

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Safety of laser products –
Part 2: Safety of optical fibre communication systems (OFCs)**

**Sécurité des appareils à laser –
Partie 2: Sécurité des systèmes de télécommunications par fibres optiques
(STFO)**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SAFETY OF LASER PRODUCTS –

Part 2: Safety of optical fibre communication systems (OFCs)

FOREWORD

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International Standard IEC 60825-2 has been prepared by IEC technical committee 76: Optical radiation safety and laser equipment.

This fourth edition cancels and replaces the third edition published in 2004, Amendment 1:2006 and Amendment 2:2010. This edition constitutes a technical revision.

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

- a) Recommendations for individual components and subassemblies have been clarified; see Clause 1, paragraph 3.
- b) C_7 has been revised in accordance with IEC 60825-1:2014, but with an additional limitation related to the skin MPE; see 4.7.2.
- c) Condition 2 has been changed, and a detailed description of the measurement and determination method for hazard level has been added; see 4.7.1 and 4.7.2.
- d) Annex B has been moved into 4.9. Annex F has been moved forward as Annex B.
- e) Clause D.4 Hazard level evaluation examples – Additional examples have been added.
- f) Clause D.5 Fault analysis – Explanation and guidance has been simplified.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
76/670/FDIS	76/674/RVD

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

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

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

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

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- withdrawn,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

INTRODUCTION

The objective of this document is to:

- protect people from optical radiation emitted by OFCSs;
- provide requirements for manufacturers, installation organizations, service organizations and operating organizations in order to establish procedures and supply information so that proper precautions can be adopted;
- ensure adequate warnings are provided to individuals regarding the potential hazards associated with OFCSs through the use of signs, labels and instructions.

Annex A gives a more detailed rationale for this document.

The safety of an OFCS depends to a significant degree on the characteristics of the equipment forming that system. Depending on the characteristics of the equipment, relevant safety information needs to be marked on the product or included within the instructions for use.

Where required by the level of potential hazard, the installation organization or end-user / operating organization or both are responsible for the safe deployment and use of OFCSs.

The installation organization and service organization are responsible for adherence to safety instructions during installation and service operations, respectively. The end-user or operating organization is responsible for adherence to safety instructions during operation and maintenance functions.

It is recognized that the user of this document can fall into one or more of the aforementioned categories of manufacturer, installation organization, end-user or operating organization.

SAFETY OF LASER PRODUCTS –

Part 2: Safety of optical fibre communication systems (OFCSs)

1 Scope

This document provides requirements and specific guidance for the safe operation and maintenance of optical fibre communication systems (OFCSs). In these systems, optical power is possibly accessible outside the confines of the transmitting equipment and/or at great distance from the optical source.

This document requires the assessment of hazard level at each accessible location of the OFCS as a replacement for product classification according to IEC 60825-1. It applies to the installed OFCS as an engineered, end-to-end assembly for the generation, transfer and receipt of optical radiation arising from lasers, light-emitting diodes (LEDs) or optical amplifiers, in which the transference is by means of optical fibre for communication and/or control purposes.

NOTE 1 Throughout this document, a reference to 'laser' is taken to include LEDs and optical amplifiers.

Individual components and subassemblies that fall under the definition of a laser product are subject to the applicable subclause(s) of IEC 60825-1. This document is applicable to individual components and subassemblies intended to be installed within OFCSs.

This document does not apply to optical fibre systems primarily designed to transmit optical power for applications such as material processing or medical treatment.

In addition to the hazards resulting from laser radiation, OFCSs possibly give rise to other hazards, such as fire.

This document does not address safety issues associated with explosion or fire with respect to OFCSs deployed in explosive atmospheres.

NOTE 2 The hazard presented by optical radiation emerging from a fibre is determined by the wavelength and power emerging from the fibre and also by the optical characteristics of the fibre itself (see Annex A).

2 Normative references

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

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

3 Terms and definitions

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

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

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

accessible location

part or location within an OFCS at which, under reasonably foreseeable events, human access to laser radiation is possible without the use of a tool

3.2

automatic power reduction

APR

feature of an OFCS whereby the accessible power is reliably reduced to a specified level within a specified time, whenever there is an event which could result in human exposure to radiation

Note 1 to entry: The term "automatic power reduction" (APR) used in this document encompasses the following terms used in ITU-T Recommendation G.664 [1]:

- automatic laser shutdown (ALS);
- automatic power reduction (APR);
- automatic power shutdown (APSD).

Note 2 to entry: The term automatic laser shut off (ALSO) has also been used by some manufacturers in the industry.

Note 3 to entry: A fibre-cable break is an example of an event which could result in human exposure to radiation.

3.3

end-user

person or organization using the OFCS in the manner the system was designed to be used

Note 1 to entry: The end-user cannot necessarily control the power generated and transmitted within the system.

Note 2 to entry: If the person or organization is using the OFCS for a communications application in a manner other than as designed by the manufacturer, then that person/organization assumes the responsibilities defined in this document applicable to a manufacturer or installation organization.

3.4

hazard level

level of potential hazard at any accessible location within an OFCS

Note 1 to entry: It is based on the level of laser radiation which could become accessible in a reasonably foreseeable event, e.g. a fibre cable break. It is closely related to the laser classification procedure defined in 5.3 in IEC 60825-1:2014. The meaning of hazard level is clarified in Annex B.

3.5

hazard level 1

hazard level at which, under a reasonably foreseeable event, human access to laser radiation (accessible emission), evaluated by the measurement conditions for hazard level 1 as defined in 4.7.2 a) and 4.7.3, will not exceed the accessible emission limits of Class 1 in IEC 60825-1 for the applicable wavelength and emission duration, with additional constraints as defined in 4.7.2 a)

Note 1 to entry: "Additional constraints" refers to additional and stricter constraints than 4.7.2 a) of this document places on the values specified in IEC 60825-1:2014 for the accessible emission limits of Class 1 in the wavelength range 1200 nm to 1400 nm.

3.6

hazard level 1M

hazard level at which, under a reasonably foreseeable event, human access to laser radiation (accessible emission), evaluated by the measurement conditions for hazard level 1M as defined in 4.7.2 a) and 4.7.3, will not exceed the accessible emission limits of Class 1 in IEC 60825-1 for the applicable wavelength and emission duration, with additional constraints as defined in 4.7.2 a)

Note 1 to entry: "Additional constraints" refers to additional and stricter constraints than 4.7.2 a) of this document places on the values specified in IEC 60825-1:2014 for the accessible emission limits of Class 1 in the wavelength range 1200 nm to 1400 nm.

3.7

hazard level 2

hazard level at which, under a reasonably foreseeable event, human access to laser radiation (accessible emission), evaluated by the measurement conditions for hazard level 2 as defined in 4.7.2 b) and 4.7.3, will not exceed the accessible emission limits of Class 2 in IEC 60825-1 for the applicable wavelength and emission duration

3.8

hazard level 2M

hazard level at which, under a reasonably foreseeable event, human access to laser radiation (accessible emission), evaluated by the measurement conditions for hazard level 2M as defined in 4.7.2 b) and 4.7.3, will not exceed the accessible emission limits of Class 2 in IEC 60825-1 for the applicable wavelength and emission duration

3.9

hazard level 3R

hazard level at which, under a reasonably foreseeable event, human access to laser radiation (accessible emission), evaluated by the measurement conditions for hazard level 3R as defined in 4.7.2 c) and 4.7.3, will not exceed the accessible emission limits of Class 3R in IEC 60825-1 for the applicable wavelength and emission duration, with additional constraints as defined in 4.7.2 c)

Note 1 to entry: "Additional constraints" refers to additional and stricter constraints than 4.7.2 c) of this document places on the values specified in IEC 60825-1:2014 for the accessible emission limits of Class 3R in the wavelength range 1200 nm to 1400 nm.

