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Transmission media and optical systems characteristics – Characteristics of optical components and subsystems

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Definitions and test methods for the relevant generic parameters of optical amplifier devices and subsystems

ITU-T Recommendation G.661

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ITU-T Recommendation G.661

Definitions and test methods for the relevant generic parameters of optical amplifier devices and subsystems

Summary

ITU-T Recommendation G.661 provides the definitions of the relevant parameters, common to the different types of optical amplifiers and the test methods of said parameters to be followed, as far as applicable, for optical amplifier devices and subsystems covered by ITU-T Recommendations.

Source

ITU-T Recommendation G.661 was approved on 29 July 2007 by ITU-T Study Group 15 (2005-2008) under the ITU-T Recommendation A.8 procedure.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure e.g. interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

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As of the date of approval of this Recommendation, ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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ITU-T Recommendation G.661

Definitions and test methods for the relevant generic parameters of optical amplifier devices and subsystems

1 Scope

This Recommendation applies to all commercially available optical amplifiers (OAs), optically amplified subsystems and optical network elements (ONEs) containing OAs. It applies to OAs using optically pumped fibres (OFAs based either on rare-earth doped fibres or on the Raman effect), semiconductors (SOAs) and waveguides (POWAs).

This Recommendation provides the definitions of the relevant parameters, common to the different types of OAs, listed in clause 5, and the test methods of said parameters described in clause 6, to be followed, as far as applicable, for OA devices and subsystems covered by ITU-T Recommendations. Parameter definitions applicable specifically to distributed Raman amplifiers, however, can be found in [ITU-T G.665].

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.662]	ITU-T Recommendation G.662 (2005), *Generic characteristics of optical amplifier devices and subsystems*.
[ITU-T G.663]	ITU-T Recommendation G.663 (2000), *Application related aspects of optical amplifier devices and subsystems*.
[ITU-T G.665]	ITU-T Recommendation G.665 (2005), *Generic characteristics of Raman amplifiers and Raman amplified subsystems.*
[ITU-T G.680]	ITU-T Recommendation G.680 (2007), *Physical transfer functions of optical network elements*.
[IEC 61290]	IEC 61290 (all parts), *Basic specification for optical amplifier test methods*.
[IEC 61291-1]	IEC 61291-1 (2006), *Optical amplifiers – Part 1: Generic specification.*

Parameters specified for OAs are those characterizing the transmission, operation, reliability and environmental properties of the OA seen as a "black box" from a general point of view. In [ITU-T G.662], a subset of these parameters is specified according to the type and application of the particular OA device or subsystem.

3 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ASE	Amplified Spontaneous Emission
BER	Bit Error Ratio
Bsp-sp	Spontaneous-spontaneous optical bandwidth

DGD	Differential Group Delay
DOP	Degree of Polarization
EDFA	Erbium-Doped (silica-based) Fibre Amplifier
F	noise Factor
FIT	Failures In Time
FWHM	Full-Width Half-Maximum
MPI	Multi-Path Interference
MTBF	Mean Time Between Failures
NF	Noise Figure
OA	Optical Amplifier
OAR	Optically Amplified Receiver
OAT	Optically Amplified Transmitter
OFA	Optical Fibre Amplifier
ONE	Optical Network Element
OSA	Optical Spectrum Analyser
PDG	Polarization Dependent Gain
PDL	Polarization Dependent Loss
PMD	Polarization Mode Dispersion
POWA	Planar Optical Waveguide Amplifier
PSP	Principal State of Polarization
SNR	Signal-to-Noise Ratio
SOA	Semiconductor Optical Amplifier
SOP	State Of Polarization
TM	Test Method

4 Classification

Different OA application categories are defined depending on the technology used and the utilization of the OA itself. Classification of optical amplifier technologies is also given in IEC/TR 61292-3.

These categories are identified by a capital letter, a number and a lower case letter, as follows:

Capital letter

A	OFAs using silica-based fibres doped with erbium ions to produce an active fibre
B	OFAs using other doped active fibres
C	Raman amplifiers
D	SOA
E	POWA

Number

1	Power amplifiers (post-amplifiers or booster amplifiers)
2	Pre-amplifiers
3	Line amplifiers
4	Optically amplified transmitter (OAT)
5	Optically amplified receiver (OAR)
6	Distributed amplifiers
7	Composite distributed and discrete amplifiers

Lower case letter

a	Amplifiers for analogue, single (wavelength) channel transmission
b	Amplifiers for digital, single (wavelength) channel transmission
c	Amplifiers for digital, multichannel (wavelength) transmission

EXAMPLE – Category A2b refers to optical pre-amplifiers for single-channel digital transmission which use a silica-based fibre doped with Erbium ions.

The *power amplifier* is a high saturation-power OA device to be used directly after the optical transmitter to increase its signal power level.

The *pre-amplifier* is a very low noise OA device to be used directly before an optical receiver to improve its sensitivity.

The *line amplifier* is a low noise OA device to be used between passive fibre sections to increase the distance covered before regeneration is necessary or in correspondence with a point-multipoint connection to compensate for branching losses in the optical access network.

The OAT is an OA subsystem in which a power amplifier is integrated with an optical transmitter, resulting in a higher power transmitter.

The OAR is an OA subsystem in which a pre-amplifier is integrated with an optical receiver, resulting in a higher sensitivity receiver.

The *distributed amplifier* is a device configuration that provides amplification over an extended length of the optical fibre used for transmission, as by Raman pumping, and is thus distributed over part or all of the transmission span.

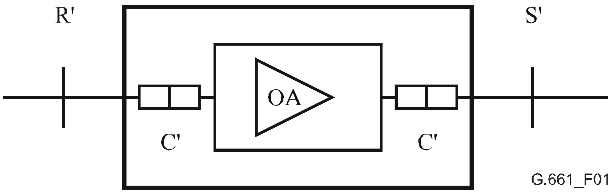
The *composite distributed and discrete amplifiers* are defined in [ITU-T G.665].

5 Definitions

The list of parameter definitions of OAs, given in the following part of this clause, is divided into two parts: the first part lists those parameters relevant for OA devices, namely power, pre-, line-, distributed amplifiers and ONEs containing OAs; the second part lists the parameters relevant for optically amplified, elementary subsystems, namely the optically amplified transmitter (OAT) and the optically amplified receiver (OAR).

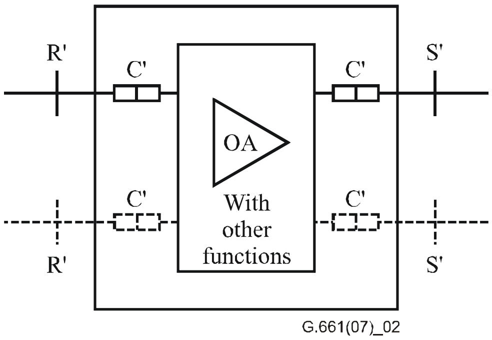
Where the value of a parameter is given for a particular device, it will be necessary to specify certain appropriate operating conditions such as temperature, bias current, pump optical power, etc. In this clause, two different operating conditions are referred to: *nominal operating conditions*, which are those suggested by the manufacturer for normal use of the OA, and *limiting operating conditions*, in which all the parameters adjustable by the user (e.g., temperature, gain, pump laser injection current, etc.) are at their maximum values, according to the *absolute maximum ratings* stated by the manufacturer.

