

TECHNICAL REPORT



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



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2022 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Secretariat
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

Preview generated by EVS

TECHNICAL REPORT



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

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 31.260

ISBN 978-2-8322-1087-7

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD.....	7
INTRODUCTION.....	9
1 Scope.....	10
2 Normative references	10
3 Terms, definitions and symbols.....	11
3.1 Terms and definitions.....	11
3.2 Symbols.....	11
4 Administrative policies	13
4.1 Safety responsibilities	13
4.2 Competent Person	13
4.3 Laser Safety Officer	13
4.4 Information and training	14
4.5 Levels of competence	15
4.5.1 Laser Protection Adviser.....	15
4.5.2 Laser Safety Officer.....	15
4.5.3 Laser Safety Supervisor	17
4.5.4 Laser user	17
4.5.5 Awareness for other persons	17
4.6 Training requirements	18
4.7 Accreditation.....	18
5 Laser radiation hazards	19
5.1 Laser products.....	19
5.1.1 Laser product classification	19
5.1.2 Product classes	19
5.1.3 Embedded lasers.....	22
5.1.4 Optical fibres	23
5.1.5 Laser demonstrations and displays.....	23
5.1.6 Consumer laser products.....	24
5.2 Exposure to laser radiation	24
5.2.1 Maximum permissible exposure	24
5.2.2 Transient visual effects.....	24
5.3 Determining the level of laser exposure	25
5.3.1 The effective exposure	25
5.3.2 Limiting apertures	26
5.3.3 Angle of acceptance for the assessment of exposure from extended sources.....	27
5.3.4 Use of binoculars.....	29
6 Determining the maximum permissible exposure (MPE).....	29
6.1 General remarks	29
6.2 Repetitively pulsed or modulated lasers	36
6.3 Multiple wavelengths.....	38
6.4 Extended source MPEs	38
6.5 Hazard distance and hazard area.....	39
6.5.1 Nominal ocular hazard distance	39
6.5.2 Nominal ocular hazard area	39
7 Associated hazards	40

7.1	Additional health hazards	40
7.2	Hazards arising from the laser	40
7.2.1	Electricity	40
7.2.2	Collateral radiation	40
7.2.3	Other laser radiation	41
7.2.4	Hazardous substances	41
7.2.5	Fume	41
7.2.6	Noise	41
7.2.7	Mechanical hazards	41
7.2.8	Fire, explosion and thermal damage	41
7.2.9	Heat and cold	42
7.3	Hazards arising from the environment	42
7.3.1	Temperature and humidity	42
7.3.2	Mechanical shock and vibration	42
7.3.3	Atmospheric effects	42
7.3.4	Electromagnetic and radio-frequency interference	42
7.3.5	Power supply interruption or fluctuation	42
7.3.6	Computer software problems	42
7.3.7	Ergonomic and human-factor considerations	42
7.4	Control of associated hazards	43
8	Evaluating risk	43
8.1	Hazards and risks	43
8.2	Risk assessment: Stage 1 – Identifying potentially injurious situations	44
8.2.1	General	44
8.2.2	The hazards involved	44
8.2.3	The laser environment	44
8.2.4	The people at risk	44
8.3	Risk assessment: Stage 2 – Assessing risk for potentially injurious situations	45
8.3.1	General	45
8.3.2	Frequency	45
8.3.3	Severity	45
8.3.4	Resultant risk	45
8.4	Risk assessment: Stage 3 – Selecting control measures	46
9	Control measures	46
9.1	General	46
9.2	Hazard reduction	47
9.3	Enclosing the hazard	48
9.3.1	Beam enclosures	48
9.3.2	Viewing windows	48
9.3.3	Interlock protection	48
9.4	Hazard mitigation	49
9.4.1	Preventing access	49
9.4.2	Laser controlled areas	50
9.4.3	Local rules and procedures	56
9.4.4	Localized risk reduction	57
9.4.5	Personal protection	58
9.4.6	Protective clothing	61
9.5	Equipment servicing	61
9.5.1	Increased risks during laser equipment servicing	61

