INTERNATIONAL STANDARD

IEC 60825-4

First edition
1997-11

Safety of laser products –

Part 4:
Laser guards

Sécurité des appareils à laser –
Partie 4: Barrières laser

Reference number
IEC 60825-4: 1997 (E)

Numéros des publications

Depuis le 1er janvier 1997, les publications de la CEI sont numérotées à partir de 60000.

Publications consolidées

Les versions consolidées de certaines publications de la CEI incorporant les amendements sont disponibles. Par exemple, les numéros d'édition 1.0, 1.1 et 1.2 indiquent respectivement la publication de base, la publication de base incorporant l'amendement 1, et la publication de base incorporant les amendements 1 et 2.

Validité de la présente publication

Le contenu technique des publications de la CEI est constamment revu par la CEI afin qu'il reflète l'état actuel de la technique.

Des renseignements relatifs à la date de reconfirmation de la publication sont disponibles dans le Catalogue de la CEI.

Les renseignements relatifs à ces révisions, à l'établissement des éditions révisées et aux amendements peuvent être obtenus auprès des Comités nationaux de la CEI et dans les documents ci-dessous:

- **Bulletin de la CEI**
- **Annuaire de la CEI**
  Accès en ligne*
- **Catalogue des publications de la CEI**
  Publié annuellement et mis à jour régulièrement
  (Accès en ligne)*

Terminologie, symboles graphiques et littéraux

En ce qui concerne la terminologie générale, le lecteur se reportera à la CEI 60050: *Vocabulaire Electrotechnique International* (VEI).

Pour les symboles graphiques, les symboles littéraux et les signes d'usage général approuvés par la CEI, le lecteur consultera la CEI 60027: *Symboles littéraux à utiliser en électrotechnique*, la CEI 60417: S*ymboles graphiques utilisables sur le matériel. Index, relevé et compilation des feuilles individuelles*, et la CEI 60617: *Symboles graphiques pour schémas.*

Publications de la CEI établies par le même comité d'études

L'attention du lecteur est attirée sur les listes figurant à la fin de cette publication, qui énumèrent les publications de la CEI préparées par le comité d'études qui a établi la présente publication.

* Voir adresse «site web» sur la page de titre.

Numbering

As from the 1st January 1997 all IEC publications are issued with a designation in the 60000 series.

Consolidated publications

Consolidated versions of some IEC publications including amendments are available. For example, edition numbers 1.0, 1.1 and 1.2 refer, respectively, to the base publication, the base publication incorporating amendment 1 and the base publication incorporating amendments 1 and 2.

Validity of this publication

The technical content of IEC publications is kept under constant review by the IEC, thus ensuring that the content reflects current technology.

Information relating to the date of the reconfirmation of the publication is available in the IEC catalogue.

Information on the revision work, the issue of revised editions and amendments may be obtained from IEC National Committees and from the following IEC sources:

- **IEC Bulletin**
- **IEC Yearbook**
  On-line access*
- **Catalogue of IEC publications**
  Published yearly with regular updates
  (On-line access)*

Terminology, graphical and letter symbols

For general terminology, readers are referred to IEC 60050: *International Electrotechnical Vocabulary* (IEV).

For graphical symbols, and letter symbols and signs approved by the IEC for general use, readers are referred to publications IEC 60027: *Letter symbols to be used in electrical technology*, IEC 60417: *Graphical symbols for use on equipment. Index, survey and compilation of the single sheets* and IEC 60617: *Graphical symbols for diagrams.*

IEC publications prepared by the same technical committee

The attention of readers is drawn to the end pages of this publication which list the IEC publications issued by the technical committee which has prepared the present publication.

* See web site address on title page.

INTERNATIONAL STANDARD

IEC 60825-4

First edition
1997-11

Safety of laser products –

Part 4: Laser guards

Sécurité des appareils à laser –
Partie 4: Barrières laser

International Electrotechnical Commission 3, rue de Varembé Geneva, Switzerland
Telefax: +41 22 919 0300 e-mail: inmail@iec.ch IEC web site http: //www.iec.ch

Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

PRICE CODE S

For price, see current catalogue

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

SAFETY OF LASER PRODUCTS –

Part 4: Laser guards

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the 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, the IEC publishes International Standards. 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. The 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 the 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 National Committees.
3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical reports or guides and they are accepted by the National Committees in that sense.
4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.
5) The IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with one of its standards.
6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 60825-4 has been prepared by IEC technical committee 76: Optical radiation safety and laser equipment.

The text of this standard is based on the following documents:

FDIS	Report on voting
76/159/FDIS	76/168/RVD

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

Annexes A, B and C are for information only.

The French version of this standard will be issued separately.

INTRODUCTION

At low levels of irradiance or radiant exposure, the selection of material and thickness for shielding against laser radiation is determined primarily by a need to provide sufficient optical attenuation. However, at higher levels, an additional consideration is the ability of the laser radiation to remove guard material – typically by melting, oxidation or ablation; processes that could lead to laser radiation penetrating a normally opaque material.

IEC 60825-1 deals with basic issues concerning laser guards, including human access, interlocking and labelling, and gives general guidance on the design of protective housings and enclosures for high-power lasers.

This part of IEC 60825 deals with protection against laser radiation only. Hazards from secondary radiation that may arise during material processing are not addressed.

