BRITISH STANDARD

BS EN 60825-12:2004

Safety of laser products —

Part 12: Safety of free space optical communication systems used for transmission of information

The European Standard EN 60825-12:2004 has the status of a British Standard

ICS 31.260

British Standards

National foreword

This British Standard is the official English language version of EN 60825-12:2004. It is identical with IEC 60825-12:2004.

The UK participation in its preparation was entrusted to Technical Committee EPL/76, Optical radiation safety and laser equipment, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

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EUROPEAN STANDARD **EN 60825-12**

NORME EUROPÉENNE

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English version

Safety of laser products
Part 12: Safety of free space optical communication systems used for transmission of information
(IEC 60825-12:2004)

Sécurité des appareils à laser
Partie 12 : Sécurité des systèmes de communications optiques en espace libre utilisés pour la transmission d'informations
(CEI 60825-12:2004)

Sicherheit von Lasereinrichtungen
Teil 12: Sicherheit von optischen Freiraumkommunikationssystemen für die Informationsübertragung
(IEC 60825-12:2004)

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Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

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Foreword

The text of document 76/281/FDIS, future edition 1 of IEC 60825-12, prepared by IEC TC 76, Optical radiation safety and laser equipment, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60825-12 on 2004-04-01.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2005-01-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2007-04-01

This European Standard was prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association and supports the essential requirements of Directive 1999/5/EC.

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60825-12:2004 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60812	NOTE	Harmonized as HD 485 S1:1987 (not modified).
IEC 61508	NOTE	Harmonized in EN 61508 series (not modified).

CONTENTS

SAFETY OF LASER PRODUCTS –

Part 12: Safety of free space optical communication systems used for transmission of information

1 Scope

This part of IEC 60825 provides requirements and specific guidance for the manufacture and safe use of laser products and systems used for point-to-point or point-to-multipoint free space optical data transmission. This standard only addresses the open beam portion of the system. If portions of the equipment or system incorporate optical fibre that extends from the confinements of the enclosure(s), the manufacturing and safety requirements under IEC 60825-1 apply to those portions only. This standard does not apply to systems designed for purposes of transmitting optical power for applications such as material processing or medical treatment. This standard also does not apply to the use of systems in explosive atmospheres.

Throughout this part of IEC 60825, light-emitting diodes (LEDs) are included whenever the word “laser” is used.

The objective of this part of IEC 60825 is to:

- provide information to protect people from potentially hazardous optical radiation produced by free space optical communication systems (FSOCS) by specifying engineering controls and requirements, administrative controls and work practices according to the degree of the hazard;

- specify requirements for manufacturing, installation, service and operating organisations in order to establish procedures and provide written information so that proper precautions can be adopted.

Because of the nature of FSOCS, also known as optical wireless or free-air information transmission systems, care must be taken in their manufacture as well as their installation, operation, maintenance and service to assure the safe deployment and use of these systems. This standard places the responsibility for certain product safety requirements, as well as requirements for providing appropriate information on how to use these systems safely, on the manufacturer of the system and/or transmitters. It places the responsibility for the safe deployment and use of these systems on the installer and/or operating organisation. It places the responsibility for adherence to safety instructions during installation and service operations on the installation and service organisations as appropriate, and during operation and maintenance functions on the operating organisation. It is recognised that the user of this standard may fall into one or more of the categories of manufacturer, installer, service organisation and/or operating organisation as mentioned above.

Any laser product is exempt from all further requirements of this part of IEC 60825 if

- classification by the manufacturer according to IEC 60825-1 shows that the emission level does not exceed the accessible emission limit (AEL) of Class 1 under all conditions of operation, maintenance, service and failure, and

- it does not contain an embedded laser product.

2 Normative references

The following referenced documents are indispensable for the application 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 60825-1:1993, *Safety of laser products – Part 1: Equipment classification, requirements and user's guide* [1]
Amendment 1 (1997)
Amendment 2 (2001)

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

3 Terms and definitions

3.1
access level
potential hazard at any accessible position associated with a free space optical communication system (FSOCS) installation

NOTE 1 The access level is based on the level of optical radiation which could become accessible in reasonably foreseeable circumstances, e.g. walking into an open beam path. It is closely related to the laser classification procedure in IEC 60825-1.

NOTE 2 Practically speaking, it takes two or more seconds to fully align an optical aid with a beam, (which might occur in an unrestricted location), and this delay is incorporated into the method for determining access level.

3.2
access level 1
level for which, under reasonably foreseeable circumstances, human access to laser radiation in excess of the accessible emission limits (AEL) of Class 1 for the applicable wavelengths and emission duration will not occur

3.3
access level 1M
level for which, under reasonably foreseeable circumstances, human access to laser radiation in excess of the accessible emission limits (AEL) of Class 1M for the applicable wavelengths and emission duration will not occur

NOTE If the applicable limit of access level 1M is larger than the limit of 3R and less than the limit of 3B, access level 1M is allocated.

3.4
access level 2
level for which, under reasonably foreseeable circumstances, human access to laser radiation in excess of the accessible emission limits of Class 2 for the applicable wavelengths and emission duration will not occur

3.5
access level 2M
level for which, under reasonably foreseeable circumstances, human access to laser radiation in excess of the accessible emission limits of Class 2M for the applicable wavelengths and emission duration will not occur

NOTE If the applicable limit of access level 2M is larger than the limit of 3R and less than the limit of 3B, access level 2M is allocated.

[1] A consolidated edition (1.2) exists comprising IEC 60825-1 (1993) and its Amendments 1 (1997) and 2 (2001).

3.6
access level 3R
level for which, under reasonably foreseeable circumstances, human access to laser radiation in excess of the accessible emission limits of Class 3R for the applicable wavelengths and emission duration will not occur

NOTE If the applicable limit of access level 1M or 2M is larger than the limit of 3R and less than the limit of 3B, access level 1M or 2M is allocated.

3.7
access level 3B
level for which, under reasonably foreseeable circumstances, human access to laser radiation in excess of the accessible emission limits of Class 3B for the applicable wavelengths and emission duration will not occur

3.8
access level 4
level for which, under reasonably foreseeable circumstances, it is possible that human access to laser radiation in excess of the accessible emission limits of Class 3B for the applicable wavelengths and emission duration could occur

3.9
automatic power reduction (APR)
feature of a transmitter of a FSOCS, provided by the system equipment manufacturer, by which the accessible power in the nominal hazard zone (NHZ) or NHZ-Aided is reduced to a specified value within a specified time, whenever there is an event which could result in human exposure to optical radiation above the maximum permissible exposure (MPE), e.g. by a person entering the NHZ or NHZ-Aided as applicable. In FSOCS, this feature may be used by the transmitter manufacturer to determine the classification

3.10
beacon
optical source whose function is to aid in pointing or alignment of an optical system

3.11
embedded laser product
See definition 3.29 in IEC 60825-1.

3.12
end-to-end system
FSOCS that is comprised of at least one transmitter, one receiver, and any peripheral hardware necessary for the effective transfer of data along the transmission path from one position in space to another

3.13
free space optical communication system (FSOCS)
installed, portable, or temporarily mounted, through-the-air system typically used, intended or promoted for voice, data or multimedia communications and/or control purposes via the use of modulated optical radiation produced by a laser or LED. “Free space” means indoor and outdoor optical wireless applications with both non-directed and directed transmission. Emitting and detecting assemblies may or may not be separated

NOTE Refer to the conditions within Clause 1 (Scope) by which Class 1 FSOCS products are exempt from all requirements of this standard.

3.14
FSOCS transmitter; transmitter
optical transmitter emitting radiation through the air and used in FSOCS

3.15
installation organisation; installer
organisation or individual who is responsible for the installation of a FSOCS

3.16
installation protection system (IPS)
feature of an installation site, provided by the installer or operating organisation, that has two functions: (1) it detects human entry into the accessible volume of either the NHZ for restricted or controlled locations or the NHZ-Aided for an unrestricted location, and; (2) once such entry is detected, causes reduction of the accessible power of the laser to a specified level within a specified time

3.17
location
position or site occupied or available for occupancy

NOTE Other standards may use the same terms for location types (3.18 – 3.21) with somewhat different definitions.

3.18
location of inaccessible space; inaccessible space
volume where a person cannot normally be located. All open space that is neither an unrestricted, restricted nor controlled location, i.e. the space that has a horizontal spacing more than 2,5 m from any unrestricted location and is both greater than 6 m above a surface in any unrestricted location, and more than 3 m above a surface in any restricted location

NOTE Inaccessible space may be entered by, for example, aircraft.

3.19
location with controlled access; controlled location
location where an engineering or administrative control measure is present to make it inaccessible except to authorized personnel with appropriate laser safety training

3.20
location with restricted access; restricted location
location that is normally inaccessible by the general public (including workers, visitors, and residents in the immediate vicinity) by means of any administrative or engineering control measure but that is accessible to authorized personnel (e.g. maintenance or service personnel including window cleaners in exterior locations) that may not have laser safety training

3.21
location with unrestricted access; unrestricted location
location where access to the transmission/receiver equipment and open beam is not limited (accessible to the general public)

3.22
manufacturer
organisation or individual who makes or assembles optical devices and other components for the construction or modification of an FSOCS

3.23
nominal hazard zone (NHZ) and NHZ-Aided
a) NHZ: the volume within which the level of the direct, reflected or scattered radiation exceeds the applicable MPE (under measurement conditions indicated in IEC 60825-1). Exposure levels outside the boundary of the NHZ are below the applicable MPE

b) NHZ-Aided: the volume within which, when optical aids are used, the level of the direct, reflected or scattered radiation exceeds the applicable MPE. Exposure levels outside the boundary of the NHZ-Aided are below the applicable MPE when optical aids are used

NOTE 1 These volumes are determined prior to activation of any IPS or APR systems unless the APR is used for classification under the conditions of 4.3 of this standard.

