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Safety of laser products –

Part 14: A user's guide

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SAFETY OF LASER PRODUCTS –

Part 14: A user's guide

FOREWORD

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IEC 60825-14, which is a technical report, has been prepared by IEC technical committee 76: Optical radiation safety and laser equipment.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
76/271/DTR	76/282/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

IEC consists of the following parts, under the general title *Safety of laser products*:

Part 1: Equipment classification, requirements and user's guide

Part 2: Safety of optical fibre communication systems

Part 3: Guidance for laser displays and shows

Part 4: Laser guards

Part 5: Manufacturer's checklist for IEC 60825-1

Part 6: Safety of products with optical sources, exclusively used for visible information transmission to the human eye

Part 7: Safety of products emitting infrared optical radiation, exclusively used for wireless 'free air' data transmission and surveillance

Part 8: Guidelines for the safe use of medical laser equipment

Part 9: Compilation of maximum permissible exposure to incoherent optical radiation

Part 10: Application guidelines and explanatory notes to IEC 60825-1

Part 12: Safety of free space optical communication systems used for transmission of information[1)]

Part 13: Measurements for classification of laser products[1)]

Part 14: A user's guide

The committee has decided that the contents of this publication will remain unchanged until 2007. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

1) To be published

INTRODUCTION

To help in the use of this technical report, an outline of the topics that are covered within it is given below. The topics are presented in the order in which they would normally be considered as part of a laser safety programme.

– Safety responsibilities with regard to the operation of lasers and the need for appropriate training are covered in Clause 3.

– The meaning of the laser product classes and the assessment of laser exposure are covered in Clause 4.

– The determination of the maximum permissible exposure (MPE), and the concept of the hazard distance and hazard zone within which the MPE can be exceeded, are covered in Clause 5.

– Associated laser hazards (that is, hazards other than those of eye or skin exposure to the emitted laser beam) are covered in Clause 6.

– A three-stage process for evaluating risk (arising from both the laser radiation hazards discussed in Clauses 4 and 5, and the associated laser hazards discussed in Clause 6) is covered in Clause 7. These three stages are:

  1) the identification of all potentially injurious situations,

  2) the assessment of the risk arising from these situations and

  3) the determination of the necessary protective measures.

– The use of control measures for reducing the risk to an acceptable level is covered in Clause 8.

– The need to ensure the continuation over time of safe laser operation is covered in Clause 9.

– The reporting of laser-related hazardous incidents and the investigation of accidents is covered in Clause 10.

– The role of medical surveillance (eye examinations) is covered in Clause 11.

– Additional information on the use of interlock protection is given in Annex A.

– Examples of laser safety calculations are given in Annex B.

– An explanation of the biophysical effects of laser exposure to the eyes and skin is given in Annex C.

SAFETY OF LASER PRODUCTS –

Part 14: A user's guide

1 Scope and object

This technical report provides guidance on best practice in the safe use of laser products that conform to IEC 60825-1. The terms "laser product" and "laser equipment" as used in this document also refer to any device, assembly or system, which is capable of emitting optical radiation produced by a process of stimulated emission. However, unlike IEC 60825-1, this document does not cover light-emitting diodes (LEDs).

Class 1 laser products normally pose no hazard and Class 2 laser products present only a minimal hazard. With these products, it is normally sufficient to follow the warnings on the product labels and the manufacturer's instructions for safe use. Further protective measures as described in this document should not be necessary.

This document emphasizes evaluation of the risk from higher power lasers, but the users of the lower power lasers may benefit from the information contained. See Table 1 for an overview.

This technical report can be applied to the use of any product that incorporates a laser, whether or not it is sold or offered for sale. Therefore, it applies to specially constructed lasers (including experimental and prototype systems).

This technical report is intended to help laser users and their employers to understand the general principles of safety management (Clause 3), to identify the hazards that may be present (Clauses 4 to 6), to assess the risks of harm that may arise (Clause 7), and to set up and maintain appropriate control measures (Clauses 8 to 11).

