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Optical amplifiers – Test methods – Part 1: Power and gain parameters

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Optical amplifiers – Test methods – Part 1: Power and gain parameters

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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OPTICAL AMPLIFIERS – TEST METHODS –

Part 1: Power and gain parameters

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 61290-1:2014. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

IEC 61290-1 has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics. It is an International Standard.

This second edition cancels and replaces the first edition published in 2014. This edition constitutes a technical revision.

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

a) specification of gain ripple as a new parameter;
b) specification of test method and test report for gain ripple measurements;
c) use of the term “measurement uncertainty” instead of “measurement accuracy”.

The text of this International Standard is based on the following documents:

Draft	Report on voting
86C/1746/FDIS	86C/1783/RVD

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

The language used for the development of this International Standard is English.

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

A list of all parts in the IEC 61290 series, published under the general title *Optical amplifiers – Test methods*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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OPTICAL AMPLIFIERS – TEST METHODS –

Part 1: Power and gain parameters

1 Scope ~~and object~~

This part of IEC 61290 applies to all commercially available optical amplifiers (OAs) and optically amplified subsystems. It applies to OAs using optically pumped fibres (optical fibre amplifiers (OFAs) based on either rare-earth doped fibres or on the Raman effect), semiconductors (semiconductor optical amplifiers (SOAs)), and waveguides (planar optical waveguide amplifiers (POWAs)). It is specifically directed to single-channel amplifiers. Test methods for multichannel amplifiers are defined in the IEC 61290-10 series.

This document establishes uniform requirements for accurate and reliable measurements of the following OA parameters, as defined in IEC 61291-1:~~2012~~2018, Clause 3:

a) nominal output signal power;
b) gain;
c) reverse gain;
d) maximum gain;
e) maximum gain wavelength;
f) maximum gain variation with temperature;
g) gain wavelength band;
h) gain wavelength variation;
i) gain stability;
j) polarization-dependent gain;
k) gain ripple (SOA only);
l) large-signal output stability;
m) saturation output power;
n) maximum output signal power;
o) maximum total output power.

NOTE 1 The applicability of the test methods described in this document to distributed Raman amplifiers is still under study.

NOTE 2 All numerical values followed by (‡) are suggested values for which the measurement is assured. Other values are acceptable if verified.

~~The object of this standard is specifically directed to single-channel amplifiers. For multichannel amplifiers, one should refer to the IEC 61290-10 series.~~

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61290-1-1, *Optical amplifiers – Test methods – Part 1-1: Power and gain parameters – Optical spectrum analyzer method*

IEC 61290-1-2, *Optical amplifiers – Test methods – Part 1-2: Power and gain parameters – Electrical spectrum analyzer method*

IEC 61290-1-3, *Optical amplifiers – Test methods – Part 1-3: Power and gain parameters – Optical power meter method*

IEC 61291-1:~~2012~~2018, *Optical amplifiers – Part 1: Generic specification*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61291-1 apply.

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

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

3.2 Abbreviated terms

ASE	amplified spontaneous emission
FWHM	full width at half maximum
OA	optical amplifier
OFA	optical fibre amplifier
OSA	optical spectrum analyzer
POWA	planar optical waveguide amplifier
SOA	semiconductor optical amplifier

4 Optical power and gain test method

~~Three commonly practised procedures for quantifying the optical power and gain of an OA are considered in this standard.~~

One of the three test methods described in IEC 61290-1-1, IEC 61290-1-2, and IEC 61290-1-3 for quantifying the optical power and gain of an OA shall be followed in this document.

~~The aim of the first procedure (see~~ The test method described in IEC 61290-1-1~~) is to~~ determines the optical power and gain by means of an optical spectrum analyzer ~~test method~~.

~~The aim of the second procedure (see~~ The test method described in IEC 61290-1-2~~) is to~~ determines the optical power and gain by means of an optical detector and an electrical spectrum analyzer.

~~The aim of the third procedure (see~~ The test method described in IEC 61290-1-3~~) is to~~ determines the optical power and gain by means of an optical power meter and an optical bandpass filter.

5 Optical power and gain parameters

The parameters listed below are required for gain and power:

a) Nominal output signal power: The nominal output signal power is given by the minimum output signal optical power for an input signal optical power specified in the relevant detail specification and under nominal operating conditions given in the relevant detail specification. To find this minimum value, input and output signal power levels shall be continuously monitored for a given duration of time and in the presence of changes in the state of polarization and other instabilities, as specified in the relevant detail specification. The measurement procedures and calculations are described in each test method.

b) Gain: The measurement procedures and calculations are described in each test method.

c) Reverse gain: As in b), but with the OA operating with the input port used as an output port and vice-versa.

d) Maximum gain: As in b), but use a wavelength-tuneable optical source and repeat all procedures at different wavelengths in such a way as to cover the wavelength range specified in the relevant detail specification.