9.5.2	Temporary laser controlled areas.....	61
9.5.3	Controls during servicing	62
9.5.4	Visiting installation and service engineers	62
10	Maintenance of safe operation	62
11	Contingency plans	63
11.1	General.....	63
11.2	Dealing with an actual eye injury.....	63
11.3	Dealing with an actual skin injury	63
11.4	Dealing with a suspected eye injury	64
12	Incident reporting and accident investigation	64
13	Medical surveillance	64
Annex A	(informative) Examples of interlock systems for laser controlled areas	65
A.1	General.....	65
A.2	Common elements	65
A.2.1	Interlock control system.....	65
A.2.2	Door interlock switches.....	65
A.2.3	Override switches.....	65
A.2.4	Shutter	66
A.2.5	Illuminated warning sign	66
A.2.6	Emergency stop switch.....	66
A.2.7	Electric locks (door strikes).....	66
A.2.8	Non-locking interlock systems (see Figure A.1)	66
A.2.9	Locking interlock systems (see Figure A.2).....	66
Annex B	(informative) Examples of calculations.....	69
B.1	General.....	69
B.2	Symbols used in the examples of Annex B.....	69
B.3	Maximum permissible exposure (MPE) – Overview	69
B.4	Maximum permissible exposure (MPE) – Single small source	70
B.4.1	General	70
B.4.2	Example for a helium-cadmium laser	70
B.4.3	Example for a pulsed ruby laser.....	70
B.4.4	Example for a single pulse of a gallium-arsenide laser.....	70
B.4.5	Example for a continuous wave helium-neon laser.....	71
B.5	Maximum permissible exposure (MPE) – Repetitively pulsed systems.....	71
B.5.1	General	71
B.5.2	Example for a pulsed argon laser.....	71
B.5.3	Example for a pulsed Nd:YAG laser.....	73
B.6	Nominal ocular hazard distance (NOHD).....	74
B.6.1	General	74
B.6.2	Example NOHD for a Gaussian beam with negligible atmospheric attenuation	79
B.6.3	Example of NOHD with beam expanding optics	80
B.6.4	Example of NOHD with atmospheric attenuation	80
B.6.5	Example of NOHD for a helium-neon laser with an expanding beam	81
B.6.6	Example for an infrared surveying instrument	82
B.6.7	Example for a Q-switched rangefinder	83
B.6.8	Example for a CW optical fibre transmitter	85
B.7	Diffuse reflections that are extended sources.....	87

B.7.1	General	87
B.7.2	Example for a reflection from a perfect diffuser	88
B.7.3	Example for close viewing of reflection from a perfect diffuser	89
B.7.4	Example for assessing the minimum safe viewing distance	90
B.8	Eye protection	90
B.8.1	General	90
B.8.2	Example protective eyewear for example B.6.7	91
B.8.3	Example protective eyewear for example B.6.2	91
B.9	Example for a complex laser diode array source	92
B.9.1	General	92
B.9.2	Single diode	94
B.9.3	Horizontal two-diode group	95
B.9.4	Vertical two-diode group	95
B.9.5	Four-diode group	95
B.9.6	One row of 10 diodes	96
B.9.7	20-diode group	97
B.9.8	Additional remarks	97
B.9.9	Required optical density	98
B.9.10	Use of an optical device	98
Annex C (informative)	Biophysical considerations	100
C.1	Anatomy of the eye	100
C.2	The effects of laser radiation on biological tissue	101
C.2.1	General	101
C.2.2	Hazards to the eye	103
C.2.3	Skin hazards	106
C.3	MPEs and irradiance averaging	107
Bibliography	108
Figure 1	– Measurement set-ups to achieve a well-defined angle of acceptance	28
Figure 2	– Combination of safety signs	54
Figure 3	– Warning; Laser beam symbol (ISO 7010-W004:2011-05),	54
Figure 4	– Wear eye protection symbol (ISO 7010-M004:2011-05)	55
Figure 5	– No thoroughfare symbol (ISO 7010-P004:2011-05)	56
Figure A.1	– Non-locking interlock system	67
Figure A.2	– Locking interlock system	68
Figure B.1	– Nominal ocular hazard distance	75
Figure B.2	– Chart for determining the NOHD (with various atmospheric attenuation factors from the NOHD found without considering atmospheric attenuation)	78
Figure B.3	– Laser diode array with three groupings	92
Figure C.1	– Anatomy of the eye	100
Figure C.2	– Diagram of laser-induced damage in biological systems	102
Table 1	– Default protective control measures for laser products	22
Table 2	– The diameter of the limiting aperture applicable to measurements of irradiance and radiant exposure (t is time of the relevant exposure, either pulse duration or total exposure)	26
Table 3	– Typical transmission percentages for binoculars	29

Table 4 – Maximum permissible exposure (MPE) at the cornea for small sources expressed as irradiance or radiant exposure ^{a,b}	31
Table 5 – Maximum permissible exposure (MPE) at the cornea for extended sources in the wavelength range from 400 nm to 1 400 nm (retinal hazard region) expressed as irradiance or radiant exposure	32
Table 6 – Maximum permissible exposure (MPE) of Table 4 ($C_6 = 1$) for the wavelength range from 400 nm to 1 400 nm expressed as power or energy ^{a,b}	33
Table 7 – Maximum permissible exposure (MPE) of Table 5 (extended sources) for the wavelength range from 400 nm to 1 400 nm expressed as power or energy ^{a,b}	34
Table 8 – Maximum permissible exposure (MPE) of the skin to laser radiation ^{a,b}	35
Table 9 – Correction factors and breakpoints for use in MPE evaluations	35
Table 10 – Duration T_i below which pulse groups are summed up	38
Table 11 – Additivity of effects on eye (O) and skin (S) of radiation of different spectral regions	38
Table 12 – Laser controlled areas	51
Table C.1 – Summary of pathological effects from excessive exposure to light	104
Table C.2 – Explanation of measurement apertures applied to the MPEs	107

IEC TR 60825-14:2022 © IEC 2022
a preview generated by EVS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

SAFETY OF LASER PRODUCTS –**Part 14: A user's guide****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.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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*