NOTE 2 Examples of NHZ and NHZ-Aided are provided in A.2.

3.24
operating organisation; operator
organisation or individual who is responsible for the operation and maintenance of an FSOCS

3.25
optically-aided viewing
use of optical aids (for example binoculars or magnifiers) to view an emitting source from within the emitted beam

NOTE 1 It is possible that telescopic optics, including binoculars, could increase the hazard to the eye by intrabeam viewing of a collimated beam when viewed at a distance.

NOTE 2 It is possible that hand magnifiers or eye-loupes could increase the hazard to the eye from viewing a close, but highly divergent, source.

3.26
primary beam
beam that transmits the modulated data signal

3.27
reasonably foreseeable event
event (or condition) when it is credible and its likelihood of occurrence (or existence) cannot be disregarded

3.28
service organisation
organisation or individual who is responsible for the service of an FSOCS

3.29
special tool
tool that is not readily available at retail consumer hardware stores

NOTE Typical tools in this category are intended for use with tamper-resistant fasteners.

3.30
spillover
beam radiant energy that propagates past the receiving terminal

3.31
unaided viewing; without optical aids
viewing an emitting source from within the emitted beam without using magnifiers or other optical aids, as with the naked eye (prescription eyeglasses and contact lenses are not considered optical aids)

4 Requirements

4.1 General remarks

FSOCS have limitations imposed by this standard that are dependent on the location type(s) in which they are installed. Product classification and access level restrictions by location type are summarized in Table 1.

In each location where emission is transmitted, crosses or is received, respective exposure conditions must be individually evaluated. Furthermore, potentially occupied locations along the beam path, within the NHZ or NHZ-Aided, must also be evaluated for acceptable access levels (Table 1) and appropriate controls applied. Locations traversed by partial reflections from windows within the beam path must also be evaluated if the emission could exceed access level 1 or 2. At a given location, the installation and operational constraints applied from 4.2 shall be determined by whichever is the more hazardous; the transmitted or the received optical radiation.

Example 1: In the case of a location that receives access level 1 or 2 radiation but uses a Class 1M transmitter in the opposite direction, these combined conditions are acceptable for restricted locations but not for an unrestricted location unless the transmission equipment is installed as described in 4.2.1.1 to reduce the transmit access level to 1 or 2.

Example 2: For links with spillover beyond the receiver, but within the NHZ-Aided that is of access level 1M or 2M, the spillover (and any accessible radiation otherwise outside of the receiver path, e.g. in front of it) must be contained within a restricted or controlled location, an unrestricted location compliant with 4.2.1.1, or inaccessible space.

For Class 3B and Class 4 transmitters in controlled locations, the entire beam path that potentially passes through other location types, including inaccessible space, must comply with the access level restrictions of Table 1. This may be satisfied in some applications by continually monitoring the entire NHZ to ensure rapid automatic power reduction in the event of human interception of the beam path. Any spillover beyond the receiver, (and any accessible radiation otherwise outside of the receiver path – e.g. in front of it), within the NHZ, must also be contained in a controlled location or inaccessible space. Any additional spillover within the NHZ-Aided must be contained within a restricted or controlled location, an unrestricted location compliant with 4.2.1.1, or inaccessible space.

The following ranking of the access levels (in increasing order of hazard) shall apply in this part of IEC 60825: 1, 2, 1M, 2M, 3R, 3B, 4.

NOTE Because of the application, this is not the same as the ranking used in IEC 60825-1.

Table 1 – Restrictions for product classes and access levels

Location type	Permissible product classes and installation conditions	Permissible access levels
Unrestricted	Class 1 or 2 – No conditions Class 1M or 2M – See 4.2.1.1 Class 3R – See 4.2.1.2	1 or 2
Restricted	Class 1, 2, 1M or 2M – No conditions Class 3R – See 4.2.2.1	1, 2, 1M or 2M
Controlled	Class 1, 2, 1M, 2M, or 3R – No conditions Class 3B or 4 – See 4.2.3.1	1, 2, 1M, 2M, or 3R 3B or 4 – See 4.2.3.1
Inaccessible space	Not applicable	1, 2, 1M, 2M or 3R

The operating organisation has the ultimate responsibility for the installation, service, maintenance and safe use of the end-to-end system. This includes, especially

– identification of the location type at all portions of the entire transmission path, including beam spillover outside the receiver collection area and partial reflections from intermediate windows, where people may have access;
– ensuring that the product classification, access level requirements, and installation conditions from Table 1 are satisfied for those location types;
– ensuring that installation, maintenance and service are performed only by organisations with the capability of satisfying the requirements of 4.2.

Requirements for transmitter manufacturers, installers and service organisations are also included in this standard.

4.2 Access level and classification requirements by location type

The location of the FSOCS shall determine the permissible access levels of emissions and the classification of equipment to be used and subsequent types of controls. Table 1 shows the acceptable product classes, and access levels for the different types of locations. Figures 1 and 2 illustrate some of the location types described in this section for commercial and residential areas.

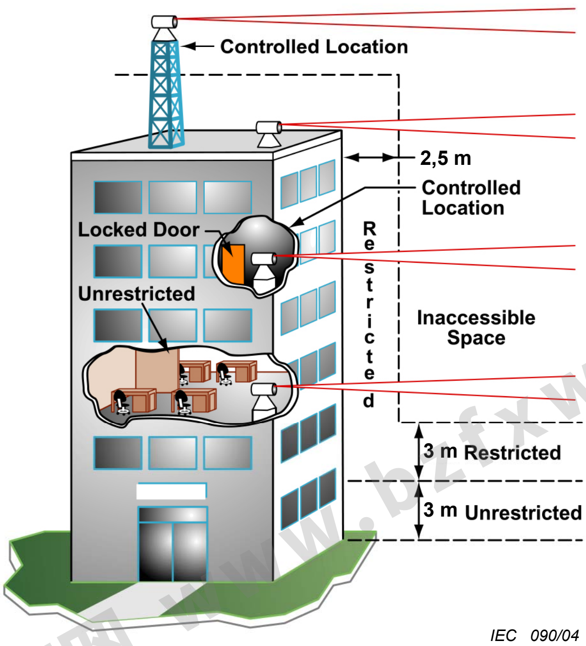


Figure 1 – Commercial structures

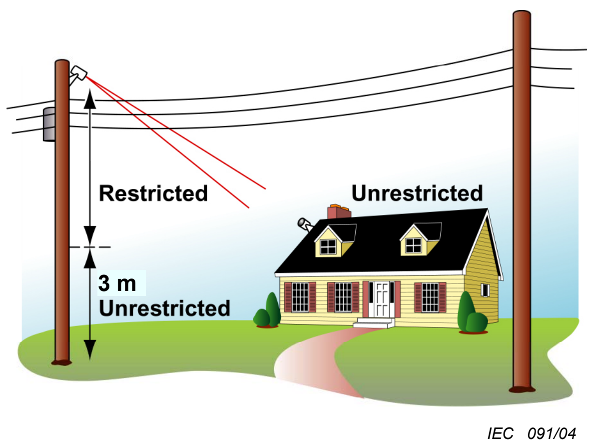


Figure 2 – Residential areas

4.2.1 Requirements for unrestricted locations

Unrestricted locations are those areas that are normally accessible to the public (e.g., unrestricted areas of rooftops, public areas at ground level, open areas of offices and industrial premises, etc). For windows that can be opened or unenclosed balconies, the unrestricted region extends 1 m horizontally from a perimeter boundary as shown in Figure 3.

The FSOCS emissions crossing or received in an unrestricted location shall be access level 1 or 2.

The open beam laser transmitters that are used in FSOCS and are installed without added conditions in unrestricted locations shall be Class 1 or Class 2.