Laser guards may also comply with standards for laser protective eyewear, but such compliance is not necessarily sufficient to satisfy the requirements of this standard.

Where the term “irradiance” is used, the expression “irradiance or radiant exposure, as appropriate” is implied.

SAFETY OF LASER PRODUCTS –

Part 4: Laser guards

1 General

1.1 Scope

This part of IEC 60825 specifies the requirements for laser guards, permanent and temporary (for example for service), that enclose the process zone of a laser processing machine, and specifications for proprietary laser guards.

This standard applies to all component parts of a guard including clear (visibly transmitting) screens and viewing windows, panels, laser curtains and walls. Requirements for beam path components, beam stops and those other parts of a protective housing of a laser product which do not enclose the process zone are contained in IEC 60825-1.

In addition this part of IEC 60825 indicates:

a) how to assess and specify the protective properties of a laser guard; and

b) how to select a laser guard.

1.2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 60825. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 60825 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60825-1: 1993, *Safety of laser products – Part 1: Equipment classification, requirements and user's guide*

ISO/TR12100-1: 1992, *Safety of machinery – Basic concepts, general principles for design – Part 1: Basic terminology, methodology*

ISO/TR12100-2: 1992, *Safety of machinery – Basic concepts, general principles for design – Part 2: Technical principles and specifications*

ISO 11553: 1996, *Safety of machinery – Laser processing machines – Safety requirements*

1.3 Definitions

For the purpose of this part of IEC 60825, the following definitions apply in addition to the definitions given in IEC 60825-1.

1.3.1
active guard protection time
for a given laser exposure of the front surface of an active laser guard, the minimum time, measured from the issue of an active guard termination signal, for which the active laser guard can safely prevent laser radiation accessible at its rear surface from exceeding the class 1 AEL.

1.3.2
active guard termination signal
the signal issued by an active guard in response to an excess exposure of its front surface to laser radiation and which is intended to lead to automatic termination of the laser radiation

NOTE – The action of a safety interlock becoming open circuit is considered a "signal" in this context.

1.3.3
active laser guard
a laser guard which is part of a safety-related control system. The control system generates an active guard termination signal in response to the effect of laser radiation on the front surface of the laser guard

1.3.4
foreseeable exposure limit (FEL)
the maximum laser exposure on the front surface of the laser guard, within the maintenance inspection interval, assessed under normal and reasonably foreseeable fault conditions

1.3.5
front surface
the face of the laser guard intended for exposure to laser radiation

1.3.6
laser guard:
a physical barrier which limits the extent of a danger zone by preventing laser radiation accessible at its rear surface from exceeding the class 1 AEL

1.3.7
laser processing machine
a machine which uses a laser to process materials and is within the scope of ISO 11553

1.3.8
laser termination time
the maximum time taken, from generation of an active guard termination signal, for the laser radiation to be terminated

NOTE – Laser termination time does not refer to the response of an active laser guard but to the response of the laser processing machine, in particular the laser safety shutter.

1.3.9
maintenance inspection interval
the time between successive safety maintenance inspections of a laser guard

1.3.10
passive laser guard
a laser guard which relies for its operation on its physical properties only

1.3.11
process zone
the zone where the laser beam interacts with the material to be processed

1.3.12
proprietary laser guard
a passive or active laser guard, offered by its manufacturer as a guard with a specified protective exposure limit

1.3.13
protective exposure limit (PEL):
the maximum laser exposure of the front surface of a laser guard which is specified to prevent laser radiation accessible at its rear surface from exceeding the class 1 AEL

NOTE 1 – In practice, there may be more than one maximum exposure.

NOTE 2 – Different PELs may be assigned to different regions of a laser guard if these regions are clearly identifiable (for example a viewing window forming an integral part of a laser guard).

1.3.14
rear surface
any surface of a laser guard that is remote from the associated laser radiation and usually accessible to the user

1.3.15
reasonably foreseeable
an event (or condition) when it is credible and its likelihood of occurrence (or existence) cannot be disregarded

1.3.16
safety maintenance inspection
documented inspection performed in accordance with manufacturer's instructions

1.3.17
temporary laser guard
a substitute or supplementary active or passive laser guard intended to limit the extent of the danger zone during some service operations of the laser processing machine

2 Laser processing machines

This clause specifies the requirements for laser guards that enclose the process zone and are supplied by the laser processing machine manufacturer.

2.1 Design requirements

A laser guard shall satisfy ISO/TR12100-2 with respect to the general requirements for guards and also the more specific requirements with regard to its location and method of fixture. In addition, the following specific laser requirements shall be met.

2.1.1 General requirements

A laser guard, in its intended location, shall not give rise to any associated hazard at or beyond its rear surface when exposed to laser radiation up to the foreseeable exposure limit.

NOTE 1 – Examples of associated hazards include: high temperature, the release of toxic materials, fire, explosion, electricity.

NOTE 2 – See annex B for assessment of foreseeable exposure limit.

2.1.2 Consumable parts of laser guards

Provision shall be made for the replacement of parts of a laser guard prone to damage by laser radiation.

NOTE – An example of such a part would be a sacrificial or interchangeable screen.

