Non-binding guide to good practice for implementing Directive 2006/25/EC

'Artificial Optical Radiation'

Social Europe

European Commission

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'Artificial Optical Radiation'

European Commission

Directorate-General for Employment, Social Affairs and Inclusion
Unit B.3

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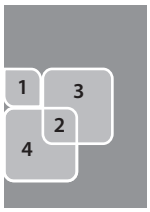

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Contents

1. Introduction

Directive 2006/25/EC (termed the 'Directive') covers all artificial sources of optical radiation. Most of the requirements of the Directive are similar to existing requirements of, for example, the Framework Directive 89/391/EEC. Therefore, the Directive should place no greater burden on employers than is already required by other directives. However, since the Directive is so all-embracing, there is a need to identify applications of artificial optical radiation that are so insignificant with regard to health, that no further assessment is required. This guide is intended to give an indication of such trivial applications, to provide guidance for a number of other specific applications, present an assessment methodology and also, in some cases, suggest that further assistance should be sought.

A number of industries have well-developed guidance covering specific applications of optical radiation and references to such sources of information are made.

Artificial optical radiation covers a very wide range of sources that employees may be exposed to in the workplace and elsewhere. These sources will include area and task lighting, indicator devices, many displays and other similar sources which are essential to the well-being of workers. Therefore, it is not reasonable to take a similar approach to many other hazards by necessarily minimising the artificial optical radiation hazard. To do so may increase the risk from other hazards or activities in the workplace. A simple example of this is that turning the lights off in an office may put everyone in the dark.

A range of artificial optical radiation sources are used as input to manufacturing processes, for research and communication. Optical radiation also may be incidental, such as when a material is hot and radiates optical radiation energy.

There are a number of applications of artificial optical radiation which require direct exposure of employees at levels that may exceed the exposure limits given in the Directive. These include some entertainment and medical applications. Such applications will need critical assessments to ensure that the exposure limits are not exceeded.

Artificial optical radiations are separated into laser and non-coherent radiation in the Directive. This separation is only used in this guide where there is a clear benefit in doing so. The traditional view is that laser radiation exists as a beam of a single wavelength. A worker can be very close to the beam path but suffer no adverse health effects. However, if they get directly into the beam then they may immediately exceed the exposure limit. For non-coherent radiation, the optical radiation is less likely to be a well collimated beam and the level of exposure increases as the source is approached. It could be claimed that with a laser beam, the probability of being exposed is low, but the consequence may be severe; for a non-coherent source, the probability of exposure may be high, but the consequence less severe. This traditional distinction is becoming less obvious with some evolving optical radiation technologies.

The Directive was adopted under Article 137 of the Treaty establishing the European Community, and this article expressly does not prevent Member States from maintaining or introducing more stringent protective measures compatible with the Treaty.

1.1 How to use this guide

Artificial optical radiations exist in most workplaces. Many present little or no risk of causing injury and some allow work activities to be carried out safely.

This guide should be read in conjunction with Directive 2006/25/EC (the 'Directive') and the Framework Directive 89/391/EEC.

The Directive lays down the minimum safety requirements regarding the exposure of workers to risks arising from artificial optical radiation. Article 13 requires the Commission to draw up a practical guide to the Directive.

The guide is primarily intended to assist employers, and in particular small and medium-sized enterprises. However, it may also be useful for employee representatives and regulatory authorities in Member States.

The guide falls naturally into three sections:

All employers should read Sections 1 and 2 of this guide.

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If all of the sources in the workplace are included in the list of trivial sources in section 2.3, there is no need for further action.

Where sources not listed in section 2.3 are present, risk assessment will be more complex. The employer should additionally consider Sections 3–9 of this guide.

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This should inform a decision on whether to carry out self-assessment or to seek external assistance.

The appendices contain further information which may be useful for employers who are carrying out risk assessments themselves.

Data from product manufacturers may help the employer with its risk assessment. In particular, some types of artificial optical radiation source should be classified to provide an indication of the accessible optical radiation hazard. It is suggested that employers should request appropriate information from the suppliers of sources of artificial optical radiation. Many products will be subject to the requirements of European Community directives, for example for CE marking, and a specific reference to this is made in paragraph (12) of the preamble to the Directive (see Appendix K). Chapter 8 of this guide provides guidance on the use of manufacturers' data.

All workers are exposed to artificial optical radiation. Examples of sources are given in Chapter 2. One of the challenges is to ensure that sources that may present a risk of exposing workers to levels in excess of the exposure limit values are adequately assessed without the burden of having to assess the majority of sources that do not present a risk under reasonably foreseeable circumstances — the so-called 'trivial' sources.

This guide aims to lead users through a logical path for assessing the risk from exposure of workers to artificial optical radiation:

If the only sources of exposure to artificial optical radiation are trivial, no further action is required. Some employers may wish to record that they have reviewed the sources and reached this conclusion.

If sources are not trivial or the risk is unknown, employers should follow a process to assess the risk and implement appropriate control measures, if necessary.

Chapter 3 of this guide outlines the potential health effects.

Chapter 4 describes the requirements of the Directive and the exposure limit values are presented in Chapter 5. These two chapters therefore cover the legal requirements.

Chapter 6 contains a suggested methodology for carrying out the risk assessment. It is possible that the conclusion is that there is no risk, so the process stops here.

Where inadequate information exists to carry out the risk assessment, it may be necessary to undertake measurements (Chapter 7) or make use of manufacturers' data (Chapter 8).

Chapter 9 covers control measures where it is necessary to reduce the risk.

Should someone get exposed to artificial optical radiation at levels in excess of the exposure limit values then Chapter 10 covers contingency plans and Chapter 11 covers health surveillance.

The appendices provide further information for employers and others who may be involved with the risk assessment process:

A — Nature of optical radiation
B — Biological effects of optical radiation to the eye and the skin
C — Artificial optical radiation quantities and units
D — Worked examples. Some of the examples in this appendix provide the justification for specific sources being classed as trivial.
E — Requirements of other European directives
F — Existing Member State legislation and guidance
G — European and international standards
H — Photosensitivity
I — Resources
J — Glossary
K — Bibliography
L — Text of Directive 2006/25/EC

1.2 Relationship with Directive 2006/25/EC

In accordance with Article 13 of Directive 2006/25/EC of the European Parliament and of the Council on the minimum health and safety requirements regarding the exposure of workers to risks arising from artificial optical radiation, this guide addresses Articles 4 (Determination of exposure and assessment of risk) and 5 (Provisions aimed at avoiding or reducing risks), and Annexes I and II (Exposure limit values for non-coherent radiation and laser radiation, respectively) of the Directive (see Appendix L). Guidance is also provided on other articles of the Directive.

Table 1.1 Relationship between articles of the Directive and sections of this guide

Articles of Directive 2006/25/EC	Title	Sections of the guide
Article 2	Definitions	Appendix I
Article 3	Exposure limit values	Chapters 6, 7, 8, and 9
Article 4	Determination of exposure and assessment of risk	Chapters 7, 8, and 9
Article 5	Provisions aimed at avoiding or reducing risks	Chapter 9
Article 6	Worker information and training	Chapter 9
Article 7	Consultation and participation of workers	Chapter 9
Article 8	Health surveillance	Chapter 11

1.3 Scope of the guide

This guide is intended for all undertakings where workers may be exposed to artificial optical radiations. The Directive does not provide a definition for artificial optical radiations. Sources such as volcanic eruptions, the sun and reflected solar radiation from, for example, the moon, are clearly excluded. However, there may be a number of sources that are ambiguous. Would a fire started by human action be considered an artificial source, but one started by lightning not?

The Directive does not specifically exclude any artificial optical radiation source. However, many sources, such as indicator lights on electrical equipment, will be trivial sources of optical radiation. This guide provides a list of sources that can be generically assessed as not likely to exceed the exposure limit values.

There will be some potential worker exposure scenarios which are complex and therefore beyond the scope of this guide. Employers should seek further advice on assessing complex exposure scenarios.

1.4 Pertinent regulations and further information

Use of this guide does not of itself ensure compliance with statutory artificial optical radiation protection requirements in the various EU Member States. The authoritative instruments are the rules of law by which the Member States have transposed Directive 2006/25/EC. These may go beyond the minimum requirements of the Directive, on which this guide is based.

As a further aid to implementing the requirements of the Directive, manufacturers may manufacture equipment emitting artificial optical radiation to European standards. References are made to relevant standards in this guide. Such standards may be obtained from the national standardisation institutions against payment.

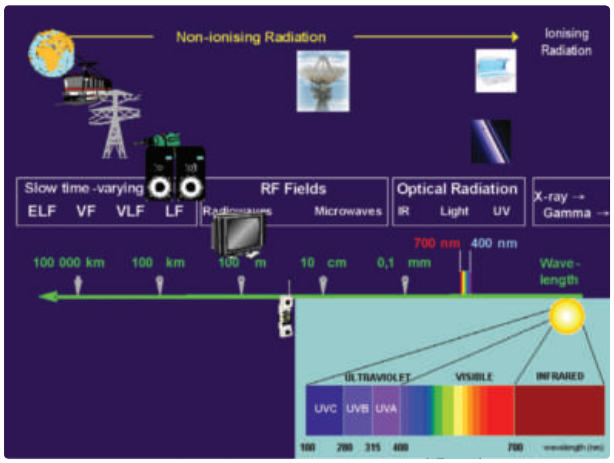
Further information can be obtained from the national regulations and standards and the pertinent literature. Appendix F contains references to individual publications by the competent Member State authorities. However, inclusion of a publication in the appendix does not mean that all of the contents are entirely consistent with this guide.

1.5 Official and non-official advice centres

Where this guide does not answer questions arising on how to fulfil the artificial optical radiation protection requirements, the national resources should be contacted directly. They include labour inspectorates, accident insurance agencies or associations and chambers of commerce, industry and craft trades.

2. Sources of artificial optical radiation

2.1 Sources of non-coherent radiation



2.1.1. Work activities

It is difficult to think of an occupation that does not involve, at some point, exposure to artificially generated optical radiation. Everyone who works in an indoor environment is likely to be exposed to optical emissions from lighting and computer screens. Outdoor workers may require some form of task lighting when natural illumination is insufficient. Persons travelling during the course of the working day are quite likely to be exposed to artificial illumination, even if this is merely exposure to lights from other persons' vehicles. All of these are artificially generated forms of optical radiation and so may be taken to fall within the scope of the Directive.

Apart from ever-present sources, such as lighting and computer screens, artificial optical radiation may be produced either deliberately, as a necessary part of some process, or else adventitiously, that is as an unwanted by-product. For example, in order to induce fluorescence in a penetrant dye, it is necessary to produce ultraviolet radiation and expose the dye to it. On the other hand, the production of copious ultraviolet during arc welding is in no way essential to the process — although it is unavoidable.

Whether optical radiation is produced deliberately for use or as an unintended by-product of a process, it is still necessary to control exposure to it, at least to the degree set out in the Directive. Artificially generated optical radiation is present in most workplaces, but particularly in the following types of industry.

- Hot industries, such as glass and metal working, where furnaces emit infrared radiation.
- Print industries, where inks and paints are often set by the process of photo-induced polymerisation.
- Art and entertainment, where performers and models may be directly illuminated by spotlights, effect lighting, modelling lights and flashlamps.
- Entertainment, where the workers in the audience area may be illuminated by general and effect lighting.
- Non-destructive testing, which may involve the use of ultraviolet radiation to reveal fluorescent dyes.
- Medical treatment, where practitioners and patients may be exposed to operating theatre spot lighting and to therapeutic use of optical radiation.
- Cosmetic treatment, which makes use of lasers and flashlamps, as well as ultraviolet and infrared sources.
- Shop floor and warehousing industries, where large open buildings are illuminated by powerful area lights.
- Pharmaceuticals and research, where ultraviolet sterilisation may be in use.
- Sewage treatment, where ultraviolet sterilisation may be in use.
- Research, where lasers may be in use and ultraviolet-induced fluorescence may be a useful tool.
- Metal working involving welding.
- Plastics manufacturing involving laser bonding.

The above list is not intended to be exhaustive.

2.1.2. Applications

The table below gives some idea of the sorts of uses that different spectral regions have. It is also intended to indicate what spectral regions may be present despite their not being needed for a particular process. The spectral regions are described in Appendix A.

Wavelength region	Used for	Adventitiously produced during
UVC	Germicidal sterilisation Fluorescence (laboratory) Photolithography	Ink curing Some area and task lighting Some projection lamps Arc welding
UVB	Sunbeds Phototherapy Fluorescence (laboratory) Photolithography	Germicidal lamps Ink curing Some area and task lighting Projection lamps Arc welding
UVA	Fluorescence (laboratory, non-destructive testing, entertainment effects, crime detection, forgery detection, property marking) Phototherapy Sunbeds Ink curing Insect traps Photolithography	Germicidal lamps Area and task lighting Projection lamps Arc welding
Visible	Area and task lighting Indicator lamps Traffic signals Hair and thread vein removal Ink curing Insect traps Photolithography Photocopying Projection TV and PC screens	Sunbeds Some heating/drying applications Welding
IRA	Surveillance illumination Heating Drying Hair and thread vein removal Communications	Some area and task lighting Welding
IRB	Heating Drying Communications	Some area and task lighting Welding
IRC	Heating Drying	Some area and task lighting Welding

Some of the spectral regions that are listed as adventitiously produced may only be emitted in fault conditions. For example, certain types of floodlights are based on a high pressure mercury discharge lamp. This produces radiation in all spectral regions, but it is usually enclosed by an outer envelope which prevents significant emission of UVB and UVC. If the envelope is broken, and the lamp continued to function, it will emit hazardous levels of UV radiation.

2.2 Sources of laser radiation

The laser was first successfully demonstrated in 1960. Initially lasers tended to be confined to research and military applications. They were usually operated by the people who designed and built them, and these same people were at risk from the laser radiation. However, the laser is now truly ubiquitous. They are used in many applications in the workplace, sometimes in equipment where the laser radiation is controlled by effective engineering means so that the user does not need to know that the equipment contains a laser.

Lasers beams are usually characterised as being of a single, or small number of, discrete wavelengths; the emission has low divergence, so approximately maintaining the power or energy within a given area over considerable distances; and the laser beam is coherent, or the individual waves of the beam are in step. Laser beams can usually be focused to a small spot with the potential to cause injuries and damage to

surfaces. These are all generalisations. There are lasers that produce laser beams over a wide wavelength spectrum; there are devices that produce widely divergent beams; and some laser beams are not coherent over most of their path length. Laser beam emissions may be continuous, termed continuous wave (CW) or they may be pulsed.

Lasers are categorised on the basis of the 'active medium' used to generate the laser beam. This medium may be a solid, liquid or a gas. Lasers with a solid medium are divided into crystal-type solids, termed solid-state lasers, and semiconductor lasers. The following table lists some typical lasers and the wavelengths emitted by them.

Type	Laser	Principal wavelength	Output
GAS	Helium Neon (HeNe)	632.8 nm	CW up to 100 mW
	Helium Cadmium (HeCd)	422 nm	CW up to 100 mW
	Argon Ion (Ar)	488 nm, 514 nm plus blue lines	CW up to 20 W
	Krypton Ion (Kr)	647 nm plus UV, blue and yellow	CW up to 10 W
	Carbon dioxide (CO2)	10 600 nm (10.6 µm)	Pulsed or CW up to 50 kW
	Nitrogen (N)	337.1 nm	Pulsed > 40 µJ
	Xenon chloride (XeCl) Krypton fluoride (KrF) Xenon fluoride (XeF) Argon fluoride (ArF)	308 nm 248 nm 350 nm 193 nm	Pulsed up to 1 J
SOLID STATE	Ruby	694.3 nm	Pulsed up to 40 J
	Neodymium: YAG (Nd:YAG)	1 064 nm and 1 319 nm 532 nm and 266 nm	Pulsed or CW up to TW, 100 W average CW
	Neodymium: Glass (Nd:Glass)	1 064 nm	Pulsed up to 150 J
FIBRE	Ytterbium (Yb)	1 030–1 120 nm	CW up to kW
THIN DISK	Ytterbium: YAG (Yb:YAG)	1 030 nm	CW up to 8 000 W
SLAB	Carbon dioxide (CO2) Laser crystal	10 600 nm	CW up to 8 000 W
SEMI-CON-DUCTOR	Various materials — e.g. GaN GaAlAs InGaAsP	400–450 nm 600–900 nm 1 100–1 600 nm	CW (some pulsed) up to 30 W
LIQUID (DYE)	Dye — Over 100 different laser dyes act as laser media	300–1 800 nm 1 100–1 600 nm	Pulsed up to 2.5 J CW up to 5 W

Further information on lasers can be found in the publications referenced in the Bibliography in Appendix K.

The following is a summary of some laser applications.

Category	Example applications
Materials processing	Cutting, welding, laser marking, drilling, photolithography, rapid manufacturing
Optical measurement	Distance measurement, surveying, laser velocimetry, laser vibrometers, electronic speckle pattern interferometry, optical fibre hydrophones, high speed imaging, particle sizing
Medical	Ophthalmology, refractive surgery, photodynamic therapy, dermatology, laser scalpel, vascular surgery, dentistry, medical diagnostics
Communications	Fibre, free-space, satellite
Optical information storage	Compact disc/DVD, laser printer
Spectroscopy	Substance identification
Holography	Entertainment, information storage
Entertainment	Laser shows, laser pointers

2.3 Trivial sources

Appendix D of this guide contains worked examples of some artificial sources of optical radiation which may be common to many workplaces, for example shops and offices. For each type of source which has been considered, because innumerable examples of different designs of equipment will exist in the marketplace, it is not possible here to create a comprehensive list which contains all existing optical radiation sources and applications. Differences in, for example, the curvature of a reflector, the thickness of a glass cover or the manufacturer of a fluorescent lamp can have a considerable effect on the optical radiation produced by a source. Each example is therefore, strictly speaking, unique to the particular type and model of source which has been examined.

However, where a worked example shows that:

- a particular source may be responsible for exposures which are only a small fraction (≈< 20 %) of the Exposure Limits, or
- a source may produce exposures in excess of the limits, but only in extremely unlikely situations,

then normal exposure to sources of these types may be considered to present a trivial risk to health, i.e. the source can be considered 'safe'.

The tables below present these common types of source in two groupings:

- trivial (i.e. due to insignificant accessible emissions);
- not hazardous in normal use (i.e. potential over-exposure only occurs in unusual circumstances).

Where a workplace contains only those sources listed in these tables, and where they are only used in the circumstances described, it may be considered that no further risk assessment is necessary. If these conditions are not satisfied, the person responsible for safety should consider the information provided in the remainder of this guide: extensive appendices which contain more detail are also provided.

Sources only likely to produce insignificant exposures, which can be considered 'safe'
Ceiling-mounted fluorescent lighting with diffusers over the lamps
Computer or similar display-screen equipment
Ceiling-mounted compact fluorescent lighting
Compact fluorescent floodlighting
UVA insect traps
Ceiling-mounted tungsten halogen spotlighting
Tungsten lamp task lighting (including daylight spectrum bulbs)
Ceiling-mounted tungsten lamps
Photocopiers
Interactive whiteboard presentation equipment
Indicator LEDs
Personal digital assistants
Vehicle indicator, brake, reversing and foglamps
Photographic flashlamps
Gas-fired overhead radiant heaters
Street lighting

Sources not likely to present a health risk under specific circumstances	
Source	Circumstances for safe use
Ceiling-mounted fluorescent lighting without diffusers over the lamps	Safe at normal working illumination levels (≈ 600 lux)
Metal halide/high pressure mercury floodlighting	Safe if front cover glass intact and if not in line of sight
Desktop projectors	Safe if beam not looked into
Low pressure UVA blacklight	Safe if not in line of sight
Any 'Class 1' laser device (to EN 60825-1)	Safe if covers intact. May be unsafe if covers removed.
Any 'Exempt Group' product (to EN 62471)	Safe if not in line of sight. May be unsafe if covers removed.
Vehicle headlights	Safe if extended direct intra-beam viewing avoided

3. Health effects from exposure to optical radiation

Optical radiation is absorbed in the outer layers of the body and, therefore, its biological effects are mostly confined to the skin and eyes but systemic effects may also occur. Different wavelengths cause different effects depending on which part of the skin or eye absorbs the radiation, and the type of interaction involved: photochemical effects dominate in the ultraviolet region, and thermal effects in the infrared. Laser radiation can produce additional effects characterised by very rapid absorption of energy by tissue, and is a particular hazard for the eyes where the lens can focus the beam.

The biological effects can be broadly divided into acute (rapidly occurring) and chronic (occurring as a result of prolonged and repeated exposures over a long time). It is generally the case that acute effects will only occur if the exposure exceeds a threshold level, which will usually vary from person to person. Most exposure limits are based on studies of thresholds for acute effects, and derived from statistical consideration of these thresholds. Therefore, exceeding an exposure limit will not necessarily result in an adverse health effect. The risk of an adverse health effect will increase as exposure levels increase above the exposure limit. The majority of effects described below will occur, in the healthy adult working population, at levels substantially above the limits set in the Directive. However, persons who are abnormally photosensitive may suffer adverse effects at levels below the exposure limits.

Chronic effects often do not have a threshold below which they will not occur. As such, the risk of these effects occurring cannot be reduced to zero. The risk can be reduced — by reducing exposure — and observance of the exposure limits should reduce risks from exposure to artificial sources of optical radiation to levels below those which society has accepted with respect to exposures to naturally occurring optical radiation.

Wavelength (nm)		Eye	Skin
100–280	UVC	Photokeratitis Photoconjunctivitis	Erythema Skin cancer
280–315	UVB	Photokeratitis Photoconjunctivitis Cataracts	Erythema Elastosis (photoageing) Skin cancer
315–400	UVA	Photokeratitis Photoconjunctivitis Cataracts Photoretinal damage	Erythema Elastosis (photoageing) Immediate Pigment Darkening Skin cancer
380–780	Visible	Photoretinal damage (Blue Light Hazard) Retinal burn	Burn
780–1 400	IRA	Cataracts Retinal burn	Burn
1 400–3 000	IRB	Cataracts	Burn
3 000–10^6	IRC	Corneal burn	Burn

4. Requirements of the artificial optical radiation directive

The full text of the Directive is included in Appendix L of this guide. This chapter provides a summary of the key requirements.

The Directive lays down the minimum requirements for the protection of workers from risks to their health and safety arising or likely to arise from exposure to artificial optical radiation during their work. Therefore, Member States may introduce, or already have in place, more restrictive requirements.

4.1 Article 4 — Determination of exposure and assessment of risks

The main emphasis of the Directive is that employers should ensure that workers are not exposed to levels of artificial optical radiation in excess of the exposure limit values contained within the Annexes of the Directive. Employers may be able to demonstrate this through information supplied with sources, through generic assessments carried out by themselves or others, by undertaking theoretical assessments or by doing measurements. The Directive does not specify a methodology, so it is up to the employer how this key objective is achieved. However, the employer is guided to existing published standards and where this is not appropriate, to 'available national or international science-based guidelines'.

Many of the requirements of the Directive are similar to those of Directive 89/391/EEC and, as such, an employer already complying with the requirements of that directive is unlikely to require significant additional work to comply with this Directive. However, when carrying out the assessment, the employer is required to give particular attention to the following (Article 4.3):

To be considered	Comment
(a) the level, wavelength range and duration of exposure to artificial sources of optical radiation;	This is the fundamental information about the scenario considered. If the exposure level is significantly below the exposure limit that would apply for exposure for a complete working day (assumed to be eight hours) then no further assessment is required unless exposure to multiple sources are a concern. See (h).
(b) the exposure limit values referred to in Article 3 of this Directive;	From the information in (a) it should be possible to identify the applicable exposure limit values.
(c) any effects concerning the health and safety of workers belonging to particularly sensitive risk groups;	It is suggested that the approach should be reactive rather than proactive. There may be some workers who know that they are particularly sensitive to flickering light, for example. The employer should then consider whether modifications to the work activity can be introduced.
(d) any possible effects on workers' health and safety resulting from workplace interactions between optical radiation and photosensitising chemical substances;	It is suggested that employers should specifically consider the possibility of photosensitisation from chemical substances used in the workplace. However, as with (c), the employer may need to react to issues raised by workers where the photosensitivity is caused by chemical substances used outside of the workplace.
(e) any indirect effects such as temporary blinding, explosion or fire;	Eye exposure to bright lights may be an issue for some work practices. The normal aversion responses should provide a level of protection at exposure levels below the exposure limit value. However, the employer should consider sources of artificial optical radiation that may cause distraction, dazzle, glare and afterimages, where such exposures could compromise the safety of the worker or others. The optical radiation from some artificial optical radiation sources may be capable of causing an explosion or a fire. This is particularly relevant for Class 4 lasers, but should also be considered for other sources, especially in environments where flammable or explosive agents may be present.
(f) the existence of replacement equipment designed to reduce the levels of exposure to artificial optical radiation;	It is suggested that this should be considered where the exposure of workers to artificial optical radiation above the exposure limit values is possible.

To be considered	Comment
(g) appropriate information obtained from health surveillance, including published information, as far as possible;	This information may come from within the employer's organisation, from industry representative groups or from international organisations such as the World Health Organisation and the International Commission on Non-Ionizing Radiation Protection.
(h) multiple sources of exposure to artificial optical radiation;	From the information obtained in (a) and (b), it may be possible to determine the proportion of the exposure limit that will be provided by each artificial optical radiation source. A simplified approach will be to consider this for the number of sources that may expose workers and add the proportions. If the sum is less than one, then the exposure limit values are unlikely to be exceeded. If the sum exceeds one then a more detailed assessment will be required.
(i) a classification applied to a laser as defined in accordance with the relevant Cenelec standard and, in relation to any artificial source likely to cause damage similar to that of a laser of class 3B or 4, any similar classification;	Class 3B and Class 4 laser products emit accessible laser radiation that could lead to the exposure limit values being exceeded. However, under some circumstances, lower-hazard-class lasers may also need assessment. EN 62471 assigns non-laser artificial optical radiation sources into a different classification scheme. Risk Group 3 devices should be assessed, but consideration should also be given to the likely exposure scenarios for lower risk groups.
(j) information provided by the manufacturers of optical radiation sources and associated work equipment in accordance with the relevant Community directives.	Employers should request adequate information from manufacturers and suppliers of artificial optical radiation sources and products to ensure that they can undertake the assessments required by the Directive. It is suggested that the availability of such information could form the basis for procurement policy.

4.2 Article 5 — Provisions aimed at avoiding or reducing risks

It is important to recognise that, unlike many other hazards, reducing the level of artificial optical radiation below a certain level may actually increase the risk of injury. An obvious example of this is area lighting. Indicator lamps and signals need to emit an appropriate level of optical radiation to be fit for purpose. Therefore, Article 5 concentrates on avoiding or reducing risk. The approach used is similar to that in Directive 89/391/EEC and these principles are discussed further in Chapter 9 of this guide.

4.3 Article 6 — Worker information and training

The requirements of Article 6 are similar to those in Directive 89/391/EEC. It is important that the risks are put in perspective. Workers should be aware that many of the sources of artificial optical radiation in the workplace do not present a risk to their health and indeed many will contribute to their welfare. However, where risks have been identified then appropriate information and training should be provided. This is discussed further in Chapter 9.

4.4 Article 7 — Consultation and participation of workers

This article refers to the requirements under Directive 89/391/EEC.

4.5 Article 8 — Health surveillance

Article 8 builds on the requirements of Directive 89/391/EEC. Many of the specific details are likely to depend on systems in place in Member States. Some guidance on health surveillance is provided in Chapter 11 of this guide.

4.6 Summary

Many of the requirements of the Directive are already covered in other directives, particularly Directive 89/391/EEC (See Appendix E). Specific guidance on how to comply with the articles of the Directive is provided in chapters of this guide.

5. Use of exposure limits

Annexes I and II of the Directive provide exposure limit values (ELVs) for non-coherent optical radiation and laser radiation, respectively. These ELVs take account of the biological effectiveness of the optical radiation at causing harm at different wavelengths, the duration of exposure to the optical radiation and the target tissue. The ELVs are based on the guidelines published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). Further information on the rationale for the ELVs can be found in the guidelines, which are available from http://www.icnirp.org (see References). It is worth noting that these guidelines may be altered by ICNIRP: should this happen, the ELVs in the Directive may subsequently be modified.

Similar, but not identical, exposure limits have also been published by the American Conference of Governmental Industrial Hygienists (ACGIH).

It is necessary to know the wavelength range of the optical radiation before the correct ELV can be selected. It should be noted that more than one ELV may apply for a given wavelength range. The ELVs for laser radiation are generally simpler to determine because the emission is at a single wavelength. However, for laser products that emit laser radiation at more than one wavelength, or for exposure scenarios involving multiple sources, it may be necessary to take account of additive effects.

Full analyses of worker exposure and comparison with the ELVs can be complex and beyond the scope of this guide. The information presented below is intended to provide guidance to employers on whether to seek further assistance.

5.1 Laser ELVs

The laser classification scheme (see Chapter 8.1.1) provides guidance to users on the magnitude of the laser beam hazard — as assessed under specific measurement conditions. Class 1 laser products should be safe for normal use and therefore should require no further assessment. However, an assessment will be required when a Class 1 laser product is maintained or serviced if this product contains an embedded laser of a higher class. Unless information is supplied to the contrary, employers should assume that laser beams from Class 3B and Class 4 lasers present a risk of eye injury. Class 4 lasers also present a risk of skin injury.

A competent person, such as a Laser Safety Officer should be appointed where Class 3B and Class 4 lasers are used.

The assignment of a laser product to Class 2 is on the basis of the ELV not being exceeded for an accidental exposure of up to 0.25 s. If the use of the product means that the eyes of workers are likely to be repeatedly exposed to the laser beam, then a more detailed assessment should be carried out to determine if the ELV is likely to be exceeded.

Class 1M, Class 2M and Class 3R lasers should be assessed to determine likely exposure scenarios.

The ELVs for laser radiation are presented in Annex II of the Directive, which is reproduced in Appendix K of this guide. The ELVs are expressed in terms of irradiance (watts per square metre, W m^{-2}) or radiant exposure (joules per square metre, J m^{-2}).

The irradiance or radiant exposure from a laser beam should be averaged over an aperture, called the limiting aperture, as specified in Tables 2.2, 2.3 and 2.4 of Annex II of the Directive, when calculating the irradiance or radiant exposure.

To find the correct laser ELV table:
Eye exposure — short duration (< 10 s) — Table 2.2
Eye exposure — 10 s or longer — Table 2.3
Skin exposure — Table 2.4

When deciding on the time of exposure, it will depend on whether the exposure is accidental or intended. For accidental exposures, 0.25 s is generally assumed for laser beams from 400 nm to 700 nm and 10 s or 100 s for all other wavelengths, where the eye is the exposed organ. If only the skin is exposed, then it would be reasonable to use 10 s or 100 s for all wavelengths.

It is possible to calculate the maximum power through the stated aperture, for these exposure durations, before the ELV is exceeded. The results of such calculations are presented below for eye exposure to a continuous wave laser beam with a small source.

Wavelength range (nm)	Limiting aperture (mm)	Exposure duration (s)	ELV (W m^{-2})	Maximum power through aperture (W)	Maximum power through aperture (mW)
180 to 302.5	1	10	3.0	0.000 002 4	0.002 4
≥ 302.5 to 315	1	10	3.16 to 1 000	0.000 002 5 to 0.000 79	0.002 5 to 0.79
305	1	10	10	0.000 007 9	0.007 9
308	1	10	39.8	0.000 031	0.031
310	1	10	100	0.000 079	0.079
312	1	10	251	0.000 20	0.20
≥ 315 to 400	1	10	1 000	0.000 79	0.79
≥ 400 to 450	7	0.25	25.4	0.000 98	0.98
≥ 450 to 500	7	0.25	25.4	0.000 98	0.98
≥ 500 to 700	7	0.25	25.4	0.000 98	0.98
≥ 700 to 1 050	7	10	10 to 50	0.000 39 to 0.001 9	0.39 to 1.9
750	7	10	12.5	0.000 49	0.49
800	7	10	15.8	0.000 61	0.61
850	7	10	19.9	0.000 77	0.77
900	7	10	25.1	0.000 97	0.97
950	7	10	31.6	0.001 2	1.2
1 000	7	10	39.8	0.001 5	1.5
≥ 1 050 to 1 400	7	10	50 to 400	0.001 9 to 0.015	1.9 to 15
≥ 1 050 to 1 150	7	10	50	0.001 9	1.9
1 170	7	10	114	0.004 4	4.4
1 190	7	10	262	0.010	10
≥ 1 200 to 1 400	7	10	400	0.015	15
≥ 1 400 to 1 500	3.5	10	1 000	0.009 6	9.6
≥ 1 500 to 1 800	3.5	10	1 000	0.009 6	9.6
≥ 1 800 to 2 600	3.5	10	1 000	0.009 6	9.6
≥ 2 600 to 10^5	3.5	10	1 000	0.009 6	9.6
≥ 10^5 to 10^6	11	10	1 000	0.095	95

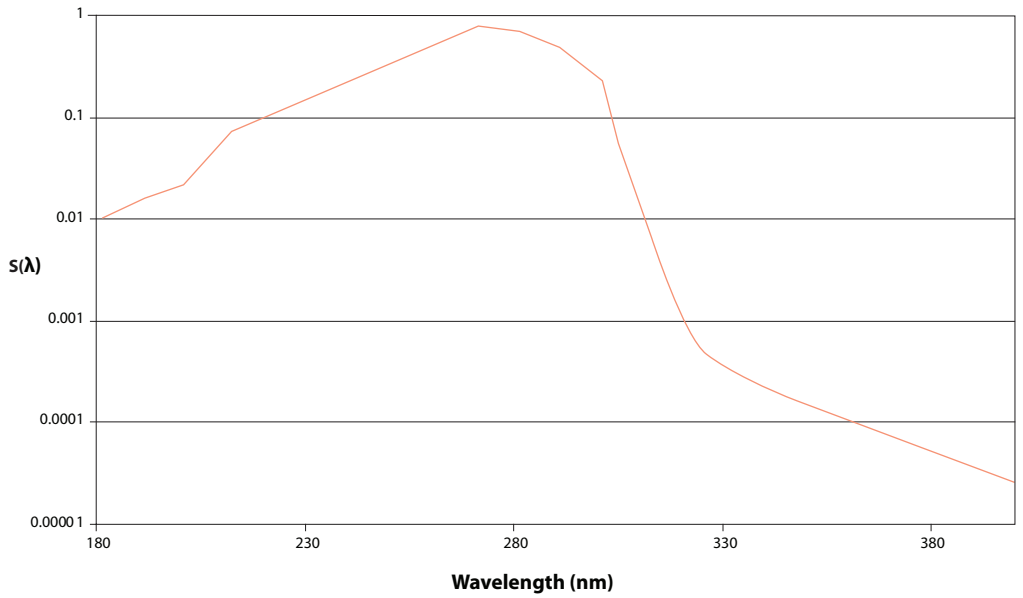
Further guidance on the assessment of ELVs is available in IEC TR 60825-14. It should be noted that the document uses the term maximum permissible exposure (MPE) instead of ELV.

5.2 Non-coherent optical radiation

The use of the ELVs for non-coherent optical radiation is generally more complex than for laser radiation. This is due to worker exposure potentially being to a range of wavelengths instead of a single wavelength. However, it is possible to make a number of simplifying, worst-case, assumptions to determine if a more detailed assessment is required.

Three dimensionless modifying factors are provided in Tables 1.2 and 1.3 of Annex I to the Directive. The weighting function S(λ) applies from 180 nm to 400 nm and is used to modify spectral irradiance or spectral radiant exposure data to take account of the wavelength dependency of adverse health effects on the eye and the skin. When a weighting function has been applied, the subsequent data are usually referred to by terms such as effective irradiance or effective radiant exposure.

Figure 5.1 Weighting function S(λ)



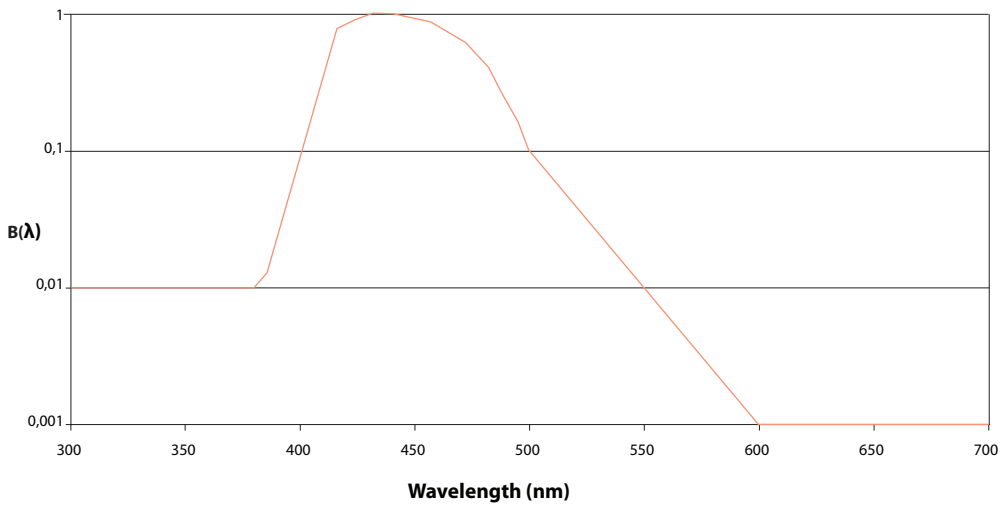
The peak value for S(λ) is 1.0 at 270 nm. A simple approach is to assume that all of the emission between 180 nm and 400 nm is at 270 nm (since the S(λ) function has a maximum value of 1, this is equivalent to simply ignoring the function altogether). Since the ELV is expressed in terms of radiant exposure (J m^{-2}), if the irradiance of the source is known it is possible to use the table below to see the maximum time a worker can be exposed if they are not to exceed the ELV, which is set at 30 J m^{-2}.

If this time is not exceeded by assuming all of the emission is at 270 nm then no further assessment is required. If the ELV is exceeded then a more detailed spectral assessment is required.

Duration of exposure per 8-hour day	Irradiance (Effective) — W m^{-2}
8 hours	0.001
4 hours	0.002
2 hours	0.004
1 hour	0.008
30 minutes	0.017
15 minutes	0.033
10 minutes	0.05
5 minutes	0.1
1 minute	0.5
30 seconds	1.0
10 seconds	3.0
1 second	30
0.5 second	60
0.1 second	300

The factor B(λ) is applied between 300 nm and 700 nm to take account of the wavelength dependence of the photochemical injury risk to the eye. The wavelength dependence is plotted below.

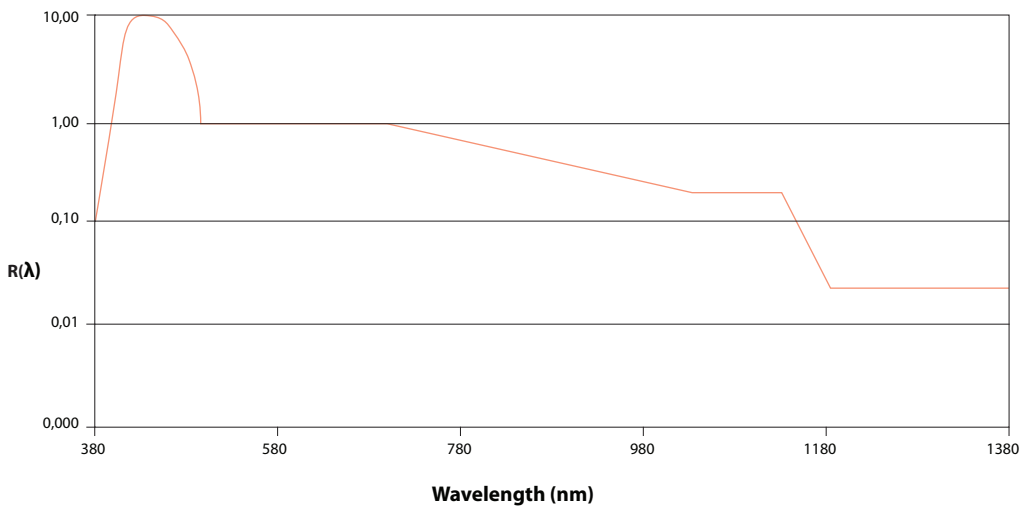
Figure 5.2 Weighting function B(λ)



The peak weighting factor is 1.0 between 435 and 440 nm. If the ELV is not exceeded by assuming that all of the emission between 300 nm and 700 nm is at about 440 nm (since the B(λ) function has a maximum value of 1, this is equivalent to simply ignoring the function altogether), then it will not be exceeded when a more detailed assessment is carried out.

The weighting factor R(λ) is defined between 380 and 1 400 nm and is plotted below.

Figure 5.3 Weighting function R(λ)



The peak of R(λ) is between 435 and 440 nm. If the ELV is not exceeded by assuming that all of the emission between 380 nm and 1 400 nm is at about 440 nm (since the R(λ) function has a maximum value of 10, this is equivalent to simply multiplying all of the unweighted values by 10), then it will not be exceeded when a more detailed assessment is carried out.

Table 1.1 of Annex I of the Directive provides the ELVs for different wavelengths. In some wavelength regions, more than one exposure limit will apply. None of the relevant exposure limits should be exceeded.

5.3 References

Guidelines on Limits of Exposure to Ultraviolet Radiation of Wavelengths Between 180 nm and 400 nm (Incoherent Optical Radiation), Health Physics 87 (2): pp. 171–186, 2004.

Revision of the Guidelines on Limits of Exposure to Laser radiation of wavelengths between 400 nm and 1.4 µm, Health Physics 79 (4): pp. 431–440, 2000.

Guidelines on Limits of Exposure to Broadband Incoherent Optical Radiation (0.38 to 3 µm), Health Physics 73 (3): pp. 539–554, 1997.

Guidelines on UV Radiation Exposure Limits, Health Physics 71 (6): p. 978, 1996.