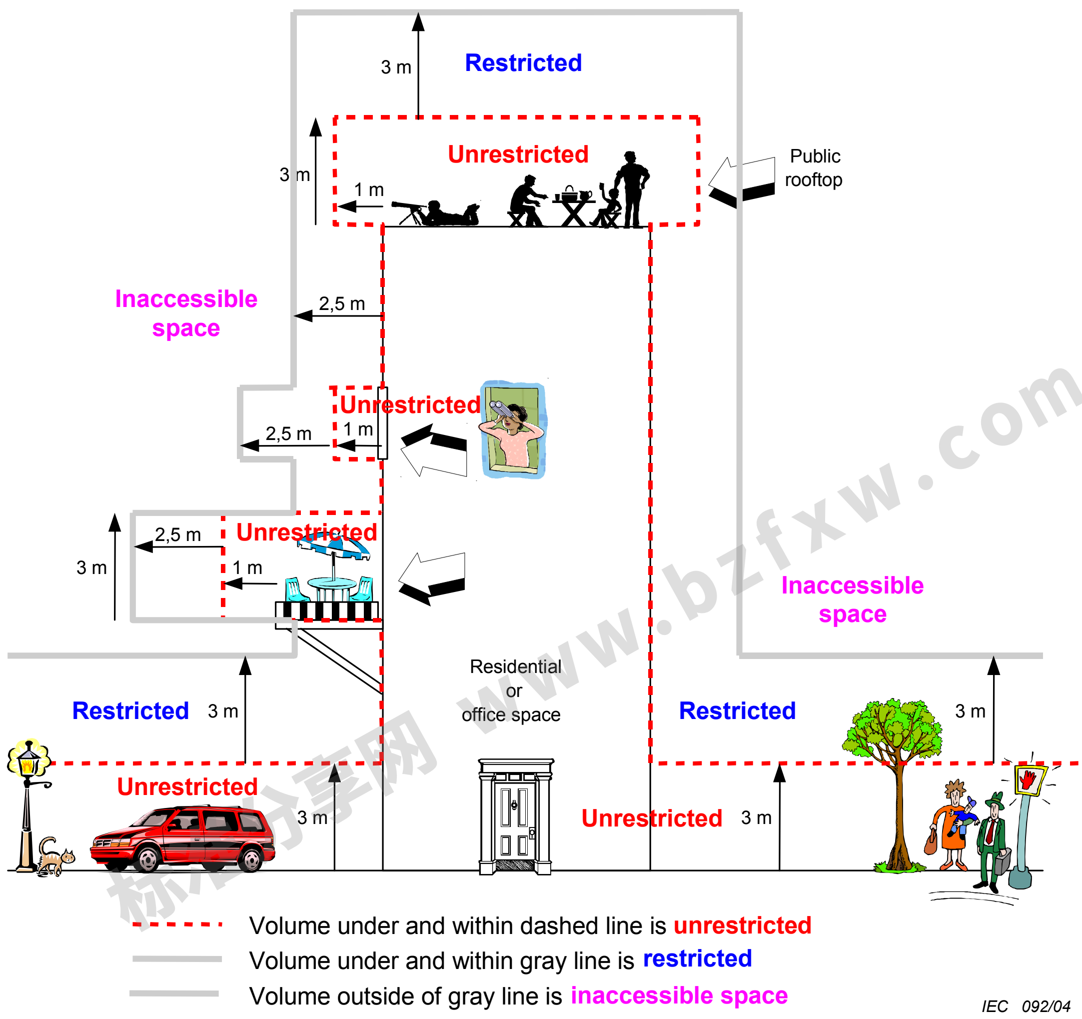


Figure 3 – Examples of external location types

4.2.1.1 Use of Class 1M and Class 2M laser products in unrestricted locations

Installation and use of Class 1M or 2M transmitters in unrestricted locations is permitted if all the following conditions are satisfied:

1) The transmitter shall be installed and comply with at least one of the following:
   a) The use of optical aids within the NHZ-Aided is not a reasonably foreseeable event.
      - Collimated beam transmitters

        For collimated beam transmitters, transmitters that do not satisfy condition 1 of Table 10 in IEC 60825-1, the installation shall not allow access to the NHZ-Aided with binoculars or telescopes at distances greater than 2 m from the transmitter. For example, locating Class 1M or 2M equipment near the edge of an unrestricted roof is permissible provided that all points within the NHZ-Aided at distances greater than 2 m from the transmitter are in a restricted location, (beyond the 1 m extension of the unrestricted location next to the roof edge as indicated in Figure 3). This condition is illustrated in Figure 4.

NOTE It is not considered a reasonably foreseeable event to make use of binoculars or telescopes at distances closer than 2 m from a transmitter. However, transmitters should be placed as close to a window or roof edge as reasonably possible.

- Diverging beam transmitters

  For diverging beam transmitters, transmitters that do not satisfy condition 2 of Table 10 in IEC 60825-1, the installation shall not allow access to the NHZ-Aided with eye loupes or magnifiers at distances closer than 100 mm from the transmitter. For example, locating a Class 1M or 2M wireless transmitter on a ceiling is permissible provided that a window or other barrier prevents access to points within the beam path closer than 100 mm from the transmitter.

  NOTE Determination of what constitutes a reasonably foreseeable event is the responsibility of the operating organisation (EN 1050 is a risk assessment standard, for example).

b) The transmitter shall provide an interlock connector that is interfaced with an IPS at the time of installation so that the accessible energy is limited to access level 1 or 2 as indicated in Figure 5.

2) The installation shall ensure that there is no laser energy reflected back into the unrestricted location (from a window for example) that exceeds access level 1 or 2;

3) The transmitter and/or shielding shall require a special tool to move/remove it, and a label that is visible to warn of the hazard before and after the transmitter or shielding is displaced. Alternatively, the transmitter and/or shielding shall be equipped with an interlock.

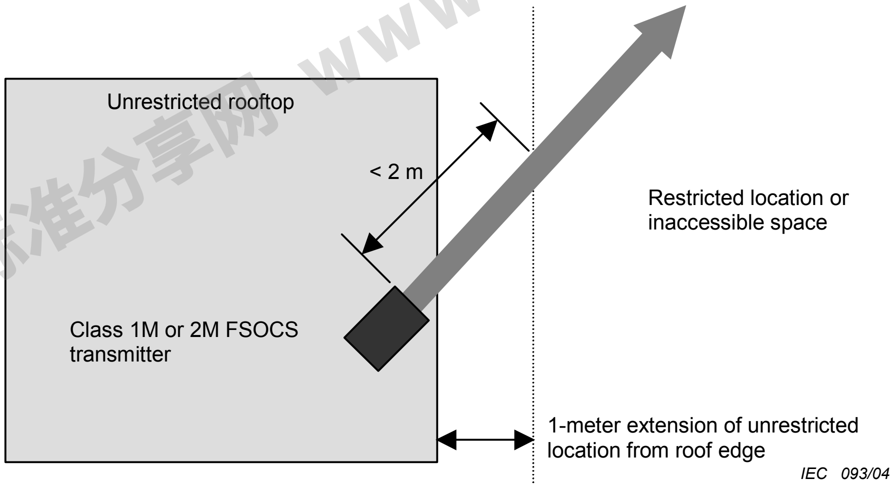
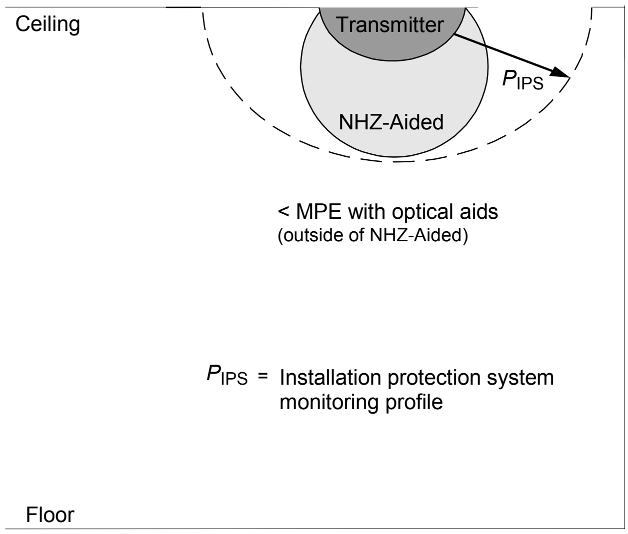


Figure 4 – Class 1M or 2M transmitter near edge of unrestricted rooftop



This is an example of an IPS that monitors the NHZ-Aided of a Class 1M transmitter. Power would be reduced to below the optically-aided MPE level if the monitored volume has been violated.

IEC 094/04

Figure 5 – Class 1M transmitter in unrestricted location

4.2.1.2 Use of Class 3R equipment in unrestricted locations

Installation and use of a Class 3R FSOCS transmitter in an unrestricted location is permitted if the following conditions are satisfied:

1) The transmitter shall be installed and comply with at least one of the following:
   a) an eye exposure within the NHZ and the use of optical aids within the NHZ-Aided are not reasonably foreseeable events, or
   b) the transmitter shall provide an interlock connector that is interfaced with an IPS at the time of installation so that the accessible energy is limited to access level 1 or 2 as indicated in Figure 5.

   NOTE Determination of what constitutes a reasonably foreseeable event is the responsibility of the operating organisation (EN 1050 is a risk assessment standard, for example).

2) The installation shall ensure that there is no laser energy reflected back into the unrestricted location (from a window for example) that exceeds access level 1 or 2.
3) The transmitter and/or shielding shall require a special tool to move/remove it, and a label is visible to warn of the hazard before and after the transmitter or shielding is displaced. Alternatively, the transmitter and/or shielding shall be equipped with an interlock.

4.2.2 Requirements for restricted locations

Restricted locations are those areas that are inaccessible by the general public but that are accessible to authorized personnel that may not have laser safety training. Where optically-aided viewing conditions are reasonably foreseeable, a suitable warning sign shall be provided as indicated in Table 2.

Examples of interior restricted locations are: equipment cabinets and closets (cupboards) in offices and industrial buildings and locked/dedicated rooms. Interior restricted locations could be occupied by service/maintenance personnel or escorted visitors without FSOCS laser safety training.

Restricted locations also exist outdoors. The restricted location on the exterior sides of a building extends outward 2,5 m from the exterior surfaces, balconies or stairways of the building as shown in Figure 3. Examples of exterior restricted locations are: limited access areas of commercial or industrial rooftops, telephone poles, or areas where scaffolding might exist. Exterior restricted space could be occupied by window cleaners or service/maintenance personnel without FSOCS laser safety training.

Exterior locations are also considered restricted if either of the following conditions is satisfied:

a) the location is within the range of 3 m to 6 m above a surface in an unrestricted location, or

b) the location is within 2,5 m in horizontal spacing from any unrestricted location and, if applicable, is greater than 3 m above the surface of any underlying unrestricted location.

Free space optical signals crossing or received in a restricted location shall not exceed access level 1M or 2M, (i.e. below the MPE limits without optical aids).

