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TECHNICAL REPORT

colour inside

Optical amplifiers – Part 3: Classification, characteristics and applications

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CONTENTS

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FOREWORD

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IEC TR 61292-3, 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 2003. This edition constitutes a technical revision.

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

a) document architecture now focuses on EDFA, FRA and SOA;
b) the description of PDFA and TDFA has been moved to the annexes;
c) the EDWA description has been deleted;

d) information on single channel amplification, multi-channel amplification, configuration and control method for EDFA, FRA and SOA has been added;

e) information on future amplifiers, arrayed amplifiers and SDM amplifiers has been added.

The text of this document is based on the following documents:

Draft TR	Report on voting
86C/1597/DTR	86C/1630/RVDTR

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

This document 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 document will remain unchanged until the stability date indicated on the IEC website under "http://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- withdrawn,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.

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OPTICAL AMPLIFIERS –

Part 3: Classification, characteristics and applications

1 Scope

This part of IEC 61292, which is a Technical Report, establishes the classification of optical amplifiers (OAs). It also includes a brief description of each amplifier, its general properties, performance, configurations and applications.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60050-731, *International Electrotechnical Vocabulary – Part 731: Optical fibre communication* (available at www.electropedia.org)

IEC 61291-1, *Optical amplifiers – Part 1: Generic specification*

IEC TR 61931, *Fibre optic – Terminology*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-731, IEC 61291-1, IEC TR 61931, and the following apply.

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

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

3.1.1
erbium-doped fibre amplifier
EDFA
rare earth-doped fibre amplifier, where the core of the fibre is doped with erbium ions

3.1.2
semiconductor optical amplifier
SOA
optical amplifier that uses a semiconductor to provide the gain medium

Note 1 to entry: These amplifiers have a similar structure to Fabry-Pérot laser diodes but with anti-reflection design elements at the end faces. The signal is amplified through the stimulated emission phenomenon of gain medium.

3.1.3
single channel amplifier
optical amplifier amplifying one signal

3.1.4
multichannel amplifier
optical amplifier amplifying two or more signals whose wavelengths differ

3.1.5
remote optically pumped amplifier
ROPA
optical fibre amplifier in which pumping light(s) is transmitted remotely to active fibre through a transmission fibre

3.1.6
space division multiplexing amplifier
SDM amplifier
optical fibre amplifier that uses space division multiplexing (SDM) transmission system

Note 1 to entry: There are two types of SDM amplifier: one is a multi-core fibre amplifier, and the other is a few-mode fibre amplifier.

3.1.7
multi-core erbium-doped fibre amplifier
multi-core EDFA
space division multiplexing EDFA for multi-core transmission

3.1.8
few-mode erbium-doped fibre amplifier
few-mode EDFA
space division multiplexing EDFA for few-mode transmissions

3.1.9
arrayed amplifier
optical amplifier formed by arranging several semiconductor amplifiers and EDFAs in parallel

3.2 Abbreviated terms

ACC automatic current control
AGC automatic gain control
ALC automatic level control
APC automatic power control
ASE amplified spontaneous emission
DRA distributed Raman amplifier
EDF erbium-doped fibre
EDFA erbium-doped fibre amplifier
EDFFA erbium-doped fluoride fibre amplifier
EDSFA erbium-doped silica fibre amplifier (commonly known as EDFA)
EDTFA erbium-doped tellurite fibre amplifier
EDWA erbium-doped waveguide amplifier
EYDFA erbium ytterbium-doped fibre amplifier
EYDSFA erbium ytterbium-doped silica fibre amplifier (commonly known as EYDFA)
FMF few-mode fibre
FRA fibre Raman amplifier
GFF gain flattening filter
LD laser diode
MCF multi-core fibre

MQW	multiple quantum well
NF	noise figure
OA	optical amplifier
OFA	optical fibre amplifier
OSNR	optical signal-to-noise ratio
OWGA	optical waveguide amplifier
PD	photo diode
PDFA	praseodymium-doped fibre amplifier
PDFFA	praseodymium-doped fluoride fibre amplifier (also known as PDFA)
PDG	polarization-dependent gain
ROADM	reconfigurable optical add/drop multiplexer
ROPA	remote optically pumped amplifier
SDM	space division multiplexing
SMF	single-mode fibre
SOA	semiconductor optical amplifier
TEC	thermo-electric cooler
TDFA	thulium-doped fibre amplifier
TDFFA	thulium-doped fluoride fibre amplifier (also known as TDFA)
VOA	variable optical attenuator
WDM	wavelength division multiplexing
WSS	wavelength selective switch

