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Edition 3.0 2014-10

TECHNICAL REPORT

colour inside

Optical amplifiers – Part 4: Maximum permissible optical power for the damage-free and safe use of optical amplifiers, including Raman amplifiers

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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

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IEC TR 61292-4, which is a technical report, has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics.

This third edition cancels and replaces the second edition, published in 2010, and constitutes a technical revision with updates reflecting new research in the subject area.

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

Enquiry draft	Report on voting
86C/1158/DTR	86C/1200/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 in the IEC 61292 series, published under the general title, *Optical amplifiers*, 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- withdrawn,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.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This technical report is dedicated to the subject of maximum permissible optical power for damage-free and safe use of optical amplifiers, including Raman amplifiers. Since the technology is quite new and still evolving, amendments and new editions to this report can be expected.

Many new types of optical amplifiers are entering the marketplace and research is also stimulating many new types of fibre and non-fibre based optical amplifier research. With the introduction of such technologies as long-haul, over 40 Gb/s, WDM transmission and Raman amplification, some optical amplifiers may involve optical pump sources with extremely high optical power – up to, possibly, several watts.

Excessively high optical power may cause physical damage to the fibres/optical components/equipment as well as present medical danger to the human eye and skin.

The possibility of fibre damage caused by high optical intensity has recently been discussed at some technical conferences. The use of high intensity optical amplifiers may cause problems in the fibre such as a fibre fuse, a heating in the splice point (connection point), and the fibre end-face damage due to dust and the fibre coat burning due to tight fibre bending. IEC SC 86A (Fibres and cables) has published IEC TR 62547, and SC 86B (Fibre optic interconnecting devices and passive components) has published IEC TR 62627-01. IEC TC 31 (Equipment for explosive atmospheres) is also discussing the risk of ignition of hazardous environments by radiation from optical equipment.

Medical aspects have long been discussed at standards groups. IEC TC 76 (Optical radiation safety and laser equipment) precisely describes in IEC 60825-2 the concept of hazard level and labelling and addresses the safety aspects of lasers specifically in relation to tissue damage.

ITU-T Study Group 15 (Optical and other transport networks) has published Recommendation G.664, which primarily discusses the automatic laser power reduction functionality for safety.

With the recent growth of interest in fibre Raman amplifiers, however, some difficulties have been identified among optical amplifier users and manufacturers in fully understanding the technical details and requirements across all such standards and agreements.

This technical report provides a simple informative guideline on the maximum optical power permissible for optical amplifiers for optical amplifier users and manufacturers.

OPTICAL AMPLIFIERS

Part 4: Maximum permissible optical power for the damage-free and safe use of optical amplifiers, including Raman amplifiers

1 Scope and object

This part of IEC 61292, which is a technical report, applies to all commercially available optical amplifiers (OAs), including optical fibre amplifiers (OFAs) using active fibres, as well as Raman amplifiers. Semiconductor optical amplifiers (SOAs) using semiconductor gain media are also included.

This technical report provides a simple informative guideline on the threshold of high optical power that causes high-temperature damage of fibre. Also discussed is optical safety for manufacturers and users of optical amplifiers by reiterating substantial parts of existing standards and agreements on eye and skin safety.

To identify the maximum permissible optical power in the optical amplifier from damage-free and safety viewpoints, this technical report identifies the following values:

a) the optical power limit that causes thermal damage to the fibre, such as fibre fuse and fibre-coat burning;
b) the maximum permissible exposure (MPE) to which the eyes/skin can be exposed without consequential injury;
c) the optical power limit in the fibre that causes MPE on the eyes/skin after free-space propagation from the fibre;
d) the absolute allowable damage-free and safe level of optical power of the optical amplifier by comparing (a) and (c).

The objective of this technical report is to minimize potential confusion and misunderstanding in the industry that might cause unnecessary alarm and hinder the progress and acceptance of advancing optical amplifier technologies and markets.