3.10

hazard level 3B

hazard level at which, under a reasonably foreseeable event, human access to laser radiation (accessible emission), evaluated by the measurement conditions for hazard level 3B as defined in 4.7.2 d) and 4.7.3, will not exceed the accessible emission limits of Class 3B in IEC 60825-1 for the applicable wavelength and emission duration

3.11

hazard level 4

hazard level at which, under a reasonably foreseeable event, human access to laser radiation (accessible emission), evaluated by the measurement conditions for hazard level 4 as defined in 4.7.2 e) and 4.7.3, will exceed the accessible emission limits of Class 3B in IEC 60825-1 for the applicable wavelength and emission duration

Note 1 to entry: This document is applicable for the operation and maintenance of OFCS. In order to achieve an adequate level of safety for persons who might come into contact with the optical transmission path, hazard level 4 is not permitted within this document. It is permitted to use protection systems, such as automatic power reduction, to achieve the required hazard level where the transmitted power under normal operating conditions (e.g. no fault exists in the fibre path) exceeds that permitted for a particular location type. For instance, it is possible for accessible parts of an OFCS to be hazard level 1 even though the power transmitted down the fibre under normal operating conditions is Class 4.

3.12

installation organization

organization or individual that is responsible for the installation of an OFCS

3.13**controlled location****location with controlled access**

accessible location where an engineering or administrative control is present to make it inaccessible, except to authorized personnel with appropriate laser safety training

Note 1 to entry: For examples, see D.2.1 a).

3.14**restricted location****location with restricted access**

accessible location that is normally inaccessible by the general public by means of any administrative or engineering control measure, but that is accessible to authorized personnel who might not have laser safety training

Note 1 to entry: For examples, see D.2.1 b).

3.15**unrestricted location****location with unrestricted access**

accessible location where there are no measures restricting access to members of the general public

Note 1 to entry: For examples, see D.2.1 c).

3.16**manufacturer**

organization or individual that constructs or modifies OFCSs by assembling or incorporating optical devices and other components

Note 1 to entry: Typical components in OFCSs are shown in D.2.2.

3.17**operating organization**

organization or individual that is responsible for the operation of an OFCS

3.18**optical fibre communication system****OFCS**

engineered, end-to-end assembly for the generation, transfer and reception of optical radiation arising from lasers, LEDs or optical amplifiers, in which the transference is by means of optical fibre for communication and/or control purposes

3.19**reasonably foreseeable event**

event whose occurrence under given circumstances can be predicted fairly accurately, and the occurrence probability or frequency of which is not low or very low

Note 1 to entry: Examples of reasonably foreseeable events might include the following: fibre cable break, optical connector disconnection, operator error or inattention to safe working practices.

Note 2 to entry: Any intentional act to create a hazard is not considered as a reasonably foreseeable event.

3.20**service organization**

organization or individual that is responsible for the servicing of an OFCS

3.21

subassembly

discrete unit, subsystem, network element, or module of an OFCS which contains an optical emitter or optical amplifier

Note 1 to entry: The definition of subassembly is different from that of optical sub-assembly defined in IEC TS 62538 [2].

4 Requirements

4.1 General

Clause 0 defines the restrictions that are to be placed on an OFCS and on the location types in which an OFCS can operate, in accordance with the hazard that arises from optical radiation becoming accessible as a result of a reasonably foreseeable event, such as an open connector or fibre break, etc. Whenever one or more alterations are made to an OFCS, the organization responsible for such alteration(s) shall determine whether each alteration could affect the originally assigned hazard level. If the originally assigned hazard level has changed, the organization responsible for the alteration(s) shall, if necessary, re-label those locations in the system that are accessible so as to ensure continued compliance with this document.

Each accessible location within an OFCS shall be separately assessed to determine the hazard level at that location. Where multiple communications systems are present at a location, the hazard level for the location shall be evaluated by the following methods depending on the types of the fibre cables.

- a) For a conventional loose tube fibre optic cable without ribbon fibre structures, the radiation shall be assessed individually from each of the fibres in a cable, and the maximum radiation from one fibre shall be used as the basis for the hazard level evaluation.
- b) For a ribbon fibre optic cable, the cumulative radiation from one flat ribbon fibre shall be assessed as either an extended source or a point source, as appropriate.

It is noted that there is no need to perform the complete evaluation for extended sources if the simplified point source analysis for the ribbon fibres results in a hazard level acceptable to the operating organization. Additionally, in order to perform the extended source analysis, it is necessary to know the radiation from each individual fibre in the ribbon. If this information is not available then a point source analysis using $C_6 = 1$ is applied.

Based on the determined hazard level, appropriate actions shall be taken to ensure compliance with this document. These actions could for example involve restriction of access to the location, or the implementation of additional safety features or redesign of the optical communications system to reduce the hazard level.

Visual observation of fibre tips using magnifying optics should be avoided in situations where there is potential for optical emission from the fibre.

Electric power transmitting cables comprising OFCSs with optical fibre cables defined in the IEC 60794-4 series [3]¹ shall meet the requirements of any applicable electrical standard besides this document.

4.2 Protective housing of OFCS

Each OFCS shall have a protective housing which, when in place, prevents human access to laser radiation in excess of hazard level 1 limits under normal operating conditions.

¹ Numbers in square brackets refer to the Bibliography.

4.3 Fibre cables

For all hazard levels, the fibre optic cable shall have mechanical properties appropriate to its physical location. Cables for various physical locations are described in the IEC 60794-2 series [4], IEC 60794-3 series [5] and IEC 60794-4 series [3]. Where necessary, additional protection, for example ducting, conduit or raceway, might be required for locations where the fibre would otherwise be susceptible to damage. Even if the potential hazard at any accessible location within an OFCS is the lowest hazard level, the mechanical properties need to be considered as optical power in fibre cable can exceed the MPE.

4.4 Cable connectors

4.4.1 General

The following requirements for cable connectors can be achieved by the mechanical design of the connectors, or by the positioning of the connector, or by any other suitable means. Whichever means is chosen, human access to radiation above that permitted for connectors in a particular location type shall be prevented.

Hazard level is required to be assigned more strictly for connectors than that for fibre cables. For example in an unrestricted location, accessible radiation level is allowed up to hazard level 1M for cables whereas the accessible radiation from an optical connector is limited to hazard level 1.

NOTE The use of a tool for disconnection is one example of a mechanical solution.

4.4.2 Unrestricted locations

In unrestricted locations,

- if the accessible radiation level exceeds hazard level 2 within the wavelength range 400 nm to 700 nm, then suitable means shall limit access to the radiation exceeding hazard level 2 from the connector,
- if the accessible radiation level exceeds hazard level 1 in all other cases, then suitable means shall limit access to the radiation exceeding hazard level 1 from the connector.

NOTE In an unrestricted location the highest hazard levels are hazard level 2M for the wavelength range 400 nm to 700 nm and hazard level 1M in all other cases (see 4.9.2).

4.4.3 Restricted locations

In restricted locations,

- if the accessible radiation level exceeds hazard level 2M within the wavelength range 400 nm to 700 nm, then suitable means shall limit access to the radiation exceeding hazard level 2M from the connector,
- if the accessible radiation level exceeds hazard level 1M in all other cases, then suitable means shall limit access to the radiation exceeding hazard level 1M from the connector.

NOTE In a restricted location the highest hazard level is hazard level 1M, 2M or 3R, whichever is the higher (see 4.9.3).

4.4.4 Controlled locations

In controlled locations,

- if the accessible radiation level exceeds hazard level 2M within the wavelength range 400 nm to 700 nm, then suitable means shall limit access to the radiation exceeding hazard level 2M from the connector,
- if the accessible radiation level exceeds hazard level 1M in all other cases, then suitable means shall limit access to the radiation exceeding hazard level 1M from the connector.

NOTE In a controlled location the highest hazard level is hazard level 3B (see 4.9.4).

4.5 Labelling and marking

4.5.1 General requirements

Where required by 4.5, each optical connector, splice box or other part emitting radiation when opened, shall be marked (e.g. with a label, sleeve, tag, tape, etc.), if the hazard level at the location is in excess of hazard level 1. The information shall consist of the information identified in Table 1, Table 2 or Table 3, as applicable.

Where the accessible radiation at points of disconnection is hazard level 1 or hazard level 1M, it is permitted for the above information to be provided in information for the user instead of as a marking on the product.

Labelling of hazard level 1M is permitted but not mandatory since it is only in restricted or controlled locations that the connector outputs assigned as hazard level 1M are allowed and only appropriately trained technical staff are allowed to work in such locations.

Markings shall be coloured black on a yellow background. Labels reproduced in the documentation provided by the manufacturer or by the operating organization are permitted to be black on a white background.

It is acceptable to reduce the marking in size, provided that the result is legible. All hazard level labelling is the responsibility of the installation organization or end-user / operating organization, including the labelling of subassemblies containing lasers or optical amplifiers. This is because hazard level is a feature of the (end-to-end) OFCS, and might therefore depend on system wide features such as APR, etc.