Laser control measures vary widely. They depend on the type of laser equipment in use, the task or process being performed, the environment in which the equipment is used and the personnel who may be at risk of harm. Specific requirements for certain laser applications is given in other documents in the IEC 60825 series (see the Foreword or bibliography for the titles of these documents).

The terms "reasonably foreseeable" and "reasonably foreseeably" are used in this document in relation to certain specific events, situations or conditions. It is the responsibility of the person using this document to determine what is "reasonably foreseeable" and what might occur "reasonably foreseeably", and to be able to defend, on the basis of risk-assessment criteria, any such judgements that are made.

Reference is made in this document to laser "users". This should be taken to include persons having responsibility for safety in addition to those who actually work with or operate laser equipment.

2 Terms and definitions

For the purposes of this document, the following definitions apply.

2.1
administrative control
safety measures of a non-engineering type such as key supervision, safety training of personnel, warning notices, countdown procedures, and range safety controls

2.2
alpha min
α min
See angular subtense (2.4)

2.3
angle of acceptance
γ
plane angle within which a detector will respond to optical radiation, usually measured in radians. This angle of acceptance may be controlled by apertures or optical elements in front of the detector

NOTE 1 The angle of acceptance is also sometimes referred to as the field of view.

NOTE 2 For evaluation of the photochemical hazard, a limiting measurement angle of acceptance, γ_p, is specified. The angle γ_p is biologically related to eye movements and is not dependent upon the angular subtense of the source. If the angular subtense of the source is smaller than the limiting angle of acceptance, the actual measurement angle of acceptance does not have to be limited. If the angular subtense of the source is larger than the specified limiting angle of acceptance, the angle of acceptance has to be limited and the source has to be scanned for hotspots. If the measurement angle of acceptance is not limited to the specified level, the hazard may be over-estimated.

2.4
angular subtense
α
angle subtended by an apparent source as viewed at a point in space

NOTE 1 In this standard, for classification, the angular subtense is determined at a point not less than 100 mm from the apparent source (or at the exit window or lens of the product if the apparent source is located at a distance greater than 100 mm within the window or lens). For an analysis of the maximum permissible exposure levels, the angular subtense is determined at the viewing distance from the apparent source but not less than 100 mm.

NOTE 2 The angular subtense of an apparent source is applicable in this part of IEC 60825 only in the wavelength range from 400 nm to 1 400 nm, the retinal hazard region.

NOTE 3 The angular subtense of the source should not be confused with the divergence of the beam.

2.5
aperture
any opening in the protective housing or other enclosure of a laser product through which laser radiation is emitted, thereby allowing human access to such radiation

2.5.1
aperture stop
opening serving to define the area over which radiation is measured

2.6
apparent source
real or virtual object that forms the smallest possible retinal image

NOTE This definition is used to determine the location of the apparent origin of laser radiation in the wavelength range of 400 nm to 1 400 nm, with the assumption of the apparent source being located in the eye's range of accommodation (≥100 mm). In the limit of vanishing divergence, i.e. in the case of an ideally collimated beam, the location of the apparent source goes to infinity.

The concept of an apparent source is used in the extended wavelength region 302,5 nm to 4 000 nm since focusing by conventional lenses might be possible in that region.

2.7
beam
laser radiation that may be characterized by direction, divergence, diameter or scan specifications

NOTE Scattered radiation from a non-specular reflection is not considered to be a beam.

2.8
beam attenuator
device which reduces the laser radiation to or below a specified level

2.9
beam diameter
d_u
beam width
diameter of the smallest circle which contains *u* % of the total laser power (or energy). For the purpose of this standard d_{63} is used

NOTE In the case of a Gaussian beam, d_{63} corresponds to the point where the irradiance (radiant exposure) falls to 1/e of its central peak value.

2.10
beam divergence
far field plane angle of the cone defined by the beam diameter

NOTE 1 If the beam diameters at two points separated by a distance *r* are d_{63} and d'_{63}, the divergence is given by:

$$\varphi = 2 \arctan\left(\frac{d_{63} - d'_{63}}{2r}\right)$$

NOTE 2 SI unit: radian.

