TECHNICAL SPECIFICATION

IEC TS 60825-7

First edition
2000-06

Safety of laser products –

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

Sécurité des appareils à laser –

Partie 7:
Sécurité des sources optiques infrarouges pour transmission de données et surveillance, sans fil à l'air libre

Reference number
IEC/TS 60825-7:2000(E)

Numbering

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

Consolidated publications

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Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

PRICE CODE S

For price, see current catalogue

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SAFETY OF LASER PRODUCTS –

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

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.

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- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC 60825-7, which is a technical specification, has been prepared by IEC technical committee 76: Optical radiation safety and laser equipment.

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

Enquiry draft	Report on voting
76/198/CDV	76/215/RVC

Full information on the voting for the approval of this technical specification 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 3.

Annexes A and B are for information only.

The committee has decided that the contents of this publication will remain unchanged until 2002. At this date, the publication will be

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- withdrawn;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

A bilingual version of this specification may be issued at a later date.

INTRODUCTION

Probably because of the increasing radiation power available from LEDs, and their physical similarity to laser diodes, these devices have been included in the scope of the laser safety standard IEC 60825-1. However, the optical radiation from LEDs differs in various aspects from laser sources; generally, they lie between incoherent broadband sources, and coherent laser sources.

The safety philosophy and classification requirements of IEC 60825-1, developed for coherent point sources (with the assumption of Gaussian radiation characteristics), has been transferred to incoherent intermediate sources (with typically Lambertian radiation characteristics) which are often made for intentional viewing. The result has been an overestimation of the real risk from this kind of source.

In Europe, and effective since January 1997, EN 60825-1, which includes LEDs, is valid. According to the European product safety laws, this means that each LED product has to be classified under single-fault conditions.

IEC technical committee 76 (jointly with subcommittee 100C/working group 17) was established with the objective of preparing additional parts to the 60825 series, for specific application-related requirements.

Due to problems with LED source, the basic standard IEC 60825-1 is also under consideration and technical development. If a new edition of IEC 60825-1 with a changed safety philosophy becomes valid in the future, it will influence all subsidiary standards. This development will influence and/or change the basis for a more realistic assessment of the optical hazard of LEDs in the future. With this background, the value of this technical specification could be temporary if a suitable treatment is developed in IEC 60825-1.

This technical specification is considered as a "prospective standard for provisional application" in the field of optical radiation safety of LEDs. This is because there is an urgent need for guidance on how standards in this field should be used to meet an identified need.

SAFETY OF LASER PRODUCTS –

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

1 Scope and object

This technical specification provides the requirements and specific guidance for the safe use of products that are within the scope of IEC 60825-1, which emit infrared optical radiation, where such products are used exclusively for wireless "free air" data transmission and surveillance.

The peak wavelength for these products must be greater than 780 nm. This specification is limited to sources with *NOHD* less than 2,5 m. Also, Class 4-products are not covered by this specification and should be treated by the requirements of IEC 60825-1.

NOTE Applications with nearly collimated beams (e.g. free space point to point transmission lines) are not covered by this specification. In most cases, the selected application group diode emitter sources, which cover laser diodes and infrared LEDs as well, will be used. However, throughout this specification, all sources covered by the scope are included whenever the word "diode emitter" is used.

The object of this specification is as follows:

– to protect persons from exposure to hazardous infrared optical radiation, resulting from products used for free air infrared data transmission, remote control, surveillance;

– to lay down requirements, for both user and manufacturer, to establish procedures and supply information so that proper precautions can be adopted;

– to ensure adequate warning to individuals of hazards associated with accessible optical radiation from products with infrared optical sources, through signs, labels and instructions;

– to reduce the possibility of injury by minimizing unnecessary accessible radiation, and to give improved control of the optical radiation emitted by products with infrared optical sources, through protective features and also to provide safe usage of products.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this technical specification. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this technical specification are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

IEC 60050(845):1987, *International Electrotechnical Vocabulary (IEV) – Chapter 845: Lighting*

IEC 60825-1:1993, *Safety of laser products – Part 1: Equipment classification, requirements and users guide*
Amendment 1:1997

IEC 60825-2:1993, *Safety of laser products – Part 2: Safety of optical fibre communication systems*

IEC 60825-6:1999, *Safety of laser products – Part 6: Safety of products with optical sources, exclusively used for visible information transmission to the human eye*

3 Definitions

For the purpose of this technical specification, the following definitions apply. They repeat or supplement those given in IEC 60825-1, IEC 60825-2 and IEC 60050(845).

3.1
angular subtense
the visual angle α subtended by the *apparent source* (including diffuse reflections) at the eye of an observer or at the point of measurement. The angular subtense is measured from the apparent source at either the distance of intended use or, at the distance of the expected exposure, whichever is applicable. This distance must not be smaller than 100 mm. (See also *maximum angular subtense* and *minimum angular subtense*.)

NOTE The requirements for the determination of the angular subtense are in 6.2.2 and 6.3.

3.2
apparent source
the real or virtual object (source of optical radiation) that forms the smallest possible retinal image

NOTE The size of the apparent source is the parameter that defines the limits of an *intermediate source*.

3.3
automatic power reduction
a feature of a bi-directional *wireless optical transmission system* by which the accessible power is reduced to a specified level within a specified time, whenever there is an event which could result in hazardous human exposure to radiation, for example a break of the transmission by misalignment or insertion of an object or part of a person's body into the beam path such that the intended signal is not received by the receiver

NOTE This feature may be used to determine the classification level.