It is important to point out that the reader should always refer to the latest international standards and agreements because the technologies concerned are rapidly evolving.

The present technical report will be frequently reviewed and will be updated by incorporating the results of various studies related to OAs and OA-supported optical systems in a timely manner.

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 60825-1:2007, *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)*
Amendment 1 (2006)
Amendment 2 (2010)

IEC TR 60825-14:2004, *Safety of laser products – Part 14: A user's guide*

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

IEC TR 62627-01, *Fibre optic interconnecting devices and passive components – Part 01: Fibre optic connector cleaning methods*

ITU-T Recommendation G.664:2012, *Optical safety procedures and requirements for optical transport systems*

3 Abbreviated terms

For the purposes of this document, the following abbreviated terms apply.

ALS	automatic laser shutdown
APR	automatic power reduction
DSF	dispersion shifted fibre
LOS	loss of signal
MFD	mode field diameter
MPE	maximum permissible exposure
MPI-R	single channel receive main path interface reference point
MPI-S	single channel source main path interface reference point
NOHD	nominal ocular hazard distance
NZ-DSF	non-zero dispersion shifted single-mode optical fibre
OA	optical amplifier
OFA	optical fibre amplifier
SMF	single mode fibre
SOA	semiconductor optical amplifier

4 Maximum transmissible optical power to keep fibres damage-free

4.1 General

The use and reasonably foreseeable misuse of high intensity optical amplifiers may cause problems in the fibre such as

a) fibre fuse and its propagation,
b) heating in the splice point/connection point,
c) fibre end-face damage due to dust and other contamination,
d) fibre coat burning and ignition of hazardous environments due to tight fibre bending or breakage.

This clause introduces their results concerning the above issues to give guidelines for the damage-free use of optical amplifiers. However, it should be noted that the following results are only valid under the conditions tested and that a higher power might be allowed under different conditions.

4.2 Fibre fuse and its propagation

The safety of optical amplifiers should be discussed from the viewpoint of laser hazard to the eyes and skin as well as fibre damage such as fibre-coat burning and fibre fusing. This clause experimentally analyses the fibre fuse and its propagation caused by high optical power and discusses the threshold power of fibre fuse propagation [1][1]. It is defined that the fibre fuse is the phenomenon in which an intense blue-white flash occurred and ran along the fibre toward the high power light source while forming periodic and/or non-periodic voids.

Figure 1 shows a typical measurement set-up for the threshold power of fibre fuse propagation. The fibre fuse is initiated by heating the optical fibre from outside of the fibre by using an independent heat source, while a high optical power is continuously launched into the fibre. Once the fibre fuse began propagating, the optical source power is continuously reduced until the fuse propagation stopped for measuring the threshold power. Table 1 shows the threshold powers which were measured at various wavelengths of the high-power optical source for various fibres. Although the threshold power depends on the wavelength of the high-power optical source, the power for the fuse propagation is less than 1,4 W and 1,2 W for a standard single mode fibre (SMF) and a dispersion shifted fibre (DSF) respectively, which are used as the optical fibre for typical optical fibre communication systems.