Except for the case of subassemblies used for stand-alone applications, each optical connector, splice box or other part that is intended to permit access to optical radiation when opened shall be marked (e.g. with a label, sleeve, tag, tape, etc.) in accordance with Table 1, Table 2 or Table 3, as applicable.

Subassemblies used for stand-alone applications shall be allocated a class and marked according to IEC 60825-1.

Subassemblies that are installed as part of an OFCS shall be allocated a hazard level and marked according to this document.

Table 1 – Marking in unrestricted locations

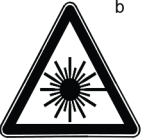
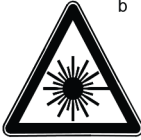
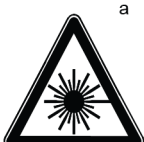
Accessible hazard level	Required marking – Unrestricted location
1	No marking required
1M	No marking required ^a
2	 ^b CAUTION HAZARD LEVEL 2 LASER RADIATION DO NOT STARE INTO BEAM ^{c d e} <i>IEC</i>
2M	 ^b CAUTION HAZARD LEVEL 2M LASER RADIATION DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH NON-ATTENUATING OPTICAL INSTRUMENTS ^{c d e} <i>IEC</i>
3R	Not permitted
3B	Not permitted
NOTE See 4.5.5 regarding invisible laser beam hazards.	
^a 4.4.2 requires access to radiation from a connector to be limited to hazard level 1 by suitable means, and the mechanical design of the fibre cables is consistent with the relevant parts of IEC 60794 [3], [4], [5] (see 4.3) . Therefore, hazard level 1M is exempt from marking requirements. ^b Hazard symbol warning label according to Figure 3 of IEC 60825-1:2014. ^c Where the source of the radiation is a light emitting diode, the word "LASER" above shall be replaced by "LED". ^d Replacing the word "RADIATION" with "LIGHT" for radiation in the range 400 nm to 700 nm is optional. ^e Explanatory label (outline) according to Figure 4 of IEC 60825-1:2014. It is permitted for this outline to also encompass the hazard symbol according to Figure 3 of IEC 60825-1:2014.	

Table 2 – Marking in restricted locations

Accessible hazard level	Required marking – Restricted location
1	No marking required
1M	Marking required only for those cases where the requirements for cable connectors in unrestricted locations are not met (see 4.4.2): ^e
	 ^a CAUTION HAZARD LEVEL 1M LASER RADIATION DO NOT VIEW DIRECTLY WITH NON-ATTENUATING OPTICAL INSTRUMENTS ^{b c d} IEC
2	 ^a CAUTION HAZARD LEVEL 2 LASER RADIATION DO NOT STARE INTO BEAM ^{b c d} IEC
2M	 ^a CAUTION HAZARD LEVEL 2M LASER RADIATION DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH NON-ATTENUATING OPTICAL INSTRUMENTS ^{b c d} IEC
3R	 ^a CAUTION HAZARD LEVEL 3R LASER RADIATION AVOID DIRECT EYE EXPOSURE ^{b c d} IEC
3B	Not permitted.
NOTE See 4.5.5 regarding invisible laser beam hazards.	
^a Warning label according to Figure 3 of IEC 60825-1:2014. ^b Where the source of the radiation is a light emitting diode, the word "LASER" above shall be replaced by "LED". ^c If the radiation is in the range 400 nm to 700 nm it is optional to replace the word "RADIATION" with "LIGHT". ^d Explanatory label (outline) according to Figure 4 of IEC 60825-1:2014. It is permitted for this outline to also encompass the hazard symbol according to Figure 3 of IEC 60825-1:2014. ^e Where the accessible radiation at points of disconnection is hazard level 1 or hazard level 1M, it is permitted for this to be noted in information for the user instead of as a marking on, for example, the product, fibre or connector.	

Table 3 – Marking in controlled locations

Accessible hazard level	Required marking – Controlled location	
1	No marking required	
1M	No marking required ^e	
2		CAUTION HAZARD LEVEL 2 LASER RADIATION DO NOT STARE INTO BEAM b c d IEC
2M		CAUTION HAZARD LEVEL 2M LASER RADIATION DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH NON-ATTENUATING OPTICAL INSTRUMENTS b c d IEC
3R		CAUTION HAZARD LEVEL 3R LASER RADIATION AVOID DIRECT EYE EXPOSURE b c d IEC
3B		CAUTION HAZARD LEVEL 3B LASER RADIATION AVOID EXPOSURE TO BEAM b c d IEC
NOTE See 4.5.5 regarding invisible laser beam hazards.		
^a Warning label according to Figure 3 of IEC 60825-1:2014. ^b Where the source of the radiation is a light emitting diode, the word "LASER" above shall be replaced by "LED". ^c If the radiation is in the range 400 nm to 700 nm it is optional to replace the word "RADIATION" with "LIGHT". ^d Explanatory label (outline) according to Figure 4 of IEC 60825-1:2014. It is permitted for this outline to also encompass the hazard symbol according to Figure 3 of IEC 60825-1:2014. ^e It is recommended but not required to identify those connectors having an optical output by using the warning label according to Figure 3 of IEC 60825-1:2014.		

4.5.2 Marking of connectors of optical transmitters and optical amplifiers

For connectors of optical transmitters and optical amplifiers in each of which an optical port (optical connector) can be connected to an optical fibre, the requirements of 4.5.1 are modified as below. The same applies to a group of optical ports (optical connectors), see 4.5.3.

If 4.5.1 requires a marking to be provided, then the wavelength range shall be added to the information already required by Table 1, Table 2 or Table 3. Preferred values of wavelength ranges are:

- 400 nm to 700 nm;
- 700 nm to 1 150 nm;
- 1 200 nm to 1 250 nm;
- 1 400 nm to 1 600 nm.

From 1 150 nm to 1 200 nm and from 1 250 nm to 1 400 nm, the exact wavelength shall be marked.

NOTE 1 From 1 150 nm to 1 200 nm and from 1 250 nm to 1 400 nm, the value of C_7 (and hence the value of the respective AEL) increases significantly with wavelength (see IEC 60825-1:2014).

NOTE 2 The above are examples of wavelength ranges: the actual wavelength range of operation is included in the marking, e.g. 1 300 nm to 1 600 nm.

Input ports of, for example, Raman Amplifiers are also to be labelled accordingly so as to prove a warning that hazardous levels of optical radiation can be emitted from such ports.

4.5.3 Markings for groups of connectors

Groups of connectors such as patch panels may be marked as a group, with just a single clearly visible hazard level marking rather than having each connector individually marked. If a group of connectors is enclosed within a housing and it is a foreseeable event that exposure to optical radiation above hazard level 1M could result from accessing the connectors in that housing, then a marking shall be clearly visible both before and after the housing is opened. This might require the use of more than one marking.

4.5.4 Durability – Indelibility requirements for safety markings

Any marking required by this document shall be durable and legible. In considering the durability of the marking, the effect of normal use shall be taken into account.

NOTE The requirement and test for durability are contained in 1.7.11 of IEC 60950-1:2005 [6] and IEC 62368-1 [7].

4.5.5 Warning for invisible radiation

If the output of the laser is outside the wavelength range 400 nm to 700 nm, the wording 'LASER RADIATION' in the labels in Table 1, Table 2 or Table 3 shall be modified to read 'INVISIBLE LASER RADIATION', or if the output is at wavelengths both inside and outside this wavelength range, to read 'VISIBLE AND INVISIBLE LASER RADIATION'. If a product is classified on the basis of the level of visible laser radiation and also emits in excess of the AEL of Class 1 at invisible wavelengths, the label shall include the words 'VISIBLE AND INVISIBLE LASER RADIATION' in lieu of 'LASER RADIATION'.