Unless otherwise specified, the wavelength should be changed by steps smaller than 1 nm (‡) around the wavelength where the ASE spectral profile, observed (e.g. with an optical spectrum analyzer or a monochromator) without the input signal, takes its maximum value.

NOTE 1 A wavelength measurement ~~accuracy~~ uncertainty of ±0,01 nm, within the operating wavelength range of the OA, is attainable with commercially available wavelength meters based on interference-fringes counting techniques. Some tuneable external-cavity laser-diode instruments provide a wavelength measurement ~~accuracy~~ uncertainty of ±0,2 nm.

The gain values are measured at the different wavelengths as described in b) above. The maximum gain shall be given by the highest of all these gain values at nominal operating condition. Figure 1 shows the typical behaviour of the gain as a function of the input signal power.

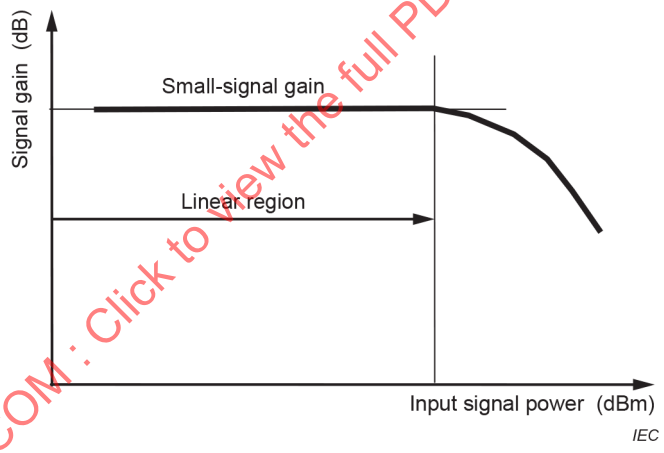

Figure 1 – Typical behaviour of the gain as a function of input signal power

e) Maximum gain wavelength: As in d), the maximum gain wavelength shall be the wavelength at which the maximum gain occurs. Refer to Figure 2 for typical gain behaviour for different wavelengths.

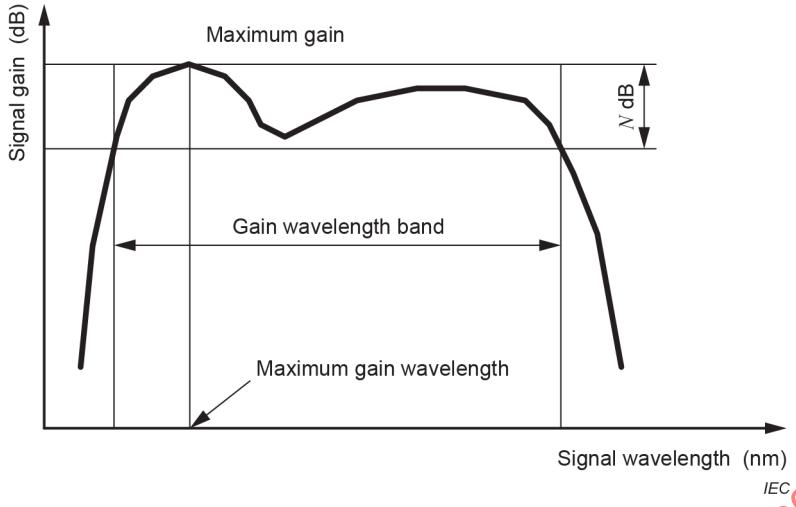

Figure 2 – Typical behaviour of the gain as a function of wavelength

f) Maximum gain variation with temperature: The maximum change of signal gain for a certain specified temperature range. The measurement procedures and calculations described below shall be followed, with reference to the measurement set-up and procedure for each test method:

1) as described in b), measure the maximum gain $G_{\text{max-tmp}}$ within the variation of temperature, as specified in the relevant detail specification;

2) as described in b), measure the minimum gain $G_{\text{min-tmp}}$ within the variation of temperature, as specified in the relevant detail specification;

3) the maximum gain variation with temperature ΔG_{tmp} is given by Formula (1):

$$\Delta G_{\text{tmp}} = G_{\text{max-tmp}} - G_{\text{min-tmp}} \text{ (dB)} \quad (1)$$

Refer to Figure 3.

