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SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Transmission media characteristics – Characteristics of optical components and subsystems

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

ITU-T Recommendation G.661

(Previously CCITT Recommendation)

ITU-T G-SERIES RECOMMENDATIONS

TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

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ITU-T RECOMMENDATION G.661

DEFINITION AND TEST METHODS FOR THE RELEVANT GENERIC PARAMETERS OF OPTICAL AMPLIFIER DEVICES AND SUBSYSTEMS

Summary

This Recommendation intends to provide 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 revised by ITU-T Study Group 15 (1997-2000) and was approved under the WTSC Resolution No. 1 procedure on the 13th of October 1998.

FOREWORD

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As of the date of approval of this Recommendation, the ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

CONTENTS

Recommendation G.661

DEFINITION AND TEST METHODS FOR THE RELEVANT GENERIC PARAMETERS OF OPTICAL AMPLIFIER DEVICES AND SUBSYSTEMS

(revised in 1998)

1 Scope

This Recommendation applies to Optical Amplifier (OA) devices and subsystems to be used in transmission networks. It covers both Optical Fibre Amplifiers (OFAs) and Semiconductor Optical Amplifiers (SOAs).

This Recommendation intends to provide the definitions of the relevant parameters, common to the different types of OAs, listed in clause 4, and the test methods of said parameters described in clause 5, to be followed, as far as applicable, for OA devices and subsystems covered by ITU-T Recommendations.

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; all 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.

- ITU-T Recommendation G.662 (1998), *Generic characteristics of optical amplifier devices and subsystems*.
- ITU-T Recommendation G.663 (1996), *Application related aspects of optical fibre amplifier devices and subsystems*.
- IEC Publication 61290 (All Parts – some not yet published), *Basic specification for optical amplifier test methods*.

3 Abbreviations

This Recommendation uses the following abbreviations:

ASE	Amplified Spontaneous Emission
Bsp-sp	Spontaneous-spontaneous optical bandwidth
EDFA	Erbium-Doped (silica-based) Fibre Amplifier
F	Noise Factor
NF	Noise Figure
OA	Optical Amplifier
OFA	Optical Fibre Amplifier
PDG	Polarization-Dependent Gain

PHB Polarization Hole Burning

PMD Polarization Mode Dispersion

SOA Semiconductor Optical Amplifier

TM Test Method

4 Definitions

This Recommendation defines the following terms:

Optical Amplifiers (OAs) are devices or subsystems in which optical signals can be amplified by means of the stimulated emission taking place in an suitable active medium. In this active medium a population inversion, needed to advantage stimulated emission with respect to absorption, is achieved and maintained by means of a suitable pumping system.

OAs covered by this Recommendation include OFAs and SOAs.

Optical Fibre Amplifiers (OFAs) are OAs in which the active medium is constituted by an active fibre, doped with ions of rare earths, and the pumping system is optical. At present, the most mature OFAs are the Erbium-Doped (silica-based) Fibre Amplifiers (EDFAs) in which the active fibre is silica-based and doped (or co-doped) with Erbium ions.

Semiconductor Optical Amplifiers (SOAs) are OAs in which the active medium is constituted by semiconductor material and the pumping system is electrical.

The OA is to be considered as a black box, as shown in Figure 1, for an OA device with two optical ports and electrical connections for power supply. The optical ports are usually distinguished as input and output ports and may consist of unterminated fibres or optical connectors.

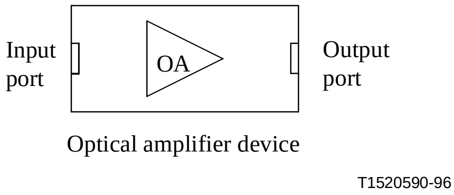

Figure 1/G.661 – The optical amplifier device

Hereafter, two different operating conditions will be usually referred to: nominal operating conditions, for a normal use of the OA, and limit operating conditions, in which all the adjustable parameters (e.g. temperature, gain, pump laser injection current for OFAs or pump current for SOAs, etc.) are at their maximum values, according to the stated absolute maximum ratings.

NOTE 1 – If one of these parameters is specified for a particular OA, it will be generally necessary to provide certain appropriate operating conditions such as temperature, bias current, pump power, etc.

NOTE 2 – The OA amplifies signals in a nominal operating wavelength region. In addition, other signals out of the band of operating wavelength could, in some applications, also cross the device. The purpose of these out-of-band signals and their wavelength or wavelength region can be specified explicitly case-by-case. For OFAs described in this Recommendation, the operating wavelength will be in the 1550 nm region.

NOTE 3 – All gains are measured as the dB ratio of the output signal over the input signal in a fibre pigtail. If connectors are used, then the signals are measured in fibre pigtails joined to connectors which are connected to the OA ports. The measured input and output optical power levels refer to the signal only and discriminate against pump or spontaneous emission radiation.