2.2 Performance requirements

2.2.1 General

When the front surface of a laser guard is subjected to exposure to laser radiation at the foreseeable exposure limit, the laser guard shall prevent laser radiation accessible at its rear surface from exceeding the class 1 AEL at any time over the period of the maintenance inspection interval. For automated laser processing machines, the minimum value of the maintenance inspection interval shall be 8 h.

This requirement shall be satisfied over the intended lifetime of the laser guard under expected conditions of operation.

NOTE 1 – This requirement implies both low transmission of laser radiation and resistance to laser-induced damage.

NOTE 2 – Some materials may lose their protective properties due to ageing, exposure to ultraviolet radiation, certain gases, temperature, humidity and other environmental conditions. Additionally, some materials will transmit laser radiation under high-intensity laser exposure, even though there may be no visible damage (i.e. reversible bleaching).

2.2.2 Active laser guards

a) The active guard protection time shall exceed the laser termination time up to the foreseeable exposure limits.

b) The generation of an active guard termination signal shall give rise to a visible or audible warning. A manual reset is required before laser emission can recommence.

NOTE – See annex C.2 for an elaboration of terms.

2.3 Validation

If the laser processing machine manufacturer chooses to make a laser guard, the manufacturer shall confirm that the guard complies with the design requirements of 2.1 and can satisfy the performance requirements set out in 2.2.

NOTE – See annex A for guidance on the design and selection of laser guards.

2.3.1 Validation of performance

2.3.1.1 The complete laser guard, or an appropriate sample of the material of construction of the laser guard, shall be tested at each FEL identified.

NOTE 1 – A table of predetermined PELs for common combinations of lasers and guarding materials, together with suitable testing procedures shall be issued as an informative annex in a future amendment to this standard. This could provide a simple alternative to direct testing for the majority of cases.

NOTE 2 – See annex B for the assessment of FEL.

2.3.1.2 For testing purposes, the FEL exposure shall be achieved either:

a) by calculating or measuring the exposure and reproducing the conditions; or

b) without quantifying the FEL, by creating the machine conditions under which the FEL is produced.

The condition of the laser guard or sample shall be such as to replicate those physical conditions of the front surface permitted within the scope of the routine inspection instructions and within the service life of the guard, which minimize the laser radiation protective properties of the laser guard (for example wear and tear and surface contamination) (see 2.4.2).

2.4 User information

2.4.1 The manufacturer shall document and provide to the user the maintenance inspection interval for the laser guard, and details of inspection and test procedures, cleaning, replacement or repair of damaged parts, together with any restrictions of use.

2.4.2 The manufacturer shall document and provide to the user instructions that after any actuation of the safety control system of an active guard, the cause shall be investigated, checks shall be made for damage, and the necessary remedial action to be taken before resetting the control system.

3 Proprietary laser guards

This clause specifies the requirements to be satisfied by suppliers of proprietary laser guards.

3.1 Design requirements

A proprietary laser guard shall not create any associated hazard at or beyond its rear surface when exposed to laser radiation up to the specified PEL when used as specified in the user information (see 3.6).

3.2 Performance requirements

The accessible laser radiation at the rear surface of the laser guard shall not exceed the class 1 AEL when its front surface is subjected to laser radiation at the specified PEL. For an active laser guard, this requirement shall apply to laser radiation accessible over the period of the active guard protection time, measured from the moment an active guard termination signal is issued.

This requirement shall be satisfied over the intended lifetime of the guard under expected service conditions.

3.3 Specification requirements

The full specification of a PEL shall include the following information:

a) the magnitude and variation with time of irradiance or radiant exposure at the front surface of the laser guard (in units of Wm^{-2} or Jm^{-2} respectively), specifying any upper limit to the area of exposure;

b) the overall duration of exposure under these conditions;

c) the wavelength for which this PEL applies;

d) the angle of incidence and (if relevant) the polarization of the incident laser radiation;

e) any minimum dimensions to the irradiated area (for example as might apply to an active laser guard with discrete sensor elements so that a small diameter laser beam could pass through the guard undetected);

f) for an active laser guard, the active guard protection time.

NOTE 1 – See clause B.1 for an elaboration of terms.

NOTE 2 – In all cases, a range or set of values can be stated rather than a single value.

NOTE 3 – A graphical form of presentation (for example irradiance vs. duration with all other parameters constant).

3.4 Test requirements

3.4.1 General

Testing shall be performed using the complete laser guard or an appropriate sample of the material used to construct the guard. In either case, the condition of the guard or sample shall be such as to replicate or exceed the worst permissible physical condition of the front surface, including reduced surface reflection and damage permitted within the scope of the routine maintenance instructions (see 3.6).

The front surface irradiation shall be either as specified by the PEL or, in the case of sample testing, as specified in 3.4.2 below.

When the front surface is subjected to the PEL exposure conditions, the accessible laser radiation measured at the rear surface of the laser guard shall not exceed the class 1 AEL (tests as prescribed in clause 8 of 60825-1). This requirement applies over the exposure duration specified in the PEL or, in the case of an active guard, over the specified active guard protection time measured from the moment an active guard termination signal is issued.

NOTE – In cases where materials opaque at the laser wavelength(s) are used (for example metals), the transmitted radiation will only rise to the class 1 AEL when complete (or almost complete) physical removal of material along a path through to the rear surface has been achieved. In such cases, the rise from zero transmission to a value greatly in excess of the class 1 AEL will therefore be rapid, and sensitive radiation detectors will not be required.