The OA is considered as a "black box", as shown in Figure 1. The OA device has two optical ports, namely an input and an output port. The ONE, as shown in Figure 2, contains one or more OAs, which can be located at the input as well as at the output. The location and number of OAs depends on their function in the ONE. Some ONE examples are described in [ITU-T G.680]. Each ONE has, at a minimum, one input and one output. The ONE is considered as a "black box". The OAT and OAR are considered as an OA integrated with a transmitter or a receiver, respectively. Both kinds of integration imply that the connection between the transmitter or the receiver and the OA is proprietary and not to be specified. Consequently, only the optical output port can be defined for the OAT (after the OA, as shown in Figure 3) and only the optical input port can be defined for the OAR (before the OA, as shown in Figure 4). The optical ports may consist of unterminated fibres or optical connectors. Electrical connections for power supply (not shown in Figures 1 to 4) are also necessary. Following this "black box" approach, the loss of both pairs of connectors directly associated with the device (labelled C or C' in Figures 1 to 4) and the corresponding uncertainty will be included within the values of gain, noise figure and other parameters of the OA device.



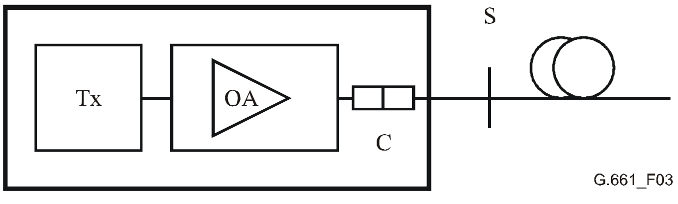
S' Reference point in the optical fibre just after the optical connection (C') of the OA device.
R' Reference point in the optical fibre just before the optical connection (C') of the OA device.

Figure 1 – OA device reference diagram



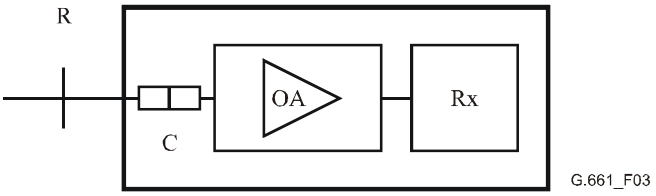
S' Reference point in the optical fibre just after the optical connection (C') of the ONE device.
R' Reference point in the optical fibre just before the optical connection (C') of the ONE device.

Figure 2 – ONE device reference diagram



S Reference point in the optical fibre just after the optical connection (C) of the OAT.

Figure 3 – OAT reference diagram



R Reference point in the optical fibre just before the optical connection (C) of the OAR.

Figure 4 – OAR reference diagram

It should be noted that the configurations in Figures 1 to 4 are shown in the context of ITU-T reference points. It indicates the loss of two connector pairs are included in the black box OA or ONE rather than one. ITU-T reference planes normally account for connector losses differently, as indicated in [ITU-T G.662]. More complete treatment of this topic can be found in Appendix III of [ITU-T G.665]. The user is advised to take the appropriate loss differences into consideration.

The OA amplifies signals in a nominal *operating wavelength* region. In addition, other signals outside of the band of operating wavelength can in some applications also cross the OA. The purpose of these *out-of-band* signals and their wavelength, or wavelength region, can be specified in the detailed specifications.

When signals at multiple wavelengths are incident on the OA, as is the case in multichannel systems, suitable adjustment of the definitions of some existing relevant parameters is needed together with the introduction of definitions of new parameters relevant to this different application.

A typical configuration of an OA in a multichannel application is shown in Figure 5. At the transmitting side *n* signals, coming from *n* optical transmitters, Tx1, Tx2, . . . Txn, each with a unique wavelength, λ_1, λ_2, . . . λ_n, respectively, are combined by an optical multiplexer (OM). At the receiving side, the *n* signals at λ_1, λ_2, . . . λ_n, are separated with an optical demultiplexer (OD) and routed to separate optical receivers, Rx1, Rx2, . . . Rxn, respectively. To characterize the OA in this multichannel application, an input reference plane and an output reference plane are defined at the OA input and output ports, respectively, as shown in Figure 5.

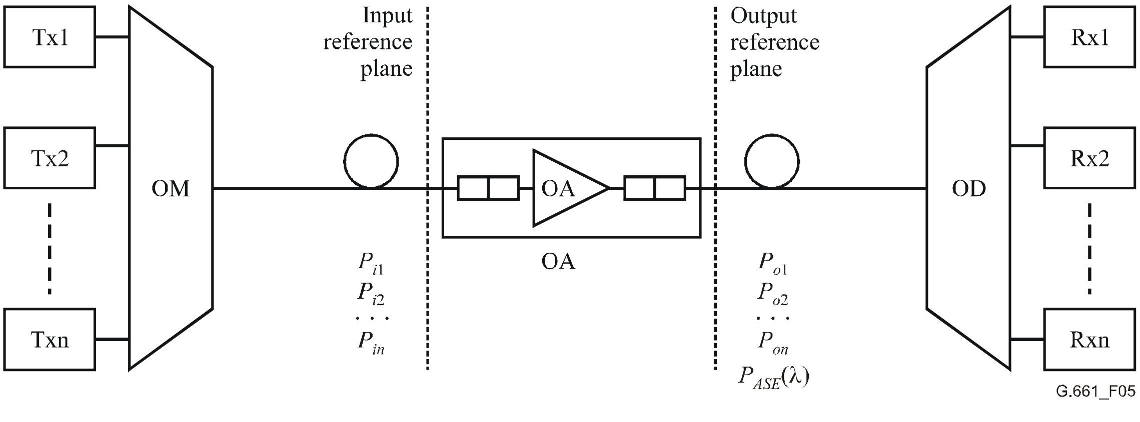


Figure 5 – An optical amplifier in a multichannel application

At the input reference plane, *n* input signals at the *n* wavelengths are considered, each with a unique power level, P_{i1}, P_{i2}, . . . P_{in}, respectively. At the output reference plane, *n* output signals at the *n* wavelengths, resulting from the optical amplification of the corresponding *n* input signals, are considered, each with power level P_{o1}, P_{o2}, . . . P_{on}, respectively. Moreover, the amplified spontaneous emission, ASE, with a noise power spectral density, $P_{ASE}(\lambda)$, is also to be considered at the OA output port.

It should be noted that the location of the reference planes in Figure 3 are provided in context of the nomenclature normally used in ITU-T Recommendations. IEC nomenclature treats connector losses differently. A more complete discussion of this topic can be found in Appendix III of [ITU-T G.665].

Most definitions of relevant single-channel parameters can be suitably extended to multichannel applications. When this extension is straightforward, the word "channel" is used in the pertinent parameter. In particular, the noise figure and the signal-spontaneous noise figure may be extended to multichannel applications, channel by channel, by considering the value of $P_{ASE}(\lambda)$ at each channel wavelength and the channel signal bandwidth. For each channel wavelength, there is a unique value of noise figure that is a function of the input power level of all signals. In this case, the parameters channel noise figure and channel signal-spontaneous noise figure are introduced. However, some additional parameters also need to be defined. For each parameter, the particular multichannel configuration, including the full set of channel signal wavelengths and input powers, needs to be specified.

NOTE 1 – Except where noted, the optical powers mentioned in the following are average powers.

NOTE 2 – The parameters defined below will, in general, depend also on temperature and polarization state of input channels. The temperature and state of polarization should be kept constant or controlled or be measured and reported together with the measured parameter.

NOTE 3 – In the case of the distributed amplifier, all the parameters are related to a suitable reference fibre used to emulate the transmission fibre in conjunction with the pumping module.