3.4
bystander
a person who may be exposed to infrared radiation and who is not expected to be aware of the hazard or potential hazard of exposure

3.5
diode emitter (DE)
any semiconductor pn-junction device which can be made to produce optical electromagnetic radiation by radiative recombination of excited carriers

NOTE The following designations for diode emitters are commonly used:

LED (Light Emitting Diode) emitting in the wavelength range from 380 nm to 780 nm. In some cases (IEC 60825-1), the term LED is used for all diode emitters except LDs.

IRED (Infra-Red Emitting Diode) emitting in the wavelength range from 780 nm to 1 mm (main subject of this specification).

LD (Laser Diode) emitting stimulated radiation at any wavelength.

Note that, in this specification, the term diode emitter (DE) is used for both LEDs and LDs.

3.6
DE product
any product where the primary intent is to emit infrared radiation which originates from a *diode emitter* source forming part of the product

3.7
embedded DE product
in this specification, a *DE product* which, because of engineering features limiting the accessible emissions, has been assigned in a class number lower than the inherent capability of the incorporated DE

3.8
intermediate source viewing
the viewing conditions whereby the *apparent source*, at a distance of 100 mm or more, subtends an angle at the eye greater than the *minimum angular subtense* (α_{min}) but smaller than the *maximum angular subtense* (α_{max})

NOTE In contrast to small sources and large sources, the hazard to the eye caused by intermediate sources depends significantly on the actual size of the image on the retina.

3.9
infrared sources
the optical radiation must be not capable of causing a visual sensation. The peak wavelength of infrared sources, covered by this specification, must be greater than 780 nm. Fixation on the source shall be impossible.

3.10
irradiance (at a point on a surface)
the radiant flux *Φe* incident on an element of a surface divided by the area d*A* of that element:
$E = \mathrm{d}\Phi e / \mathrm{d}A$

Unit: $\mathrm{W/m^2}$

3.11
large source viewing
the viewing conditions whereby the *apparent source*, at a distance of 100 mm or more, subtends an angle at the eye greater than the *maximum angular subtense* (α_{max})

NOTE For example viewing of diffusely reflected laser radiation from large expanded beams and some *DE*-arrays.

3.12
limited emission duration
a feature of a transmission system (e.g. hand-pushed buttons) by which the accessible power is reduced to a specified level within a specified time

NOTE This feature may be used to determine the classification level.

3.13
magnification (*M*)
the angular magnification *M* of an optical instrument is the ratio of the visual angles subtended (*angular subtense*) by the object with and without the instrument

NOTE Optical devices (which are to be considered for inherently safe viewing conditions) between the source and the eye may therefore increase the hazard due to increased power collection of the source, imaged onto the retina. The value of the magnification can influence the hazard aspects of the different viewing conditions (see 3.8, 3.11, 3.24).

3.14
maximum angular subtense (α_{max})
the value of *angular subtense* of the *apparent source,* above which a source is considered to be a *large source*

3.15
maximum permissible exposure (*MPE*)
a value of exposure to the eye or skin which, under normal circumstances, is not expected to result in adverse biological effects. The *MPE* levels represent the maximum level to which the eye or the skin can be exposed without consequential injury under acute or chronic conditions. They are related to the wavelength of the radiation, the exposure duration, the tissue at risk and the size of the retinal image (*apparent source* size). Maximum permissible exposure levels, expressed in *irradiance* or *radiant exposure*, are specified in IEC 60825-1, clause 13

3.16
minimum angular subtense (α_{min})
the value of *angular subtense* of the *apparent source*, above which a source is considered an *intermediate* or *large source*

3.17
nominal ocular hazard distance (*NOHD*)
the maximum distance from the source where the irradiance finally falls below the appropriate *MPE* (see 6.5)

3.18
peak wavelength
wavelength at the maximum of the spectral distribution of the *DEs*

NOTE In contrast to monochromatic laser radiation, the spectral radiation bandwidth of *LEDs* amounts to some ten nanometers and is neither monochromatic nor broadband. However, the wavelength band of *LEDs* can be described by stating a single wavelength – the peak wavelength – because the *MPE* does not vary significantly within this wavelength band. For calculating *MPE* values from the tables in IEC 60825-1, either the peak wavelength of *DEs* can be used or alternatively the wavelength dependence of factor C_4 can be taken into account.

3.19
radiant energy
time integral of the *radiant flux* over a given duration Δt: $Q = \int \Phi_e \, dt$

Unit: J (joule)

3.20
radiant exposure (at a point on a surface)
the *radiant energy Q* incident on an element of a surface divided by the area d*A* of that element: $H = dQ / dA = \int E \, dt$

Unit: J/m^2

3.21
radiant flux
power, emitted, transferred or received in the form of radiation. Symbol Φ_e

Unit: W

3.22
radiant intensity (of a source, in a given direction)
quotient of the of radiant flux $d\Phi_e$ leaving the source and propagated in the element of solid angle $d\Omega$ containing the given direction, by the element of solid angle: $I_e = d\Phi_e / d\Omega$

Unit: W/sr

3.23
reasonably foreseeable event
an event the occurrence of which under given circumstances can be predicted fairly accurately, and the occurrence probability or frequency of which is not low

NOTE Examples of reasonably foreseeable events might include operator error or inattention to safe working practices. Reckless use or use for completely inappropriate purposes is not to be considered as a reasonably foreseeable event.

3.24
small source viewing
the viewing conditions whereby the *apparent source*, at a distance of 100 mm or more, subtends an angle at the eye smaller than the *minimum angular subtense* (α_{min})

NOTE For example intrabeam viewing of parallel collimated laser beams.