Guidelines on Limits of Exposure to Laser Radiation of Wavelengths between 180 nm and 1 mm, Health Physics 71 (5): pp. 804–819, 1996.

6. Risk assessment in the context of the directive

Risk assessment is a general requirement of Directive 89/391/EEC. The approach presented here is based on the European Agency for Safety and Health at Work stepwise approach to risk assessment:

A stepwise approach to risk assessment
Step 1. Identifying hazards and those at risk
Step 2. Evaluating and prioritising risks
Step 3. Deciding on preventive action
Step 4. Taking action
Step 5. Monitoring and reviewing

A full risk assessment will need to consider all of the hazards associated with the work activity. However, for the purposes of the Directive, only the optical radiation hazard will be addressed here. For some applications, adequate information will be supplied by the product manufacturer to conclude that the risk is adequately managed. Therefore, the risk assessment process need not be particularly onerous. Unless national legislation requires it, the risk assessment need not be written down for trivial sources. However, employers may decide to make a record to demonstrate that an assessment has been carried out.

6.1 Step 1. Identifying hazards and those at risk

All optical radiation sources should be identified. Some sources will already be contained within equipment such that worker exposure is not possible during normal use. However, it will be necessary to consider how workers may get exposed throughout the life of the source. If workers manufacture optical radiation products then they may be at greater risk than users. The typical life cycle of an optical radiation product is as follows:

Product Life Cycle
1. Manufacture
2. Testing
3. Installation
4. Planning and design
5. Commissioning
6. Normal operation
7. Failure modes
8. Routine maintenance
9. Servicing
10. Modification
11. Disposal

Exposure to optical radiation usually occurs when the product is operating. Stages 1 to 3 of the product life cycle may take place on another employer's premises. Stages 4 to 11 usually occur at the normal place of work. It should also be noted that some parts of the life cycle are indeed cyclic. For example, an item of work equipment may need routine maintenance every week: servicing may take place every six months. A degree of commissioning may be required after each service operation. At other times, the item of work equipment is at the 'normal operation' stage.

The employer should consider which groups of employees or contractors are likely to be exposed to optical radiation at each part of the life cycle.

Step 1
Record all of the likely sources of exposure to artificial optical radiation and consider who may be exposed.

6.2 Step 2. Evaluating and prioritising risks

The Directive requires exposures of workers to optical radiation to be below the exposure limit values contained in Annexes I and II of the Directive. Many sources of optical radiation in the workplace will be trivial. Appendix D of this guide provides guidance for some specific applications. The judgement on whether a source is trivial will also need to take into account how many sources the worker is likely to be exposed to. For a single source, if the exposure at the location of the worker is less than 20 % of the ELV for a full working day, then it might be considered trivial. However, if there are 10 such sources, then the exposure from each source would need to be less than 2 % of the ELV to be considered trivial.

It is important to stress that the Directive requires 'risks' to be eliminated or reduced to a minimum. This doesn't necessarily mean that the amount of optical radiation should be reduced to a minimum. Clearly, turning all of the lights out will compromise safety and increase the risk of injury.

An approach to evaluating the risk is as follows:

Decide which sources are 'trivial'. Consideration should be given to making a record of this decision

↓

Decide which exposure scenarios need further assessment

↓

Assess the exposure against the exposure limit value

↓

Consider exposure to multiple sources

↓

If the exposure limit value is likely to be exceeded, take action (See Steps 3 and 4)

↓

Record the significant conclusions

Determining the risk of exposure, i.e. how likely the exposure is, may not be straightforward. A well-collimated laser beam can be present in the workplace and the risk of exposure to the laser beam may be small. However, the consequences, should an exposure take place, may be great. In contrast, the risk of exposure to the optical radiation from many non-coherent artificial sources may be high, but the consequences could be low.

For most workplaces, the requirement to quantify the risk of exposure is not justified, beyond assigning a 'common sense' high, medium or low probability.

The Directive does not define the term 'likely' in the context of 'likely to be exposed'. Therefore, unless national requirements suggest otherwise, common sense is adequate.

Step 2
Consider making a record of trivial sources
Record sources where a risk of exceeding the exposure limit value exists
Make a judgement on the risk
Consider any workers who may be particularly photosensitive
Prioritise control measures for sources likely to expose workers above the exposure limit value

Although the exposure limit values for ultraviolet radiation can be used to determine the maximum irradiance that a worker can receive over a working day, such repeated exposures for every working day are not ideal. Consideration should be given to reducing ultraviolet radiation exposures to values as low as reasonably practicable, rather than working up to the exposure limit value.

6.3 Step 3. Deciding on preventive action

Chapter 9 of this guide provides guidance on the control measures that may be used to minimise the risk of exposure to artificial optical radiation. Collective protection is generally preferred to personal protection.

Step 3
Decide on the appropriate preventive action
Record the justification for the decision

6.4 Step 4. Taking action

It is necessary to implement the preventive action. A judgement on the risk from the exposure to the artificial optical radiation will determine whether the work may proceed with caution until the preventive measures are in place, or whether the work should stop until they are in place.

Step 4
Decide whether work can continue
Implement preventive action
Inform workers of the basis for the preventive action

6.5 Step 5. Monitoring and reviewing

It is important to determine if the risk assessment was effective and the preventive measures are adequate. It is also necessary to review the risk assessment if artificial optical radiation sources change, or work practices are modified.

Workers may not necessarily know that they are photosensitive, or they may develop photosensitivity after the risk assessment has been completed. All claims should be recorded and, where appropriate, health surveillance used (see Chapter 11 of this guide). It may be necessary to change the source(s) of artificial optical radiation or otherwise adjust work practices.

Step 5
Decide on an appropriate routine review interval — perhaps 12 months
Ensure that reviews are carried out if the situation changes, such as new sources are introduced, work practices change, or adverse incidents occur
Record the reviews and the conclusions

6.6 References

European Agency for Safety and Health at Work: http://osha.europa.eu/en/topics/riskassessment

7. Measurement of optical radiation

7.1 Requirements under the Directive

The measurement of optical radiation is something that may be done as part of the risk assessment process. The Directive sets out its requirements for risk assessments in Article 4. It is stated that:

'... the employer, in the case of workers exposed to artificial sources of optical radiation, shall assess, and, if necessary, measure and/or calculate the levels of exposure to optical radiation to which workers are likely to be exposed ...'

This statement allows the employer to determine the worker's exposure levels by means other than measurement, i.e. by calculation (using data supplied by a third party, such as the manufacturer).

If it is possible to acquire data which are adequate for the purposes of risk assessment, then measurement is not necessary. This is a desirable situation: workplace measurement of optical radiation is a complex task. The measurement equipment is likely to be relatively expensive and can only be used successfully by a competent person. An inexperienced operator can easily make mistakes which will lead to highly inaccurate data being produced. It will also often be necessary to assemble time and motion data for the workplace tasks which are the subject of the risk assessment.

7.2 Seeking further assistance

Unless the employer is willing to purchase, and has the expertise to use, optical radiation measurement equipment, then assistance will be required. The requisite measurement equipment might be found (together with the expertise to use it) in:

- national health and safety establishments;
- research establishments (such as universities with an optics department);
- manufacturers of optical measurement equipment (and possibly their agents);
- specialist private health and safety consultancies.

When approaching any of these potential sources of assistance, it is worth bearing in mind that they should be able to demonstrate:

- knowledge of the exposure limits and their application;
- equipment which can measure all of the wavelength regions of interest;
- experience in the use of the equipment;
- a method of calibrating the equipment traceably to some nationally maintained standard;
- the ability to estimate the uncertainty on any measurements that are made.

Unless all of these criteria can be satisfied, it is possible that the resulting risk assessment could be defective due to:

- failure to apply the correct limits, or failure to apply them correctly;
- failure to acquire data which can be compared to all of the applicable limits;
- gross errors in the numerical values of the data;
- data which cannot be compared with the appropriate limits to give an unequivocal conclusion.

8. Use of manufacturers' data

Because of the wide variety of sources emitting optical radiation, the risks arising in their use vary considerably. Data provided by manufacturers of equipment emitting optical radiation should assist users in hazard evaluation and determination of required control measures. In particular, safety classification of laser and non-laser sources and hazard distances could be very useful for carrying out the risk assessment.

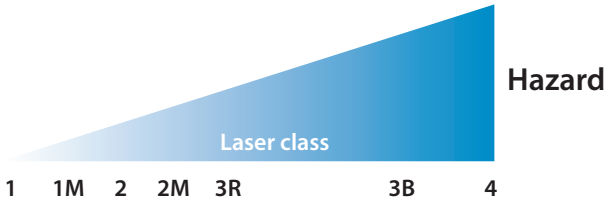
8.1 Safety classification

The classification schemes for lasers and non-laser sources indicate the potential risk of adverse health effects. Depending upon conditions of use, exposure time or environment, these risks may or may not actually lead to adverse health effects. With the help of classification, users may select appropriate control measures to minimise these risks.

8.1.1. Laser safety classification

The classification of lasers is based on the concept of accessible emission limit (AEL); these are defined for each laser class. AEL takes into account not only the output of the laser product but human access to the laser emission. Lasers are grouped into seven classes: the higher the class, the bigger the potential to cause harm. The risk could be greatly reduced by additional user-protective measures, including additional engineering controls such as enclosures.

Useful to remember
'M' in Class 1M and Class 2M is derived from Magnifying optical viewing instruments
'R' in Class 3R is derived from Reduced, or Relaxed, requirements: reduced requirements both for the manufacturer (e.g. no key switch, beam stop or attenuator and interlock connector required) and the user
The 'B' for Class 3B has historical origins



8.1.1.1. Class 1

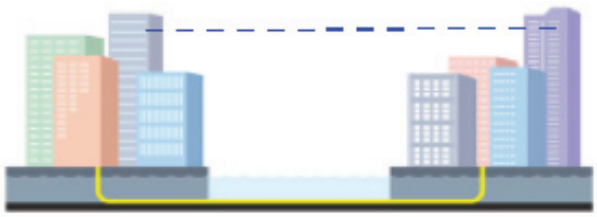
Laser products that are considered safe during use, including long-term direct intrabeam viewing, even when using optical viewing instruments (eye loupes or binoculars). Users of Class 1 laser products are generally exempt from optical radiation hazard controls during normal operation. During user maintenance or service, a higher level of radiation might become accessible.

This class includes products that contain high-power lasers within an enclosure that prevents human exposure to the radiation and that cannot be opened without shutting down the laser, or require tools to gain access to the laser beam:

- Laser printer
- CD and DVD players and recorders
- Materials processing lasers

8.1.1.2. Class 1M

Safe for the naked eye under reasonably foreseeable conditions of operation, but may be hazardous if the user employs optics (e.g. loupes or telescopes) within the beam.



Example: a disconnected fibre optic communication system

Intra-beam viewing of visible Class 1 and 1M laser products may still cause dazzle, particularly in low ambient light

8.1.1.3. Class 2

Laser products that emit visible radiation and are safe for momentary exposures, even when using optical viewing instruments, but can be hazardous for deliberate staring into the beam. Class 2 laser products are not inherently safe for the eyes, but protection is assumed to be adequate by natural aversion responses, including head movement and the blink reflex.

Examples: bar code scanners

8.1.1.4. Class 2M

Laser products that emit visible laser beams and are safe for short time exposure only for the naked eye; possible eye injury for exposures when using loupes or telescopes. Eye protection is normally provided by aversion responses, including the blink reflex.

Examples: level and alignment instruments for civil engineering applications

8.1.1.5. Class 3R

Direct intra-beam viewing is potentially hazardous but practically the risk of injury in most cases is relatively low for short and unintentional exposure; however, may be dangerous for improper use by untrained persons. The risk is limited because of natural aversion behaviour for exposure to bright light for the case of visible radiation and by the response to heating of the cornea for far infrared radiation.

Class 3R lasers should only be used where direct intra-beam viewing is unlikely.

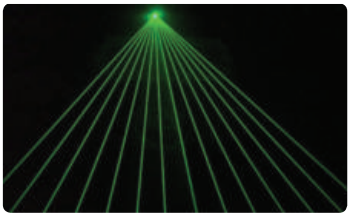
Examples: surveying equipment, higher power laser pointers, alignment lasers

Aversion response doesn't happen universally

Viewing of Class 2, 2M or visible-beam 3R laser products may cause dazzle, flash-blindness and afterimages, particularly in low ambient light. This may have indirect general safety implications resulting from temporary disturbance of vision or from startle reactions. Visual disturbances could be of particular concern when performing safety-critical operations such as working with machines or at height, with high voltages or driving.

8.1.1.6. Class 3B

Hazardous for the eyes if exposed to the direct beam within the nominal ocular hazard distance (NOHD — see 8.2.1).



Viewing diffuse reflections is normally safe, provided the eye is no closer than 13 cm from the diffusing surface and the exposure duration is less than 10 s. Class 3B lasers which approach the upper limit for the class may produce minor skin injuries or even pose a risk of igniting flammable materials.

Examples: lasers for physiotherapy treatments; research laboratory equipment

8.1.1.7. Class 4

Laser products for which direct viewing and skin exposure is hazardous within the hazard distance and for which the viewing of diffuse reflections may be hazardous. These lasers also often represent a fire hazard.

Examples: laser projection displays, laser surgery and laser metal cutting

Class 3B and Class 4 laser products should not be used without first carrying out a risk assessment to determine the protective control measures necessary to ensure safe operation

Table 8.1. Summary of required controls for different laser safety classes

	Class 1	Class 1M	Class 2	Class 2M	Class 3R	Class 3B	Class 4
Description of hazard class	Safe under reasonably foreseeable conditions	Safe for naked eye;, may be hazardous if the user employs optics	Safe for short exposures; eye protection is afforded by aversion response	Safe for naked eye for short exposures,; may be hazardous if the user employs optics	Risk of injury is relatively low, but may be dangerous for improper use by untrained persons	Direct viewing is hazardous	Hazardous for eye and skin; fire hazard
Controlled area	Not required	Localised or enclosed	Not required	Localised or enclosed	enclosed	Enclosed and interlock protected	Enclosed and interlock protected
Key control	Not required	Not required	Not required	Not required	Not required	required	required
Training	Follow manufacturer instruction for safe use	Recommended	Follow manufacturer instruction for safe use	Recommended	Required	Required	Required
PPE	Not required	Not required	Not required	Not required	May be required – subject to the findings of the risk assessment	required	required
Protective measures	Not necessary under normal use	Prevent use of magnifying, focusing or collimating optics	Do not stare into the beam	Do not stare into the beam. Prevent use of magnifying, focusing or collimating optics	Prevent direct eye exposure	Prevent eye and skin exposure to the beam. Guard against unintentional reflections	Prevent eye and skin exposure from direct and diffuse reflection of the beam.

Limitations of the laser classification scheme
Laser safety classification relates to accessible laser radiation — this classification doesn't take into account additional hazards, such as electricity, collateral radiation, fume, noise, etc
Laser safety classification relates to normal use of the product — it might not be applicable to maintenance or service, or when the original device forms a part of a complex installation
Laser safety classification relates to a single product — it doesn't account for accumulative exposure from multiple sources

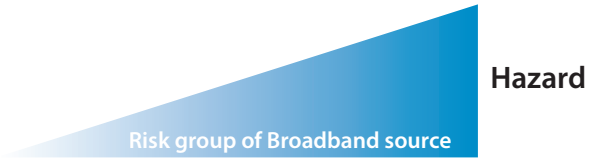
8.1.2. Safety classification of non-coherent sources

The safety classification of non-coherent (broadband) sources is defined in EN 62471: 2008 and is based on the maximum accessible emission over the full range of capability of the product during operation at any time after manufacture. Classification takes account of the quantity of optical radiation, the wavelength distribution and human access to optical radiation. Broadband sources are grouped into four risk groups: the higher the risk group, the bigger potential to cause harm.

The classification indicates the potential risk of adverse health effects. Depending upon conditions of use, exposure time or environment, these risks may or may not actually lead to adverse health effects. With the help of classification, the user may select appropriate control measures to minimise these risks.

In increasing order of risk, the following ranking of the risk groups is used:

- Exempt Group — no photobiological hazard under foreseeable conditions;
- Risk Group 1 — Low-risk group, the risk is limited by normal behavioural limitations on exposure;
- Risk Group 2 — Moderate-risk group, the risk is limited by the aversion response to very bright light sources. However, such reflex responses do not occur universally;
- Risk Group 3 — High-risk group, may pose a risk even for momentary or brief exposure.



Within each risk group, different time criteria have been set for each hazard. These criteria have been chosen so that the applicable ELV will not be exceeded within the chosen time.

8.1.2.1. Exempt group

No direct optical radiation risks are reasonably foreseeable, even for continuous, unrestricted use. These sources do not pose any of the following photo-biological hazards:

- an actinic ultraviolet hazard within 8 hours exposure
- a near-UV hazard within 1 000 s
- a retinal Blue-Light hazard within 10 000 s
- a Retinal Thermal hazard within 10 s
- an infrared radiation hazard for the eye within 1 000 s
- an infrared radiation hazard without a strong visual stimulus within 1 000 s

Examples: domestic and office lighting, computer monitors, equipment displays, indicator lamps.

8.1.2.2. Risk Group 1 — Low risk

Example: domestic torch

These products are safe for most applications, except for very prolonged exposures where direct ocular exposures may be expected. These sources do not pose any of following hazards due to normal behavioural limitations on exposure:

- an actinic ultraviolet hazard within 10 000 s
- a near-UV hazard within 300 s
- a retinal Blue-Light hazard within 100 s
- an infrared radiation hazard for the eye within 100 s
- an infrared radiation hazard without a strong visual stimulus within 100 s

8.1.2.3. Risk Group 2 — Moderate risk

The sources that do not pose any of following hazards due to aversion response to very bright light sources, due to thermal discomfort or where lengthy exposures are unrealistic:

- an actinic ultraviolet hazard within 1 000 s
- a near-UV hazard within 100 s
- a retinal Blue-Light hazard within 0.25 s (aversion response)
- a Retinal Thermal hazard within 0.25 s (aversion response)
- an infrared radiation hazard for the eye within 10 s
- an infrared radiation hazard without a strong visual stimulus within 10 s

8.1.2.4. Risk Group 3 — High risk

The sources that may pose a risk even for momentary or brief exposure within hazard distance. Safety control measures are essential.

Filtering of unwanted excessive optical radiation (e.g. UV), shielding the source to prevent access to optical radiation or employing beam expanding optics may lower a risk group and decrease the risk from optical radiation.

Limitations of the broadband sources classification scheme
Safety classification relates to accessible optical radiation — this classification doesn't take into account additional hazards, such as electricity, collateral radiation, fume, noise, etc
Safety classification relates to normal use of the product — it might not be applicable to maintenance or service, or when the original device forms a part of a complex installation
Safety classification relates to a single product — it doesn't account for accumulative exposure from multiple sources
Products are classified at a distance which produces an illuminance of 500 lx for General Lighting Systems (GLS) and at 200 mm from the source for other applications — it may not be representative for all use conditions

8.1.3. Safety classification of machinery

Machinery which produces optical radiation may be also classified to EN 12198. This standard applies to all emissions, either intentional or adventitious, apart from sources used purely for illumination.

Machinery is classified into one of three categories, depending on the accessible emission. The three categories, in increasing order of risk, are listed in Table 8.2.

Table 8.2 Safety classification of machinery according to EN 12198

Category	Restrictions and protective measures	Information and training
0	No restriction	No information needed
1	Restrictions: limitation of access, protective measures may be needed.	Information about hazards, risks and secondary effects to be provided by manufacturer.
2	Special restrictions and protective measures essential.	Information about hazards, risks and secondary effects to be provided by manufacturer. Training may be necessary.

Assignment of a machine to one of these categories is based on the effective radiometric quantities presented below in Table 8.3, as measured at a distance of 10 cm.

Table 8.3. Emission limits for machinery classification according to EN 12198

E_{eff}	E_R (for $\alpha < 11$ mrad)	L_R (for $\alpha \geq 11$ mrad)	E_R	Category
≤ 0.1 mW m^{-2}	≤ 1 mW m^{-2}	≤ 10 W m^{-2} sr^{-1}	≤ 33 W m^{-2}	0
≤ 1.0 mW m^{-2}	≤ 10 mW m^{-2}	≤ 100 W m^{-2} sr^{-1}	≤ 100 W m^{-2}	1
> 1.0 mW m^{-2}	> 10 mW m^{-2}	> 100 W m^{-2} sr^{-1}	> 100 W m^{-2}	2

8.2 Hazard distance and hazard values information

In some applications it can be useful to know the distance over which the hazards from optical radiation might extend.

The distance at which the level of exposure has dropped to the level of the applicable Exposure Limit Value is known as the hazard distance: beyond this distance there is no risk of harm. This information, if provided by manufacturers, may be useful for the risk assessment and for ensuring a safe work environment.

8.2.1. Lasers — Nominal ocular hazard distance

At some distance, as the laser beam diverges, the irradiance will equal the ELV for eyes. This distance is called the Nominal ocular hazard distance (NOHD). At greater distances the ELV will not be exceeded — the laser beam is considered safe beyond this distance.

Manufacturers often provide the information on NOHD with product specification. If this information is not available, it is possible to calculate the NOHD using the following parameters for the laser radiation from manufacturer data:

- Radiant power (W)
- Initial beam diameter (m)
- Divergence (radians)
- Exposure Limit Value (ELV) (W m^{-2})

Although the situation may be complicated if the distance is large or if the beam is not circular, the following equation gives a good estimate of the NOHD:

$$NOHD = \frac{\sqrt{\frac{4 \times radiant\ power}{\pi \times ELV}} - initial\ diameter}{divergence}$$

8.2.2. Broadband sources — Hazard distance and hazard value

The distance at which the level of exposure has dropped to the level of the applicable Exposure Limit Value is known as the Hazard Distance (HD): beyond this distance there is no risk of harm. The HD should be taken into account when specifying the boundaries of the area within which access to optical radiation and the activity of personnel is subject to control and supervision for the purpose of protection from optical radiation. Hazard distances may be defined for eye or skin exposure.

Optical radiation hazards information could also be presented as Hazard Value (HV), which is the ratio of the Exposure Level at a specific distance to the Exposure Limit Value at that distance:

$$HV(\text{distance, exposure time}) = \frac{\text{Exposure Level (distance, exposure time)}}{\text{Exposure Limit Value}}$$

The Hazard Value, HV, has significant practical importance. If the HV is greater than one, it gives guidance on appropriate control measures: either to limit the exposure duration or the accessibility of a source (attenuation, distance), as applicable. If the HV is less than one, the ELV is not exceeded at that location for the exposure time considered.

Manufacturers often provide information on HD and Hazard Values with the product specification. This information should assist the user in undertaking the risk assessment and the choice of appropriate control measures.

8.3 Further useful information

EN 60825-1: 2007, Safety of Laser Products, Part 1: Equipment classification and requirements.

IEC TR 60825-14: 2004, Safety of Laser Products, Part 14: A user's guide.

EN 62471: 2008, Photobiological safety of lamps and lamp systems.

EN 12198 — 1: 2000, Safety of Machinery — Assessment and reduction of risks from radiation emitted by machinery, Part 1: General principles.

EN 12198 — 2: 2002, Safety of Machinery — Assessment and reduction of risks from radiation emitted by machinery, Part 2: Radiation emission measurement procedure.

EN 12198 — 3: 2000, Safety of Machinery — Assessment and reduction of risks from radiation emitted by machinery, Part 3: Reduction of radiation by attenuation and screening.

9. Control measures

The hierarchy of control measures is based on the principle that if any hazard is identified, then this hazard must be controlled by engineering design. Only when this is not possible, should alternative protection be introduced. There are very few circumstances where it is necessary to rely on personal protective equipment and administrative procedures.

The selection of appropriate measures in any specific situation should be guided by the outcome of the risk assessment. All available information about the sources of optical radiation and the possible personal exposure should be gathered. In general, a comparison of either the radiation exposure obtained from the equipment specifications or measured data together with the applicable Exposure Limit Value(s) allows an assessment of a personal workplace exposure to optical radiation. The aim is to get an unambiguous result stating whether the applicable limit value(s) is likely to be exceeded or not.

If a clear statement can be made that optical radiation exposure is insignificant and that the exposure limit values will not be exceeded, no further action is necessary.

If emissions are significant and/or occupancy is high, it may be possible that the limits will be exceeded and that some form of protective measures will be required. The assessment procedure should be repeated after the application of protective measures.

Repetition of the measurement and assessment may be necessary if:

- the radiation source has changed (e.g. if another source has been installed or if the source is operated under different operating conditions);
- the nature of the work has changed;
- the duration of exposure has changed;
- protective measures have been applied, discontinued or changed;
- a long period of time has elapsed since the last measurement and assessment so that the results may no longer be valid;
- a different set of exposure limit values is to be applied.

Control measures applied at the design and installation stage can offer significant advantages in safety and operation. The later addition of such control measures may be expensive.

9.1 Hierarchy of control measures

Where there is a potential for exposure above the ELV, the hazard should be managed through application of a combination of appropriate control measures. The control priorities are common for risk management:

Elimination of the hazard

Substitution by less hazardous process or equipment

Engineering measures

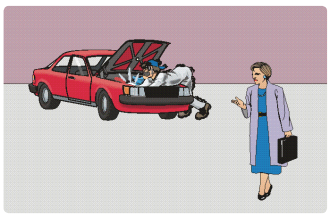
Administrative controls

Personal protective equipment

9.2 Elimination of the hazard

Is the source of hazardous optical radiation really necessary?

Do you really need these lights ON?



9.3 Substitution by less hazardous process or equipment

Is the hazardous level of optical radiation essential?

Do you really need it so bright?

9.4 Engineering controls

Could the equipment be re-designed or hazardous optical radiation controlled or reduced at the source?

If the higher priority controls (elimination or substitution) are not possible, preference should be given to engineering means of reduction of exposure. Administrative controls may be used in combination with higher control measures. If reduction of personal exposure is not feasible, impracticable or incomplete, personal protective equipment (PPE) should be considered as a last resort.

Protective housing Enclosures Interlocks Delayed operation switches	Warning lights Audio signals	Attenuators shutters Viewing and filtered windows Elimination of reflections
	Remote controls Alignment aids	

9.4.1. Access prevention

This can be undertaken either with fixed guards or movable guards with interlocks. Fixed guards are usually applied to parts of the equipment which do not require regular access and are permanently attached.

If access is needed, then a movable/opening guard interlocked to the process can be used.

Important
Guards should be adequate and robust
They should not generate any additional risks and should cause minimal obstruction
They should not be easy to be bypassed or defeated — if it is a fixed enclosing guard
They should be located at an adequate distance from the danger zone — if it's a fixed distance guard

9.4.2. Protection by limiting operation

When frequent access is required through the physical guards, then these can often be considered too restrictive, especially if the operator is required to carry out loading/unloading or adjustment operations. In this instance, it is usual to employ sensors to detect the presence or absence of an operator and generate an appropriate stop command. They can be classed as trip devices: they do not restrict access but sense it. The time taken for the machine to reach a safe condition determines the location or proximity of any sensor.

9.4.3. Emergency stops

When personnel can access a hazardous environment, it is essential to provide emergency stops should anyone get into trouble while in the hazard zone. The emergency stop must have a fast response and stop all services in the hazard zone. Most people will be familiar with the red mushroom-headed emergency stop buttons; they should be suitably located around the facility in sufficient quantity to ensure there will always be one in reach. An alternative is a grab wire linked to an emergency stop button, this is often a more convenient means of providing protection in a hazard area. Other forms of trip switch can be located around any moving parts which sense unexpected proximity such as a toggle switch, safety bar or rod.

9.4.4. Interlocks

There are many variations of interlock switches and each design comes with its own features. It is important that the right device be chosen for the application.

Important
Interlock should be well constructed and reliable under the foreseeable extreme conditions
They should fail-to-safety and be tamper proof
The status of the interlock should be clearly indicated, e.g. by large flags on the defeat keys and warning status indicators on operators panels
The interlock should limit the operation whilst the guard door is not fully closed

Further useful information

- EN 953: 1997 The Safety of Machinery, Guards, General requirements for the Design and Construction of Fixed and Moveable Guards.
- EN 13857: 2008 Safety of Machinery, Safety distances to prevent danger zones being reached by upper and lower limbs.
- EN 349: 1993 Safety of Machinery, Minimum gaps to avoid crushing of parts of the human body.
- EN 1088: 1995 Interlocking Devices Associated with Guards.
- EN 60825-4: 2006 Laser Guards.

9.4.5. Filters and viewing windows

Many industrial processes can be fully or partially enclosed. It is then possible to monitor the process remotely, via a suitable viewing window, optics or television camera. Safety can be ensured by using appropriate filter materials to block the transmission of hazardous levels of optical radiation. This removes any need for reliance upon safety goggles and improves operator safety and working conditions.

Examples can range from large-scale control rooms to a viewing window fitted within a small local enclosure around the interaction region.

Important
Filter material should be durable and appropriate
Impact resistant
Doesn't compromise safety of operation

Vision panels in guarded area

Transmission of optical radiation through windows and other optically translucent panels should be evaluated as a potential risk. Although the optical beam may not present a direct retinal hazard, temporary flash issues may cause secondary safety problems with other procedures in the vicinity.

9.4.6. Alignment aides

When routine maintenance requires the alignment of beam path components, some safe means of achieving this should be provided. Some examples may include:

- use of a lower power sighting laser that follows the axis of the higher power beam;
- masks or targets.

Important
The human eye or skin should never be used as an alignment aid

9.5 Administrative measures

Administrative controls are the second stage of the hierarchy of control. They tend to need people to act on information and, therefore, are only as effective as the actions of those people. However, they do have a role and may be the principal control measure under some circumstances, such as during commissioning and servicing.

The appropriate administrative controls depend on the risk and include the appointment of people as part of the safety management structure, restricting access, signs and labels, and procedures.

It is good practice to provide formal arrangements for an integrated approach to the management of optical radiation safety. These arrangements should be documented to record what measures have been adopted and why. This documentation also may prove useful in the event of an incident investigation. It may include:

- a statement of the optical radiation safety policy;
- a summary of the principal organisational arrangements (appointments and what is expected of the person appointed to each position);
- a documented copy of the risk assessment;
- an action plan detailing any additional controls identified through the risk assessment together with a timetable for their implementation;
- a summary of the control measures implemented, together with a brief justification for each;
- a copy of any specific written arrangements or local rules applying to work in the optical radiation controlled area;
- the Authorised Users' Register;
- plan for maintaining the control measures. This may include schedules for positive actions required to maintain or test the control measures;
- details of formal arrangements to manage interactions with external agents such as service engineers;
- details of contingency plans;
- an audit plan;
- copies of audit reports;
- copies of relevant correspondence.

It should be normal practice to review the effectiveness of the programme at regular intervals (for example, annually) in the light of the audit reports and changes in legislation and standards.

9.5.1. Local rules

Where the risk assessment identified a potential for exposure to hazardous level of optical radiation, it is appropriate to put in place a system of written safety instructions (or local rules) to regulate how work with optical radiation is carried out. These should include a description of the area, contact details for an optical radiation advisor (see 9.5.4), details of who is authorised to use the equipment, details of any pre-use tests required, operating instructions, an outline of the hazards, and details of contingency arrangements.

Local rules should normally be available in the areas to which they relate and should be issued to all those affected by them.

9.5.2. Controlled area

A controlled area may need to be designated where access to optical radiation in excess of the ELV is likely. A controlled area should be one to which access is restricted, except to authorised persons. This should preferably be by physical means, for example, using the walls and doors of the entire room. The area may be restricted by locks, number pads, or barriers.

Arrangements should be put in place for the formal authorisation of users by management. There should be a formal process for evaluating the suitability of personnel prior to authorisation and this should include an assessment of their training, competence and knowledge of the local rules. The results of this assessment should be recorded and the names of all authorised users should be recorded in a formal register.

9.5.3. Safety signs and notices

These form an important part of any system of administrative controls. Safety signs are only effective if they are clear and unambiguous, and if they are displayed only when appropriate — otherwise they are often ignored.

Warning signs may include information about the type of equipment in use. If there is a requirement for personnel to use personal protective equipment, then this should also be indicated.

Warning signs are more effective if they are displayed only when the equipment is in use. All safety signs should be placed at eye level to maximise their visibility.

Typical signs used in the work environment to advise of hazards and recommend the use of personal protective equipment
All safety signs should comply with the requirements of Safety Signs Directive (92/58/EEC).

9.5.4. Appointments

Optical radiation safety should be managed through the same health and safety management structure as other potentially hazardous activities. The detail of the organisational arrangements may vary according to the size and structure of the organisation.

For many applications, the training of an expert in optical radiation safety management may not be justified. It may also be difficult for staff to keep up to date with optical radiation safety if they are only required to use their skills infrequently. Therefore, some companies make use of advice provided by external advisers in optical radiation safety. They may provide recommendations on:

- engineering control solutions;
- written procedures for the safe use of the equipment; operational and occupational safety measures;
- selection of personal protective equipment;
- education and training of staff.

To supervise the day-to-day aspects of optical radiation safety in a workplace, it may be appropriate to appoint a sufficiently knowledgeable member of staff.

9.5.5. Training and consultation

9.5.5.1. Training

The Directive (Article 6) requires information and training for workers who are exposed to risks from artificial optical radiation (and/or their representatives). This is required to cover in particular:

Measures taken to implement this Directive
The exposure limit values and the associated potential risks
The results of the assessment, measurement and/or calculations of the levels of exposure to artificial optical radiation carried out in accordance with Article 4 of this Directive together with an explanation of their significance and potential risks
How to detect adverse health effects of exposure and how to report them
The circumstances in which workers are entitled to health surveillance
Safe working practices to minimise risks from exposure
Proper use of appropriate personal protective equipment

It is suggested that the level of training should be balanced with the risk from exposure to artificial optical radiation. Where all of the sources are considered 'trivial' then it should be adequate to inform workers and/or their representatives of this. However, workers or their representatives should be made aware that there could be particularly sensitive risk groups and the process for managing these.

Where accessible artificial optical radiation that is likely to exceed the exposure limit value is present in the workplace then consideration should be given to formal training, and perhaps the appointment of workers to specific roles. When determining the level of training required, the employer should consider the following:

Expertise of staff and current awareness of the risks from artificial optical radiation
Existing risk assessments and their conclusions
Whether the workers are required to assist with risk assessments or their review
Whether the workplace is static and the risks have been formally assessed as acceptable or whether the environment changes frequently
Whether the employer has access to external expertise to assist with the management of risks
Workers new to the workplace or to work with artificial optical radiation

It is important that the risks are put into perspective. For example, requiring formal training courses for the use of a Class 2 laser pointer is not justified. Training for workers using Class 3B and Class 4 lasers, and non-coherent sources of Risk Group 3, will almost always be required. However, it is not possible to define a specific length of a training programme or indeed how this is to be delivered. This is why the risk assessment is important.

Ideally, the requirement for training, and how this should be delivered, should be identified before the source of artificial optical radiation is brought into use.

9.5.5.2. Consultation

Article 7 of the Directive refers to the general requirements of Article 11 of Directive 89/391/EEC:

Article 11
Consultation and participation of workers

1. Employers shall consult workers and/or their representatives and allow them to take part in discussions on all questions relating to safety and health at work.

This presupposes:
— the consultation of workers,
— the right of workers and/or their representatives to make proposals,
— balanced participation in accordance with national laws and/or practices.

2. Workers or workers' representatives with specific responsibility for the safety and health of workers shall take part in a balanced way, in accordance with national laws and/or practices, or shall be consulted in advance and in good time by the employer with regard to:

(a) any measure which may substantially affect safety and health;
(b) the designation of workers referred to in Articles 7 (1) and 8 (2) and the activities referred to in Article 7 (1);
(c) the information referred to in Articles 9 (1) and 10;
(d) the enlistment, where appropriate, of the competent services or persons outside the undertaking and/or establishment, as referred to in Article 7 (3);
(e) the planning and organisation of the training referred to in Article 12.

3. Workers' representatives with specific responsibility for the safety and health of workers shall have the right to ask the employer to take appropriate measures and to submit proposals to him to that end to mitigate hazards for workers and/or to remove sources of danger.

4. The workers referred to in paragraph 2 and the workers' representatives referred to in paragraphs 2 and 3 may not be placed at a disadvantage because of their respective activities referred to in paragraphs 2 and 3.

5. Employers must allow workers' representatives with specific responsibility for the safety and health of workers adequate time off work, without loss of pay, and provide them with the necessary means to enable such representatives to exercise their rights and functions deriving from this Directive.

6. Workers and/or their representatives are entitled to appeal, in accordance with national law and/or practice, to the authority responsible for safety and health protection at work if they consider that the measures taken and the means employed by the employer are inadequate for the purposes of ensuring safety and health at work.

Workers' representatives must be given the opportunity to submit their observations during inspection visits by the competent authority.

IEC TR 60825-14: 2004 recommends a minimum training requirement for laser users.
EN 60825-2: 2004 specifies additional requirements for users working on optical fibre communication systems.
EN 60825-12: 2004 specifies additional requirements for users working on free-space communication systems.
CLC/TR 50448: 2005 provides a guide to levels of competency required in laser safety.

9.6 Personal protective equipment

Reduction of unintended exposure to optical radiation should be included in the design specifications of the equipment. Exposure to optical radiation should be reduced, as far as reasonably practicable, by means of physical safeguards, such as engineering controls. Personal protective equipment should only be used when engineering and administrative controls are impracticable or incomplete.

The purpose of PPE is to reduce optical radiation to the level which does not cause adverse health effects in the exposed individual. The optical radiation injuries may not be apparent at the time of the exposure. It should be noted that Exposure Limits are wavelength dependent, therefore the degree of protection offered by PPE may also be wavelength dependent.

Although an acute skin injury resulting from exposure to optical radiation is less likely to affect the individual's quality of life, it should be recognised that the probability of skin injury may be high, especially for hands and face. Exposure of the skin to optical radiation below 400 nm, which may increase the risk of skin cancer, is of particular concern.

Important
PPE should be appropriate for the risks involved, without itself leading to any increased risk
PPE should be appropriate for the conditions at the workplace
PPE should take account of ergonomic requirements and the worker's state of health

9.6.1. Protection against other hazards

The following non-optical hazards should also be considered when selecting appropriate PPE to protect against exposure to optical radiation:

- Impact
- Penetration
- Compression
- Chemical
- Heat/Cold
- Harmful dust
- Biological
- Electrical

Examples are given in the table below:

Personal Protective Equipment	Function
Protective eyewear: safety spectacles, goggles, face shields, visors	Eyewear should allow the worker to see everything in the work area but restrict the optical radiation to acceptable levels. Selection of appropriate eyewear depends upon many factors including: wavelength, power/energy, optical density, need for prescription lenses, comfort, etc.
Protective clothing and gloves	Sources of optical radiation may present a fire hazard and protective clothing may be necessary. Equipment that produces UV radiation may present a skin hazard and skin should be covered using suitable protective clothing and gloves. Gloves should be worn when working with chemical or biological agents. Protective clothing or gloves may be required by application specifications.
Respiratory equipment	Toxic and harmful fumes or dusts may be produced during processing. Respiratory equipment may be necessary for emergency use.
Ear defenders	Noise can be a hazard from some industrial applications.

9.6.2. Eye protection

The eye is at risk of injury from optical radiation if exposures are in excess of the Exposure Limit Values (ELVs). If the other measures are inadequate to control the risk of eye exposure in excess of any applicable ELVs, eye protection recommended by the equipment manufacturer or optical radiation safety advisor and specifically designed for the wavelengths and output should be worn.

Protective eyewear should be clearly marked with the wavelength range and corresponding protection level. This is particularly important if there are multiple sources that require different types of protective eyewear, such as different wavelength lasers that require their own unique eyewear. Additionally, it is recommended that an unambiguous and robust method of marking the safety eyewear should be employed to ensure that there is a clear link to the particular equipment for which PPE has been specified.

The level of attenuation of optical radiation provided by protective eyewear in the hazard spectral region should be, at least, sufficient to decrease the exposure level below applicable ELVs.

Luminous transmittance and the colour of the environment as seen through the protective filters are important characteristics of eyewear which may affect the operator's ability to perform the required operations without compromising non-optical radiation safety.

Protective eyewear should be correctly stored, regularly cleaned, and subject to a defined inspection regime.

Considerations for choice of protective eyewear

Q: Level of protection required?	→	Choose eyewear with the attenuation > $\frac{\text{exp level}}{\text{ELVs}}$
Q: Luminous transmittance? Quality of vision?	→	Choose eyewear with luminous transmittance > 20 % If not available, increase illumination level Check filters for scratches and scatter
Q: Colour perception of the working environment?	→	Check that equipment controls and emergency signs are clearly seen through protective eyewear
Q: Too much reflection?	→	Avoid mirror finish or high gloss filters and frames
Q: If eyewear is powered by mains or batteries and power is interrupted, does it fail to safety?	→	Choose filter that provides maximum attenuation when not powered

9.6.3. Skin protection

For occupational exposure to optical radiation, the areas of the skin most usually at risk are the hands, the face, the head and the neck, as other areas are generally covered by working clothes. The hands can be protected by wearing gloves with low transmission to hazardous optical radiation. The face can be protected by an absorbing face shield or visor, which may also offer eye protection. Suitable headwear will protect the head and neck.

9.7 Further useful information

Council Directive 89/656/EEC on the minimum health and safety requirements for the use by workers of personal protective equipment at the workplace.

9.7.1. Basic standards

EN 165: 2005 — Personal eye-protection — Vocabulary
EN 166: 2002 — Personal eye-protection — Specifications
EN 167: 2002 — Personal eye-protection — Optical test methods
EN 168: 2002 — Personal eye-protection — Non-optical test methods

9.7.2. Standards by type of product

EN 169: 2002 — Personal eye-protection — Filters for welding and related techniques — Transmittance requirements and recommended use
EN 170: 2002 — Personal eye-protection — Ultraviolet filters — Transmittance requirements and recommended use
EN 171: 2002 — Personal eye-protection — Infrared filters — Transmittance requirements and recommended use

9.7.3. Welding

EN 175: 1997 — Personal protection — Equipment for eye and face protection during welding and allied processes
EN 379: 2003 — Personal eye-protection — Automatic welding filters
EN 1598: 1997 Health and safety in welding and allied processes — Transparent welding curtains, strips and screens for arc welding processes.