5.1 Definitions for OA devices and ONEs containing OAs

The definitions listed in this clause refer to the meaning of the terms used in the specifications of OA devices and ONEs containing OAs.

5.1.1 gain: In an OA, the increase of signal optical power from the input reference point R' to the output reference point S', expressed in dB.

NOTE 1 – Care should be taken to exclude the amplified spontaneous emission power from the signal optical powers at both the input and output.

NOTE 2 – This definition is different from the corresponding IEC definition in that it includes the effects of any connectors directly associated with the OA device at both the input and output.

5.1.2 small-signal gain: The gain of the amplifier, when operated in linear regime, where it is essentially independent of the input signal optical power at a given signal wavelength and pump optical power level.

NOTE – This property can be described at a discrete wavelength or as a function of wavelength.

5.1.3 reverse small-signal gain: The small-signal gain measured in the reverse direction, i.e., from output port to input port.

5.1.4 maximum small-signal gain: The highest small-signal gain that can be achieved when the OA is operated within the stated nominal operating conditions.

5.1.5 maximum small-signal gain wavelength: The wavelength at which the maximum small-signal gain occurs.

5.1.6 maximum small-signal gain variation with temperature: The change in small-signal gain for temperature variation within a specified range, expressed in dB.

5.1.7 gain-slope under single wavelength operation (for analogue operation): In the presence of a signal of given wavelength and input power, the derivative of the gain of a small probe versus wavelength, at the signal wavelength, expressed in dB/nm.

NOTE – The probe total average power level should be at least 20 dB below the input signal level, to minimize the effect on the gain wavelength-profile.

5.1.8 small-signal gain variation with wavelength: The peak-to-peak variation of the small-signal gain over a given wavelength range.

5.1.9 small-signal gain stability: The degree of small-signal gain fluctuation expressed by the ratio (in dB) of the maximum and minimum small-signal gain, for a certain specified test period, under nominal operating conditions.

5.1.10 large-signal output stability: The degree of output optical power fluctuation expressed by the ratio (in dB) of the maximum and minimum output signal optical powers, for a certain specified test period, under nominal operating conditions and a specified large input signal optical power.

5.1.11 polarization dependent gain (PDG): The maximum variation of the OA gain due to a variation of the state of polarization of the input signal under nominal operating conditions.

NOTE – A source of PDG in OAs is the polarization dependent loss of the passive components used inside.

5.1.12 saturation output power (gain compression power): The optical power level associated with the output signal at which the gain is reduced by N dB (typically N = 3) with respect to the small-signal gain at the signal wavelength.

NOTE 1 – The wavelength at which the parameter is specified should be stated.

NOTE 2 – The optical pump power, for OFAs, or the pump current, for SOAs, should be stated when applicable.

5.1.13 nominal output signal power: The signal optical power at the output for a specified signal optical power at the input under nominal operating conditions.

5.1.14 maximum output signal power: The highest signal optical power at the output that can be obtained from the OA under nominal operating conditions.

5.1.15 input power range: The range of optical power levels at the input for which the corresponding output signal optical power lies in the specified output power range, where the OA performance is ensured.

5.1.16 channel input power range: The range of optical channel power levels at the input of the OA or ONE over which all of the other parameters of the device are required to remain within the allowed limits.

5.1.17 output power range: The range of optical power levels at the output of the OA for which the corresponding input signal power lies in the specified input power range, where the OA performance is ensured.

5.1.18 channel output power range: The range of optical channel power levels at the output of the OA or ONE that must be present while the corresponding input channels are within the channel input power range.

5.1.19 optical signal-to-noise ratio (OSNR): The optical signal-to-noise ratio (OSNR) is the ratio of the signal power in the wanted channel to the highest noise power density (referred to 0.1 nm) within the channel frequency range.

5.1.20 noise figure (NF) (applicable to OA devices only): The decrease of the signal-to-noise ratio (SNR), at the output of an optical detector with unitary quantum efficiency, due to the propagation of a shot-noise-limited signal through the OA, expressed in dB.

NOTE 1 – The operating conditions at which the noise figure is specified should be stated.

NOTE 2 – This property can be described at a discrete wavelength or as a function of wavelength.

NOTE 3 – The noise degradation due to the OA is attributable to multiple contributions, e.g., signal-spontaneous beat noise, spontaneous-spontaneous beat noise, internal reflections noise, signal shot noise, and spontaneous shot noise. Each of these contributions depends on various conditions which should be specified for a correct evaluation of the noise figure.

NOTE 4 – By convention, the noise figure is a positive number.

NOTE 5 – In the case of OAs for analogue applications, the noise figure also represents the ratio between input and the output carrier-to-noise ratios.

5.1.21 forward amplified spontaneous emission (ASE) power level: The optical power in a specified wavelength range associated with the ASE exiting from the output port under nominal operating conditions.

NOTE 1 – This parameter is particularly important for OAs used as pre-amplifiers or line amplifiers and it depends mainly on the filter used.

NOTE 2 – The operating conditions (e.g., the gain and input signal optical power) at which the ASE level is specified should be stated.

5.1.22 reverse ASE power level: The optical power in a specified wavelength range associated with the ASE exiting from the optical input port under nominal operating conditions.

5.1.23 maximum input reflectance: The maximum fraction of incident optical power, at the operating wavelength and over all states of input light polarization, reflected by the OA or ONE from the input port, under nominal specified operating conditions, expressed in dB.

NOTE – The measurement is performed with a given input signal optical power.

5.1.24 output reflectance (not applicable to optically amplified receivers): The fraction of incident optical power at the operating wavelength reflected by the OA or ONE from the output port, under nominal operating conditions, expressed in dB.

5.1.25 maximum reflectance tolerable at input: The maximum fraction of power, expressed in dB, exiting the optical input port of the OA or ONE which, when reflected back into the OA or ONE, allows the device to still meet its specifications.

NOTE 1 – The measurement is performed with a given input signal optical power.

NOTE 2 – The noise figure is the parameter most sensitive to this reflectance.

5.1.26 maximum reflectance tolerable at output: The maximum fraction of power, expressed in dB, exiting the optical output port of the OA or ONE which, when reflected back into the OA or ONE, allows the device to still meet its specifications.

NOTE 1 – The measurement is performed with a given input signal optical power.

NOTE 2 – The noise figure is the parameter most sensitive to this reflectance.

5.1.27 pump leakage to output: The pump optical power which is emitted from the OA output port.

NOTE 1 – The measurement is performed with a given input signal optical power.

NOTE 2 – The maximum pump leakage to output may occur for no input signal.

5.1.28 pump leakage to input: The pump optical power which is emitted from the OA input port.

NOTE 1 – The measurement is performed with a given input signal optical power.

NOTE 2 – The maximum pump leakage to input may occur for no input signal.

5.1.29 out-of-band insertion loss: OA insertion loss for a signal at the specified out-of-band wavelength(s).

5.1.30 out-of-band reverse insertion loss: OA insertion loss for a signal at the specified out-of-band wavelength(s), measured in the reverse direction, i.e., from output port to input port.

5.1.31 powering and control requirements: Those electrical currents and/or voltages as well as those electrical signals necessary for OA operation within the stated maximum ratings. Necessary tolerances on electrical powering and switching on and off procedures are included.

5.1.32 maximum power consumption: Electrical power needed by the OA operating within the absolute maximum ratings.

5.1.33 maximum total output power: The highest optical power level at the output port of the OA or ONE operating within the absolute maximum ratings.