3.25
wireless optical transmission system
an engineering assembly for the generation and transmission of mostly infrared optical radiation, in which the transfer is accomplished via "free air" for communication and/or control purposes. "Free air" means indoor and outdoor wireless applications with both non-directed and directed (point-to-point) transmission; emitting and detecting assemblies may or may not be separated

NOTE Wireless optical transmission systems with nearly collimated beams with *NOHD* less than 2,5 m are not covered by this specification.

4 Manufacturer's requirements

4.1 Engineering specifications

4.1.1 General remarks

It is the responsibility of the manufacturer of *DE products*, or his agent, to determine a classification according to 6.4 of this specification. The applicable requirements are given in the following clauses and subclauses. The requirements of IEC 60825-1, clause 4 shall not be applicable to *wireless optical transmission* systems with infrared optical power levels above the limits of Class 3A of IEC 60825-1 that are within the scope of this specification. Instead, the additional requirements given in 4.1.8 and 4.2 shall apply.

NOTE Some products require certain built-in safety features to realize Class 1 or Class 3A conditions.

4.1.2 Modification

If the modification of a previously classified product affects any aspect of the product's performance or intended functions within the scope of this specification, the person or organization performing any such modification is responsible for ensuring the reclassification and relabelling of the product.

4.1.3 Fault analysis

The optical output of an embedded DE product in Class 3A is dependent upon the integrity of other components and the performance of the circuit design. In these cases, a single fault analysis, including *reasonably foreseeable events*, shall be carried out.

4.1.4 Limited emission duration

Limited emission duration and limited repetition rate may be used to control the classification level of hand-operated products. The reliability of the control system must fulfil the requirements of 4.1.3.

4.1.5 Automatic power reduction

In free air bi-directional wireless optical transmission systems, automatic power reduction may be used to control the classification level (see 3.3). The reliability of the control system must fulfil the requirements of 4.1.3.

4.1.6 Infrared pass filter

Any visible radiation emitted by sources covered by this specification shall be cut off by an infrared pass-filter in order to avoid a bystander's or user's attention and possible fixation on the source caused by this radiation.

4.1.7 Transmission aperture

The transmission aperture shall not be located adjacent to visible light sources or indicators that could likely be visual fixation targets.

4.1.8 Requirements for Class 3B products

In some cases, the *infrared* sources (e.g. conference systems, traffic or exhibition guides) are placed relatively far from the bystander (receiver) for common distribution of information. Sometimes the optical power levels required to obtain an acceptable level of system performance may exceed the *MPE* in minimum viewing distance.

For these Class 3B products, the *nominal ocular hazard distance NOHD* (see 6.5) of the Class 3B-emitter shall be determined and included in the warning label, see 5.4. The reliability must fulfil the requirements of 4.1.3. Manufacturing and maintenance personnel must be protected by wearing adequate protective eyewear and shall have received appropriate safety training.

4.2 Provision of information for installation and use

The class, the name and the publication date of the standard to which the product was classified shall be documented in the operating manual.

Manufacturers of *infrared wireless optical transmission systems* with classifications in excess of Class 3A, or for which the classification is controlled by engineering requirements (see 4.1), shall provide the user with the following information:

a) adequate description of the engineering design features incorporated into the product to prevent access to hazardous levels of optical radiation and a clear statement that the safety is dependent upon how the users install and use the product;

b) adequate instructions for proper assembly, maintenance and safe use, including clear warnings concerning precautions to avoid possible exposure to hazardous radiation;

c) a statement in SI units of the power propagating through the air (radiant intensity) and the peak wavelength, together with the pulse duration and pulse repetition frequency or maximum modulation frequency. The cumulative measurement uncertainty and any expected variation in the measured quantities at any time after manufacture shall also be provided;

d) the reaction time of any automatic power reduction system;

e) a listing of controls, adjustments and procedures for operation and maintenance, including a warning where appropriate;

f) advice on safe operating procedures and warnings concerning known malpractices, malfunctions and hazardous failure modes. Where maintenance procedures are detailed, they shall wherever possible include explicit instructions on safe procedures to be followed;

g) where installation or servicing requires that an automatic power reduction system is overridden, information to enable the operating organization to specify a safe system of work at such times, and a safe procedure for reinstating and safe testing of the automatic power reduction system;

h) *nominal ocular hazard distance* according to 6.5. Information for the installer, that a minimum separation of 2,5 m must be maintained between beams that exceed the *MPE* and any surface upon which a *bystander* can stand. In most situations, the minimum distance for the installation of the transmitter above the ground or the floor is the *NOHD* plus 2,5 m;

i) a statement that the installation condition, mentioned in item h), provides safety for the bystander, but safety measures have to be applied for service and installation within the *NOHD*;

j) legible reproductions (colour optional) of required labels and hazard warnings to be affixed to the DE product.

5 Labelling

5.1 General

Products shall carry label(s) in accordance with the requirements for the following clauses. Labels shall be permanently fixed, legible, and clearly visible during operation, maintenance or service, according to their purpose. They shall be so positioned that they can be read without the necessity for human exposure to optical radiation, during operation, manufacturing and maintenance, in excess of the limits for Class 3A as determined according to clause 6. Text borders and symbols shall be in accordance with the requirements of IEC 60825-1, clause 5.

The label size should be adapted to the size of the product.

If the size or design of the product makes labelling impractical, the label shall be included with the user information or on the package and also with the service information if present.

5.2 Class 1

Each Class 1 product shall have affixed an explanatory label bearing the words:

CLASS 1 LASER-PRODUCT

or instead, at the discretion of the manufacturer, the same statement may be included in the information for the user.

