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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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SAFETY OF LASER PRODUCTS –

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FOREWORD

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

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

Enquiry draft	Report on voting
76/425/DTR	76/435/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 web site 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- withdrawn,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 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 optical power fibre communication systems.

This technical report 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 referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60825-1:2007, *Safety of laser products – Part 1: Equipment classification and requirements*

IEC 60825-2:2005, *Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCS)*

IEC/TR 61292-4, *Optical Amplifiers – Part 4: Maximum permissible optical power for the damage-free and safe use of optical amplifiers, including Raman amplifiers*

IEC/TR 62547, *Guidelines for the measurement of high-power damage sensitivity of single-mode fibres to bends – Guidance for the interpretation of results*

3 Terms and definitions

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)
technique (procedure) to automatically reduce the output power of optical amplifiers to avoid exposure to hazardous levels

3.3
automatic power shutdown (APSD)
technique (procedure) to automatically shutdown the output power of optical amplifiers to avoid exposure to hazardous levels

NOTE In the context of this technical report the term APSD is equivalent to the term ALS.

3.4
optical fibre communication system (OFCS)
an 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

3.5
loss of continuity (of an optical link)
any event which may cause hazardous optical power levels to be emitted from some point along the path of an optical transmission system

NOTE Common causes of loss of continuity of an optical link are a cable break, equipment failure, connector unplugging, etc.

3.6
high optical power
an optical power of 500 mW or greater (in the context of this technical report)

NOTE 1 500 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 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 references [1] [1)] and [2]..

3.7
hazard level
the potential hazard at any accessible location within an OFCS. It is based on the level of optical 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 in IEC 60825-1

[IEC 60825-2, definition 3.4]

3.8
unrestricted location
location with unrestricted access
an accessible location where there are no measures restricting access to members of the general public

[IEC 60825-2, definition 3.15]

3.9
restricted location
location with restricted access
an 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

[IEC 60825-2, definition 3.14]

3.10
controlled location
location with controlled access
an accessible location where an engineering or administrative control is present to make it inaccessible, except to authorized personnel with appropriate laser safety training

[IEC 60825-2, definition 3.13]

1) Figures in square brackets refer to the Bibliography.

3.11
class of laser product
see IEC 60825-1, sections 3.18 to 3.23 for definition of 'class of laser product'

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 [7]):

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

Studies [3] 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 [4] 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 G.657 specifications – are a possible solution (see Section 2.5 in [8]). 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 4.5 and 4.9, show the need to consider the implications of high power damage research, as discussed in IEC/TR 62547.

4.2 Additional recommendations for 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. Systems employing high optical power operation in fibres may necessitate the incorporation of automatic power reduction within one section of a main optical path in the event of recovery from the loss of optical power within that particular section of the main optical path.

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 signals present in both directions on the optical path, as described in the following excerpt reproduced with permission from Recommendation ITU-T G.664 (1999), *Optical safety procedures and requirements for optical transport systems*):

> "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 at various wavelengths may need to be made both at pump laser wavelength and at main signal wavelength."

ITU-T G.664 Appendix II.3 describes automatic laser shutdown (ALS) and restart procedures for single channel synchronous digital hierarchy systems with the additional presence of optical amplification.

Operational aspects of APR should also comply with all relevant subclauses in IEC 60825-2:2005, notably 4.5 ("Automatic power reduction (APR) and restart pulses") and 4.5.4 ("Disabling of the APR").

4.3 The need for additional user information and its recommended format

Due to the potentially increased hazards arising from higher optical powers, additional user information may be needed. This subclause describes possible extra requirements that may be placed on manufacturers, operating organizations and users (including extra training, additional user manual requirements and others). Manufacturers of high optical power OFCS, turnkey end-to-end high optical power systems or subassemblies intended to be incorporated into high optical power systems should ensure that the equipment satisfies IEC 60825-2 and the applicable advice of this technical report.