PD IEC TR 61292-6:2023



BSI Standards Publication

Optical amplifiers

Part 9: Distributed Raman amplification

bsi.

National foreword

This Published Document is the UK implementation of IEC TR 61292-6:2023. It supersedes PD IEC/TR 61292-6:2010, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/86/3, Fibre optic systems and active devices.

A list of organizations represented on this committee can be obtained on request to its committee manager.

Contractual and legal considerations

This publication has been prepared in good faith, however no representation, warranty, assurance or undertaking (express or implied) is or will be made, and no responsibility or liability is or will be accepted by BSI in relation to the adequacy, accuracy, completeness or reasonableness of this publication. All and any such responsibility and liability is expressly disclaimed to the full extent permitted by the law.

This publication is provided as is, and is to be used at the recipient's own risk.

The recipient is advised to consider seeking professional guidance with respect to its use of this publication.

This publication is not intended to constitute a contract. Users are responsible for its correct application.

This publication is not to be regarded as a British Standard.

© The British Standards Institution 2023
Published by BSI Standards Limited 2023

ISBN 978 0 539 20539 8

ICS 33.160.10; 33.180.30

Compliance with a Published Document cannot confer immunity from legal obligations.

This Published Document was published under the authority of the Standards Policy and Strategy Committee on 31 January 2023.

Amendments/corrigenda issued since publication

Date	Text affected

IEC TR 61292-6

Edition 2.0 2023-01

TECHNICAL REPORT

colour inside

Optical amplifiers –
Part 6: Distributed Raman amplification

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 33.160.10; 33.180.30

ISBN 978-2-8322-6340-2

Warning! Make sure that you obtained this publication from an authorized distributor.

® Registered trademark of the International Electrotechnical Commission

CONTENTS

FOREWORD 4
INTRODUCTION 6
1 Scope 7
2 Normative references 7
3 Terms, definitions, and abbreviated terms 7
3.1 Terms and definitions 7
3.2 Abbreviated terms 7
4 Background 8
4.1 General 8
4.2 Raman amplification process 8
4.3 Distributed vs. lumped amplification 10
4.4 Tailoring the Raman gain spectrum 11
4.5 Forward and backward pumping configuration 11
4.6 Typical performance of DRA 13
5 Applications of distributed Raman amplification 14
5.1 General 14
5.2 All-Raman systems 14
5.3 Hybrid EDFA Raman systems 15
5.3.1 General 15
5.3.2 Long repeaterless links 15
5.3.3 Long span masking in multi-span links 16
5.3.4 High capacity long haul and ultra-long-haul systems 16
6 Performance characteristics and test methods 16
6.1 General 16
6.2 Performance of the Raman pump module 16
6.2.1 Basic configuration 16
6.2.2 Pump wavelengths 17
6.2.3 Pump output power 17
6.2.4 Pump degree-of-polarization (DOP) 17
6.2.5 Pump relative intensity noise (RIN) 18
6.2.6 Insertion loss 18
6.2.7 Other passive characteristics 19
6.3 System level performance 19
6.3.1 General 19
6.3.2 On-off signal gain 19
6.3.3 Gain flatness 20
6.3.4 Polarization dependant gain (PDG) 21
6.3.5 Equivalent noise figure 21
6.3.6 Multi-path interference (MPI) 21
7 Operational issues 22
7.1 General 22
7.2 Dependence of Raman gain on transmission fibre 22
7.3 Fibre line quality 23
7.4 High pump power issues 23
7.4.1 General 23
7.4.2 Laser safety 24

7.4.3 Damage to the fibre line....24
8 Conclusions....25
Bibliography....26

Figure 1 – Stimulated Raman scattering process and Raman gain spectrum for silica fibres....9
Figure 2 – Distributed vs. lumped amplification....10
Figure 3 – The use of multiple pump wavelengths to achieve flat broadband gain....11
Figure 4 – Simulation results showing pump and signal propagation along an SMF span....12
Figure 5 – On-off gain and equivalent NF for SMF using a dual pump backward DRA with pumps at 1 424 nm and 1 452 nm....13
Figure 6 – Typical configuration of an amplification site in an all-Raman system....15
Figure 7 – Typical configuration of a Raman pump module used for counter-propagating DRA....17
Figure 8 – Model for signal insertion loss (IL) of a Raman pump module used for counter-propagating DRA....18
Figure 9 – Typical configuration used to measure on-off gain of DRA....20
Figure 10 – Variations of Raman on-off gain for different transmission fibres....23

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

OPTICAL AMPLIFIERS –

Part 6: Distributed Raman amplification

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.

IEC TR 61292-6 has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics. It is a Technical Report.

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

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

a) correction of the formula for noise figure;
b) correction of errors in Figure 10.

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

Draft	Report on voting
86C/1822/DTR	86C/1831/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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 document will remain unchanged until the stability date indicated on the IEC website under 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.

IMPORTANT – The "colour inside" logo on the cover page of this document 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

Distributed Raman amplification (DRA) describes the process whereby Raman pump power is introduced into the transmission fibre, leading to signal amplification within the transmission fibre though stimulated Raman scattering. This technology has become increasingly widespread in recent years due to many advantages that it offers to optical system designers, including improved system optical signal-to-noise ratio (OSNR) and the ability to tailor the gain spectrum to cover any or several transmission bands.

A fundamental difference between distributed Raman amplification and amplification using discrete amplifiers, such as erbium-doped fibre amplifiers (EDFAs), is that the latter can be described using a black box approach, while the former is an inherent part of the transmission system in which it is deployed. Thus, a discrete amplifier is a unique and separate element with well-defined input and output ports, allowing rigorous specifications of the amplifier performance characteristics and the methods used to test these characteristics. On the other hand, a distributed Raman amplifier is basically a pump module, with the actual amplification process taking place along the transmission fibre. This means that many of the performance characteristics of distributed Raman amplification are inherently coupled to the transmission system in which a Raman amplifier is deployed.

This document provides an overview of DRA and its applications. It also provides a detailed discussion of the various performance characteristics related to DRA, as well as some of the methods that can be used to test these characteristics. Information is also provided on some of the operational issues related to the distributed nature of the amplification process, such as the sensitivity to transmission line quality and eye-safety.

The material provided is intended to provide a basis for future development of specifications and test method standards related to DRA.

OPTICAL AMPLIFIERS –

Part 6: Distributed Raman amplification

1 Scope

This part of IEC 61292, which is a Technical Report, relates to distributed Raman amplification (DRA). Its main purpose is to provide background material for future standards related to DRA, such as specifications, test methods and operating procedures. This document covers the following aspects:

– general overview of Raman amplification;
– applications of DRA;
– performance characteristics and test methods related to DRA;
– operational issues relating to the deployment of DRA.

As DRA is a relatively new technology, and still rapidly evolving, some of the material in this document can become obsolete or irrelevant in a fairly short period of time. This document will be updated frequently to minimize this possibility.

2 Normative references

There are no normative references in this document.

3 Terms, definitions, and abbreviated terms

3.1 Terms and definitions

No terms and definitions are listed in this document.

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

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

3.2 Abbreviated terms

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

APR	automatic power reduction
DCF	dispersion compensating fibre
DOP	degree of polarization
DRA	distributed Raman amplification
DRB	double Rayleigh backscattering
DWDM	dense wavelength division multiplexing
EDFA	erbium-doped fibre amplifier
ESA	electrical spectrum analyzer
FBG	fibre Bragg grating
FWHM	full width half maximum