5.3 Class 3A

Each Class 3A product shall have affixed a warning label and an explanatory label bearing the words:

INVISIBLE LASER RADIATION
DO NOT STARE INTO BEAM OR VIEW
DIRECTLY WITH OPTICAL INSTRUMENTS
CLASS 3A LASER PRODUCT

or instead, at the discretion of the manufacturer, the same statement may be included in the information for the user if the source is not capable of causing a visual sensation directly according to the definition in 3.9.

5.4 Class 3B

Each Class 3B product shall have affixed a warning label and an explanatory label bearing the words:

INVISIBLE LASER RADIATION
AVOID EXPOSURE TO BEAM
CLASS 3B LASER PRODUCT

NOMINAL OCULAR HAZARD DISTANCE OF XXX mm

NOTE XXX = *NOHD*, the minimum safe viewing distance to be determined by the manufacturer.

5.5 Warning for infrared LED radiation

For *infrared* LED radiation (see 3.5) the word "LASER" on the labels shall be replaced by "LED".

6 Tests and measurements for classification

6.1 General

Measurement of optical radiation may be necessary to classify a *DE product* in accordance with 6.4. Measurements are unnecessary when the physical characteristics and limitations of the *DE*s place the *DE product* clearly into a particular class. In circumstances where direct measurements are impractical, the classification shall be based on the manufacturer's design calculations. Measurements shall be carried out according to 6.4, under *reasonably foreseeable* single-fault conditions. This is valid for products with classifications in excess of Class 1 only.

Tests of Class 1-products, as long as they do not contain an embedded device greater than Class 3A, are exempt from single-fault considerations.

NOTE The worst case approach of the test conditions are chosen to ensure that the *MPE* values cannot be exceeded by infrared sources under reasonably realistic viewing conditions and exposure durations. This is particularly valid for the lower Class 1-limits. Within this "safety range" fault induced electrical overstress above the maximum ratings must not allow the optical output power to exceed the *MPE*.

6.2 Determination of the apparent source size

6.2.1 General

Optical sources used for *infrared wireless optical data transmission* are usually arrangements of single or multiple *DE*s.

Viewed at normal or minimal accommodation distance, the single diode emitters are distinguishable and considered as small or intermediate sources. If the angular separation between single emitters under these viewing conditions is larger than α_{max} the possible hazard of the whole arrangement is given by the *MPE* of one single emitter. For angular separation less than α_{max}, the most restrictive *MPE* resulting from each individual source and possible grouping, according to 13.4.2 of IEC 60825-1, shall be determined (see also IEC 60825-1, Annex A: Example A.2-4 and A.7). According to the definition in IEC 60825-1, the *apparent source* size shall be determined by the smallest circle containing 63 % of the total output power (or energy). In the case of plastic encapsulated *DE*s, including built-in lenses, reflectors and scattering materials, the *apparent source* size due to *magnification* of the optics as viewed from the direction of maximum *radiant intensity* shall be determined.

6.2.2 Measurement of the dimension of the apparent source

If the dimensions of the *apparent source* are not known and the source is not accessible for measurements, the source has to be imaged by, for example a lens. Distance and diameter of the lens shall be comparable with the required measurement condition for Class 1-AEL (see 6.4). The dimensions of the image of the source have to be determined according to the definition of the *apparent source* as follows:

a) for source images with circular symmetry, a detector shall be used with a circular aperture stop in front of it. Both the detector and the aperture stop shall be larger than the image of the source to be measured. This assembly is placed in the plane of the image of the source, centred on the optical axis of the propagating beam, and the incident total power is measured;

b) the diameter of the aperture is reduced until the power passing through the aperture stop is equal to 63 % of the total incident power. The diameter of the aperture stop at this point gives the diameter *D* of the beam in this plane;

c) for rectangular and oblong sources in place of the circular aperture stop, a rectangular aperture stop has to be used;

d) with apparent source distance *g* and image distance *b* from the lens, the dimension *D′* of the apparent source may be determined by the relation $D = D' \times g/b$. When the radiator distance is not known, or the apparent source does not coincide with the radiation source (e.g. when the radiator contains lenses or reflectors), the distance *g* can be determined by the following formula: $g = 1/(1/f - 1/b)$, where f is the focal length of the lens used to image the apparent source.

   Alternatively, a CCD camera system can be used to obtain the *apparent source* size from the power/energy density distribution on the detector. This is recommended if the shape of the source is not circular or rectangular.

6.3 Determination of the angular subtense

The *angular subtense* of a source is defined by the equation:

$$\alpha = 2 \arctan D/2r \cong D/r$$

D is represented by the real or *apparent source size* (see 6.2) and *r* by the applied viewing or measurement distance (see 6.4) respectively.

For circular or square sources, the value of the *angular subtense* is determined by the angular subtense of the diameter or the lateral length respectively. The value of the angular subtense of a rectangular or linear source is determined by the arithmetic mean of the two angular dimensions. Any angular dimension that is greater than α_{max} or less than 1,5 mrad should be limited to α_{max} or 1,5 mrad respectively, prior to determining the mean.

6.4 Measurements and classification

Tests and measurements shall be carried out according to IEC 60825-1, clause 8 and classification according to IEC 60825-1, clause 9. For the purpose of this specification, *MPE*s are equivalent to the Class 3A-AEL. *MPE*-values are found in table 6 of IEC 60825-1. The accessible emission limits of Classes 1 and 3B are found in tables 1 and 4 of IEC 60825-1.