The gain variation with temperature ~~may~~ can depend on the signal wavelength, owing to its active fibre characteristics. The wavelength at which the parameter is specified and measured should be stated.

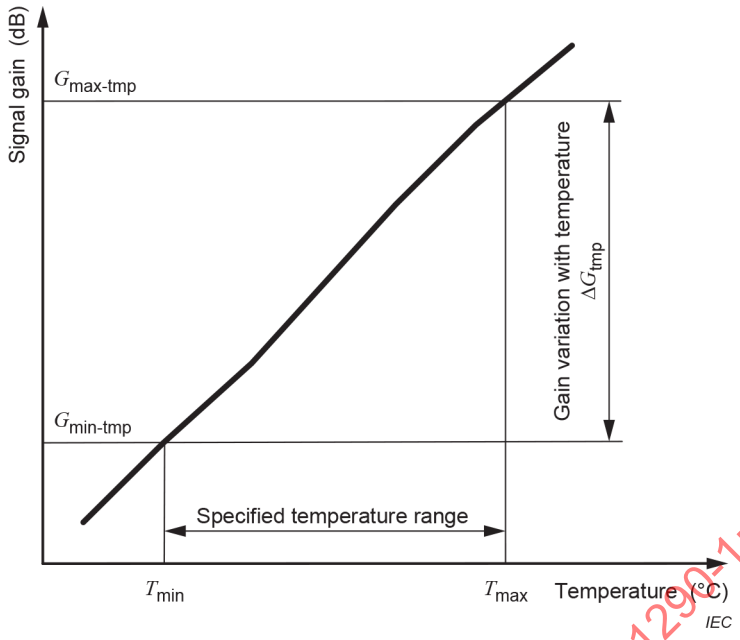

Figure 3 – Typical behaviour of the gain as a function of temperature

g) Gain wavelength band: Measure the maximum gain as described in d). Identify those wavelengths at which the gain is N dB below the maximum gain. The gain wavelength band shall be given by the wavelength interval(s) that comprise(s) those wavelengths at which the gain is between the maximum gain value and the value N dB below the maximum gain. Calculations are processed according to the following procedure:

1) plot the gain ~~of~~ at each wavelength ~~to the gains of adjacent wavelengths~~ as a function of wavelength, as shown in Figure 2;
2) draw a horizontal line ~~N dB down from the maximum gain point~~ N dB below the maximum gain value;
3) the two or more intersection points of this line with the gain profile plotted in 1) yield two (or more) N dB-down wavelengths, which define the range of the gain wavelength band. The wavelength interval with the minimum difference in N dB-down wavelengths is the gain wavelength band.

NOTE 2 A value of N = 3 is typically applied.

h) Gain wavelength variation: Measure the maximum gain and minimum gain over the specified measurement wavelength range as described in d). The gain variation shall be the difference between the maximum and the minimum gain values. Calculations are processed according to the following procedure:

1) plot the gain of each wavelength as shown in Figure 4;
2) find the maximum gain, $G_{max\text{-}\lambda}$ (dB) within the specified wavelength band;
3) find the minimum gain, $G_{min\text{-}\lambda}$ (dB) within the specified wavelength band;
4) calculate the gain wavelength variation, ΔG_{λ} (dB) from Formula (2):

$$\Delta G_{\lambda} = G_{max\text{-}\lambda} - G_{min\text{-}\lambda} \text{ (dB)} \quad (2)$$

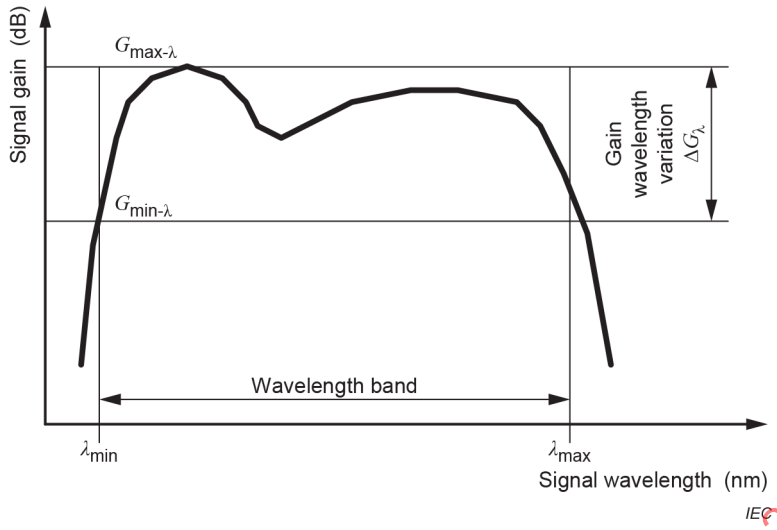

Figure 4 – Typical behaviour of the gain as a function of wavelength

i) Gain stability: The maximum degree of gain fluctuation of the maximum and minimum signal gain for a certain specified test period, as specified in the relevant detail specification. The measurement procedure and calculations described below shall be followed with reference to the measurement set-up for each test method. Refer to Figure 5 for typical behaviour of the gain fluctuation:

1) as for b), measure the maximum gain $G_{max\text{-}stability}$ for a certain specified test period, as specified in the relevant detail specification;
2) as for b), measure the minimum gain $G_{min\text{-}stability}$ for a certain specified test period, as specified in the relevant detail specification;
3) the gain stability $\Delta G_{stability}$ (dB) is given by Formula (3):

$$\Delta G_{stability} = G_{max\text{-}stability} - G_{min\text{-}stability} \text{ (dB)} \quad (3)$$

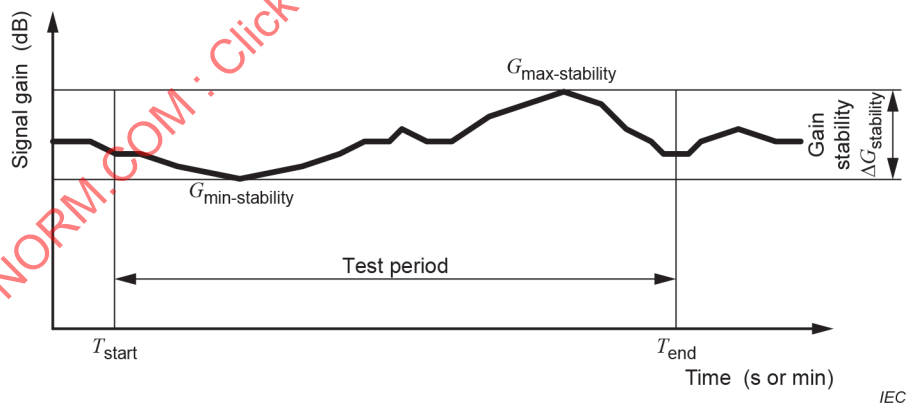

Figure 5 – Typical behaviour of the gain fluctuation as a function of time

j) Polarization-dependent gain: Gain values at the different states of polarization as described in b). The procedure and calculations are described in each test method.

j) Gain ripple: Details of the measurement procedures and calculations are described in IEC 61290-1-1.

k) Large-signal output stability: The maximum degree of gain fluctuation of the maximum and minimum output optical power for a certain specified test period, as specified in the relevant detail specification. The measurement procedure and calculations described below shall be followed, with reference to the measurement set-up for each test method. Refer to Figure 6 for typical behaviour of the output power fluctuation:

1) as described in a), measure the maximum output signal power $P_{\text{max-stability}}$ for a certain specified test period at a given wavelength and maximum signal input power, as specified in the relevant detail specification;
2) as described in a), measure the minimum output signal power $P_{\text{min-stability}}$ for a certain specified test period at a given wavelength and maximum signal input power, as specified in the relevant detail specification;
3) compare $P_{\text{max-stability}}$ with $P_{\text{min-stability}}$, and subtract $P_{\text{min-stability}}$ from $P_{\text{max-stability}}$ to obtain the large signal output stability;
4) large-signal output stability $\Delta P_{\text{stability}}$ (dB) is given by Formula (4):

$$\Delta P_{\text{stability}} = P_{\text{max-stability}} - P_{\text{min-stability}} \text{ (dB)} \quad (4)$$