3.4.2 Sample testing

3.4.2.1 Sample testing shall be performed by irradiating one face of a circular or square sample of uniform thickness and composition, of diameter or side of not less than 50 mm. The sample shall be held in a clamping arrangement that encroaches no more than 2,5 mm from the edge of the sample. The clamping materials in contact with the sample shall be of low thermal conductivity and at least 1 mm thick, and compatible with use at the temperatures generated.

3.4.2.2 Where the PEL is quoted without specifying a limit to the area of irradiation (see 3.3 a)), the test shall expose not less than 90 % of the sample area, and the total laser power or energy incident on the sample divided by the total irradiated area shall be not less than the specified irradiance.

3.5 Labelling requirements

3.5.1 All labelling shall be placed on the rear surface of the guard.

3.5.2 The rear surface of the guard shall be clearly identified if the orientation of the guard is important.

3.5.3 If only part of the front surface of the guard is a laser guard, this area shall be clearly identified by a bold coloured outline and words to indicate the outer boundary of the laser guard.

3.5.4 The labelling shall state the full PEL specification.

3.5.5 The manufacturer's name, the date and place of manufacture according to ISO 11553, and a statement of compliance with this standard shall be provided.

3.6 User information

In addition to the specifications listed in 3.3, the following information shall be supplied to the user by the manufacturer of a proprietary laser guard:

a) a description of the permitted uses of the laser guard;

b) a description of the form of mounting and connection of the laser guard;

c) information on the installation of the laser guard – for active laser guards this shall include interface and supply requirements for the guard;

d) maintenance requirements, including for example details of inspection and test procedures, cleaning, replacement or repair of damaged parts;

e) instructions, that after any actuation of the safety control system of an active guard, the cause shall be investigated, checks shall be made for damage, and the necessary remedial action to be taken before resetting the control system;

f) the labels in 3.5 and their locations. If only part of the front surface of the guard is a laser guard, this area shall be identified;

g) a statement of compliance with this standard.

Annex A
(informative)

General guidance on the design and selection of laser guards

A.1 Design of laser guards

A.1.1 Passive laser guards

Examples of a passive laser guard include the following.

a) A metal panel relying on thermal conduction, if necessary enhanced by forced air or water cooling, to maintain the surface temperature below its melting point under normal and reasonably foreseeable fault conditions.

b) A transparent sheet, opaque at the laser wavelength, which is unaffected by low value of laser exposure under normal operation of the laser processing machine.

A.1.2 Active laser guards

Examples of an active laser guards include the following.

a) A guard, with discrete embedded thermal sensors, which detects overheating.

NOTE – The spacing between sensors should be considered in relation to the minimum dimensions of an errant laser beam.

b) A laser guard comprising two panels between which is contained a pressurized liquid or gaseous medium in combination with a pressure-sensing device capable of detecting the pressure drop following perforation of the front surface.

A.1.3 Hazard indication (passive guards)

Visible indication of exposure of the laser guard to hazardous amounts of laser radiation should be provided where feasible (for example by adding a layer of an appropriate paint on both sides of the laser guard).

A.1.4 Power supply (active guards)

If power is required for the proper functioning of an active guard, its supply should be arranged so that laser operation is not possible in the absence of such power.

A.2 Selection of laser guards

A simple selection process is as follows:

a) identify the preferred position for the laser guard and estimate the FEL at this position. Annex B gives guidance on the estimation of FEL values;

b) if necessary, minimize the FEL under fault conditions, preferably by including automatic monitoring in the machine which will detect the fault conditions and limit the exposure time. Examples of alternatives include the following:

   – ensure that the laser guard is sufficiently far away from beam focus produced by focusing optics;

   – install vulnerable parts of laser guard (such as viewing windows) away from regions that could be exposed to high irradiance;

– move the laser guard farther away from the laser process zone;
– required in the essential servicing documentation for temporary laser guards, additions such as:
  - one or more persons to be present to supervize the condition of the front surface of the laser guard, to reduce the assessed exposure duration of a passive guard;
  - a hold-to-operate controller to be used by the person(s) supervising the condition of the front surface of the laser guard, to reduce the assessed exposure duration of a passive guard;
  - additional local temporary guarding, apertures and beam dumps to be employed, to absorb any powerful errant laser beams;
  - the danger zone to be bounded by errant beam warning devices and the guard placed beyond this zone to reduce the assessed exposure duration;
– incorporate in the design of the machine, when using temporary laser guards, beam control features to facilitate improved laser beam control during servicing operations, such as:
  - holders for precise location of additional beam forming components (for example turning mirrors) required during servicing;
  - mounts which allow only limited scope for beam steering.

Three options then follow. The order below does not indicate a preference.

A.2.1 Option 1: passive laser guard

This is the simplest option.

NOTE – Design and quality control are particularly important considerations where the absorption at the laser wavelength is dominated by a minority additive, such as a dye in a plastic. In such cases, where the manufacturer of the material does not specify the concentration of the absorber or the material optical attenuation at the laser wavelength, samples from the same batch of the material should first be tested as described in 2.3.1.

A.2.2 Option 2: active laser guard

If the FEL cannot be reduced to a value where common guarding materials provide adequate protection in the form of a passive laser guard, an active laser guard can always be used.