6.5 Nominal ocular hazard distance

In the far-field (where the size of the source is small compared to the distance) the basic "inverse-square-law" of radiometry may be used to determine the *NOHD* (see 3.17) by the following formula:

$$NOHD = \sqrt{\frac{I_e}{MPE}} \text{ in metres}$$

If the *MPE* is expressed in W/m², the *radiant intensity* I_e shall be expressed in W/sr. If the *MPE* is expressed in J/m², the integrated *radiant intensity* I_e shall be expressed in J/sr.

NOTE The formula is valid only if the solid angle determined by the beam divergence is larger than the solid angle over which the power or energy is averaged. For example, the formula is not valid for collimated beams.

6.6 Repetitively pulsed, modulated or scanned radiation

The AEL- and *MPE*-values for repetitively pulsed, modulated or scanned radiation shall be determined by using the most restrictive requirement of IEC 60825-1, subclause 9.4.

NOTE (see also IEC 60825-1, amendment 1, annex A, example A.2-4) For frequencies greater than the following limits, the most restrictive requirement is given by the average power assessment:

– For wavelengths between 700 nm and 1 050 nm, when the pulse duration is in the range from 10^{-9} s to $1,8 \times 10^{-5}$ s and the exposure time is in the range from $1,8 \times 10^{-5}$ s to 10^{3} s, the value of the limit is 55 174 Hz.
– For wavelengths between 1 050 nm and 1 400 nm, when the pulse duration is in the range from 10^{-9} s to 5×10^{-5} s and the exposure time is in the range from 5×10^{-5} s to 10^{3}, the value of the limit is 21 896 Hz.
– For exposures longer than 0,7 s, the limits are valid only for angular subtenses not greater than 1,5 mrad. For greater *angular subtenses*, the limits can be at lower frequencies. For exposures shorter than 0,7 s, the limits are valid for all *angular subtenses*.

6.7 Simplified classification procedure for continuously emitting sources with wavelengths between 860 nm and 960 nm

If the (averaged) radiant intensity of a source (in W/sr) is known, the following simplified classification procedure is recommended:

- determination or provision (from data sheet) of the actual *radiant intensity* and *peak wavelength*;
- determination or provision (from manufacturer, or according to 6.3) of the *apparent source* size;
- comparison against the worst case Class 1-related limits of *radiant intensity* in figure 1;
- if these limits are not exceeded, then classify as Class 1, with no further requirement;
- if these limits are exceeded: comparison against the worst case *MPE*-related limits of *radiant intensity* in figure 2;
- if these limits are not exceeded under single fault condition, then classify as Class 3A, and label accordingly. Alternatively, at the discretion of the manufacturer, the Class 3A-statement may be included in the information for the user.