4.6 Organizational requirements

4.6.1 Manufacturers of ready-to-use OFCSs or turnkey systems

Manufacturers of OFCSs or turnkey end-to-end systems shall:

- a) ensure that the equipment satisfies the applicable requirements of this document;
- b) provide the following information:
 - 1) adequate description of the engineering design features incorporated into the product to prevent exposure to radiation above the MPE values;
 - 2) adequate instructions for proper assembly, maintenance and safe use including clear warnings concerning precautions to avoid possible exposure to radiation above the MPE values;

- 3) adequate instructions to installation organizations and service organizations to ensure the product can be installed and serviced in such a manner that the radiation accessible under reasonably foreseeable events meets the requirements of Clause 0;
- 4) the hazard levels at accessible locations within the system and the parameters upon which those hazard levels are based;
- 5) for systems with APR:
 - the reaction time and operating parameters of the APR;
 - where installation or service requires overriding an APR, information shall be included to enable the operating organization to specify safe work practices while the APR is overridden and safe procedures for reinstating and testing such systems;
 - if a manual initiated restart temporarily inactivates the APR, the timing of the restart shall be stated clearly in the user manual;
 - all scenarios (e.g. removal or failure of a controller or other element) where the APR would not be operable including appropriate precautions that need to be taken under such conditions.
- 6) any other information relevant to the safe use of the OFCS;
- 7) a statement that the equipment shall be installed according to the manufacturer's instructions, including the warning "CAUTION: Use of controls or adjustments or performance of procedures other than those specified herein might result in hazardous radiation exposure."

4.6.2 Installation and service organization

The organization responsible for the installation and servicing of OFCS shall follow the manufacturer's instructions for installation of equipment in a manner that will ensure that the accessible radiation under reasonably foreseeable events satisfies the requirements of Clause 4.

Before placing an OFCS into service, the installation organization or service organization, as applicable, shall ensure that APR, if used, is in appropriate working condition as designated in 4.7.3, 4.7.4, 4.7.5 and 4.8.

For systems with accessible locations other than hazard level 1 or 2, the installation organization and/or the service organization shall:

- a) provide adequate laser safety training of personnel responsible for carrying out installation and service activities;
- b) ensure that suitable access controls and warning labels are employed on controlled and restricted locations.

4.6.3 Operating organization

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

- a) identification of the location type at all accessible locations of the entire OFCS;
- b) ensuring that the hazard levels are not exceeded for those location types under reasonably foreseeable events;
- c) ensuring that installation and service is performed only by organizations with the capability of satisfying the requirements of 4.2 to 4.9;
- d) ensuring that access to restricted and controlled locations is appropriately addressed with respect to laser safety;
- e) ensuring continuous compliance with system manufacturing, operating, installation, service and safety requirements.

NOTE Guidance for service and maintenance is described in Annex E.

4.7 Assessment of hazard level

4.7.1 Determination of hazard level and the use of Condition 2

The hazard level is determined by the measurement of the optical radiation that could become accessible following any reasonably foreseeable event (e.g. fibre break) during operation and maintenance. The methods for the determination of compliance with the specified radiation limit values for Condition 2 are used as specified in Table 4 and 4.7.2 in addition to Conditions 1 and 3 that are the same as those described for classification in IEC 60825-1.

For all wavelengths, refer to Table 4 to establish the hazard levels.

Table 4 – Measurement aperture diameters and distances for the default (simplified) evaluation

Wavelength	Condition 1		Condition 2 ^a		Condition 3	
	applies to collimated beams where, for example, use of a telescope or binoculars increases the hazard		applies to divergent beams where, for example, eye loupes or high power magnifiers increases the hazard		applies to naked eye viewing or viewing with low power magnifiers	
	Aperture stop	Distance	Aperture stop	Distance	Aperture stop/limiting aperture	Distance
nm	mm	mm	mm	mm	mm	mm
< 302,5	–	–	–	–	See IEC 60825-1	See IEC 60825-1
≥ 302,5 to 400	See IEC 60825-1	See IEC 60825-1	3,5	35	See IEC 60825-1	See IEC 60825-1
≥ 400 to 1 400	See IEC 60825-1	See IEC 60825-1	3,5	35	See IEC 60825-1	See IEC 60825-1
≥ 1 400 to 4 000	See IEC 60825-1	See IEC 60825-1	3,5	14	See IEC 60825-1	See IEC 60825-1
≥ 4 000 to 10 ⁵	–	–	–	–	See IEC 60825-1	See IEC 60825-1
≥ 10 ⁵ to 10 ⁶	–	–	–	–	See IEC 60825-1	See IEC 60825-1
Limitations of the classification scheme are discussed in Clause C.3 of IEC 60825-1:2014, suggesting cases where additional risk analysis and warnings might be appropriate.						
NOTE The descriptions below the "Condition" headings are typical cases for information only and are not intended to be exclusive.						
^a The definition of Condition 2 in this table is modelled on ×7 and ×18 magnifying optics for the wavelength ranges of 302,5 nm to 1 400 nm and 1 400 nm to 4 000 nm, respectively. This is represented by a 3,5 mm aperture stop at a distance of 35 mm or 14 mm from the end of the fibre. The aperture stop diameter of 3,5 mm (rather than 7 mm) is used because a magnifying optics would only be used in a situation where there is sufficient light, and thus the pupil would be constricted. Also note that when multimode fibres having large core diameters are used for OFCSs, the mitigating effect of the large angular subtense is considered.						

4.7.2 Hazard level assignment of OFCS

a) Hazard level 1 and 1M

For wavelengths less than 302,5 nm and greater than 4 000 nm, if the accessible emission is

- less than or equal to the AEL of Class 1 for Condition 3, then the OFCS is assigned to hazard level 1.

For wavelengths between 302,5 nm and 4 000 nm, if the accessible emission is

- less than or equal to the AEL of Class 1 for Condition 1, and Condition 2 and Condition 3, then the OFCS is assigned to hazard level 1;
- otherwise, if the accessible emission is
 - greater than the AEL of Class 1 for Condition 1 or Condition 2, and
 - less than the AEL of Class 3B for Condition 1 and Condition 2, and
 - less than or equal to the AEL of Class 1 for Condition 3,then the OFCS is assigned to hazard level 1M.

NOTE 1 AEL is defined in IEC 60825-1:2014, 3.3.

NOTE 2 Typically, the accessible emission of hazard level 1M exceeds the Class 1 AEL for either Condition 1 or Condition 2. However, it is also classified as hazard level 1M when it exceeds that AEL for both Condition 1 and Condition 2.

NOTE 3 The reason for verifying the AEL of Class 3B is to limit the maximum power passing through an optical instrument.

For wavelengths between 1 200 nm and 1 400 nm, the AEL of Class 1 shall be limited to the equivalent radiant power corresponding to the skin MPE evaluated with a 3,5 mm diameter aperture (see D.4.1).

NOTE 4 The above-mentioned check on the skin MPE is additional to, and stricter than, the test on the Class 3B AEL specified in footnotes d) and f) to Tables 3 and 4 of IEC 60825-1:2014, respectively.

NOTE 5 The rationale for the skin MPE limit is based on the following footnote in Tables A.1 to A.4 of IEC 60825-1:2014: "In the wavelength range between 1 250 nm and 1 400 nm, the limits to protect the retina given in this table might not adequately protect the anterior part of the eye (cornea, iris) and caution needs to be exercised. There is no concern for the anterior parts of the eye if the exposure does not exceed the skin MPE values". The values of the skin MPE are shown in Table A.5 of IEC 60825-1:2014.

For all wavelengths, in hazard levels 1 and 1M, the accessible emission determined with a 3,5 mm diameter aperture placed at the fibre tip shall not exceed the AEL of Class 3B.

NOTE 6 It is possible that a Class 1M laser product with a highly diverging beam can produce high enough irradiance levels near to or in contact with the source (for instance a fibre tip) so that skin injury is possible.

b) Hazard level 2 and 2M

Hazard Level 2 and 2M are applicable to the wavelength range of 400 nm to 700 nm. If the accessible emission exceeds the limits as required for Class 1 and for Class 1M, and is

- less than or equal to the AEL of Class 2 for Condition 1, and Condition 2 and Condition 3, then the OFCS is assigned to hazard level 2.

If the accessible emission exceeds the limits as required for Class 1 and for Class 1M and is

- greater than the AEL of Class 2 for Condition 1 or Condition 2, and
- less than the AEL of Class 3B for Condition 1 and Condition 2, and
- less than or equal to the AEL of Class 2 for Condition 3,

then the OFCS is assigned to hazard level 2M.

NOTE 7 Typically, the accessible emission of hazard level 2M exceeds the AEL of Class 2 for either Condition 1 or Condition 2. However, it is also classified as hazard level 2M when it exceeds the AEL of Class 2 for both Conditions 1 and Condition 2.