5.1.34 operating temperature: The temperature range within which the OA can be operated while still meeting all its specified parameter values.

5.1.35 optical connections: The connector and/or the fibre type used as input and/or output ports of the OA.

NOTE – The optical, mechanical and environmental characteristics and performances of the optical connectors and of the connecting fibres should be in compliance with IEC 60874-1 and IEC 60793-2, respectively.

5.1.36 polarization mode dispersion (PMD): When an optical signal travels through an optical fibre, component or subsystem (such as an optical amplifier), 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 polarisation (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 – The level of PMD may depend on temperature and operating conditions.

5.1.37 principal states of polarization (PSP): At a given frequency (or wavelength), the two orthogonal input states of polarization for which the corresponding output states of polarization (SOPs) are independent of optical frequency to first order.

NOTE 1 – An optical fibre, component or subsystem is typically characterized by two PSPs that are a function of the intrinsic birefringence of the material and the induced external and internal stresses acting on it.

NOTE 2 – The DGD between these two PSPs can vary with time and wavelength.

NOTE 3 – A signal whose SOP is aligned with one of the PSPs will be unaffected by the amount of PMD, at least to first order.

5.1.38 degree of polarization (DOP) (applicable to pumping devices for fibre Raman amplifiers): For each emission wavelength of the optical pump source, the value:

$$\frac{P_{\max} - P_{\min}}{P_{\max} + P_{\min}}$$

expressed as a percentage, where $P_{\max}$ and $P_{\min}$ are, respectively, the maximum and minimum optical output powers of the pump source over all states of polarization at that wavelength of emission and measured within a specified bandwidth.

NOTE 1 – Because the Raman effect exploited in Raman amplifiers is polarization dependent, the degree of polarization can influence the polarization dependent gain of the amplifier.

NOTE 2 – Because Raman amplifiers are often pumped with multiple wavelengths and multimode lasers, it is necessary to determine separately the degree of polarization at every wavelength of emission, rather than just the degree of polarization of the total optical output.

5.1.39 noise factor (F): The noise figure expressed in linear form.

5.1.40 multi-path interference (MPI) figure of merit: The noise factor contribution caused by multi-path interference integrated over all baseband frequencies (zero to infinity).

NOTE – For example, multiple path interference can be caused by successive partial reflections in the optical path.

5.1.41 double Rayleigh scattering figure of merit: The noise factor contribution caused by multi-path interference due to double Rayleigh scattering integrated over all baseband frequencies (zero to infinity).

NOTE – Double Rayleigh scattering is particularly relevant to fibre Raman amplifiers, both distributed and discrete, because of the long amplifying fibre lengths providing substantial amounts of scattered light together with gain. Other fibre amplifiers with high gain and long fibres can also show this effect. The contribution becomes larger at higher gain levels.

5.1.42 frequency-independent contribution to noise factor: The noise factor excluding the noise contribution from multi-path interference.

5.1.43 signal-spontaneous noise figure (NF_{sig-sp}): The signal-spontaneous beat noise contribution to the noise figure, expressed in dB.

5.1.44 (equivalent) spontaneous-spontaneous optical bandwidth (B_{sp-sp}): The equivalent optical bandwidth by which the square of the ASE spectral power density, ρ_{ase}, at the signal optical frequency, ν_{sig}, is multiplied in order to obtain the integral of the squared ASE spectral power density over the full ASE bandwidth, B_{ase}, that is:

$$B_{sp-sp} = \rho_{ase}^{-2}(\nu_{sig}) \cdot \int_{B_{ase}} \rho_{ase}^{2}(\nu)d\nu$$

NOTE 1 – The equivalent spontaneous-spontaneous optical bandwidth can be minimized by using an optical filter at the output of the OA.

NOTE 2 – This parameter is related to the spontaneous-spontaneous beat noise generation, and thus it requires the use of the squared ASE spectral power density.

5.1.45 effective noise figure (only applicable to distributed amplifiers): The decrease of the signal-to-noise ratio (SNR) at the output of an optical detector with unitary quantum efficiency, due to the propagation of a shot-noise-limited signal through an optical fibre providing distributed amplification when the pumping is active compared to when the pumping is disabled, expressed in dB.

NOTE 1 – The effective noise figure differs from the noise figure in that it does not compare the SNR at the output with the SNR at the input of the amplifier. The increase in signal strength relevant to the change in SNR is thus the effective gain rather than the gain. In particular, the contribution of signal-spontaneous noise figure, which can be calculated from the difference between ASE power and gain expressed in dB, is then reduced in the effective noise figure by the amount of passive loss between the input and output. It is thus possible for the effective noise figure of distributed amplification to be negative, expressed in dB.

NOTE 2 – The effective noise figure can be understood as the noise figure of an equivalent discrete optical amplifier placed at the end of the optical fibre, which produces the effective gain and the same ASE output power as the distributed amplification. Because the ASE produced within the fibre of the distributed amplifier is also partially reduced by the attenuation of this fibre, the ASE output power can be lower than physically realisable from such a discrete amplifier.

5.1.46 equivalent signal-spontaneous noise figure (only applicable to distributed amplifiers): The signal-spontaneous beat noise contribution to the effective noise figure.

5.1.47 ASE bandwidth: The difference between the two wavelengths at which a specified decrease of the output ASE from the peak value of the output ASE spectrum is observed.

NOTE 1 – A decrease of 30 to 40 dB is considered to be adequate.

NOTE 2 – Due to possible distortion of the measured spectrum, e.g., caused by pump leakage, a suitable extrapolation may be necessary.

5.1.48 in-band insertion loss (applicable to OA devices only): In an electrically unpowered condition, the signal insertion loss for the OA at a given input signal wavelength and a given signal power level.

NOTE 1 – This property can be described at a discrete wavelength or as a function of wavelength.

NOTE 2 – Care should be taken to exclude the output ASE contribution in the measurement of this parameter.

NOTE 3 – The in-band insertion loss is a function of the input signal power level.

5.1.49 maximum reflectance tolerable at input and output (applicable to OA devices only): The maximum reflectance of two identical reflectors simultaneously placed at both input and output ports of an OA, for which the OA still meets its specifications.

NOTE 1 – The measurement is performed with a given input signal optical power.

NOTE 2 – The noise figure is the most sensitive parameter to reflectance.

5.1.50 power wavelength band (applicable to power amplifiers only): The wavelength range within which the OA output signal power is maintained in the specified output power range, while the OA input signal power lies within the specified input power range.

5.1.51 available signal wavelength band (applicable to pre-amplifiers with optical filter(s) only): The resulting pre-amplifier OA wavelength band including the effect of the optical filter(s).

5.1.52 tuneable wavelength range (applicable to pre-amplifiers and optically amplified receivers with tuneable optical filter(s) only): The wavelength range within which the tuneable optical filter(s) inside the pre-amplifier OA can be tuned.

5.1.53 channel gain (for multichannel operation): Gain for each channel (at wavelength λj) in a specified multichannel configuration, expressed in dB.

Channel gain (G_j) can be expressed as follows (P_{ij} and P_{oj} being respectively the input and output power levels, in dBm, of the j-th channel and $j = 1, 2, \dots n$; n total number of channels):

$$G_j = P_{oj} - P_{ij}$$

NOTE – Since the amplifier saturation power level is determined by the combined effect of the input signals at all wavelengths, the channel gain is dependent on the input power level of all signals.