The open beam laser transmitters that are used in an FSOCS and are installed without added conditions in restricted locations shall be Class 1, 2, 1M or 2M.

4.2.2.1 Use of Class 3R laser products in restricted locations

Installation and use of Class 3R transmitters in restricted locations is permitted if all of the following conditions are satisfied:

1) The transmitter shall be installed and comply with at least one of the following:
   a) an eye exposure within the NHZ and the use of optical aids within the NHZ-Aided are not reasonably foreseeable events, or
   b) the transmitter shall have an interlock connector that shall be interfaced with an IPS at the time of installation so that the access level shall be limited to 1, 2, 1M or 2M as indicated in Figure 6.
2) The installation shall ensure that there is no laser energy reflected back into the restricted location (from a window for example) that exceeds access level 1M or 2M.
3) The transmitter and/or shielding shall require a special tool to move/remove it, and a label that is visible to warn of the hazard before and after the transmitter or shielding is displaced. Alternatively, the transmitter and/or shielding shall be equipped with an interlock.
4) Any additional spillover beyond the receiving terminal within the NHZ-Aided shall be within the restricted location, or if in unrestricted location must comply with conditions in 4.2.1.1.

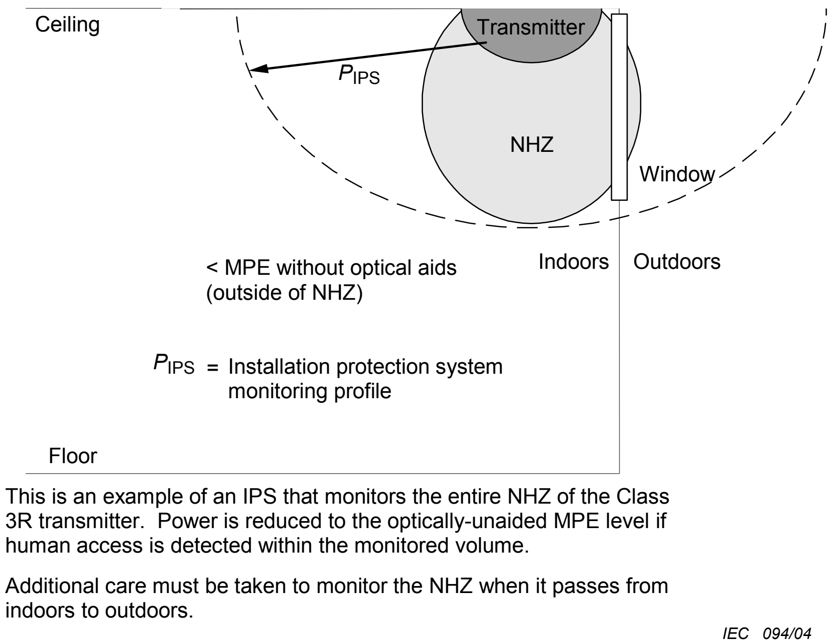


Figure 6 – Class 3R transmitter in restricted location

4.2.3 Requirements for controlled locations

Controlled locations are those areas that are normally inaccessible except to authorized personnel with appropriate laser safety training, (e.g., tower-mounted terminals, fenced/ secure areas of rooftops, locked rooms with strictly-controlled access, etc.).

Installation and use of Class 1, 2, 1M, 2M and 3R transmitters is permitted in controlled locations without added conditions.

FSOCS emissions crossing into or received in controlled locations shall not exceed access level 1M, 2M or 3R except as described in 4.2.3.1.

4.2.3.1 Use of Class 3B and Class 4 laser products in controlled locations

Generally, installation and use of FSOCS equipment in a manner that avoids access levels of 3B and 4 is preferred. However, provided the zone where access level 1M, 2M or 3R is exceeded is confined to a controlled location, industry standard safe practices, (e.g. IEC 60825-1), are permitted to prevent human exposure to access levels of 3B and 4. Note that access levels of 3B or 4 are not permitted outside of a controlled location.

Open beam laser transmitters of Class 3B and 4 may be installed and used in controlled locations if all of the following conditions are satisfied:

a) An IPS is in place that detects human entry to a volume containing the entire portion of the NHZ that extends outside of the boundaries of the controlled location and causes reduction of the power of the laser to a specified level within a specified time (see 4.5).

   NOTE Care should be taken to determine an NHZ that includes sources of error or beam mis-steer.

b) If the receiver is located within the NHZ, any spillover beyond the receiving terminal within the NHZ shall also be contained in a controlled location.

c) Any additional spillover beyond a receiver within the NHZ-Aided shall not enter an unrestricted location unless conditions of 4.2.1.1 are met.

d) A laser safety officer (see IEC 60825-1) from the operating organisation shall be responsible for establishing and implementing control measures for laser hazards within the controlled location.

4.2.4 Requirements for inaccessible space

Inaccessible space includes all space that is in neither unrestricted, restricted, nor controlled locations. This space extends outward horizontally

a) 2,5 m from the exterior surfaces of all buildings, or 3,5 m from locations that may be occupied (e.g. balconies, stairways or openable windows) of all buildings, or

b) from the boundaries of restricted locations,

and extends upward vertically either from 6 m above a surface in an unrestricted location, or from 3 m above a surface in a restricted location. These conditions are indicated in Figure 3.

Access to free space optical radiation in inaccessible space shall not exceed access level 1M, 2M or 3R.

If the NHZ from an FSOCS transmitter intercepts navigable airspace, the appropriate aviation authorities shall be notified. There may be additional regulatory requirements if visible laser beams are used near airports.

4.3 Classification

Classification of the optical transmitter is determined by the manufacturer based on measurement or analysis of accessible optical radiation as specified in IEC 60825-1. Both the primary beam and any alignment or beacon beams accessible during operation must be considered in classifying the product and determining its use in appropriate locations as indicated in Table 1. Verification tests shall be made under the appropriate conditions, e.g. at accessible positions, using the limiting apertures and time durations specified in IEC 60825-1.

FSOCS equipment may be designed to operate with an APR system so that the emitted power is reduced when a human crosses into the NHZ, or NHZ-Aided, (see 4.3.1). For FSOCS applications, it is permissible to determine classification of FSOCS transmitters and the access level assignment based on the emission that is accessible following a 2-second delay from the time of initial human exposure. During the 2-second period the MPE, measured using viewing conditions without optical aids shall not be exceeded for equipment classified as Class 1, 2, 1M or 2M. For viewing conditions without optical aids refer to Table 7 of IEC 60825-1. An APR system is only permitted on transmitters that are classified as Class 1, 2, 1M or 2M with the APR system enabled.

NOTE **Rationale for 2 s:** Because of the difficulty of a person with binoculars or other optical aid to fully align with a free space optical beam, it is not reasonably foreseeable that a person could intercept the beam's full power within 2 s.

4.3.1 Automatic power reduction mechanisms (APR)

An APR system is a feature that a manufacturer may supply with an FSOCS transmitter by which the accessible power is reduced to a specific level within a specific time, whenever there is an event that could result in human exposure to radiation above the applicable MPE, e.g. a person intercepting the beam or even a very small portion of the beam that would accommodate a 50 mm, 25 mm, 7 mm or 3,5 mm or other aperture, as described in Table 10 of IEC 60825-1.

The operation of an APR system affects the classification of the FSOCS transmitter and the access level at monitored locations as described in 4.4. The APR only refers to that mechanism that monitors the NHZ or NHZ-Aided and reduces power. It does not extend to installation protection systems used for limiting access in a unrestricted, restricted or controlled location.

FSOCS transmitters which would be Class 4 without an APR system, shall not be installed in a manner such that access level 4 could be present in an unrestricted location in the event of an APR failure.

4.3.1.1 APR performance requirements

An APR shall accomplish the following:

a) monitor the entire NHZ or NHZ-Aided depending on the reduced access level;

b) detect human interception of the NHZ or NHZ-Aided, as appropriate, and reduce accessible power to a specified level within the specified time, and maintain the power at or below the specified level for the duration of the potential hazard;

c) during the 2-second period allowed for power reduction, ensure that the MPE without optical aids (as indicated in IEC 60825-1) at the point of interception shall not be exceeded for a Class 1, 2, 1M or 2M product;

d) have an adequate level of reliability for all subsystems, (including, for example, switches, electronics, software and sensors) and be single fault tolerant, e.g., when single faults of the system occur that could permit an accessible energy above access level 1 or 2 within the NHZ-Aided for Class 1 or 2 products, or access level 1M or 2M within the NHZ for Class 1M or 2M products, the safety function of the APR is performed;

   NOTE Annex B shows some examples of reliability assessment methods.

e) if an APR override mechanism is provided, for installation or servicing work, while enabled, the resumption of normal operation must be prevented, and a visible or audible warning must clearly indicate that the APR has been overridden, (based on interlock override requirements from IEC 60825-1);

f) in transmitters which would be Class 3B or 4 without an APR system, a single fault in the safety function of the APR system shall cause:

   1) reduction of transmitter emission level within 2 s of fault occurrence to Class 1 or 2 if installed in an unrestricted location or to Class 1, 2, 1M or 2M if installed in either a restricted or controlled location, (during the 2-second reduction period, the optically unaided MPE shall not be exceeded), and

   2) notification of the single fault condition to the operating organisation by means of a required network monitoring system; and

g) due to the wide range of possible detection methods, the manufacturer shall determine a test procedure to adequately verify the performance of the detection system which triggers the APR. The test should account for humans between infant and adult (unless the age is reasonably restricted by the location type). Similarly, the tests should account for speeds of entry into the beam that are reasonably foreseeable for the intended installation location.