NOTE 8 The reason for verifying the AEL of Class 3B is to limit the maximum power passing through an optical instrument, and to preclude high irradiance levels near to or in contact with diverging sources so as not to lead to skin injury.

In hazard levels 2 and 2M, the accessible emission determined with a 3,5 mm diameter aperture placed at the fibre tip shall not exceed the AEL of Class 3B.

NOTE 9 It is possible that a Class 2M laser product with a highly diverging beam can produce high enough irradiance levels near to or in contact with the source (for instance, a fibre tip) so that skin injury is possible.

c) Hazard level 3R

For wavelengths less than 302,5 nm and greater than or equal to 4 000 nm, if the accessible emission for Condition 3

- is less than or equal to the AEL of Class 3R, and
- exceeds the AEL of Class 1,

then the OFCS is assigned to hazard level 3R.

For wavelengths greater than or equal to 302,5 nm and less than 4 000 nm, if the accessible emission

- is less than or equal to the AEL of Class 3R for Condition 1, and Condition 2 and Condition 3, and
- exceeds the AEL for Class 1 and Class 2 for Condition 3,

then the OFCS is assigned to hazard level 3R.

For wavelengths between 1 200 nm and 1 400 nm, the AEL of Class 3R shall be limited to the equivalent radiant power corresponding to five times the skin MPE evaluated with a 3,5 mm diameter aperture.

NOTE 10 The above-mentioned check on the five times the skin MPE is additional to, and stricter than, the test on the Class 3B AEL specified in footnotes d) and c) to Tables 6 and 7 of IEC 60825-1:2014, respectively.

NOTE 11 See D.4.1.

For all wavelengths, in hazard level 3R, the accessible emission determined with a 3,5 mm diameter aperture placed at the fibre tip shall not exceed the AEL of Class 3B.

d) Hazard level 3B

For wavelengths less than 302,5 nm and greater than or equal to 4 000 nm, if the accessible emission for Condition 3

- is less than or equal to the AEL of Class 3B, and
- exceeds the AEL of Class 3R,

then the OFCS is assigned to hazard level 3B.

For wavelengths greater than or equal to 302,5 nm and less than 4 000 nm, if the accessible emission

- is less than or equal to the AEL of Class 3B for Condition 1, and Condition 2 and Condition 3, and
- exceeds the AEL for Class 3R for Condition 1, or Condition 2 or Condition 3, and
- exceeds the AEL for Class 1 and Class 2 for Condition 3,

then the OFCS is assigned to hazard level 3B.

For all wavelengths, in hazard levels 3B, the accessible emission determined with a 3,5 mm diameter aperture placed at the fibre tip shall not exceed the AEL of Class 3B.

e) Hazard level 4

If the total accessible emission from the fibre end (or measured with a 3,5 mm diameter aperture placed at the fibre tip) exceeds the AEL for Class 3B, the OFCS is assigned to hazard level 4.

4.7.3 Additional requirements applicable to all hazard levels

The assessment of the hazard level with and without automatic power reduction shall take place:

- 1 s after the reasonably foreseeable event (e.g. fibre break) for unrestricted locations, unless measurement at a later time would result in a larger exposure;
- 3 s after the reasonably foreseeable event for restricted and controlled locations, unless measurement at a later time would result in a larger exposure.

In circumstances where it is difficult to carry out direct measurements, an assessment of hazard level based on calculations is acceptable. For example, the knowledge of the laser or amplifier power and fibre attenuation can allow an assessment of the hazard at any particular location.

For OFCS with automatic power reduction, the hazard level will be determined by the accessible emission (pulse or continuous wave) after the time interval given above (1 s for unrestricted locations, 3 s for restricted locations or controlled locations). Additionally, the MPE requirement in 4.7.4 shall be met.

NOTE 1 The level of exposure is determined at a location where it is reasonably foreseeable that a person could be exposed to radiation coming from the OFCS. If the OFCS incorporates an APR system, the exposure level is kept to a level that does not exceed the MPE value, which in this case is determined by considering the full period to complete the APR system as specified in 4.7.4.

NOTE 2 MPEs for the eye and the skin of employees in the workplace and the general public are in many countries specified in national laws. These legally-binding national exposure limits might differ from and override the MPEs given in the informative Annex A of IEC 60825-1:2014.

4.7.4 Requirements for transient accessible exposures when using APR

An OFCS uses an automatic power reduction feature so as to meet the limits of a hazard level that is lower than that which would have to be assigned if no automatic power reduction feature were present. During the maximum time to reach the lower hazard level specified in 4.7.1, which is not greater than 1 s for unrestricted locations, 3 s for restricted or controlled locations, the irradiance or radiant exposure shall not exceed their limits for either the eye or skin (equivalent to MPEs for the eye and skin), corresponding to the shutdown period of the APR. For unrestricted/restricted locations and controlled locations the measurement distances are 100 mm and 250 mm, respectively, for 4.7.4 only.

NOTE 1 If the shutdown period of the APR is larger than 1 s for unrestricted locations, or 3 s for restricted/controlled locations, then the above MPE evaluations are conducted for the exposure time of 1 s for unrestricted locations or that of 3 s for restricted/controlled locations.

NOTE 2 See also Clause D.7.

4.7.5 Conditions for tests and assessment

Tests and assessments shall be carried out under reasonably foreseeable fault conditions.

In some complex systems (e.g. where the optical output is dependent on the integrity of other components and the performance of circuit design and software), other recognized methods for hazard/safety assessment may be used where necessary (see Annex C).

However, faults which result in the emission of radiation in excess of the hazard level need not be considered if:

- it is a fault that relates only to a limited time period during which the level of the radiation exceeds the hazard level; and
- it is not reasonably foreseeable that human access to the radiation will occur before the product is taken out of service.

NOTE When applying the relevant MPE requirement in 4.7 in relation to a beam exiting, e.g. a broken fibre-end or un-made connector, two questions are important:

- a) Is it reasonably foreseeable that a person's eye could be exposed to the beam?
- b) Is it reasonably foreseeable that a person's skin could be irradiated by the beam?

When determining what is reasonably foreseeable, consideration is given to the physical location of the beam exit point, the distance between the exit point and the eye or skin, and the time taken for the APR to reduce the exposure to the level required by 4.9.

Even if naked eye or skin exposure is not reasonably foreseeable, the possibility of fire hazard is also to be considered.

4.8 Automatic power reduction (APR)

4.8.1 General

If an OFCS makes use of an automatic power reduction (APR) function in order to meet its required hazard level, then the restart function shall operate according to restrictions which are described in 4.8.2, 4.8.3 or 4.8.4, as applicable. In addition, the APR shall be designed to have an adequate level of reliability.

NOTE 1 Examples of calculating the reliability of APR systems are given in Clause D.5.

NOTE 2 The restart interval described in the following scenarios is wavelength dependent.

NOTE 3 For further information on APR, see ITU-T Recommendation G.664 [1].

4.8.2 Automatic restart

In the case where the restart is initiated automatically, the timing and optical power of the restart process shall be restricted such that the hazard level assigned to each accessible location of the system shall not be exceeded.

4.8.3 Manual restart with assured continuity

In the case where the restart is initiated manually and the continuity of the communications path is assured by the use of administrative controls or other means, the timing and optical power of the restart process is not restricted.

NOTE Since in this case the timing and optical power of the restart process is not restricted, the administrative or other controls will need to take into consideration any increased risk of new hazards (such as fire). It is important that these additional controls be documented in the appropriate service instructions.

The manufacturer's instructions shall specify that administrative controls (or other means) shall take into account that the assigned hazard level at any accessible location might be exceeded during this restart procedure.

4.8.4 Manual restart without assured continuity

In the case where the restart is initiated manually and the continuity of the communications path is not assured, the timing and optical power of the restart process shall be restricted such that the hazard level assigned to each accessible location of the system is not exceeded.

4.8.5 Disabling of the APR

If a manual initiated reboot of the system temporarily deactivates the APR, the system shall indicate that the APR is not operable for the duration of the reboot so that the operating organization can take the appropriate precautions. Unless these conditions are met, the hazard level shall be assigned using the transmitting power level assuming that the APR is not in place.

Disabling of the APR mechanism shall not be permitted for Class 3B and 4 transmitting powers, unless all of the conditions are met:

- a) such disabling is necessary only for the infrequent incidences of system installation and service;
- b) such disabling can only be done via suitably reliable software commands or a manual lockout key system;

NOTE 1 For software reliability issues see the IEC 61508 series [8].

