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TECHNICAL REPORT

Optical amplifiers –
Part 1: Parameters of amplifier components

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FOREWORD

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IEC 61292-1, 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 1998. It is a technical revision with updates reflecting new technology.

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

Enquiry draft	Report on voting
86C/853/DTR	86C/871/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.

A list of all parts of the IEC 61292 series, published under the general title *Optical amplifiers,* can be found on the IEC website.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result 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- withdrawn,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 technical report may be published later.

OPTICAL AMPLIFIERS –

Part 1: Parameters of amplifier components

1 Scope and object

This part of IEC 61292, which is a technical report, applies to optical components of rare-earth doped fibre amplifiers. It provides information about the most relevant parameters of optical components especially for erbium doped fibre amplifiers (EDFAs).

The object of this technical report is to provide introductory information for a better understanding of EDFA operation and applications.

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/TR 61931, *Fibre optic – Terminology*

ITU-T Recommendation G. 650.1, *Definition and test methods for linear, deterministic attributes of single-mode fibre and cable*

NOTE A list of informative references is given in the Bibliography.

3 Abbreviations

For the purposes of this document, the following abbreviations apply.

ASE	amplified spontaneous emission
EDFA	erbium-doped fibre amplifier
EDF	erbium-doped fibre
OFA	optical fibre amplifier
OA	optical amplifier
RMS(r.m.s)	root mean square
LD	laser diode
TEC	thermo-electric cooler
FBG	fibre Bragg grating
FWHM	full-width at half maximum
WDM	wavelength division multiplexing
GFF	gain flattening filter
PIN-PD	PIN-photodiode
VOA	variable optical attenuator
EDF	erbium doped fibre
PDL	polarization dependent loss (variation)
PMD	polarization mode dispersion
MTBF	mean time between failure

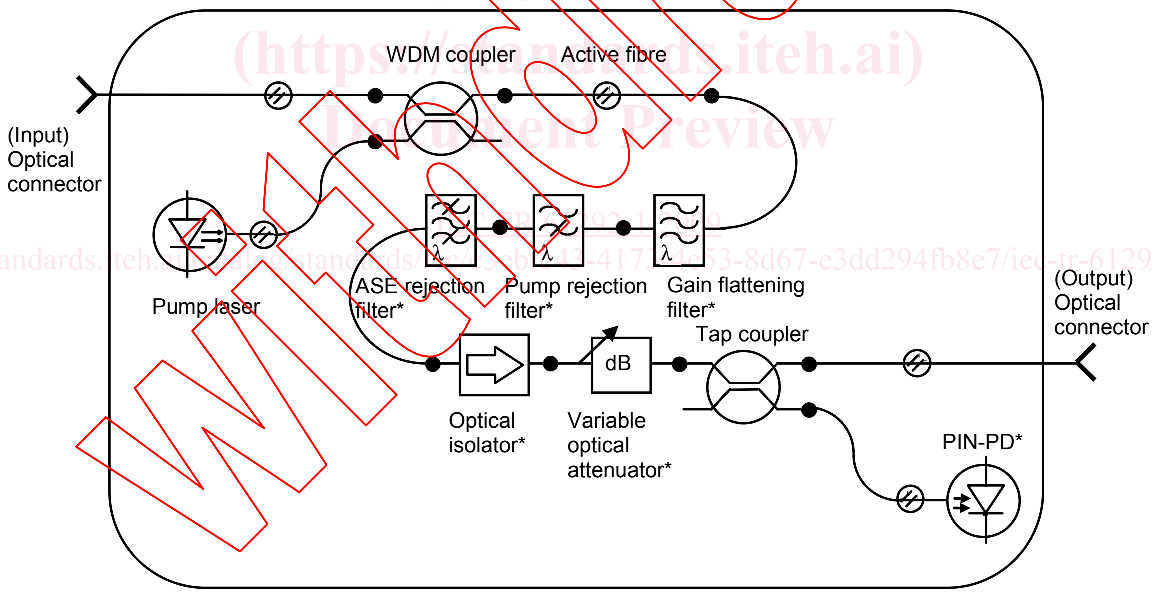
FIT failure in time

4 OFA components

The parameters relevant for a satisfactory understanding of OFA operation are covered by the following optical component definitions:

– active fibre;
– pump laser;
– wavelength division multiplexing (WDM) coupler;
– optical isolator;
– amplified spontaneous emission (ASE) rejection filter;
– pump rejection filter;
– gain flattening filter (GFF);
– tap coupler;
– PIN-photodiode (PIN-PD);
– variable optical attenuator (VOA);
– optical connectors.

Figure 1 provides an example of the component layout for an OFA.