NOTE If power reduction occurs in less than 2 s, the MPE for that duration may be used.

Tests and assessments shall be carried out under reasonably foreseeable fault conditions. In some complex systems, where the optical output is dependent on the integrity of other components and the performance of circuit design and software, it may be necessary to use other recognized methods for hazard/safety assessment (see annex B).

Once the APR determines a safe condition, full power operation of the transmitter is permissible.

NOTE Classification and access level evaluation of the APR-based FSOCS shall account for start up and restart conditions for all applicable time bases. Until a safe condition is established, the appropriate emission/exposure limits for its installed location type shall not be exceeded.

4.4 Determination of access level

Determination of access levels is the ultimate responsibility of the operating organisation. However, they may be determined by the maintenance, installation or service organisation. The methods for determining compliance with an access level are the same as those described for classification in IEC 60825-1 except for the following:

a) The access level within a designated location shall be determined at any position relative to an FSOCS transmitter where the access level is maximized, and could depend on intermediate system elements such as windows.

b) The access level may depend on the activation of an IPS or APR system.

c) If an IPS or APR system is monitoring the location in question, during the 2 s immediately following any human interception, the accessible emission shall not exceed the MPE. Otherwise, the same method used for classification is also used for determination of access level. For viewing conditions without optical aids refer to Table 7 of IEC 60825-1.

NOTE **Rationale for 2 s:** Because of the difficulty of a person with binoculars or other optical aid to fully align with the beam, it is unlikely that a person could intercept the beam's full power within 2 s. During the 2-second period following exposure, no part of the body would be exposed above the optically unaided MPE for access levels of 1, 2, 1M, 2M or 3R.

Verification testing of access levels shall be carried out under reasonably foreseeable single fault conditions to ensure that the APR and/or IPS, if used, is operating properly. In circumstances where it is difficult to carry out direct measurements, an assessment of the access level based on calculations may be acceptable. Faults which result in the emission of radiation in excess of the applicable AEL for a limited period only and for which it is not reasonably foreseeable that human access to the radiation will occur before the product is taken out of service or adjusted down below the AEL, need not be considered.

4.5 Installation protection systems (IPS)

An IPS is a feature that functions similar to an APR system but is not integrated with an FSOCS transmitter by a manufacturer. Instead, an installer may incorporate an IPS with an FSOCS transmitter so that the accessible power at defined locations is reduced to a specific level within a specific time, whenever there is an event that could result in human exposure to radiation above the applicable MPE. The requirements of 4.3.1.1 for APR systems are applicable to an IPS, however transmitter classification may not be determined based on the operation of an IPS.

The interface between the IPS and the FSOCS transmitter shall be through an interlock connector that is provided by the transmitter manufacturer or by equivalent means. FSOCS transmitters that do not provide an interlock connector or equivalent shall not be installed with an IPS.

4.6 Specular reflections

When installing and operating an FSOCS, care should be exercised to prevent unintentional reflection (total and/or partial) of the primary and, if used, beacon or alignment transmitter beams. (This should apply to all laser classes as a matter of good work practice.) The possibility of accidental misdirection of the laser beam and unintentional reflections shall be taken into account in the evaluation of the access level, and NHZ, as appropriate, by the system installer/operating organisation.

4.7 Organisational requirements

4.7.1 Requirements for manufacturers of ready-to-use FSOCS transmitters or turn key systems

Manufacturers of FSOCS transmitter and receiver equipment and/or turnkey end to end systems shall

- ensure that the equipment satisfies the product requirements of IEC 60825-1, including:

  a) product classification;

  b) engineering features (e.g. emission indicator, remote interlock connector, etc.);

  c) labels for that classification as well as manuals and other proper documentation;

- ensure that the equipment satisfies the product requirements of IEC 60825-2 when the FSOCS incorporates optical fibre that extends from the transmitting or receiving enclosure(s);

- provide the following additional information:

  a) adequate description of any engineering design features incorporated into the product that prevent exposure to radiation in excess of access level 1, 2, 1M, 2M or 3R;

  b) adequate instructions for proper assembly, alignment, maintenance and safe use including clear warnings concerning precautions to avoid exposure to radiation above access level 1, 2, 1M, 2M or 3R;

  c) adequate instructions to installation and service organisations to ensure the product can be installed and serviced in such a manner that the accessible radiation does not exceed the requirements of 4.2. These include requirements on horizontal and vertical spacing, definitions and requirements for unrestricted, restricted and controlled locations and inaccessible space, and, if allowed, the procedures and precautions applicable for any adjustments needed to increase/reduce beam divergence in order to reduce possible exposures;

  d) the reaction time and operating parameters of the APR system or IPS, if provided by the manufacturer, e.g. the time to reach the desired access level;

  e) where installation or service requires overriding an APR or IPS system, information shall be included to specify safe work practices and/or protection while the power reduction system or monitor is overridden, and safe procedures for reinstating and testing such systems;

  f) sufficient information shall be provided by a FSOCS equipment manufacturer to allow the installer or operating organisation to determine a maximum access level at any position relative to the transmitter;

  g) instructions for connection of an IPS to the remote interlock connector or equivalent transmitter interface;

  h) information that describes the condition upon which the classification is based, (IEC 60825-1, Table 10, condition 1 or condition 2);

  i) if the product is classified in excess of Class 1M or 2M, the NHZ should be provided;

  j) for all products other than Class 1, the NHZ-Aided, if present, should be described (see examples in A.2).

  k) any other information relevant to the safe use of the FSOCS product.

4.7.1.1 Additional manufacturer’s instructions

In the installation manual, the manufacturer shall explicitly define the area location type per the definitions of this standard, and state whether the FSOCS is intended for installation in a unrestricted, restricted, or controlled access location type.

NOTE Products equipped with APR may have installation locations limited by 4.3.1.1(f).

The installation manual shall include the following statements:

“CAUTION – Use of controls, or adjustments, or performance of procedures other than those specified herein may result in hazardous radiation exposure.”

"The appropriate aviation authorities shall be notified if the nominal hazard zone (NHZ) intercepts navigable airspace."

4.7.1.1.1 Transmitters

The following statements that apply to the particular classification of the transmitter of the FSOCS shall be included in the installation manual.

Class 1 FSOCS transmitters: "This is a Class 1 FSOCS transmitter and may be installed in unrestricted, restricted, or controlled locations as defined in this manual."

NOTE This statement is not required for transmitters that satisfy the exemption described in Clause 1 (Scope).

Class 1M FSOCS transmitters: "Caution, this is a Class 1M FSOCS transmitter and may be installed in unrestricted, restricted, or controlled locations as defined in this manual. See installation constraints for use in unrestricted locations."

Class 2 FSOCS transmitters: "Caution, this is a Class 2 FSOCS transmitter and may be installed in unrestricted, restricted, or controlled locations as defined in this manual."

Class 2M FSOCS transmitters: "Caution, this is a Class 2M FSOCS transmitter and may be installed in unrestricted, restricted, or controlled locations as defined in this manual. See installation constraints for use in unrestricted locations."

Class 3R FSOCS transmitters: "Caution, this is a Class 3R FSOCS transmitter and may be installed in unrestricted, restricted, or controlled locations as defined in this manual. See installation constraints for use in unrestricted and restricted locations."

Class 3B FSOCS transmitters: "Caution, this is a Class 3B FSOCS transmitter and may be installed in controlled locations as defined in this manual."

Class 4 FSOCS transmitters: "Caution, this is a Class 4 FSOCS transmitter and may be installed in controlled locations as defined in this manual."

4.7.1.1.2 Receivers

Appropriate information must be provided on systems whose receivers or receive locations may not employ transmitters, on whether the receiver requires reception of optical emissions in excess of the MPE with optical aids and how to deploy that receiver properly.

4.7.2 Installation and service organisation requirements

Installation and service organisations for FSOCS shall follow the manufacturer's instructions for installation and service of equipment in a manner that will ensure that the accessible radiation satisfies the requirements of 4.2.

For systems other than Class 1 or 2, the installation and service organisation(s) shall:

a) provide adequate laser safety training to installation and service personnel;
b) ensure that suitable access controls and warning signs are employed per Table 2. Each location requiring a sign shall contain the words, "Access level xx, IEC 60825-12:2004". Signs are to be posted adjacent to the equipment (to adequately warn against entry into hazardous areas), and next to entrance doors as indicated in Table 2;
c) ensure that IPS monitors, if used, are providing the protection intended.
d) for Class 3B and 4 FSOCS, verify by analysis or test that the access level limits in 4.2 for received radiation in unrestricted and restricted locations and received or transmitted radiation in controlled locations are met under reasonably foreseeable conditions including consideration of beam alignment stability and mounting limitations.

Table 2 – Requirements for warning signs

Access level	Location type		
	Unrestricted	**Restricted**	**Controlled**
1	None	None	None
2	None	None	None
1M [a]	Not applicable [b]	None [c]	None [c]
2M [a]	Not applicable [b]	Adjacent	Adjacent
3R	Not applicable [b]	Not applicable [b]	Adjacent & Entrance
3B	Not applicable [b]	Not applicable [b]	Adjacent & Entrance
4	Not applicable [b]	Not applicable [b]	Adjacent & Entrance

[a] For access level 1M or 2M, the warning sign, if present, must include statement: “Do not use optical aids (binoculars or telescopes)”. If the product is classified 1M or 2M because it fails condition 2 of IEC 60825-1, Table 10 (highly diverging beam), then replace "(binoculars or telescopes)" with "(magnifiers)".

