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TECHNICAL REPORT

colour inside

Safety of laser products – Part 14: A user's guide

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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IEC TR 60825-14 has been prepared by IEC technical committee 76: Optical radiation safety and laser equipment. It is a Technical Report.

This second edition cancels and replaces the first edition published in 2004. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) incorporates changes made in IEC 60825-1:2014;
b) adds information to users of laser equipment on administrative controls to ensure safety in the workplace, including the training and appointment of people to specific laser safety management roles;
c) updates an approach to risk assessment;
d) includes updated guidance on the management of incidents and accidents;
e) includes updated guidance on medical surveillance for laser workers;
f) includes revised examples of calculations.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
76/661/DTR	76/693/RVDTR

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

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts of the IEC 60825 series, published under the general title *Safety of laser products*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

To help in the use of this document, 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 4.

– The meaning of the laser product classes and the assessment of laser exposure are covered in Clause 5.

– 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 6.

– Associated laser hazards (that is, hazards other than those of eye or skin exposure to the emitted laser beam) are covered in Clause 7.

– A three-stage process for evaluating risk (arising from both the laser radiation hazards discussed in Clause 5 and Clause 6, and the associated laser hazards discussed in Clause 7) is covered in Clause 8. These three stages are

  1) the identification of 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 9.

– The need to ensure the continuation over time of safe laser operation is covered in Clause 10.

– The reporting of laser-related hazardous incidents and the investigation of accidents is covered in Clause 11 and Clause 12.

– The role of medical surveillance (eye examinations) is covered in Clause 13.

– 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

This document provides guidance on best practices 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 that is capable of emitting optical radiation produced by a process of stimulated emission.

Class 1 laser products normally pose no beam hazard and Class 2 and Class 3R laser products present only a minimal beam hazard. With these products, it is normally sufficient to follow the warnings on the product labels and the manufacturer's instructions for safe use. It is unlikely that further protective measures as described in this document will be necessary.

This document emphasizes evaluation of the risk from higher power lasers, but the users of the lower power lasers can benefit from the information provided

This document 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 document is intended to help laser users and their employers to understand the general principles of safety management, to identify the hazards that can be present, to assess the risks of harm that can arise, and to set up and maintain appropriate control measures. Although the guidance given in this document is aimed principally at organizations (whether private, corporate or public) where systems of safety management would be expected to be in place, it can be applied by anyone using lasers.

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 are at risk of harm. Specific requirements for certain laser applications are given in other documents in the IEC 60825 series.

The terms "reasonably foreseeable" and "reasonably foreseen" 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 occurrences might be "reasonably foreseen", 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 includes persons having responsibility for safety in addition to those who actually work with or operate laser equipment.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60825-1:2014, *Safety of laser products – Part 1: Equipment classification and requirements*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60825-1:2014 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

– IEC Electropedia: available at http://www.electropedia.org/

– ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
control measure
precaution adopted to reduce the risk of harm occurring

Note 1 to entry: Control measures include engineering controls (safety features incorporated into the laser equipment), administrative controls (documented policies, operating procedures, safety training, etc.) and personnel protection (safety equipment including eye protection that is worn by individuals).

3.1.2
laser equipment
laser product
assembly that is a laser or contains a laser

3.1.3
optical density
OD
$D(\lambda)$
logarithm to base ten of the reciprocal of the transmittance τ

$D(\lambda) = -\log_{10} \tau$

3.1.4
protective enclosure
physical means for preventing human exposure to laser radiation unless such access is necessary for the intended functions of the installation

3.2 Symbols

Symbol	Unit	Definition
a	m	Diameter of the emergent laser beam.
α	rad	The angle subtended by an apparent source (or a diffuse reflection) as viewed at a point in space.
α_f	rad	Angle at the eye subtending the apparent source of radiation at a distance of r_f = 100 mm.
α_{min}	rad	Minimum angle subtended by a source for which the extended source criterion applies (α_{min} = 1,5 mrad).
α_{max}	rad	The value of angular subtense of the apparent source above which the MPEs are independent of the source size (α_{max} = 5 mrad to 100 mrad, see Table 10).
C_1, C_2, …, C_7	no units	Correction factors (see Table 9).
d_u	m	Diameter of the smallest circle at a specified distance, r, from the apparent source that contains u % of the total laser power (or energy). In the case of a Gaussian beam, d_{63} corresponds to the points where the irradiance (or radiant exposure) falls to $1/e$ of its central peak value.
$D(\lambda)$	no units	Optical (transmittance) density defined as the logarithm to base 10 of the reciprocal of the transmittance (see also IEV 845-04-66).