5.1.54 multichannel gain variation (inter-channel gain difference) (for multichannel operation): The difference between the channel gains of any two of the channels in a specified multichannel configuration, expressed in dB.

Multichannel gain variation can be expressed as follows (G_j and G_l being respectively the channel gains of j-th and l-th channel and $j, l = 1, 2, \dots n$; $j \neq l$; n total number of channels):

$$\Delta G_{jl} = G_j - G_l$$

NOTE – Normally, this parameter is specified as the maximum multichannel gain variation, intended as the maximum absolute value of multichannel gain variation, considering all possible combinations of channel pairs. The input power levels would normally be set to their minimum and maximum specified values. Input power levels may also be specified to achieve certain gain values or total output power levels. Maximum multichannel gain variation can be expressed as follows:

$$\Delta G_{MAX} = MAX_{j,l}\left\{\left|\Delta G_{jl}\right|\right\}$$

5.1.55 gain cross-saturation (for multichannel operation): For a specified multichannel configuration, the ratio of the change in channel gain of one channel, ΔG_j, to a given change in the input power level of another channel, ΔP_l, while the input power levels of all other channels are kept constant, expressed in dB per dB.

Gain cross-saturation can be expressed as follows ($j, l = 1, 2, \dots, n; j \neq l; n$ total number of channels):

$$GXS_{jl} = \Delta G_j / \Delta P_l$$

NOTE – Normally, this parameter is specified for an initial input power distribution among channels in which each channel is at the minimum allowed power level. Other distributions may be indicated in the appropriate product specification.

5.1.56 multichannel gain-change difference (inter-channel gain-change difference) (for multichannel operation): For a specified channel allocation, the difference of change in gain in one channel with respect to the change in gain of another channel for two specified sets of channel input powers, expressed in dB.

Multichannel gain-change difference can be expressed as follows ($G_j^{(1)}$, $G_j^{(2)}$ and $G_l^{(1)}$, $G_l^{(2)}$ being the channel gains of the *j*-th and *l*-th channel at each of the two specified sets of channel input power (1) and (2) respectively, and $j, l = 1, 2, \ldots n$; *n* total number of channels):

$$GD_{jl} = \left[G_j^{(1)} - G_j^{(2)}\right] - \left[G_l^{(1)} - G_l^{(2)}\right]$$

NOTE 1 – The two specified sets of channel input powers are in general: (1) all input power levels set to the minimum value and (2) all input power levels set to the maximum value.

NOTE 2 – Normally, the maximum multichannel gain-change difference will be specified. Different sets of input conditions could be defined in the appropriate product specification.

NOTE 3 – Forward ASE power level can be relevant for OAs used as pre-amplifiers or line amplifiers. In this case, the channel input power will include the forward ASE contribution.

NOTE 4 – This parameter can be used instead of the multichannel gain tilt when the definition of the gain tilt cannot be applied.

5.1.57 multichannel gain tilt (inter-channel gain-change ratio) (for multichannel operation): The ratio of the changes in gain in each channel to the change in gain at a reference channel as the input conditions are varied from one set of input channel powers to a second set of input channel powers, expressed in dB per dB.

Multichannel gain tilt can be expressed as follows ($G_j^{(1)}$, $G_j^{(2)}$ and $G_r^{(1)}$, $G_r^{(2)}$ being, respectively, the channel gains of the *j*-th and the reference channel at each of the two specified sets of channel input powers and $j = 1, 2, \ldots n$; *n* total number of channels):

$$GT_j = \left[G_j^{(1)} - G_j^{(2)}\right] / \left[G_r^{(1)} - G_r^{(2)}\right]$$

NOTE 1 – Multichannel gain tilt is normally used to predict the gains for each channel for various sets of input channel powers based on observed changes in the reference channel.

NOTE 2 – The sets of input channel powers are generally those in which (1) all power levels are set equal to the maximum allowed and (2) all powers are set equal to the minimum allowed.

NOTE 3 – The reference channel should be specified in the appropriate product specification. The multichannel gain tilt of the reference channel is by definition equal to 1 dB/dB.

NOTE 4 – Application of multichannel gain tilt to prediction of channel gain under different conditions could be impaired in the cases of hybrid multistage amplifiers, inhomogeneous gain media and, in particular, for amplifiers with automatic gain control.

5.1.58 channel addition/removal (steady-state) gain response (for multichannel operation): For a specified multichannel configuration, the steady-state change in channel gain of any one of the channels due to the addition/removal of one or more other channels, expressed in dB.

NOTE 1 – Normally, the parameter specified is the maximum channel addition/removal gain response when the final or initial power level of each of the input channels is equal to the minimum allowed. However, different final or initial power levels may be indicated in the appropriate product specification.

NOTE 2 – The worst-case channel addition/removal gain response is generally expected to occur when all but one of the channels are added or removed.

5.1.59 channel addition/removal transient gain response (for multichannel operation): For a specified multichannel configuration, the maximum change in channel gain of any one of the channels due to the addition/removal of one or more other channels during the transient period after channel addition/removal, expressed in dB.

NOTE 1 – Normally, the parameter specified is the maximum channel addition/removal transient gain response when the final or initial power level of each of the input channels is equal to the minimum allowed. However, different final or initial power levels may be indicated in the appropriate product specification.

NOTE 2 – The worst-case channel addition/removal transient gain response is generally expected to occur when all but one of the channels are added or removed.

NOTE 3 – This definition includes both transient gain increase and transient gain reduction in a single parameter and is an alternative method of describing the gain response to the parameters in clauses 5.1.65 and 5.1.66.

5.1.60 channel addition/removal transient response time constant (for multichannel operation): The time period from the addition/removal of a channel to the time when the output power level of that or another channel reaches and remains within ± N dB from its steady-state value.

NOTE 1 – The value of N should be specified in the relevant product specification.

NOTE 2 – This definition is an alternative method of describing the transient duration to the parameter in clause 5.1.64.

5.1.61 rate of change of power: This is the maximum rate of change (in dB/ms) of the total optical power at the input of an OA or ONE for which all other parameters of the device (e.g., transient gain increase or reduction) must remain within the allowed limits for the undisturbed channels.

5.1.62 total input power range: The range of total optical power level (the sum of all of the channel powers) at the input of the OA or ONE over which all of the other parameters of the device are required to remain within the allowed limits.

5.1.63 input (or output) power change: The maximum change of the total optical power at the input (or output) of an OA or ONE due to the addition/removal of one or more channels where the power of one or more of the input channels remains undisturbed. This is illustrated in Figure 6. The left side of the figure shows a negative input power change (resulting in a negative value in dB) and the right side shows a positive input power change (resulting in a positive value in dB).