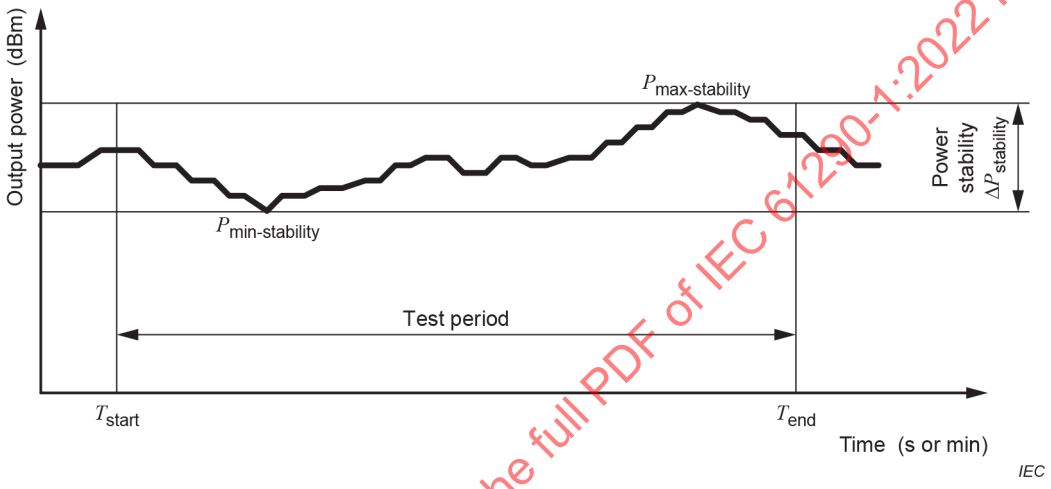

Figure 6 – Typical behaviour of the output power fluctuation as a function of time

l) Saturation output power: The measurement procedure described below shall be followed with reference to the measurement set-up for each test method. The saturation output power shall be given by the output power at which the gain is reduced by N dB (typically N = 3) with respect to the small-signal gain at the same signal wavelength. Calculations are processed according to the following procedure:

1) plot the gain versus input power as described in d). Refer to Figure 7 for typical behaviour of the gain;
2) plot the output power versus input power. Refer to Figure 8 for typical behaviour of the output power;
3) find the gain G_{sat} (dB) which is N -dB smaller than the small signal gain G_{max} in the linear gain region (see Figure 7);
4) find the input power $P_{\text{in-sat}}$ (dBm) that produces the gain G_{sat};
5) find the output power $P_{\text{out-sat}}$ (dBm) at the input power $P_{\text{in-sat}}$ (see Figure 8);
6) $P_{\text{out-sat}}$ is the saturation output power.

NOTE 3 A value of N = 3 is typically applied.

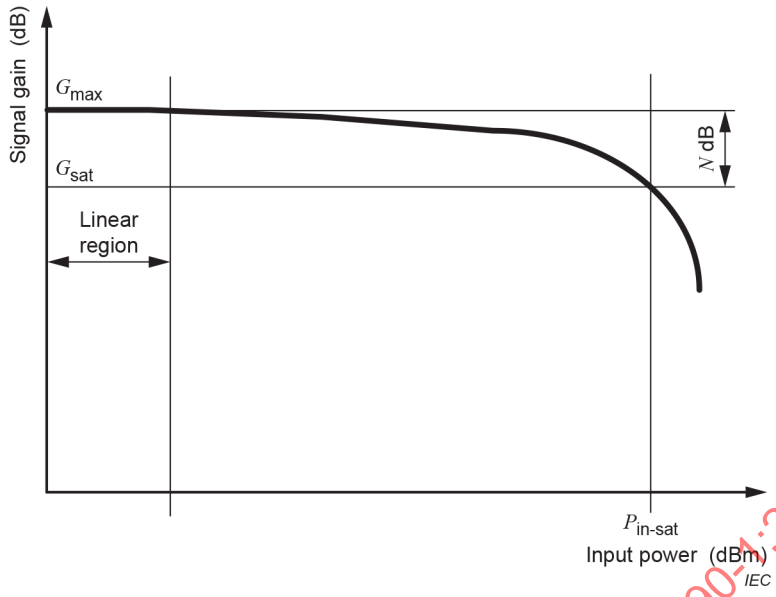

Figure 7 – Typical behaviour of the gain as a function of input signal power

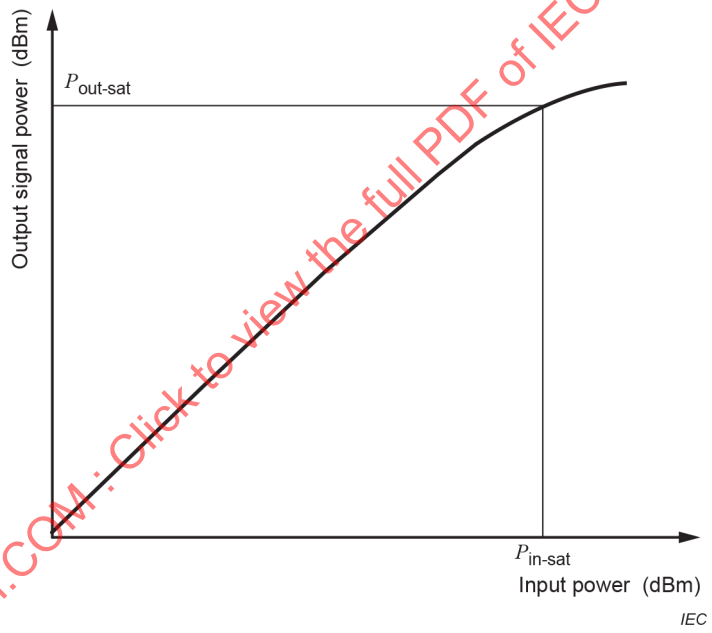

Figure 8 – Typical behaviour of the output power as a function of input signal power

m) Maximum output signal power: The measurement procedure and calculations are described in each test method.

n) Maximum total output power: The measurement procedure and calculations are described in each test method.