Symbol	Unit	Definition
D_e	m	Diameter of the exit pupil of an optical system.
D_o	m	Diameter of the objective of an optical system.
η	no units	Fraction of the total laser power (or energy) collected through a specified aperture located at a specified distance, r, from the apparent source.
F	Hz	Pulse repetition frequency.
G	no units	Square root of the ratio of retinal irradiance or radiant exposure received by an optically aided eye to that received by an unaided eye.
H E	$J \cdot m^{-2}$ $W \cdot m^{-2}$	Radiant exposure or irradiance at a specified distance, r, from the apparent source.
H_o E_o	$J \cdot m^{-2}$ $W \cdot m^{-2}$	Emergent beam radiant exposure or irradiance at zero distance from the apparent source.
k	no units	Irradiance averaging factor with values ranging from k = 1 for beams having Gaussian profiles to k = 2,5 for beams of unknown mode structure.
L_p	$J \cdot m^{-2} \cdot sr^{-1}$	Integrated radiance of an extended source.
λ	nm	Wavelength of laser radiation.
M	no units	Magnification of an optical instrument.
H_{MPE} or E_{MPE}	$J \cdot m^{-2}$ $W \cdot m^{-2}$	Maximum permissible exposure.
μ	m^{-1}	Atmospheric attenuation coefficient at a specified wavelength.
N	no units	Number of pulses contained within an exposure duration.
NA	no units	Numerical aperture of a laser source.
NA_m	no units	Numerical aperture of a microscope objective
P_o	W	Total radiant power (radiant flux) of a CW laser, or average radiant power of a repetitively pulsed laser.
P_p	W	Radiant power within a pulse of a pulsed laser.
R_{NOH}	m	Nominal ocular hazard distance.
$R_{NOH,E}$	m	Extended nominal ocular hazard distance.
φ	rad	Divergence angle of an emergent laser beam
π	no units	The numerical constant 3,142.
Q	J	Total radiant energy of a pulsed laser.
r	m	Distance from the apparent source to the viewer, measurement aperture, or diffuse target.
r_1	m	Distance from the laser target to the viewer or measurement aperture.
$r_{1,max}$	m	Maximum distance from the laser target to the viewer where extended source viewing conditions apply.
t	s	Time duration of a single laser pulse.
T	s	Total exposure duration of a train of pulses.
T_1, T_2	s	Time breakpoints (see Table 10).

4 Administrative policies

4.1 Safety responsibilities

Safety responsibilities may be specified by national or local regulations. In the absence of any specific legislation or regulations, the following are some general guides on responsibilities for the safe use of lasers.

Employers and employees, and all users of lasers (including students) and those supervising or overseeing them, have a role to play in maintaining a safe place of work (environment) and in ensuring that their activities do not present unacceptable levels of risk to themselves or to others.

In any place of work in which lasers are in use, it is the employer's responsibility to ensure that the risks to health arising from the use and reasonably foreseeable misuse of laser equipment are properly assessed. The employer needs to take all necessary steps to ensure that these risks are either eliminated or, where this is not reasonably practicable, reduced to an acceptably low level.

Wherever potentially hazardous lasers are in use, the employer (or any other person having overall responsibility) should establish a general policy for the safe management of these hazards, although specific safety tasks may be delegated to others. This policy, which should be an integral part of the organization's overall safety policy, should require that all reasonably foreseeable hazards arising from laser use are identified and that steps are taken to control them so far as is reasonably practicable. Significant findings of this assessment should be documented and appropriate protective measures implemented wherever necessary to reduce the identified health and safety risks. The effectiveness of such protective measures should be reviewed regularly. These requirements for establishing a specific safety policy for lasers are not normally necessary where only laser products in Class 1, Class 1C, Class 2, or Class 3R are in use, and may not always be necessary for laser products in Class 1M or Class 2M, but see Table 1 concerning protective control measures, 5.1.3 concerning embedded lasers and 5.2.2 concerning transient visual effects.

4.2 Competent Person

Where the employer or laser user is not able, without assistance, to properly determine the necessary safety arrangements and protective measures for eliminating or minimizing the risks to health arising from the use of laser equipment, then the advice of a Competent Person should be sought. The Competent Person should have sufficient skill in, and knowledge and experience of, matters relevant to laser safety, relating particularly to the specific technical area within which advice is being sought, and should provide appropriate assistance to the employer (or to the employer's delegated representative, or laser user) in hazard determination, risk assessment, and protective control and procedure provision.

The Competent Person (often termed the Laser Protection Adviser (4.5.1) when considering laser beam hazards) need not be an employee of the organization concerned but may instead be an external adviser. The advice and assistance of a Competent Person is often only necessary temporarily, for example when first establishing appropriate protective control measures or when evaluating the risk prior to significant changes to procedures or equipment.

4.3 Laser Safety Officer

A Laser Safety Officer (LSO) should be appointed in organizations in which Class 3B or Class 4 laser products are in use. The appointment of a Laser Safety Officer is also recommended where Class 1M and Class 2M laser products generating well-collimated beams are in use, and which could present a hazard if viewed through binoculars or telescopes at a considerable distance from the laser. (This can include the installation and servicing of embedded lasers where access may be gained to higher levels of laser radiation than is implied by the laser product's class (see 5.1.3), or where the use of lasers of a lower class than 3B or 4 may