A.2.3 Option 3: proprietary laser guard

A proprietary laser guard can be used if the assessed FEL values are less than the PEL values quoted by the laser guard manufacturer.

Annex B
(Informative)

Assessment of foreseeable exposure limit

B.1 General

FEL values may be assessed either by measurement or by calculation (see below).

The standard prEN 1050 provides a general methodology for risk assessment. The assessment should include consideration of cumulative exposure in normal operation (for example during each part processing cycle of the machine) over the maintenance inspection interval.

From this assessment, the most demanding combinations of irradiation, area of exposure and exposure duration should be identified. It is quite likely that several FELs will be identified; for example one condition may maximize the duration of exposure at a relatively low irradiance, while another may maximize the irradiance over a shorter duration of exposure.

The full specification of an FEL comprises the following information.

a) The maximum irradiance at the front surface of the laser guard.

NOTE – Irradiance is expressed as the total power or energy divided by the area of the front surface of the guard, or specified limited area, as appropriate.

b) Any upper limit to the area of exposure of the front surface at this level of irradiance.

NOTE – No limit to the area would be appropriate for protection against scattered laser radiation while an upper limit to the exposed area would be appropriate for direct exposure to laser beams.

c) The temporal characteristics of the exposure, i.e. whether continuous wave or pulsed laser radiation, and if the latter, then the pulse duration and pulse repetition frequency.

d) The full duration of exposure.

NOTE – See clause B.4 for an elaboration of this term.

e) The wavelength of the radiation.

f) The angle of incidence and (if relevant) the polarization of the radiation.

NOTE 1 – Stipulation of angle of incidence is particularly important for laser guards exploiting interference layers to reflect impinging laser radiation.

NOTE 2 – CAUTION: At Brewster's angle of incidence "p" polarized radiation is strongly coupled into the surface of the guard.

g) Any minimum dimensions to the irradiated area (for example as might apply to an active laser guard with discrete sensor elements so that a small diameter laser beam could pass through the laser guard undetected).

h) For an active laser guard, the active guard protection time.

B.2 Reflection of laser radiation

B.2.1 Diffuse reflections

Assuming a Lambertian reflector with 100 % reflectivity

$$E_A = \frac{P_o}{\pi} \cdot \frac{\cos\theta}{R^2} \cdot \cos\varphi$$

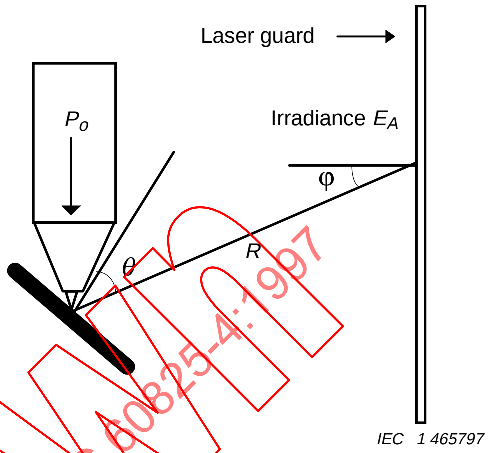

Figure B.1 – Calculation of diffuse reflections

B.2.2 Specular reflections

It is difficult to generalize for the case of specular reflections.

For a circularly symmetric laser beam with a Gaussian distribution, power P_o and diameter d_{63} at the focusing lens, focal length f, the maximum irradiance (at the centre of the Gaussian distribution) in a normal plane distance R from the focus is:

$$E_{AA'} = \frac{4P_o\rho}{\pi d_{63}^2}\left(\frac{f}{R}\right)^2$$

where ρ is the reflectivity of the workpiece surface.

CAUTION: Certain curved surfaces may increase the reflection hazard.

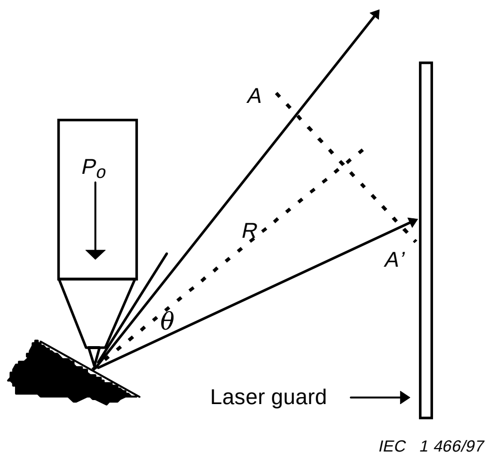

Figure B.2 – Calculation of specular reflections

B.3 Examples of assessment conditions

FELs should be assessed for the worst reasonably foreseeable combination(s) of available laser parameters, workpiece materials, geometry and processes likely to be encountered during normal operation (annex E of IEC 60825-1 provides a list of common fault conditions).