6 Test results

~~Test results are as follows:~~

The following information and data shall be recorded in the test results.

a) Nominal optical signal power:

~~The following details shall be presented:~~

1) arrangement of the test set-up;
2) spectral linewidth (FWHM) of the optical source;
3) indication of the optical pump power and possibly driving current of pump lasers for OFAs, and injection current for SOAs (if applicable);
4) operating temperature (if required);
5) input signal optical power, P_{in};
6) time-averaged input signal power (if applicable);
7) resolution bandwidth of the optical spectrum analyzer (if applicable);
8) resolution bandwidth of the electrical spectrum analyzer (if applicable);
9) FWHM of the optical bandpass filter (if applicable);
10) central wavelength of the optical bandpass filter (if applicable);
11) wavelength of the measurement;
12) nominal optical signal power levels, P;
13) change in the state of polarization given to the input signal light.

b) Gain: Items 1) to 11) listed for nominal optical signal power levels shall be presented and:
12) gain.

Items 5) and 12) may be replaced with the gain versus input optical signal power curve.

c) Reverse gain: Items 1) to 11) listed for gain shall be presented and:
12) reverse gain.

Items 5) and 12) may be replaced with the reverse gain versus input optical signal power curve.

d) Maximum gain: Items 1) to 11) listed for gain shall be presented and:
12) wavelength range of the measurement;
13) maximum gain.

Items 5) and 13) may be replaced with the maximum gain versus input optical signal power curve.

e) Maximum gain wavelength: Items 1) to 11) listed for gain shall be presented and:
12) wavelength range of the measurement;
13) wavelength measurement ~~accuracy~~ uncertainty;
14) maximum gain wavelength.

Items 12) and 14) may be replaced with the gain versus input signal wavelength curve.

f) Maximum gain variation with temperature: Items 1) to 11) listed for gain shall be presented and:
12) the maximum and minimum gain with temperature, $G_{max\text{-}tmp}$ and $G_{min\text{-}tmp}$;
13) maximum gain variation with temperature.

g) Gain wavelength band: Items 1) to 11) listed for gain shall be presented and:
12) wavelength range of the measurement;
13) wavelength measurement ~~accuracy~~ uncertainty;
14) gain wavelength band;
15) N value chosen for the determination of the wavelength bandwidth.

Items 12), 14) and 15) may be replaced with the gain versus input signal wavelength curve.

h) Gain wavelength variation: Items 1) to 11) listed for gain shall be presented and:
12) wavelength range of the measurement;
13) wavelength measurement ~~accuracy~~ uncertainty of the optical spectrum analyzer;

14) gain variation.

Items 12) and 14) may be replaced with the gain versus input signal wavelength curve.

i) Gain stability: Items 1) to 11) listed for gain shall be presented and:

12) the maximum and minimum gain, $G_{\text{max-stability}}$ and $G_{\text{min-stability}}$;

13) gain stability.

j) Polarization-dependent gain: Items 1) to 11) listed for gain shall be presented and:

12) polarization dependency of the apparatus for detecting optical power for each test method;

13) maximum and minimum gain, $G_{\text{max-pol}}$ and $G_{\text{min-pol}}$;

14) polarization-dependent gain;

15) change in the state of polarization given to the input signal light.

k) Gain ripple:

The following items shall be presented:

1) arrangement of the test set-up;

2) type of optical source;

3) operating temperature (when required);

4) case temperature;

5) input signal optical power, P_{in} (if applicable);

6) resolution bandwidth of the OSA;

7) wavelength of the measurement;

8) injection current (only for SOAs).

l) Large-signal output stability: Items 1) to 11) listed for gain shall be presented and:

12) the maximum and minimum output power $P_{\text{max-stability}}$ and $P_{\text{min-stability}}$;

13) large-signal output stability.

l) Saturation output power: Items 1) to 11) listed for gain shall be presented and:

12) saturation figure N;

13) saturation gain G_{sat};

14) saturation input power $P_{\text{in-sat}}$;

15) saturation output power $P_{\text{out-sat}}$.

n) Maximum output signal power: Items 1) to 11) listed for gain shall be presented and:

12) maximum output signal power $P_{\text{sig-out-max}}$.

o) Maximum total output power: Items 1) to 11) listed for gain shall be presented and:

12) maximum total output power $P_{\text{out-max}}$.