9.7.4. Laser

EN 207: 1998 — Filter and eye protectors against laser radiation
EN 208: 1998 — Eye protectors for adjustment work on lasers and laser systems

9.7.5. Intense light sources

BS 8497-1: 2008. Eyewear for protection against intense light sources used on humans and animals for cosmetic and medical applications. Part 1: Specification for products.
BS 8497-2: 2008. Eyewear for protection against intense light sources used on humans and animals for cosmetic and medical applications. Part 2: Guidance on use.

10. Managing adverse incidents

Within the context of this guide, adverse incidents include situations where someone is injured or falls ill (termed 'accidents'), or near misses or undesired circumstances occur (termed 'incidents').

Where collimated laser beams are used, the risk of getting exposed to the laser beam is generally low, but the consequence may be high. In contrast, with non-coherent sources of artificial optical radiation, the risk of getting exposed is high, but the consequence may be low.

It is suggested that contingency plans are prepared to deal with reasonably foreseeable adverse events involving artificial optical radiation. The level of detail and complexity will depend on the risk. It is likely that the employer will have general contingency arrangements so there will be an advantage in using similar approaches for optical radiation.

It is suggested that detailed contingency plans should be prepared for work practices where access to optical radiation from the following is likely:
Class 3B Lasers
Class 4 Lasers
Risk Group 3 Non-coherent sources

The contingency plans should address actions and responsibilities in the event of:
An actual worker exposure in excess of the ELV
A suspected worker exposure in excess of the ELV

11. Health surveillance

Article 8 of the Directive describes the requirements for health surveillance, referencing the general requirements of Directive 89/391/EEC. The detail for any health surveillance is likely to rely on national requirements. Therefore, the proposal presented in this Chapter is very generic.

The requirements of this Article need to be considered in the context of over 100 years of worker exposure to artificial optical radiation. The number of reported adverse health effects are small, and restricted to a small number of industries, where control measures have generally been implemented to reduce the number of incidences even further.

Following the invention of the laser, recommendations were published on routine eye examinations for laser workers. However, nearly 50 years of experience has shown that such examinations have no value as part of a health surveillance programme and possibly introduce an additional risk to the worker.

A worker exposed to artificial optical radiation at work should not receive pre-employment, routine and post-employment eye examinations, just because they carry out such work. Similarly, skin examinations may be of benefit to workers, but are not usually justified purely on the basis of routine exposure to artificial optical radiation.

11.1 Who should carry out the health surveillance?

Health surveillance should be carried by:

- a doctor,
- an occupational health professional, or
- a medical authority responsible for health surveillance in accordance with national law and practice.

11.2 Records

Member States are responsible for establishing arrangements to ensure that individual records are made and kept up to date. The records should contain a summary of the results of the health surveillance carried out.

The records should be in a form which allows them to be consulted at a later date, taking account of confidentiality. Individual workers should have access to their own records on request.

11.3 Medical examination

A medical examination should be made available to a worker if it is suspected or known that they have been exposed to artificial optical radiation in excess of the exposure limit value.

A medical examination should be carried out if a worker is found to have an identifiable disease or adverse health effects, which is considered to be a result of exposure to artificial optical radiation.

A challenge for implementing this requirement is that many adverse health effects may be due to exposure to natural optical radiation. Therefore, it is important that the person carrying out the medical examination is familiar with the potential adverse health effects from the specific sources of workplace exposure to artificial optical radiation.

11.4 Actions if an exposure limit is exceeded

If the exposure limits are thought to have been exceeded or if the adverse health effect or identifiable disease is considered to have been caused by artificial optical radiation in the workplace then the following actions should be triggered.

- The worker should be informed of the results.
- The worker should receive information and advice regarding follow-up health surveillance.
- The employer should be informed, respecting any medical confidentiality.
- The employer should review the risk assessment.
- The employer should review the existing control measures (which may involve seeking specialist advice).
- The employer should arrange any necessary continued health surveillance.

Appendix A. Nature of optical radiation

Light is an everyday example of optical radiation — artificial optical radiation, if it is emitted by a lamp. The term 'optical radiation' is used because light is a form of electromagnetic radiation, and because it has effects on the eye — i.e. it enters the eye, is focused and then detected.

Light comes in a spectrum of colours, ranging from purples and blues through greens and yellows to oranges and reds. The colours that we perceive in light are determined by the wavelengths present in the light spectrum. Shorter wavelengths are perceived as lying at the blue end of the spectrum, and longer wavelengths at the red end. It is convenient to consider light to consist of a stream of massless particles, called photons, each of which has a characteristic wavelength.

The spectrum of electromagnetic radiation extends far beyond those wavelengths that we are able to see. Infrared radiation, microwave radiation and radio waves are examples of electromagnetic radiation with increasingly long wavelengths. Ultraviolet radiation, x-rays and gamma rays have increasingly short wavelengths.

The wavelength of an electromagnetic radiation can be used to determine other useful information about it.

Whenever electromagnetic radiation interacts with a material, it is likely to deposit some energy at the point of interaction. This may cause some effect in the material — for example, visible light arriving at the retina deposits enough energy to trigger biochemical reactions which produce a signal sent via the optic nerve to the brain. The amount of energy available for such interactions depends on both the quantity of radiation and on how energetic the radiation happens to be. The amount of energy available in electromagnetic radiation can be related to the wavelength. The shorter the wavelength, the more energetic the radiation is. Thus, blue light is more energetic than green light which, in turn, is more energetic than red light. Ultraviolet radiation is more energetic than any visible wavelength.

The wavelength of radiation also determines the degree to which it penetrates and interacts with the body. For example, UVA is transmitted to the retina less efficiently than green light.

Some of the invisible portions of the electromagnetic spectrum are included in the term 'optical radiation'. These are the ultraviolet and infrared spectral regions. Although they cannot be seen (the retina doesn't have detectors for these wavelengths) portions of these spectral regions can penetrate the eye, to a greater or lesser degree. For convenience, the optical radiation spectrum is divided up, by wavelength, as follows:

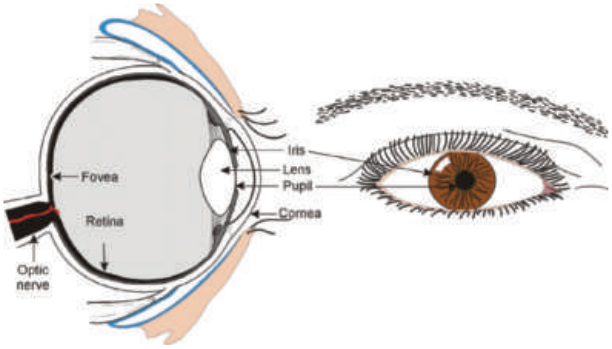
Ultraviolet 'C' (UVC)	100–280 nm
UVB	280–315 nm
UVA	315–400 nm
Visible	380–780 nm
Infrared 'A' (IRA)	780–1 400 nm
IRB	1 400–3 000 nm
IRC	3 000–1 000 000 nm (3 µm–1 mm)

The Directive contains exposure limits covering the spectral region 180–3 000 nm for non-coherent optical radiation and from 180 nm to 1 mm for laser radiation.

Appendix B. Biological effects of optical radiation on the eye and the skin

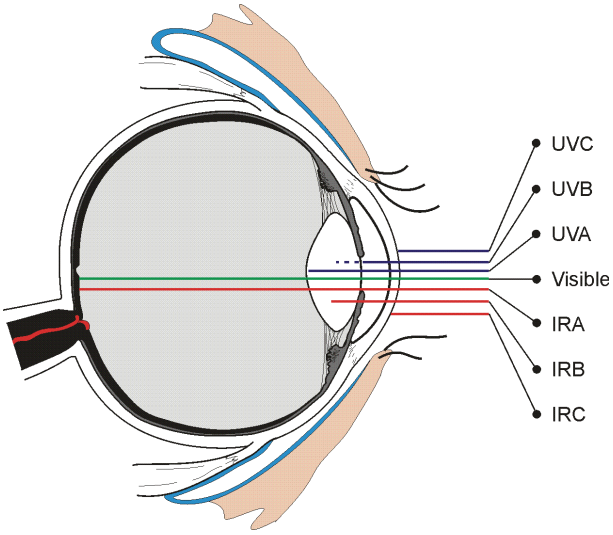
B.1 The eye

Figure B.1.1. Structure of the eye



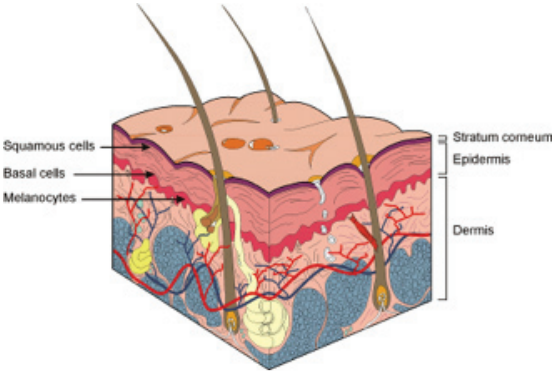
Light entering the eye passes through the cornea, aqueous humour, then through a variable aperture (pupil), and through the lens and vitreous humour to be focused on the retina. The optic nerve carries signals from the photoreceptors of the retina to the brain.

Figure B.1.2. Penetration of different wavelength through the eye



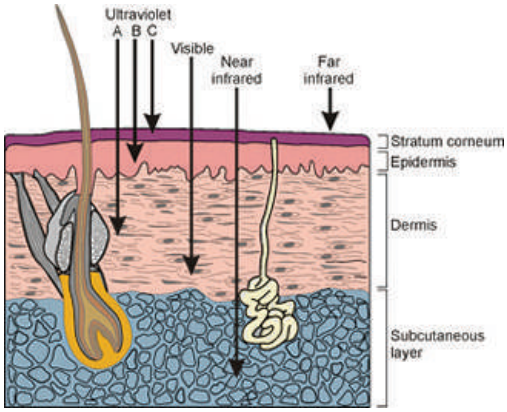
B.2 The skin

Figure B.2.1. The structure of the skin



The outer layer of the skin, the epidermis, contains mainly keratinocytes (squamous cells) which are produced in the basal layer and rise to the surface to be sloughed off. The dermis is composed mainly of collagen fibres and contains nerve endings, sweat glands, hair follicles and blood vessels.

Figure B.2.2. Penetration of different wavelength through the skin



B.3 Biological effect of different wavelengths on the eye and the skin

B.3.1. Ultraviolet radiation: UVC (100–280 nm); UVB (280–315 nm); UVA (315–400 nm)

Effects on the skin

Much of any ultraviolet radiation (UVR) incident on the skin is absorbed in the epidermis, although penetration increases markedly for the longer UVA wavelengths.

Excessive short-term exposure to UV radiation causes erythema — a reddening of the skin, and swelling. Symptoms can be severe, and the maximum effect occurs 8–24 hours after exposure, subsiding over 3–4 days with subsequent dryness and skin peeling. This may be followed by an increase in skin pigmentation (delayed tanning). Exposure to UVA radiation can also cause an immediate but temporary change in skin pigmentation (Immediate Pigment Darkening).

Some people have abnormal skin responses to UVR exposure (photosensitivity) because of genetic, metabolic, or other abnormalities, or because of intake or contact with certain drugs or chemicals.

The most serious long-term effect of UV radiation is the induction of skin cancer. The non-melanoma skin cancers (NMSCs) are basal cell carcinomas and squamous cell carcinomas. They are relatively common in white people, although they are rarely fatal. They occur most frequently on sun-exposed areas of the body such as the face and hands and show an increasing incidence with increasing age. The findings from epidemiological studies indicate that the risk of both of these skin cancers can be related to cumulative UV radiation exposure, although the evidence is stronger for squamous cell carcinomas. Malignant melanoma is the main cause of skin cancer death, although its incidence is less than NMSC. A higher incidence is found in people with large numbers of naevi (moles), those with a fair skin, red or blond hair and those with a tendency to freckle, to sunburn and not to tan on sun exposure. Both acute burning episodes of sun exposure and chronic occupational and recreational exposure may contribute to the risk of malignant melanoma.

Chronic exposure to UVR can also cause photoageing of the skin, characterised by a leathery wrinkled appearance and loss of elasticity: UVA wavelengths are the most effective as they can penetrate to the collagen and elastin fibres of the dermis. There is also evidence suggesting that exposure to UVR can affect immune responses.

The main known beneficial effect of UVR exposure is the synthesis of vitamin D; although short exposures to sunlight in everyday life will produce sufficient vitamin D if dietary intake is inadequate.

Effects on the eyes

UVR falling on the eye is absorbed by the cornea and lens. The cornea and conjunctiva absorb strongly at wavelengths shorter than 300 nm. UVC is absorbed in the superficial layers of the cornea and UVB is absorbed by the cornea and lens. UVA passes through the cornea and is absorbed in the lens.

Responses of the human eye to acute overexposure of UVR include photokeratitis and photoconjunctivitis (inflammation of the cornea and the conjunctiva, respectively), more commonly known as snow blindness, arc-eye or welder's flash. Symptoms, ranging from mild irritation, light sensitivity and tearing to severe pain, appear within 30 minutes to a day depending on the intensity of exposure and are usually reversible in a few days.

Chronic exposure to UVA and UVB can cause cataracts due to protein changes in the lens of the eye. Very little UV (less than 1 % UVA) normally gets through to the retina due to absorption by the anterior tissues of the eye. However, there are some people who do not have a natural lens as a result of cataract surgery, and unless there is an implanted artificial lens which absorbs it, the retina can be damaged by UVR (at wavelengths as short as 300 nm) entering the eye. This damage is a result of photochemically produced free radicals attacking the structures of the retinal cells. The retina is normally protected from acute damage by involuntary aversion responses to visible light, but UVR does not produce these responses: persons lacking a UVR absorbing lens are therefore at higher risk of suffering retinal damage if working with UVR sources.

Chronic UVR exposure is a major contributor to the development of corneal and conjunctival disorders such as

climatic droplet keratopathy (an accumulation of yellow/brown deposits in the conjunctiva and cornea), pterygium (an overgrowth of tissue which may spread over the cornea) and probably pinguecula (a proliferative yellow lesion of the conjunctiva).

B.3.2. Visible radiation

Effects on the skin

Visible radiation (light) penetrates into the skin and may raise the local temperature enough to cause burning. The body will adjust to gradual temperature rises by increasing blood flow (which carries heat away) and perspiration. If the irradiation is insufficient to cause an acute burn (in 10 s or less), the exposed person will be protected by natural aversion responses to heat.

For long exposure durations, heat strain from thermal stress (increased core body temperature) is the principal adverse effect. Although this is not specifically covered by the Directive, ambient temperature and workload must be considered.

Effects on the eyes

Because the eyes act to collect and focus visible radiation, the retina is at greater risk than the skin. Gazing at a bright light source can cause retinal damage. If the lesion is in the fovea, e.g. if looking directly along a laser beam, severe visual handicap may result. Natural protective measures include an aversion to bright light (the aversion response operates in about 0.25 seconds; the pupil contracts and can reduce retinal irradiance by about a factor of 30; and the head may be turned involuntarily away).

Retinal temperature increases of 10–20 °C can lead to irreversible damage due to denaturation of proteins. If the radiation source covers a large part of the field of view so that the retinal image is large, it is difficult for the retinal cells in the central region of the image to shed heat quickly.

Visible radiation can cause the same type of photochemically induced damage as UVR (although, at visible wavelengths, the aversion to bright light can act as a protective mechanism). This effect is most pronounced at wavelengths around 435–440 nm, and so it is sometimes called the 'Blue-Light hazard'. Chronic exposure to high ambient levels of visible light may be responsible for photochemical damage to the cells of the retina, resulting in poor colour and night vision.

Where radiation enters the eye in an essentially parallel beam (i.e. very low divergence from a distant source or a laser) it may be imaged onto the retina in a very small area, concentrating the power tremendously and resulting in severe damage. This focusing process could in theory increase the irradiance on the retina compared to that falling on the eye by up to 500 000 times. In these cases, the brightness can exceed all known natural and man-made light sources. Most laser injuries are burns: pulsed high peak power lasers can produce such a rapid rise in temperature that cells literally explode.

B.3.3. IRA

Effects on the skin

IRA penetrates several millimetres into tissue, that is, well into the dermis. It can produce the same thermal effects as visible radiation.

Effects on the eyes

Like visible radiation, IRA is also focused by the cornea and lens and transmitted to the retina. There, it can cause the same sort of thermal damage as visible radiation can. However, the retina does not detect IRA, and so there is no protection from natural aversion responses. The spectral region from 380 to 1 400 nm (visible and IRA) is sometimes called the 'retinal hazard region'.

Chronic exposure to IRA may also induce cataracts.

IRA does not have sufficiently energetic photons for there to be a risk of photochemically induced damage.

B.3.4. IRB

Effects on the skin

IRB penetrates less than 1 mm into tissue. It can cause the same thermal effects as visible radiation and IRA.

Effects on the eyes

At wavelengths around 1 400 nm, the aqueous humour is a very strong absorber; and longer wavelengths are attenuated

by the vitreous humour, thus the retina is protected. Heating of the aqueous humor and iris can raise the temperature of the adjacent tissues, including the lens, which is not vascularised and so cannot control its temperature. This, along with direct absorption of IRB by the lens induces cataracts, which have been an important occupational disease for some groups, principally glass blowers and chain makers.

B.3.5. IRC

Effects on the skin

IRC penetrates only to the uppermost layer of dead skin cells (stratum corneum). Powerful lasers, which may be capable of ablating the stratum corneum and damaging underlying tissues, are the most serious acute hazard in the IRC region. The damage mechanism is mainly thermal, but high peak power lasers may cause mechanical/acoustic damage.

As for visible, IRA and IRB wavelengths, heat strain and discomfort from thermal stress must be considered.

Effects on the eyes

IRC is absorbed by the cornea, and so the main hazard is corneal burns. The temperature in adjacent structures of the eye may increase due to thermal conduction, but heat loss (by evaporation, and blinking) and gain (due to body temperature) will influence this process.

Appendix C. Artificial optical radiation quantities & units

As pointed out in the section on 'The Nature of Optical Radiation', the effects of optical radiation depend on the energy of the radiation and the quantity of radiation. There are many ways of quantifying optical radiation: those used in the Directive are outlined briefly below.

C.1 Fundamental quantities

C.1.1. Wavelength

This refers to the characteristic wavelength of the optical radiation. It is measured in small sub-divisions of the metre — usually the nanometre (nm), which is equal to one millionth of 1 millimetre. At longer wavelengths, it is sometimes more convenient to use the micrometre (μm). One micrometre is equal to 1 000 nanometres.

In many cases, the optical radiation source under consideration will be emitting photons of many different wavelengths.

When writing formulae, wavelength is represented by the symbol λ (lambda).

C.1.2. Energy

This is measured in joules (J). It may be used to refer to the energy of each photon (which is related to the photon's wavelength). It may also refer to the energy contained in a given quantity of photons, for example, a laser pulse.

Energy is represented by the symbol Q.

C.1.3. Other useful quantities

Angular subtense

This is the apparent width of an object (usually an optical radiation source) as seen from some location (usually the point at which measurements are being made). It is calculated by dividing the true width of the object by the distance to the object. It is important that both of these values are in the same units. Whatever units these values are in, the resulting angular subtense is in radians (r).

If the object is at an angle to the viewer, the angular subtense must be multiplied by the cosine of the angle.

Angular subtense is represented in the Directive by the symbol α (alpha).

Solid angular subtense

This is the three-dimensional equivalent of the angular subtense. The area of the object is divided by the square of the distance. Again, the cosine of the viewing angle may be used to correct for off-axis viewing. The unit is the steradian (sr) and the symbol is ω (omega).

Beam divergence

This is the angle by which a beam of optical radiation diverges as it moves away from the source. It can be calculated by taking the beam width at two points, and dividing the change in width by the distance between the points. It is measured in radians.

C.1.4. Quantities used in exposure limits

Radiant power

Power is defined here as the rate at which energy passes through a given location in space. It is measured in watts (W), with 1 watt equal to 1 joule per second. It is represented by the symbol Φ (phi).

The term 'power' may refer to the power in a defined beam of optical radiation, in which case it is often referred to as CW power. For example, a CW laser with a beam power of 1 mW is emitting photons with a total energy of 1 mJ every second.

Power may also be used to describe a pulse of optical radiation. For example, if a laser emits a discrete pulse containing 1 mJ of energy in 1 ms, the pulse power was 1 W. If the pulse had been emitted in a shorter time, say 1 μs, the power would have been 1 000 W.

Irradiance

Irradiance can be thought of as the rate at which energy arrives, per unit area, at a given location. As such, it depends on the optical radiation power, and the area of the beam on the surface. It is calculated by dividing the power by the area, giving units which are some multiple of watts per square metre (W m^{-2}). It is represented by the symbol E.

Radiant exposure

Radiant exposure is the amount of energy that has arrived, per unit area, at a given location. It is calculated by multiplying the irradiance, in W m^{-2}, by the exposure duration, in seconds. Its units will then be joules per square metre (J m^{-2}). It is represented by the symbol H.

Radiance

Radiance is a quantity which is used to describe how concentrated a beam of optical radiation is. It can be calculated by dividing the irradiance at a given location by the solid angle of the source, as seen from that location. Its units are watts per square metre per steradian (W m^{-2} sr^{-1}). It is represented by the symbol L.

C.1.5. Spectral quantities and broadband quantities

Where an optical radiation source, such as a laser, emits at only one wavelength (for example, 633 nm), then any quantities which are quoted will naturally be descriptions of the emissions at that wavelength only. For example, $\Phi = 5$ mW.

Where more than one wavelength is present, each discrete wavelength will have its own quantities. For example, a laser may emit 3 mW at 633 nm and 1 mW at 1 523 nm. This is a description of the spectral power distribution, often written $\Phi\lambda$, of the source. It is equally true to state that $\Phi = 4$ mW for this laser, this being the total radiant power: this value is a broadband value.

Broadband data are calculated by summing all of the spectral data within the wavelength region of interest.

C.1.6. Radiometric quantities and effective quantities

All of the quantities discussed so far are radiometric quantities. Radiometric data quantify and describe some aspects of a field of radiation. They do not necessarily indicate the effects of the radiation on a biological target. For example, an irradiance of 1 W m^{-2} at 270 nm is more dangerous to the cornea than 1 W m^{-2} at 400 nm. Where information relating to biological effects is required, effective quantities must be used. Many of the exposure limits are expressed in effective quantities, as they are intended for the avoidance of a biological effect.

Effective quantities only exist where scientists have some idea of how the capacity for a given effect varies with wavelength. For example, the effectiveness of radiation in causing photokeratitis rises in the range from 250 nm to a peak at 270 nm, then falls off rapidly in the range from 270 nm to 400 nm. Where the relative spectral effectiveness is known, it is often given a symbol, such as S_λ, B_λ, R_λ. These are, respectively, the relative spectral efficacies for causing photokeratitis/erythema, retinal photochemical damage and Retinal Thermal damage.

Relative spectral efficacy values may be used to multiply a set of spectral radiometric data and produce spectral effective data. These effective data may then be summed to produce a broadband effective quantity, often denoted by a subscript referring to the spectral efficacy values used. For example, L_B is the symbol denoting a broadband radiance value (L) which has been spectrally weighted using the B_λ spectral weighting values.

C.1.7. Luminance

One example of a biologically effective quantity which has so far gone unmentioned is luminance. Although not used for any exposure limit, it is very useful for preliminary assessment of the potential of broadband white light sources to cause retinal damage.

Luminance has the symbol L_v, and is measured in candela per square metre (cd m^{-2}). The biological effect which it describes is illumination, as seen by the daylight adapted eye, and it is related to the quantity illuminance (E_v, measured in lux) which is familiar to many lighting engineers.

The relationship may be described as $L_v = E_v/\omega$. Given the illuminance from a source onto a surface, the distance to the source and the dimensions of the source, the luminance may be easily calculated.

Appendix D. Worked examples

D.1 Office

The following examples cover a variety of common optical radiation sources which are likely to be found in most, or many, working environments.

A common approach has been used to assess the risk from these simple sources. This approach is set out in some detail below, and has been followed in outline form for each of the later examples.

D.1.1. Explanation of general method

This general method draws on EN 62471 (2008), but wherever possible makes simplifying assumptions which err on the side of caution as far as retinal hazards are concerned. The explanation given below is rather full, as it is intended to cover all of the examples given later. The risk assessment is carried out in a number of steps:

Describe the source
↓
Decide what exposure distance should be assumed
↓
Decide which exposure limits should be applied
↓
Calculate any geometrical factors required by the exposure limits
↓
If appropriate, make a quick preliminary assessment
↓
Carry out assessment using simplifying assumptions
↓
If assessment indicates possible unacceptable risk, carry out a more realistic assessment

Firstly, the source is described, and its dimensions listed. These dimensions will be needed if the source emits in the visible or IRA spectral regions.

A decision has to be made as to what distance to carry out the risk assessment: the measurement distance is usually chosen to be a realistic, if slightly pessimistic, closest approach that persons may make to the source — it is not chosen to be the closest possible approach.

Choice of exposure limits

Which exposure limits are appropriate? Considering the worst possible exposure, which is that someone stares into the source for 8 hours, and referring to Table 1.1 of the Directive:

Index	Wavelength, nm	Units	Part of the body	Hazard	Appropriateness
a	180–400 (UVA, UVB, UVC)	J m^{-2}	eye cornea conjunctiva lens skin	photokeratitis photoconjunctivitis cataractogenesis erythema elastosis skin cancer	Yes, if source emits UVR
b	315–400 (UVA)	J m^{-2}	eye lens	cataractogenesis	Yes, if source emits UVR
c	300–700 (Blue Light) (where α ≥ 11 mrad and t ≤ 10 000 s)	W m^{-2} sr^{-1}	eye retina	photoretinitis	No, worst case would be for longest exposure.
d	300–700 (Blue Light) (where α ≥ 11 mrad and t > 10 000 s)	W m^{-2} sr^{-1}			Yes, if source emits in visible region. This limit covers a worst-case exposure of 8 hours.
e	300–700 (Blue Light) (where α < 11 mrad and t ≤ 10 000 s)	W m^{-2}			Not often, as common sources are usually quite large.
f	300–700 (Blue Light) (where α < 11 mrad and t > 10 000 s)	W m^{-2}			
g	380–1 400 (visible and IRA) (for t > 10 s)	W m^{-2} sr^{-1}	eye retina	retinal burn	Yes, if source emits in visible region. This limit covers a worst-case exposure of 8 hours.
h	380–1 400 (visible and IRA) (for t 10 µs to 10 s)	W m^{-2} sr^{-1}			No, worst case is for longest exposure.
i	380–1 400 (visible and IRA) (for t < 10 µs)	W m^{-2} sr^{-1}			
j	780–1 400 (IRA) (for t > 10 s)	W m^{-2} sr^{-1}	eye retina	retinal burn	Not often, as common sources usually emit visible radiation which makes limits g, h and I more appropriate.
k	780–1 400 (IRA) (for t 10 µs to 10 s)	W m^{-2} sr^{-1}			
l	780 –1 400 (IRA) (for t < 10 µs)	W m^{-2} sr^{-1}			
m	780–1 400 (IRA, IRB) (for t ≤ 1 000 s)	W m^{-2}	eye cornea lens	corneal burn	
n	780–3 000 (IRA, IRB) (for t > 1 000 s)	W m^{-2}			
o	380–3 000 (visible, IRA, IRB)	J m^{-2}	skin	burn	Not often, as this is only a concern for powerful heat generating industrial sources.

Therefore, we are usually concerned to apply exposure limits a and b (if the source emits UVR), and/or limits d and g (if the source emits visible and IRA).

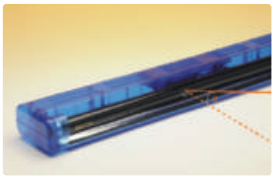
In exceptional circumstances, other exposure limits may be appropriate, for example exposure limit c is used if exposure limit d is likely to be broken; exposure limit h is used if exposure limit g is likely to be broken. Such circumstances will only become apparent as the risk assessment progresses.

These exposure limits involve the use of spectral weighting curves S(λ), B(λ) and R(λ). These factors are explained in section 5.2. Their use implies that spectral data will be required.

Geometric factors

If the source emits visible and/or IRR, the appropriate exposure limits and radiometric quantities will depend on geometric factors which must be calculated. Some of these factors are defined in the Directive, and others are explained in EN 62471 (2008). If the source only emits UVR, these factors are all irrelevant.

The geometric factors are:



- θ (angle between perpendicular to source surface and line-of-sight used for measurement), (see diagram, right)
- Z (mean dimension of source)
- α (angle subtended by the source)
- C_α (factor dependent on α),
- ω (solid angle subtended by the source).

Before calculating any of these factors, it is important to note whether the source emits a relatively spatially homogenous field or not. If the source is homogenous, any dimensions (length, width, etc.) should be understood to refer to the entire source area. If the source is obviously not homogenous (such as a bright lamp in front of a poor reflector), these dimensions should be taken as being of the brightest area only. Where a source comprises two or more identical emitters, each can be treated as a separate source contributing a pro rata quantity of the measured emissions.

To calculate Z:

apparent length, l, of source = actual length × cosθ

apparent width, w, of source = actual width × cosθ

Z is the average of l and w

Note that:

- if the source is viewed perpendicularly to its surface, cosθ = 1
- if the source is circular and viewed at 90°, Z is equal to the diameter

The apparent area, A, of the source is equal to:

The actual area × cos θ (for a circular source), or

l × w for other sources

If the distance to the source = r, and if all dimensions have been measured in the same units, then:

α = Z/r, in radians (rad)

$\omega = A/r^2$, in steradians (sr)

C_α is based on α, and is used solely to calculate a value for the Retinal Thermal hazard exposure limits. As all assessments here are based on simplifying assumptions explained below, C_α is not calculated.

Preliminary assessment

According to the body which developed the exposure limits, ICNIRP, there is no need to carry out a full spectral assessment for retinal hazards from a 'white light' general lighting source which has a luminance < 10_4 cd m^{-2}. This is stated to cover unfiltered incandescent, fluorescent and arc lamps.

This guidance limit will not serve to assess risks from ultraviolet radiation emissions. However, it can be used to decide whether it is necessary to fully assess the risks from visible and IRR emissions, or not.

To apply this guidance limit, the spectral irradiance from 380–760 nm can be weighted by the CIE photopic spectral efficacy curve, V(λ), and then summed to calculate the photopic effective irradiance, Ev. This is expressed in W m^{-2} and then multiplied by a standard luminous efficacy factor of 683 lm W^{-1}, which gives the illuminance, in lux. The luminance is equal to illuminance divided by ω.

However, it should be noted that it is not necessary to make spectral measurements in order to find out the illuminance of a luminaire — any well-designed and calibrated 'lux meter' should be capable of determining this value. This makes the preliminary assessment quick and easy to apply.

Data required

Generally speaking, it will be necessary to find data that cover the complete spectral range of all exposure limits which are to be applied. At worst, this would seem to require data extending from 180 nm to 1 400 nm.

The spectral range over which data are required can be reduced. This is obvious when a particular exposure limit does not apply: if a source does not emit UVR, then only data from 400 nm to 1 400 nm are needed.

It is also possible that a source is known to have zero emissions in a particular spectral region. For example:

- LEDs often emit in a fairly narrow spread of wavelengths. If a green LED were to be assessed, it may be sufficient to only measure from about 400 nm to about 600 nm, with data beyond this range assumed to be zero;
- sources which emit below 254 nm are very rare, and not likely to be encountered in most workplaces;
- many luminaires have glass covers which will prevent emissions below about 350 nm;
- apart from incandescent sources, most common sources will have negligible IRR emissions.

In any case, once the spectral range of the data has been decided, the data must be acquired (by measurement or other means). The most useful data will be spectral irradiance. These data can be weighted using the functions (S (λ), B (λ), R (λ) and possibly V(λ)) appropriate to the exposure limits to be used. Weighted data should then be summed.

Simplifying assumptions

These assumptions have been used to simplify the measurement and assessment process in the visible spectral region. They are not necessary if the only hazard under consideration is from UVR emissions.

Any spectral irradiance measurements must be made with an appropriate instrument: for exposure limits concerning the retina, the instrument must have a field of view which is limited to specific values of γ, depending on the expected exposure duration. For exposure limit d, this expected duration will be 8 hours. For exposure limit g, the maximum exposure duration which need be considered is 10 seconds, as the limit is constant above this duration.

Table 2.5 of the Directive gives the appropriate values of γ:

- γ = 110 mrad for retinal photochemical hazard exposure limits (i.e. limit d for 10 000 s exposures).
- γ = 11 mrad for Retinal Thermal hazard exposure limits (i.e. limit g for 10 s exposures).

These field-of-view requirements might seem to require multiple sets of measurements. However, if the actual source subtends an angle which is larger than γ, measuring with an unrestricted field of view will collect more of the irradiance and so err on the side of caution for risk assessment purposes. This allows all calculations to be carried out on the basis of a single set of measurement data made with an unrestricted field-of-view.

In order to calculate radiance from irradiance data, the irradiance should be divided by a solid angle. This solid angle should be either the actual value of ω, or a value based on γ, whichever is larger.

- For exposure limit d, the field-of-view should have been γ=110 mrad, which corresponds to a solid angle of = 0.01 sr.
- For exposure limit g the field-of-view should have γ = 11 mrad, which corresponds to a solid angle of = 0.0001 sr.

In the examples below, these values will be referred to as:
ω = the true solid angle subtended by the source
ω_B = 0.01 sr or ω, whichever is larger
ω_R = 0.0001 sr or ω, whichever is larger

These simplifying assumptions might give artificially high results for non-homogenous sources which are larger than γ. If such a source is being assessed and the exposure limit appears to be exceeded, it may be desirable to repeat the measurements with the field-of-view actually limited to an appropriate value of γ.

Comparison with exposure limits

Limit a
The exposure limit is $H_{eff} = 30$ J m^{-2}
If the effective irradiance, E_{eff} , is expressed in W m^{-2}, then the maximum permissible exposure (MPE) time, in seconds, = 30 J m^{-2}/E_{eff}.
If this is > 8 hours, there is no risk that the exposure limit will be exceeded at distance r
Limit b
The exposure limit is $H_{UVA} = 10^4$ J m^{-2}
If the effective irradiance, E_{UVA} , is expressed in W m^{-2} then the maximum permissible exposure (MPE) time, in seconds, = 10^4 J m^{-2}/E_{UVA}
If this is > 8 hours, there is no risk that the exposure limit will be exceeded at distance r
Limit d
The exposure limit is 100 W m^{-2} sr^{-1}
If the effective radiance, L_B, is less than the exposure limit, there is no risk that the exposure limit will be exceeded. This applies to all distances, so long as θ remains the same.
Limit g
The exposure limit is $2.8 \times 10^7/C_\alpha$. In this case, C_α. depends upon α. The most restrictive exposure limit comes when α ≥ 100 mrad. In this case, C_α = 100 mrad and the exposure limit is 280 000 W m^{-2} sr^{-1}
If the effective radiance, L_R, is less than the exposure limit, there is no risk that the exposure limit will be exceeded. This applies to all distances, so long as θ remains the same.

If the exposure limits are exceeded

ICNIRP luminance limit
If the source luminance exceeds 10^4 cd m^{-2}, the assessment must be repeated with sufficient data to allow for comparison with exposure limits d and g.
Limit a
If the MPE time is < 8 hours, it will be necessary to demonstrate that actual personal occupancy at r is less than the MPE time.
Limit b
If the MPE time is < 8 hours, it will be necessary to demonstrate that actual personal occupancy at r is less than the MPE time. In this case, occupancy can exclude any time spent with the face oriented away from the source.
If the source is very bright, it may be assumed that the aversion response will limit exposure episodes to 0.25 seconds.
Limit d
If L_B is greater than the exposure limit, an MPE time should be calculated. This is based on exposure limit c.
Exposure limit c is $L_B \leq 10^6/t$. Therefore the MPE time (in seconds), $t_{max} \leq 10^6/L_B$. It will then be necessary to demonstrate that actual personal occupancy along line-of-sight θ is less than t_{max}. In this case, occupancy can exclude any time spent with the face oriented away from the source.
If the source is very bright, it may be assumed that the aversion response will limit exposure episodes to 0.25 seconds.
Exposure limit e may also be used: the relationships α = Z/r and $L_B = E_B/\omega$ should be used to calculate a distance at which α = 11 mrad. If, at this or any greater distance, $E_B \leq 10$ mW m^{-2}, then the exposure limits are not exceeded beyond this point.
Limit g
If L_R is greater than the exposure limit, then the exposure limit may have been too restrictive: if the source actually subtended α < 100 mrad, recalculate the exposure limit.
If L_R is still greater than the new exposure limit an MPE time should be calculated. This is based on exposure limit h.
Exposure limit h is $L_R \leq 5 \times 10^7/c_\alpha t^{0.25}$. Therefore the MPE time (in seconds), $t_{max} \leq (5 \times 10^7/c_\alpha L_R)^4$. Use $c_\alpha = \alpha$. It will then be necessary to demonstrate that actual personal occupancy along line-of-sight θ is less than t_{max}. In this case, occupancy can exclude any time spent with the face oriented away from the source.
If the source is very bright, it may be assumed that the aversion response will limit exposure episodes to 0.25 seconds.

D.1.2. Format of examples

The worked examples below have been set out in a series of steps similar to that used above. In cases where a simplifying assumption has been made, the example has still been worked out in full, but steps that should not be required if the assumptions are accepted have been shown in grey, thus allowing the applicability of any initial assumptions to be demonstrated.

A summary of the results of these examples is presented at the end of this appendix.

D.1.3. Ceiling-mounted fluorescent lamps behind a diffuser

A bank of 3 × 36 W fluorescent general lighting lamps are mounted in a ceiling luminaire which measures 57.5 cm × 117.5 cm. The luminaire has a plastic diffuser completely covering the lamps. This renders the source reasonably homogenous.

Choice of exposure limits

This type of lamp does not emit significant quantities of infrared radiation. Any hazard will arise from exposure to visible or ultraviolet wavelengths. Ultraviolet wavelengths will also be attenuated by the plastic diffuser. Only limit d applies.

Geometric factors

Spectral irradiance data will be measured at a distance of 100 cm from the lamp, looking directly at it.

The source has an average dimension of 87.5 cm.
Therefore $\alpha = 0.875$ rad.
The source has a surface area of 6 756 cm^2.
Therefore $\omega = 0.68$ sr.
Therefore $\omega_B = 0.68$ sr and $\omega_R = 0.68$ sr.

Preliminary assessment

The photopic effective irradiance was measured and is 1 477 mW m^{-2}. This equates to an illuminance of 1 009 lux.
The luminance of this source is therefore 1 009/0.68 = 1 484 cd m^{-2}.

No further assessment is necessary.

Radiometric data

Measured effective irradiance values are:
Effective irradiance $E_{eff} < 10$ µW m^{-2}
UVA irradiance, $E_{UVA} = 17$ mW m^{-2}
Effective irradiance (Blue Light), $E_B = 338$ mW m^{-2}
Effective irradiance (thermal injury), $E_R = 5\,424$ mW m^{-2}

Simplifying assumptions

Effective radiance (Blue Light), $L_B = 338$ mW m^{-2}/0.68 sr = 0.5 W m^{-2} sr^{-1}
Effective radiance (thermal injury), L_R = 5 424 mW m^{-2}/0.68 sr = 8 W m^{-2} sr^{-1}

Comparison with exposure limits

Limit a				
The exposure limit is $H_{eff} = 30$ J m^{-2}	→	$E_{eff} < 10$ µW m^{-2}	→	The MPE time is > 8 hours
Limit b				
The exposure limit is $H_{UVA} = 10^4$ J m^{-2}	→	$E_{UVA} = 17$ mW m^{-2}	→	The MPE time is > 8 hours
Limit d				
The exposure limit is 100 W m^{-2} sr^{-1}	→	$L_B = 0.5$ W m^{-2} sr^{-1}	→	The exposure limit is not exceeded
Limit g				
The exposure limit is 280 kW m^{-2} sr^{-1}	→	$L_R = 8$ W m^{-2} sr^{-1}	→	The exposure limit is not exceeded

D.1.4. A single ceiling-mounted fluorescent lamp with no diffuser

A 153 cm × 2 cm 58 W fluorescent general lighting lamp is mounted in a 153 cm × 13 cm ceiling luminaire which incorporates reflectors behind the lamp and is open fronted. The source is not homogenous, and the lamp is the brightest part of it.

Also see example D.1.5.

Choice of exposure limits

This type of lamp does not emit significant quantities of infrared radiation. Any hazard will arise from exposure to visible or ultraviolet wavelengths. Limits a, b and d apply.

Geometric factors

Spectral irradiance data will be measured at a distance of 100 cm from the lamp, looking directly at it.

The lamp has an average dimension of 77.5 cm.
Therefore α = 0.775 rad.
The lamp has a surface area of 306 cm^2.
Therefore ω = 0.03 sr.
ω_B = 0.03 sr and ω_R = 0.03 sr.

Preliminary assessment

The photopic effective irradiance was measured and is 1 640 mW m^{-2}. This equates to an illuminance of 1 120 lux.
The luminance of this source is therefore 1 120/0.03 = 37 333 cd m^{-2}.
Further assessment of retinal hazard seems to be necessary. UVR must also be assessed.