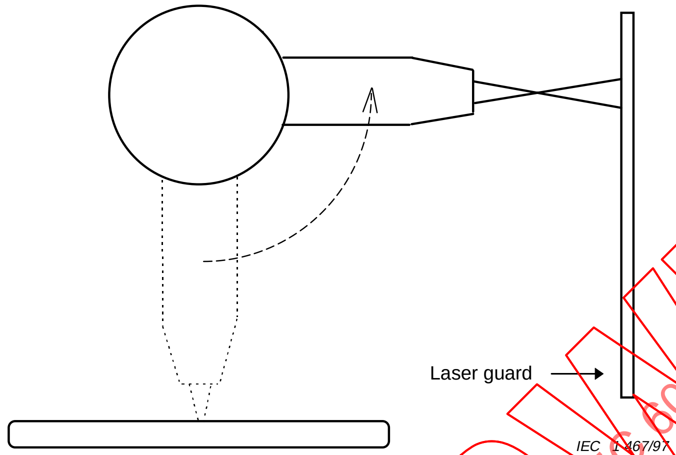

Figure B.3a – Software failure

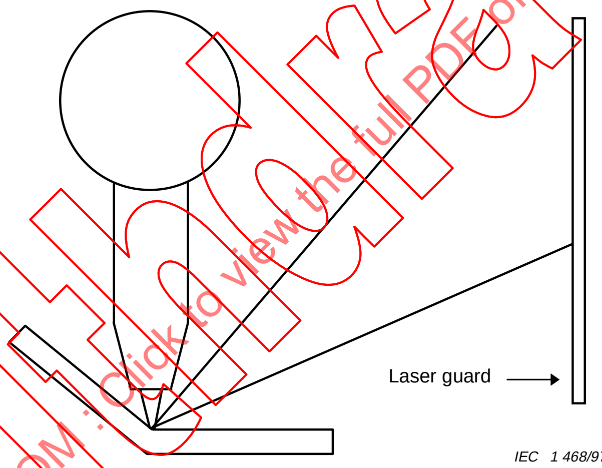

Figure B.3b – Workpiece bends or is inadequately clamped

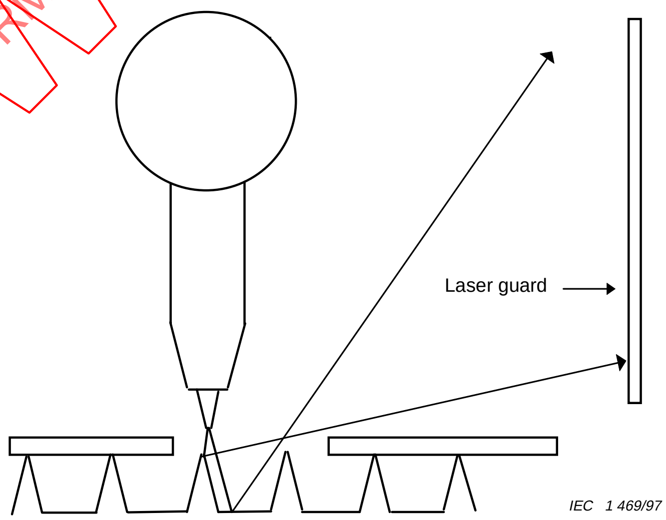

Figure B.3c – Workpiece missing

Figure B.3 – Some examples of a foreseeable fault condition

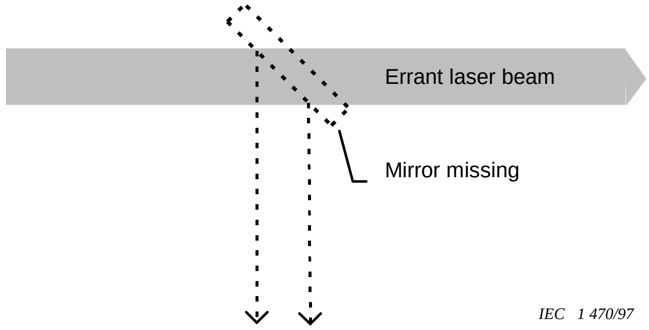

Figure B.4a – Laser is operated with turning mirror missing

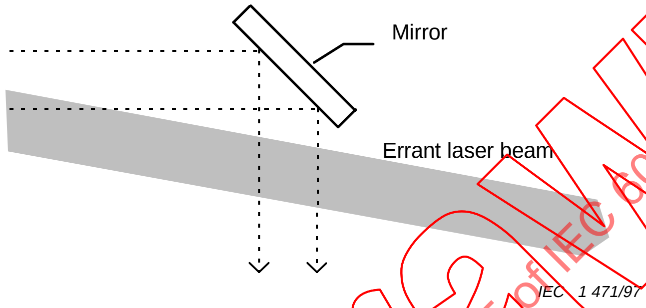

Figure B.4b – Beam displaced off mirror during alignment procedure

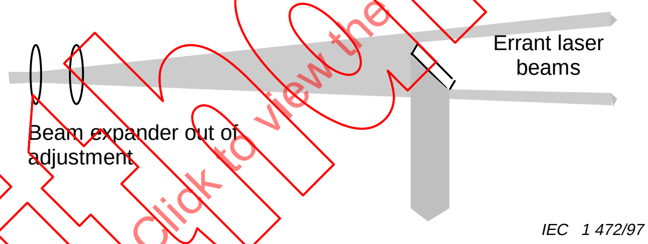

Figure B.4c – Beam expands beyond range of optics

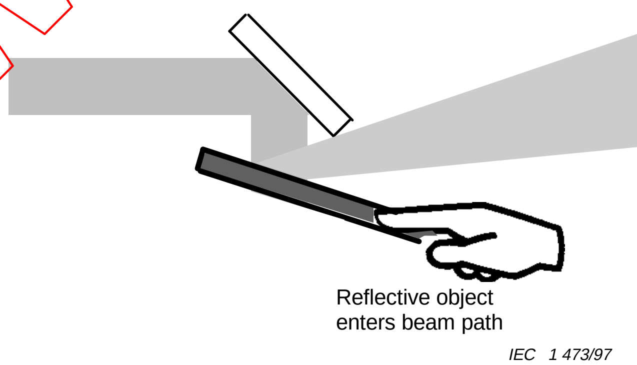

Figure B.4d – Reflective objects intercept laser beam

Figure B.4 – Four examples of errant laser beams that might have to be contained by a temporary guard under service conditions

