which meets the requirements of 1.9.3.

2. DOOR AND AREA SIGNS AND WARNING NOTICES

2.1. The points of access to areas in which class 3A, class 3B or class 4 laser products are used shall be marked with warning signs complying with BS 5378. The laser signs shall incorporate the following information:

i) The hazard warning symbol, of a preferred minimum height (H) of 120 mm (see Fig 1).

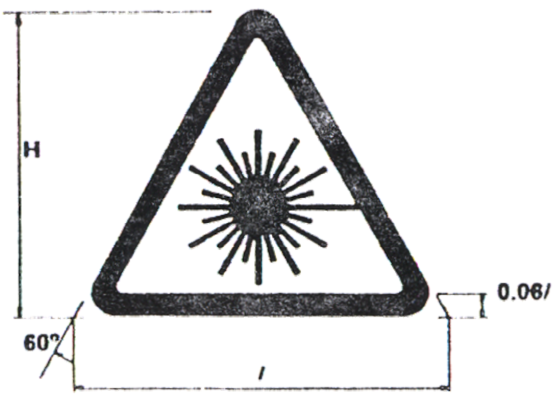
ii) The highest class of laser used in the area and whether it is a Designated Laser Area as defined in Section 4 para 4.4.6 e.g.

'**CLASS 3A LASER AREA**'
or '**CLASS 4 DESIGNATED LASER AREA**'

iii) Details of the personnel responsible for the laser area concerned, together with the telephone numbers by which they may be contacted both at the university and at home.

2.2. For instructions such as 'Authorised Personnel Only' or 'No entry when warning light is on', the appropriate mandatory and prohibition signs must be used in accordance with BS 5378.

Figure 1. Details of hazard symbol to be used in labels and signs



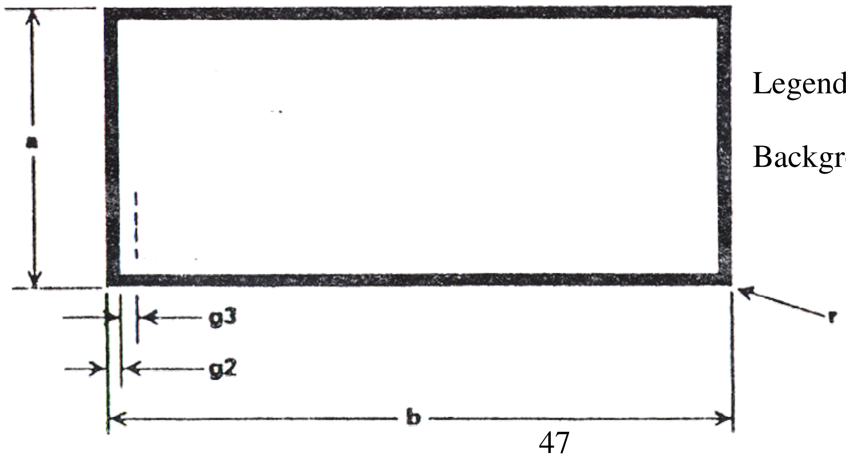
Triangular band and symbol: black

Background: yellow

Symbol placed centrally on the background

Yellow covers at least 50% of the area of the label or sign.

Figure 2. Details of explanatory labels



Legend and border: black

Background: yellow

N.B. *In the above labels and signs the greatest distance 'L' in metres from which the label/sign can be understood and the minimum area 'A' of the label in m^2 is given by $A = L^2/_{2000}$ for distances less than 50 metres.*

EXAMPLES OF CLASS LABELS (not to scale)

Colour: Black on yellow background *(except no specification for Class 1)*

Figure 4

Figure 3

Figure 5

EXAMPLES OF EXPLANATORY LABELS (not to scale)

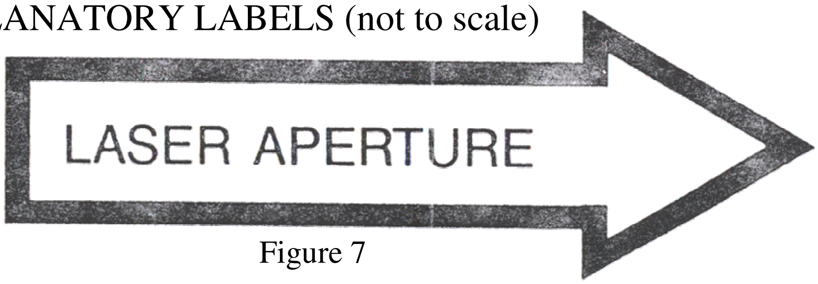


Figure 7

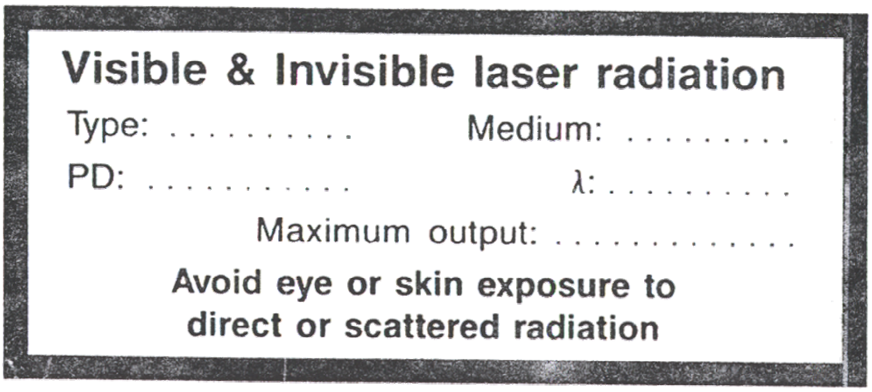


Figure 6

Colour:
Black on yellow background

APPENDIX IV

The Duties of the Departmental Supervisor

A guide to the duties of the Departmental Laser Supervisor is given below. In smaller institutions these could be looked upon as the duties of the Laser Safety Officer as well.