Radiometric data

Measured effective irradiance values are:
Effective irradiance E_{eff} = 600 µW m^{-2}
UVA irradiance, E_{UVA} = 120 mW m^{-2}
Effective irradiance (Blue Light), E_B = 561 mW m^{-2}
Effective irradiance (thermal injury), E_R = 7 843 mW m^{-2}

Simplifying assumptions

Effective radiance (Blue Light), L_B = 561 mW m^{-2}/0.03 sr = 19 W m^{-2} sr^{-1}
Effective radiance (thermal injury), L_R = 7 843 mW m^{-2}/0.03 sr = 261 W m^{-2} sr^{-1}

Comparison with exposure limits

Limit a			
The exposure limit is H^{eff} = 30 J m^{-2}	→	E_{eff} = 600 µW m^{-2}	→ The MPE time is > 8 hours
Limit b			
The exposure limit is H_{UVA} = 10^4 J m^{-2}	→	E_{UVA} = 120 mW m^{-2}	→ The MPE time is > 8 hours
Limit d			
The exposure limit is 100 W m^{-2} sr^{-1}	→	L_B = 19 W m^{-2} sr^{-1}	→ The exposure limit is not exceeded
Limit g			
The exposure limit is 280 kW m^{-2} sr^{-1}	→	L_R = 261 W m^{-2} sr^{-1}	→ The exposure limit is not exceeded

D.1.5. A bank of ceiling-mounted fluorescent lamps with no diffuser

Four 57 cm × 2 cm 18 W fluorescent general lighting lamps are mounted in a 57 cm × 57 cm ceiling luminaire which incorporates reflectors behind each lamp and is open fronted. This is very similar to the luminaire seen in example D.1.4, except that the lamps are from a different manufacturer. The source is not homogenous, with the four lamps being the brightest emitters.

Choice of exposure limits

This type of lamp does not emit significant quantities of infrared radiation. Any hazard will arise from exposure to visible or ultraviolet wavelengths. Limits a, b and d apply.

Geometric factors

Spectral irradiance data will be measured at a distance of 100 cm from the lamp, looking directly at it.

Each lamp has an average dimension of 29.5 cm.
Therefore $\alpha = 0.295$ rad.
Each lamp has a surface area of 114 cm^2.
Therefore $\omega = 0.011$ sr.
$\omega_B = 0.011$ sr and $\omega_R = 0.011$ sr.

Preliminary assessment

The photopic effective irradiance was measured and is 1 788 mW m^{-2}. This was from four lamps: as each lamp is a separate visual source, each contributes 447 mW m^{-2} to the total. This equates to an illuminance of 305 lux per lamp.

The luminance of each Vlamp is therefore 305/0.011 = 28 000 cd m^{-2}.

Further assessment of retinal hazard is necessary. UVR must also be assessed.

Radiometric data

Measured effective irradiance values are:
Effective irradiance $E_{eff} = 1.04$ mW m^{-2}
UVA irradiance, $E_{UVA} = 115$ mW m^{-2}
Effective irradiance (Blue Light), $E_B = 555$ mW m^{-2} = 139 mW m^{-2} per lamp

Effective irradiance (thermal injury), $E_R = 8\,035$ mW m^{-2} = 2 009 mW m^{-2} per lamp

Simplifying assumptions

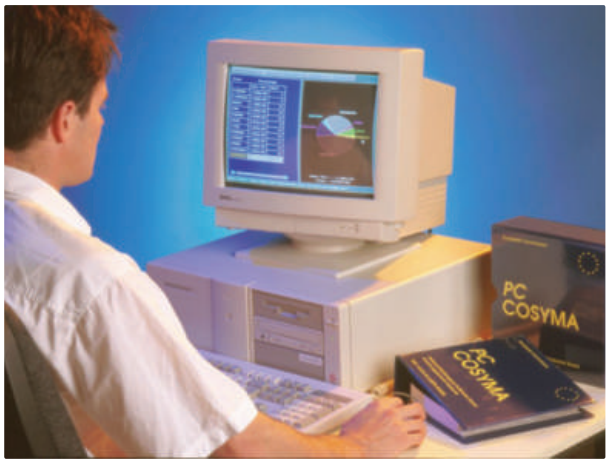
Effective radiance (Blue Light), $L_B = 139$ mW m^{-2}/0.011 sr = 13 W m^{-2} sr^{-1}

Effective radiance (thermal injury), L_R = 2 009 mW m^{-2}/0.011 sr = 183 W m^{-2} sr^{-1}

Comparison with exposure limits

Limit a			
The exposure limit is $H_{eff} = 30$ J m^{-2}	→	$E_{eff} = 1.04$ mW m^{-2}	→ The MPE time is 8 hours. This is close to exceeding the exposure limit.
Although, in practice, continual exposure at 100 cm is unlikely, this exposure must be borne in mind if other UVR sources are present in the environment.			
Limit b			
The exposure limit is $H_{UVA} = 10^4$ J m^{-2}	→	$E_{UVA} = 115$ mW m^{-2}	→ The MPE time is > 8 hours
Limit d			
The exposure limit is 100 W m^{-2} sr^{-1}	→	$L_B = 13$ W m^{-2} sr^{-1}	→ The exposure limit is not exceeded
Limit g			
The exposure limit is 280 kW m^{-2} sr^{-1}	→	$L_R = 183$ W m^{-2} sr^{-1}	→ The exposure limit is not exceeded

D.1.6. A cathode ray tube visual display unit



A desktop personal computer has a visual display unit incorporating a cathode ray tube.

Choice of exposure limits

Cathode ray tubes do not emit significant quantities of ultraviolet or infrared radiation. Any hazard will arise from exposure to visible wavelengths. Limit d applies.

Geometric factors

The VDU mixes three primary colours to produce colour images. The worst case will be when all three primary colours are present — a white image. Spectral irradiance data will be measured at a distance of 10 cm from a homogenous white rectangle, looking directly at it.

The source has an average dimension of 17 cm.
Therefore $\alpha = 1.7$ rad
The source has a surface area of 250 cm^2.
Therefore $\omega = 2.5$ sr.
Therefore $\omega_B = 2.5$ sr and $\omega_R = 2.5$ sr.

Preliminary assessment

The photopic effective irradiance was measured and is 64 mW m^{-2}. This equates to an illuminance of 43 lux.
The luminance of this source is therefore 43/2.5 = 17 cd m^{-2}.
No further assessment is necessary.

Radiometric data

Measured effective irradiance values are:
Effective irradiance $E_{eff} = 130$ µW m^{-2}
UVA irradiance, $E_{UVA} = 8$ mW m^{-2}
Effective irradiance (Blue Light), $E_B = 61$ mW m^{-2}
Effective irradiance (thermal injury), $E_R = 716$ mW m^{-2}

Simplifying assumptions

Effective radiance (Blue Light), $L_B = 61$ mW m^{-2}/2.5 sr = 24 mW m^{-2} sr^{-1}
Effective radiance (thermal injury), $L_R = 716$ mW m^{-2}/2.5 sr = 286 mW m^{-2} sr^{-1}

Comparison with exposure limits

Limit a				
The exposure limit is $H_{eff} = 30$ J m^{-2}	→	$E_{eff} = 130$ µW m^{-2}	→	The MPE time is > 8 hours
Limit b				
The exposure limit is $H_{UVA} = 10^4$ J m^{-2}	→	$E_{UVA} = 8$ mW m^{-2}	→	The MPE time is > 8 hours
Limit d				
The exposure limit is 100 W m^{-2} sr^{-1}	→	$L_B = 24$ mW m^{-2} sr^{-1}	→	The exposure limit is not exceeded
Limit g				
The exposure limit is 280 kW m^{-2} sr^{-1}	→	$L_R = 286$ mW m^{-2} sr^{-1}	→	The exposure limit is not exceeded

D.1.7. A laptop computer display

A laptop personal computer has an LCD screen.

Choice of exposure limits

LCD displays do not emit significant quantities of ultraviolet or infrared radiation. Any hazard will arise from exposure to visible wavelengths. Limit d applies.

Geometric factors

The LCD mixes three primary colours to produce colour images. The worst case will be when all three primary colours are present — a white image. Spectral irradiance data will be measured at a distance of 10 cm from a homogenous white rectangle, looking directly at it.

The source has an average dimension of 13 cm.
Therefore $\alpha = 1.3$ rad
The source has a surface area of 173 cm^2.
Therefore $\omega = 1.7$ sr.
Therefore $\omega_B = 1.7$ sr and $\omega_R = 1.7$ sr.

Preliminary assessment

The photopic effective irradiance was measured and is 134 mW m^{-2}. This equates to an illuminance of 92 lux.
The luminance of this source is therefore 92/1.7 = 54 cd m^{-2}.
No further assessment is necessary.

Radiometric data

Measured effective irradiance values are:
Effective irradiance $E_{eff} = 70$ µW m^{-2}
UVA irradiance, $E_{UVA} = 4$ mW m^{-2}
Effective irradiance (Blue Light), $E_B = 62$ mW m^{-2}
Effective irradiance (thermal injury), $E_R = 794$ mW m^{-2}

Simplifying assumptions

Effective radiance (Blue Light), $L_B = 62$ mW $m^{-2}/1.7$ sr = 36 mW m^{-2} sr^{-1}
Effective radiance (thermal injury), $L_R =$ 794 mW $m^{-2}/1.7$ sr = 467 mW m^{-2} sr^{-1}

Comparison with exposure limits

Limit a				
The exposure limit is $H_{eff} = 30$ J m^{-2}	→	$E_{eff} = 70$ µW m^{-2}	→	The MPE time is > 8 hours
Limit b				
The exposure limit is $H_{UVA} = 10^4$ J m^{-2}	→	$E_{UVA} = 4$ mW m^{-2}	→	The MPE time is > 8 hours
Limit d				
The exposure limit is 100 W m^{-2} sr^{-1}	→	$L_B = 36$ mW m^{-2} sr^{-1}	→	The exposure limit is not exceeded
Limit g				
The exposure limit is 280 kW m^{-2} sr^{-1}	→	$L_R = 467$ mW m^{-2} sr^{-1}	→	The exposure limit is not exceeded

D.1.8. An outdoor area floodlight incorporating a metal halide lamp

A 70 W metal halide lamp is incorporated into a luminaire which also features a rear reflector, measuring 18 × 18 cm, and a transparent cover. It is intended to be mounted on building parapets and to illuminate the area below. The source is not homogenous — the brightest region is the arc itself, which has been estimated to be roughly spherical and about 5 mm across.

Choice of exposure limits

Any hazard will arise from exposure to visible or possibly to ultraviolet wavelengths. Metal halide lamps produce copious ultraviolet: this example has an outer envelope which may reduce emissions and the luminaire has a cover which will reduce emissions, but enough UVA may still be emitted to be of concern. Limits b, d and g apply.

Geometric factors

Spectral irradiance data will be measured at a distance of 100 cm from the lamp, looking directly at it.

The arc has an average dimension of 0.5 cm.
Therefore α = 0.005 rad. This is < 11 mrad, and so limit d may be replaced by limit f if fixated viewing of the source is intended. This is not the case here, and so limit d will be used for the assessment. See note 2 to Table 1.1 in the Directive.
The source has a surface area of 0.2 cm^2.
Therefore ω = 0.00002 sr.
Therefore ω_B = 0.01 sr and ω_R = 0.0001 sr.

Preliminary assessment

The photopic effective irradiance was measured and is 4 369 mW m^{-2}. This equates to an illuminance of 2 984 lux.
The luminance of this source is therefore 2 984/0.00002 = 149 000 000 cd m^{-2}.
Further assessment of retinal hazard is necessary, and potential UVR hazard remains to be assessed.

Radiometric data

Measured effective irradiance values are:

Effective irradiance E_{eff} = 110 µW m^{-2}

UVA irradiance, E_{UVA} = 915 mW m^{-2}
Effective irradiance (Blue Light), E_B = 2 329 mW m^{-2}
Effective irradiance (thermal injury), E_R = 30 172 mW m^{-2}

Simplifying assumptions

Effective radiance (Blue Light), L_B = 2 329 mW m^{-2}/0.01 sr = 233 W m^{-2} sr^{-1}
Effective radiance (thermal injury), L_R = 30 172 mW m^{-2}/0.0001 sr = 302 kW m^{-2} sr^{-1}

Comparison with exposure limits

Limit a			
The exposure limit is H_{eff} = 30 J m^{-2}	→	E_{eff} = 110 µW m^{-2}	→ The MPE time is > 8 hours
Limit b			
The exposure limit is H_{UVA} = 10^4 J m^{-2}	→	E_{UVA} = 915 mW m^{-2}	→ The MPE time is 3 hours
However, the intense brightness of the lamp is likely to limit each exposure episode to about 0.25 seconds.			
Limit d			
The exposure limit is 100 W m^{-2} sr^{-1}	→	L_B = 233 W m^{-2} sr^{-1}	→ The exposure limit is exceeded
Therefore, limit c should be used to calculate an MPE time.			
Limit c			
The exposure limit is $L_B < 10^6/t$ W m^{-2}	→	$t_{max} = 10^6/L_B$	→ The MPE time for this source is about 70 minutes
However, the intense brightness of the lamp is likely to limit each exposure episode to about 0.25 seconds. Note that if fixated viewing were intended, t_{max} based on limit e = 100/E_B, or about 40 seconds			
Limit g			
The exposure limit is 280 kW m^{-2} sr^{-1}	→	L_R = 302 kW m^{-2} sr^{-1}	→ The exposure limit is exceeded, based on the simplifying assumption that α > 0.1 rad
If we recalculate the exposure limit based on actual α (= 5 mrad), a more realistic exposure limit would be 5 600 kW m^{-2} sr^{-1}. In this case, the exposure limit is not exceeded.			

D.1.9. An outdoor area floodlight incorporating a compact fluorescent lamp

A 26 W compact fluorescent lamp, measuring 3 × 13 cm is incorporated into a luminaire which also features a crude rear reflector and a transparent cover. It is intended to be mounted on building parapets and to illuminate the area below. The lamp is the strongest emitter in this non-homogenous source.

Choice of exposure limits

This type of lamp does not emit significant quantities of infrared radiation. Any hazard will arise from exposure to visible or ultraviolet wavelengths. Ultraviolet wavelengths will also be attenuated by the plastic diffuser. Limit d applies.

Geometric factors

Spectral irradiance data will be measured at a distance of 100 cm from the lamp, looking directly at it.

The source has an average dimension of 8 cm.
Therefore α = 0.08 rad.
The source has a surface area of 39 cm^2.
Therefore ω = 0.0039 sr.
Therefore ω_B = 0.01 sr and ω_R = 0.0039 sr.

Preliminary assessment

The photopic effective irradiance was measured and is 366 mW m^{-2}. This equates to an illuminance of 250 lux.
The luminance of this source is therefore 250/0.0039 = 64 000 cd m^{-2}.
Further assessment of retinal hazard is necessary.

Radiometric data

Measured effective irradiance values are:

Effective irradiance E_{eff} = 10 µW m^{-2}
UVA irradiance, E_{UVA} = 2 mW m^{-2}

Effective irradiance (Blue Light), E_B = 149 mW m^{-2}

Effective irradiance (thermal injury), E_R = 1 962 mW m^{-2}

Simplifying assumptions

Effective radiance (Blue Light), L_B = 149 mW m^{-2}/0.01 sr = 15 W m^{-2} sr^{-1}

Effective radiance (thermal injury), L_R = 1 962 mW m^{-2}/0.0039 sr = 503 W m^{-2} sr^{-1}

Comparison with exposure limits

Limit a				
The exposure limit is H_{eff} = 30 J m^{-2}	→	E_{eff} = 10 µW m^{-2}	→	The MPE time is > 8 hours
Limit b				
The exposure limit is H_{UVA} = 10^4 J m^{-2}	→	E_{UVA} = 2 mW m^{-2}	→	The MPE time is > 8 hours
Limit d				
The exposure limit is 100 W m^{-2} sr^{-1}	→	L_B = 15 W m^{-2} sr^{-1}	→	The exposure limit is not exceeded
Limit g				
The exposure limit is 280 kW m^{-2} sr^{-1}	→	L_R = 503 W m^{-2} sr^{-1}	→	The exposure limit is not exceeded

D.1.10. An electronic insect killer

Electronic Insect Killers (EIKs) often use low pressure mercury discharge lamps, emitting in the UVA and blue parts of the spectrum, to lure flying insects onto a high-tension grid. This example consumes 25 W and incorporates two lamps, each 26 × 1 cm, mounted 10 cm apart in the horizontal plane.

Choice of exposure limits

EIKs should conform to product standard EN 60335-2-59, which specifies that the UVReff irradiance at 1 m should be ≤ 1 mW m^{-2}. Hence, there is no need to consider limit a. Limit b will still apply. As this is not a white light source, use of luminance as a control measure is not appropriate. However, EIKs typically produce little visual stimulus, therefore there should be no need to consider retinal hazards.

Geometric factors

Spectral irradiance data will be measured at a distance of 100 cm from the EIK. As the EIK is wall-mounted, it will be measured from approximately head height. Hence the detector will be looking up at the EIK at an angle of approx 30° from horizontal. As the lamps in the EIK are circular in cross section, it is still possible to assume that they are being viewed at 90° relative to their surfaces.

Each lamp has an average dimension of 13.5 cm.

Therefore α = 0.135 rad.

Each lamp has an apparent surface area of 26 cm^2.

Therefore ω = 0.0026 sr.

Therefore ω_B = 0.01 sr and ω_R = 0.0026 sr.

Radiometric data

Measured effective irradiance values are:

Effective irradiance E_{eff} = 10 µW m^{-2}

UVA irradiance, E_{UVA} = 34 mW m^{-2}

Effective irradiance (Blue Light), E_B = 17 mW m^{-2} = 8.5 mW m^{-2} per lamp

Effective irradiance (thermal injury), E_R = 172 mW m^{-2} = 86 mW m^{-2} per lamp

Simplifying assumptions

Effective radiance (Blue Light), L_B = 8.5 mW m^{-2}/0.01 sr = 0.85 W m^{-2} sr^{-1}

Effective radiance (thermal injury), L_R = 86 mW m^{-2}/0.0026 sr = 33 W m^{-2} sr^{-1}

Comparison with exposure limits

Limit a				
The exposure limit is H_{eff} = 30 J m^{-2}	→	E_{eff} = 10 µW m^{-2}	→	The MPE time is > 8 hours
Limit b				
The exposure limit is H_{UVA} = 10^4 J m^{-2}	→	E_{UVA} = 34 mW m^{-2}	→	The MPE time is > 8 hours
Limit d				
The exposure limit is 100 W m^{-2} sr^{-1}	→	L_B = 0.85 W m^{-2} sr^{-1}	→	The exposure limit is not exceeded
Limit g				
The exposure limit is 280 kW m^{-2} sr^{-1}	→	L_R = 33 W m^{-2} sr^{-1}	→	The exposure limit is not exceeded

D.1.11. A ceiling-mounted spotlight

A ceiling-mounted spotlight incorporates a 50 W tungsten halogen lamp in a sealed luminaire with a dichroic reflector and a glass front cover. The sealed luminaire has a diameter of 4 cm. When lit, the source appears homogenous.

Choice of exposure limits

Any hazard will arise from exposure to visible wavelengths (tungsten halogen lamps produce some ultraviolet, but this example has a front cover which will reduce emissions). Limits d and g apply.

Geometric factors

Spectral irradiance data will be measured at a distance of 100 cm from the lamp, looking directly at it.

The source has an average dimension of 4 cm.
Therefore $\alpha = 0.04$ rad.
The source has a surface area of 13 cm^2.
Therefore $\omega = 0.001$ sr.
Therefore $\omega_B = 0.01$ sr and $\omega_R = 0.001$ sr.

Preliminary assessment

The photopic effective irradiance was measured and is 484 mW m^{-2}. This equates to an illuminance of 331 lux.
The luminance of this source is therefore 331/0.001 = 331 000 cd m^{-2}.
Further assessment of retinal hazard is necessary.

Radiometric data

Measured effective irradiance values are:

Effective irradiance $E_{eff} = 30$ µW m^{-2}
UVA irradiance, $E_{UVA} = 12$ mW m^{-2}

Effective irradiance (Blue Light), $E_B = 129$ mW m^{-2}
Effective irradiance (thermal injury), $E_R = 2\,998$ mW m^{-2}

Simplifying assumptions

Effective radiance (Blue Light), $L_B = 129$ mW m^{-2}/0.01 sr = 12.9 W m^{-2} sr^{-1}
Effective radiance (thermal injury), L_R = 2 998 mW m^{-2}/0.001 sr = 2 998 W m^{-2} sr

Comparison with exposure limits

Limit a				
The exposure limit is $H_{eff} = 30$ J m^{-2}	→	$E_{eff} = 30$ µW m^{-2}	→	The MPE time is > 8 hours
Limit b				
The exposure limit is $H_{UVA} = 10^4$ J m^{-2}	→	$E_{UVA} = 12$ mW m^{-2}	→	The MPE time is > 8 hours
Limit d				
The exposure limit is 100 W m^{-2} sr^{-1}	→	$L_B = 12.9$ W m^{-2} sr^{-1}	→	The exposure limit is not exceeded
Limit g				
The exposure limit is 280 kW m^{-2} sr^{-1}	→	$L_R = 2\,998$ W m^{-2} sr^{-1}	→	The exposure limit is not exceeded

D.1.12. A desk-mounted task light

A desk-mounted task light incorporates a standard tungsten lamp in an open-fronted luminaire. The luminaire has a diameter of 17 cm. The 60 W lamp, which has a diffuse finish, has a diameter of 5.5 cm. The source is not homogenous, with the lamp being a stronger emitter than the reflector.

Choice of exposure limits

Any hazard will arise from exposure to visible wavelengths (tungsten filaments produce some ultraviolet emissions, but the glass envelope will act as a filter). Limits d and g apply.

Geometric factors

Spectral irradiance data will be measured at a distance of 50 cm from the lamp, looking directly at it.

The source has an average dimension of 5.5 cm.
Therefore $\alpha = 0.11$ rad.
The source has a surface area of 24 cm^2.
Therefore $\omega = 0.0096$ sr.
Therefore $\omega_B = 0.01$ sr and $\omega = 0.0096$ sr.

Preliminary assessment

The photopic effective irradiance was measured and is 522 mW m^{-2}. This equates to an illuminance of 357 lux.
The luminance of this source is therefore 357/0.006 = 37 188 cd m^{-2}.
Further assessment of retinal hazard is necessary.

Radiometric data

Measured effective irradiance values are:

Effective irradiance, $E_{eff} = 50$ µW m^{-2}
UVA irradiance, $E_{UVA} = 18$ mW m^{-2}

Effective irradiance (Blue Light), $E_B = 92$ mW m^{-2}
Effective irradiance (thermal injury), $E_R = 4\,815$ mW m^{-2}

Simplifying assumptions

Effective radiance (Blue Light), $L_B = 92$ mW $m^{-2}/0.1$ sr = 0.92 W m^{-2} sr^{-1}
Effective radiance (thermal injury), L_R = 4 815 mW $m^{-2}/0.0096$ sr = 501 W m^{-2} sr^{-1}

Comparison with exposure limits

Limit a				
The exposure limit is $H_{eff} = 30$ J m^{-2}	→	$E_{eff} = 50$ µW m^{-2}	→	The MPE time is > 8 hours
Limit b				
The exposure limit is $H_{UVA} = 10^4$ J m^{-2}	→	$E_{UVA} = 18$ mW m^{-2}	→	The MPE time is > 8 hours
Limit d				
The exposure limit is 100 W m^{-2} sr^{-1}	→	$L_B = 0.92$ W m^{-2} sr^{-1}	→	The exposure limit is not exceeded
Limit g				
The exposure limit is 280 kW m^{-2} sr^{-1}	→	$L_R = 501$ W m^{-2} sr^{-1}	→	The exposure limit is not exceeded

D.1.13. A 'daylight spectrum' desk-mounted task light

A desk-mounted task light incorporates a 60 W tungsten lamp in an open-fronted luminaire. The lamp is tinted to emulate the colour properties of natural daylight, but does not have a diffusely transmitting surface finish. The luminaire has a diameter of 14 cm. The source is not homogenous. When the lamp is lit, its filament stands out clearly. It is difficult to describe the dimensions of the filament, but it is approximately 3 cm long and 0.5 mm diameter.

Choice of exposure limits

Any hazard will arise from exposure to visible wavelengths (tungsten filaments produce some ultraviolet emissions, but the glass envelope will act as a filter). Limits d and g apply.

Geometric factors

Spectral irradiance data will be measured at a distance of 50 cm from the lamp, looking directly at it.

The filament has an average dimension of 1.5 cm.
Therefore $\alpha = 0.03$ rad.
The filament has a surface area of 0.15 cm^2.
Therefore $\omega = 0.00006$ sr.
Therefore $\omega_B = 0.01$ sr and $\omega_R = 0.0001$ sr.

Preliminary assessment

The photopic effective irradiance was measured and is 559 mW m^{-2}. This equates to an illuminance of 383 lux.
The luminance of this source is therefore 383/0.00006 = 6 000 000 cd m^{-2}.
Further assessment of retinal hazard is necessary.

Radiometric data

Measured effective irradiance values are:

Effective irradiance, E_{eff} = 110 µW m^{-2}
UVA irradiance, E_{UVA} = 26 mW m^{-2}

Effective irradiance (Blue Light), E_B = 138 mW m^{-2}
Effective irradiance (thermal injury), E_R = 5 172 mW m^{-2}

Simplifying assumptions

Effective radiance (Blue Light), L_B = 138 mW m^{-2}/0.01 sr = 14 W m^{-2} sr^{-1}
Effective radiance (thermal injury), L_R = 5 172 mW m^{-2}/0.0001 sr = 52 kW m^{-2} sr^{-1}

Comparison with exposure limits

Limit a				
The exposure limit is H_{eff} = 30 J m^{-2}	→	E_{eff} = 110 µW m^{-2}	→	The MPE time is > 8 hours
Limit b				
The exposure limit is H_{UVA} = 10^4 J m^{-2}	→	E_{UVA} = 26 mW m^{-2}	→	The MPE time is > 8 hours
Limit d				
The exposure limit is 100 W m^{-2} sr^{-1}	→	L_B = 14 W m^{-2} sr^{-1}	→	The exposure limit is not exceeded
Limit g				
The exposure limit is 280 kW m^{-2} sr^{-1}	→	L_R = 52 kW m^{-2} sr^{-1}	→	The exposure limit is not exceeded

D.1.14. A photocopier

A photocopier incorporates a scanning light source in the form of two illuminated strips. These strips are 21 cm long and are mounted 1.5 cm apart. They can be seen on the left of the photocopier cover glass in the figure right. Each illuminated strip is approximately 3 mm across.

Choice of exposure limits

Any hazard will arise from exposure to visible wavelengths (the cover glass should reduce any ultraviolet emissions). Limits d and g apply.

Geometric factors

Spectral irradiance data will be measured at a distance of 30 cm from the cover glass. The distance between the cover glass and the optical radiation source is negligible. Measurements will be made looking directly at the source: this is pessimistic, as human exposure is likely to be at an angle.

Each source has an average dimension of 10.7 cm.
Therefore α = 0.36 rad.
Each source has a surface area of 6.3 cm^2.
Therefore ω = 0.007 sr.
Therefore ω_B = 0.01 sr and ω_R = 0.007 sr.

Preliminary assessment

The photopic effective irradiance was measured and is 197 mW m^{-2}. This was from two strips: as each strip is a separate visual source, each contributes 98.5 mW m^{-2} to the total. This equates to an illuminance of 67 lux per lamp.
The luminance of this source is therefore 67/0.007 = 9 643 cd m^{-2}.
No further assessment is necessary.

Radiometric data

Measured effective irradiance values are:

Effective irradiance, E_{eff} = 10 µW m^{-2}
UVA irradiance, E_{UVA} = 22 mW m^{-2}
Effective irradiance (Blue Light), E_B = 124 mW m^{-2} = 62 mW m^{-2} per strip
Effective irradiance (thermal injury), E_R = 1 606 mW m^{-2} = 803 mW m^{-2} per strip

Simplifying assumptions

Effective radiance (Blue Light), L_B = 62 mW m^{-2}/0.01 sr = 6.2 W m^{-2} sr^{-1}
Effective radiance (thermal injury), L_R = 803 mW m^{-2}/0.007 sr = 115 W m^{-2} sr^{-1}

Comparison with exposure limits

Limit a				
The exposure limit is H_{eff} = 30 J m^{-2}	→	E_{eff} =10 µW m^{-2}	→	The MPE time is > 8 hours
Limit b				
The exposure limit is H_{UVA} = 10^4 J m^{-2}	→	E_{UVA} = 22 mW m^{-2}	→	The MPE time is > 8 hours
Limit d				
The exposure limit is 100 W m^{-2} sr^{-1}	→	L_B = 6.2 W m^{-2} sr^{-1}	→	The exposure limit is not exceeded
Limit g				
The exposure limit is 280 kW m^{-2} sr^{-1}	→	L_R = 115 W m^{-2} sr^{-1}	→	The exposure limit is not exceeded

D.1.15. A desktop digital data projector

A 150 W data projector has a front projection lens with a diameter of 4.7 cm.

See also example D.1.16.

The projector creates images by mixing the three colours. The worst case should be when all colours are present — i.e. a white image being projected. A graphics software package can be used to create a blank white image. Spectral irradiance data will be measured at a distance of 200 cm from the projector, with the projector focused to produce the smallest possible sharp image at that distance. The projector lens has an apparent diameter of 4.7 cm. However, when in use the lens does not appear to be homogenously illuminated. The main illuminated area is about 3 cm across.

Choice of exposure limits

This type of source does not emit measurable quantities of ultraviolet or infrared, and so any hazard will arise from exposure to visible wavelengths. Exposure limits d and g apply.

Geometric factors

The three primary colours are mixed to produce colour images. The worst case will be when all three primary colours are present — a white image. Spectral irradiance data will be measured at a distance of 200 cm from the lamp, looking directly at it.

The source has an average dimension of 3 cm.
Therefore $\alpha = 0.02$ rad.
The source has a surface area of 7 cm^2.
Therefore $\omega = 0.0001$ sr.
Therefore $\omega_B = 0.01$ sr and $\omega_R = 0.0001$ sr.

Preliminary assessment

The photopic effective irradiance was measured and is 2 984 mW m^{-2}. This equates to an illuminance of 2 038 lux.
The luminance of this source is therefore 2 038/0.0001 = 20 000 000 cd m^{-2}.

Further assessment of retinal hazard is necessary.

Radiometric data

Measured effective irradiance values are:

Effective irradiance, $E_{eff} = 30$ µW m^{-2}
UVA irradiance, $E_{UVA} = 1.0$ mW m^{-2}

Effective irradiance (Blue Light), $E_B = 2\,237$ mW m^{-2}
Effective irradiance (thermal injury), $E_R =$ 24 988 mW m^{-2}

Simplifying assumptions

Effective radiance (Blue Light), $L_B = 2\,237$ mW m^{-2}/0.01 msr = 224 W m^{-2} sr^{-1}
Effective radiance (thermal injury), $L_R =$ 24 988 mW m^{-2}/0.0001 msr = 250 kW m^{-2} sr^{-1}

Comparison with exposure limits

Limit a				
The exposure limit is $H_{eff} = 30$ J m^{-2}	→	$E_{eff} = 30$ µW m^{-2}	→	The MPE time is > 8 hours
Limit b				
The exposure limit is $H_{UVA} = 10^4$ J m^{-2}	→	$E_{UVA} = 1$ mW m^{-2}	→	The MPE time is > 8 hours
Limit d				
The exposure limit is 100 W m^{-2} sr^{-1}	→	$L_B = 224$ W m^{-2} sr^{-1}	→	The exposure limit is exceeded
Therefore, limit c should be used to calculate an MPE time				
Limit c				
The exposure limit is $L_B < 10^6/t$ W m^{-2}	→	$t_{max} = 10^6/L_B$	→	The MPE time for this source is about 70 minutes
However, the intense brightness of this source is likely to limit each exposure episode to about 0.25 seconds				
Limit g				
The exposure limit is 280 kW m^{-2} sr^{-1}	→	$L_R = 250$ kW m^{-2} sr^{-1}	→	The exposure limit is not exceeded

D.1.16. A portable digital data projector

A 180 W data has a front projection lens with a diameter of 3.5 cm. See also example D.1.15.

The projector creates images by mixing the three colours. The worst case should be when all colours are present — i.e. a white image being projected. A graphics software package can be used to create a blank white image. Spectral irradiance data will be measured at a distance of 200 cm from the projector, with the projector focused to produce the smallest possible sharp image at that distance. The projector lens has a diameter of 3.5 cm and appears homogenous when in use.

Choice of exposure limits

This type of source does not emit measurable quantities of ultraviolet or infrared, and so any hazard will arise from exposure to visible wavelengths. Exposure limits d and g apply.

Geometric factors

The three primary colours are mixed to produce colour images. The worst case will be when all three primary colours are present — a white image. Spectral irradiance data will be measured at a distance of 200 cm from the lamp, looking directly at it.

The source has an average dimension of 3.5 cm.
Therefore $\alpha = 0.02$ rad.
The source has a surface area of 9.6 cm^2.
Therefore $\omega = 0.0002$ sr.
Therefore $\omega_B = 0.01$ sr and $\omega_R = 0.0002$ sr.

Preliminary assessment

The photopic effective irradiance was measured and is 681 mW m^{-2}. This equates to an illuminance of 465 lux. The luminance of this source is therefore 465/0.0002 = 2 325 000 cd m^{-2}.

Further assessment of retinal hazard is necessary.

Radiometric data

Measured effective irradiance values are:

Effective irradiance $E_{eff} = >10$ µW m^{-2}

UVA irradiance, $E_{UVA} = 0.5$ mW m^{-2}

Effective irradiance (blue light), $E_B = 440$ mW m^{-2}

Effective irradiance (thermal injury), $E_R = 5\,333$ mW m^{-2}

Simplifying assumptions

Effective radiance (Blue Light), $L_B = 440$ mW m^{-2}/ 0.01 msr = 44 W m^{-2} sr^{-1}

Effective radiance (thermal injury), $L_R = 5\,333$ mW m^{-2}/ 0.0002 msr = 27 kW m^{-2} sr^{-1}

Comparison with exposure limits

Limit a				
The exposure limit is $H_{eff} = 30$ J m^{-2}	→	$E_{eff} = 30$ µW m^{-2}	→	The MPE time is > 8 hours
Limit b				
The exposure limit is $H_{UVA} = 10^4$ J m^{-2}	→	$E_{UVA} = 1$ mW m^{-2}	→	The MPE time is > 8 hours
Limit d				
The exposure limit is 100 W m^{-2} sr^{-1}	→	$L_B = 44$ W m^{-2} sr^{-1}	→	The exposure limit is not exceeded
Limit g				
The exposure limit is 280 kW m^{-2} sr^{-1}	→	$L_R = 27$ kW m^{-2} sr^{-1}	→	The exposure limit is not exceeded

D.1.17. A digital interactive whiteboard

A wall-mounted digital interactive whiteboard has dimensions of 113 × 65 cm.

Choice of exposure limits

This type of source does not emit measurable quantities of ultraviolet or infrared, and so any hazard will arise from exposure to visible wavelengths. Exposure limit d applies.

Geometric factors

The interactive whiteboard mixes three primary colours to produce colour images. The worst case will be when all three primary colours are present — a white image. Spectral irradiance data will be measured at a distance of 200 cm from the source, looking directly at it.

The source has an average dimension of 89 cm.
Therefore $\alpha = 0.45$ rad.
The source has a surface area of 7 345 cm^2.
Therefore $\omega = 0.18$ sr.
Therefore $\omega_B = 0.18$ sr and $\omega_R = 0.18$ sr.

Preliminary assessment

The photopic effective irradiance was measured and is 11 mW m^{-2}. This equates to an illuminance of 8 lux.
The luminance of this source is therefore 8/0.18 = 44 cd m^{-2}.

No further assessment is necessary.

Radiometric data

Measured effective irradiance values are:
Effective irradiance, E_{eff} <10 µW m^{-2}
UVA irradiance, E_{UVA} = 250 µW m^{-2}
Effective irradiance (Blue Light), E_B = 10 mW m^{-2}
Effective irradiance (thermal injury), E_R = 112 mW m^{-2}

Simplifying assumptions

Effective radiance (Blue Light), L_B = 10 mW m^{-2}/0.18 sr = 56 mW m^{-2} sr^{-1}
Effective radiance (thermal injury), L_R = 112 mW m^{-2}/0.18 sr = 0.6 W m^{-2} sr^{-1}

Comparison with exposure limits

Limit a				
The exposure limit is H_{eff} = 30 J m^{-2}	→	E_{eff} < 10 µW m^{-2}	→	The MPE time is > 8 hours
Limit b				
The exposure limit is H_{UVA} = 10^4 J m^{-2}	→	E_{UVA} = 250 µW m^{-2}	→	The MPE time is > 8 hours
Limit d				
The exposure limit is 100 W m^{-2} sr^{-1}	→	L_B = 56 mW m^{-2} sr^{-1}	→	The exposure limit is not exceeded
Limit g				
The exposure limit is 280 kW m^{-2} sr^{-1}	→	L_R = 0.6 W m^{-2} sr^{-1}	→	The exposure limit is not exceeded

D.1.18. A ceiling-mounted recessed compact fluorescent lamp

A pair of 2 cm × 13 cm 26 W compact fluorescent lamps are mounted in an open-fronted luminaire recessed into a ceiling. The luminaire incorporates a rear reflector, and has a diameter of 17 cm. The reflector is of a high quality, and the source appears to be almost homogenous. It will be evaluated as if it is not homogenous, as this errs on the side of caution.

Choice of exposure limits

This type of lamp does not emit significant quantities of infrared radiation. Any hazard will arise from exposure to visible or ultraviolet wavelengths. Limits a, b and d apply.

Geometric factors

Spectral irradiance data will be measured at a distance of 100 cm from the lamp, looking directly at it.

Each lamp has an average dimension of 7.5 cm.
Therefore $\alpha = 0.075$ rad.
Each lamp has a surface area of 26 cm^2.
Therefore $\omega = 0.0026$ sr.
Therefore $\omega_B = 0.01$ sr and $\omega_R = 0.0026$ sr.

Preliminary assessment

The photopic effective irradiance was measured and is 1 558 mW m^{-2}. This was from two lamps: as each lamp is a separate visual source, each contributes 779 mW m^{-2} to the total. This equates to an illuminance of 532 lux per lamp.
The luminance of each lamp is therefore 532/0.0026 = 204 615 cd m^{-2}.

Further assessment of retinal hazard is necessary. UVR must still be assessed.

Radiometric data

Measured effective irradiance values are:

Effective irradiance, $E_{eff} = 40$ µW m^{-2}
UVA irradiance, $E_{UVA} = 55$ mW m^{-2}
Effective irradiance (Blue Light), $E_B = 321$ mW m^{-2} = 161 mW m^{-2} per lamp
Effective irradiance (thermal injury), $E_R = 5\,580$ mW m^{-2} = 2 790 mW m^{-2} per lamp

Simplifying assumptions

Effective radiance (Blue Light), $L_B = 161$ mW m^{-2}/0.01 sr = 16 W m^{-2} sr^{-1}
Effective radiance (thermal injury), L_R = 2 790 mW m^{-2}/0.0026 sr = 1 073 W m^{-2} sr^{-1}

Comparison with exposure limits

Limit a				
The exposure limit is $H_{eff} = 30$ J m^{-2}	→	$E_{eff} = 40$ µW m^{-2}	→	The MPE time is > 8 hours
Limit b				
The exposure limit is $H_{UVA} = 10^4$ J m^{-2}	→	$E_{UVA} = 55$ mW m^{-2}	→	The MPE time is > 8hours
Limit d				
The exposure limit is 100 W m^{-2} sr^{-1}	→	$L_B = 16$ W m^{-2} sr^{-1}	→	The exposure limit is not exceeded
Limit g				
The exposure limit is 280 kW m^{-2} sr^{-1}	→	$L_R = 1\,073$ W m^{-2} sr^{-1}	→	The exposure limit is not exceeded

D.1.19. An indicator LED

Green LEDs are used as indicators on a computer keyboard. Each LED is a separate source, measuring 1 × 4 mm.

Choice of exposure limits

LEDs only emit in a narrow band of wavelengths: as this one is green, there will be no emissions in the ultraviolet or infrared. Only limit d applies.

Geometric factors

Spectral irradiance data will be measured at a distance of 5 mm from the LED, looking directly at it.

The luminaire has an average dimension of 2.5 mm.
Therefore $\alpha = 0.5$ rad.

The luminaire has a surface area of 4 mm^2.
Therefore $\omega = 0.16$ sr.
Therefore $\omega_B = 0.16$ sr and $\omega_R = 0.16$ sr.

Preliminary assessment

The photopic effective irradiance was measured and is 30 mW m^{-2}. This equates to an illuminance of 20 lux.
The luminance of this source is therefore 20/0.16 = 125 cd m^{-2}.

No further assessment is necessary.

Data required

Measured effective irradiance values are:
Effective irradiance, E_{eff} <10 μW m^{-2}
UVA irradiance, E_{UVA} = 40 μW m^{-2}
Effective irradiance (Blue Light), E_B = 190 μW m^{-2}
Effective irradiance (thermal injury), E_R = 35 mW m^{-2}

Simplifying assumptions

Effective radiance (Blue Light), L_B = 190 μW m^{-2}/0.16 sr = 1.2 mW m^{-2} sr^{-1}
Effective radiance (thermal injury), L_R = 35 mW m^{-2}/0.16 sr = 0.22 W m^{-2} sr^{-1}

Comparison with exposure limits

Limit a				
The exposure limit is H_{eff} = 30 J m^{-2}	→	E_{eff} < 10 μW m^{-2}	→	The MPE time is > 8 hours
Limit b				
The exposure limit is H_{UVA} = 10^4 J m^{-2}	→	E_{UVA} = 40 μW m^{-2}	→	The MPE time is > 8 hours
Limit d				
The exposure limit is 100 W m^{-2} sr^{-1}	→	L_B = 1.2 mW m^{-2} sr^{-1}	→	The exposure limit is not exceeded
Limit g				
The exposure limit is 280 kW m^{-2} sr^{-1}	→	L_R = 0.22 W m^{-2} sr^{-1}	→	The exposure limit is not exceeded

D.1.20. A PDA

A personal digital assistant (PDA) has a display screen measuring 5 cm × 3.5 cm.