B.4 Exposure duration

B.4.1 Normal operation

The exposure of a guard to laser radiation during fault-free operation may comprise exposures to low levels of reflected, scattered and transmitted radiation which are repeated on each machine cycle. In this case, the assessed FEL for fault-free operation would encompass the variation in irradiance of the guard during the cycle, repeated for the maximum number of machine cycles within a safety maintenance inspection interval.

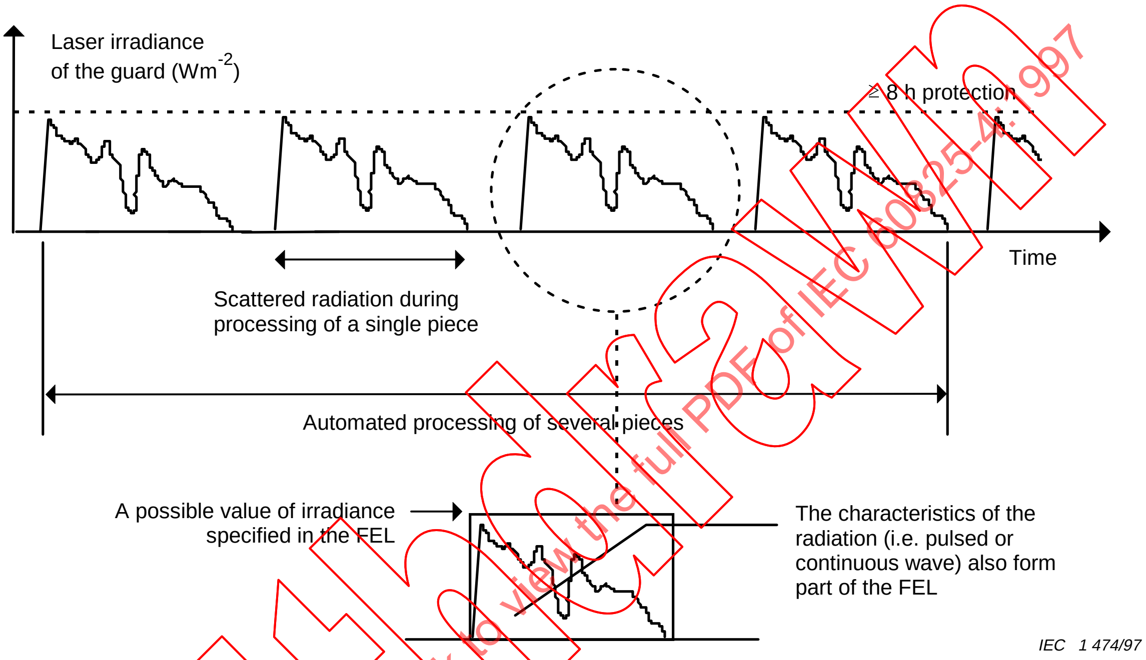

Figure B.5 – Illustration of laser guard exposure during repetitive machine operation

B.4.2 Fault Conditions

A safety control system involving some form of machine monitoring can reduce the time for which the guard must safely contain the radiation hazard under fault conditions. Two examples are given below.