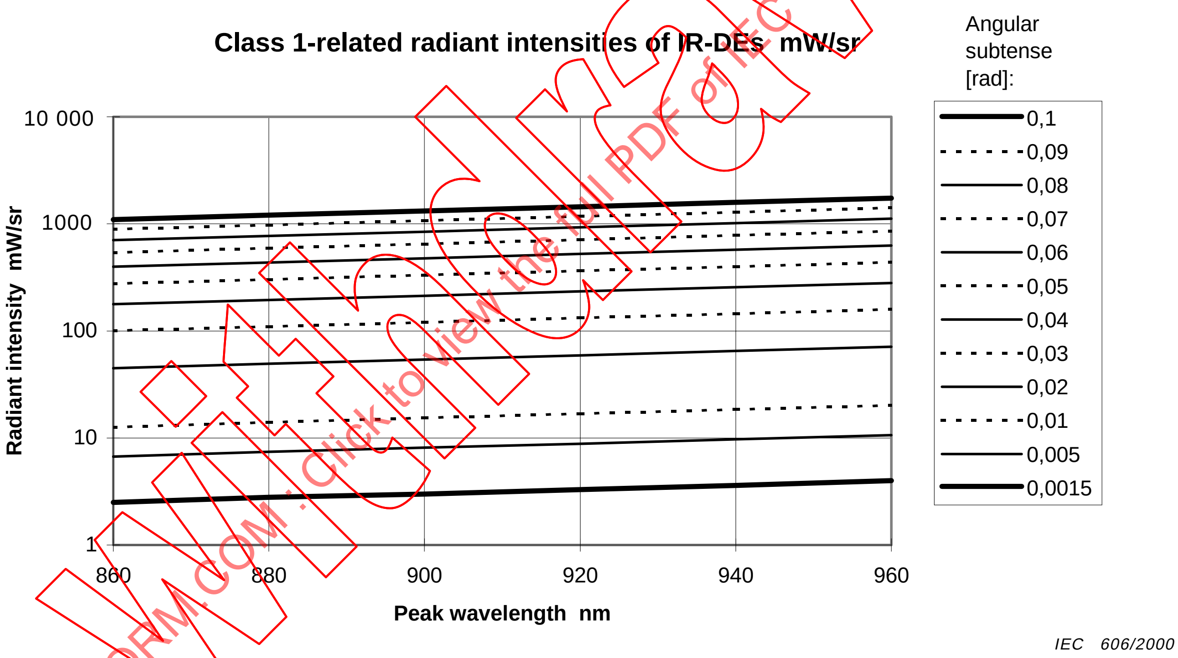

Figure 1 – Class 1-related maximum allowable radiant intensities of IR-sources

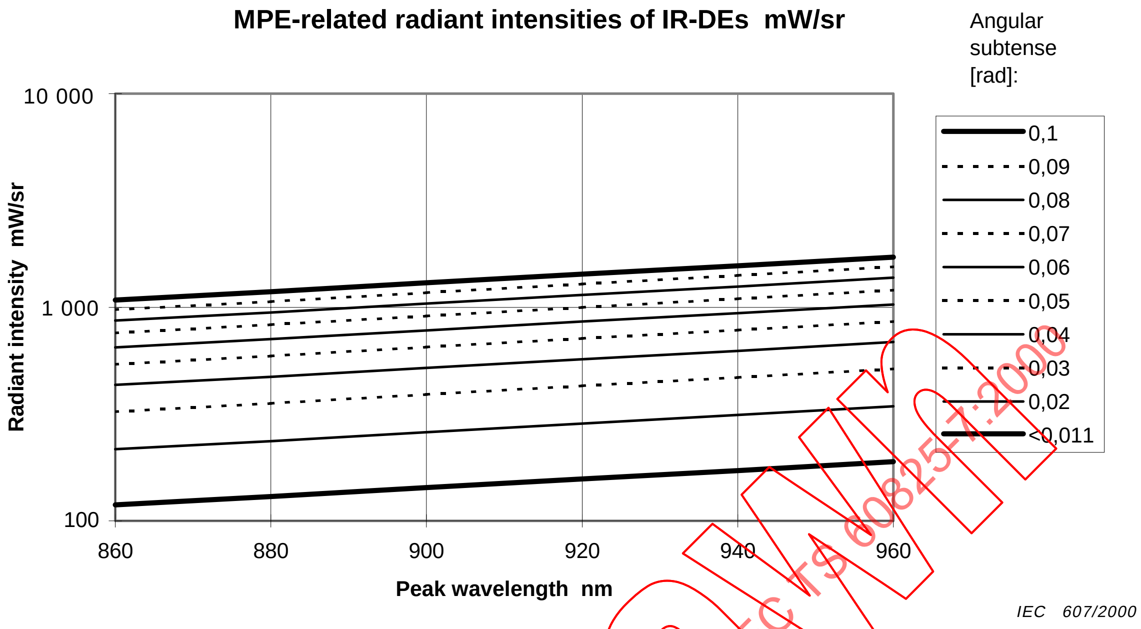

Figure 2 – Class 3A *MPE*-related maximum allowable radiant intensities of IR-sources

NOTE The Class 1 and *MPE*-related allowable *radiant intensities* of *DEs* with different *angular subtenses* in figure 1 and figure 2 are calculated applying the following parameters:

– time basis: 100 s (unintended viewing);
– viewing distance: 100 mm (minimum accommodation distance);
– radiation geometry characterized by Lambertian model (worst case).

The limits are related to the averaged power during CW-operation. If the averaged power requirement for repetitively pulsed or modulated sources is most restrictive (see 6.6), the *radiant intensity* of a single pulse in the train may be determined by the applied duty cycle.

NOTE Details on the conversion of the AEL and *MPE* limits into luminous intensity limits of LEDs are provided in annex B.

Annex A
(informative)

Rationale

The safety of laser products, equipment classification, requirements and user's guide are covered by IEC 60825-1. Laser radiation differs significantly from that of other sources due to the unique feature of coherency and the extremely narrow spatial and spectral distribution, with the power concentrated in a narrow beam and in a nearly monochromatic spectral line. Intrabeam viewing of collimated parallel laser beams leads to concentration of the whole of the radiation in a small spot on the viewer's retina. Similarly, due to the extremely small dimensions of fibres or the active area of laser diode chips, the retinal image may be a diffraction limited point. IEC 60825-1 and IEC 60825-2 mainly cover the (new) hazard aspects for the human eye from these point sources. In this context, extended source viewing originally meant the viewing of diffusely reflected laser beam spots (e.g. on a laboratory wall).

Because of the increased radiated power available from LEDs and their physical similarity to laser diodes, they have been included in the scope of IEC 60825-1. However, the optical radiation of LEDs differs in various aspects from laser sources:

- the spectral radiation bandwidth of some 10 nanometers is neither monochromatic nor broadband with peak wavelengths in near infrared;
- the spatial distribution of the emitted radiation ranges from Lambertian characteristics up to a nearly concentrated beam with any other variation in between, largely dependent on the package (built-in lenses, reflectors, scattering materials, etc.);
- the area of emission, the virtual source size, in most cases, is determined by the package and mainly acts as an intermediate source compared to the measurement (minimum viewing) distance;
- for characterization of laser radiation, the model of a Gaussian beam is commonly used; in the case of LEDs, modified Lambertian source models are preferred.

Lasers are mostly used in selected sophisticated applications while most semiconductor LEDs as mass product plastic encapsulated optoelectronic devices with limited radiance are widely used to improve system performance or convenience in the consumer area. But, modern optoelectronic semiconductor devices range from coherent single-mode over multi-mode laser diodes (LD), "superluminescent diodes" (SLD), "high radiance diodes" up to really incoherent surface emitting LEDs – "on a sliding scale", depending on the design and the mode of operation. A simple distinction only in technical terms between what we call "laser" and "LED" (stimulated/ spontaneous emission, coherency, etc.) cannot be made at this time. On the other hand, today there is no generally agreed scientific basis to distinguish between hazards raised by incoherent or coherent optical sources. The spectral linewidth of LEDs, SLDs or LDs in the wavelength interval of consideration is of very minor importance for the hazard assessment. This has not been altered by recent studies.

Therefore, the hazard assessment for this kind of emitters has to depend on the emitted power or energy, the extension of the source and the related radiation beam characteristic only, rather than on the nature of the source.

Related to optical radiation safety, the (new) intermediate emitters are divided into two groups, due to differences in possible safety mechanisms:

– "visible" (LEDs) for displays and indication purposes and "invisible" (IREDs).