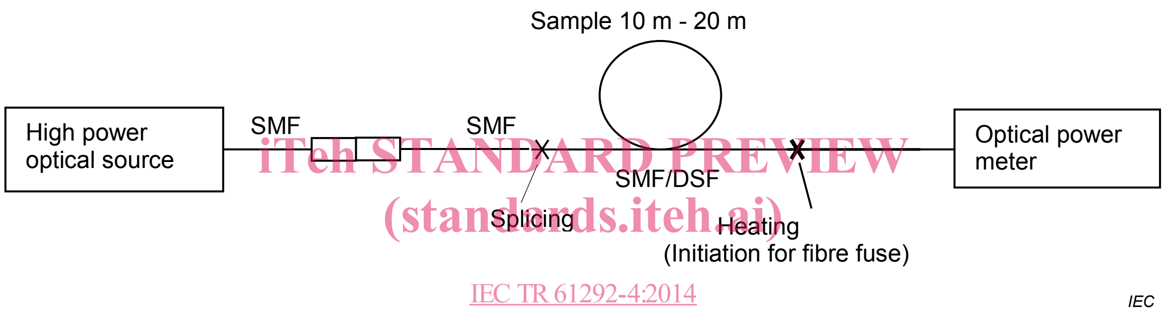

Figure 1 – Experimental set-up for fibre fuse propagation

Table 1 – Threshold power of fibre fuse propagation for various fibres

Fibre type	Measurement wavelength µm	Threshold power of fibre fuse propagation W
Standard single mode fibre	1,064	1 [2]
	1,467	1,4 [2]
	1,48	~1,2 [3]
	1,55	1,39 [4]
Dispersion shifted fibre	1,064	1,2 [2]
	1,467	0,65 [2]
	1,55	~1,1 [5]
Dispersion compensation fibre	1,55	~0,7 [5]

The difference in the fibre mode-field diameter has been the major reason for the difference in the threshold powers because the fibre fuse depends on the power density [1].

On the other hand, it is difficult to identify the threshold powers for the fibre fuse self-initiation (without any external cause) because it varied significantly, although they well exceeded

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1 Figures in square brackets refer to the Bibliography.

1,4 W and 1,2 W for standard single mode fibre (SMF) and dispersion shifted fibre (DSF) respectively.

Further information such as the generating mechanism, the characteristics of fibre fuse and the prevention and the termination for the fibre fuse is described in Annex A.

4.3 Loss-induced heating at connectors or splices

In extremely high power optical amplifiers, the loss-induced heating at fibres and connectors or splices could lead to damage, including fibre-coat burning, fibre fuse, etc. This subclause provides experimental data and considerations for the information of the thermal effects induced by connector and splice losses in high-power amplifiers [6].

Figure 2 shows temperature increase versus connection loss, which are measured by the conditions that shown in Table 2. MU type optical connectors for standard single mode fibre (SMF) and dispersion shifted fibre (DSF) were used for this measurement. The connector loss was increased by optical fibre misalignment. The optical source used was a 2-W Raman pump at 1 480 nm. The connector temperature was measured by a thermocouple placed on the sleeve. Since the MU ferrule diameter was only 1,25 mm, the sleeve temperature was almost the same as that of the ferrule; ferrule temperature is the most important factor determining the long-term reliability of optical connectors [7].

Larger increase in temperature is observed in DSF than in SMF due to higher power density. The result suggests that the temperature increase could be within 10 °C under practical conditions of loss and power. A commercial dry-type connector cleaner was used in every test for cleaning the endface of the connectors.

During repeated connection-disconnection of the connectors, neither damage nor fibre fuse was observed. The experiments with the use of the cleaner identified no problems in terms of fibre/connector damage and reliability. Without the cleaner, however, the experiment with the DSF connector indicated that fibre fuse could occur after repeated connection-disconnection of more than 200 times.

Such temperature increase, and accordingly the danger of fibre fuse, for non-zero dispersion shifted single-mode optical fibre (NZ-DSF) connectors will be worse than SMF connectors but better than DSF connectors; the effective areas are SMF>NZDSF>DSF. Further quantitative studies are needed. Other types of physical contact (PC) connectors such as SC connectors will show similar temperature responses because only their ferrule radii differ.

In conclusion, it is shown that the thermal effects induced by connector and splice losses in high-power amplifiers could be acceptable under any practical conditions foreseeable at this moment. However, special care should be taken to eliminate dust and contamination from the connector end faces and splice points that could locally induce high-temperature increases according to the power density absorbed.

Table 2 – Measurement conditions

Parameter	Conditions
Fibre	SMF, DSF
Connectors	MU type
Ferrule	Zirconia
Connector/splice loss	Imperfect alignment
Wavelength	Raman pump – 1 480 nm
Power	2 W
Temperature measurement	Thermocouple on the sleeve