IEC/TR 61292-4

Edition 2.0 2010-03

TECHNICAL REPORT

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

IEC/TR 61292-4:2010(E)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: www.iec.ch

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

- Catalogue of IEC publications: www.iec.ch/searchpub

The IEC on-line Catalogue enables you to search by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, withdrawn and replaced publications.

- IEC Just Published: www.iec.ch/online_news/justpub

Stay up to date on all new IEC publications. Just Published details twice a month all new publications released. Available on-line and also by email.

- Electropedia: www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 20 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary online.

- Customer Service Centre: www.iec.ch/webstore/custserv

If you wish to give us your feedback on this publication or need further assistance, please visit the Customer Service Centre FAQ or contact us:

Email: csc@iec.ch
Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00

IEC/TR 61292-4

Edition 2.0 2010-03

TECHNICAL REPORT

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

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE **S**

ICS 33.160.10; 33.180.30

ISBN 978-2-88910-481-9

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

OPTICAL AMPLIFIERS –

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

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC 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 second edition cancels and replaces the first edition published in 2004 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/889/DTR	86C/921/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 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 document can be expected.

Many new types of optical amplifiers are entering the marketplace and research on it is also stimulating many new types of fibre and non-fibre based optical amplifier research. With the introduction of such technologies as long-haul, 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. IEC technical committee 86 (Fibres optics) and subcommittee 86A (Fibres and cables) has published IEC 62547: *Guidelines for the measurement of high-power damage sensitivity of single-mode fibres to bends – Guidance for the interpretation of results*. IEC technical committee 31 (Equipment for explosive atmospheres) is also discussing the risk of ignition of hazardous environments by radiation from optical equipment.

The medical aspects have long been discussed at standards groups. IEC technical committee 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, therefore, provides a simple informative guideline on the maximum optical power permissible for optical amplifiers.

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:

– the optical power limit that causes thermal damage to the fibre, such as fibre fuse and fibre-coat burning;
– the maximum permissible exposure (MPE) to which the eyes/skin can be exposed without consequential injury;
– the optical power limit in the fibre that causes MPE on the eyes/skin after free-space propagation from the fibre;
– 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. In fact, the concept of hazard level and labelling is still evolving: more rigorous labelling requirements are under discussion in IEC Technical Committee 76 as of October 2008.

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 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 60825-2:2006, *Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCS)*
Amendment 1(2006)

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

ITU-T Recommendation G. 664, *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 the experiments and their results concerning the above issues to give guidelines for the damage-free use of optical amplifiers. However, it must be noted that the following results are only valid under the conditions tested and that a higher power might be allowed under different conditions.

NOTE The test method for the failure time (the time until the catastrophic failure of the glass, or the catastrophic failure to the fibre coating happens) characteristics as a function of the launch power and bend conditions (bend angle and diameter) is described in IEC 62547.

4.2 Fibre fuse and its propagation

4.2.1 Introduction

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 technical report experimentally analyzes the fibre fuse and its propagation caused by high optical power and discusses the threshold of optical power.

4.2.2 Experiment and results

The experimental setup is shown in Figure 1, in which the fibre fuse was initiated by heating the optical fibre from outside of the fibre by using an independent heat source, while a high optical power was continuously launched into the fibre. The wavelength of the high-power optical source was 1 467nm, which is a typical pump wavelength for distributed Raman amplification.

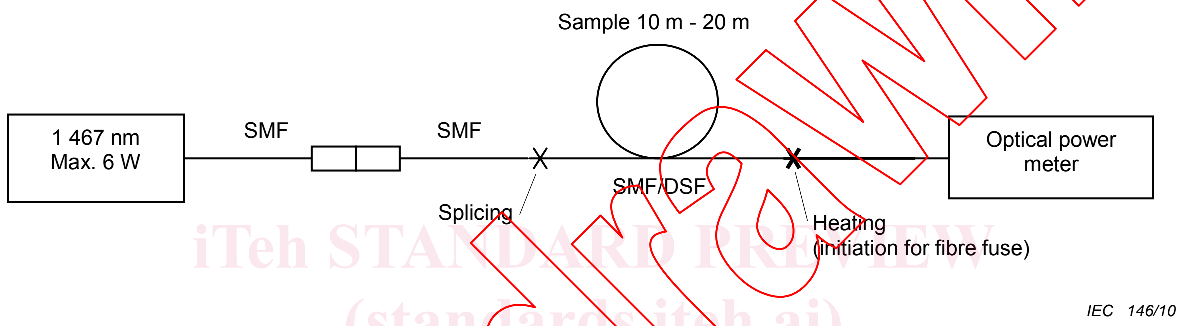

Figure 1 – Experimental setup for fibre fuse propagation

It was confirmed that the temperature of the fibre portion heated when the fuse initiated was greater than 1 000 °C. Once the fibre fuse began propagating, the optical source power was continuously reduced until the fuse propagation stopped. The threshold power for the fuse propagation was 1,4 W and 1,2 W for standard single mode fibre (SMF) and dispersion shifted fibre (DSF) respectively as shown in Table 1. The results for three trials are shown.

Table 1 – Experimental results of the threshold power of fibre fuse propagation

Standard single mode fibre	1,41 W, 1,45 W, 1,51 W
Dispersion shifter fibre	1,19 W, 1,19 W, 1,20 W

The difference in the fibre mode-field diameter might have been the major reason for the difference in the threshold powers because the fibre fuse depends on the power density [1][1]. The threshold power for the fibre fuse propagation was quite reproducible.

On the other hand, it was difficult to identify the threshold power for the fibre fuse initiation based on the above experiments because it varied significantly.

Although the mechanism of fibre fuse initiation is not yet well understood, the threshold seems to depend on the conditions, i.e., clean or dirty, of the fibre end faces where the very first fibre fuse takes place.

It was confirmed through repeated experiments, however, that the initiation threshold well exceeded 1,2 W and 1,4 W for various fibre end-face conditions.

1 Figures in square brackets refer to the Bibliography.