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TECHNICAL REPORT

Safety of laser products –
Part 17: Safety aspects for use of passive optical components and optical cables in high power optical fibre communication systems

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FOREWORD

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IEC TR 60825-17, which is a Technical Report, has been prepared by IEC technical committee TC 76: Optical radiation safety and laser equipment.

This second edition cancels and replaces the first edition published in 2010. This edition constitutes a technical revision.

The changes with respect to the previous edition include changes to harmonize with SC86A and SC86B documents.

The text of this Technical Report is based on the following documents:

Enquiry draft	Report on voting
76/510/DTR	76/526/RVC

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

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

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

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

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- withdrawn,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

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

INTRODUCTION

The rapid growth of applications such as the internet and business intranets requiring high bitrates has caused a dramatic increase in the need for high capacity data connections. This increase in capacity has resulted in a requirement for a corresponding increase in power levels used in optical fibre communications systems. There are a number of areas of concern including but not exclusively the use of erbium-doped fibre amplifiers (EDFA), high power dense wavelength division multiplexing (DWDM) systems, and Raman amplification.

The power levels associated with these systems are typically greater than 500 mW (i.e. Class 4), but some studies have shown additional thermal effects can occur at lower powers. These additional thermal and related hazards mean that it is necessary to address a number of new issues. It should be noted that the vast majority of these systems use single-mode fibre.

SAFETY OF LASER PRODUCTS –

Part 17: Safety aspects for use of passive optical components and optical cables in high power optical fibre communication systems

1 Scope

This part of IEC 60825 recommends safety measures to protect against effects caused exclusively by thermal, opto-mechanical and related effects in passive optical components and optical cables used in high power optical fibre communication systems.

This part of IEC 60825 does not apply to the use of high power optical systems in explosive atmospheres or the use of optical fibres in material processing machines. Throughout this part of IEC 60825, a reference to 'laser' is taken to include light-emitting diodes (LEDs) and optical amplifiers.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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*

IEC 60825-2:2004, *Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCS)*
IEC 60825-2:2004/AMD1:2006
IEC 60825-2:2004/AMD2:2010[1]

ITU-T Recommendation G.664, *Optical safety procedures and requirements for optical transmission systems*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
automatic laser shutdown
ALS
technique (procedure) to automatically shutdown the output power of laser transmitters and optical amplifiers to avoid exposure to hazardous levels

3.2
automatic power reduction
APR
feature of an optical fibre communication system (OFCS) by which the accessible power is reduced to a specified level within a specified time, whenever there is an event which could result in human exposure to radiation, e.g. a fibre cable break

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1 A consolidated edition 3.2 exists, including IEC 60825-2:2004 and its Amendment 1 and Amendment 2.

Note 1 to entry: The term “automatic power reduction” (APR) used in this document encompasses the following terms used in recommendations of the International Telecommunication Union ITU:

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

[SOURCE: IEC 60825-2:2004, 3.2]

3.3
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

[SOURCE: IEC 60825-2:2004, 3.13]

3.4
hazard level
potential hazard at any accessible location within an OFCS, based on the level of optical radiation which could become accessible in a reasonably foreseeable event, e.g. a fibre cable break

Note 1 to entry: It is closely related to the laser classification procedure in IEC 60825-1.

[SOURCE: IEC 60825-2:2004, 3.4, modified — Supplementary information has been moved from the definition to a Note to entry.]

3.5
high optical power
optical power of 500 mW or greater potentially capable of causing damage to fibres, optical components or systems (typically Class 4)

Note 1 to entry: 500 mW is recommended partly as it is the breakpoint between Class 3B laser products (unlikely to cause fire) and Class 4 laser products (may cause fire).

Note 2 to entry: Studies have shown damage is significantly more likely at powers in excess of 1 W, but damage has also been shown to occur at powers as low as 200 mW – see [1] and [2][2].

3.6
loss of continuity of an optical link
event which may cause hazardous optical power levels to be emitted from some point along the path of an optical transmission system

Note 1 to entry: Common causes of loss of continuity of an optical link are a cable break, equipment failure, connector unplugging, etc.

3.7
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

[SOURCE: IEC 60825-2:2004, 3.18]

[2] The numbers in square brackets refer to the Bibliography.

3.8
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 may not have laser safety training

[SOURCE: IEC 60825-2:2004, 3.14]

3.9
unrestricted location
location with unrestricted access
accessible location where there are no measures restricting access to members of the general public

[SOURCE: IEC 60825-2:2004, 3.15]

4 Recommendations

4.1 General considerations – the background to optical fibre damage at high powers

When optical fibres are operated at high power levels (typically > 500 mW), fibres and optical connectors can be damaged. In optical communications systems the optical power is transmitted in CW mode or at high repetition rates, and therefore catastrophic damage is predominantly caused by thermal mechanisms. It has been shown that several effects can cause high optical power-induced damage of single-mode fibre systems leading to fibre failures. Systems employing high optical power operation in fibres, connectors, collimators and attenuators thus carry additional safety concerns. For example, local heating in contaminated connectors/attenuators carrying high optical power can pose a potential fire hazard to surrounding materials, depending on the flammability of those materials.