Choice of exposure limits

PDA displays do not emit significant quantities of ultraviolet or infrared radiation. Any hazard will arise from exposure to visible wavelengths. Limit d applies.

Geometric factors

The screen mixes three primary colours to produce colour images. The worst case will be when all three primary colours are present — a white image. Spectral irradiance data will be measured at a distance of 2 cm from a screen which is as white as possible, looking directly at it.

The source has an average dimension of 4.25 cm.
Therefore $\alpha = 2.1$ rad.
The source has a surface area of 17.5 cm^2.
Therefore $\omega = 4.4$ sr.
Therefore $\omega_B = 4.4$ sr and $\omega_R = 4.4$ sr.

Preliminary assessment

The photopic effective irradiance was measured and is 47 mW m^{-2}. This equates to an illuminance of 32 lux. The luminance of this source is therefore 32/4.4 = 7.3 cd m^{-2}.

No further assessment is necessary.

Data required

Measured effective irradiance values are:
Effective irradiance, E_{eff} <10 µW m^{-2}
UVA irradiance, E_{UVA} = 30 µW m^{-2}
Effective irradiance (Blue Light), E_B = 27 mW m^{-2}
Effective irradiance (thermal injury), E_R = 330 mW m^{-2}

Simplifying assumptions

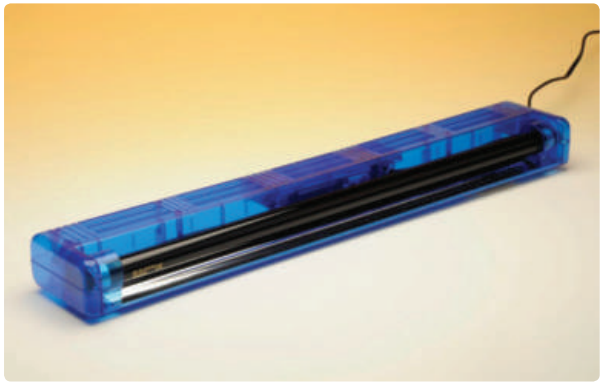
Effective radiance (Blue Light), L_B = 27 mW m^{-2}/4.4 sr = 6 mW m^{-2} sr^{-1}
Effective radiance (thermal injury), L_R = 330 mW m^{-2}/4.4 sr = 75 mW m^{-2} sr^{-1}

Comparison with exposure limits

Limit a				
The exposure limit is H_{eff} = 30 J m^{-2}	→	E_{eff} < 10 µW m^{-2}	→	The MPE time is > 8 hours
Limit b				
The exposure limit is H_{UVA} = 10^4 J m^{-2}	→	E_{UVA} = 30 µW m^{-2}	→	The MPE time is > 8 hours
Limit d				
The exposure limit is 100 W m^{-2} sr^{-1}	→	L_B = 6 mW m^{-2} sr^{-1}	→	The exposure limit is not exceeded
Limit g				
The exposure limit is 280 kW m^{-2} sr^{-1}	→	L_R = 75 mW m^{-2} sr^{-1}	→	The exposure limit is not exceeded

D.1.21. A UVA blacklight

UVA blacklights are often low pressure mercury discharge lamps, emitting in the UVA with very little visible emission. They are used to induce fluorescence for a variety of purposes (non-destructive testing, forgery detection, property marking, entertainment effects). This example incorporates one 20 W lamp measuring 55 × 2.5 cm. The lamp is mounted on an open batten (i.e. with no glass/plastic cover over the lamp).



Choice of exposure limits

This source is similar to a fluorescent lamp, but with the visible output suppressed in favour of UVA. Hence, there is no need to consider retinal hazards, and limits a and b apply. Assessment of luminance is not appropriate as this is not a white-light source.

Geometric factors

Spectral irradiance data will be measured at a distance of 50 cm from the lamp.
The lamp has an average dimension of 29 cm.
Therefore $\alpha = 0.575$ rad.
Each lamp has an apparent surface area of 138 cm^2.
Therefore $\omega = 0.055$ sr.
Therefore $\omega_B = 0.055$ sr and $\omega_R = 0.055$ sr.

Radiometric data

Measured effective irradiance values are:

Effective irradiance, $E_{eff} = 30\ \mu W\ m^{-2}$

UVA irradiance, $E_{UVA} = 176\ mW\ m^{-2}$

Effective irradiance (Blue Light), $E_B = 3\ mW\ m^{-2}$
Effective irradiance (thermal injury), $E_R = 14\ mW\ m^{-2}$

Simplifying assumptions

Effective radiance (Blue Light), $L_B = 3\ mW\ m^{-2}/0.055\ sr = 55\ mW\ m^{-2}\ sr^{-1}$
Effective radiance (thermal injury), $L_R = 14\ mW\ m^{-2}/0.055\ sr = 255\ mW\ m^{-2}\ sr^{-1}$

Comparison with exposure limits

Limit a				
The exposure limit is $H_{eff} = 30\ J\ m^{-2}$	→	$E_{eff} = 30\ \mu W\ m^{-2}$	→	The MPE time is > 8 hours
Limit b				
The exposure limit is $H_{UVA} = 10^4\ J\ m^{-2}$	→	$E_{UVA} = 176\ mW\ m^{-2}$	→	The MPE time is > 8 hours
Limit d				
The exposure limit is $100\ W\ m^{-2}\ sr^{-1}$	→	$L_B = 55\ mW\ m^{-2}\ sr^{-1}$	→	The exposure limit is not exceeded
Limit g				
The exposure limit is $280\ kW\ m^{-2}\ sr^{-1}$	→	$L_R = 255\ mW\ m^{-2}\ sr^{-1}$	→	The exposure limit is not exceeded

D.1.22. A streetlight incorporating a metal halide lamp

A streetlight incorporates a 150 W metal halide lamp mounted in a housing surrounded by silvered metal louvres. The louvres are directed downwards, and are 2.5 cm apart. The lamp itself is approximately 1 × 2 cm, and is mounted inside a secondary envelope measuring 8 × 5 cm. The entire luminaire is further encased in a cylindrical plastic weatherproof casing. The source is not homogenous — the brightest region is the inner lamp bulb. It is possible to view the lamp directly, by looking upwards between the louvres at an appropriate angle.

Choice of exposure limits

Any hazard will arise from exposure to visible or possibly to ultraviolet wavelengths. Metal halide lamps produce copious ultraviolet: this example has an outer envelope which may reduce emissions and the luminaire has a cover which will reduce emissions, but enough UVA may still be emitted to be of concern. Limits b, d and g apply.

Geometric factors

Because the lamp housing is intended for use atop a lamp-post, the worst case exposure scenario (i.e. looking directly through the louvres) is only possible at distances of the order of 7 m. However, spectral irradiance data will be measured at a distance of 100 cm from the lamp, looking upwards through the louvres.

The arc has an average dimension of 1.5 cm.
Therefore α = 0.015 rad.
The source has a surface area of 2 cm^2.
Therefore ω = 0.0002 sr.
Therefore ω_B = 0.01 sr and ω_R = 0.0002 sr.

Preliminary assessment

The photopic effective irradiance was measured and is 327 mW m^{-2}. This equates to an illuminance of 223 lux.
The luminance of this source is therefore 223/0.0002 = 1 115 000 cd m^{-2}.
Further assessment of retinal hazard is necessary, and potential UVR hazard remains to be assessed.

Radiometric data

Measured effective irradiance values are:

Effective irradiance, E_{eff} = 7 µW m^{-2}
UVA irradiance, E_{UVA} = 29 mW m^{-2}
Effective irradiance (Blue Light), E_B = 86 mW m^{-2}
Effective irradiance (thermal injury), E_R = 1 323 mW m^{-2}

Simplifying assumptions

Effective radiance (Blue Light), L_B = 86 mW m^{-2}/0.01 sr = 8.6 W m^{-2} sr^{-1}
Effective radiance (thermal injury), L_R = 1 323 mW m^{-2}/0.0002 sr = 6.7 kW m^{-2} sr^{-1}

Comparison with exposure limits

Limit a				
The exposure limit is H_{eff} = 30 J m^{-2}	→	E_{eff} = 7 µW m^{-2}	→	The MPE time is > 8 hours
Limit b				
The exposure limit is H_{UVA} = 10^4 J m^{-2}	→	E_{UVA} = 29 mW m^{-2}	→	The MPE time is > 8 hours
Limit d				
The exposure limit is 100 W m^{-2} sr^{-1}	→	L_B = 8.6 mW m^{-2} sr^{-1}	→	The exposure limit is not exceeded
Limit g				
The exposure limit is 280 kW m^{-2} sr^{-1}	→	L_R = 6.7 kW m^{-2} sr^{-1}	→	The exposure limit is not exceeded

D.1.23. Summary of data from examples

The data presented in the 18 examples given above can be compared with the exposure limits by dividing the effective radiance or 8-hour radiant exposure by the appropriate exposure limit. These values are presented below: values which were < 1 % of the exposure limits are not further elaborated. Values > 1 are shown in red.

Source	Distance	Hazard value (Ratio of emission to exposure limit)				
		Luminance	Effective UVR (limit a)	UVA (limit b)	Blue Light hazard (limit d)	Retinal Thermal hazard (limit g)
Fluorescent area lamps (behind diffuser)	100 cm	0.15	< 0.01	0.05	0.01	< 0.01
Fluorescent area lamp (no diffuser)	100 cm	3.7	0.58	0.35	0.19	< 0.01
Four fluorescent area lamps (no diffuser)	100 cm	2.8	1.0	0.33	0.13	< 0.01
CRT display	10 cm	< 0.01	0.12	0.02	< 0.01	< 0.1
Laptop display	10 cm	< 0.01	0.07	0.01	< 0.01	< 0.01
Metal halide floodlight	100 cm	15 000	0.1	2.6	2.3	1.08
Compact fluorescent floodlight	100 cm	6.4	0.01	< 0.01	0.15	< 0.01
Insect killer	100 cm	n/a	0.01	0.10	< 0.01	< 0.1
Tungsten halogen spotlight	100 cm	33.1	0.03	0.04	0.13	0.01
Task light	50 cm	3.7	0.05	0.05	< 0.01	< 0.01
Task light (daylight spectrum)	50 cm	600	0.11	0.08	0.14	0.19
Photocopier	30 cm	0.96	0.01	0.06	0.06	< 0.01
Desktop projector	200 cm	2 000	0.03	< 0.01	2.2	0.89
Portable projector	200 cm	233	< 0.01	< 0.01	0.44	0.10
Interactive whiteboard	200 cm	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Compact fluorescent area lamps	100 cm	20	0.04	0.16	0.16	< 0.01
Indicator LED	0.5 cm	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
PDA	2 cm	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
UVA blacklight	50 cm	n/a	0.03	0.51	< 0.01	< 0.01
Streetlight	100 cm	112	< 0.01	0.08	0.09	0.02

The table shows that, in all instances where source luminance was < 10^4 cd m^{-2}, neither of the retinal exposure limits (d and g) would be exceeded. Even where the source luminance exceeded 10^4 cd m^{-2}, most of the sources were subsequently shown not to present a hazard to the retina.

Of the sources examined here, only the metal halide floodlight and the desktop projector were likely to lead to exposure limits being exceeded. In most cases, these were exposure limits set to protect the retina: subsequent calculations (see the individual examples) suggest that the exposure limits are unlikely to actually be exceeded due to aversion responses and to the overly conservative conditions of the original assessment. This does not imply that these sources need not be treated with caution, as it is possible that the aversion responses will not operate. If a source is in the peripheral visual field, the aversion responses might not be invoked. This could result in the exposure limits being exceeded.

Two very similar open-fronted ceiling luminaires with fluorescent lamps have been examined here. It is noteworthy that, at lighting levels around 1 100–1 200 lux, one luminaire came close to the effective UVR limit and the other did not. This difference is due to the fluorescent lamps being from different manufacturers, and indicates that apparently similar lamps may have very different levels of unintentional emissions.

Different emission levels from similar sources are also shown by comparison of the two data projectors examined. Although it is less powerful, the desktop projector appears (under the assumptions made regarding source area) more hazardous than the portable projector.

D.2 Laser show

Lasers have been used in entertainment to support live and recorded music since the 1970s. The principal concern has been the exposure of the public to laser radiation in excess of the exposure limit values. However, the Directive requires consideration of worker exposure only. This example considers the installation and performance of a laser show at a temporary event. However, the principles should be applicable to any laser show.

D.2.1. Hazards and people at risk

The only hazard considered here is the laser beam. Other hazards may present a greater risk of injury or even death.

Many laser shows use Class 4 lasers. By definition, the radiant power will be in excess of 500 mW. Assuming a single accidental ocular exposure to the laser beam, the exposure limit value (ELV) can be determined from Table 2.2 of Annex II of the Directive.

The ELV is 18 $t^{0.75}$ J m^{-2} for wavelengths between 400 and 700 nm. Substituting for t = 0.25 s, the ELV is 6.36 J m^{-2}. Since the laser beam is likely to be emitted as a continuous beam, it is useful to convert this radiant exposure into irradiance by dividing by the exposure duration (0.25 s). This gives an ELV, in terms of irradiance, of 25.4 W m^{-2}.

The limiting aperture for ocular exposure for visible laser beams is 7 mm. Therefore, it is possible to determine the maximum power that is permissible in this 7 mm aperture to ensure that the ELV is not exceeded. This is calculated by multiplying the ELV by the area of the 7 mm aperture. It is assumed that the aperture is circular so the area is 3.85×10^{-5} m^2. Multiplying 25.4 W m^{-2} by 3.85×10^{-5} m^2 gives about 0.001 W, or 1 mW.

> The ELV will be exceeded by a factor of at least 500, i.e. the number of mW above 1 mW, if the laser beam is 7 mm diameter or smaller.

This assessment shows that the beam should not be directed at workers' eyes unless the beam has diverged sufficiently to reduce the irradiance to a value less than 25.4 W m^{-2}.

The following is a suggested list of workers who may be at risk during parts of the life cycle of the laser installation. Consideration is only given to those stages of the life cycle when the laser beam is emitted.

Beam alignment
Laser installation engineer
Laser operator
Other installation engineers
Security staff
Venue staff
Laser show
Laser operator
Lighting and sound desk engineers
Performers
Security staff
Venue staff
Vendors

Laser shows rarely consist of static laser beams. Scan patterns are generated by moving the laser beam, generally with computer-controlled orthogonal galvanometer-mounted mirrors. However, many scan patterns require the same location to be repeatedly scanned, so the eye of a person may receive a burst of laser pulses as the pattern passes across their face.

If a pulsed laser is used then the assessment should consider whether the ELV could be exceeded for an exposure to a single pulse of laser radiation at accessible locations, as well as a train of pulses.

D.2.2. Evaluating and prioritising risk

The assessment of the potential exposure against the ELV demonstrates that the ELV is likely to be exceeded. For a 500 mW laser it is also possible to determine the time needed for any control measure to be effective. IEC TR 60825-3 suggests that consideration should be given to the time from a fault condition occurring to a control measure being effective.

Assuming that the beam contains 500 mW, the irradiance will be 0.5 W/3.85 × 10^{-5} m^2, or about 13 000 W m^{-2}. Since the ELVs are expressed in terms of radiant exposure (J m^{-2}) for exposure durations less than 10 s, the irradiance can be converted into radiant exposure by multiplying by the exposure duration: 13 000 × t J m^{-2}.

The value of t is determined by solving for each of the ELVs as a function of time until t is within the range of validity for the ELV. This is determined as 3.8 × 10^{-7} s using the ELV of 5 × 10^{-3} J m^{-2} within the time frame 10^{-9} to 1.8 × 10^{-5} s.

For a 500 mW CW laser, any control measure to ensure that the ELV for the eye was not exceeded would need to be effective within 0.38 µs.

This conclusion suggests that exposures to the laser beam should be avoided as a high priority.

D.2.3. Deciding on preventive action and taking action.

Since the laser beam presents a major risk of injury, it is important that the risk of eye exposure is minimised. However, the laser beam needs to be visible either within the air volume or as a reflection from a screen to produce the intended entertainment effects. Therefore, the risk should be managed by ensuring that workers are not in the beam paths. The following are suggested ways of managing the risk.

Laser operators and support staff should be adequately trained.

The minimum number of people should be present during alignment.

All beams should be directed into unoccupied areas.

Lasers and supporting equipment, including bounce mirrors, should be suitably attached and fixed to ensure no inappropriate movement for the duration of the performance.

Beam paths should be blocked by physical blanking to ensure occupied areas are not targeted. Software blanking should only be used if it is certified to appropriate safety critical standards.

Operators should be in a position to monitor all beam paths and be able to terminate emissions if required.

When operating in outdoor environments, consideration should be given to the safety of air traffic. National requirements may apply.

D.2.4. Monitoring and reviewing

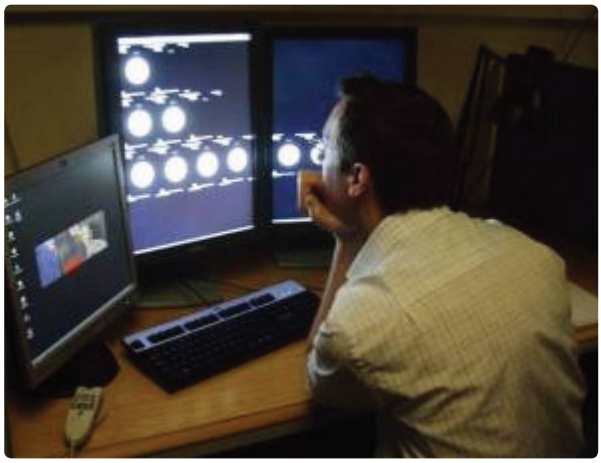
Staff should continuously monitor the laser paths during alignment and the performance and be prepared to take timely corrective action, if required. If the laser is a permanent installation, it will be necessary to review the assessment periodically and probably have pre-show check lists.

D.2.5. Conclusion

Designing the show to ensure that no workers are exposed to the laser beam means that detailed, and usually complex and time-consuming, assessments against the ELVs are not required. The combined use of operator training and straightforward control measures should ensure that the ELVs are not exceeded for workers.

D.3 Medical Applications of Optical Radiation

Artificial optical radiation sources are used for a wide variety of purposes in the medical environment. Some sources such as those used in area lighting, visual display equipment (see photograph), indicator lights, photography, laboratory analysis and vehicle lights are commonly encountered in other environments and are discussed elsewhere in this guide. For these sources, providing the sources have not been modified and are not used in a substantially different way then there is no reason why exposures would be substantially different to those occurring in other more general environments.



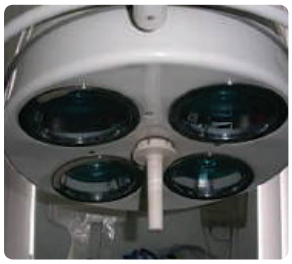
Use of display screens in radiography

There are, however, a large number of specialist sources developed specifically for medical applications. These include:

Task Lighting	Therapeutic sources
Operating theatre lights	Ultraviolet phototherapy sources
Birthing lights	Blue Light phototherapy sources
Spotlights	Photodynamic therapy sources
X-ray viewing boxes	Physiotherapy lasers
Diagnostic lights	Surgical lasers
Fetal transilluminators	Ophthalmic lasers
Slit lamps and other ophthalmic instruments	Intense pulsed light sources
Laser diagnostic devices such as retinal scanners	Specialist test sources
Woods lamps	Solar simulators

D.3.1. Task lighting

The most powerful lights falling into the task lighting category will normally be operating theatre lights. Table D.3.1. provides example assessments of a variety of operating theatre lights and it can be seen that one of the assessed units could present a Blue Light hazard for direct viewing of the source.



Examples of operating theatre lights

Table D 3.1. Assessment of theatre lighting assuming direct viewing of source (*)

Source	Actinic UV hazard	UVA hazard	Blue Light hazard	Other optical radiation hazards
Hanalux 3210	None	None	May be exceeded in ~ 30 minutes for direct viewing	None
Hanalux Oslo	None	Below exposure limit for 8 hours exposure	May be exceeded in ~ 30 minutes for direct viewing	None
Hanalux 3004	None	None	< 20 % of ELV	None
Martin ML702HX	None	None	< 20 % of ELV	None
Martin ML502HX	None	None	< 20 % of ELV	None
Martin ML1001	None	None	< 20 % of ELV	None
(*) Assessment data courtesy of Medical Physics Department, Guy's & Thomas' NHS Foundation Trust, London				

It should be noted that the lights are used to provide illumination from above and it would therefore be unlikely that anyone would look directly into the source at close range. In addition, the lights are bright and it would be uncomfortable to look directly into them for extended periods. Hence, in practice, exposures will be much lower than those assessed in table D.3.1. and are unlikely to be hazardous.

Other task lighting specific to the medical sector includes spotlights used to provide local illumination during examinations and birthing lights. Both types of light will raise similar issues to theatre lights in terms of likely exposure scenarios. Both are directional sources used to provide local illumination and it is unlikely that anyone would stare into the source for significant periods. In general both spotlights and birthing lights are likely to have lower outputs than operating theatre lights and on this basis it is not generally expected that they will constitute a hazard.

Examples of birthing lights

Illuminated magnifiers are widely used in medical practice and essentially provide a source of localised illumination in combination with a large magnifying lens as indicated in the image below.

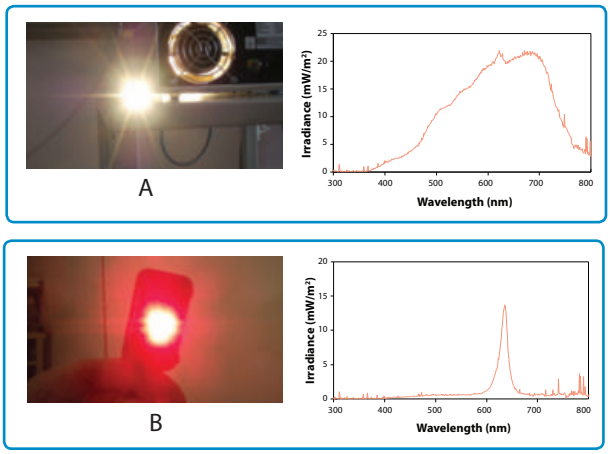
Example of an illuminated magnifier, in this case a Luxo Wave Plus illuminator

An assessment by the Medical Physics Department at Guy's & Thomas' NHS Foundation Trust indicated that the Luxo Wave Plus illuminator had emissions in the ultraviolet and visible regions of the spectrum. However, continuous exposure in close proximity would not exceed the ELV for actinic UV. Although there was significant Blue Light emission, this would not exceed 1 % of the relevant ELV. There were no significant UVA or thermal hazards. It is likely that other similar devices would present a similarly low risk.

X-ray viewers provide relatively low intensity diffuse illumination. Assessments undertaken by the Medical Physics Department at Guy's & Thomas' NHS Foundation Trust suggest that direct viewing of the source at close proximity, which is likely given the way in which this type of source is used, would result in a Blue Light exposure that constitutes less than 5 % of the exposure limit value. There was no significant hazard from actinic UV, UVA or thermal mechanisms.

D.3.2. Diagnostic lighting

Fetal transilluminators are commonly used in fetal care units and may be used for visualising internal structures as an aid to diagnosis or for the identification of blood vessels. As a result these sources are normally required to illuminate small volumes but must be sufficiently intense to pass through the tissues and be visible on the exit side.



Images of fetal transilluminators together with measured output spectra, (A) Neonate 100, (B) Wee Wee Sight™.

The output spectrum of the Neonate 100 transilluminator shows a broad emission across the entire visible range with some emission in both the UVA and IRA ranges. Assessment shows that even for exposure at close proximity the UV emission will not constitute a hazard (Table D.3.2.). However, there is significant Blue Light emission and this would constitute a hazard for exposures in excess of 10 minutes. As can be seen from the photograph above, the source is extremely bright and the normal aversion response can be expected to limit individual exposures to 0.25 seconds. These would be cumulative during a working day, but total usage of the device is relatively low so that even with pessimistic assumptions cumulative exposures are expected to be less than 5 % of the ELV. With strong emission across the visible region and into the near infrared it is also necessary to evaluate the Retinal Thermal hazard. However, this will be limited by the aversion response and would not exceed 2 % of the ELV even with prolonged staring at the source, which would be extremely uncomfortable. The Wee Sight™ device has a relatively narrow emission characteristic of LED sources, and as expected does not present any optical hazard.

Table D.3.2. Assessment of fetal transilluminators (*)

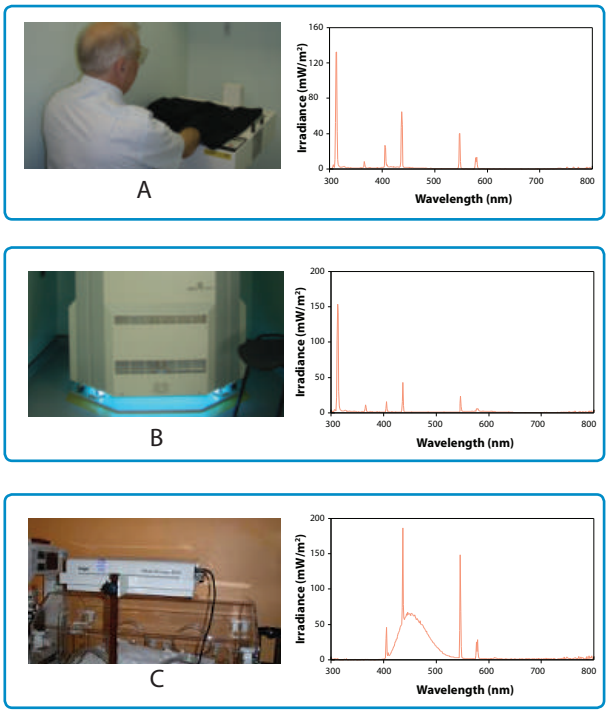
Source	Actinic UV hazard	UVA hazard	Blue Light hazard	Thermal hazards
Neonate 100	None	None	< 5 % of ELV	~ 2 % of ELV
Wee Sight™	None	None	None	None
(*) Measurements facilitated courtesy of Radiation Protection Department, Royal Berkshire NHS Foundation Trust, Reading				

Slit lamps and other ophthalmic instruments incorporate slit lamps, but are intended for use in ophthalmic examinations and should therefore present a minimal hazard. Moreover, they are highly directional and consequently unlikely to result in significant unintended occupational exposures. Similarly, recent diagnostic ophthalmic instruments such as retinal scanners may well incorporate laser sources, but have been assessed for deliberate exposures and will generally be Class 1 devices. Hence the risk of hazardous exposures to staff should be minimal.

Woods lamps may be used for diagnostic purposes and are essentially mercury lamps incorporating a Woods glass filter to remove both short wavelength UV and visible emissions. Hence they would be expected to present a UVA hazard and, depending on the effectiveness of the filtration, may also present an actinic UV hazard. An assessment undertaken by the Medical Physics Department at Guy's & Thomas' NHS Foundation Trust indicated that direct exposure to the output from a Woods lamp for over 50 minutes would result in the ELV for UVA being exceeded. The same assessment showed that it would take in excess of 7.5 hours to exceed the ELV for actinic UV, whilst other optical radiation hazards were insignificant. Woods lamps are used for examinations and a combination of operator training and personal protective eyewear should limit both direct exposure to the source and exposure to scattered UVA. Given that the ELV for actinic UV would only be exceeded after prolonged exposure to the direct emission, it is unlikely that scattered actinic UV would present a significant hazard.

D.3.3. Therapeutic sources

There is a range of sources used for phototherapy treatments. In particular ultraviolet phototherapy sources are used for the treatment of skin conditions, whilst Blue Light phototherapy sources are commonly used for the treatment of hyperbilirubinemia in newborn babies, up to 60 % of who may suffer from this condition.



Images of phototherapy devices along with measured output spectra, (A) Waldmann UV 7001 UVB, (B) Waldmann UV 181 BL, (C) Dräger PhotoTherapy 4000.

The spectra presented above show that ultraviolet phototherapy sources (examples A and B) generally have strong emission in the UV region of the spectra and may also emit in the visible, particularly towards the blue end. As expected, assessment of the hazard (Table D.3.3.) suggests that the principal hazards from these units relate to either actinic UV or UVA. Example C shows the spectrum from a Blue Light phototherapy source and, as expected, this emits strongly in the blue region of the visible spectrum but has little if any emission in the ultraviolet or near infrared regions.

Table D.3.3. Assessment of phototherapy sources

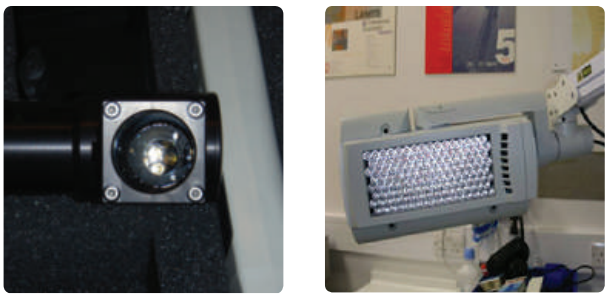
Source	Actinic UV hazard	UVA hazard	Blue Light hazard	Other optical radiation hazards
Waldmann UV 7001 UVB (*)	May be exceeded in ~ 5 h	Below exposure limit	Below exposure limit	None
Waldmann TL01 UV5000 (†)	May be exceeded in ~ 7.5 h	Below exposure limit	None	None
Waldmann UV6 UV5001BL (†)	May be exceeded in ~ 4 h	Below exposure limit	None	None
Waldmann UV 181 BL (*)	Below exposure limit	Below exposure limit	Below exposure limit	None
Waldmann UV 7001 UVA (†)	None	May be exceeded in ~ 5 h	Below exposure limit	None
Sellamed UVA1 24000 (†)	None	May be exceeded in ~ 45 min	Below exposure limit	None
Draeger 4000 (*) (†)	None	Below exposure limit	Below exposure limit	None
(*) Measurements facilitated courtesy of Radiation Protection Department, Royal Berkshire NHS Foundation Trust, Reading (†) Assessment data courtesy of Medical Physics Department, Guy's & Thomas' NHS Foundation Trust, London				

The most widely used ultraviolet phototherapy cabinets do not permit access to the direct emissions whilst the equipment is in operation. However, there may be leakage (see example A above) that can be a source of concern for staff. In particular, the need for air flow and to minimise the claustrophobic nature of enclosure for the patient means that the top of the cabinet is often open. This can result in significant scatter of UV from the ceiling. In general the hazard is relatively low as staff are unlikely to stand close to the cabinet all the time it is operating. Nevertheless, there is a risk of long-term effects from cumulative exposure to UV and this can be minimised by the use of straightforward engineering controls including: designated treatment rooms; curtains around the cabinet; and remote control of monitoring workstations. For example in (A) above, the use of a curtain around the cabinet increased the time required to reach the ELV for actinic UV from 5 hours to almost 13 hours. Some other phototherapy devices, such as the unit for hand and foot exposure shown in example (B) require a high degree of procedural control to minimise staff exposure. In this case staff place black towels over the unit when in use to reduce stray UV in the environment. Again this control can be simply supplemented by placing the unit in a curtained cubicle. Occasionally hospital staff may require close access to operational equipment for QA checks. As part of the control measures they may be required to wear a UV protective face shield, appropriate gloves and clothing. Where there is a strong dependence on procedural controls these should be clearly documented.

The Blue Light phototherapy units are positioned above the cots of newborn babies, generally at a height of around 0.3 m. In general this will prevent staff from looking directly into the source and in any case staff monitor babies periodically for around 10 minutes in every hour, so that exposures will be further limited. Even allowing for the 12-hour shifts worked in some units, this will still result in an exposure that is less than 1 % of the ELV.

Photodynamic therapies involve the use of optical radiation to produce photochemical reactions and often involve pre-treatment with a chemical photosensitiser. In general ultraviolet wavelengths are often very effective at exciting photosensitisers, but are not commonly used due to poor penetration through tissue. It would be expected that the exposure would have much less effect on staff, who should not have been exposed to the photosensitiser, although appropriate controls would need to be in place to ensure that this was the case.

A B



Images of photodynamic therapy sources, (A) UV-X, (B) Aktilite CL128.

Table D.3.4. Assessment of photodynamic therapy sources

Source	Actinic UV hazard	UVA hazard	Blue Light hazard	Thermal hazards
UV-X	Below exposure limit	Below exposure limit	None	None
Aktilite CL128 lamp (*)	None	None	< 3 % of ELV	None
(*) **Assessment data courtesy of Medical Physics Department, Guy's & Thomas' NHS Foundation Trust, London**				

The assessments presented in Table D.3.4. illustrate that, as expected, photodynamic therapy sources appear to present little hazard in the absence of the photosensitising agent.

Class 3B lasers may be used in physiotherapy to deliver energy directly to injured tissues. Such lasers present a hazard to the eye (normally Retinal Thermal) but are usually highly divergent and consequently hazardous over relatively short distances. The risk is normally managed through procedural means (use of curtained cubicles, signage and staff training) and the use of laser protective eyewear.

Surgical lasers are widely used for a number of procedures and are normally Class 4 devices that present significant hazards to the eye and skin. Again the risks are normally managed through procedural controls and the use of personal protective equipment. In some cases the beam may be delivered through a fibre inserted via an endoscope into the body. In these cases the risk is greatly reduced provided the fibre does not break. Lasers are also widely used in ophthalmology and are usually either Class 3B or Class 4. As for other medical uses of lasers the risks to the eye and, where appropriate, the skin are controlled through procedural controls and the use of personal protective equipment.

Due to the possibility of reflections back into the viewing fibre of an endoscope, adequate filters should be in place and/or the endoscope should be viewed through the camera.

Intense pulsed light sources are widely used in skin treatments. These devices are generally based on a xenon flashlamp with added filtration to remove short wavelengths in the ultraviolet region of the spectrum. As a consequence of the high peak powers these devices can present thermal hazards to the eye and skin. This risk is normally managed through the use of procedural controls to avoid staff exposure to the direct output and the use of personal protective eyewear. Depending on the quality of the filtration there may also be a Blue Light hazard from such devices.

D.3.4. Specialist test sources

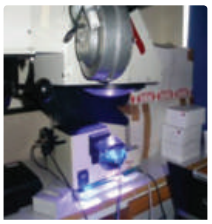


Image of solar simulator

A variety of more specialist sources may be used in some medical disciplines for diagnosis and research. In general it is likely that these will have to be assessed on a case by case basis. The example presented in Table D.3.5. below illustrates that for broadband sources, such as a solar simulator, it may be necessary to carry out assessments for a number of possible optical radiation hazards.

Table D.3.5. Assessment of solar simulator (*)

Source	Actinic UV hazard	UVA hazard	Blue Light hazard	Other optical radiation hazards
Oriel 81292 Solar Simulator: direct exposure	**May be exceeded in ~ 6 min**	**May be exceeded in ~ 3 min**	Below exposure limit	None
Oriel 81292 Solar Simulator: reflected from body	Below exposure limit	Below exposure limit	Below exposure limit	None
(*) **Assessment data courtesy of Medical Physics Department, Guy's & Thomas' NHS Foundation Trust, London**				

In general, task and diagnostic lighting used in medical practice are not expected to present a significant hazard in normal use.

Therapeutic sources may be hazardous under some circumstances. Many of these sources have the potential to give rise to exposures in the ultraviolet and Blue Light hazard regions where exposures will be cumulative during the working day and may carry a risk of long-term adverse health effects. Hence, in assessing exposures it is important to assess realistic exposures scenarios and combine these with a consideration of work patterns to assess total exposures. Where significant risks are identified, these should be controlled through restricting access to the emission wherever possible. If it is necessary to rely on procedural controls, these should be robust and recorded in writing.

D.4 Driving at work

People at work may be exposed to optical radiation from cars when:

- Driving
- Working at the roadside, such as traffic policemen and road workers
- Servicing and repairing cars in workshops

As will be shown, the first two examples represent a trivial level of exposure: it is not necessary to compromise visibility and road safety to reduce the exposure. Potential exposure to optical radiation above Exposure Limits during servicing and repairing cars could be managed by appropriate working procedures and local rules.

Four cars were assessed to determine the level of optical radiation exposure:

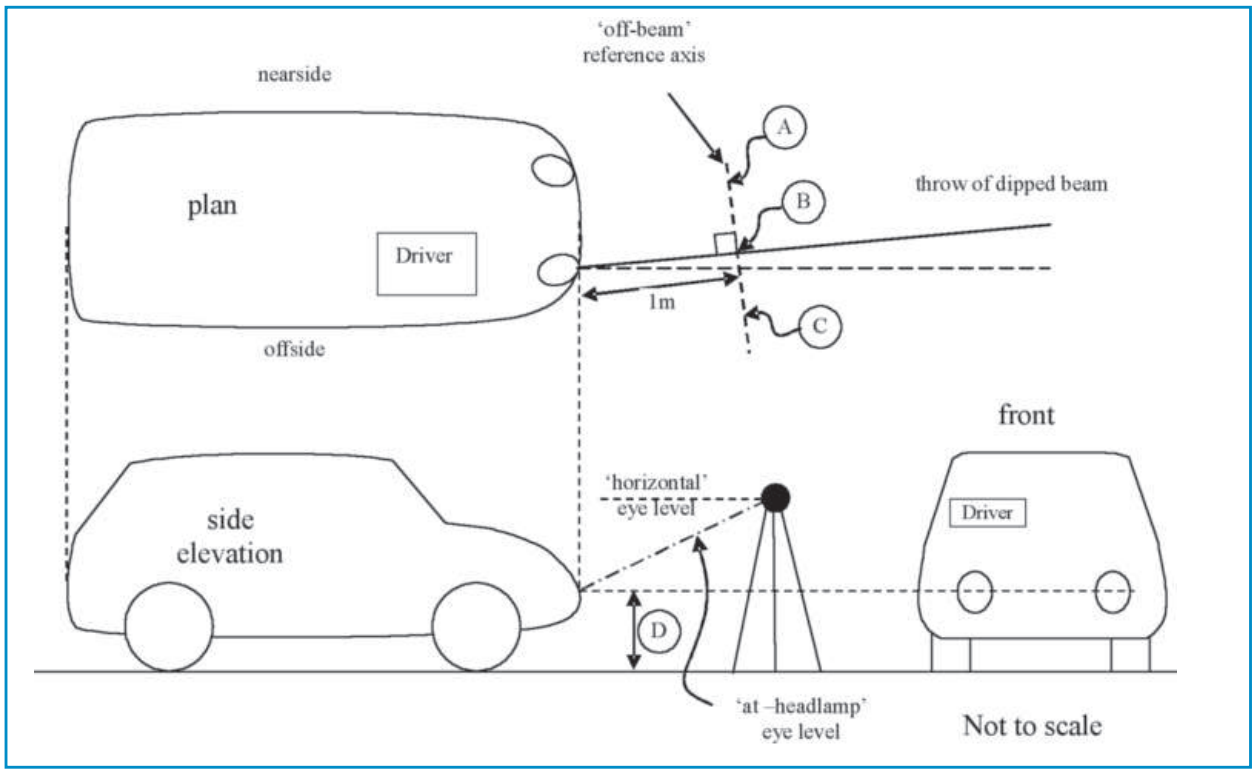
- High performance Mazda RX8 with Xe headlamps
- Medium family car Mercedes A180
- Compact Fiat 500
- Minibus LDV

Assessment conditions were chosen to represent worst case of foreseeable occupational exposure: see Table D.4.6 and Fig D.4.1

Table D.4.6. Assessment conditions for car lighting

	Position with respect to lamp		Distance	When people may be exposed
Headlamp: dipped and high beam	Lamp level: looking directly into the beam		0.5 m, 1 m, 2 m and 3 m	Servicing and repair: car on elevated platform Driving
	Eye level	Looking at lamp	1 m	Servicing and repair: car on floor level Road workers, traffic police
		Looking horizontally		
Indicator, brake, reverse and fog lights	Lamp level: looking directly into the beam		0.5 m	Driving Servicing and repairing Road workers, traffic police

Figure D.4.1. Schematic diagram of car lights measurements



Measurements of spectral irradiance and specific configurations of the car lamps were used to assess optical radiation hazards and compare them with Exposure Limit Values (ELVs).

Table D.4.7. Summary of optical radiation hazards from car lighting

Hazard	RX8	A180	F500	LDV
Actinic UV	None	None	None	None
UVA	None	None	None	None
Blue Light	May be exceeded: see Table D.4.8. for details	May be exceeded: see Tables D.4.8. and D.4.9. for details	May be exceeded: see Table D.4.8. for details	May be exceeded: see Table D.4.8. for details
Retinal burn	< 30 % of ELV	< 10 % of ELV	< 3 % of ELV	< 2 % of ELV

Table D.4.8. Blue Light hazard from car headlamps

Time to exceed Blue Light ELV	RX8	A180	F500	LDV
Lamp level: looking directly into the beam	~ 3 min	~ 5 min	~ 30 min	~ 1 h
Eye level: looking at the beam	~ 2 h	~ 8 h	> 8 h	> 8 h
Eye level: looking horizontally	> 8 h	> 8 h	> 8 h	> 8 h

Table D.4.9. Blue Light hazard levels from Mercedes A180 lights

Car lights	Time to exceed Blue Light exposure limits		Risk of overexposure
Headlamp, lamp level at 1 m, looking directly into the beam — position B in Fig. D.4.1.	dipped	~ 45 min	Unlikely, direct intra-beam viewing should be prevented by aversion response to very bright light. Working procedures should be adopted to minimise unnecessary exposure
	high beam	~ 15 min	
Headlamp, lamp level at 1 m, looking directly into the beam — positions A and C = 0.5 m in Fig. D.4.1.	dipped	> 8 h	None
	high beam	> 8 h	
Headlamp, eye level at 1 m, looking at lamp	dipped	> 8 h	None
	high beam	> 8 h	
Headlamp, eye level at 1 m, looking horizontally	dipped	> 8 h	None
	high beam	> 8 h	
Fog light	> 8 h		None
Brake light	> 8 h		None
Indicator light	> 8 h		None
Reverse light	> 8 h		None

Looking directly into the beam at headlamp level may constitute a Blue Light hazard and present a risk of overexposure. However, overexposure is unlikely because:

- extended intra-beam viewing should be prevented by the aversion response to very bright light;
- the hazard level decreases rapidly with moving away from the centre of the beam;
- the hazard level decreases substantially at eye level.