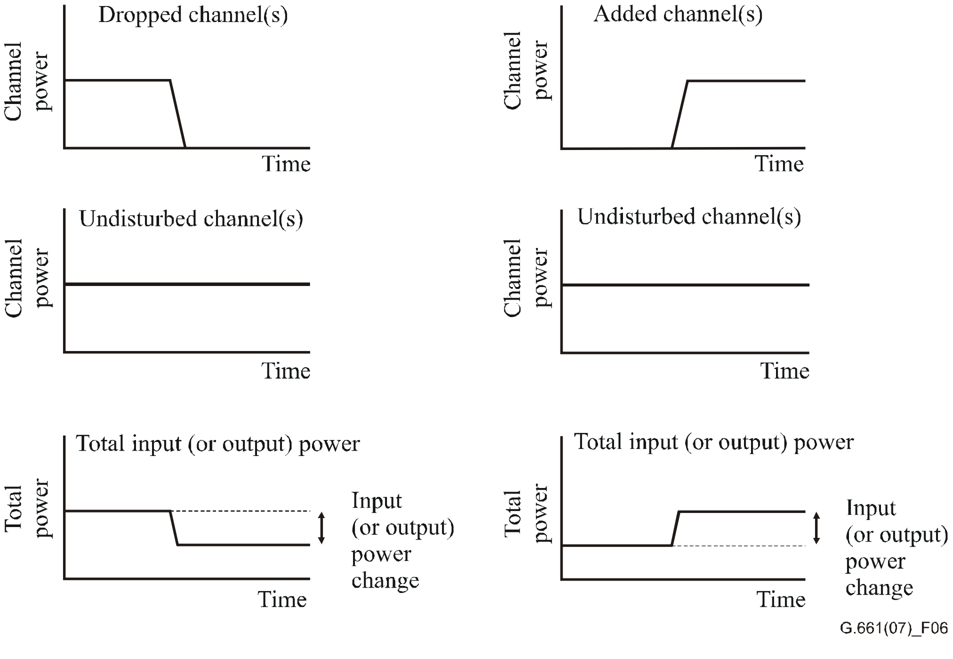


Figure 6 – Illustration of input (or output) power change

5.1.64 transient duration (for multichannel operation): The time period from the addition/removal of one or more channels to the time when the output power level all of the other channels reaches and remains within ±0.2 dB from its steady-state value. This is illustrated in Figure 7.

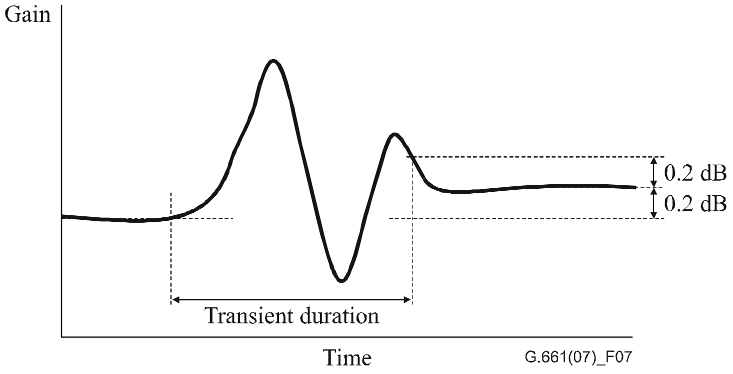


Figure 7 – Illustration of transient duration

5.1.65 transient gain increase (for multichannel operation): For a specified multichannel configuration, the maximum increase in channel gain of any one of the channels due to the addition/removal of one or more other channels during the transient duration after channel addition/removal, expressed in dB. This is illustrated in Figure 8.

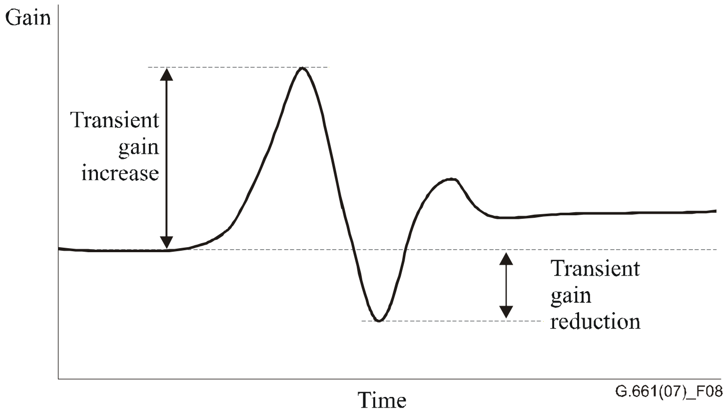


Figure 8 – Illustration of transient gain increase and reduction

5.1.66 transient gain reduction (for multichannel operation): For a specified multichannel configuration, the maximum reduction in channel gain of any one of the channels due to the addition/removal of one or more other channels during the transient duration after channel addition/removal, expressed in dB. This is illustrated in Figure 8.

5.1.67 channel noise figure (for multichannel operation): For a specified multichannel configuration, the noise figure for each channel in a specified optical bandwidth, expressed in dB.

5.1.68 channel signal-spontaneous noise figure (for multichannel operation): The signal-spontaneous noise figure for each channel in a specified multichannel configuration, expressed in dB.

5.1.69 channel allocation (for multichannel operation): The channel allocation is given by the number of channels, the nominal central frequencies/wavelengths of the channels and their central frequency/wavelength tolerance.

5.1.70 optical safety: The precautions or agreed safety standards that installers, operators and manufacturers should observe for safe operation with OAs. Unless otherwise specified, IEC 60825-1 and IEC 60825-2 should be used. Additional guidance can be found in ITU-T Rec. G.664, *Optical safety procedures and requirements for optical transport systems*, and IEC/TR 61292-4, *Optical amplifiers – Part 4: Maximum permissible optical power for the damage-free and safe use of optical amplifiers, including Raman amplifiers*.

5.2 Parameters for OA subsystems

Definitions contained in this clause concern the relevant parameters of elementary OA subsystems, namely the optically amplified transmitter (OAT) and the optically amplified receiver (OAR).

5.2.1 Generic OA subsystem

5.2.1.1 signal wavelength: The wavelength of the signal optical carrier.

5.2.1.2 signal linewidth: The full-width half-maximum (FWHM) of the signal optical spectrum.

5.2.2 Optically amplified transmitter (OAT) subsystem

5.2.2.1 signal power after output connector: The optical power associated with the signal exiting the optical output port of the OAT.

5.2.2.2 operating signal wavelength range: The wavelength range within which the OAT output signal power is maintained in a specified output power range.

5.2.2.3 ASE power level: The optical power associated with ASE (amplified spontaneous emission) exiting the optical output port of the OAT, under nominal operating conditions.

5.2.2.4 output reflectance: The fraction of incident optical power, at the operating wavelength, reflected by the OAT from the optical output port, under nominal operating conditions, expressed in dB.

5.2.2.5 maximum return optical power: The maximum optical power that can enter the output port of the OAT, for which the OAT still meets its specifications.

5.2.2.6 pump leakage to output: The pump optical power which is emitted from the OAT output port, under nominal operating conditions.

NOTE 1 – The measurement is performed with a given signal optical power.

NOTE 2 – The maximum pump leakage to output may occur for no signal.

5.2.2.7 optical connections: The connector type and/or the fibre type used as the output port of the OAT.

NOTE – The optical, mechanical and environmental characteristics and performances of the optical connector and of the connecting fibre should be in compliance with IEC 60874-1 and IEC 60793-2, respectively.

5.2.3 Optically amplified receiver (OAR) subsystem

5.2.3.1 sensitivity: The minimum optical power associated with the input signal, immediately before the input connector, necessary to achieve a fixed BER value (e.g., 10^{-12}).

NOTE – Other definitions may be applicable for this parameter and are under consideration.

5.2.3.2 operating signal wavelength range: The wavelength range within which the OAR has the specified sensitivity and overload input power at a specified BER (e.g., 10^{-12}) and at a specified bit rate.

5.2.3.3 tunable wavelength range (for OARs with tunable optical filter(s) only): The wavelength range (within the operating signal wavelength range) over which the tunable optical filter(s) inside the OAR can be tuned.

5.2.3.4 ASE power level: The optical power associated with ASE exiting the input optical port of the OAR, under nominal operating conditions.