LEDs, or more generally optical sources, covered by IEC 60825-1, exclusively used for visible information transmission to the human eye have to meet the requirements of IEC 60825-6.

IREDs, mainly operating in the near infrared spectral range, are used for invisible free air-transmission of signals (remote control) or data. Under normal conditions, direct intrabeam viewing is not intended. The application requirements for IREDs are different from those for LEDs: whereas for visible emitting LEDs, a wide viewing angle is normally important, for IREDs, a narrow beam width and high on-axis intensity are normally important. The desire to operate wireless data transmission systems reliably over long distances at high data rates is partly causing manufacturers to use high radiance optical sources. Sometimes, the optical power levels required to obtain an acceptable level of system performance may even exceed the *MPE* of human the eye. In this wavelength region, the primary danger is almost instantaneous damage to the retina of the eye:

– radiation of wavelength of less than approximately 1,4 µm penetrates the ocular media and is absorbed significantly in the retina;

– no protection of the eye is given by aversion reactions (blink reflex);

– in the worst case of a fully opened eye pupil (7 mm diameter), intrabeam viewing and minimum accommodation distance, the irradiance at the exposed cornea will be focused on the retina and there it will be increased due to the imaging properties of the eye;

– additional optics between the source and the eye may extend the hazard due to increased power collection of the extended entrance aperture and simultaneous magnification of the source image in the eye.

A bystander cannot realize the hazard and therefore must be protected by the classification system given in IEC 60825-1.

But, if a source is really "invisible" without any visual stimulus, there is no reason or chance for the bypassers' or users' attention for longer fixation, especially with optical instruments. Therefore, the definition of Class 1 (lasers which are safe under reasonably foreseeable conditions of operation) and the related safety measures can be extended up to the *MPE*-related limits (originally Class 3A without power limitation). By this argument, the main difference between this specification compared with the base standard (IEC 60825-1, first edition and its amendment 1) is a relaxation of the labelling requirement for infrared sources in Class 3A. Additionally, if these Class 3A sources are embedded in a product in compliance with Class 1 limits, the product is exempted from the single fault consideration. If the requirements for "invisibility" are provided, any fixation on the source is considered to be unlikely.

The main parameter in the selected application area is the radiant intensity (in mW/sr) of the infrared transmitter because it is connected by the inverse square law with the irradiance on a detector located at some distance. In order to simplify the classification procedure, the AELs and *MPE*s were transformed into radiation limits (based on worst case assumptions) to be compared with data in the manufacturer's data sheets. In practical cases, a brief view of the supplied figures of the radiant intensity limits in this specification may help to decide if actions are necessary or not. At least, mass applications of low power (low cost) infrared transmitters (for remote controls or car keys, etc.) may be checked in this way and should not be classified under single fault conditions as required by the base standard.

Annex B
(informative)

Conversion of AEL and *MPE* limits into radiant intensities of IREDs

The measurement conditions in IEC 60825-1 represent a cone "filled" with an AEL- or *MPE*-related partial radiant flux (see figure B.2). This can be transferred into a corresponding allowable radiant intensity if the spatial distribution characteristic of the source is known. For characterization of the radiation geometry of IREDs, the model of a modified Lambertian source is commonly used. For nearly all theoretical investigations, this cosine approach of IRED spatial distributions is sufficiently close to the measured distributions. Compared to the homogeneous radiance in all directions of a Lambertian source, most of the narrower beam profiles of LEDs may be represented by a raised cosine function:

$$I(\phi)=I_0 \cos^m \phi$$

where

I_0 is the on-axis intensity;

ϕ is the angle considered;

m is the modification parameter of the ideal (m = 1) cosine distribution depending on the half-intensity angle γ_{HW} of the measured spatial distribution (LED data sheet):

$m = \log 0{,}5 / \log(\cos \gamma_{HW})$

Examples are given in figure B.1.

In IEC 60825-1 the AELs and *MPEs* are given in radiation power (in W) or energy (in J), respectively in irradiance (in W/m^2) or radiant exposure (in J/m^2). These values have to be measured by using apertures with different diameters at defined distances, representing a measurement cone with the cone angle θ (see figure B.2).

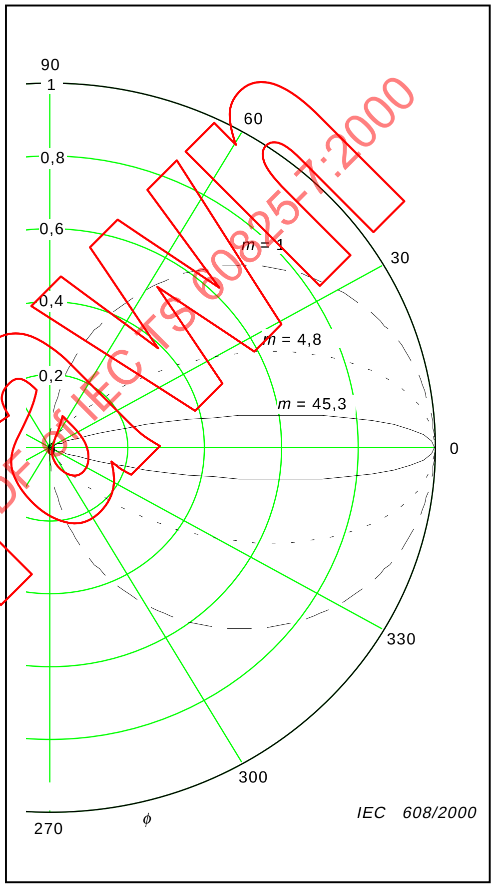

Figure B.1 – Examples of modified cosine distributions with: m = 1 (ideal Lambertian source), *m* = 4,8 for γ_{HW} = 30° and *m* = 45,3 for 10° half-intensity angle

Measurement conditions are according to IEC 60825-1, including amendment 1 ("sliding" aperture at distance r = 100 mm).