The DLS is responsible for the safe operation of lasers in the department in accordance with these Notes of Guidance and safety rules issued by the safety committee. The DLS should also ensure that:

1. all lasers except for low power Class 1 lasers are registered with the Laser Safety Officer;

2. all lasers are labelled in accordance with these guidance notes;

3. schemes of work are drawn up where necessary for the safe operation of lasers. (These will generally be required when using Class 3B** and Class 4 lasers and the beam paths are not totally enclosed.)

4. all personnel intending to work with Class 3A lasers or above are registered for work with lasers;

5. all registered laser workers receive copies of local rules and relevant schemes of work and are informed of the arrangements relating to eye examinations;

6. all registered laser workers receive training in the safe use of lasers. (To assist in this the CVCPs would recommend the use of the Laser Safety Video produced by the University of Southampton.)

7. laser safety goggles are provided for all work with Class 3B** and Class 4 lasers where the laser beam is not totally enclosed;

8. undergraduates work with the minimum power laser practicable and that they operate under schemes of work (see section 7).

The DLS or LSO as appropriate should also carry out routine surveys of laser installations to monitor that these guidance notes are being observed. To facilitate this task a Laser Survey Form has been drawn up which acts as a summary of the requirements of BS EN 60825 (see page 51). Where there is a blank box then you need to check if the precautions specified have been fulfilled. A fuller explanation of these is given below:

1.	Remote Interlock	—	interlocked to the door or enclosure – required for all class 4 lasers and the higher powered Class 3B.

2.	Key Control	—	all Class 3B** and Class 4 lasers should be provided with this to ensure that only authorised personnel use the laser.
3.	Emission Indicator	—	all Class 3B** and Class 4 lasers should have this, may also be sited outside the laboratory to give warning of lasers in use.
4.	Beam Shutter	—	should be provided for all Class 3B and Class 4 lasers.
5.	Beam Stop	—	for Class 2 and above to ensure that the lasers is terminated within the confines of the laser bench or experimental area.
6.	Beam Level	—	avoid eye level.
7.	Beam Enclosure	—	needed to guard against specular reflection from Class 3B and Class 4 lasers – can mean anything from screening the experimental area or beam up to a total enclosure.
8.	Eye Protection	—	may be required for Class 3B** and Class 4 lasers.
9.	Protective Clothing	—	mainly required for Class 4 lasers.
10.	Eye examinations	—	only required after an accident but may be provided for people working with Class 3B** and Class 4 lasers.
11.	Training	—	all people working with Class 3A and above should receive training.
12.	Laser Labels	—	all lasers should display the appropriate labels.
13.	Door Signs	—	required for all laser areas where Class 3A or above are used.

If all the engineering features required by items 1-7 are not in place, (particularly item 7), then appropriate administrative controls should be drawn up to ensure the safe use of the laser. These should briefly be stated on the survey form and given in more detail in the written Scheme of Work.

LASER SURVEY FORM

Date : ....
Dept : ....
Lab : ....

Type : ....
Make : .... Mode : ....
Model : .... λ : ....
S/N : .... Max Power : ....

Precautions	Class 1	Class 2	Class 3A	Class 3B*	Class 3B**	Class 4	Class 1(E)
Remote Interlock							
Key Control							
Emission Indicator							
Beam Shutter							
Beam Stop							
Beam Level							
Beam Enclosure							
Eye Protection							
Protective Clothing							
Eye Examinations							
Training							
Laser Labels							
Door Signs							

Administrative Controls: ....
....
....
....

Recommendations: ....
....

APPENDIX V

Literature References

1. British Standard BS EN 60825:1992 Radiation Safety of Laser Products, Equipment Classification, Requirements and User's Guide, BSI, Linford Wood, Milton Keynes, MK14 6LE.

2. American National Standards Institute, ANSI-Z-136, 'Standard for the Safe Use of Lasers'. ANSI, 1430 Broadway, New York City, NY 10018, USA.

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4. American Conference of Governmental and Industrial Hygienists (ACGIH). 'A Guide for the Control of Laser Hazards', and 'Threshold Limit Values and Biological Exposure Indices' published annually: ACGIH, 6500 Glenway Avenue, Building D-5, Cincinnati, Ohio, OH 45211, USA.

5. Department of Health and Social Security (DHSS), 'Guidance on the Safe Use of Lasers in Medical Practice'. HMSO ISBN 0-11-320857-X.

6. Health and Safety Executive (HSE). Guidance Note PM19 'Use of Lasers for Display Purposes'. (Updated version expected by end of 1992.) HSE, Baynards House, 1 Chepstow Place, Westbourne Grove, London.

7. University of Southampton. 'Laser Safety in Higher Education'. A video available from Department of Teaching Media, University of Southampton, 31 University Road, Southampton, S09 5NH.

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