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IEC 60793-1-40, *Optical fibres – Part 1-40: ~~Measurement methods and test procedures –~~ Attenuation measurement methods*

IEC 60825-1, *Safety of laser products – Part 1: Equipment classification and requirements*

IEC 60825-2, *Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCSs)*

~~IEC 60874-1, *Fibre optic interconnecting devices and passive components – Connectors for optical fibres and cables – Part 1: Generic specification*~~

IEC 61290-10 (all parts), *Optical amplifiers – Test methods – Part 10-X: Multichannel parameters*

IEC TR 61931, *Fibre optic – Terminology*

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Optical amplifiers – Test methods – Part 1: Power and gain parameters

Amplificateurs optiques – Méthodes d'essai – Partie 1: Paramètres de puissance et de gain

IEC 61290-1:2022-06(en-fr)

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b) specification of test method and test report for gain ripple measurements;
c) use of the term "measurement uncertainty" instead of "measurement accuracy".

The text of this International Standard is based on the following documents:

Draft	Report on voting
86C/1746/FDIS	86C/1783/RVD

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

The language used for the development of this International Standard is English.

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

A list of all parts in the IEC 61290 series, published under the general title *Optical amplifiers – Test methods*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

OPTICAL AMPLIFIERS – TEST METHODS –

Part 1: Power and gain parameters

1 Scope

This part of IEC 61290 applies to all commercially available optical amplifiers (OAs) and optically amplified subsystems. It applies to OAs using optically pumped fibres (optical fibre amplifiers (OFAs) based on either rare-earth doped fibres or on the Raman effect), semiconductors (semiconductor optical amplifiers (SOAs)), and waveguides (planar optical waveguide amplifiers (POWAs)). It is specifically directed to single-channel amplifiers. Test methods for multichannel amplifiers are defined in the IEC 61290-10 series.

This document establishes uniform requirements for accurate and reliable measurements of the following OA parameters, as defined in IEC 61291-1:2018, Clause 3:

a) nominal output signal power;
b) gain;
c) reverse gain;
d) maximum gain;
e) maximum gain wavelength;
f) maximum gain variation with temperature;
g) gain wavelength band;
h) gain wavelength variation;
i) gain stability;
j) polarization-dependent gain;
k) gain ripple (SOA only);
l) large-signal output stability;
m) saturation output power;
n) maximum output signal power;
o) maximum total output power.

NOTE 1 The applicability of the test methods described in this document to distributed Raman amplifiers is still under study.

NOTE 2 All numerical values followed by (‡) are suggested values for which the measurement is assured. Other values are acceptable if verified.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61290-1-1, *Optical amplifiers – Test methods – Part 1-1: Power and gain parameters – Optical spectrum analyzer method*

IEC 61290-1-2, *Optical amplifiers – Test methods – Part 1-2: Power and gain parameters – Electrical spectrum analyzer method*

IEC 61290-1-3, *Optical amplifiers – Test methods – Part 1-3: Power and gain parameters – Optical power meter method*

IEC 61291-1:2018, *Optical amplifiers – Part 1: Generic specification*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61291-1 apply.

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

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

3.2 Abbreviated terms

ASE amplified spontaneous emission
FWHM full width at half maximum
OA optical amplifier
OFA optical fibre amplifier
OSA optical spectrum analyzer
POWA planar optical waveguide amplifier
SOA semiconductor optical amplifier

4 Optical power and gain test method

One of the three test methods described in IEC 61290-1-1, IEC 61290-1-2, and IEC 61290-1-3 for quantifying the optical power and gain of an OA shall be followed in this document.

The test method described in IEC 61290-1-1 determines the optical power and gain by means of an optical spectrum analyzer.

The test method described in IEC 61290-1-2 determines the optical power and gain by means of an optical detector and an electrical spectrum analyzer.

The test method described in IEC 61290-1-3 determines the optical power and gain by means of an optical power meter and an optical bandpass filter.