[b] Not applicable because access level not permitted in the location type (see Table 1).

[c] If a sign is not present for access level 1M in restricted or controlled locations, it is the responsibility of the operating organisation to ensure alternate administrative controls effectively prevent hazardous optically aided viewing.

4.7.3 Operating organisation requirements

The operating organisation has the ultimate responsibility for the safety of the end-to-end system. This includes, especially:

a) identification of the location type at all portions of the entire transmission path within the NHZ-Aided where people may have access;

b) ensuring that the classification and access level requirements are not exceeded for those location types;

c) ensuring that installation and service is performed only by organisations with the capability of satisfying the applicable requirements of 4.2 and 4.7.2;

d) ensuring that access to restricted and controlled locations is appropriately addressed with respect to laser safety;

e) ensuring compliance with operating, installation, service and safety requirements;

f) ensuring that a laser safety officer is assigned to controlled locations that contain Class 3B or 4 equipment;

g) after receiving notification of a fault in the APR system of an FSOCS transmitter that would be Class 3B or 4 without an APR system, repair of the fault condition shall occur in a time frame that reasonably prevents a second fault from occurring.

Annex A
(informative)

Examples of applications and calculations

A.1 Viewing a specular (mirror-like) reflection

Specular (mirror-like reflections; Fresnel reflections) can in some cases be of concern from Class 1M and higher classes where the beam is transmitted through building windows. If the beam is directed at another building transceiver site, a specular reflection can be produced at each glass-air interface. The typical reflectance per surface is 0,04 (but depends upon index of refraction). Thus for a beam incident upon a single-paned window at near-normal (perpendicular) incidence, 4 % + 4 % will be reflected, i.e., 8 %. If the emitted beam irradiance is more than 1/(0,08) = 12-fold greater than the MPE, the reflected beam would exceed the MPE. Furthermore, Fresnel's Law of Reflection states that the reflectance increases at off-normal incidence angles. Thus further safety evaluations may be necessary. It is important to determine the direction of a reflected beam back into occupied space in the transmitter room. With regard to reflections from a beam entering the transceiver or receiver site, it would be unusual for the beam irradiance to be far exceeding the MPE and therefore a reflection back into space that is of concern would be very rare. Nevertheless, the installer should consider this.

Example: A collimated beam from a Class 3B free-space laser operating at 4 W with a 0,2-m diameter beam and at a wavelength of 1,15 µm is directed out an office-building window at an angle 20 degrees from the normal. Evaluate the specular reflection back into the transmitter room.

$$E = 1{,}27 \times \Phi / a^2 = (5{,}08\ \text{W})/(0{,}2\ \text{m})^2 = 127\ \text{W}\cdot\text{m}^{-2} \qquad (1)$$

The MPE at this wavelength for continuous (> 10 s) viewing is 50 $\text{W}\cdot\text{m}^{-2}$. Since the window reflectance is much less than 50/127 = 0,39, the reflected beam irradiance is below the MPE; however, the reflected beam would be equivalent to Class 1M and if a telescope (without safety filter) were to be aimed out the window along the reflected beam path a risk from optically-aided viewing could exist. The reflectance for this type of glass at this angle was measured to be 0,10 (10 %). Thus the reflected beam irradiance would be 13 $\text{W}\cdot\text{m}^{-2}$ and this could pose a hazard for an unattenuated telescope having a magnifying power greater than 50/13. Needless to say, off-axis beam angles must be evaluated. The transmitter is best placed very close to the window glass, or a tube between transmitter aperture and window glass installed. For reflections external to the building, Class 1M beams may be created and must be evaluated.

A.2 Examples of NHZ and NHZ-Aided

The concepts of NHZ and NHZ-Aided are not always immediately understandable from the definitions alone, and some illustrative examples are provided here for assistance. Correct interpretation of this standard also depends on the reader's clear understanding of access levels as defined in this standard. For example, a Class 1M product (which is potentially a hazard for aided viewing conditions) may be installed in a manner that renders optically aided viewing not reasonably foreseeable (4.2.1.1). In this case, even though there is a NHZ-Aided, the installation is access level 1.

Assumptions are made in the following examples to simplify the analysis and still illustrate the concepts. Further related examples that consider other wavelengths and more typically encountered irradiance profiles, such as Gaussian, are provided in Annex A of IEC 60825-1.

Example A.2-1

Consider first a collimated beam Class 1M product, (that does not satisfy condition 1 of Table 10 in IEC 60825-1). For this case, there is no NHZ, and the NHZ-Aided is confined to a region that begins 2 m from the point of closest human access. This is because 2 m is considered the closest distance of reasonably foreseeable use of telescopic optical aids (such as binoculars) that typically have a limited range of focus adjustment. The extent of the NHZ-Aided beyond 2 m is dependent on additional details of the product including: wavelength, angular subtense, time dependence of emitted power, peak power, beam divergence, minimum beam diameter, and irradiance distribution.

Example A.2-2

Next consider a diverging beam Class 1M transmitter (that does not satisfy condition 2 of Table 10 in IEC 60825-1). For this case, there is also no NHZ, and the NHZ-Aided volume is confined to a region between 14 mm and 100 mm from the apparent source location. This is because 14 mm and 100 mm are the minimum and maximum distances of applicability of condition 2. As in the preceding example, the rationale for this distance range is based on reasonably foreseeable use of short range optical aids such as eye loupes. As in the preceding example, additional detail about the extent of the NHZ-Aided within the 14 mm to 100 mm region from the apparent source location is dependent on transmitter characteristics.

Example A.2-3

A Class 3B product with condition 2 being the most restrictive.

Specifically, consider:

- uniform-irradiance beam with diameter at the emitting aperture of d_0 = 1 mm;
- full divergence of ϕ = 0,1 rad;
- wavelength of 1 500 nm;
- average cw beam power of P = 360 mW.

We assume here for simplicity that for any fixed distance from the transmitting aperture, the beam irradiance is constant within the beam divergence cone and is zero outside this cone. The beam diameter at any distance r is given by

$$d(r) = d_0 + 2\, r \tan(\phi / 2) \cong d_0 + r\,\phi$$

The maximum extent of the NHZ is referred to in IEC 60825-1 as the nominal optical hazard distance (*NOHD*), and is determined by calculating the distance at which the irradiance averaged within the measurement aperture applicable for optically unaided viewing (from IEC 60825-1, Table 10) falls below the MPE. This is equivalent to setting the power collected by the measurement aperture to the *AEL* for Class 1 and Class 1M (from IEC 60825-1, Table 1). Using the uniform irradiance assumption of this example, this collected power is determined by the ratio of the measurement aperture area to the beam area

$$AEL = 10 \text{ mW} = P\,(d_{UM} / d(NOHD))^2$$

where d_{UM} = 3,5 mm is the applicable unaided measurement aperture diameter. Using the above equations to solve for *NOHD* yields

$$NOHD = \frac{d_{UM}\sqrt{\dfrac{P}{AEL}} - d_0}{\phi}$$

$$NOHD = (3{,}5 \times (360 / 10)^{1/2} - 1) / 0{,}1 \text{ mm} = 200 \text{ mm}$$

Therefore, the NHZ begins 100 mm from the apparent source location, and extends to a distance of 200 mm.

There are two parts of the NHZ-Aided, based on conditions 1 and 2 respectively from IEC 60825-1, Table 10. The part of the NHZ-Aided determined by condition 2 is smaller than the NHZ, extending only from 14 mm to 100 mm (measured from the apparent source location).

The part of the NHZ-Aided based on condition 1 is determined by calculating the distance at which the power collected by the measurement aperture applicable for optically aided viewing (again from IEC 60825-1, Table 10) falls below the AEL for Class 1 and Class 1M (from IEC 60825-1, Table 1). This distance is referred to in IEC 60825-1 as the "extended NOHD." The NHZ-Aided analysis is the same as for the NHZ except that the measurement aperture diameter is now d_{AM} = 25 mm. Substituting this into the above equation yields

$$NOHD_{\text{extended}} = (25 \times (360 / 10)^{½} - 1) / 0{,}1 \text{ mm} = 1\,490 \text{ mm}$$

Because this distance is less than 2 m, there is no contribution to the NHZ-Aided determined by condition 1.

A.3 Example of divergent, diffuse IR transmitter

In this example, consider an infrared laser diode emitter used for broadcast (point to multi-point) communication in a conference room. Use the following for the transmitter properties:

- peak wavelength — 940 nm
- spectral bandwidth — 4 nm (full-width at half maximum)
- divergence — 120 deg (full-width at half maximum, Lambertian cosine distribution)
- radiant intensity: — 400 mW·sr $^{-1}$ (maximum axial emission)

First consider the case that the source size is not known, and therefore, the most restrictive source angular subtense must be assumed. Referring to IEC 60825-1, Table 1, the applicable AEL is 1,18 mW.

To satisfy the conditions for Class 1, this AEL must not be exceeded when measuring the output of the device with an aperture of 7 mm diameter at a distance of 14 mm. Similarly, for Class 1M, this AEL must not be exceeded when measuring the output of the device with an aperture of 7 mm diameter at a distance of 100 mm.