Car lighting is not expected to present a risk of over-exposure to optical radiation for road users, including drivers, traffic police and road workers. However, specific operations requiring extended direct viewing of headlamps on lamp level may constitute a low risk of a Blue Light hazard.

Important

Car lighting is not expected to present a UV hazard when the lamp's front glass or filters are intact. However, working with car lighting without the front glass or with damaged front glass may increase the risk of UV exposure. Working procedures should be adopted to avoid exposure from car lighting with damaged front glass or filters.

Modification of headlamp and headlamp optics may change hazard levels.

Although a risk of overexposure from direct intra-beam viewing of car headlamps is low, where possible working procedures should be adopted to minimise unnecessary exposure.

D.5 Military

Artificial optical radiation sources are widely used by the military. During combat operations, commanders may need to take decisions on the cost/benefit of courses of action to weigh the small risk of real injury if the exposure limits are exceeded against the risk of serious injury or death from other hazards. Therefore, this section will only deal with non-combat guidance, including training.

Military uses of artificial optical radiation may include:

- Searchlights
- Lighting at military airfields
- Infrared communication systems
- Infrared target illuminators
- Laser target designators
- Simulated weapons systems
- Infrared countermeasures
- Magnesium flares
- Optical radiation from explosions

Most of these applications require the artificial optical radiation to be in the open environment and usually out of doors. This means that the standard hierarchy of enclosing the optical radiation as the primary control measure is unlikely to be appropriate. A great deal of reliance is placed on training: military personnel are trained to obey instructions and orders.

When undertaking the risk assessment, as required by Article 4 of the Directive, consideration needs to be given to workers within the military and elsewhere. It may not always be possible to ensure that potential exposure levels are below the exposure limit values. Therefore, one approach used in this sector is Probabilistic Risk Assessment (PRA). This can be used to quantify 'likely', as required by Article 4. Various values may be adopted as part of the PRA. However, an event with a probability of 10^{-8} is considered acceptable, even for an adverse event which, if it happened, could have catastrophic consequences.

An event with a probability of less than 10^{-8} is not considered 'likely'.

The use of PRA is complex and requires specialist expertise. However, the benefits for the military are that it may permit the use of artificial optical radiation in situations that may not be considered acceptable with a less rigorous assessment.

D.6 Gas-fired overhead radiant heaters

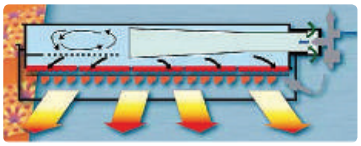
These assessments are provided by courtesy of the European association ELVHIS.



People may be exposed to optical radiation from gas-fired overhead radiant heaters which are used for a wide range of environments for heating of:

- industrial buildings
- public buildings
- logistic buildings
- fire stations
- exhibition halls
- indoor sport facilities
- terraces in restaurants and bars, and many others

According to manufacturers' specifications, such heaters are installed at a minimum height above the workers so that they are not in the direct line of vision.



Gas-fired overhead radiant heater (luminous type)

The surface temperature range of gas-fired luminous radiant heaters is between 700 °C and 1 000 °C, corresponding to a wavelength λ_{max} between 2 275 nm and 2 980 nm, using the Wien's law:

$$\lambda_{max} = \frac{hc}{4.965 \cdot kT} = \frac{2.898 \cdot 10^{-3}}{T} \text{ [m.°K]}$$

As recommended by AICVF, it results in an emission of

E_{IR} [W.m^{-2}] = 0.71 × α_k × f_p × η_r × P_u / d^2

where:

α_k – human absorption factor
f_p – direction factor
η_r – radiant efficiency factor
P_u – heater capacity
d – distance between human body and heater

Highest values (worst case scenario for manufacturer SBM):

α_k = 0.97
f_p = 0.10
η_r = 0.65
P_u = 27 000 W

Worst case for the distance d between human body and heater, for heater capacity P and maximum inclination angle I of 35°, was calculated by

d = h_i – 1 , where $h_i = \left[\left(\sqrt{\frac{Pu}{540}} - 0.5\right) \times \cos I\right] + 2$

and equals to d = 6.4 m

Worst case exposure in this case corresponds to $E_{IR\,max}$ = 29.1 ≈ 30 W m^{-2}

Exposure Limit Values in the wavelength range 780–3 000 nm for exposure durations t > 1 000 s is:

E_{IR} = 100 W m^{-2}

Gas luminous radiant heaters are not expected to present a risk of overexposure to optical radiation and could be considered as trivial sources: worst case foreseeable exposure from such heaters is substantially below applicable Exposure Limit Values.

Further information

AICVF : Association des Ingénieurs en Climatique, Ventilation et Froid – France

ELVHIS: Association Européenne Principale des Fabricants de Panneaux Radiants Lumineux à Gaz

Recommendation 01-2006; 'CHAUFFAGE: déperditions de base' based on the EN 12831 — March 2004: Heating systems in buildings; Methods for calculation of the design heat load.

SBM International — 3 Cottages de la Norge — 21490 Clenay — France

D.7 Material Processing Laser

Lasers are used in a wide range of applications, generically termed materials processing. The example here will consider a laser used to cut metal, but the principles are the same for laser welding, drilling and marking.

It is assumed that the radiant power or energy per pulse of the laser is such that the laser is a Class 4 system. As such, any accidental exposure to the laser beam — either to the eye or the skin — is likely to result in serious injury.

Many thousands of such lasers are routinely used throughout Europe. This assessment only considers the laser beam. Other hazards may present a greater risk of injury or death.

D.7.1. Identifying hazards and those at risk

There are a number of parts of the life cycle for a materials processing laser where workers could be exposed to laser radiation:

Commissioning
Normal operation
Maintenance
Servicing

Operations at some parts of the life cycle may be carried out by workers from other employers' organisations, such as from the supplier or a servicing company. However, it will be necessary to determine the risks from these operations to workers on site.

Due to the nature of the laser beams used, the direct beam is always going to exceed the ELV in close proximity. However, the scattered beam may need to be assessed.

If the workpiece is very large, for example in the shipbuilding industry, the nominal ocular hazard distance may be smaller than the size of the workpiece.

D.7.2. Evaluating and prioritising risks

The simplest assessment is to assume that the laser beam will always exceed the ELV and therefore access to the beam should be restricted. Other hazards associated with the process may also indicate that the process should be contained. Some of these hazards may present a greater risk to workers than the laser beam.

An assessment of the irradiance or radiant exposure of the laser beam may be required to determine any protection measures. The worst case is to assume that a collimated beam from the laser is incident at the position of interest.

D.7.3. Deciding on preventive action

Decisions on preventive action should take account of the degree of protection required and the requirements of the workers to carry out their specific work activity. Protection measures that impede the work activity will not be successful.

It should also be noted that it will not necessarily be a requirement to build an enclosure around the whole materials processing installation. An enclosure may only be required around the process volume.

The objective should be to be able to carry out all work activities, including maintenance and servicing, without the use of personal protective equipment. If it is necessary to view the process then suitably filtered viewing windows may be provided or remote viewing aids, such as cameras, used.

When deciding on protection measures, it may be necessary to assess optical radiation generated as part of the process. This may be in a different part of the optical spectrum to the incident laser beam, and is likely to be non-coherent.

D.8 Hot Industries

The assistance of Mr M Brose of Fachbereich Elektrotechnik, Referat Optische Strahlung, Berufsgenossenschaft Elektro Textil Feinmechanik, Germany, with these assessments is gratefully acknowledged.

D.8.1. Steel processing

(Saarstahl AG, Völklingen, Germany)

Saarstahl AG specialises in the production of wire rods, steel bars and semi-finished products of various grades. Facilities in Völklingen include steelmaking plants, rolling mills and forging from ingots of up to 200 tons.

Optical radiation safety is an essential part of company safety management.

Although emission of highly dangerous levels of optical radiation (mainly infrared) is intrinsic for steel production and processing, the implemented control measures minimise human access to hazardous optical radiation and ensure safe working conditions. These measures include:

- remote control and monitoring of the manufacturing process to minimise human exposure to hazardous levels of optical radiation;
- working procedures restricting operation in the hot conditions to 15 minutes, with compulsory change of activity;
- remote monitoring of worker's body temperature to avoid overheating, which is being planned;
- extensive professional and safety training of personnel;
- full body personal protective equipment when human access is required by manufacturing process;
- medical surveillance input into risk assessment;
- involvement of employees' representatives in health and safety management.

D.8.2. Glass works

Hazardous levels of optical radiation, mainly in the ultraviolet and infrared spectral regions, are emitted as a part of glass processing and glass forming. Manual manipulation

requires human access in close proximity to the source of hazardous emission, e.g. burner.

Because the accessible emission levels for workers are expected to exceed the Exposure Limits, risk assessment is required to ensure adequate control of optical radiation hazards. In this case the Exposure Limits may be exceeded for more than one optical radiation hazard and the most restrictive conditions should apply.

The risk assessment should take into account:

- the emissions of equipment, including any additional burners, at the position of worker, e.g. hands and face;
- foreseeable exposure duration during work shift — UV limits are accumulative for 8 hours;
- attenuation provided by shields and personal protective equipment.

UV exposure limits are accumulative. If they may be exceeded, human access should be restricted: either by decreasing emission level (shields, protective eyewear, hand protection) or by exposure duration (maximum permitted time).

If eye protection is supplied with the equipment, it is necessary to reassess its suitability if additional burners are used or new working procedures are introduced.

If equipment emits optical radiation in the actinic UV hazard region (180–400 nm), where exposure limits apply to skin as well as to the eyes, hand exposure should also be assessed. If protective gloves are impractical or may cause secondary safety concerns, exposure should be time limited.

D.8.3. Further information

BGFE • Informationen für die Glasbearbeitung mit Brennern — SD 53

D.9 Flash Photography

Artificial optical radiation sources are an essential part of professional studio photography. They are used for area and spot illumination, as background or flash exposure.

Two categories of occupational exposures can be considered in this case:

- Photographer
- Person being photographed (e.g. model)

Professional photographic studio may include:

- Diffuse illumination source
- Flash projector
- Flash from professional camera
- Flash from domestic camera

Table D.9.1. Worst case exposure scenario for simultaneous direct intra-beam exposure

	Diffuse illumination source	Flash projector	Flash from professional camera	Flash from domestic camera
Photographer	√	√	-	-
Model	√	√	√	√

Spectral irradiance and temporal characteristics (flash duration) for each source at the range of distances were used to evaluate the worst case exposure level and to compare it with applicable Exposure Limit values.

For UV and Blue Light limits worst case exposures are accumulative over an 8 hours exposure period and may be additive for multiple sources: they are expressed in terms of the number of photographic shots (flash or illumination) to exceed the applicable exposure limit.

Retinal Thermal hazard does not change with time for exposure durations longer than 10 seconds and is limited by field-of-view of 100 mrad: only a single shot from a single source is considered for the assessment of this hazard.

Hazard levels of UV, UVA and IR limits for all tested sources were insignificant

Table D.9.2. Worst case hazard levels from flash photographic sources

	Diffuse illumination source	Flash projector	Flash from professional camera	Flash from domestic camera
Number of shots to exceed Blue Light ELV	$> 10^7$	$> 10^6$	> 20 000	> 13 000
% of Retinal Thermal ELV in a single shot	< 0.03 %	< 1 %	< 1 %	< 1 %

Photography is not expected to present a real risk of over-exposure to optical radiation for a photographer or a person being photographed: number of flashes to exceed Blue Light ELV is in excess of few thousands for worst case simultaneous intra-beam exposure from multiple sources.

Appendix E. Requirements of other European directives

A European directive results from a mutually binding collective decision made by the Member States, acting through their national government ministers (in the Council of the European Union) and members (in the Parliament). Both bodies must approve the text of the directive in identical terms. A directive fixes the agreed objectives to be pursued by the Member States, but allows flexibility in the means of achieving them. How each Member State implements the directive will depend on its legal structure, and may vary. In practice, the Union addresses directives to all Member States, and specifies a date by which the Member States must have implemented the directive.

In 1989 Directive 89/391/EEC, 'on the introduction of measures to encourage improvements in the safety and health of workers at work', was published. This directive concerned the management of health and safety at work, its obligations taking the form of principles applicable to such management. Given the wide scope of this directive, it is not possible to adequately summarise it in a short space: there is no substitute for reading the whole directive, or the appropriate regulations which transpose it into the laws of the Member State in which the particular employer is operating. In general, the directive established the obligation to carry out risk assessments according to a set of general principles.

Directive 89/391/EEC is often referred to as the 'Framework Directive'. This is because one of its articles undertook to create a number of individual directives which would expand on the management of health and safety for specific areas or hazards: these individual directives are to be complied with in a manner consistent with the principles of the Framework Directive.

Directive 2006/25/EC, the 'Artificial Optical Radiation Directive', is one of the directives issued within the framework of Directive 89/391/EEC. Other relevant directives are Directive 89/654/EEC, concerning the minimum safety and health requirements for the workplace (the 'Workplace Directive') and Directive 89/655/EEC concerning the minimum safety and health requirements for the use of work equipment by workers at work (the 'Use of Work Equipment Directive').

The Use of Work Equipment Directive has been amended by Directive 95/63/EC (also 'concerning the minimum safety and health requirements for the use of work equipment by workers at work').

In order to comply with their legal obligations with respect to artificial optical radiation, employers must satisfy at least the requirements of the four directives mentioned above. However, in any Member State, local law may impose additional obligations beyond those set out in the directives.

Consequently, when an employer is seeking to comply with the requirements of the Artificial Optical Radiation Directive, it is worth remembering that there are other obligations concerning the health and safety management of optical radiation:

Framework Directive	Workplace Directive	Work Equipment Directive (as amended)
Where possible, risks must be avoided. Risks which cannot be avoided must be evaluated. Risks are to be combated at source. Work practices are to be adapted to the individual. Work practices are to be adapted to technical progress. That which is dangerous is to be replaced with non- or less dangerous alternatives. A coherent overall prevention policy covering technology, organisation, working conditions and social relationships is to be developed. Collective protective measures are to be given priority over individual ones. Workers are to be appropriately instructed.	Technical maintenance of equipment must be carried out and faults rectified as quickly as possible. Safety equipment must be regularly maintained and checked. Workers (or their representatives) must be informed of measures to be taken concerning safety and health at the workplace. The workplace, whether indoors or outdoors, shall be adequately illuminated to provide for worker's safety and health. If natural illumination is insufficient, artificial illumination must be used.	Use of equipment which involves specific health risks must be limited to those tasked with using it. Repairs, modifications and servicing are only carried out by those designated to do so. Workers are adequately trained in the use of equipment. Safety critical controls must be clearly visible. Controls must be situated outside of danger zones. The operator must be able to see that nobody is in a danger zone, or a warning signal must be given when the equipment is about to become hazardous. A fault in a control system must not result in a dangerous situation. Equipment must only start as a result of a deliberate action on a control. Equipment must only restart as a result of a deliberate action on a control. Equipment must be fitted with a control to stop it completely and safely. Areas for working on equipment must be suitably lit. Warnings must be unambiguous, clearly perceptible and easily understood. It must be possible to carry out maintenance safely. Equipment must bear any warnings or markings needed to ensure safety of workers. Where safe use is dependent upon the installation conditions, equipment must be inspected after assembly and before it is put into use. Equipment exposed to conditions which cause deterioration must be regularly inspected and the results recorded.

There are five other directives which have some relevance to safe working with artificial optical radiation. These all concern the supply of equipment which may produce, or may be intended to mitigate the effects of, optical radiation. As such, these are mainly of concern to the manufacturers and suppliers of equipment, rather than to the employer.

However, the employer should be aware that these directives exist, and that any plant or production equipment, or protective equipment which is found on the European market must comply with them. Two of these directives also mandate that the supplier shall provide the user with detailed information as to the nature of the radiation, means of protecting the user, means of avoiding misuse and means of eliminating any risks inherent during installation.

These supplier's directives are:

- Directive 2006/42/EC on machinery (the 'Machinery Directive').
- Directive 2006/95/EC on the harmonisation of the laws of the Member States relating to electrical equipment designed for use within certain voltage limits (the 'Low Voltage Directive').
- Directive 89/686/EEC on the approximation of the laws of the Member States relating to personal protective equipment (the 'PPE Directive').
- Directive 93/42/EEC concerning medical devices (the 'MD Directive').
- Directive 98/79/EC on in vitro diagnostic medical devices (the 'in-vitro Directive').

Some of the relevant provisions of these directives are summarised below:

Machinery Directive	Low Voltage Directive	PPE Directive	MD and in-vitro Directives
Machinery shall be supplied with sufficient integral lighting to allow safe use. Undesirable emissions must be eliminated or reduced to levels that do not have effects on persons. Functional emissions during setting, operation and cleaning must be limited to levels that do not have adverse effects on persons. If lasers are incorporated into the machine, there must be no accidental emissions. Lasers must be installed so that any emission by diffusion or reflection, or any secondary radiation, does not damage health. Optical equipment used to view or adjust laser beams must be designed so that it creates no health risk. If any design features have been implemented to comply with the above, the relevant Standards should be indicated.	The Low Voltage Directive applies to any work equipment intended to operate at 50–1 000 V a.c. or 75–1 500 V d.c. It is a stipulation that any such equipment must not produce radiation which would cause a danger.	PPE must protect the user without prejudice to the health or safety of other individuals. The majority of radiation likely to be harmful must be absorbed or reflected without unduly affecting the user's vision. PPE must be selected such that, under no circumstances will the user's eyes be exposed above maximum permissible exposure value. The optics of the PPE must not deteriorate as a result of exposure to the radiation that they are intended to protect against, under foreseeable conditions of use.	Devices must be designed to reduce exposure to patients, users and other persons. It must be possible for the user to control the level of emissions. Devices must be fitted with visible/audible emission warnings. Operating instructions shall contain detailed information as to the nature of the radiation, means of protecting the user, means of avoiding misuse and means of eliminating any risks inherent during installation.

Appendix F. EU Member State's national regulations transposing Directive 2006/25/CE (to the date of 10 December 2010) and guidance

Country	Current legislation	Current guidance
Austria	Oö. Landes- und Gemeinde-Dienstrechtsänderungsgesetz 2007 [Landesgesetzblatt (LGBl.), 25/07/2007, , 56/2007]. Verordnung der Landesregierung über den Schutz der Landes- und Gemeindebediensteten vor der Gefährdung durch künstliche optische Strahlung [Landesgesetzblatt (LGBl.), 18/02/2010, , 4/2010]. Landesgesetz, mit dem das Oö. Gemeinde-Dienstrechts- und Ge¬haltsgesetz 2002, das Oö. Gemeindebedienstetengesetz 2001; das Oö. Statutargemeinden-Beamtengesetz 2002, das Oö. Gemeinde¬bediensteten-Schutzgesetz 1999, das Oö. Gemeinde-Gehandlungs¬gesetz, das Oö. Landesbeamtengesetz 1993 und das Oö. Landes-Vertragsbedienstetengesetz geändert werden (Oö. Gemeinde- und Landes-Dienstrechtsänderungsgesetz 2008) [Landesgesetzblatt (LGBl.), 29/08/2008, , 73/2008]. Verordnung der Wiener Landesregierung, mit der die Verordnung der Wiener Landesregierung über den Schutz der in Dienststellen der Gemeinde Wien beschäftigten Bediensteten vor der Einwirkung durch optische Strahlung erlassen und die Verord¬nung der Wiener Landesregierung über die Gesund¬heitsüberwachung am Arbeitsplatz in Dienststellen der Gemeinde Wien geändert wird [Landesgesetzblatt (LGBl.), 51/2010, 24/09/2010] Verordnung der Oö. Landesregierung, mit der die Verordnung über den Schutz der Dienstnehmerinnen und Dienstnehmer in der Land- und Forstwirtschaft vor der Einwirkung durch künstliche optische Strahlung (Oö. VOPST-LF) erlassen wird und mit der die Verordnung über die Gesundheitsüberwachung in der Land- und Forstwirtschaft und die Verordnung über Beschäftigungsverbote und -beschränkungen für Jugendliche in land- und forstwirtschatlichen Betrieben geändert werden [Landesgesetzblatt (LGBl.), 65/2010, 30/09/2010] Gesetz, mit dem die Dienstordnung 1994 (28. Novelle zur Dienstordnung 1994), die Besoldungsordnung 1994 (36. Novelle zur Besoldungsordnung 1994), die Ver-tragsbedienstetenordnung 1995 (32. Novelle zur Ver-tragsbedienstetenordnung 1995), die Pensionsordnung 1995 (20. Novelle zur Pensionsordnung 1995), das Ruhe- und Versorgungsgenusszulagegesetz 1995 (9. Novelle zum Ruhe- und Versorgungsgenusszulagegesetz 1995), das Unfallfürsorgegesetz 1967 (17. Novelle zum Unfall-fürsorgegesetz 1967), das Wiener Bedienstetenschutzge-setz 1998 (5. Novelle zum Wiener Bedienstetenschutzge-setz 1998), das Wiener Personalvertretungsgesetz (16. Novelle zum Wiener Personalvertretungsgesetz), das Wiener Bezügegesetz 1995 (10. Novelle zum Wiener Bezügegesetz 1995), das Wiener Verwaltungssenat-Dienstrechtsgesetz 1995 (11. Novelle zum Wiener Ver-waltungssenat-Dienstrechtsgesetz 1995) und das Gesetz über den Unabhängigen Verwaltungssenat Wien (8. No-velle zum Gesetz über den Unabhängigen Verwaltungs-senat Wien) geändert werden und das Wiener Eltern-Karenzgeldzuschussgesetz aufgehoben wird [Landesgesetzblatt (LGBl.), 42/2010, 17/09/2010] Verordnung der Salzburger Landesregierung vom 1. Juli 2010 über Schutzvorschriften vor Gefährdung durch künstliche optische Strahlung (S.koS-V) [Landesgesetzblatt (LGBl.), 55/2010, 06/08/2010] Verordnung des Bundesministers für Arbeit, Soziales und Konsumentenschutz, mit der die Verordnung über den Schutz der Arbeitnehmer/innen vor der Einwirkung durch optische Strahlung (Verordnung optische Strahlung – VOPST) erlassen wird und mit der die Verordnung über die Gesundheitsüberwachung am Arbeitsplatz und die Verordnung über Beschäftigungsverbote und –beschränkungen für Jugendliche geändert werden [Bundesgesetzblatt für die Republik Österreich (BGBl.), II Nr. 221/2010, 08/07/2010]	Sicherheitsinformation der Allgemeinen Unfallversicherungsanstalt: Sicherheit Kompakt: M 014 UV-Strahlenbelastung am Arbeitsplatz M 080 Grundlagen der Lasersicherhet

Country	Current Legislation	Current Guidance
Belgium	FEDERALE OVERHEIDSDIENST WERKGELEGENHEID, ARBEID EN SOCIAAL OVERLEG - 22 APRIL 2010. - Koninklijk besluit betreffende de bescherming van de gezondheid en de veiligheid van de werknemers tegen de risico's van kunstmatige optische straling op het werk [Moniteur Belge, 06/05/2010, 25349-25386].	
Bulgaria	Наредба № 5 от 11 юни 2010 г. за минималните изисквания за осигуряване на здравето и безопасността на работещите при рискове, свързани с експозиция на изкуствени оптични лъчения [Държавен вестник, 49, 29/06/2010, 00035-00048] Кодекс на труда [Държавен вестник, 15, 23/02/2010] Закон за здравословни и безопасни условия на труд [Държавен вестник, 12, 12/02/2010] Наредба № 7 от 23.09.1999 г. за минималните изисквания за здравословни и безопасни условия на труд на работните места и при използване на работното оборудване [Държавен вестник, 40, 18/04/2008]	
Cyprus	Οι Περί Ασφάλειας και Υγείας στην Εργασία (Τεχνητή Οπτική Ακτινοβολία) Κανονισμοί του 2010 [Cyprus Gazette, 4433, 11/06/2010, 01473-01493]	
Czech Republic	Zákon č. 320/2002 Sb., o změně a zrušení některých zákonů v souvislosti s ukončením činnosti okresních úřadů [Sbirka Zakonu CR, 18/07/2002]. Zákon č. 20/1966 Sb., o péči o zdraví lidu [Sbirka Zakonu CR, 30/03/1966]. Zákon č. 111/2007 Sb., kterým se mění zákon č. 20/1966 Sb., o péči o zdraví lidu, ve znění pozdějších předpisů a některé další zákony [Sbirka Zakonu CR, 15/05/2007]. Zákon č. 309/2006 Sb., kterým se upravují další požadavky bezpečnosti a ochrany zdraví při práci v pracovněprávních vztazích a o zajištění bezpečnosti a ochrany zdraví při činnosti nebo poskytování služeb mimo pracovněprávní vztahy (zákon o zajištění dalších podmínek bezpečnosti a ochrany zdraví při práci) [Sbirka Zakonu CR, 22/06/2006]. Nařízení vlády č. 106/2010 Sb., kterým se mění nařízení vlády č. 1/2008 Sb., o ochraně zdraví před neionizujícím zářením [Sbirka Zakonu CR, 19/04/2010]. Zákon č. 14/1997 Sb., kterým se mění a doplňuje zákon č. 20/1966 Sb., o péči o zdraví lidu, ve znění pozdějších předpisů, a zákon České národní rady č. 36/1975 Sb., o pokutách za porušování právních předpisů o vytváření a ochraně zdravých životních podmínek, ve znění zákona České národní rady č. 137/1982 Sb. [Sbirka Zakonu CR, 24/02/1997]. Zákon České národní rady č. 548/1991 Sb., kterým se mění a doplňuje zákon č. 20/1966 Sb., o péči o zdraví lidu, ve znění zákona České národní rady č. 210/1990 Sb. a zákona České národní rady č. 425/1990 Sb. [Sbirka Zakonu CR, 30/12/1991]. Nařízení vlády č. 1/2008 Sb., o ochraně zdraví před neionizujícím zářením [Sbirka Zakonu CR, 09/01/2008]. Zákon č. 392/2005 Sb., kterým se mění zákon č. 258/2000 Sb., o ochraně veřejného zdraví a o změně některých souvisejících zákonů, ve znění pozdějších předpisů, a některé další zákony [Sbirka Zakonu CR, 27/09/2005]. Zákon č. 274/2003 Sb., kterým se mění některé zákony na úseku ochrany veřejného zdraví [Sbirka Zakonu CR, 27/08/2003]. Zákon č. 258/2000 Sb., o ochraně veřejného zdraví a o změně některých souvisejících zákonů [Sbirka Zakonu CR, 11/08/2000]. Zákon č. 262/2006 Sb., zákoník práce [Sbirka Zakonu CR, 07/06/2006]. Zákon č. 48/1997 Sb., o veřejném zdravotním pojištění a o změně a doplnění některých souvisejících zákonů [Sbirka Zakonu CR, 07/03/1997]. Zákon č. 362/2007, kterým se mění zákon č. 262/2006 Sb., zákoník práce, ve znění pozdějších předpisů, a další související zákony [Sbirka Zakonu CR, 28/12/2007].	Guidance for work with lasers No. 61 UV Zareni poster (warning of dangers of UV radiation) ICNIRP Guidelines

Country	Current Legislation	Current Guidance
Denmark	Bekendtgørelse om beskyttelse mod udsættelse for kunstig optisk stråling i forbindelse med arbejdet [Lovtidende A, 29/05/2010]. Bekendtgørelse om beskyttelse mod risici ved udsættelse for kunstig optisk stråling på offshoreanlæg m.v. [Lovtidende A, 21/04/2010].	The Danish Working Environment Act is to provide a "safe and healthy working environment". In the administration thereof, the ICNIRP recommendations on optical radiation are used as guidelines together with the relevant European norms (eg. EN 60825 and EN 207/208).
Estonia	TÖÖTERVISHOIU JA TÖÖOHUTUSE SEADUSE MUUTMISE SEADUS [Elektroon-iline Riigi Teataja, , , RTI, 16.01.2007, 3, 11]. Töötervishoiu ja tööohutuse nõuded tehislikust optilisest kiirgusest mõjutatud töökeskkonnas, tehisliku optilise kiirguse piirnormid ja kiirguse mõõtmise kord1 [Elektrooniline Riigi Teataja, , , RTI, 22.04.2010, 16, 84].	
Finland	Valtioneuvoston asetus työntekijöiden suojelemiseksi optiselle säteilylle altistumisesta aiheutuvilta vaaroilta / Statsrådets förordning om skydd av arbetstagare mot risker som uppstår vid exponering för optisk strålning [Suomen Saadoskokoelma (SK), 05/03/2010, 00703-00720, 146/2010]	
France	Décret no 2010-750 du 2 juillet 2010 relatif à la protection des travailleur-scontre les risques dus aux rayonnements optiques artificiels [Journal Officiel de la République Française (JORF), 04/07/2010]	
Germany	Verordnung zur Umsetzung der Richtlinie 2006/25/EG zum Schutz der Arbe-itnehmer vor Gefährdungen durch künstliche optische Strahlung und zur Änderung von Arbeitsschutzverordnungen vom 19. Juli 2010 [Bundesgesetz-blatt Teil 1 (BGB 1), 38, 26/07/2010, 00960-00967]	Information BGI 5006: "Exposure Limit Values for Artificial Optical Radiation" Non-ionizing Radiation Guideline: "Laser Radiation" Non-ionizing Radiation Guideline: "Ultraviolet Radiation from Artificial Sources" Non-ionizing Radiation Guideline: "Visible and Infrared Radiation" Risks assessment methods for optical radiation from artificial sources are described in the following documents: Accident Prevention Regulation BGV B2: "Laser Radiation" DIN EN 60825-1: 2008: "Safety of Laser Products - Part 1: Equipment Classification, Requirements and User's Guide" DIN EN 14255-1: 2005: „Measurement and Assessment of Personal Exposures to Incoherent Optical Radiation - Part 1: Ultraviolet Radiation Emitted by Artificial Sources in the Workplace" IEC 62471: 2006: "Photobiological Safety of Lamps and Lamp Systems" DIN EN 12198-1:2000 „Safety of Machinery – Assessment and Reduction of Risks Arising from Radiation Emitted by Machinery – Part 1: General Principles" Non-ionizing Radiation Guideline: "Ultraviolet Radiation from Artificial Sources" BGR 107: Safety Rules for Dryers of Printing and Paper Processing Machines Risk reduction methods for optical radiation from artificial sources are described in the following documents: Accident Prevention Regulation BGV B2: "Laser Radiation" Information BGI 5006: „Exposure Limit Values for Artificial Optical Radiation" Information BGI 5007: Laser Devices for Shows and Projections DIN EN 12198-3:2002 „Safety of Machinery - Assessment and Reduction of Risks arising from radiation emitted by machinery - Part 3: Reduction of Radiation by Attenuation or Screening" Non-ionizing Radiation Guideline: "Laser Radiation" Non-ionizing Radiation Guideline: "Ultraviolet Radiation from Artificial Sources" Risk reduction methods on branch level are also described in the following documents: Accident Prevention Regulation BGV D1: "Welding, Cutting and Related Methods" "UV-Drying", Professional Association Printing and Paper Conversion Merkblatt über Betrachtungsplätze für die fluoreszierende Prüfung mit dem Magnetpulver- und Eindringverfahren – Ausrüstung und Schutzmaßnahmen bei Arbeiten mit UV-Strahlung Information BGI 5092 Auswahl von Laser-Schutzbrillen und Laser-Justierbrillen Information BGI 5031 Umgang mit Lichtwellenleiter-Kommunikations-Systems (LWKS) Leaflets and flyers: Leaflet of the Federal Institute for Occupational Safety and Health: „Damit nichts ins Auge geht... - Schutz vor Laserst-rahlung" Flyer of the Federal Institute for Occupational Safety and Health: "Dazzle: Blind for a Moment. Protection Against Optical Radiation" Flyer of the Federal Institute for Occupational Safety and Health: "Hand-held Lasers to Work Materials"

Country	Current Legislation	Current Guidance
Greece	Ελάχιστες προδιαγραφές υγείας και ασφάλειας όσοναφορά στην έκθεση των εργαζομένων σε κινδύνους προερχόμενους από φυσικούς παράγοντες (τεχνητή οπτική ακτινοβολία), σε συμμόρφωση με την οδηγία 2006/25/ΕΚ [Εφημερίς της Κυβερνήσεως (ΦΕΚ) (Τεύχος Α), 145, 01/09/2010, 03075-03094]	
Hungary	1991. évi XI. Törvény az Állami Népegészségügyi és Tisztiorvosi Szolgálatról [Magyar Közlöny, , 00753-00759] 2/1998. (I. 16.) MüM rendelet a munkahelyen alkalmazandó biztonsági és egészségvédelmi jelzésekről [Magyar Közlöny, 16/01/1998, 174-192, 2] A Kormány 218/1999. (XII. 28.) Korm. rendelete az egyes szabálysértésekről [Magyar Közlöny, 28/12/1999, 08942-08968, 1999/125] Az egészségügyi miniszter 22/2010. (V. 7.) EüM rendelete a munkavállalókat érő mesterséges optikai sugárzás expozícióra vonatkozó minimális egészségi és biztonsági követelményekről [Magyar Közlöny, , 14597-14614] 1997. évi XLVII. Törvény az egészségügyi és a hozzájuk kapcsolódó személyes adatok kezeléséről és védelméről [Magyar Közlöny, 05/06/1997, 03518-03528, 1997/49] 2009. évi CLIV. Törvény az egyes egészségügyi tárgyú törvények módosításáról [Magyar Közlöny, , 47035-47090] 1993. évi XCIII. tv. a munkavédelemről [Magyar Közlöny, 03/11/1993, 9942-9953, 160] 33/1998. (VI. 24.) NM rendelet a munkaköri, szakmai, illetve személyi higiénés alkalmasság orvosi vizsgálatáról és véleményezéséről [Magyar Közlöny, 24/06/1998, 4489-4516, 54]	The European Standards are also applicable in Hungary ie. IEC 60825 -1, -2, -4, -12, IEC 60335-2-27 IEC 60601-2-22 EN 12198-1 EN 14255-1, -2, -4
Ireland	S.I. No. 176 of 2010 SAFETY, HEALTH AND WELFARE AT WORK (GENERAL APPLICATION) (AMENDMENT) REGULATIONS 2010 [Iris Oifigiúl, 04/05/2010, 00628-00629, 176 of 2010]	ICNIRP Guidelines
Italy	Attuazione dell'articolo 1 della legge 3 agosto 2007, n. 123, in materia di tutela della salute e della sicurezza nei luoghi di lavoro [Gazzetta Ufficiale della Repubblica Italiana, 30/04/2008, , S.O. N.108/L - GU N. 101].	
Latvia	Ministru kabineta 2009.gada 30.jūnija noteikumi Nr.731 "Darba aizsardzības prasības nodarbināto aizsardzībai pret mākslīgā optiskā starojuma radīto risku darba vidē" [Latvijas Vēstnesis, 07/07/2009, , 105]	Latvian Standard: Measurement and assessment of personal exposures to incoherent optical radiation – Part 2: Visible and infrared radiation emitted by artificial sources in the workplace

Country	Current Legislation	Current Guidance
Lithuania	LIETUVOS RESPUBLIKOS ADMINISTRACINIŲ TEISĖS PAŽEIDIMŲ KODEKSO 5, 41, 51(3), 51(12), 55, 58, 70, 76, 77, 77(1), 81, 82, 84(1), 87, 89(1), 91, 99(8), 183, 188(4), 188(9), 189(1), 214(3), 221, 224, 225, 232(1), 237, 242, 244, 246(2), 259(1), 262, 263, 268, 320 STRAIPSNIŲ PAKEITIMO BEI PAPILDYMO IR KODEKSO PAPILDYMO 42(4), 51(18), 51(19), 51(20), 51(21), 51(22), 56(2), 58(1), 78(1), 89(2), 99(9), 99(10), 148, 173(20), 173(21) STRAIPSNIAIS ĮSTATYMAS Nr. X-691 [Nouvelles de l'Etat, 30/06/2006, , 73]. Lietuvos Respublikos socialinės apsaugos ir darbo ministro ir Lietuvos Respublikos sveikatos apsaugos ministro 2007 m. spalio 5 d. įsakymas Nr. A1-277/V-785 „Dėl 2007 m. birželio 20 d. Europos Parlamento ir Tarybos direktyvos 2007/30/EB, iš dalies keičiančios Tarybos direktyvą 89/391/EEB, jos atskiras direktyvas ir Tarybos direktyvas 83/477/EEB, 91/383/EEB, 92/29/EBB bei 94/33/EB, siekiant supaprastinti ir racionalizuoti praktinio įgyvendinimo ataskaitas, įgyvendinimo" 2007 m. spalio 5 d. Nr. A1-277/V-785 [Nouvelles de l'Etat, 11/10/2007, , 105] Lietuvos Respublikos socialinės apsaugos ir darbo ministro ir Lietuvos Respublikos sveikatos apsaugos ministro 2007 m. gruodžio 14 d. įsakymas Nr.A1-366/V-1025 „Dėl darbuotojų apsaugos nuo dirbtinės optinės spinduliuotės keliamos rizikos nuostatų patvirtinimo" [Nouvelles de l'Etat, 22/12/2007, , 136] Lietuvos Respublikos administracinių teisės pažeidimų kodekso pakeitimo ir papildymo įstatymas Nr. VIII-1543 [Nouvelles de l'Etat, 15/03/2000, , 22]	
Luxembourg	Règlement grand-ducal du 26 juillet 20101. relatif aux prescriptions minimales de sécurité et de santé relatives à l'exposition des salariés aux risques dus aux agents physiques (rayonnements optiques artificiels et rayonnement solaire)2. portant modification du règlement grand-ducal modifié du 17 juin 1997 concernant la périodicité des examens médicaux en matière de médecine du travail [Mémorial Luxembourgeois A, 131, 12/08/2010, 02164-02182]	
Malta	L.N. 250 of 2010 OCCUPATIONAL HEALTH AND SAFETY AUTHORITY ACT (CAP. 424) Work Place (Minimum Health and Safety Requirements for the Protection of Workers from Risks resulting from Exposure to Artificial Optical Radiation) Regulations, 2010 [The Malta government gazette, 30/04/2010, 02403-02450, 18586]	
Netherlands	Besluit van 1 februari 2010 tot wijziging van het Arbeidsomstandighedenbesluit, houdende regels met betrekking tot de blootstelling van werknemers aan de risico's van kunstmatige optische straling [Staatsblad (Bulletin des Lois et des Décrets royaux), 09/03/2010, 00001-00021, Stb. 2010, 103]	Optische straling in arbeidssituaties
Poland	Rozporządzenie Ministra Pracy i Polityki Społecznej z dnia 27 maja 2010 r. w sprawie bezpieczeństwa i higieny pracy przy pracach związanych z ekspozycją na promieniowanie optyczne [Dziennik Ustaw, 2010/100/643, 09/06/2010] Rozporządzenie Ministra Pracy i Polityki Społecznej z dnia 29 lipca 2010 r. zmieniające rozporządzenie w sprawie najwyższych dopuszczalnych stężeń i natężeń czynników szkodliwych dla zdrowia w środowisku pracy [Dziennik Ustaw, 2010/141/950, 06/08/2010]	There are some publications available pertaining to occupational risk assessment method and guidelines which cover optical radiation. These are: "Occupational risk assessment. Part I :Methodological basis". ed. M.W Zawieska, CIOP-PIB, Warszawa 2004 (3-rd edition) "Occupational risk assessment. Part 2. STER-computer aided support". ed. M.W Zawieska, CIOP, Warszawa 2000 "Occupational risk . Methodological basis of evaluation" ed. M.W .Zawieska, CIOP-PIB Warszawa, 2007.