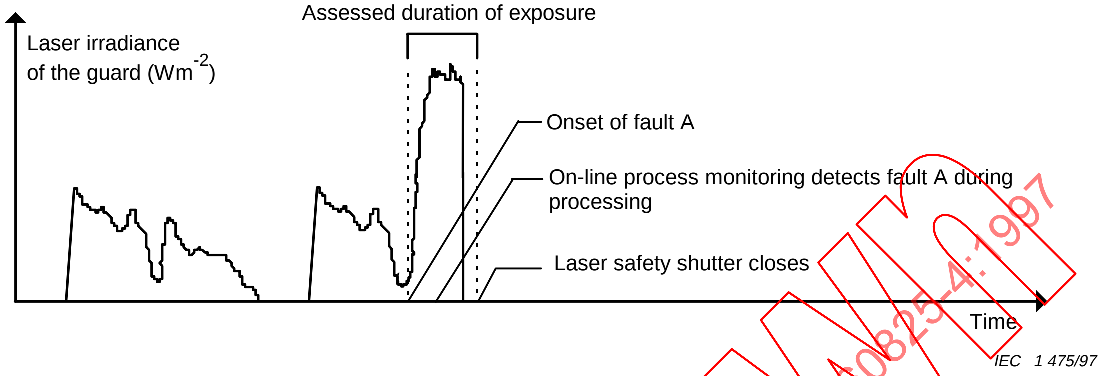

Figure B.6a – Shut-down with on-line machine safety monitoring

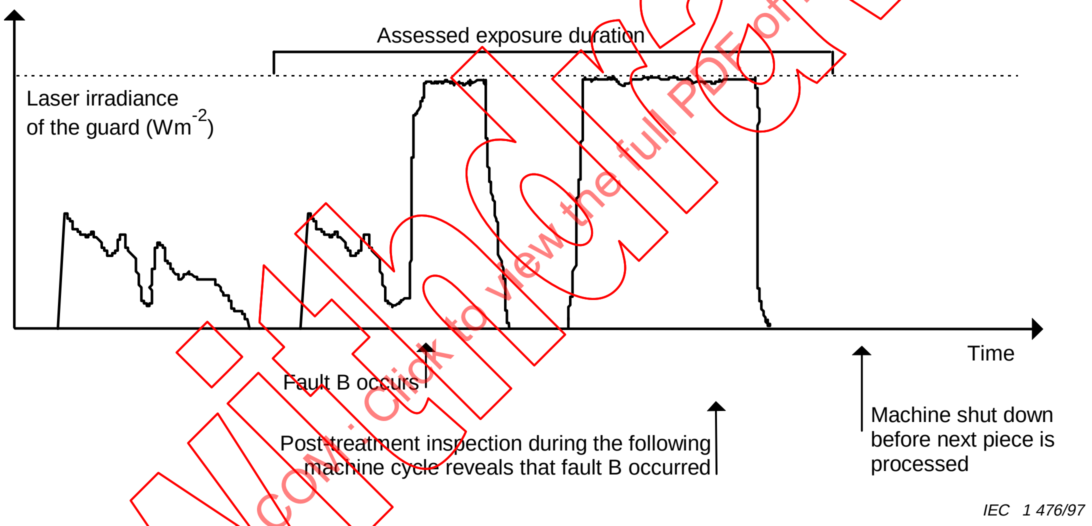

Figure B.6b – Shut-down with off-line machine safety monitoring

Figure B.6 – Two examples of assessed duration of exposure

For reasonably foreseeable fault conditions which are not detected by some safety-related control system, the assessed duration of exposure is the full safety maintenance inspection interval.

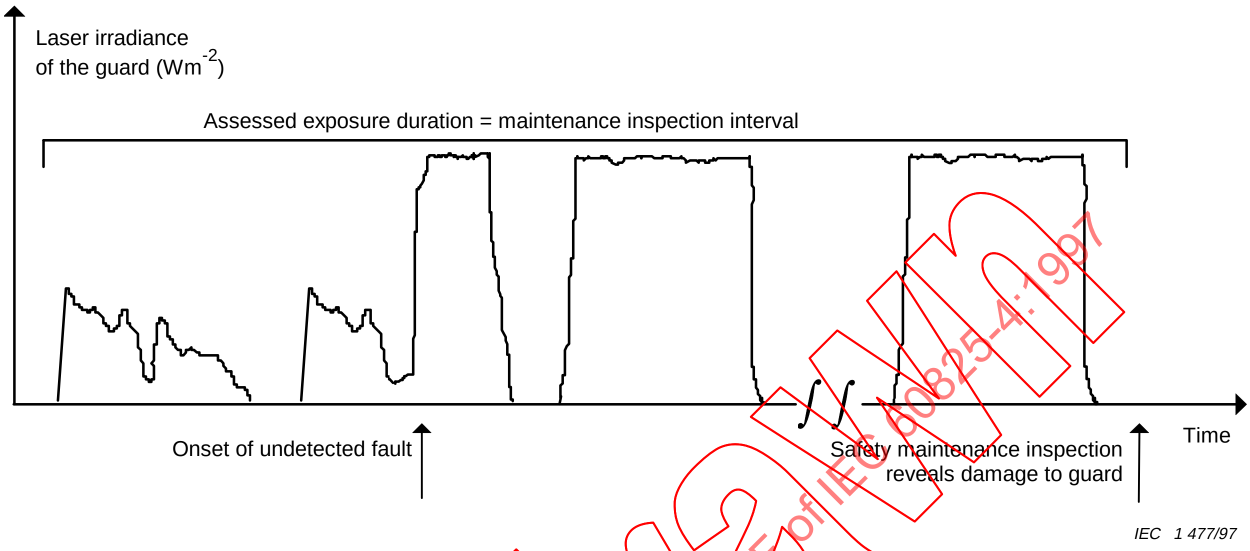

Figure B.7 – Assessed duration of exposure for a machine with no safety monitoring

B.4.3 Servicing operations

The factors which directly affect the time to laser termination measured from the onset of exposure of a temporary guard during servicing operations include:

– the use of a pre-set laser-on time;

– the degree of control over fault conditions;

– provision of persons to supervize the condition of the guard (passive guards);

– provision of a hold-to-operate controller;

– degree of warning provided by the response of the guard to excessive laser exposure (passive guards);

– degree of concealment of the front surface of the guard (passive guards);

– total area of guard to be supervized (passive guards);

– degree of training of service personnel.

A risk assessment should be performed to identify hazardous situations and to assess the foreseeable exposure level. Where human intervention is required to limit the duration of exposure of a temporary guard, a value of not less than 10 s should be used. All reasonably practicable engineering and administrative control measures should be implemented to reduce reliance on temporary screens to provide protection.

B.5 Reference document

prEN 1050: 1993, *Safety of machines – Risk assessment*