2.11
beam stop
device which terminates a laser beam path

2.12
Class 1 laser product
any laser product which does not permit human access to laser radiation in excess of the accessible emission limits of Class 1 for applicable wavelengths and emission durations

2.13
Class 1M laser product
any laser product in the wavelength range from 302,5 nm to 4 000 nm which does not permit human access to laser radiation in excess of the accessible emission limits of Class 1 for applicable wavelengths and emission durations, where the level of radiation is measured but is evaluated with smaller measurement apertures or at a greater distance from the apparent source than those used for Class 1 laser products

NOTE The output of a Class 1M product is therefore potentially hazardous when viewed using an optical instrument.

2.14
Class 2 laser product
any laser product, which does not permit human access to laser radiation in excess of the accessible emission limits of Class 2 for applicable wavelengths and emission durations

2.15
Class 2M laser product
any laser product in the wavelength range from 400 nm to 700 nm which does not permit human access to laser radiation in excess of the accessible emission limits of Class 2 for applicable wavelengths and emission durations, where the level of radiation is measured but is evaluated with smaller measurement apertures or at a greater distance from the apparent source than those used for Class 2 laser products

NOTE The output of a Class 2M product is therefore potentially hazardous when viewed using an optical instrument.

2.16
Class 3R and Class 3B laser products
any laser product which permits human access to laser radiation in excess of the accessible emission limits of Class 1 and Class 2 as applicable, but which does not permit human access to laser radiation in excess of the accessible emission limits of Classes 3R and 3B (respectively) for any emission duration and wavelength

2.17
Class 4 laser product
any laser product which permits human access to laser radiation in excess of the accessible emission limits of Class 3B

2.18
collateral radiation
any electromagnetic radiation, within the wavelength range between 180 nm and 1 mm, except laser radiation, emitted by a laser product as a result of, or physically necessary for, the operation of a laser

2.19
collimated beam
"parallel" beam of radiation with very small angular divergence or convergence

2.20
continuous wave
CW
output of a laser which is operated in a continuous rather than pulsed mode. In this part of IEC 60825, a laser operating with a continuous output for a period equal to or greater than 0,25 s is regarded as a CW laser

2.21
defined beam path
an intended path of a laser beam within the laser product

2.22
diffuse reflection
change of the spatial distribution of a beam of radiation by scattering in many directions by a surface or medium.

NOTE 1 A perfect diffuser destroys all correlation between the directions of the incident and emergent radiation.

NOTE 2 This definition is different from IEV 845-04-47.

2.23
embedded laser product
laser product which, because of engineering features limiting the accessible emissions, has been assigned a class number lower than the inherent capability of the laser incorporated

NOTE The laser which is incorporated in the embedded laser product is called the embedded laser.

2.24
emission duration
temporal duration of a pulse, of a train or series of pulses, or of continuous operation, during which human access to laser radiation could occur as a result of operation, maintenance or servicing of a laser product. For a train of pulses, this is the duration between the first half-peak power point of the leading pulse and the last half-peak power point of the trailing pulse

2.25
exposure duration
see exposure time (2.26).

2.26
exposure time
duration of a pulse, or series, or train of pulses or of continuous emission of laser radiation incident upon the human body. For a train of pulses, this is the duration between the first half-peak power point of the leading pulse and the last half-peak power point of the trailing pulse

2.27
extended source viewing
viewing conditions whereby the apparent source at a distance of 100 mm or more subtends an angle at the eye greater than the limiting angular subtense (α_{min})

NOTE Two extended source conditions are considered in this standard when considering retinal thermal injury hazards: intermediate source and large source, which are used to distinguish sources with angular subtenses, α, between α_{min} and α_{max} (intermediate sources), and greater than α_{max} (large sources).

Examples are viewing of some diffuse reflections and of some laser diode arrays.