Before elaborate (and costly) measurements are performed, it is often desirable to check the implications of IEC 60825-1 theoretically by transforming the applicable AEL and measurement conditions into a radiant intensity limit which may be compared directly with typical component data sheet specifications. For this purpose, the "inverse square law" can be applied, which states that

$$E = I / r^2$$

where E is the irradiance (or radiant exposure) at a source distance r, and I is the radiant intensity. The irradiance corresponding to the AEL and 7 mm diameter measurement aperture, (with an area of $A = 3{,}85 \times 10^{-5}$ m^2) from above is

$$E_{\text{AEL}} = (1{,}18 \times 10^{-3} \text{ W}) / (3{,}85 \times 10^{-5} \text{ m}^2) = 30{,}6 \text{ W·m}^{-2}$$

Note that this equals the MPE from IEC 60825-1, Table 6. In order to determine the appropriate maximum allowable radiant intensity from this irradiance, the above formula for the "inverse square law" can be transformed to be

$$I_{AEL} = E_{AEL}\, r^2$$

Insertion of the above-mentioned measurement distances leads to:

- Class 1 $I_{AELClass\ 1} = 6{,}00\ \text{mW·sr}^{-1}$
- Class 1M $I_{AELClass\ 1M} = 306\ \text{mW·sr}^{-1}$
- Class 3R (5 x Class 1) $I_{AELClass\ 3R} = 30{,}0\ \text{mW·sr}^{-1}$

In most applications that use "IRED-sources," this point source approach will be sufficient. However, in the current example with a radiant intensity of 400 mW·sr $^{-1}$ the Class 1, 1M and 3R limits shown above (which apply for source angular subtense < α_{min}, where α_{min} =1,5 mrad) are exceeded, and the transmitter would be Class 3B. Note that by applying the same considerations used in the examples in A.2, the NHZ is determined to be confined to a small region between 100 mm and 114 mm from the source. From Table 1, Class 3B FSOCS transmitters are only permitted in controlled locations.

Since the analysis above yields a very restrictive condition, it is certainly important to consider the source angular subtense (or apparent size) of the transmitter. Assume here that the source size (which contains 63 % of the total emitted power) is D = 1 mm (this is a typical value for commercially available devices). From a viewing distance of 100 mm, the corresponding angular subtense is α = 0,01 rad. (IEC 60825-1 specifies a distance of 100 mm for the determination of angular subtense).

The above-mentioned small-source-AEL now increases by the factor $C_6 = \alpha / \alpha_{min}$ = 6,67 (α_{min} = 1,5 mrad) for an AEL of 7,87 mW. The corresponding irradiance limit is E_{AEL} = 204 W·m^{-2}. For Classes 1 and 3R, the measurement distance for the 7 mm aperture must also be increased to 32,3 mm (this is specified by the formula in IEC 60825-1, Table 10). The measurement distance applicable for Class 1M remains 100 mm. Again applying the equation above for the maximum allowable radiant intensity yields:

- Class 1: $I_{AELClass\ 1} = 213\ \text{mW·sr}^{-1}$
- Class 1M: $I_{AELClass\ 1M} = 2{,}04\ \text{W·sr}^{-1}$
- Class 3R: $I_{AELClass\ 3R} = 1{,}06\ \text{W·sr}^{-1}$

Comparing these radiant intensities (that apply now for a 10 mrad source angular subtense) with the radiant intensity of the example device (400 mW·sr^{-1}), the device is seen to be Class 1M and actually emits only 20 % of the Class 1M emission limit. The appropriate conditions for such transmitters in unrestricted locations must be observed (see 4.2.1.1). The region of the NHZ-Aided is confined to only a small range between 32,3 mm and 45 mm from the source.

As this example shows, the angular subtense of the source, for wavelengths in the range 400 nm to 1 400 nm, is significant in the determination of the NHZ and NHZ-Aided. Typically, an optical diffuser can be used to increase the source angular subtense unless a well collimated beam is required.

NOTE 1 The "inverse square law" can only be used where the source approximates a point source, i.e. as a "rule of thumb", where the measurement distance to the source is greater than five times the maximum source dimension. Since the measurement distance increases with the source size (following the formulas in IEC 60825-1, Table 10, this condition is always satisfied).

NOTE 2 The above calculation holds especially for ideal Lambertian (or cosine law) sources. In cases where the spatial emission distribution is narrower (half angle smaller than about 30 deg.), a safety factor of 0,5 should be applied to the calculated limits.

A.4 FSOCS link between two restricted locations

Consider the deployment of two widely separated FSOCS terminals in a link as shown in Figure A.1. For the purpose of simplifying this example while illustrating the important principles of this safety standard, let both terminals transmit laser beams with constant irradiance within the beam divergence cones and send no radiation outside the cones. Terminal A is installed in a restricted location. A building window that does not open is in front of terminal A and has a transmission of T_w = 0,3, and for this example, let the reflectivity of the window be 1 – T_w = 0,7. Note that in general, window transmission and reflection characteristics are dependent on wavelength, angle of incidence, number of panes and polarization. The distance from terminal A to terminal B is the link range R_L = 300 m. Terminal B is mounted on a rooftop in a controlled location. There are five locations to consider in this example besides the locations of the terminals:

- the location traversed by the beam from terminal A that partially reflects from the window in front of terminal A;
- the location immediately outside the window in the building where terminal A is located;
- the rooftop of an intermediate building located R_{INT} = 140 m from both terminal A and terminal B that the beam path clears by 2 m vertically;
- an unrestricted building a distance R_S = 50 m beyond terminal B that is in line to receive spillover radiation from terminal A;
- an unrestricted location a distance R_R = 75 m from terminal A that is in line to receive radiation from terminal B that reflects from the window just in front of terminal A.

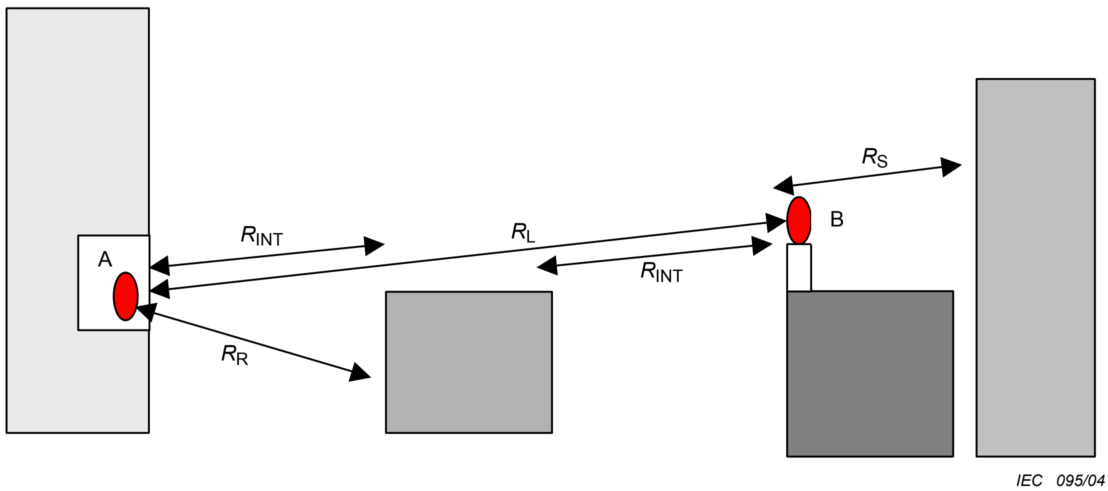


Figure A.1 – Link between two widely separated locations

Characteristics of the transmitters of these terminals are as follows:

Terminal A transmitter:

- Class 1M
- Uniform irradiance distribution within diverging cone
- Beam diameter at transmitter: D_A = 100 mm
- Full axially symmetric beam divergence: ϕ_A = 2 mrad
- Wavelength: λ = 1 550 nm

Terminal B transmitter:

- Class 3B
- Uniform irradiance distribution within diverging cone
- Beam diameter at transmitter: D_B = 10 mm
- Full axially symmetric beam divergence: ϕ_B = 1 mrad
- Wavelength: λ = 1 550 nm

First consider the limits on the transmit power from terminal A imposed by safety limits along the beam path. Since it is a Class 1M device, the emitted beam does not exceed the MPE without optical aids at 1 550 nm. At this wavelength, the unaided MPE is 1 000 W·m^{-2}. The applicable measurement condition for this is that the collected power within a 3,5 mm diameter aperture placed immediately in front of the transmit aperture does not exceed 10 mW. Therefore, the total beam power within the full transmit aperture with uniform irradiance is limited to (D_A / 3,5 mm)^2 × (10 mW) = 8,16 W. Note that for this example the apparent source is located far behind the transmit aperture, on the order of (D_A / ϕ_A) = 50 m, and the measurement aperture is certainly more than 2 m from the apparent source.

Moving along the transmitted beam from terminal A, the beam is partially reflected by the window at the restricted location. In this example, 70 % of the power is reflected back into the restricted location where terminal A is installed and can exceed the MPE with optical aids. Therefore, it is important to note that the restricted location where terminal A is installed must provide adequate means to prevent such reflected beams from passing out of the restricted location and into unrestricted locations. This condition can typically be satisfied by enclosing the restricted location with non-transmitting (or perhaps highly diffusive) partitions. Also, the administrative policy of the operating organisation should be to have entry doors or other passages into unrestricted internal locations normally closed.

The portion of the beam from terminal A that passes through the window enters the space next to the building where terminal A is installed. If this is within 3 m vertically from an unrestricted surface, the emitted beam in this location must not exceed the MPE with optical aids. In this short distance from the transmitter, (for the given divergence of 2 mrad), the enlargement of the beam diameter is negligible, and the maximum beam power just outside the window is limited to (D_A / 25 mm)^2 × (10 mW) = 160 mW. Accounting for the transmission loss of the window, this limits the transmit power from terminal A to (160 mW) / T_w = 530 mW. If instead, the beam traverses a region next to the building just outside the window that is more than 3 m above an unrestricted surface, the region is considered a restricted location. Given that the beam size has not significantly expanded from the transmitter, the maximum beam power is again 8,16 W in this location. Accounting for the transmission loss of the window, this condition limits the transmit power from Terminal A to (8,16 W) / T_w = 27,2 W. In this case, the Class 1M limit of the terminal A transmitter is more restrictive.