5.2.3.5 input reflectance: The fraction of incident optical power, at the operating wavelength, reflected by the OAR from the optical input port, under nominal operating conditions, expressed in dB.

5.2.3.6 ASE filter bandwidth: The wavelength FWHM of the ASE filter.

NOTE – The ASE filter bandwidth fixes the maximum linewidth of the input signal.

5.2.3.7 maximum input optical power: The maximum optical power that can enter the input port of the OAR, for which the OAR still meets its specifications.

5.2.3.8 pump leakage to input: The pump optical power which is emitted from the OAR input port, under nominal operating conditions.

NOTE 1 – The measurement is performed with a given input signal optical power.

NOTE 2 – The maximum pump leakage to input may occur for no input signal.

5.2.3.9 optical connections: The connector type and/or the fibre type used as the input port of the OAR.

NOTE – The optical, mechanical and environmental characteristics and performances of the optical connector and of the connecting fibre should be in compliance with IEC 60874-1 and IEC 60793-2, respectively.

5.2.3.10 safety: The precautions or agreed safety standards that installers, operators and manufacturers should observe for safe operation with OA subsystems. Unless otherwise specified, IEC 60825-1 and IEC 60825-2 should be used. Additional guidance can be found in ITU-T Rec. G.664, *Optical safety procedures and requirements for optical transport systems*, and IEC/TR 61292-4, *Optical amplifiers – Part 4: Maximum permissible optical power for the damage-free and safe use of optical amplifiers, including Raman amplifiers*.

6 Test methods

According to an agreement with IEC-SC86C/WG3, the guidelines to be followed for the measurement of most of the parameters defined in clause 5 are generally given in [IEC 61290]. Each test method is generally given for the measurement of a group of related parameters. The grouping of the related parameters is given in Table 1, together with the corresponding test method specification reference. The test methods presently reported in [IEC 61290] for each group of parameters are also given in Table 1.

NOTE 1 – The test methods contained in these IEC documents relate to IEC parameter definitions which treat connector losses differently from the definitions contained in this Recommendation. A more complete discussion of this topic can be found in Appendix III of [ITU-T G.665].

NOTE 2 – The comparative evaluation of the test methods given in the IEC basic specifications is currently under development. When it is available, the chosen reference test methods and possible alternative test methods for each relevant parameter defined in this Recommendation will be indicated.

Table 1 – Recommended test methods for parameters defined in clause 5

Group of test parameters	**Test method specification number**	**Test methods (TMs)**
Gain parameters	IEC 61290-1	IEC 61290-1-1: Optical spectrum analyser (OSA) TM IEC 61290-1-2: Electrical spectrum analyser TM IEC 61290-1-3: Optical power meter TM IEC 61290-10-1: Multichannel pulse method with optical switch and OSA TM IEC 61290-10-2: Multichannel pulse method with gated OSA TM IEC 61290-10-3: Multichannel probe methods TM
Optical power parameters	IEC 61290-1	IEC 61290-1-1: Optical spectrum analyser TM IEC 61290-1-2: Electrical spectrum analyser TM IEC 61290-1-3: Optical power meter TM IEC 61290-10-1: Multichannel pulse method with optical switch and OSA TM IEC 61290-10-2: Multichannel pulse method with gated OSA TM IEC 61290-10-3: Multichannel probe methods TM
Noise parameters	IEC 61290-3: Test methods for noise figure parameters	IEC 61290-3-1: Optical spectrum analyser TM IEC 61290-3-2: Electrical spectrum analyser TM IEC 61290-10-1: Multichannel pulse method with optical switch and OSA TM IEC 61290-10-2: Multichannel pulse method with gated OSA TM IEC 61290-10-3: Multichannel probe methods TM
Polarization mode dispersion	IEC 61290-11	IEC 61290-11-1: Jones matrix eigenanalysis TM IEC 61290-11-2: Poincaré sphere analysis TM
Reflectance parameters	IEC 61290-5	IEC 61290-5-1: Optical spectrum analyser TM IEC 61290-5-2: Electrical spectrum analyser TM IEC 61290-5-3: Reflectance tolerance test, electrical spectrum analyser TM
Pump leakage parameters	IEC 61290-6	IEC 61290-6-1: Optical demultiplexer TM
Insertion loss parameters	IEC 61290-7	IEC 61290-7-1: Filtered power meter TM
OA subsystem parameters	IEC 61290-9	Under consideration

Appendix I

Main differences between optical fibre amplifiers and semiconductor optical amplifiers

(This appendix does not form an integral part of this Recommendation)

This appendix discusses key differences between optical fibre amplifiers and semiconductor optical amplifiers. Broad classes of optical amplifiers including semiconductor amplifiers, optical fibre amplifiers using many types of rare earth dopants and other types of amplifiers are more fully treated in IEC/TR 61292-3, *Optical amplifiers – Part 3: Classification, characteristics and applications*. Additional information on distributed Raman optical amplifiers can be found in [ITU-T G.665].

I.1 General remarks

The physical mechanism providing gain in semiconductor optical amplifiers (SOAs) differs in various aspects from that of optical fibre amplifiers. Basically, SOAs are semiconductor lasers without the optical cavity feedback (the facets of the chip have an anti-reflection coating) and so the population inversion is generated in the active region by an electrical current. The stimulated emission of photons occurs via electron-hole recombination processes induced by the signal photons (at wavelengths included in the amplification band of the semiconductor material). The gain of semiconductor materials per unit length is much greater than that of rare-earth doped active fibres (REDFs); this accounts for the very short lengths of these devices: 0.5 mm against some tens of metres for REDFs. This fact, together with direct pumping via the bias current, renders the SOAs very simple and compact devices compared to OFAs that require long active fibres, laser sources for optical pumping and various fibre-optic components.

Moreover, SOAs are flexible in terms of operating wavelength and, depending on the composition of the semiconductor material, can be used in second (1310 nm) or third (1550 nm) wavelength region while, at present, high-grade OFAs operate typically around 1550 nm.

Another important difference is that the gain dynamics of SOAs is much faster than that of OFAs. The characteristic time required for the gain to recover completely is typically 200 ps in a SOA against 0.5-10 ms in an OFA. Consequently, SOAs are not immune from cross-saturation interference and saturation induced waveform distortion as OFAs are.

The fast gain-dynamics also implies that SOAs are strongly non-linear when operated in the saturation regime, contrary to OFAs which behave linearly in almost all the operating conditions of interest in optical telecommunications. This feature, which may be detrimental for applications of SOAs as line amplifiers in WDM systems, can be turned to advantage in the implementation of some important system functionalities, such as wavelength conversion, optical switching and demultiplexing.

Finally, the geometry of SOA active guides does not match with that of optical fibres, producing quite high coupling losses with the fibres of the line and, due to the rectangular symmetry, can cause a marked PDG.

These structural differences among SOAs and OFAs do reflect on the performance of the devices. The scope of this appendix is to compare the characteristics of the two types of optical amplifiers. The list of the main optical parameters that should be considered to characterize and to compare the optical performance of the SOAs and EDFA is given in clause I.2. In the following, some indications are given about the values that can be associated with the mentioned SOA parameters and a comparison with the corresponding values for the OFAs. The values reported for OFAs are those typical for EDFAs.

In fact EDFAs represent the most mature OFA technology; EDFA technology is very well consolidated and EDFAs have been distributed on the market for several years and are produced by various manufacturers worldwide. On the other hand, SOAs are still at the R&D stage. Today, very few manufacturers produce them and the yield is very low. Even though the technology of SOAs is based on the very well assessed semiconductor laser technology, several important problems related to packaging, pig tailing, anti-reflection coating and polarization sensitivity have not found yet satisfactory mass scale production solutions.