- c) if disabling is done via software commands, incorporated in such software is a security system that prevents inadvertent disabling of the APR mechanism;
- d) such software incorporates a warning indicator that the APR will be disabled if the procedure is continued;

- e) continuous operation of the traffic-carrying OFCS with the APR disabled is prevented by suitable engineering means;

NOTE 2 Regarding condition e), an example of a 'suitable engineering means' is a control system that automatically re-enables the APR as soon as practicable after a time interval that is long enough to complete the task that caused the APR to be initially deactivated.

- f) proper instructions on the safe use of the equipment with the disabled APR are included in the documentation;
- g) it is not possible to disable the APR permanently – the APR is automatically re-enabled (see also NOTE 2 in 4.8.5 e);
- h) it is only possible to disable the APR by action taken locally at the transmitting equipment (i.e. remote disabling of the APR is not normally permitted), except when in direct communication with persons (possibly at remote locations) likely to be exposed to higher levels of radiation than before the APR is disabled;

NOTE 3 Raman systems usually emit high power from the receive termination.

- i) a clear and unambiguous warning is displayed continuously while the APR remains disabled;
- j) high power systems with APR disabled are rebooted only by means of manual start-up or manual re-start.

It is recognized that long-distance transmission systems (by their very nature) commonly use high powers to ensure continuity. Therefore, it is permitted to use high powers (Class 4) at initial system start-up, provided this is done by trained personnel under defined conditions.

An administrative organization shall make effort to ensure system continuity [e.g. optical time domain reflectometry (OTDR) continuity test] and to ensure personnel are not exposed to Class 3B or Class 4 radiation. This can also be done by rigorous administrative controls.

Except where otherwise explicitly stated, this document does not permit end-to-end OFCS to operate if accessible locations within that system are hazard level 4.

NOTE 4 If the transmitting power of a transmitter, amplifier, etc. is Class 4 and the APR has been disabled, then the result would be accessible locations operating at hazard level 4. Nevertheless, it is recognized that sometimes it is necessary to disable the APR in certain conditions, but these conditions are well controlled and time-limited so that the probability of exposure to Class 4 radiation is very low.

NOTE 5 One hour is a suitable time after which the APR is re-enabled, either manually or automatically.

4.9 Hazard level requirements by location type

4.9.1 General

The required hazard level shall be determined for each accessible location within an OFCS.

NOTE 1 This includes access to optical fibres that can become broken.

NOTE 2 This document is applicable for the operation and maintenance of OFCS. Where systems employ normal transmitting power levels exceeding the acceptable hazard level for the particular location type, the use of protection systems such as automatic power reduction determines the actual hazard level.

Table 5 shows the summary of location types in OFCS.

4.9.2 Unrestricted locations

At a location with unrestricted access the hazard level shall be 1, 1M, 2 or 2M.

NOTE If the applicable limit of hazard level 1M is larger than the limit of hazard level 2 and less than the limit of hazard level 3B, hazard level 1M is allocated (see the definition of hazard level 1M in 4.7.2 a)).

4.9.3 Restricted locations

At a location with restricted access the hazard level shall be 1, 1M, 2, 2M or 3R.

NOTE 1 If the applicable limit of hazard level 1M or 2M is larger than the limit of hazard level 3R and less than the limit of hazard level 3B, hazard level 1M or 2M is allocated, respectively (see the definitions of hazard level 1M and 2M in 4.7.2 a) and b), respectively).

NOTE 2 If the applicable limit of hazard level 1M is larger than the limit of hazard level 2 and less than the limit of hazard level 3B, hazard level 1M is allocated (see the definition of hazard level 1M in 4.7.2 a)).

4.9.4 Controlled locations

At a location with controlled access the hazard level shall be 1, 1M, 2, 2M, 3R or 3B.

Table 5 – Summary of requirements for location types in OFCS

Hazard level	Location type		
	Unrestricted	Restricted	Controlled
1	No requirements	No requirements	No requirements
1M	Hazard level 1 for output power from connectors that can be opened by an end-user ^a No labelling or marking required ^b	No labelling or marking required if output power from connectors that can be opened by end-user are hazard level 1. If output is hazard level 1M then labelling or marking is required ^b	No requirements
2	Labelling or marking ^b	Labelling or marking ^b	Labelling or marking ^b
2M	Labelling or marking ^b , and hazard level 2 from connector ^a	Labelling or marking ^b	Labelling or marking ^b
3R	Not permitted ^c	Labelling or marking ^b , and hazard level 1M or 2M from connector ^a	Labelling or marking ^b , and hazard level 1M or 2M from connector ^a
3B	Not permitted ^c	Not permitted ^c	Labelling or marking ^b , and hazard level 1M or 2M from connector ^a
4	Not permitted ^c	Not permitted ^c	Not permitted ^c
^a See 4.4. ^b See 4.5. ^c Where systems employ normal transmitting power levels exceeding the acceptable hazard level for the particular location type (see 4.9), protection systems such as automatic power reduction may be used to determine the actual hazard level. See 4.7.2 and 4.8.			

Annex A (informative)

Rationale

The safety of laser products, equipment classification, requirements and user's guide are covered by IEC 60825-1 and IEC TR 60825-14 [9]. IEC 60825-1 is primarily aimed at self-contained products which are under effective local control. An OFCS will be safe under normal operating conditions because the optical radiation is totally enclosed under intended operation. However, because of the extended nature of these systems (where optical power, under certain conditions, might be accessible many kilometres from the optical source), the precautions to minimize the hazard will be different from those concerning laser sources which are normally under local operator control. It should be noted that many OFCSs contain LEDs, which are excluded from the scope of IEC 60825-1.

The potential hazard of an OFCS depends on the likelihood of the protective housing being breached (e.g. a disconnected fibre connector or a broken cable) and on the nature of the optical radiation that might subsequently become accessible. The engineering requirements and user precautions that are required to minimize the hazard are specified in this document.

Each accessible location within an OFCS is allocated, by the system operating organization or its delegate, a hazard level that gives a guide as to the potential hazard if optical radiation becomes accessible. These hazard levels are described as hazard levels 1 to 4, in a fashion similar to the classification procedure described in IEC 60825-1. In fibre optic applications the limits of hazard levels 1M and 2M are often higher than the limit of hazard level 3R, but less than the limit of hazard level 3B. For these applications hazard level 3R is not applicable.

Where operating organizations subcontract the installation, operation or maintenance of fibre optic communication systems, the responsibilities in relation to laser safety should be clearly defined by the operator.

In summary, the primary differences between IEC 60825-1 and this document are as follows.

- An OFCS will not be classified as required by IEC 60825-1. This is because under intended operation, the optical radiation is totally enclosed, and it can be argued that a rigorous interpretation of IEC 60825-1 would give a Class 1 allocation to all systems, which might not reflect the potential hazard accurately. However, if the source can be operated separately, it should be classified according to IEC 60825-1.
- Each accessible location in the extended enclosed optical transmission system will be designated by a hazard level by following similar procedures as those for classification in IEC 60825-1. However, this level will be based not on accessible radiation but on radiation that could become accessible under reasonably foreseeable circumstances (fibre cable break, disconnected fibre connector, etc.).
- The nature of the safety precautions required for any particular hazard level will depend on the type of location, i.e. domestic premises, industrial areas where there would be limited access, and switching centres where there could be controlled access. For example, it is specified that in the home a disconnected fibre connector should only be able to emit radiation corresponding to Class 1 or 2, whilst in controlled locations it could be higher.
- In this document, measurement under Condition 2 with magnifying optics is applied for the determination of hazard levels as well as Conditions 1 and 3.

Annex B (informative)

Clarification of the meaning of "hazard level"

B.1 General

In Annex B, the difference between "laser class" defined in IEC 60825-1 and "hazard level" defined in this document is further clarified.

B.2 Class

The word "class" refers to a scheme by which, based on emission levels, a product or internal emitter can be classified with respect to its safety. These levels are described in the accessible emission limit tables in IEC 60825-1. Classes range from Class 1, which is safe under reasonably foreseeable conditions, to Class 4, which is potentially the most hazardous case. In IEC 60825-1, the classification of products is based on reasonably foreseeable operating conditions including single fault conditions.