Country	Current Legislation	Current Guidance
Portugal	Assembleia da República-Estabelece as prescrições mínimas para protecção dos trabalhadores contra os riscos para a saúde e a segurança devidos à exposição, durante o trabalho, a radiações ópticas de fontes artificiais, transpondo a Directiva n.º 2006/25/CE, do Parlamento Europeu e do Conselho, de 5 de Abril [Diaro da Republica, 168, 30/08/2010, 03770-03782] Assembleia da RepúblicaRectifica a Lei n.º 25/2010, de 30 de Agosto, que estabelece as prescrições mínimas para protecção dos trabalhadores contra os riscos para a saúde e a segurança devidos à exposição, durante o trabalho, a radiações ópticas de fontes artificiais, transpondo a Directiva n.º 2006/25/CE, do Parlamento Europeu e do Conselho, de 5 de Abril, publicada no Diário da República, 1.ª série, n.º 168, de 30 de Agosto de 2010 [Diaro da Republica I, 209, 27/10/2010, 04849-04859]	
Romania	Hotărârea Guvernului privind cerinţele minime de securitate şi sănătate în muncă referitoare la expunerea lucrătorilor la riscuri generate de radiaţiile optice artificiale [Monitorul Oficial al României, 427, 25/06/2010, 00002-00015]	
Slovakia	Zákon č. 355/2007 Z. z. o ochrane, podpore a rozvoji verejného zdravia a o zmene a doplnení niektorých zákonov [Zbierka zákonov SR, 31/07/2007, , 154] Nariadenie vlády Slovenskej republiky č. 410/2007 Z. z. o minimálnych zdravotných a bezpečnostných požiadavkách na ochranu zamestnancov pred rizikami súvisiacimi s expozíciou umelému optickému žiareniu [Zbierka zákonov SR, 01/09/2007, , 178]	
Slovenia	Uredba o varovanju delavcev pred tveganji zaradi izpostavljenosti umetnim optičnim sevanjem [Uradni list RS, 34/2010, 30/04/2010, 04892-04909]	

Country	Current Legislation	Current Guidance
Spain	Real Decreto 486/2010, de 23 de abril, sobre la protección de la salud y la seguridad de los trabajadores contra los riesgos relacionados con la exposición a radiaciones ópticas artificiales [Boletín Oficial del Estado (B.O.E), 24/04/2010, 36103-36120, 99/2010] Corrección de errores del Real Decreto 486/2010, de 23 de abril, sobre la protección de la salud y la seguridad de los trabajadores contra los riesgos relacionados con la exposición a radiaciones ópticas artificiales [Boletín Oficial del Estado (B.O.E), 06/05/2010, 40171-40171, 110/2010]	STANDARDS UNE-CR 13464: 1999 "Guía para la selección, utilización y mantenimiento de los protectores oculares y faciales de uso profesional". UNE EN 166: 2002 "Protección individual del ojo. Requisitos" UNE EN 169: 2003 "Protección individual de los ojos. Filtros para soldadura y técnicas relacionadas. Especificaciones del coeficiente de transmisión (transmitancia) y uso recomendado" UNE EN 170: 2003 "Protección individual de los ojos. Filtros para el ultravioleta. Especificaciones del coeficiente de transmisión (transmitancia) y uso recomendado". UNE EN 207 "Filtros y protectores de los ojos contra la radiación láser (gafas de protección láser)". (Esta norma tiene ampliaciones y modificaciones). UNE EN 208 "Gafas de protección para los trabajos de ajuste de láser y sistemas láser (gafas de ajuste láser)". Esta norma tiene ampliaciones y modificaciones). UNE-EN 60825 "Seguridad de los productos láser" esta norma tiene varias partes y numerosas correcciones UNE-EN 14255 Medición y evaluación de la exposición de las personas a la radiación óptica incoherente. (Esta norma tiene varias partes) POSTERS La Directiva 2006/25/CE sobre exposición laboral a radiaciones ópticas artificiales. Methodology to assess occupational exposure to optical radiations Spectralimit: an Application to Assess the Occupational Exposure to UV & Visible Radiation OTHER INSHT'S DOCUMENTS NTP 755: "Radiaciones ópticas: Metodología de evaluación de la exposición laboral". NTP 654: Láseres: nueva clasificación del riesgo (UNE EN 60825-1 /A2: 2002). NTP 261: Láseres: riesgos en su utilización. FDN-17: Selección de pantallas faciales y gafas de protección. FDN-23: Comercialización de las Pantallas de Protección para Soldadores. Guías orientativas para la selección y utilización de EPI - Protectores oculares y faciales. CD_R. Prevention of Labour Risks. Advanced training course for the performance of functions of Superior Level. Version 2. Algunas cuestiones sobre seguridad Láser. (Some topics about laser safety). Evaluación de las Condiciones de Trabajo en la pequeña y mediana empresa. Riesgos por radiaciones ópticas procedentes de fuentes luminosas. La exposición laboral a radiaciones ópticas
Sweden	Arbetsmiljöverkets föreskrifter om artificiell optisk strålning (AFS 2009:7) [Arbetsmiljöverkets författningssamling (AFS), 10/11/2009, , 2009:7]	
United Kingdom	The Control of Artifical Optical Radiation at Work Regulations 2010 [Her Majesty's Stationery Office (HMSO), 06/04/2010, , GB SI 2010 No. 1140] The Control of Artificial Optical Radition at Work Regulations (Northern Ireland) 2010 [Her Majesty's Stationery Office (HMSO), , , SR of NI 2010 No.180] Factories (Protection of Workers from Physical Agents) (Artifical Optical Radiation) Regulations 2010 [Gibraltar Gazette, 3801, 29/07/2010]	MHRA DB2008(03) Guidance on the safe use of lasers, intense light source systems and LEDs in medical, surgical, dental and aesthetic practices. HSG95 The radiation safety of lasers used for display purposes.

Appendix G. European and international standards

There are a number of European Standards that relate to products that emit optical radiation, characterising the emissions and cover protection measures. There are also a number of international standards from ISO, IEC and CIE, which have not been published as European Standards. A third group are guidance documents, which have been published internationally, but may not have been adopted by all Member States.

Inclusion of a document in this appendix does not necessarily mean than an employer needs to obtain and read the document. However, some of the documents may assist employers with their risk assessments and risk management.

G.1 Euronorms

EN 165:2005 Personal eye protection — Vocabulary

EN 166: 2002 Personal eye protection — Specifications

EN 167: 2002 Personal eye protection — Optical test methods

EN 168: 2002 Personal eye protection — Non-optical test methods

EN 169: 2002 Personal eye protection — Filters for welding and related techniques — Transmittance requirements and recommended use

EN 170: 2002 Personal eye protection — Ultraviolet filters — Transmittance requirements and recommended use

EN 171: 2002 Personal eye protection — Infrared filters — Transmittance requirements and recommended use

EN 175: 1997 Personal protection — Equipment for eye and face protection during welding and allied processes

EN 207: 1998 Filters and eye protection against laser radiation

EN 208: 1998 Eye protectors for adjustment work on lasers and laser systems

EN 349: 1993 Safety of machinery, minimum gaps to avoid crushing of parts of the human body

EN 379: 2003 Personal eye protection — Automatic welding filters

EN 953: 1997 The safety of machinery, guards — General requirements for the design and construction of fixed and moveable guards

EN 1088: 1995 Interlocking devices associated with guards

EN 1598: 1997 Health and safety in welding and allied processes — Transparent welding curtains, strips and screens for arc-welding processes

EN ISO 11145: 2001 Optics and optical instruments — Lasers and laser-related equipment — Vocabulary and symbols

EN ISO 11146-1: 2005 Lasers and laser-related equipment — Test methods for laser beam widths, divergence angles and beam propagation ratios — Stigmatic and simple astigmatic beams

EN ISO 11146-2: 2005 Lasers and laser-related equipment — Test methods for laser beam widths, divergence angles and beam propagation ratios — General astigmatic beams

EN ISO 11149: 1997 Optics and optical instruments — Lasers and laser-related equipment — Fibre optic connectors for non-telecommunication laser applications

EN ISO 11151-1: 2000 Lasers and laser-related equipment — Standard optical components. Components for the UV, visible and near-infrared spectral ranges

EN ISO 11151-2: 2000 Lasers and laser-related equipment — Standard optical components — Components for the infrared spectral range

EN ISO 11252: 2004 Lasers and laser-related equipment — Laser device — Minimum requirements for documentation

EN ISO 11254-3: 2006 Lasers and laser-related equipment — Determination of laser-induced damage threshold of optical surfaces — Assurance of laser power (energy) handling capabilities

EN ISO 11551: 2003 Optics and optical instruments — Lasers and laser-related equipment — Test method for absorptance of optical laser components

EN ISO 11553-1: 2005 Safety of machinery — Laser processing machines — General safety requirements

EN ISO 11553-2: 2007 Safety of machinery — Laser processing machines — Safety requirements for hand-held laser processing devices

EN ISO 11554: 2006 Optics and photonics — Lasers and laser-related equipment — Test methods for laser beam power, energy and temporal characteristics

EN ISO 11670: 2003 Lasers and laser-related equipment — Test methods for laser beam parameters — Beam positional stability

EN ISO 11810-1: 2005 Lasers and laser-related equipment — Test method and classification for the laser resistance of surgical drapes and/or patient protective covers — Primary ignition and penetration

EN ISO 11810-2: 2007 Lasers and laser-related equipment — Test method and classification for the laser-resistance of surgical drapes and/or patient-protective covers — Secondary ignition

EN ISO 11990: 2003 Optics and optical instruments — Lasers and laser-related equipment. Determination of laser resistance of tracheal tube shafts

EN ISO 12005: 2003 Lasers and laser-related equipment — Test methods for laser beam parameters. Polarisation

EN ISO 12100-1: 2003 Safety of Machinery — Basic concepts, general principles for design — Part 1: Basic terminology, methodology

EN ISO 12100-2: 2003 Safety of Machinery — Basic concepts, general principles for design — Part 2: Technical principles

EN 12254: 1998 Screens for laser working places — Safety requirements and testing

EN ISO 13694: 2001 Optics and optical instruments — Lasers and laser-related equipment — Test methods for laser beam power (energy) density distribution

EN ISO 13695: 2004 Optics and photonics — Lasers and laser-related equipment — Test methods for the spectral characteristics of lasers

EN ISO 13697: 2006 Optics and photonics — Lasers and laser-related equipment — Test methods for specular reflectance and regular transmittance of optical laser components

EN 13857: 2008 Safety of Machinery, safety distances to prevent danger zones being reached by upper and lower limbs

EN ISO 14121-1: 2007 Safety of machinery — Risk assessment — Part 1: Principles

EN 14255-1: 2005 Measurement and assessment of personal exposures to incoherent optical radiation — Part 1: Ultraviolet radiation emitted by artificial sources in the workplace

EN 14255-2: 2005 Measurement and assessment of personal exposures to incoherent optical radiation — Part 2: Visible and infrared radiation emitted by artificial sources in the workplace

EN 14255-4: 2006 Measurement and assessment of personal exposures to incoherent optical radiation — Part 4: Terminology and quantities used in UV-, visible and IR-exposure measurements

EN ISO 14408: 2005 Tracheal tubes designed for laser surgery — Requirements for marking and accompanying information

EN ISO 15367-1: 2003 Lasers and laser-related equipment — Test methods for determination of the shape of a laser beam wavefront — Terminology and fundamental aspects

EN ISO 15367-2: 2005 Lasers and laser-related equipment — Test methods for determination of the shape of a laser beam wavefront — Shack-Hartmann sensors

EN ISO 17526: 2003 Optics and optical instruments — Lasers and laser-related equipment — Lifetime of lasers

EN ISO 22827-1: 2005 Acceptance tests for Nd:YAG laser beam welding machines — Machines with optical fibre delivery — Laser assembly

EN ISO 22827-2: 2005 Acceptance tests for Nd:YAG laser beam welding machines — Machines with optical fibre delivery — Moving mechanism

EN 60601-2-22: 1996 Medical electrical equipment Part 2 — Particular Requirements for Safety — Section 2.22. — Specification for diagnostic and therapeutic laser equipment

EN 60825-1: 2007 Safety of Laser Products — Part 1: Equipment Classification and Requirements

EN 60825-2: 2004 Safety of Laser Products — Part 2: Safety of optical fibre communication systems

EN 60825-4: 2006 Safety of Laser Products — Part 4: Laser guards

EN 60825-12: 2004 Safety of Laser Products — Part 12: Safety of free space optical communication systems used for transmission of information

EN 61040: 1993 Power and Energy Measuring Detectors, Instruments, and Equipment for Laser Radiation

G.2 European Guidance

CLC/TR 50488: 2005 Guide to levels of competence required in laser safety

G.3 ISO, IEC and CIE Documents

ISO/TR 11146-3: 2004 Lasers and laser-related equipment — Test methods for laser beam widths, divergence angles and beam propagation ratios — Intrinsic and geometrical laser beam classification, propagation and details of test methods

ISO TR 11991: 1995 Guidance on airway management during laser surgery of upper airway

ISO/TR 22588: 2005 Optics and photonics — Laser and laser-related equipment — Measurement and evaluation of absorption-induced effects in laser optical components

IEC/TR 60825-3: 2008 Safety of Laser Products — Part 3: Guidance for laser displays and shows

IEC TR 60825-5: 2003 Safety of Laser Products — Part 5: Manufacturer's checklist for IEC 60825-1

IEC/TR 60825-8: 2006 Safety of Laser Products — Part 8: Guidelines for the safe use of laser beams on humans

IEC/TR 60825-13: 2006 Safety of Laser Products — Part 13: Measurements for Classification of Laser Products

IEC TR 60825-14: 2004 Safety of Laser Products — Part 14: A user's guide

IEC 62471: 2006 Photobiological safety of lamps and lamp systems

CIE S 004-2001: Colours of Light Signals

ISO 16508/CIE S006.1/E-1999: Joint ISO/CIE Standard: Road Traffic Lights — Photometric Properties of 200 mm Roundel Signals

ISO 17166/CIE S007/E-1999: Joint ISO/CIE Standard: Erythema Reference Action Spectrum and Standard Erythema Dose

ISO 8995-1: 2002(E)/CIE S 008/E: 2001: Joint ISO/CIE Standard: Lighting of Work Places — Part 1: Indoor [incl. Technical Corrigendum ISO 8995:2002/Cor. 1:2005(E)]

CIE S 009/D: 2002: Photobiologische Sicherheit von Lampen und Lampensystemen

ISO 23539: 2005(E)/CIE S 010/E: 2004: Joint ISO/CIE Standard: Photometry — The CIE System of Physical Photometry

ISO 23603: 2005(E)/CIE S 012/E: 2004: Joint ISO/CIE Standard: Standard Method of Assessing the Spectral Quality of Daylight Simulators for Visual Appraisal and Measurement of Colour

CIE S 015: 2005: Lighting of Outdoor Work Places

ISO 8995-3: 2006(E)/CIE S 016/E: 2005: Joint ISO/CIE Standard: Lighting of work places — Part 3: Lighting Requirements for Safety and Security of Outdoor Work Places

ISO 28077: 2006(E)/CIE S 019/E: 2006: Joint ISO/CIE Standard: Photocarcinogenesis Action Spectrum (Non-Melanoma Skin Cancers)

ISO 30061: 2007(E)/CIE S 020/E: 2007: Emergency Lighting

Appendix H. Photosensitivity

H.1 What is photosensitivity?

Chemical reactions triggered by visible or UV radiation are natural processes and essential for the survival of living organisms. They are also called photochemical reactions: energy must first be absorbed by a molecule or a living cell to bring it to an excited state in order to produce the reaction.

Under normal circumstances the net effect will be positive and no damage will happen to the body, in this particular case to the skin.

However the absorption, ingestion or inhalation of specific substances may induce severe amplification effects and create real damage similar to acute sunburn by several orders of magnitude. These substances are commonly named 'photosensitizers'.

Sometimes, adverse effects (like sunburn, blistering, prickling) can show up almost immediately.

The long-term consequences of repeated exposure whilst being in contact with photosensitising agents can in some cases increase risk of evolving to chronic diseases (e.g. accelerated skin ageing or skin cancer).

Most photosensitizers absorb in the UVA range and to the lesser extent in the UVB or the visible range. They can be found everywhere in your environment,

in your daily life: specific medicines such as cardiac regulators or those against hypertension, some substances in vegetables, wood protection substances such as carbonileum, garden plants, perfumes and cosmetics;

in your occupational environment: colouring substances, pesticides, printing inks, food additives for animals;

in a medical environment: light therapy, antibacterial substances, tranquilizers, diuretics, anti-infection treatments.

These lists are not exhaustive. Moreover, photosensitizers which are used in daily life or coming from medical origin can obviously affect your sensitivity to occupational exposure.

The adverse effects are dependent on the type and absorbed/ingested/inhalated amount of the photosensitising substance, the intensity and the duration of the exposure and the genetic make-up (e.g. skin type) of each individual.

H.2 Work-related aspects ... or not

As you see, adverse effects due to exposure to UV or visible radiation whilst in the presence of photosensitising agents can affect anybody and can arise either from occupational or non-occupational activities.

Moreover, the main contributor is natural radiation produced by the sun.

As adverse effects due to exposure to natural radiation do not fall within the scope of the Directive this is for information only as far as natural radiation is concerned.

H.3 As an employer what must you do?

The Directive requires an employer to perform a risk assessment taking into account the hazards and risks due to exposure to artificial optical radiation.

Part of the employer's responsibilities is the obligation to inform personnel about any potential risk.

Raising awareness of the potential hazards and risks due to photosensitising agents is essential.

H.4 What to do if your work implies exposure to sources of artificial optical radiation in combination with photosensitising substances?

When the employer is carrying out a risk assessment, he cannot be aware of any specific situation, such as a worker following a medical treatment with 'photosensitising' medicines, using 'photosensitising' products whilst refurbishing his home, or using 'photosensitising' chemical substances when enjoying his hobby (paints, inks, glue), etc.

When starting a medical treatment with specific but 'photosensitising' medicines, the doctor will normally warn you about the potentially adverse effects of an exposure to sunlight. Exposure to sunlight will sometimes be clearly forbidden. In such a situation it is also advisable to avoid excessive exposure at work to artificial (and natural) light or UV sources. Always read the label! It is strongly recommended that you inform your employer yourself or using existing channels or procedures in your country.

If you notice an adverse effect on your skin, go and see a medical doctor without delay. If you suspect that it has an occupational origin, tell the doctor. If an occupational cause can be suspected, it is again strongly recommended that you inform your employer yourself or using existing channels or procedures in your country. Only then, will appropriate adaptations to your working conditions be possible.

Appendix I. Resources

I.1 Internet

These lists are not intended to be exhaustive; no endorsement or recommendation is implied with regard to the content of external sites.

I.2 Advisory/Regulatory

European Union

Country	Organisation	Website
Austria	AUVA	http://www.auva.at
Belgium	Institut pour la Prévention, la Protection et le Bien-être au Travail	http://www.prevent.be/net/net01.nsf
Cyprus	Ημερίδα με θέμα: Ασφαλής Πρόσδεση Φορτίων	http://www.cysha.org.cy
Czech Republic	National Institute of Public Health, Czech Republic	http://www.czu.cz
	Centrum bezpečnosti práce a požární ochrany	http://www.civop.cz
Denmark	Danish Working Environment Authority	http://www.at.dk
Estonia	Tööinspektsioon	http://www.ti.ee
Finland	Työterveyslaitos	http://www.occuphealth.fi
France	Agence Française de Sécurité Sanitaire de l'Environnement et du Travail	http://www.afsset.fr
Germany	Bundesanstalt für Arbeitsschutz und Arbeitsmedizin	http://www.baua.de
	Berufsgenossenschaft Elektro Textil Feinmechanik	http://www.bgetf.de
Greece	Hellenic Institute for Occupational Health and Safety	http://www.elinyae.gr
Hungary	Public Foundation for Research on Occupational Safety	http://www.mkk.org.hu
Ireland	Health and Safety Authority	http://www.HSA.ie
Italy	National Institute of Occupational Safety and Prevention	http://www.ispesl.it
Latvia	Institute of Occupational and Environmental Health	http://home.parks.lv/ioeh
Luxembourg	Inspection du Travail et des Mines	http://www.itm.lu/itm
Malta	Occupational Health and Safety Authority	http://www.ohsa.org.mt
Netherlands	TNO Work and Employment	http://www.arbeid.tno.nl
Poland	Central Institute for Labour Protection	http://www.ciop.pl
Portugal	Autoridade para as Condições do Trabalho	http://www.act.gov.pt
Romania	Institute of Public Health	http://www.pub-health-iasi.ro
Slovakia	Public Health Authority of the Slovak Republic	http://www.uvzsr.sk
Slovenia	Ministry of Labour, Family and Social Affairs	http://www.mddsz.gov.si
Spain	National Institute of Safety and Hygiene at Work	http://www.insht.es/portal/site/Insht
	Association for the Prevention of Accidents	http://www.apa.es
Sweden	Swedish Radiation Protection Agency	http://www.ssi.se
United Kingdom	Health Protection Agency	http://www.hpa.org.uk
	Health and Safety Executive	http://www.hse.gov.uk

International

Organisation	Website
International Commission on Non-ionising Radiation Protection	http://www.icnirp.de
International Commission on Illumination	http://www.cie.co.at
World Health Organisation	http://www.who.int
American Conference on Governmental Industrial Hygienists	http://www.acgih.org
European Trade Union Confederation	http://www.etuc.org http://hesa.etui-rehs.org
European Public Health Alliance	http://www.epha.org/r/64
The European Agency for Safety and Health at Work	http://osha.europa.eu/
International Commission on Occupational Health	http://www.icohweb.org

Rest of the world

Country	Organisation	Website
USA	US Food and Drug Administration Center for Devices and Radiological Health	http://www.fda.gov/cdrh/
USA	US Food and Drug Administration Medical Accident Database	http://www.accessdata.fda.gov
USA	United States Army Center for Health Promotion and Preventive Medicine, Laser/Optical Radiation Program	http://chppm-www.apgea.army.mil/laser/laser.html
Australia	Australian Radiation Protection and Nuclear Safety Agency	http://www.arpansa.gov.au

I.3 Standards

Organisation	Website
International Electrotechnical Commission	http://www.iec.ch
European Committee for Electrotechnical Standardisation	http://www.cenelec.eu
European Committee for Standardisation	http://www.cen.eu
International Organisation for Standardisation	http://www.iso.org
American National Standards Institute	http://www.ansi.org
US Laser Safety Standards	http://www.z136.org

I.4 Associations/Web Directories

Organisation	Website
European Optical Society	http://www.myeos.org
SPIE	http://www.spie.org
Optical Society of America	http://www.osa.org
Laser Institute of America	http://www.laserinstitute.org
Association of Laser Users	http://www.ailu.org.uk
Institute of Physics	http://www.iop.org
Institute of Physics and Engineering in Medicine	http://www.ipem.org.uk
British Medical Laser Association	http://www.bmla.co.uk
European Leading Association of Luminous Radiant gas heaters Manufacturers	http://www.elvhis.com

I.5 Journals

http://www.optics.org
Opto & Laser Europe
http://www.health-physics.com
Health Physics journal
http://www.oxfordjournals.org/our_journals/rpd/about.html
Search for abstracts from laser-related publications in Radiation Protection Dosimetry
http://lfw.pennnet.com/home.cfm
Laser Focus World monthly US optics magazine
http://www.photonics.com
Photonics Spectra, Europhotonics and BioPhotonics
http://scitation.aip.org/jla/
Journal of Laser Applications
http://www.springerlink.com/content/1435-604X/
Lasers in Medical Science journal
fibers.org/fibresystems/schedule/fse.cfm
Fibre Systems Europe journal
http://www.laserist.org/Laserist/
The Laserist journal of the International Laser Display Association
http://www.ledsmagazine.com
Electronic magazine covering the application of LEDs
http://www.ils-digital.com
Industrial Laser Solutions magazine
http://www.rp-photonics.com/encyclopedia.html
Online encyclopaedia covering a range of laser and optical subjects

I.6 CD, DVD and other resources

Resource	Provider	Comments
Limits CD	Austrian Research Centers	An interactive training system (English & German) on Laser Safety in Industry and Research. The CD includes a 30 minute video which goes through the nine chapters of the CD. The chapters can also be viewed independently of the video. Includes a test section (multiple choice) and a glossary.
LIA — Mastering Light — Laser Safety DVD	LIA	Discusses applications, types of laser, laser hazards, control measures, signs and labels, storage of eyewear, etc. Includes details of old laser classification.
Laser Safety in Higher Education on DVD	University of Southampton	Discusses laser radiation and the body, safety measures, neutral density filters, etc. Includes details of old laser classification.
LIA — CLSOs' Best Practices in Laser Safety on CD	LIA	Book + CD. CD contains PowerPoint presentations of Chapters 5.2.1.1 and 5.2.1.3. The book is intended to be used as a tool in the development of a laser safety programme.
Prevention of Labour Risks on CD	INSHT	Advanced training course for the performance of functions of Superior Level. Version 2.
Guide to Laser Safety	Laservision	Booklet (English & German). The main focus of this booklet is laser safety eyewear and filters.
Laser–Augenschutz Filter–Select	BGETF	ACCESS interactive database of laser eyewear.

Appendix J. Glossary

Aversion response, voluntary or involuntary

closure of the eyelid, eye movement, pupillary constriction, or movement of the head to avoid an exposure to an optical radiation stimulant

Blue Light hazard

potential for a photochemically induced retinal injury resulting from optical radiation exposure in the wavelength range 300 nm to 700 nm

Blue Light hazard weighting function

spectral weighting function reflecting the photochemical effects of ultraviolet and visible radiation on the retina
Symbol: B(λ)
SI unit: dimensionless

Exposure Limit (ELV)

maximum level of exposure to the eye or skin that is not expected to result in adverse biological effects

Hazard distance

minimum distance from the source at which the irradiance/radiance falls below the appropriate Exposure Limit Value (ELV)

Illuminance (E_v)

(at a point of a surface)
quotient of the luminous flux $d\Phi_v$ incident on an element of the surface containing the point, by the area dA of that element

$$E_v = \frac{d\Phi_v}{dA}$$

Unit: lux (lx)

Infrared radiation (IR)

optical radiation for which the wavelengths are longer than those for visible radiation
For infrared radiation, the range between 780 nm and 10^6 nm is commonly subdivided into:
IRA (780 nm to 1 400 nm)
IRB (1 400 nm to 3 000 nm)
IRC (3 000 nm to 10^6 nm)
irradiance (at a point of the surface)
quotient of the radiant flux dΦ incident on an element of a surface containing the point, by the area dA of that element, i.e.,

$$E = \frac{d\Phi}{dA}$$

SI Unit: W m^{-2}

Luminance

$$L_v = \frac{d\Phi_v}{dA \cdot \cos\theta \cdot d\Omega}$$

quantity defined by the formula

where:
$d\Phi_v$ is the luminous flux transmitted by an elementary beam passing through the given point and propagating in the solid angle dΩ containing the given direction;
dA is the area of a section of that beam containing the given point;
θ is the angle between the normal to that section and the direction of the beam
Symbol: L_v
Unit: cd m^{-2}

Non-coherent radiation

Any optical radiation other than laser radiation

Ocular hazard distance (OHD)

distance at which the beam irradiance or radiant exposure equals the appropriate ocular ELVs

Optical radiation

electromagnetic radiation at wavelengths between the region of transition to X-rays (wavelength approximately 1 nm) and the region of transition to radio waves (wavelength approximately 10^6 nm)

Radiance

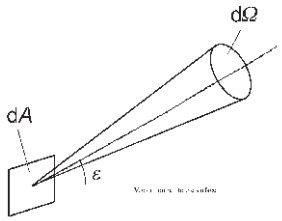
(in a given direction at a given point of a real or imaginary surface)

quantity defined by the formula

$$L = \frac{d\Phi}{dA \cdot \cos\theta \cdot d\Omega}$$

where:

dΦ is the radiant power (flux) transmitted by an elementary beam passing through the given point and propagating in the solid angle dΩ containing the given direction;



Schematic of radiance definition

dA is the area of a section of that beam containing the given point;

θ is the angle between the normal to that section and the direction of the beam

Symbol: L

SI Unit: W m^{-2} sr^{-1}

Radiant exposure

quotient of the radiant energy dQ incident on an element of the surface containing the point over the given duration by the area dA of that element

$$H = \frac{dQ}{dA}$$

Equivalently, the integral of the irradiance E at a given point over a given duration Δt

$$H = \int_{\Delta t} E \cdot dt$$

SI Unit: J m^{-2}

Retinal Thermal hazard

potential for an injury to the eye resulting from exposure to the optical radiation in the wavelength range of 380–1 400 nm

Retinal thermal hazard weighting function

spectral weighting function reflecting the thermal effects of visible and infrared radiation on the retina

Symbol: R(λ)

SI unit: dimensionless

retinal hazard region

spectral region from 380 nm to 1 400 nm (visible plus IR-A) within which the normal ocular media transmit optical radiation to the retina

Skin hazard distance

distance at which the irradiance exceeds the applicable skin exposure limit for eight hours exposure

Unit: m

Ultraviolet hazard

potential for skin and ocular acute and chronic adverse effects resulting from optical radiation exposure in the wavelength range 180 nm to 400 nm

Ultraviolet hazard weighting function

spectral weighting function intended for health protection purposes and reflecting the combined acute effects of ultraviolet radiation on the eye and the skin

Ultraviolet radiation (UV)

optical radiation for which the wavelengths are shorter than those for visible radiation

For ultraviolet radiation, the range between 100 nm and 400 nm is commonly subdivided into:

UVA, from 315 nm to 400 nm

UVB, from 280 nm to 315 nm

UVC, from 100 nm to 280 nm

Ultraviolet radiation in the wavelength range below 180 nm (vacuum UV) is strongly absorbed by the oxygen in air

Visible radiation

any optical radiation capable of directly causing a visual sensation

Note: There are no precise limits for the spectral range of visible radiation since they depend upon the amount of radiant power reaching the retina and the responsiveness of the observer. The lower limit is generally taken between 360 nm and 400 nm and the upper limit between 760 nm and 830 nm.

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Appendix L. Directive 2006/25/EC

L 114/38 EN Official Journal of the European Union 27.4.2006

DIRECTIVE 2006/25/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 5 April 2006

on the minimum health and safety requirements regarding the exposure of workers to risks arising from physical agents (artificial optical radiation) (19th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC)

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 137(2) thereof,

Having regard to the proposal from the Commission ([1]), presented after consultation with the Advisory Committee on Safety and Health at Work,

Having regard to the opinion of the European Economic and Social Committee ([2]),

After consulting the Committee of the Regions,

Acting in accordance with the procedure laid down in Article 251 of the Treaty ([3]), in the light of the joint text approved by the Conciliation Committee on 31 January 2006,

Whereas:

(1) Under the Treaty the Council may, by means of directives, adopt minimum requirements for encouraging improvements, especially in the working environment, to guarantee a better level of protection of the health and safety of workers. Such directives are to avoid imposing administrative, financial and legal constraints in a way which would hold back the creation and development of small and medium-sized enterprises (SMEs).

(2) The communication from the Commission concerning its action programme relating to the implementation of the Community Charter of the Fundamental Social Rights of Workers provides for the introduction of minimum health and safety requirements regarding the exposure of workers to the risks caused by physical agents. In September 1990 the European Parliament adopted a Resolution concerning this action programme ([4]), inviting the Commission in particular to draw up a specific directive on the risks caused by noise, vibration and any other physical agents at the workplace.

(3) As a first step, the European Parliament and the Council adopted Directive 2002/44/EC of 25 June 2002 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration) (16th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) ([5]). Next, on 6 February 2003 the European Parliament and the Council adopted Directive 2003/10/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise) (17th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) ([6]). Thereafter, on 29 April 2004, the European Parliament and the Council adopted Directive 2004/40/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (18th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) ([7]).

(4) It is now considered necessary to introduce measures protecting workers from the risks associated with optical radiation, owing to its effects on the health and safety of workers, in particular damage to the eyes and to the skin. These measures are intended not only to ensure the health and safety of each worker on an individual basis, but also to create a minimum basis of protection for all Community workers, in order to avoid possible distortions of competition.

(5) One of the aims of this Directive is the timely detection of adverse health effects resulting from exposure to optical radiation.

([1]) OJ C 77, 18.3.1993, p. 12 and OJ C 230, 19.8.1994, p. 3.

([2]) OJ C 249, 13.9.1993, p. 28.

([3]) Opinion of the European Parliament of 20 April 1994 (OJ C 128, 9.5.1994, p. 146) confirmed on 16 September 1999 (OJ C 54, 25.2.2000, p. 75), Council Common Position of 18 April 2005 (OJ C 172 E , 12.7.2005, p. 26) and Position of the European Parliament of 16 November 2005 (not yet published in the Official Journal), European Parliament Legislative Resolution of 14 February 2006 (not yet published in the Official Journal) and Decision of the Council of 23 February 2006.

([4]) OJ C 260, 15.10.1990, p. 167.

([5]) OJ L 177, 6.7.2002, p. 13.

([6]) OJ L 42, 15.2.2003, p. 38.

([7]) OJ L 159, 30.4. 2004, p. 1. Directive as corrected in OJ L 184, 24.5.2004, p. 1.

(6) This Directive lays down minimum requirements, thus giving Member States the option of maintaining or adopting more stringent provisions for the protection of workers, in particular the fixing of lower exposure limit values. The implementation of this Directive must not serve to justify any deterioration in the situation which already prevails in each Member State.

(7) A system of protection against the hazards of optical radiation should limit itself to a definition, free of excessive detail, of the objectives to be attained, the principles to be observed and the basic values to be applied, in order to enable Member States to apply the minimum requirements in an equivalent manner.

(8) The level of exposure to optical radiation can be more effectively reduced by incorporating preventive measures into the design of workstations and by selecting work equipment, procedures and methods so as to give priority to reducing the risks at source. Provisions relating to work equipment and methods thus contribute to the protection of the workers involved. In accordance with the general principles of prevention as laid down in Article 6(2) of Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work ([1]), collective protection measures have priority over individual protection measures.

(9) Employers should make adjustments in the light of technical progress and scientific knowledge regarding risks related to exposure to optical radiation, with a view to improving the safety and health protection of workers.

(10) Since this Directive is an individual directive within the meaning of Article 16(1) of Directive 89/391/EEC, that Directive applies to the exposure of workers to optical radiation, without prejudice to more stringent and/or specific provisions contained in this Directive.

(11) This Directive constitutes a practical step towards creating the social dimension of the internal market.

(12) A complementary approach that both promotes the principle of better regulation and ensures a high level of protection can be achieved where the products made by the manufacturers of optical radiation sources and associated equipment comply with harmonised standards devised to protect the health and safety of users from the hazards inherent in such products; accordingly, it is not necessary for employers to repeat the measurements or calculations already undertaken by the manufacturer to determine compliance with the essential safety requirements of such equipment as specified in the applicable Community Directives, provided that the equipment has been properly and regularly maintained.

(13) The measures necessary for the implementation of this Directive should be adopted in accordance with Council Decision 1999/468/EC of 28 June 1999 laying down the procedures for the exercise of implementing powers conferred on the Commission ([2]).

(14) Adherence to the exposure limit values should provide a high level of protection as regards the health effects that may result from exposure to optical radiation.

(15) The Commission should draw up a practical guide to help employers, in particular managers of SMEs, better to understand the technical provisions of this Directive. The Commission should strive to complete this guide as quickly as possible so as to facilitate adoption by the Member States of the measures necessary to implement this Directive.

(16) In accordance with paragraph 34 of the Interinstitutional Agreement on better law-making ([3]), Member States are encouraged to draw up, for themselves and in the interests of the Community, their own tables illustrating, as far as possible, the correlation between this Directive and the transposition measures, and to make them public,

HAVE ADOPTED THIS DIRECTIVE:

SECTION I

GENERAL PROVISIONS

Article 1

Aim and scope

1. This Directive, which is the 19th individual Directive within the meaning of Article 16(l) of Directive 89/391/EEC, lays down minimum requirements for the protection of workers from risks to their health and safety arising or likely to arise from exposure to artificial optical radiation during their work.

2. This Directive refers to the risk to the health and safety of workers due to adverse effects caused by exposure to artificial optical radiation to the eyes and to the skin.

([1]) OJ L 183, 29.6.1989, p. 1. Directive as amended by Regulation (EC) No 1882/2003 of the European Parliament and of the Council (OJ L 284, 31.10.2003, p. 1).

([2]) OJ L 184, 17.7.1999, p. 23.

([3]) OJ C 321, 31.12.2003, p. 1.

3. Directive 89/391/EEC shall apply fully to the whole area referred to in paragraph 1, without prejudice to more stringent and/or more specific provisions contained in this Directive.

Article 2

Definitions

For the purposes of this Directive, the following definitions shall apply:

(a) optical radiation: any electromagnetic radiation in the wavelength range between 100 nm and 1 mm. The spectrum of optical radiation is divided into ultraviolet radiation, visible radiation and infrared radiation:

(i) ultraviolet radiation: optical radiation of wavelength range between 100 nm and 400 nm. The ultraviolet region is divided into UVA (315-400 nm), UVB (280-315 nm) and UVC (100-280 nm);

(ii) visible radiation: optical radiation of wavelength range between 380 nm and 780 nm;

(iii) infrared radiation: optical radiation of wavelength range between 780 nm and 1 mm. The infrared region is divided into IRA (780-1 400 nm), IRB (1 400-3 000 nm) and IRC (3 000 nm-1 mm);

(b) laser (light amplification by stimulated emission of radiation): any device which can be made to produce or amplify electromagnetic radiation in the optical radiation wavelength range primarily by the process of controlled stimulated emission;

(c) laser radiation: optical radiation from a laser;

(d) non-coherent radiation: any optical radiation other than laser radiation;

(e) exposure limit values: limits on exposure to optical radiation which are based directly on established health effects and biological considerations. Compliance with these limits will ensure that workers exposed to artificial sources of optical radiation are protected against all known adverse health effects;

(f) irradiance (E) or power density: the radiant power incident per unit area upon a surface expressed in watts per square metre (W m^{-2});

(g) radiant exposure (H): the time integral of the irradiance, expressed in joules per square metre (J m^{-2});

(h) radiance (L): the radiant flux or power output per unit solid angle per unit area, expressed in watts per square metre per steradian (W m^{-2} sr^{-1});

(i) level: the combination of irradiance, radiant exposure and radiance to which a worker is exposed.

Article 3

Exposure limit values

1. The exposure limit values for non-coherent radiation, other than that emitted by natural sources of optical radiation, are as set out in Annex I.

2. The exposure limit values for laser radiation are as set out in Annex II.

SECTION II

OBLIGATIONS OF EMPLOYERS

Article 4

Determination of exposure and assessment of risks

1. In carrying out the obligations laid down in Articles 6(3) and 9(1) of Directive 89/391/EEC, the employer, in the case of workers exposed to artificial sources of optical radiation, shall assess and, if necessary, measure and/or calculate the levels of exposure to optical radiation to which workers are likely to be exposed so that the measures needed to restrict exposure to the applicable limits can be identified and put into effect. The methodology applied in assessment, measurement and/or calculations shall follow the standards of the International Electrotechnical Commission (IEC) in respect of laser radiation and the recommendations of the International Commission on Illumination (CIE) and the European Committee for Standardisation (CEN) in respect of non-coherent radiation. In exposure situations which are not covered by these standards and recommendations, and until appropriate EU standards or recommendations become available, assessment, measurement and/or calculations shall be carried out using available national or international science-based guidelines. In both exposure situations, the assessment may take account of data provided by the manufacturers of the equipment when it is covered by relevant Community Directives.

2. The assessment, measurement and/or calculations referred to in paragraph 1 shall be planned and carried out by competent services or persons at suitable intervals, taking particular account of the provisions of Articles 7 and 11 of Directive 89/391/EEC concerning the necessary competent services or persons and the consultation and participation of workers. The data obtained from the assessment, including those obtained from the measurement and/or calculation of the level of exposure referred to in paragraph 1 shall be preserved in a suitable form so as to permit their consultation at a later stage.

3. Pursuant to Article 6(3) of Directive 89/391/EEC, the employer shall give particular attention, when carrying out the risk assessment, to the following:

(a) the level, wavelength range and duration of exposure to artificial sources of optical radiation;

(b) the exposure limit values referred to in Article 3 of this Directive;

(c) any effects concerning the health and safety of workers belonging to particularly sensitive risk groups;

(d) any possible effects on workers' health and safety resulting from workplace interactions between optical radiation and photosensitising chemical substances;

(e) any indirect effects such as temporary blinding, explosion or fire;

(f) the existence of replacement equipment designed to reduce the levels of exposure to artificial optical radiation;

(g) appropriate information obtained from health surveillance, including published information, as far as possible;

(h) multiple sources of exposure to artificial optical radiation;

(i) a classification applied to a laser as defined in accordance with the relevant IEC standard and, in relation to any artificial source likely to cause damage similar to that of a laser of class 3B or 4, any similar classification;

(j) information provided by the manufacturers of optical radiation sources and associated work equipment in accordance with the relevant Community Directives.

4. The employer shall be in possession of an assessment of the risk in accordance with Article 9(1)(a) of Directive 89/391/EEC and shall identify which measures must be taken in accordance with Articles 5 and 6 of this Directive. The risk assessment shall be recorded on a suitable medium, according to national law and practice; it may include a justification by the employer that the nature and extent of the risks related to optical radiation make a further, detailed risk assessment unnecessary. The risk assessment shall be updated on a regular basis, particularly if there have been significant changes which could render it out of date, or if the results of health surveillance show it to be necessary.

Article 5

Provisions aimed at avoiding or reducing risks

1. Taking account of technical progress and of the availability of measures to control the risk at source, the risks arising from exposure to artificial optical radiation shall be eliminated or reduced to a minimum.

The reduction of risks arising from exposure to artificial optical radiation shall be based on the general principles of prevention set out in Directive 89/391/EEC.

2. Where the risk assessment carried out in accordance with Article 4(1) for workers exposed to artificial sources of optical radiation indicates any possibility that the exposure limit values may be exceeded, the employer shall devise and implement an action plan comprising technical and/or organisational measures designed to prevent the exposure exceeding the limit values, taking into account in particular:

(a) other working methods that reduce the risk from optical radiation;

(b) the choice of equipment emitting less optical radiation, taking account of the work to be done;

(c) technical measures to reduce the emission of optical radiation including, where necessary, the use of interlocks, shielding or similar health protection mechanisms;

(d) appropriate maintenance programmes for work equipment, workplaces and workstation systems;

(e) the design and layout of workplaces and workstations;

(f) limitation of the duration and level of the exposure;

(g) the availability of appropriate personal protective equipment;

(h) the instructions of the manufacturer of the equipment where it is covered by relevant Community Directives.

3. On the basis of the risk assessment carried out in accordance with Article 4, workplaces where workers could be exposed to levels of optical radiation from artificial sources exceeding the exposure limit values shall be indicated by appropriate signs in accordance with Council Directive 92/58/EEC of 24 June 1992 on the minimum requirements for the provision of safety and/or health signs at work (9th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) ([1]). The areas in question shall be identified, and access to them limited where this is technically possible and where there is a risk that the exposure limit values could be exceeded.

4. Workers shall not be exposed above the exposure limit values. In any event, if, despite the measures taken by the employer to comply with this Directive in respect of artificial sources of optical radiation, the exposure limit values are exceeded, the employer shall take immediate action to reduce exposure below the exposure limit values. The employer shall identify the reasons why the exposure limit values have been exceeded and shall adapt the protection and prevention measures accordingly in order to prevent them being exceeded again.