2.28
fail safe
design consideration in which failure of a component does not increase the hazard. In the failure mode the system is rendered inoperative or non-hazardous

2.29
human access
a) capability of a part of the human body to meet hazardous laser radiation either as emitted from an aperture, or capability of a straight 12 mm diameter probe up to 80 mm long to intercept laser radiation of Class 2, 2M or 3R; or

b) for levels of laser radiation within a housing that exceed the limits in a), the capability for any part of the human body to meet hazardous laser radiation that can be reflected directly by any single introduced flat surface from the interior of the product through any opening in its protective housing

2.30
integrated radiance
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 (usually expressed as $J \cdot m^{-2} \cdot sr^{-1}$)

2.31
intrabeam viewing
all viewing conditions whereby the eye is exposed to the direct or specularly reflected laser beam in contrast, for example, to viewing of diffuse reflections

2.32
irradiance
E
quotient of the radiant flux $d\Phi$ incident on an element of a surface by the area dA of that element:

$$E = \frac{d\Phi}{dA}$$

NOTE SI unit: watt per square metre ($W \cdot m^{-2}$).

2.33
laser
any device which can be made to produce or amplify electromagnetic radiation in the wavelength range from 180 nm to 1 mm primarily by the process of controlled stimulated emission.

NOTE This definition is different from IEV 845-04-39.

2.34
laser controlled area
area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from radiation hazards

2.35
laser energy source
any device intended for use in conjunction with a laser to supply energy for the excitation of electrons, ions, or molecules.

NOTE General energy sources such as electrical supply mains or batteries are not considered to constitute laser energy sources.

2.36
laser equipment
laser product – an assembly that is or contains a laser

2.37
laser product
any product or assembly of components which constitutes, incorporates or is intended to incorporate a laser or laser system, and which is not sold to another manufacturer for use as a component (or replacement for such component) of an electronic product

2.38
laser radiation
all electromagnetic radiation emitted by a laser product between 180 nm and 1 mm which is produced as a result of controlled stimulated emission

2.39
laser safety officer
one who is knowledgeable in the evaluation and control of laser hazards and has responsibility for oversight of the control of laser hazards

2.40
laser system
laser in combination with an appropriate laser energy source with or without additional incorporated components

2.41
limiting aperture
circular area over which irradiance and radiant exposure are averaged

2.42
maintenance
performance of those adjustments or procedures specified in user information provided by the manufacturer with the laser product, which are to be performed by the user for the purpose of assuring the intended performance of the product. It does not include operation or service

2.43
maximum angular subtense
α max
value of angular subtense of the apparent source above which the MPEs are independent of the source size

2.44
maximum permissible exposure
MPE
that level of laser radiation to which, under normal circumstances, persons may be exposed without suffering adverse effects. The MPE levels represent the maximum level to which the eye or skin can be exposed without consequential injury immediately or after a long time and are related to the wavelength of the radiation, the pulse duration or exposure time, the tissue at risk and, for visible and near infra-red radiation in the range 400 nm to 1 400 nm, the size of the retinal image

NOTE 1 The values for maximum permissible exposure used in this document are those recommended by the International Commission on Non-Ionizing Radiation Protection, and are based on the current state of knowledge of threshold levels for laser injury.

NOTE 2 Annex B gives examples of the calculations of MPE levels.

2.45
minimum angular subtense
α min
value of angular subtense of the apparent source above which a source is considered an extended source

NOTE MPEs are independent of the source size for angular subtenses less than α_{min}.

2.46
nominal ocular hazard area
NOHA
area within which the beam irradiance or radiant exposure exceeds the appropriate corneal maximum permissible exposure (MPE), including the possibility of accidental misdirection of the laser beam

NOTE If the NOHA includes the possibility of viewing through optical aids, this is termed the "extended NOHA".

2.47
nominal ocular hazard distance
NOHD
distance at which the beam irradiance or radiant exposure equals the appropriate corneal maximum permissible exposure (MPE)

NOTE If the NOHD includes the possibility of optically-aided viewing, this is termed the "extended NOHD".

2.48
operation
performance of the laser product over the full range of its intended functions. It does not include maintenance or service

2.49
optical density
OD
logarithm to base ten of the reciprocal of the transmittance τ
Symbol: D $D = -\log_{10} \tau$