B.3 Hazard level

"Hazard level" is a term used in this document which refers to the potential hazard from laser emissions at any location in an end-to-end fibre optic communication system that might be accessible during use or maintenance or in the event of a failure or fibre disconnection or other fibre discontinuity such as a fibre break. The assessment of the hazard level uses the class accessible emission limit tables which are applied to determine the product class defined in IEC 60825-1. The assessment of hazard level is described in 4.7. The assessment can be an actual measurement or be based upon calculation of emitted powers and known time constants.

Annex A gives the following additional clarification: "An OFCS will not be classified in the same way as required by IEC 60825-1. This is because, under intended operation, the optical radiation is totally enclosed and it can be argued that a rigorous interpretation of IEC 60825-1 would give a Class 1 allocation to all systems, which might not reflect the potential hazard accurately." Based upon this statement, a complete OFCS can be regarded as a Class 1 laser product because, under normal conditions, the emissions are completely enclosed (like a laser printer) and no light should be emitting outside the protective housing. It is not until the fibre becomes broken or an optical connector is unplugged that someone might be exposed to a level of optical radiation which is potentially hazardous (if the internal emitters or amplifier outputs are of high enough power).

Therefore, for each optical output port, the hazard level should be assessed. The hazard level limits are dependent on the "dominant" wavelength range, taking into consideration that IEC 60825-1:2014 defines different limits for different wavelength ranges and spectral additivity rules for the eye as shown in IEC 60825-1:2014, Figure 1. Furthermore, this document allows the use of automatic power reduction (APR) techniques to achieve a lower (less hazardous) hazard level based on the normal power in the fibre and the speed of automatic power reduction.

B.4 Rationale to 4.7

The philosophy of 4.7.1 is based on assumptions that already exist in IEC 60825-1 and IEC 60825-2. However, large portions of OFCS can sometimes be classed as "not accessible under reasonably foreseeable conditions".

Subclause 4.7.4 requires that the MPE not be exceeded if any person is exposed to radiation emerging from the port or fracture from the instant of the break or disconnection. The power is assumed to remain constant at its maximum value until the shutdown time has expired.

a) Unrestricted locations:

The 1 s shutdown requirements in 4.7.3 are based on the assumption that even if a fibre is intentionally cut, it is highly unlikely that, within 1 s, a person can get within 100 mm and position magnifying optics so as to be adversely exposed. Also, one should keep in mind that optical signals are attenuated as they move down the fibre, so the output at the failure in the unrestricted location might be considerably lower than at the transmitter or amplifier.

b) Restricted locations:

The 3 s shutdown requirements in 4.7.3 are based on the assumption that any failure of the system within a restricted location would be of an accidental nature and the 3 s limit for shutdown or power reduction would be an acceptable time period "after the reasonably foreseeable event". It is also highly unlikely that, in this time period, a person can get within 100 mm and position collimating optics so as to be adversely exposed. One should also keep in mind that optical signals are attenuated as they move down the fibre, so the output at the failure in the restricted location might be considerably lower than at the transmitter or amplifier.

c) Controlled locations:

Persons working in locations with controlled access should have received adequate training in laser safety, which should include an understanding that a broken fibre should only be viewed if the system has been properly deactivated.

B.5 Rationale to Clause D.5

Annex D is informative. The use of the term "recommended" should not be construed as forbidding the use of alternative methods of analysis. The method of fault analysis and the adoption of a suitable safety level is the prerogative of the user.

Annex C (informative)

Methods of hazard/safety analysis

Some methods of hazard/safety analysis include the following:

- 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 the IEC 61508 series [8];
- c) failure modes and effects analysis (FMEA);
- d) failure modes, effects, and criticality analysis (FMECA) (see IEC 60812 [10]);
- 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.

Annex D (informative)

Application notes for the safe use of OFCS

D.1 Overview

Annex D provides guidance on the application of this document to specific practical situations. It is an informative annex to assist the users of this document in applying the requirements of IEC 60825-1 and this document to their specific application. It does not contain any requirements.

This document applies to OFCS. In such systems the optical power can be transmitted for long distances beyond the optical source and measures need to be taken to ensure that the potential hazards from a broken communications path are minimized. In order to know the extent of the potential hazard existing in an OFCS, a hazard level needs to be assigned to those locations that can become accessible: this is similar to, but replaces, the designation of a Class to the equipment within IEC 60825-1.

It is possible to configure an optical fibre communications system to act as a closed-loop control system, such that when the communications path is broken the transmitted signal is automatically reduced in power within a short period of time to a safe value. It is therefore possible to have two systems, one with automatic power reduction (APR) and another without APR, both having the same hazard level (and therefore the same degree of safety): the signal level under normal operating conditions in the system with APR can then be much higher than the signal level in the system without APR. Because the APR feature is critical to safety, the reliability of this feature should be adequate and recommendations are provided in Annex D.

Whereas IEC 60825-1 applies to discrete laser products, this document applies to complete end-to-end systems. Because the subassemblies that generate or amplify optical radiation are critical to the safety of the OFCS, and because they have to meet part of the requirements, these items are also included within the scope of this document. The manufacturers of individual passive components or passive subassemblies that are not yet incorporated into the end-to-end system can not know the associated hazard level and so these items are excluded from the scope of this document.

This document does not address safety issues associated with explosion or fire with respect to OFCS deployed in hazardous locations.

D.2 Areas of application

D.2.1 Typical OFCS installations

a) Locations with controlled access (see 3.13):

- cable ducts;
- street cabinets;
- dedicated and delimited areas of distribution centres;
- test rooms in cable ships.

Where service access to cable ducts and street cabinets could expose the general public to radiation in excess of the accessible emission limit of Class 1, appropriate temporary exclusion provisions (e.g. a hut) should be provided.

- b) Locations with restricted access (see 3.14):
 - secured areas within industrial premises not open to the public;
 - secured areas within business/commercial premises not open to the public (for example telephone private automatic branch exchange (PABX) rooms, computer system rooms, etc.);
 - general areas within switching centres;
 - delimited areas not open to the public on trains, ships or other vehicles.
- c) Locations with unrestricted access (see 3.15):
 - domestic premises;
 - services industries that are open to the general public (e.g. shops and hotels);
 - public areas on trains, ships or other vehicles;
 - open public areas such as parks, streets, etc.;
 - non-secured areas within business/industrial/commercial premises where members of the public are permitted to have access, such as some office environments.

OFCSS might pass through unrestricted public areas (for example in the home), restricted locations within industrial premises, as well as controlled locations such as cable ducts or street cabinets.

Optical local area networks (LANs) can be deployed entirely within restricted business premises.

Fibre systems can be entirely in unrestricted domestic premises such as hi-fi interconnections.

For requirements on infra-red (IR) wireless LANs or free space optical communication systems, see IEC 60825-12 [11].

D.2.2 Typical system components

- a) Fibre cables:
 - 1) single fibre/multiple fibre/ribbon construction;
 - 2) single-mode/multimode;
 - 3) all dielectric or hybrid construction;
 - 4) carrying single/multiple wavelengths;
 - 5) uni/bidirectional fibre;
 - 6) communications/power feeding.
- b) Optical sources:
 - 1) LEDs, vertical-cavity surface-emitting lasers (VCSELs), Fabry-Perot or distributed feedback (DFB) lasers, pump lasers;
 - 2) optical amplifiers;
 - 3) bulk/distributed;
 - 4) continuous, low-/high-frequency emission.
- c) Connectors:
 - 1) simplex/duplex/multiway;
 - 2) hybrid.
- d) Passive components:
 - 1) power combiners/splitters;
 - 2) wavelength multiplexers/demultiplexers;
 - 3) attenuators.

- e) Protective enclosures and housings.
- f) Fibre distribution frames.

D.2.3 Typical operating functions

- a) Installation.
- b) Operation.
- c) Maintenance.
- d) Servicing.
- e) Fault-finding.
- f) Measurement (including OTDR).

D.3 OFCS power limits

The maximum mean power within the fibre for each hazard level for the most important wavelengths and optical fibre types used in OFCS is presented in Table D.1. The values shown assume that APR is not in operation. For most typical systems with duty cycles between 10 % and 100 %, the peak power can be allowed to increase with duty cycle in an inversely proportional manner. However, for duty cycles ≤ 50 %, it is most straightforward to limit the peak powers to twice these mean power limits, although IEC 60825-1 can be used for a more sophisticated analysis in order to identify any increase in peak powers permissible for these types of systems. This is especially valid when "visible sources" with wavelengths in the photochemical hazard area are used.