5. Pursuant to Article 15 of Directive 89/391/EEC, the employer shall adapt the measures referred to in this Article to the requirements of workers belonging to particularly sensitive risk groups.

Article 6

Worker information and training

Without prejudice to Articles 10 and 12 of Directive 89/391/EEC, the employer shall ensure that workers who are exposed to risks from artificial optical radiation at work and/or their representatives receive any necessary information and training relating to the outcome of the risk assessment provided for in Article 4 of this Directive, concerning in particular:

(a) measures taken to implement this Directive;

(b) the exposure limit values and the associated potential risks;

(c) the results of the assessment, measurement and/or calculations of the levels of exposure to artificial optical radiation carried out in accordance with Article 4 of this Directive together with an explanation of their significance and potential risks;

(d) how to detect adverse health effects of exposure and how to report them;

(e) the circumstances in which workers are entitled to health surveillance;

(f) safe working practices to minimise risks from exposure;

(g) proper use of appropriate personal protective equipment.

Article 7

Consultation and participation of workers

Consultation and participation of workers and/or of their representatives shall take place in accordance with Article 11 of Directive 89/391/EEC on the matters covered by this Directive.

SECTION III

MISCELLANEOUS PROVISIONS

Article 8

Health surveillance

1. With the objectives of the prevention and timely detection of any adverse health effects, as well as the prevention of any long-term health risks and any risk of chronic diseases, resulting from exposure to optical radiation, Member States shall adopt provisions to ensure appropriate health surveillance of workers pursuant to Article 14 of Directive 89/391/EEC.

2. Member States shall ensure that health surveillance is carried out by a doctor, an occupational health professional or a medical authority responsible for health surveillance in accordance with national law and practice.

3. Member States shall establish arrangements to ensure that, for each worker who undergoes health surveillance in accordance with paragraph 1, individual health records are made and kept up to date. Health records shall contain a summary of the results of the health surveillance carried out. They shall be kept in a suitable form so as to permit consultation at a later date, taking into account any confidentiality. Copies of the appropriate records shall be supplied to the competent authority on request, taking into account any confidentiality. The employer shall take appropriate measures to ensure that the doctor, the occupational health professional or the medical authority responsible for the health surveillance, as determined by Member States as appropriate, has access to the results of the risk assessment referred to in Article 4 where such results may be relevant to the health surveillance. Individual workers shall, at their request, have access to their own personal health records.

([1]) OJ L 245, 26.8.1992, p. 23.

4. In any event, where exposure above the limit values is detected, a medical examination shall be made available to the worker(s) concerned in accordance with national law and practice. This medical examination shall also be carried out where, as a result of health surveillance, a worker is found to have an identifiable disease or adverse health effect which is considered by a doctor or occupational health professional to be the result of exposure to artificial optical radiation at work. In both cases, when limit values are exceeded or adverse health effects (including diseases) are identified:

(a) the worker shall be informed by the doctor or other suitably qualified person of the result which relates to him personally. He shall, in particular, receive information and advice regarding any health surveillance which he should undergo following the end of exposure;

(b) the employer shall be informed of any significant findings of the health surveillance, taking into account any medical confidentiality;

(c) the employer shall:

— review the risk assessment carried out pursuant to Article 4,

— review the measures provided for to eliminate or reduce risks pursuant to Article 5,

— take into account the advice of the occupational health professional or other suitably qualified person or the competent authority in implementing any measure required to eliminate or reduce risk in accordance with Article 5, and

— arrange continued health surveillance and provide for a review of the health status of any other worker who has been similarly exposed. In such cases, the competent doctor or occupational health professional or the competent authority may propose that the exposed persons undergo a medical examination.

Article 9

Penalties

Member States shall provide for adequate penalties to be applicable in the event of infringement of the national legislation adopted pursuant to this Directive. These penalties must be effective, proportionate and dissuasive.

Article 10

Technical amendments

1. Any modification of the exposure limit values set out in the Annexes shall be adopted by the European Parliament and the Council in accordance with the procedure laid down in Article 137(2) of the Treaty.

2. Amendments to the Annexes of a strictly technical nature in line with:

(a) the adoption of Directives in the field of technical harmonisation and standardisation with regard to the design, building, manufacture or construction of work equipment and/or workplaces;

(b) technical progress, changes in the most relevant harmonised European standards or international specifications, and new scientific findings concerning occupational exposure to optical radiation,

shall be adopted in accordance with the procedure laid down in Article 11(2).

Article 11

Committee

1. The Commission shall be assisted by the Committee referred to in Article 17 of Directive 89/391/EEC.

2. Where reference is made to this paragraph, Articles 5 and 7 of Decision 1999/468/EC shall apply, having regard to the provisions of Article 8 thereof.

The period laid down in Article 5(6) of Decision 1999/468/EC shall be set at three months.

3. The Committee shall adopt its rules of procedure.

SECTION IV

FINAL PROVISIONS

Article 12

Reports

Every five years Member States shall provide the Commission with a report on the practical implementation of this Directive, indicating the points of view of the social partners.

Every five years the Commission shall inform the European Parliament, the Council, the European Economic and Social Committee and the Advisory Committee on Safety and Health at Work of the content of these reports, of its assessment of these reports, of developments in the field in question and of any action that may be warranted in the light of new scientific knowledge.

Article 13

Practical guide

In order to facilitate implementation of this Directive the Commission shall draw up a practical guide to the provisions of Articles 4 and 5 and Annexes I and II.

Article 14

Transposition

1. Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive by 27 April 2010. They shall forthwith inform the Commission thereof.

When Member States adopt these measures, they shall contain a reference to this Directive or shall be accompanied by such reference on the occasion of their official publication. The methods of making such reference shall be laid down by Member States.

2. Member States shall communicate to the Commission the text of the provisions of national law which they adopt or have already adopted in the field covered by this Directive.

Article 15

Entry into force

This Directive shall enter into force on the day of its publication in the *Official Journal of the European Union*.

Article 16

Addressees

This Directive is addressed to the Member States.

Done at Strasbourg, 5 April 2006.

For the European Parliament	*For the Council*
The President	*The President*
J. BORRELL FONTELLES	H. WINKLER

ANNEX I

Non-coherent optical radiation

The biophysically relevant exposure values to optical radiation can be determined with the formulae below. The formulae to be used depend on the range of radiation emitted by the source and the results should be compared with the corresponding exposure limit values indicated in Table 1.1. More than one exposure value and corresponding exposure limit can be relevant for a given source of optical radiation.

Numbering (a) to (o) refers to corresponding rows of Table 1.1.

(a) $H_{eff} = \int_0^t \sum_{\lambda=180\,nm}^{\lambda=400\,nm} E_\lambda(\lambda,t) \cdot S(\lambda) \cdot d\lambda \cdot dt$ (H_{eff} is only relevant in the range 180 to 400 nm)

(b) $H_{UVA} = \int_0^t \sum_{\lambda=315\,nm}^{\lambda=400\,nm} E_\lambda(\lambda,t) \cdot d\lambda \cdot dt$ (H_{UVA} is only relevant in the range 315 to 400 nm)

(c), (d) $L_B = \sum_{\lambda=300\,nm}^{\lambda=700\,nm} L_\lambda(\lambda) \cdot B(\lambda) \cdot d\lambda$ (L_B is only relevant in the range 300 to 700 nm)

(e), (f) $E_B = \sum_{\lambda=300\,nm}^{\lambda=700\,nm} E_\lambda(\lambda) \cdot B(\lambda) \cdot d\lambda$ (E_B is only relevant in the range 300 to 700 nm)

(g) to (l) $L_R = \sum_{\lambda_1}^{\lambda_2} L_\lambda(\lambda) \cdot R(\lambda) \cdot d\lambda$ (See Table 1.1 for appropriate values of λ_1 and λ_2)

(m), (n) $E_{IR} = \sum_{\lambda=780\,nm}^{\lambda=3000\,nm} E_\lambda(\lambda) \cdot d\lambda$ (E_{IR} is only relevant in the range 780 to 3 000 nm)

(o) $H_{skin} = \int_0^t \sum_{\lambda=380\,nm}^{\lambda=3000\,nm} E_\lambda(\lambda,t) \cdot d\lambda \cdot dt$ (H_{skin} is only relevant in the range 380 to 3 000 nm)

For the purposes of this Directive, the formulae above can be replaced by the following expressions and the use of discrete values as set out in the following tables:

(a) $E_{eff} = \sum_{\lambda=180\,nm}^{\lambda=400\,nm} E_\lambda \cdot S(\lambda) \cdot \Delta\lambda$ and $H_{eff} = E_{eff} \cdot \Delta t$

(b) $E_{UVA} = \sum_{\lambda=315\,nm}^{\lambda=400\,nm} E_\lambda \cdot \Delta\lambda$ and $H_{UVA} = E_{UVA} \cdot \Delta t$

(c), (d) $L_B = \sum_{\lambda=300\,nm}^{\lambda=700\,nm} L_\lambda \cdot B(\lambda) \cdot \Delta\lambda$

(e), (f) $E_B = \sum_{\lambda=300\,nm}^{\lambda=700\,nm} E_\lambda \cdot B(\lambda) \cdot \Delta\lambda$

(g) to (l) $L_R = \sum_{\lambda_1}^{\lambda_2} L_\lambda \cdot R(\lambda) \cdot \Delta\lambda$ (See Table 1.1 for appropriate values of λ_1 and λ_2)

(m), (n) $E_{IR} = \sum_{\lambda=780\,nm}^{\lambda=3\,000\,nm} E_\lambda \cdot \Delta\lambda$

(o) $$E_{skin} = \sum_{\lambda = 380\ nm}^{\lambda = 3\,000\ nm} E_\lambda \cdot \Delta\lambda \qquad \text{and } H_{skin} = E_{skin} \cdot \Delta t$$

Notes:

Eλ (λ,t), Eλ *spectral irradiance or spectral power density:* the radiant power incident per unit area upon a surface, expressed in watts per square metre per nanometre [W m^{-2} nm^{-1}]; values of Eλ (λ, t) and E_λ come from measurements or may be provided by the manufacturer of the equipment;

E_{eff} *effective irradiance (UV range)*: calculated irradiance within the UV wavelength range 180 to 400 nm spectrally weighted by S (λ), expressed in watts per square metre [W m^{-2}];

H *radiant exposure*: the time integral of the irradiance, expressed in joules per square metre [J m^{-2}];

H_{eff} *effective radiant exposure*: radiant exposure spectrally weighted by S (λ), expressed in joules per square metre [J m^{-2}];

E_{UVA} *total irradiance (UVA)*: calculated irradiance within the UVA wavelength range 315 to 400 nm, expressed in watts per square metre [W m^{-2}];

H_{UVA} *radiant exposure*: the time and wavelength integral or sum of the irradiance within the UVA wavelength range 315 to 400 nm, expressed in joules per square metre [J m^{-2}];

S (λ) *spectral weighting* taking into account the wavelength dependence of the health effects of UV radiation on eye and skin, (Table 1.2) [dimensionless];

t, Δt *time, duration of the exposure,* expressed in seconds [s];

λ *wavelength,* expressed in nanometres [nm];

Δ λ *bandwidth,* expressed in nanometres [nm], of the calculation or measurement intervals;

Lλ (λ), L_λ *spectral radiance of the source* expressed in watts per square metre per steradian per nanometre [W m^{-2} sr^{-1} nm^{-1}];

R (λ) *spectral weighting* taking into account the wavelength dependence of the thermal injury caused to the eye by visible and IRA radiation (Table 1.3) [dimensionless];

L_R *effective radiance (thermal injury)*: calculated radiance spectrally weighted by R (λ) expressed in watts per square metre per steradian [W m^{-2} sr^{-1}];

B (λ) *spectral weighting* taking into account the wavelength dependence of the photochemical injury caused to the eye by blue light radiation (Table 1.3) [dimensionless];

L_B *effective radiance (blue light)*: calculated radiance spectrally weighted by B (λ), expressed in watts per square metre per steradian [W m^{-2} sr^{-1}];

E_B *effective irradiance (blue light)*: calculated irradiance spectrally weighted by B (λ) expressed in watts per square metre [W m^{-2}];

E_{IR} *total irradiance (thermal injury)*: calculated irradiance within the infrared wavelength range 780 nm to 3 000 nm expressed in watts per square metre [W m^{-2}];

E_{skin} *total irradiance (visible, IRA and IRB):* calculated irradiance within the visible and infrared wavelength range 380 nm to 3 000 nm, expressed in watts per square metre [W m^{-2}];

H_{skin} *radiant exposure*: the time and wavelength integral or sum of the irradiance within the visible and infrared wavelength range 380 to 3 000 nm, expressed in joules per square metre (J m^{-2});

α *angular subtense*: the angle subtended by an apparent source, as viewed at a point in space, expressed in milliradians (mrad). Apparent source is the real or virtual object that forms the smallest possible retinal image.

Table 1.1

Exposure limit values for non-coherent optical radiation

Index	Wavelength nm	Exposure limit value	Units	Comment	Part of the body	Hazard
a.	180-400 (UVA, UVB and UVC)	H_{eff} = 30 Daily value 8 hours	[J m^{-2}]		eye cornea conjunctiva lens skin	photokeratitis conjunctivitis cataractogenesis erythema elastosis skin cancer
b.	315-400 (UVA)	$H_{UVA} = 10^4$ Daily value 8 hours	[J m^{-2}]		eye lens	cataractogenesis
c.	300-700 (Blue light) *see note 1*	$L_B = \frac{10^6}{t}$ for t ≤ 10 000 s	L_B :[W m^{-2} sr^{-1}] t: [seconds]	for α ≥ 11 mrad	eye retina	photoretinitis
d.	300-700 (Blue light) *see note 1*	L_B = 100 for t > 10 000 s	[W m^{-2} sr^{-1}]			
e.	300-700 (Blue light) *see note 1*	$E_B = \frac{100}{t}$ for t ≤ 10 000 s	E_B: [W m^{-2}] t: [seconds]	for α < 11 mrad *see note 2*		
f.	300-700 (Blue light) *see note 1*	E_B = 0,01 t >10 000 s	[W m^{-2}]			

Index	Wavelength nm	Exposure limit value	Units	Comment	Part of the body	Hazard
g.	380-1 400 (Visible and IRA)	$L_R = \frac{2{,}8 \cdot 10^7}{C_\alpha}$ for t >10 s	[W m^{-2} sr^{-1}]	C_α = 1,7 for α ≤ 1,7 mrad C_α = α for 1,7 ≤ α ≤ 100 mrad C_α = 100 for α > 100 mrad λ_1= 380; λ_2= 1 400	eye retina	retinal burn
h.	380-1 400 (Visible and IRA)	$L_R = \frac{5 \cdot 10^7}{C_\alpha t^{0,25}}$ for 10 µs ≤ t ≤ 10 s	L_R:[W m^{-2} sr^{-1}] t: [seconds]			
i.	380-1 400 (Visible and IRA)	$L_R = \frac{8{,}89 \cdot 10^8}{C_\alpha}$ for t <10 µs	[W m^{-2} sr^{-1}]			
j.	780-1 400 (IRA)	$L_R = \frac{6 \cdot 10^6}{C_\alpha}$ for t > 10 s	[W m^{-2} sr^{-1}]	C_α = 11 for α ≤ 11 mrad C_α = α for 11≤ α ≤ 100 mrad C_α = 100 for α > 100 mrad (measurement field-of-view: 11 mrad) λ_1= 780; λ_2= 1 400	eye retina	retinal burn
k.	780-1 400 (IRA)	$L_R = \frac{5 \cdot 10^7}{C_\alpha t^{0,25}}$ for 10 µs ≤ t ≤ 10 s	L_R: [W m^{-2} sr^{-1}] t: [seconds]			
l.	780-1 400 (IRA)	$L_R = \frac{8{,}89 \cdot 10^8}{C_\alpha}$ for t < 10 µs	[W m^{-2} sr^{-1}]			
m.	780-3 000 (IRA and IRB)	E_{IR} = 18 000 t$^{-0,75}$ for t ≤ 1 000 s	E: [W m^{-2}] t: [seconds]		eye cornea lens	corneal burn cataractogenesis
n.	780-3 000 (IRA and IRB)	E_{IR} = 100 for t > 1 000 s	[W m^{-2}]			

Index	Wavelength nm	Exposure limit value	Units	Comment	Part of the body	Hazard
o.	380-3 000 (Visible, IRA and IRB)	$H_{skin} = 20\,000\ t^{0,25}$ for $t < 10$ s	H: [J m^{-2}] t: [seconds]		skin	burn

Note 1: The range of 300 to 700 nm covers parts of UVB, all UVA and most of visible radiation; however, the associated hazard is commonly referred to as '*blue light*' hazard. Blue light strictly speaking covers only the range of approximately 400 to 490 nm.

Note 2: For steady fixation of very small sources with an angular subtense < 11 mrad, L_B can be converted to E_B. This normally applies only for ophthalmic instruments or a stabilized eye during anaesthesia. The maximum 'stare time' is found by: $t_{max} = 100/E_B$ with E_B expressed in W m^{-2}. Due to eye movements during normal visual tasks this does not exceed 100 s.

Table 1.2

S (λ) [dimensionless], 180 nm to 400 nm

λ in nm	S (λ)	λ in nm	S (λ)	λ in nm	S (λ)	λ in nm	S (λ)	λ in nm	S (λ)
180	0,0120	228	0,1737	276	0,9434	324	0,000520	372	0,000086
181	0,0126	229	0,1819	277	0,9272	325	0,000500	373	0,000083
182	0,0132	230	0,1900	278	0,9112	326	0,000479	374	0,000080
183	0,0138	231	0,1995	279	0,8954	327	0,000459	375	0,000077
184	0,0144	232	0,2089	280	0,8800	328	0,000440	376	0,000074
185	0,0151	233	0,2188	281	0,8568	329	0,000425	377	0,000072
186	0,0158	234	0,2292	282	0,8342	330	0,000410	378	0,000069
187	0,0166	235	0,2400	283	0,8122	331	0,000396	379	0,000066
188	0,0173	236	0,2510	284	0,7908	332	0,000383	380	0,000064
189	0,0181	237	0,2624	285	0,7700	333	0,000370	381	0,000062
190	0,0190	238	0,2744	286	0,7420	334	0,000355	382	0,000059
191	0,0199	239	0,2869	287	0,7151	335	0,000340	383	0,000057
192	0,0208	240	0,3000	288	0,6891	336	0,000327	384	0,000055
193	0,0218	241	0,3111	289	0,6641	337	0,000315	385	0,000053
194	0,0228	242	0,3227	290	0,6400	338	0,000303	386	0,000051
195	0,0239	243	0,3347	291	0,6186	339	0,000291	387	0,000049
196	0,0250	244	0,3471	292	0,5980	340	0,000280	388	0,000047
197	0,0262	245	0,3600	293	0,5780	341	0,000271	389	0,000046
198	0,0274	246	0,3730	294	0,5587	342	0,000263	390	0,000044
199	0,0287	247	0,3865	295	0,5400	343	0,000255	391	0,000042
200	0,0300	248	0,4005	296	0,4984	344	0,000248	392	0,000041
201	0,0334	249	0,4150	297	0,4600	345	0,000240	393	0,000039
202	0,0371	250	0,4300	298	0,3989	346	0,000231	394	0,000037
203	0,0412	251	0,4465	299	0,3459	347	0,000223	395	0,000036
204	0,0459	252	0,4637	300	0,3000	348	0,000215	396	0,000035
205	0,0510	253	0,4815	301	0,2210	349	0,000207	397	0,000033
206	0,0551	254	0,5000	302	0,1629	350	0,000200	398	0,000032
207	0,0595	255	0,5200	303	0,1200	351	0,000191	399	0,000031
208	0,0643	256	0,5437	304	0,0849	352	0,000183	400	0,000030
209	0,0694	257	0,5685	305	0,0600	353	0,000175		
210	0,0750	258	0,5945	306	0,0454	354	0,000167		
211	0,0786	259	0,6216	307	0,0344	355	0,000160		
212	0,0824	260	0,6500	308	0,0260	356	0,000153		
213	0,0864	261	0,6792	309	0,0197	357	0,000147		
214	0,0906	262	0,7098	310	0,0150	358	0,000141		
215	0,0950	263	0,7417	311	0,0111	359	0,000136		
216	0,0995	264	0,7751	312	0,0081	360	0,000130		
217	0,1043	265	0,8100	313	0,0060	361	0,000126		
218	0,1093	266	0,8449	314	0,0042	362	0,000122		
219	0,1145	267	0,8812	315	0,0030	363	0,000118		
220	0,1200	268	0,9192	316	0,0024	364	0,000114		
221	0,1257	269	0,9587	317	0,0020	365	0,000110		
222	0,1316	270	1,0000	318	0,0016	366	0,000106		
223	0,1378	271	0,9919	319	0,0012	367	0,000103		
224	0,1444	272	0,9838	320	0,0010	368	0,000099		
225	0,1500	273	0,9758	321	0,000819	369	0,000096		
226	0,1583	274	0,9679	322	0,000670	370	0,000093		
227	0,1658	275	0,9600	323	0,000540	371	0,000090		

Table 1.3

B (λ), R (λ) [dimensionless], 380 nm to 1 400 nm

λ in nm	B (λ)	R (λ)
300 ≤ λ < 380	0,01	—
380	0,01	0,1
385	0,013	0,13
390	0,025	0,25
395	0,05	0,5
400	0,1	1
405	0,2	2
410	0,4	4
415	0,8	8
420	0,9	9
425	0,95	9,5
430	0,98	9,8
435	1	10
440	1	10
445	0,97	9,7
450	0,94	9,4
455	0,9	9
460	0,8	8
465	0,7	7
470	0,62	6,2
475	0,55	5,5
480	0,45	4,5
485	0,32	3,2
490	0,22	2,2
495	0,16	1,6
500	0,1	1
500 < λ ≤ 600	$10^{0,02\cdot(450-\lambda)}$	1
600 < λ ≤ 700	0,001	1
700 < λ ≤ 1 050	—	$10^{0,002\cdot(700-\lambda)}$
1 050 < λ ≤ 1 150	—	0,2
1 150 < λ ≤ 1 200	—	$0,2\cdot 10^{0,02\cdot(1\,150-\lambda)}$
1 200 < λ ≤ 1 400	—	0,02

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ANNEX II

Laser optical radiation

The biophysically relevant exposure values to optical radiation can be determined with the formulae below. The formulae to be used depend on the wavelength and duration of radiation emitted by the source and the results should be compared with the corresponding exposure limit values indicated in the Tables 2.2 to 2.4. More than one exposure value and corresponding exposure limit can be relevant for a given source of laser optical radiation.

Coefficients used as calculation tools within the Tables 2.2 to 2.4 are listed in Table 2.5 and corrections for repetitive exposure are listed in Table 2.6.

$$E = \frac{dP}{dA} \; [W\,m^{-2}]$$

$$H = \int_0^t E(t) \cdot dt \; [J\,m^{-2}]$$

Notes:

dP *power* expressed in watt [W];

dA *surface* expressed in square metres [m^2];

E (t), E *irradiance or power density*: the radiant power incident per unit area upon a surface, generally expressed in watts per square metre [W m^{-2}]. Values of E(t), E come from measurements or may be provided by the manufacturer of the equipment;

H *radiant exposure*: the time integral of the irradiance, expressed in joules per square metre [J m^{-2}];

t *time, duration of the exposure*, expressed in seconds [s];

λ *wavelength*, expressed in nanometres [nm];

γ *limiting cone angle of* measurement *field-of-view* expressed in milliradians [mrad];

γ_m *measurement field of view* expressed in milliradians [mrad];

α *angular subtense of a source* expressed in milliradians [mrad];

limiting aperture: the circular area over which irradiance and radiant exposure are *averaged*;

G *integrated radiance:* the integral of the radiance over a given exposure time expressed as radiant energy per unit area of a radiating surface per unit solid angle of emission, in joules per square metre per steradian [J m^{-2} sr^{-1}].

Table 2.1

Radiation hazards

Wavelength [nm] λ	Radiation range	Affected organ	Hazard	Exposure limit value table
180 to 400	UV	eye	photochemical damage and thermal damage	2.2, 2.3
180 to 400	UV	skin	erythema	2.4
400 to 700	visible	eye	retinal damage	2.2
400 to 600	visible	eye	photochemical damage	2.3
400 to 700	visible	skin	thermal damage	2.4
700 to 1 400	IRA	eye	thermal damage	2.2, 2.3
700 to 1 400	IRA	skin	thermal damage	2.4
1 400 to 2 600	IRB	eye	thermal damage	2.2
2 600 to 10^6	IRC	eye	thermal damage	2.2
1 400 to 10^6	IRB, IRC	eye	thermal damage	2.3
1 400 to 10^6	IRB, IRC	skin	thermal damage	2.4

Table 2.2

Exposure limit values for laser exposure to the eye — Short exposure duration < 10 s

Wavelength [a] [nm]		Aperture	Duration [s]						
			10^{-13} - 10^{-11}	10^{-11} - 10^{-9}	10^{-9} - 10^{-7}	10^{-7} - $1{,}8 \cdot 10^{-5}$	$1{,}8 \cdot 10^{-5}$ - $5 \cdot 10^{-5}$	$5 \cdot 10^{-5}$ - 10^{-3}	10^{-3} – 10^{1}
UVC	180 - 280	1 mm for t<0,3 s; $1{,}5 \cdot t^{0,375}$ for 0,3<t<10 s	$E = 3 \cdot 10^{10} \cdot [W m^{-2}]$ See note [c]		$H = 30 [J m^{-2}]$				
UVB	280 - 302				$H = 40 [J m^{-2}]$:	if $t < 2{,}6 \cdot 10^{-9}$ then $H = 5{,}6 \cdot 10^{3} t^{0,25} [J m^{-2}]$ see note [d]			
	303				$H = 60 [J m^{-2}]$:	if $t < 1{,}3 \cdot 10^{-8}$ then $H = 5{,}6 \cdot 10^{3} t^{0,25} [J m^{-2}]$ see note [d]			
	304				$H = 100 [J m^{-2}]$:	if $t < 1{,}0 \cdot 10^{-7}$ then $H = 5{,}6 \cdot 10^{3} t^{0,25} [J m^{-2}]$ see note [d]			
	305				$H = 160 [J m^{-2}]$:	if $t < 6{,}7 \cdot 10^{-7}$ then $H = 5{,}6 \cdot 10^{3} t^{0,25} [J m^{-2}]$ see note [d]			
	306				$H = 250 [J m^{-2}]$:	if $t < 4{,}0 \cdot 10^{-6}$ then $H = 5{,}6 \cdot 10^{3} t^{0,25} [J m^{-2}]$ see note [d]			
	307				$H = 400 [J m^{-2}]$:	if $t < 2{,}6 \cdot 10^{-5}$ then $H = 5{,}6 \cdot 10^{3} t^{0,25} [J m^{-2}]$ see note [d]			
	308				$H = 630 [J m^{-2}]$:	if $t < 1{,}6 \cdot 10^{-4}$ then $H = 5{,}6 \cdot 10^{3} t^{0,25} [J m^{-2}]$ see note [d]			
	309				$H = 10^{3} [J m^{-2}]$:	if $t < 1{,}0 \cdot 10^{-3}$ then $H = 5{,}6 \cdot 10^{3} t^{0,25} [J m^{-2}]$ see note [d]			
	310				$H = 1{,}6 \cdot 10^{3} [J m^{-2}]$:	if $t < 6{,}7 \cdot 10^{-3}$ then $H = 5{,}6 \cdot 10^{3} t^{0,25} [J m^{-2}]$ see note [d]			
	311				$H = 2{,}5 \cdot 10^{3} [J m^{-2}]$:	if $t < 4{,}0 \cdot 10^{-2}$ then $H = 5{,}6 \cdot 10^{3} t^{0,25} [J m^{-2}]$ see note [d]			
	312				$H = 4{,}0 \cdot 10^{3} [J m^{-2}]$:	if $t < 2{,}6 \cdot 10^{-1}$ then $H = 5{,}6 \cdot 10^{3} t^{0,25} [J m^{-2}]$ see note [d]			
	313				$H = 6{,}3 \cdot 10^{3} [J m^{-2}]$:	if $t < 1{,}6 \cdot 10^{0}$ then $H = 5{,}6 \cdot 10^{3} t^{0,25} [J m^{-2}]$ see note [d]			
	314								
UVA	315 - 400				$H = 5{,}6 \cdot 10^{3} t^{0,25} [J m^{-2}]$				
Visible& IRA	400 - 700	7 mm	$H = 1{,}5 \cdot 10^{-4} C_E [J m^{-2}]$	$H = 2{,}7 \cdot 10^{4} t^{0,75} C_E [J m^{-2}]$	$H = 5 \cdot 10^{-5} C_E [J m^{-2}]$		$H = 18\ t^{0,75} C_E [J m^{-2}]$		
	700 - 1 050		$H = 1{,}5 \cdot 10^{-4} C_A C_E [J m^{-2}]$	$H = 2{,}7 \cdot 10^{4} t^{0,75} C_A C_E [J m^{-2}]$	$H = 5 \cdot 10^{-3} C_A C_E [J m^{-2}]$		$H = 18 \cdot t^{0,75} C_A C_E [J m^{-2}]$		
	1 050- 1 400		$H = 1{,}5 \cdot 10^{-3} C_C C_E [J m^{-2}]$	$H = 2{,}7 \cdot 10^{5} t^{0,75} C_C C_E [J m^{-2}]$	$H = 5 \cdot 10^{-2} C_C C_E [J m^{-2}]$			$H = 90 \cdot t^{0,75} C_C C_E [J m^{-2}]$	
IRB & IRC	1 400 - 1 500	See note [b]	$E = 10^{12} [W m^{-2}]$ See note [c]		$H = 10^{3} [J m^{-2}]$				$H = 5{,}6 \cdot 10^{3} t^{0,25} [J m^{-2}]$
	1 500 - 1 800		$E = 10^{13} [W m^{-2}]$ See note [c]		$H = 10^{4} [J m^{-2}]$				
	1 800 - 2 600		$E = 10^{12} [W m^{-2}]$ See note [c]		$H = 10^{3} [J m^{-2}]$				$H = 5{,}6 \cdot 10^{3} \cdot t^{0,25} [J m^{-2}]$
	2 600 - 10^{6}		$E = 10^{11} [W m^{-2}]$ See note [c]		$H = 100 [J m^{-2}]$	$H = 5{,}6 \cdot 10^{3} \cdot t^{0,25} [J m^{-2}]$			

a If the wavelength of the laser is covered by two limits, then the more restrictive applies.
b When $1\,400 \le \lambda < 10^{5}$ nm : aperture diameter = 1 mm for $t \le 0{,}3$ s and $1{,}5\ t^{0,375}$ mm for $0{,}3\ s < t < 10$ s; when $10^{5} \le \lambda < 10^{6}$ nm : aperture diameter = 11 mm.
c Due to lack of data at these pulse lengths, ICNIRP recommends the use of the 1 ns irradiance limits.
d The table states values for single laser pulses. In case of multiple laser pulses, then the laser pulse durations of pulses falling within an interval T_{min} (listed in table 2.6) must be added up and the resulting time value must be filled in for t in the formula: $5.6\ 10^{3} t^{0,25}$.

Table 2.3

Exposure limit values for laser exposure to the eye — Long exposure duration ≥ 10 s

Wavelength [a] [nm]		Aperture	Duration [s]		
			10^1 - 10^2	10^2 - 10^4	10^4 - $3 \cdot 10^4$
UVC	180 - 280	3,5 mm	$H = 30$ [J m^{-2}]		
UVB	280 - 302		$H = 30$ [J m^{-2}]		
	303		$H = 40$ [J m^{-2}]		
	304		$H = 60$ [J m^{-2}]		
	305		$H = 100$ [J m^{-2}]		
	306		$H = 160$ [J m^{-2}]		
	307		$H = 250$ [J m^{-2}]		
	308		$H = 400$ [J m^{-2}]		
	309		$H = 630$ [J m^{-2}]		
	310		$H = 1{,}0 \cdot 10^3$ [J m^{-2}]		
	311		$H = 1{,}6 \cdot 10^3$ [J m^{-2}]		
	312		$H = 2{,}5 \cdot 10^3$ [J m^{-2}]		
	313		$H = 4{,}0 \cdot 10^3$ [J m^{-2}]		
	314		$H = 6{,}3 \cdot 10^3$ [J m^{-2}]		
UVA	315 - 400		$H = 10^4$ [J m^{-2}]		
Visible 400 – 700	400 - 600 Photochemical [b] Retinal damage	7 mm	$H = 100\ C_B$ [J m^{-2}] ($\gamma = 11$ mrad) [d]	$E = 1\ C_B$ [W m^{-2}]; ($\gamma = 1{,}1\ t^{0,5}$ mrad) [d]	$E = 1\ C_B$ [W m^{-2}] ($\gamma = 110$ mrad) [d]
	400 - 700 Thermal [b] Retinal damage		if $\alpha < 1{,}5$ mrad: then $E = 10$ [W m^{-2}] if $\alpha > 1{,}5$ mrad and $t \leq T_2$: then $H = 18\ C_E\ t^{0,75}$ [J m^{-2}] if $\alpha > 1{,}5$ mrad and $t > T_2$: then $E = 18\ C_E\ T_2^{-0,25}$ [W m^{-2}]		
IRA	700 - 1 400	7 mm	if $\alpha < 1{,}5$ mrad: then $E = 10\ C_A\ C_C$ [W m^{-2}] if $\alpha > 1{,}5$ mrad and $t \leq T_2$: then $H = 18\ C_A\ C_C\ C_E\ t^{0,75}$ [J m^{-2}] if $\alpha > 1{,}5$ mrad and $t > T_2$: then $E = 18\ C_A\ C_C\ C_E\ T_2^{-0,25}$ [W m^{-2}] (not to exceed 1 000 W m^{-2})		
IRB & IRC	1 400 - 10^6	See [c]	$E = 1\ 000$ [W m^{-2}]		

a If the wavelength or another condition of the laser is covered by two limits, then the more restrictive applies.

b For small sources subtending an angle of 1,5 mrad or less, the visible dual limits E from 400 nm to 600 nm reduce to the thermal limits for 10 s≤ t<T_1 and to photochemical limits for longer times. For T_1 and T_2 see Table 2.5. The photochemical retinal hazard limit may also be expressed as a time integrated radiance $G = 10^6\ C_B$ [J m^{-2} sr^{-1}] for t > 10s up to t = 10 000 s and $L = 100\ C_B$ [W m^{-2} sr^{-1}] for t > 10 000 s. For the measurement of G and L γ_m must be used as averaging field of view. The official border between visible and infrared is 780 nm as defined by the CIE. The column with wavelength band names is only meant to provide better overview for the user. (The notation G is used by CEN; the notation L_r is used by CIE; the notation L_R is used by IEC and CENELEC.)

c For wavelength 1 400 - 10^5 nm : aperture diameter = 3,5 mm; for wavelength 10^5 - 10^6 nm: aperture Diameter = 11 mm.

d For measurement of the exposure value the consideration of γ is defined as follows: If α (angular subtense of a source) > γ (limiting cone angle, indicated in brackets in the corresponding column) then the measurement field of view γ_m should be the given value of γ, (If a larger measurement field of view is used, then the hazard would be overestimated).
If α < γ then the measurement field of view γ_m must be large enough to fully enclose the source but is otherwise not limited and may be larger than γ.

Table 2.4

Exposure limit values for laser exposure of skin

Wavelength [a] [nm]		Aperture	Duration [s]					
			$< 10^{-9}$	$10^{-9} - 10^{-7}$	$10^{-7} - 10^{-3}$	$10^{-3} - 10^{1}$	$10^{1} - 10^{3}$	$10^{3} - 3 \cdot 10^{4}$
UV (A, B, C)	180-400	3. 5mm	$E = 3 \cdot 10^{10}$ [W m^{-2}]	Same as eye exposure limits				
Visible and IRA	400-700	3. 5mm	$E = 2 \cdot 10^{11}$ [W m^{-2}]	$H = 200\ C_A$	$H = 1{,}1 \cdot 10^{4}\ C_A\ t^{0{,}25}$ [J m^{-2}]		$E = 2 \cdot 10^{3}\ C_A$ [W m^{-2}]	
	700 -1 400		$E = 2 \cdot 10^{11}\ C_A$ [W m^{-2}]	[J m^{-2}]				
IRB and IRC	1 400-1 500		$E = 10^{12}$ [W m^{-2}]	Same as eye exposure limits				
	1 500-1 800		$E = 10^{13}$ [W m^{-2}]					
	1 800-2 600		$E = 10^{12}$ [W m^{-2}]					
	2 600-10^{6}		$E = 10^{11}$ [W m^{-2}]					

a If the wavelength or another condition of the laser is covered by two limits, then the more restrictive applies.

Table 2.5

Applied correction factors and other calculation parameters

Parameter as listed in ICNIRP	Valid spectral range (nm)	Value
C_A	$\lambda < 700$	$C_A = 1{,}0$
	700 — 1 050	$C_A = 10^{\,0{,}002(\lambda - 700)}$
	1 050 — 1 400	$C_A = 5{,}0$
C_B	400 — 450	$C_B = 1{,}0$
	450 — 700	$C_B = 10^{\,0{,}02(\lambda - 450)}$
C_C	700 — 1 150	$C_C = 1{,}0$
	1 150 — 1 200	$C_C = 10^{\,0{,}018(\lambda - 1\,150)}$
	1 200 — 1 400	$C_C = 8{,}0$
T_1	$\lambda < 450$	$T_1 = 10$ s
	450 — 500	$T_1 = 10 \cdot [10^{\,0{,}02\,(\lambda - 450)}]$ s
	$\lambda > 500$	$T_1 = 100$ s
Parameter as listed in ICNIRP	Valid for biological effect	Value
α_{min}	all thermal effects	$\alpha_{min} = 1{,}5$ mrad
Parameter as listed in ICNIRP	Valid angular range (mrad)	Value
C_E	$\alpha < \alpha_{min}$	$C_E = 1{,}0$
	$\alpha_{min} < \alpha < 100$	$C_E = \alpha/\alpha_{min}$
	$\alpha > 100$	$C_E = \alpha^2/(\alpha_{min} \cdot \alpha_{max})$ mrad with $\alpha_{max} = 100$ mrad
T_2	$\alpha < 1{,}5$	$T_2 = 10$ s
	$1{,}5 < \alpha < 100$	$T_2 = 10 \cdot [10^{\,(\alpha - 1{,}5)\,/\,98{,}5}]$ s
	$\alpha > 100$	$T_2 = 100$ s

Parameter as listed in ICNIRP	Valid exposure time range (s)	Value
γ	$t \leq 100$	$\gamma = 11$ [mrad]
	$100 < t < 10^4$	$\gamma = 1{,}1\ t^{0,5}$ [mrad]
	$t > 10^4$	$\gamma = 110$ [mrad]

Table 2.6

Correction for repetitive exposure

Each of the following three general rules should be applied to all repetitive exposures as occur from repetitively pulsed or scanning laser systems:

1. The exposure from any single pulse in a train of pulses shall not exceed the exposure limit value for a single pulse of that pulse duration.

2. The exposure from any group of pulses (or sub-group of pulses in a train) delivered in time t shall not exceed the exposure limit value for time t.

3. The exposure from any single pulse within a group of pulses shall not exceed the single-pulse exposure limit value multiplied by a cumulative-thermal correction factor $C_p=N^{-0,25}$, where N is the number of pulses. This rule applies only to exposure limits to protect against thermal injury, where all pulses delivered in less than T_{min} are treated as a single pulse.

Parameter	Valid spectral range (nm)	Value
T_{min}	$315 < \lambda \leq 400$	$T_{min} = 10^{-9}$ s (= 1 ns)
	$400 < \lambda \leq 1\,050$	$T_{min} = 18 \cdot 10^{-6}$ s (= 18 μs)
	$1\,050 < \lambda \leq 1\,400$	$T_{min} = 50 \cdot 10^{-6}$ s (= 50 μs)
	$1\,400 < \lambda \leq 1\,500$	$T_{min} = 10^{-3}$ s (= 1 ms)
	$1\,500 < \lambda \leq 1\,800$	$T_{min} = 10$ s
	$1\,800 < \lambda \leq 2\,600$	$T_{min} = 10^{-3}$ s (= 1 ms)
	$2\,600 < \lambda \leq 10^6$	$T_{min} = 10^{-7}$ s (= 100 ns)

STATEMENT BY THE COUNCIL

Statement by the Council on the use of the word 'penalties' in the English version of legal instruments of the European Community

In the opinion of the Council, when the word 'penalties' is used in the English version of legal instruments of the European Community, this word is used in a neutral sense and does not relate specifically to criminal law sanctions, but could also include administrative and financial sanctions, as well as other types of sanction. When Member States are obliged under a Community act to introduce 'penalties', it is up to them to choose the appropriate type of sanction in conformity with the case law of the European Court of Justice.

In the Community language data base, the following translations are made of the word 'penalty' in some other languages:

in Spanish, '*sanciones*'; in Danish, '*sanktioner*'; in German, '*Sanktionen*'; in Hungarian, '*jogkövetkezmények*'; in Italian, '*sanzioni*'; in Latvian, '*sankcijas*'; in Lithuanian, '*sankcijos*'; in Dutch, '*sancties*'; in Portuguese, '*sanções*'; in Slovak, '*sankcie*'; and in Swedish, '*sanktioner*'.

If, in revised English versions of legal instruments where the word 'sanctions' has previously been used, this word is replaced with the word 'penalties', this does not constitute a substantive difference.

European Commission

Non-binding guide to good practice for implementing Directive 2006/25/EC
(Artificial optical radiation)

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Most workplaces contain artificial optical radiation sources and Directive 2006/25/EC lays down minimum health and safety requirements regarding exposure of workers to such sources. The European Commission non-binding guide to good practice for implementing Directive 2006/25/EC pinpoints applications posing minimal risk and provides guidance on others. It sets out an assessment methodology and outlines measures to reduce hazards and check for adverse health effects.

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