The next region for consideration along the terminal A beam path is the intermediate rooftop. If the rooftop is unrestricted, such as a public parking area or observation deck, the beam must not exceed the MPE with optical aids since it is within 3 m vertically of an unrestricted surface. The diameter of the beam at this location is D_A + R_{INT} × ϕ_A = 380 mm. The limit on total beam power at this location, (still using the uniform irradiance assumption), is (380 mm / 25 mm)^2 × (10 mW) = 2,3 W. When accounting for the window loss, the maximum transmit power allowed by this intermediate rooftop constraint is (2,3 W) / T_w = 7,6 W. If instead, the intermediate rooftop is a restricted location, Terminal A could operate at the full Class 1M power.

The beam from terminal A is partially intercepted by the receive aperture of terminal B. Since terminal B is in a controlled location, the received radiation must simply not exceed the MPE without optical aids. Therefore, this does not limit the power from the terminal A Class 1M transmitter.

Spillover radiation from terminal A that is not intercepted by terminal B passes on to an unrestricted location a distance R_s beyond Terminal B. The beam diameter of this partially occluded spillover beam is $D_A + (R_L + R_s) \times \phi_A$ = 800 mm. The limit on total beam power at this location, (assuming for the moment that terminal B is absent), is (800 mm / 25 mm)^2 x (10 mW) = 10,2 W. When accounting for the window loss, the maximum transmit power allowed by this intermediate rooftop constraint is (10,2 W) / T_w = 34 W. Therefore, this constraint does not limit the power of the terminal A Class 1M transmitter.

The preceding analysis shows that the maximum transmit power from terminal A depends on whether the location just outside the window is restricted or unrestricted and whether the intermediate location is restricted or unrestricted. The maximum transmit power from terminal A is 530 mW, 7,6 W, or 8,16 W depending on these criteria.

Now the same kind of analysis is performed for the beam emitted from terminal B. Starting at the transmit aperture, the fact that the terminal is a Class 3B device, and that D_B < 25 mm, means that the beam power is limited to 500 mW.

A condition imposed on Class 3B or Class 4 FSOCS transmitters is that the entire NHZ be monitored to ensure that emitted power is reduced below the unaided MPE if it is intercepted. In this example of a uniform irradiance beam, the extent of the NHZ is determined by finding the distance at which the beam expands to a diameter D_{min} large enough that the MPE is not exceeded, or as a formula: (D_{min} / 3,5 mm)^2 × (10 mW) = 500 mW. Solving for the beam diameter at the NHZ yields D_{min} = 24,7 mm. This diameter can also be expressed in terms of the beam divergence and the range of the NHZ as $D_{min} = D_B + R_{NHZ} \times \phi_B$. Solving this for the NHZ range, we obtain R_{NHZ} = 14,7 m.

Moving further along the Terminal B beam path, the intermediate rooftop is encountered. The diameter of the beam when it reaches this location is $D_B + R_{INT} \times \phi_B$ = 150 mm. The limit on total beam power in the case that this location is unrestricted (still using the uniform irradiance assumption) is (150 mm / 25 mm)^2 × (10 mW) = 360 mW. If instead the intermediate rooftop is restricted, since the intermediate location is beyond the NHZ, the full power from the Class 3B transmitter would be allowed.

The next region of interest along the terminal B beam path is just outside the building where terminal A is installed. The diameter of the beam when it reaches this location is $D_B + R_L \times \phi_B$ = 310 mm. The limit on total beam power in the case that this location is unrestricted is (310 mm / 25 mm)^2 × (10 mW) = 1,53 W. Since this exceeds the maximum power of the Class 3B transmitter, this condition does not restrict the power limit.

The beam from terminal B is then partially transmitted through the window in front of terminal A to be received and is partially reflected by the window towards an unrestricted location a distance R_R away. The diameter of the beam when it reaches this location is $D_B + (R_L + R_R) \times \phi_B$ = 385 mm. The limit on transmitted beam power at this location when accounting for the reflectivity of the window is (385 mm / 25 mm)^2 × (10 mW) / (1 - T_w) = 3,38 W. Again, this exceeds the maximum power of the Class 3B transmitter and is not a concern.

The above analysis shows that the maximum transmit power from terminal B is 500 mW when the intermediate rooftop is a restricted location. In the case that the intermediate location is unrestricted, the maximum transmit power is reduced to 360 mW. Neither the terminal A location nor the destination of the beam reflected from the window in front of terminal A are regions of concern since the beam irradiance is below the MPE with optical aids.

Annex B
(informative)

Methods of hazard/safety analysis

Some methods of hazard/safety analysis are as follows:

a) preliminary hazard analysis (PHA) including circuit analysis. This method may be used in its own right, but is an essential first stage in the application of other methods of hazard/safety assessment;
b) consequence analysis (see IEC 61508);
c) failure modes and effects analysis (FMEA);
d) failure modes, effects and criticality analysis (FMECA) (see IEC 60812);
e) fault tree analysis (FTA);
f) event tree analysis;
g) hazards and operability studies (HAZOPS).

Appropriate testing should be implemented to supplement the analysis whenever necessary. The method of analysis and any assumptions made in the performance of the analysis should be stated by the manufacturer/operator.

Application examples of fault analysis methods are available in Annex D of IEC 60825-2.

Annex C
(informative)

Guidance for installing, servicing and operating organisations

C.1 General working practices for FSOCS

The general working practices detailed in C.1.1 are precautions that should be applied when servicing and installing any FSOCS. In addition, the working practices detailed in C.1.2 should be applied as appropriate.

C.1.1 General working practices

The following practices should be applied when working on any FSOCS:

Alignment	Alignment, installation and testing of the system should be carried out with the system operating at the lowest possible output power, and not exceeding Class 1M or 2M, as appropriate.
Maintenance/operation	Follow only manufacturer-provided instructions for operation and routine maintenance of the system.
Service/installation	Follow only manufacturer-provided instructions for installation and for service and repair on the system. Disable safety features as infrequently as possible. Ensure that safety features are reinstated before the system is put back into normal use.
Cleaning	Use only manufacturer-provided methods for cleaning optical components of the laser system, if allowed at all. This will normally involve disabling the equipment, or at least stopping laser emission.
Modifications	Do not make any unauthorised modifications to any system or associated equipment.
Label damage	Report damaged or missing safety labels to person appointed to maintain equipment.
Key control	For equipment with key control, keys should be placed under the control of a person appointed by management who should ensure their safe use, storage and overall control. Spare keys should be retained under strict control by an authorised person. Authorization is given by the installing or operating organisation as appropriate.
Test equipment	Use only calibrated test equipment, e.g., optical power meters, approved by the operating organisation.
Signs	Erection of additional area warning signs may be appropriate in certain circumstances, e.g., temporary warning signs during service.
Optical fibres	Equipment with optical fibre interfaces or connectors should conform with IEC 60825-2, and the working practices detailed therein should be applied to the part of the equipment using optical fibres.

C.1.2 Additional working practices for Class/access level 1M, 2M, 3R, 3B and 4 systems

If access to Class/access level 1M, 2M, 3R, 3B or 4 optical energy is possible, the following additional practices should be followed.

- All general working practices defined in C.1.1,
- Except for Class/access level 1M or 2M, only trained personnel should have access to the open beam portion of the system,
- Do not stare into laser beams with the naked eye or with any optical aid (unless approved by the installing or operating organisation laser safety officer (LSO) as appropriate), and do not point the laser beam at people,
- Any viewing and alignment aids used should have valid calibration and safety labels, and should be equipped with engineering controls such as filters to prevent exposure to levels above the MPE in the appropriate wavebands,
- Where feasible, alignment and testing should be carried out using Class/access level 1 or 2,
- There should be no instance where exposure to energy in excess of access level 1M, 2M, and 3R is necessary,
- The operating organisation LSO should ensure that applicable and appropriate eye and skin protection is available to installation personnel.

C.2 Education and training

Installation, operating, maintenance and service organisations which might include persons in the vicinity of FSOCS should be notified of hazards through labels, signs and training as appropriate. In addition, persons installing and maintaining Class 3B and 4 transmitters should be informed of at least the following:

a) background information on FSOCS;

b) safety information concerning the laser classification system and access level identification;

c) identification of the biological effects and potential hazards to the eye and skin from laser exposure;

d) procedures that must be followed for safe installation and maintenance of these systems;

e) explanation of possible effects if safety rules are not followed.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following referenced documents are indispensable for the application 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.

NOTE Where an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60825-1	1993	Safety of laser products Part 1: Equipment classification, requirements and user's guide	EN 60825-1 + corr. February	1994 1995
A1	1997		A1	2002
A2	2001		A2 + corr. April	2001 2004
IEC 60825-2	- [1]	Part 2: Safety of optical fibre communication systems	EN 60825-2	2000 [2]

[1] Undated reference.

[2] Valid edition at date of issue.

Bibliography

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

IEC 60812, *Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)*

IEC 61508 (all parts), *Functional safety of electrical /electronic / programmable electronic safety-related systems*

EN 1050, *Safety of machinery – Principles for risk assessment*

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