4 Classification

4.1 Types of OA

Figure 1 shows the classification of optical amplifiers. Optical amplifiers (OAs) are classified as optical fibre amplifiers (OFAs), semiconductor amplifiers (SOAs) and others (e.g. optical wave guide amplifiers (OWGA) such as Erbium doped waveguide amplifiers (EDWA)). Furthermore, OFAs are classified as rare earth-doped optical fibre amplifiers and fibre Raman amplifiers (FRAs), and rare earth-doped optical fibre amplifiers are classified as erbium-doped optical fibre amplifiers (EDFAs) and rare earth-doped optical fibre amplifiers with alternative dopants. From these various OAs, the OAs which are practically used are EDFAs, FRAs and SOAs. General properties, performance and configurations of EDFAs, FRAs and SOAs are described in Clause 5. OAs are also classified according to amplification form, application, etc., in addition to those in Figure 1. The various amplification forms and the application of optical amplifiers are explained in 4.2 and 4.3, respectively.

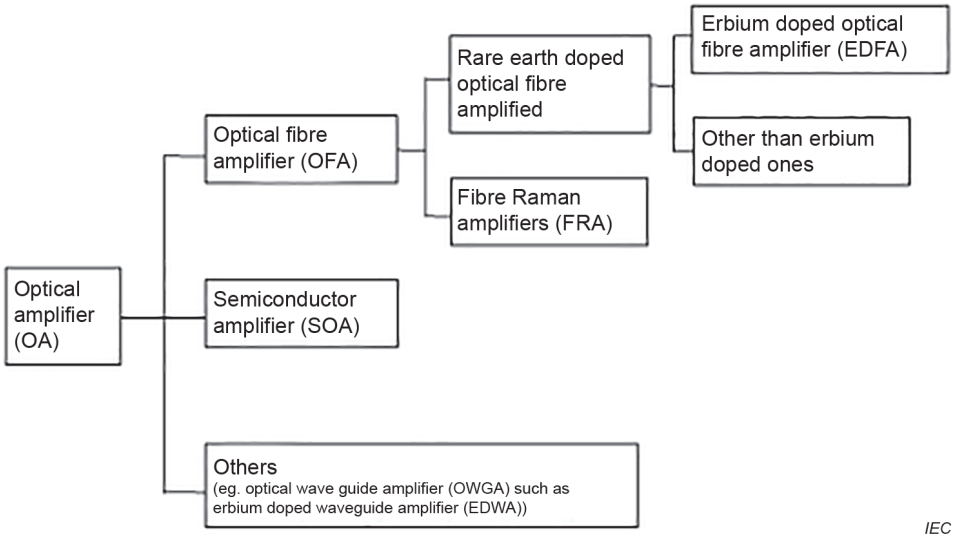

Figure 1 – Classification of optical amplifiers

Rare earth-doped optical fibre amplifiers other than erbium-doped ones have also been developed. Various rare earth-doped fibre amplifiers are often expressed as an abbreviation: X-Y-DFA. "X" indicates the type of rare earth, i.e., E, T, P, and "Y" represent erbium, thulium, praseodymium, and ytterbium, respectively. "Y" indicates the fibre type, i.e., S, F and T represent silica fibre, fluoride fibre and tellurite fibre, respectively. So, EDSFA, which is commonly known as EDFA, EDFFA and EDTFA indicate an erbium-doped silica fibre amplifier, an erbium-doped fluoride fibre amplifier and an erbium-doped tellurite fibre amplifier, respectively. When two kinds of rare earths are added, the notation X^1-X^2-Y-DFA is used. For example, EYSDFA (commonly known as EYDFA) indicates an erbium ytterbium-doped silica fibre amplifier. Although many rare earth-doped fibres have been developed, EDFA is the rare earth-doped fibre that is generally commercialized today. In addition, EYDFA is described as an EDFA that has high output characteristics in this classification. Furthermore, since praseodymium-doped fluoride fibre amplifiers (PDFFA, also known as PDFA) and thulium-doped fluoride fibre amplifiers (TDFFA, also known as TDFA) are used in special fields, they are introduced in Annex A. Furthermore, Annex B introduces SDM amplifiers that have recently appeared.

Figure 2 shows the amplification bandwidth of each type of amplifier. EDFA is used for amplification of C-band (amplification bandwidth: approximately 30 nm) and L-band (amplification bandwidth: approximately 30 nm) optical signals, and it is also applicable to amplification of a part of the S-band (amplification bandwidth: approximately 20 nm) optical signal. Rare earth-doped optical fibre amplifiers other than erbium-doped ones can achieve O-band, S-band and U-band amplification by using praseodymium and thulium as the dopant.