*Optional components (can be placed elsewhere)

IEC 660/09

Figure 1 – Example of the components inside an EDFA operating in a co-propagating pumping scheme

5 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

5.1 Active fibre

The active fibre is used as gain media in OFA. Rare earth ion is generally doped in the core region of fibre to produce signal amplification, an Er^{3+} ion is applied for 1550-nm band OFA such as an erbium doped fibre amplifier (EDFA). Erbium doped fibre (EDF) absorbs light with a wavelength of 980 nm or 1 480 nm for pumping, and emits infrared light with a wavelength in the 1 550-nm region. Optical amplification is realized utilizing stimulated emission of 1 530-nm luminescence.

5.1.1
active fibre maximum input signal power
optical power level associated with the input signal above which the active fibre gets damaged, causing impossibility of normal operation

5.1.2
active fibre insertion loss at out-of-band wavelength
active fibre insertion loss for a signal at out-of-band wavelength

5.1.3
active fibre polarization-dependent gain variation
maximum fibre gain variation due to variation of the state of polarization of the input signal

5.1.4
active fibre PMD
maximum PMD at the signal wavelength which is launched into the input port of the active fibre and exits from signal output port of the active fibre, expressed in ps (pico second)

NOTE 1 When an optical signal travels through an optical fibre, optical component or subsystem (such as an OFA), the change in the shape and width of the pulse due to the differential group delay (DGD) (the propagation delay difference between the two principal states of polarization (PSPs)) and to the waveform distortion for each PSP, is due to PMD. PMD, together with polarization dependent loss (PDL) and polarization dependent gain (PDG), may introduce large waveform distortions leading to an unacceptable bit error ratio increase.

NOTE 2 The level of PMD may depend on temperature and operating conditions.

5.1.5
active fibre mode field diameter
as in ITU-T Recommendation G.650.1 and IEC/TR 61931

5.1.6
active fibre cut-off wavelength
as in ITU-T Recommendation G.650.1 and IEC/TR 61931

5.1.7
active fibre cladding diameter
as in ITU-T Recommendation G.650.1 and IEC/TR 61931

5.1.8
active fibre cladding non-circularity
as in ITU-T Recommendation G.650.1 and IEC/TR 61931

5.1.9
active fibre mode field concentricity error
as in ITU-T Recommendation G.650.1 and IEC/TR 61931

5.1.10
active fibre composition
composition of the active fibre, intended as the host glass composition as well as the dopant element and its concentration

5.1.11
active fibre length
length of the active fibre. Changing fibre length can optimize gain characteristics of EDFA

5.1.12
active fibre dopant distribution
concentration of dopant rare-earth ions in the fibre as a function of the fibre radial coordinate

5.1.13
pumping efficiency
for a given active fibre, the slope of the gain versus pump optical power curve under specified operating conditions

5.1.14
saturation pump power
for a given active fibre, the pump optical power level above which the small-signal gain shows no further increase

5.1.15
threshold pump power
the minimum pump optical power necessary to reach a small-signal gain equal to 1 in a given active fibre when the fibre length is short enough so that the pump optical power remains constant along the fibre

5.1.16
active fibre operating temperature
temperature to be maintained for normal operating condition, given in the relevant detail specification

NOTE Amplification characteristics of active fibre strongly depend on its temperature. Thus, EDF in the many EDFA unit is maintained with the certain constant temperature. Many EDFA units include heater device or TEC in order to control active fibre temperature. Fibre operating temperatures of 40 °C ~ 70 °C are usually specified as operating temperature. Some of fixed gain EDFAs (especially smaller packaged EDFA), do not include this feature.

5.2 Pump laser

A pump laser is used to provide excitation energy for active fibre. By introducing the strong pumping light from a pump laser to active fibre, the signal light will be amplified by stimulated emission from a rare-earth ion such as Er^{3+} in EDF.

5.2.1
pumping wavelength
nominal wavelength of the emission spectrum of the pump laser. In EDFA, 980 nm and 1 480 nm are commonly used for pumping wavelength

5.2.2
pumping scheme
set-up of the EDFA characterized by the direction of pump optical power propagation with respect to signal direction

NOTE Usually, three schemes are used: co-propagating, where the pump and the signal propagate through the active fibre in the same direction; counter-propagating, where the signal and the pump propagate through the active fibre in opposite directions; bi-directional, where two pumps propagate simultaneously through the active fibre in both directions. Regarding pumping schemes other than pump direction, a polarization combining scheme and a wavelength combining scheme are considered for detailed design to enlarge pump power. However, a single laser diode pump scheme is described as a classic example in this technical report.

5.2.3
pumping power
optical power associated with the pump, injected into the active fibre

5.2.4
centre wavelength
pump efficiency of EDF depends on the overlap integral of EDF absorption spectrum and pump LD spectrum, so the centre wavelength of pump laser is crucial for EDF pumping