IEC TR 61292-4 provides extensive guidance on the following topics (see also [3]):

- fibre fuse and its propagation;
- loss-induced heating at connectors or splices;
- connector end-face damage induced by dust/contamination;
- fibre coating burn/melt induced by tight fibre bending.

4.2 Fibre coating damage occurring when bending at high powers

Studies [4–12] on tight fibre bending at high power show that coating ageing can occur slowly and catastrophic damage effects can occur after hundreds of hours. The main implication is that damage testing must be carried out for sufficiently long times; some early experiments were conducted over short times, possibly leading to incorrect conclusions. IEC TR 62547 should be followed for the measurement of high power damage sensitivity at bends.

As discussed by Bigot-Astruc, M et al. [6] and in IEC TR 62547, a fast method of testing for potential damage effects at high powers can use a thermal imaging camera. Equilibrium temperatures are established relatively quickly, allowing the consequences of high power to be rapidly assessed. The issues concerning high power at tight bends arise because of exposure of the fibre coating to high power at or near to the bend. Coating ageing occurs at a rate determined by bend loss, launch power, environmental conditions and coating resilience. New bend insensitive fibre designs – described by the ITU-T Recommendation G.657 specifications and IEC product specification IEC 60793-2-50, category B6 fibres – are a possible solution (see Section 2.5 in [7] and Subclause 4.5.3.2 of IEC TR 62547:2013). However, for extreme situations more resilient coatings may also be required.

The long-term damage effects of high power in other optical components, described for example in 4.7, show the need to consider the implications of high power damage research, as discussed in IEC TR 62547.

Well documented experiences of the ageing of coatings of fibres in tight bends under high power have shown that catastrophic effects can occur after hundreds of hours [3]. Coating ageing has been seen to be the trigger for catastrophic failure; the use of thermal imaging cameras as described by Bigot-Astruc, M et al. [6] and in IEC TR 62547 has shown that equilibrium temperatures can be a good indicator of lifetime and such cameras can be used to reduce the time required for high power evaluation and damage testing. Also, note that the rate of fibre coating ageing is usually temperature dependent, thus ambient environmental conditions may affect component resilience – see Sikora et al [8].

4.3 Information on automatic power reduction (APR)

Extra recommendations for automatic power reduction (APR) are made because APR will become more critical in systems where fire, fibre and connector damage, and other hazards are possible if fibre is mishandled. These recommendations may include additional network management and administrative controls, electrical connectivity testing for higher reliability of APR, and others. OFCSs employing high optical power may necessitate the incorporation of APR within one section of a main optical path in the event of recovery from the loss of optical power or loss of continuity of an optical link within that particular section.

Automatic power reduction should be specified and shown to have a high level of reliability for systems using high optical power operation in fibres at all installed locations. IEC 60825-2 describes an ‘adequate’ level of reliability for APR systems (500 FITs).

NOTE IEC 60825-2 defines FITs as “an indicator of reliability defined as the number of failures per 10^9 h.”

Automatic power reduction should take into account all optical power present in both directions on the optical path, as described in the following excerpts reproduced with permission from Recommendation ITU-T G.664 (10/2012):

> “APR techniques are necessary when the sum of operational power (main optical signal) and pump-laser output power at the optical interfaces exceeds the applicable hazard levels defined in IEC 60825-2. The total power is the sum of the power in any one direction from all optical channels, the power from all pump-lasers and the power from optical auxiliary channels (OAC), if used. Within the context of this Recommendation, an optical supervisory channel (OSC) is regarded as a specific case of an OAC.
>
> After power reduction, the total power level (the sum of the power from all optical channels, the remaining power from pump-lasers and power from an OAC) must be within hazard level 1M (or 3B in controlled locations), but reduction of the total power to hazard level 1 or even complete shutdown is acceptable.
>
> Optical transmission systems employing distributed Raman amplification need extra care to ensure safe optical working conditions, because high pump powers (power levels above +30 dBm are not uncommon) may be injected into optical fibre cables. Therefore, it is recommended to use APR in all systems employing distributed Raman amplification with operational power levels above hazard level 1M (or 3B in controlled locations). In this way hazards from laser radiation to the human eye or skin, and potential additional hazards such as temperature increase (or fire) caused by locally increased absorption due to connector contamination or damage are avoided. Further guidance is provided by IEC TR 61292-4.
>
> Distributed Raman-based systems differ from discrete optically amplified systems due to the possible presence of pump lasers at the "receiving" side of a link, launching high optical powers backward into the fibre. In order to ensure that the power levels radiating from broken or open fibre connections are at safe levels, it is necessary to reduce the power not only from the main optical signal sources but also from all pump lasers employed, including the reverse pump lasers. Because the operating wavelength of the Raman pump lasers is usually different from the actual data signal, separate assessments