For the most common single-mode fibres, the point source limits need to be applied while for graded index multimode fibres with a core diameter of 62,5 μm (GI 62.5), the effect of angular subtense, which is linked to C_6 , needs to be considered for wavelengths between 400 nm and 1 400 nm. See NOTE 5 in Table D.1 for multimode fibres which need to be considered as extended sources.

The following aperture diameter and measurement distances are to be used for Condition 2 measurements:

- 3,5 mm at 35 mm for wavelengths $\geq 302,5$ nm and $< 1\,400$ nm.
- 3,5 mm at 14 mm for wavelengths $\geq 1\,400$ nm and $< 4\,000$ nm.

NOTE 1 For single-mode fibres at wavelengths $\geq 1\,400$ nm, for the vast majority of cases this condition will measure all the emission from the fibre, and will therefore account for any level of magnification.

NOTE 2 An alternative to this condition for single-mode fibres at wavelengths $\geq 1\,400$ nm is simply to measure the total emission from the fibre while recognizing that in certain cases this can result in an overestimate of the actual hazard.

NOTE 3 For hazard level 3B systems, the total emission from the fibre is limited to be less than the AEL of Class 3B (thus effectively capping the optical power in the fibre at 500 mW for exposures in excess of 0,25 s, and at the appropriate level for shorter exposures including, for example, system restart pulses).

Table D.1 – OFCS power limits for 11 µm mode field diameter (MFD) single-mode (SM) fibres and 0,18 numerical aperture multimode (MM) fibres (core diameter 50 µm)

Wavelength and fibre type	Hazard level					
	1	1M	2	2M	3R	3B
633 nm (MM)	1,95 mW	3,77 mW	5,00 mW	9,66 mW	25,0 mW	500 mW
	(+2,9 dBm)	(+5,8 dBm)	(+7,0 dBm)	(+9,9 dBm)	(+14,0 dBm)	(+27,0 dBm)
780 nm (MM)	2,82 mW	5,45 mW	–	–	14,5 mW	500 mW
	(+4,5 dBm)	(+7,4 dBm)			(+11,6 dBm)	(+27,0 dBm)
850 nm (MM)	3,89 mW	7,52 mW	–	–	20,0 mW	500 mW
	(+5,9 dBm)	(+8,8 dBm)			(+13,0 dBm)	(+27,0 dBm)
980 nm (MM)	7,08 mW	13,7 mW	–	–	36,3 mW	500 mW
	(+8,5 dBm)	(+11,4 dBm)			(+15,6 dBm)	(+27,0 dBm)
980 nm (SM)	1,80 mW	2,66 mW	–	–	9,21 mW	500 mW
	(+2,5 dBm)	(+4,2 dBm)			(+9,6 dBm)	(+27,0 dBm)
1 270 nm (MM)	140 mW	270 mW	–	–	500 mW	500 mW
	(+21,4 dBm)	(+24,3 dBm)			(+27,0 dBm)	(+27,0 dBm)
1 270 nm (SM)	46,2 mW	76,5 mW	–	–	237 mW	500 mW
	(+16,6 dBm)	(+18,8 dBm)			(+23,7 dBm)	(+27,0 dBm)
1 310 nm (MM)	481 mW	500 mW	–	–	500 mW	500 mW
	(+26,8 dBm)	(+27,0 dBm)			(+27,0 dBm)	(+27,0 dBm)
1 310 nm (SM)	166 mW	277 mW	–	–	500 mW	500 mW
	(+22,2 dBm)	(+24,4 dBm)			(+27,0 dBm)	(+27,0 dBm)
1 400 nm to 1 600 nm (MM)	13,3 mW	371 mW	–	–	See Note 1 in 4.3.9	500 mW
	(+11,2 dBm)	(+25,7 dBm)				(+27,0 dBm)
1 420 nm (SM)	10,1 mW	115 mW	–	-	See Note 1 in 4.3.9	500 mW
	(+10,0 dBm)	(+20,6 dBm)				(+27,0 dBm)
1 550 nm (SM)	10,2 mW	136 mW	–	–	See Note 1 in 4.3.9	500 mW
	(+10,1 dBm)	(+21,3 dBm)				(+27,0 dBm)
NOTE 1 Hazard levels 1M and 2M						
The maximum power shown in the table for 11 µm fibre is limited by the power density. The precise fibre power limit is therefore determined by the minimum expected beam divergence, which is in turn dependent on the MFD of a single-mode fibre. This can change for different values of the MFD and there are significant changes in Class limits as the MFD changes. Some connectors use enlarged MFD and the far field divergence is lower. These connectors can result in a higher hazard level and the higher hazard level is assigned when using these connectors.						
NOTE 2 Wavelength 1 270 nm						
Wavelength 1 270 nm corresponds to the shortest wavelength in the datacom applications, e.g. LAN-WDM 8.						
NOTE 3 Fibre parameters						
The fibre parameters used are the most conservative cases; single-mode figures are calculated for a fibre with an 11 µm MFD, and multimode figures for a fibre with a numerical aperture of 0,18. Many systems operating at 980 nm and 1 550 nm use fibres with smaller MFDs. For example, the limit for hazard level 1M when a wavelength of 1 550 nm is transmitted along dispersion shifted fibre cables having upper limit values of MFD of 9,1 µm is 197 mW.						

NOTE 4 Hazard level 1M limits for < 1 310 nm

The hazard level 1M limits for single-mode fibres at 900 nm and below are not presented here, as the divergence that these wavelengths will undergo is rather variable. This is because these wavelengths are in fact multimoded in standard 1 310 nm single-mode fibre, and the exact divergence will depend on the rather unpredictable degree of mode mixing. This mode mixing variability is also a potential problem when trying to evaluate these wavelengths on true multimode fibre. If it is necessary to calculate a value for these cases, the assumption that the fibre carries all of its power in the fundamental mode and use of the single-mode equations will yield a conservative value.

NOTE 5 Multimode fibre cables with a single core

For wavelengths between 400 nm and 1 400 nm, the AEL of Class 1 is calculated considering an angular subtense of the core diameter even for low magnifying optics (See D.4.1.2). When an angular subtense exceeds 1,5 mrad, therefore these fibres are considered as extended sources. Under Condition 3, i.e. measured from a distance of 100 mm, a fibre with a core diameter of larger than 150 µm measured is an extended source. For example, hard clad silica (HCS) fibres with 200 µm or plastic optical fibres with 1 000 µm core diameter are (intermediate) extended sources. The applicable source size depends on the degree of mode filling and is determined in detail before calculating the limit values. Even under Condition 2, i.e. measured from a distance of 35 mm, a fibre with a core diameter of larger than 52,5 µm measured is considered as an extended source. GI 50 fibres as shown in this table are therefore regarded as point sources and GI 62.5 fibres as extended sources under Condition 2.

NOTE 6 Multiple fibres and ribbon cables

The limits in the table are calculated for single fibres only. If multiple fibres or ribbon fibres with single fibres located in close proximity to each other have to be assessed, each individual fibre and each possible grouping of the fibres is evaluated (see D.4.6).

NOTE 7 1 420 nm power limit

The 1 420 nm power limits are calculated for the wavelength range of Raman amplification from 1 420 nm (pump) to 1 500 nm (signal).

D.4 Hazard level evaluation examples

D.4.1 Single wavelength over the same fibre

D.4.1.1 General considerations

The diameter of a divergent beam d_{63} , that contains 63 % of the total power or energy at a distance r from the apparent point source such as an optical fibre end is required to calculate AEL and MPE involving aperture and specified with a numerical aperture or NA. The NA of a point source is defined as the sine of one-half the divergence angle φ of the output beam, as measured at the 5 %-of-peak-irradiance points. That is

$$\frac{\varphi}{2} = \arcsin(\text{NA}).$$

For a Gaussian beam, the beam diameter d_{63} is given by

$$d_{63} = \frac{2r}{1,7} \tan[\arcsin(\text{NA})] \approx \frac{2r \text{ NA}}{1,7},$$

where the denominator 1,7 is the ratio of the beam diameter d_{95} that corresponds to the 5 %-of-peak-irradiance points to d_{63} , i.e. $d_{95} / d_{63} = 1,7$.

In case of a single-mode fibre that is a special case of a point source, the beam diameter d_{63} , at a distance r is approximated by