NOTE 4 – There is a correspondence in the numbering of the parameters given in this clause and the corresponding test methods given in clause 5.

NOTE 5 – Except where noted, the optical powers mentioned in the following are intended as average powers.

NOTE 6 – Some additional definitions concerning specific types of OAs (OA devices, such as power, pre- and line amplifiers, and OA subsystems, such as optically amplified transmitters and receivers) are given in Recommendation G.662.

NOTE 7 – As far as OFAs are concerned, this Recommendation has been prepared from experience with EDFAs, operating in the 1550 nm wavelength region. Future OFAs, based on different active fibres and possibly operating in different wavelength regions, are not intended to be excluded from this Recommendation and may lead to additional definitions and test methods, as well as to modifications of the existing ones.

4.1 small-signal gain (applicable to OA devices only): The gain of the amplifier, when operated in linear regime, where it is quite independent of the input signal optical power, at a given signal wavelength and pump optical power level, for OFAs, or pump current, for SOAs.

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

4.2 reverse small-signal gain (applicable to OA devices only): The small-signal gain measured using the input port as output port and vice versa.

4.3 maximum small-signal gain (applicable to OA devices only): The highest small-signal gain that can be achieved under nominal operating conditions.

4.4 maximum small-signal gain wavelength (applicable to OA devices only): The wavelength at which the maximum small-signal gain occurs.

4.5 maximum small-signal gain variation with temperature (applicable to OA devices only): The change in small-signal gain for temperature variation within a specified range.

4.6 (small-signal gain) wavelength band (applicable to OA devices only): The wavelength range within which the small-signal gain is less than N dB below the maximum small-signal gain.

NOTE – A value of N = 3 has been proposed.

4.7 small-signal gain variation with wavelength (applicable to OA devices only): The peak-to-peak variation of the small-signal gain over a given wavelength range.

4.8 small-signal gain stability (applicable to OA devices only): 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.

4.9 large-signal output stability (applicable to OA devices only): 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.

4.10 Polarization-Dependent Gain (PDG) (applicable to OA devices only): The maximum variation of gain due to a variation of the state of polarization of the input signal at nominal operating conditions.

4.11 saturation output power (gain compression power) (not applicable to optically amplified receivers): The output signal optical power at which the gain is reduced by 3 dB, for OFAs, or 1 dB for SOAs, with respect to the small-signal gain at the signal wavelength.

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

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

4.12 nominal output signal power (not applicable to optically amplified receivers): The minimum output signal optical power for a specified input signal optical power under nominal operating conditions.

4.13 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 must 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 different 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.

4.14 forward Amplified Spontaneous Emission (ASE) power level (not applicable to optically amplified receivers): The optical power in a specified bandwidth 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 must be stated.

4.15 reverse ASE power level (not applicable to optically amplified transmitters): The optical power in a specified bandwidth associated with the ASE exiting from the input port under nominal operating conditions.

4.16 input reflectance (not applicable to optically amplified transmitters): The fraction of incident optical power at operating wavelength reflected by the input port of the OA, under nominal operating conditions, expressed in dB.

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

4.18 maximum reflectance tolerable at input (not applicable to optically amplified transmitters): The maximum reflection seen from the input port for which the device still meets its specifications.

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

4.19 maximum reflectance tolerable at output (not applicable to optically amplified receivers): The maximum reflection seen from the output port for which the device still meets its specifications.

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

4.20 pump leakage to output (applicable to OFAs only and not applicable to optically amplified receivers): The pump optical power which is emitted from the OFA output port.

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

4.21 pump leakage to input (applicable to OFAs only and not applicable to optically amplified transmitters): The pump optical power which is emitted from the OFA input port.

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

4.22 out-of-band insertion loss (applicable to OA devices only): OA insertion loss for a signal at the specified out-of-band wavelength(s).

NOTE – This parameter is strongly wavelength dependent in SOAs.

4.23 out-of-band reverse insertion loss (applicable to OA devices only): OA insertion loss for a signal at the specified out-of-band wavelength(s), measured using the input port of the OA as output port and vice versa.

NOTE – This parameter is strongly wavelength dependent in SOAs.

4.24 maximum power consumption: Electrical power needed and absorbed by the OA operating within the absolute maximum ratings.

4.25 maximum total output power (not applicable to optically amplified receivers): The highest optical power level at the output port of the OA operating within the absolute maximum ratings.

4.26 operating temperature: The temperature range within which the OA can be operated and still meets all its specified parameters values.

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

NOTE – Optical connections do not necessarily need to be specified.

4.28 input power range (applicable to OA devices only): Range of optical power levels such that, for any input signal power of the OA which lies in this range, the corresponding output signal optical power shall lie in the specified output power range, where the OA performance is ensured.

4.29 output power range (applicable to OA devices only): Range of optical power levels in which the output signal optical power of the OA shall lie, when the corresponding input signal power lies in the input power range, where the OA performance is ensured.