AEL measurements:

$$d = \left(7 \sqrt{\frac{\alpha_{max}}{\alpha + 0{,}46}} \right)$$ source size depending aperture diameter [mm] α_{max} = 0,1 rad

where

α is the angular subtense of the source at r = 100 mm measurement distance.

MPE measurement:

d = 7 mm (fixed) at distance r = 100 mm;

$\theta = \arctan(d/2r)$: half cone angle of the measurement condition.

The partial flux $\Delta\Phi$ of a spatial cosine distribution inside the solid angle represented by θ is:

$$\Delta\Phi(\theta) = I_0 2\pi(1\text{-}\cos^{m+1}\theta)/(m+1)$$

with:

$$\Delta\Phi_{\mathrm{AEL}}(\theta) = \mathrm{AEL}_{\mathrm{Class1}} \text{ for Class 1,}$$

$$\text{or } \Delta\Phi_{MPE}(\theta) = MPE \times 3{,}85 \times 10^{-5} \text{ for Class 3A (herein)}$$

as the allowable radiant power according to IEC 60825-1 for the appropriate wavelength and exposure duration, the corresponding allowable maximum radiant intensity is:

$$I_{\mathrm{AEL}} = \mathrm{AEL}\ (m + 1)/2\pi(1\text{-}\cos^{m+1}(\theta))$$

radiant intensity in axis-direction with a diminishing solid angle.

The standard condition for radiant intensity measurement (for data sheets) of IREDs uses a solid angle of 0,01 sr (represented by a half cone angle of 0,056 rad): averaged intensity will be measured.

After correction for comparison with data sheet values:

$$I_{\mathrm{Class\ 1}} = \mathrm{AEL}\ (1\text{-}\cos^{m+1}(0{,}056))/0{,}01(1\text{-}\cos^{m+1}(\theta))$$

$$I_{\mathrm{Class\ 3A}} = MPE \times 3{,}85 \times 10^{-5}(m+1)/2\pi(1\text{-}\cos^{m+1}(0{,}035))$$

By the above formula for the same allowable (AEL- or *MPE*-related) power, the radiant intensity of a narrow beam emitting IRED can be higher than for a IRED with a rather broad spatial distribution. This is also schematically shown in figure B.2.

However, a calculation shows that an essential increase (factor > 2) of the radiant intensity compared to the ideal cosine calculation will only happen for half-intensity-angles below 8°.

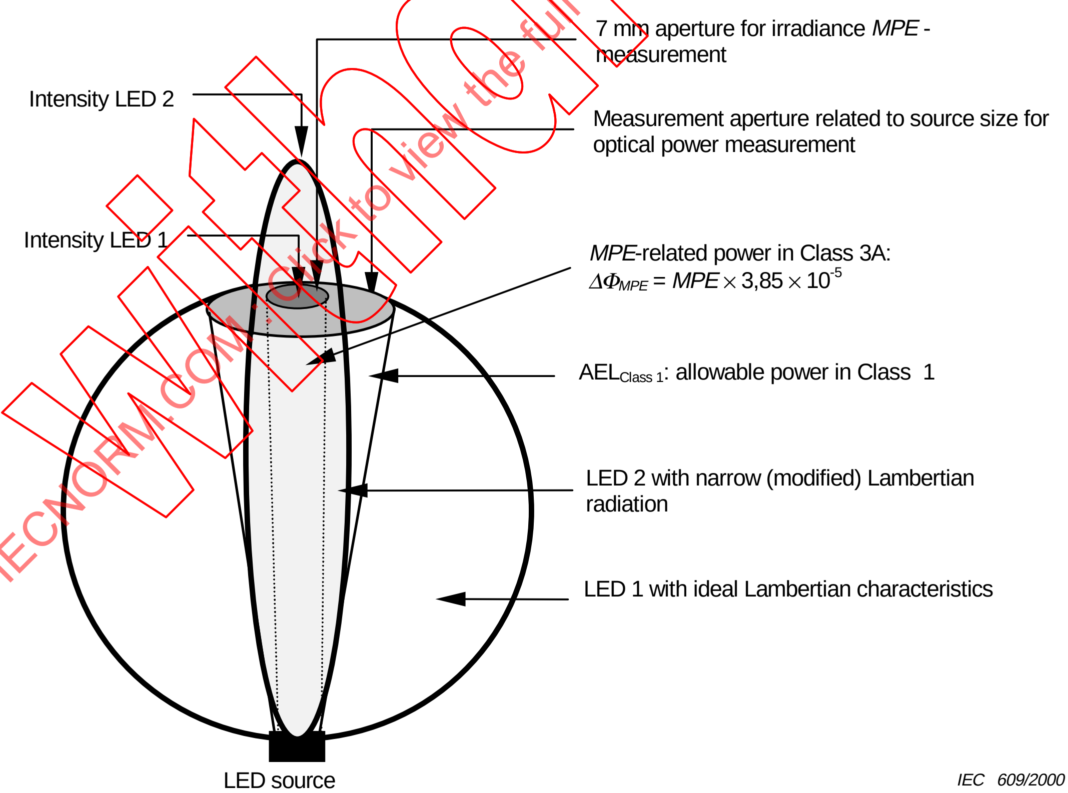

Figure B.2 – Measurement cone: different radiant intensities for the same *MPE* corresponding to the spatial distribution of the radiation