NOTE Spectral bands of O-band, S-band, C-band, L-band and U-band are defined in ITU-T G.Sup39.

FRAs and SOAs can realize amplification in the required band over the whole wavelength region by selecting the wavelength of the pump source and semiconductor composition. The amplification bandwidth of FRAs and SOAs is about 100 nm.

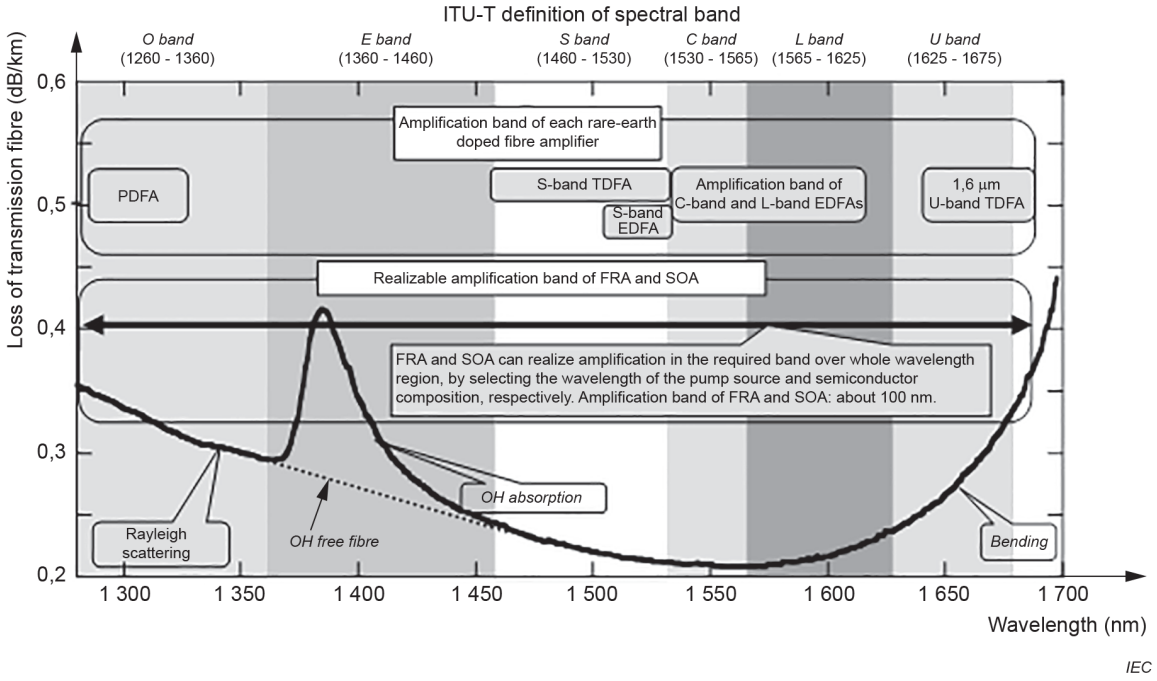

Figure 2 – Amplification bandwidth of each type of amplifier

4.2 Amplification forms

4.2.1 Lumped (or discrete) amplification and distributed amplification

In a transmission system, there are two amplification types: lumped (or discrete) amplification, which performs optical amplification between transmission fibres, and distributed amplification, which uses the transmission fibre itself as the amplification medium. EDFAs, other rare earth-doped optical fibre amplifiers and SOAs are applied to the former, and FRAs are used for both applications. However, an FRA is used as a distributed Raman amplifier (DRA) rather than a lumped (or discrete) amplifier because of its advantages and drawbacks. In addition, amplification in which an EDFA and Raman are combined is also applied in the system.

4.2.2 Single channel and multichannel amplification

OAs are classified according to the number of signals to be amplified with a single channel amplifier and a multichannel amplifier. The single channel amplifier amplifies only one signal, and the multichannel amplifier amplifies two or more signals whose wavelengths differ (that is, the WDM signal). EDFAs, other rare earth-doped optical fibre amplifiers and FRAs are applied as both amplifiers, and SOAs are generally used as single channel amplifiers due to the four wave-mixing effect.

4.2.3 Fixed and variable gain amplification

Normally, since the gain characteristic of an OA is fixed, it may be called a fixed gain type OA. However, depending on the application, the OA may change its gain characteristics as necessary, and it may be called a variable gain type OA. An EDFA that can operate variable gain functions (this may be called a variable gain EDFA or gain switchable EDFA) can be achieved by changing EDF length that is used in the EDFA, or by using a multistage configuration (see 5.1.3.3).