4.30 Polarization Hole Burning (PHB) (applicable to OA devices only): Under study.

4.31 Polarization Mode Dispersion (PMD) (applicable to OA devices only): The maximum group delay difference between any polarization states on propagation through the OA.

4.32 gain (applicable to OA devices only): In an OA which is externally connected to an input jumper fibre, the increase of signal optical power from the output end of the jumper fibre to the OA output port, expressed in dB.

NOTE 1 – The gain includes the connection loss between the input jumper fibre and the OA input port.

NOTE 2 – It is assumed that the jumper fibres are of the same type as the fibres used as input and output port of the OA.

NOTE 3 – Care should be taken to exclude the amplified spontaneous emission power from the signal optical powers.

4.33 noise Factor (F) (applicable to OA devices only): The noise figure expressed in linear form.

4.34 signal-spontaneous noise figure (applicable to OA devices only): The signal-spontaneous beat noise contribution to the noise figure.

4.35 (equivalent) spontaneous-spontaneous optical bandwidth (B_{sp-sp}) (not applicable to optically amplified receivers): The equivalent optical bandwidth by which the square of the ASE spectral power density, ρ_{ase}, at the signal optical frequency, ν_{sig}, must be 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.

4.36 ASE bandwidth (not applicable to optically amplified receivers): The span 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.

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

4.38 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.

4.39 gain ripple (applicable to SOA devices only): The peak-to-peak variation of the small-signal gain over a given wavelength range, with sub-nanometer resolution in wavelength.

4.40 gain dynamics (applicable to SOA devices only): The characteristics time and strengths of non-linearities of the gain medium.

NOTE – This definition is under study.

5 Test methods

According to an agreement with IEC-SC86C-WG 3, the guidelines to be followed for the measurement of most of the parameters defined in clause 4 are generally given in the IEC "Basic specification for OFA test methods" 61290 (All Parts). Table 1 indicates the recommended test methods, collecting the test parameters in homogeneous groups and quoting for each group the relevant IEC Basic Specification number(s).

NOTE 1 – The comparative evaluation of the Test Methods given in the IEC Basic Specifications is currently under development. When it will be available, the chosen Reference Test Methods and possible Alternative Test Methods for each relevant parameter defined in this Recommendation will be indicated.

NOTE 2 – The test methods given in the IEC Basic Specifications have been prepared for OFAs only. The extrapolation of these methods to SOAs is under study.

Table 1/G.661 – Recommended test methods for parameters defined in clause 4

Group of test parameters	Parameters of clause 4 involved	Test Method (TM) – IEC Basic Specification number
Gain parameters	4.1 to 4.8, 4.10, 4.32, 4.39, 4.40	61290-1-1: Optical spectrum analyser TM 61290-1-2: Electrical spectrum analyser TM 61290-1-3: Optical power meter TM
Optical power parameters	4.9, 4.11, 4.12, 4.25, 4.28, 4.29	61290-2-1: Optical spectrum analyser TM 61290-2-2: Electrical spectrum analyser TM 61290-2-3: Optical power meter TM
Noise parameters	4.13 to 4.15, 4.33 to 4.36	61290-3-1: Optical spectrum analyser TM 61290-3-2: Electrical spectrum analyser TM 61290-3-3: Pulse optical TM (under study)
Reflectance parameters	4.16 to 4.19, 4.38	61290-5-1: Optical spectrum analyser TM 61290-5-2: Electrical spectrum analyser TM 61290-5-3: Electrical spectrum analyser TM (for reflectance tolerance)
Pump leakage parameters	4.20, 4.21	61290-6-1: Optical demultiplexer TM
Insertion loss parameters	4.22, 4.23, 4.37	61290-7-1: Filtered optical power meter TM

APPENDIX I

Main differences between optical fibre amplifiers and semiconductor optical amplifiers

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 meters 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 markedly 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 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 [1].

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 wavelength band.

– *Saturation output power*

Saturation output power can be as high as +15 dBm for lab prototype SOAs (fibre-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 [2]). Recently, SOAs have been successfully utilised as line amplifiers in 10 Gbit/s field trials [3]. 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.

Bibliography

[1] REID (J.J.) *et al*.: Proceedings of the 11th International Conference on Integrated Optics and Optical Fibre Communications (IOOC) and of the 23rd European Conference on Optical Communications (ECOC), Vol. 1, page 83, Edinburgh, (UK), 22-25 September 1997.

[2] VAN DEN HOVEN (G.N.), TIEMEIJER, (L.F.): Technical Digest of Optical Amplifiers and their Applications (OAA), Invited Paper TuC1, Victoria (BC, Canada), 21-23 July 1997.

[3] KUINDERSMA (P.I.) *et al*.: Proceedings of the 11th International Conference on Integrated Optics and Optical Fibre Communications (IOOC) and of the 23rd European Conference on Optical Communications (ECOC), Vol. 1, page 79, Edinburgh (UK), 22-25 September 1997.

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