Moreover, field trials with SOAs have started recently and there is today only a limited experience in using SOAs in the field [b-REID].

In this appendix, only the amplifying characteristics of the SOAs are taken into consideration as their possible use for the implementation of other functionalities is outside the scope of this appendix.

I.2 Comparison of optical performance characteristics between SOA and OFA

The values of SOA parameters reported in the following comparison are only indicative and reflect the present state-of-art in SOA technology; they can be subject to changes as SOA technology evolves.

– *Small-signal gain*

  The small-signal gain of SOAs is affected by the fibre-amplifier coupling loss (negligible in the case of EDFAs). Typical values are around 30 dB for lab prototypes, not including the coupling loss, and 10-15 dB fibre-to-fibre for pigtailed commercial units. For EDFA units, small-signal gain is typically greater than 30 dB.

– *Wavelength bandwidth*

  The width of wavelength band of SOAs is typically 40 nm or more, compared to 35 nm for EDFAs. SOAs can be used in second (1310 nm) or third (1550 nm) wavelength region, depending on the composition of the semiconductor material. Recent experiments on multi-quantum well SOAs demonstrated the possibility to achieve a wavelength bandwidth as wide as 120 nm.

– *Small-signal gain variation with wavelength*

  The use of very good anti-reflection coatings on the facets of the chip has allowed to reduce, in commercial SOAs, the peak-to-peak small-signal gain variation with wavelength to less than 1 dB over the width of the wavelength band.

– *Saturation output power*

  Saturation output power can be as high as +15 dBm for lab prototype SOAs (fibre-to-fibre). The obtained values for this parameter begin to be comparable to those of commercial EDFA units (+17/+20 dBm and more).

– *Noise figure (NF)*

  The NF of SOAs is affected by the quite high coupling loss with fibres. In SOA lab modules, values around 5-6 dB have been obtained while, in commercial pigtailed units, values ranging from 7 to 9 dB are typical. Typical values for commercial EDFAs are 5-6 dB for 980 nm pumped EDFAs, and 6-7 dB for 1480 nm pumped EDFAs.

– *Polarization dependent gain (PDG)*

  In lab SOA prototypes, the PDG has been reduced down to negligible values (0.2 dB). In commercial SOAs, typical values are 2-5 dB. PDG is negligible in EDFAs (0.2 dB).

– *Gain-dynamic crosstalk*

  Under study.

I.3 Applications

At the present stage of the SOA technology, the most suitable applications of SOAs as gain blocks in optical point-to-point systems seem to be as booster amplifiers, integrated with the emitter laser, even though there are some limitations in terms of output power.

Problems related to line and pre-amplifier applications (such as polarization sensitivity and relatively high noise figure) are going to be solved (for example by using gain-clamped SOAs [b-VAN DEN HOVEN]). Recently, SOAs have been successfully utilized as line amplifiers in 10 Gbit/s field trials [b-KUINDERSMA]. In this transmission experiment, the optical system was operated at 1310 nm: a spectral window where high-grade OFAs have not been developed so far.

Moreover, SOAs have a great potential as functional devices in optical switches, to simultaneously provide gain and fast gating functions, and in other signal processing devices (wavelength converters, optical multiplexers and demultiplexers), due to the strong non-linear response they have in the saturation regime. They can also be integrated in optical switch matrices to compensate for the losses internal to the matrix itself.

Appendix II

Environmental, mechanical, physical and reliability parameters of optical amplifier devices and subsystems

(This appendix does not form an integral part of this Recommendation)

Additional terms for the environmental, mechanical, physical and reliability aspects of optical amplifier devices and subsystems are provided for information. These terms are normative terms in [IEC 61291-1].

II.1 Parameters for OA devices

II.1.1 External dimensions and weight

The maximum height, length, width and weight of the OA.

II.1.2 Environmental conditions

The range of temperature, humidity and vibration level within which the OA can be stored, operated or shipped and still meet all its specified parameter values.

II.1.3 Maximum operating relative humidity

The maximum relative humidity at which the OA can be operated and still meet all its specified parameter values.

II.1.4 Maximum operating vibration level

The maximum vibration level at which the OA can be operated and still meet all its specified parameter values.

II.1.5 Storage temperature

The temperature range within which the OA can be stored and still meet all its specified parameter values.

II.1.6 Maximum storage relative humidity

The maximum relative humidity at which the OA can be stored and still meet all its specified parameter values.

II.1.7 Maximum transport vibration/shock level

The maximum vibration and shock level that the OA can bear when shipped and still meet all its specified parameter values.

II.1.8 Reliability

The expectation of operational lifetime. The reliability of an OA is expressed by either of the following two parameters: mean operating time between failures (MTBF) or failures in time (FIT). The MTBF is the mean period of OA continuous operation without any failure at specified operating and environmental conditions. The FIT is the number of failures in 10^9 hours under specified operating and environmental conditions.

NOTE – Reliability qualification is addressed by IEC 61291-5-2.

II.1.9 Remote and local alarm control

The functions that can check the operation of the OA subsystem, detecting and signalling possible faults.

II.2 Parameters for OA subsystems

Definitions contained in this clause concern the relevant parameters for the environmental, mechanical, physical and reliability aspects of generic OA subsystems, namely the optically amplified transmitter (OAT) and the optically amplified receiver (OAR).

II.2.1 Powering and control requirements

Those electrical currents and/or voltages as well as those electrical signals necessary for OA subsystem operation within the stated maximum ratings. Necessary tolerances on electrical powering and switching on and off procedures are included.

II.2.2 Maximum power consumption

The electrical power needed to keep the OA subsystem operating at the stated maximum ratings.

II.2.3 Operating temperature

The temperature range within which the OA subsystem can be operated and still meet all its specified parameter values.

II.2.4 Maximum operating relative humidity

The maximum relative humidity at which the OA subsystem can be operated and still meet all its specified parameter values.

II.2.5 Maximum operating vibration level

The maximum vibration level at which the OA subsystem can be operated and still meet all its specified parameter values.

II.2.6 Storage temperature

The temperature range within which the OA subsystem can be stored and still meet all its specified parameter values.

II.2.7 Maximum storage relative humidity

The maximum relative humidity at which the OA subsystem can be stored and still meet all its specified parameter values.

II.2.8 Maximum transport vibration/shock level

The maximum vibration and shock level that the OA subsystem can bear when shipped and still meet all its specified parameter values.

II.2.9 Reliability

The expectation of operation lifetime. The reliability of an OA subsystem is expressed by either of the following two parameters: mean operating time between failures (MTBF) or failures in time (FIT). The MTBF is the mean period of continuous operation without any failure at specified operating and environmental conditions. The FIT is the number of failures in 10^9 hours at specified operating and environmental conditions.

NOTE – Reliability qualification is addressed by IEC 61291-5-2.

II.2.10 Remote and local alarm control

The functions that can check the operation of the OA subsystem, detecting and signalling possible faults.

II.3 Environmental and reliability test methods

The test methods presently reported in the IEC 61290 series for parameters defined in this appendix are given in Table II.1.

Table II.1 – Recommended test methods for parameters defined in Appendix II

Group of test parameters	Test method specification number	Test methods (TMs)
Environmental and reliability parameters	IEC 61291-5-2: Reliability qualification	Under consideration

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