5 Optical power and gain parameters

The parameters listed below are required for gain and power:

a) Nominal output signal power: The nominal output signal power is given by the minimum output signal optical power for an input signal optical power specified in the relevant detail specification and under nominal operating conditions given in the relevant detail specification. To find this minimum value, input and output signal power levels shall be continuously monitored for a given duration of time and in the presence of changes in the state of polarization and other instabilities, as specified in the relevant detail specification. The measurement procedures and calculations are described in each test method.

b) Gain: The measurement procedures and calculations are described in each test method.

c) Reverse gain: As in b), but with the OA operating with the input port used as an output port and vice-versa.

d) Maximum gain: As in b), but use a wavelength-tuneable optical source and repeat all procedures at different wavelengths in such a way as to cover the wavelength range specified in the relevant detail specification.

Unless otherwise specified, the wavelength should be changed by steps smaller than 1 nm (‡) around the wavelength where the ASE spectral profile, observed (e.g. with an optical spectrum analyzer or a monochromator) without the input signal, takes its maximum value.

NOTE 1 A wavelength measurement uncertainty of 0,01 nm, within the operating wavelength range of the OA, is attainable with commercially available wavelength meters based on interference-fringes counting techniques. Some tuneable external-cavity laser-diode instruments provide a wavelength measurement uncertainty of 0,2 nm.

The gain values are measured at the different wavelengths as described in b) above. The maximum gain shall be given by the highest of all these gain values at nominal operating condition. Figure 1 shows the typical behaviour of the gain as a function of the input signal power.

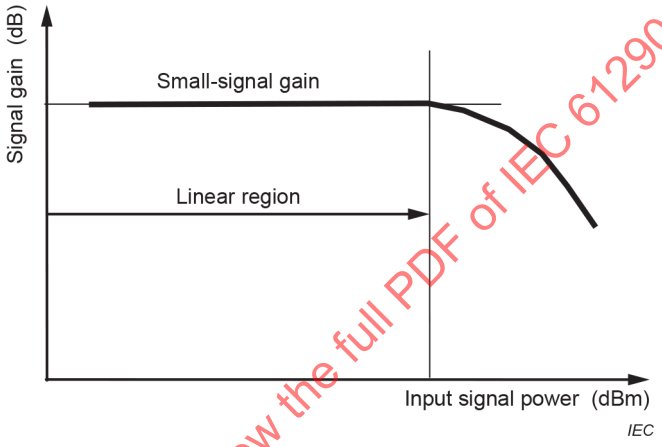

Figure 1 – Typical behaviour of the gain as a function of input signal power

e) Maximum gain wavelength: As in d), the maximum gain wavelength shall be the wavelength at which the maximum gain occurs. Refer to Figure 2 for typical gain behaviour for different wavelengths.

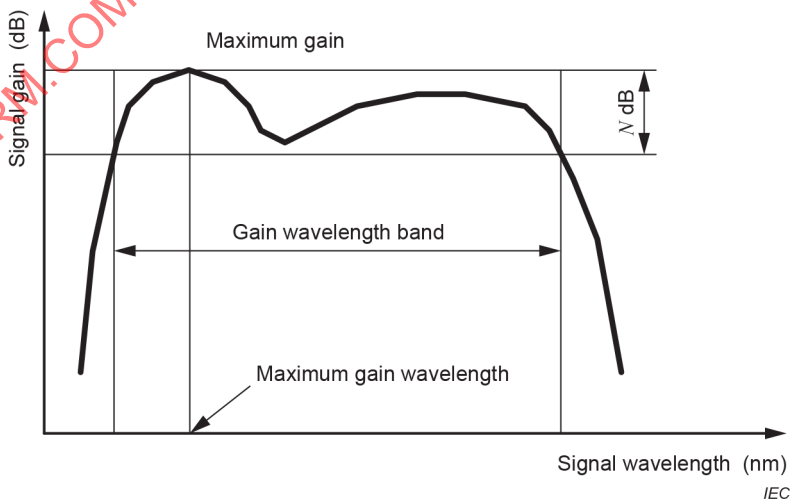

Figure 2 – Typical behaviour of the gain as a function of wavelength

f) Maximum gain variation with temperature: The maximum change of signal gain for a certain specified temperature range. The measurement procedures and calculations described

below shall be followed, with reference to the measurement set-up and procedure for each test method:

1) as described in b), measure the maximum gain $G_{\text{max-tmp}}$ within the variation of temperature, as specified in the relevant detail specification;
2) as described in b), measure the minimum gain $G_{\text{min-tmp}}$ within the variation of temperature, as specified in the relevant detail specification;
3) the maximum gain variation with temperature ΔG_{tmp} is given by Formula (1):

$$\Delta G_{\text{tmp}} = G_{\text{max-tmp}} - G_{\text{min-tmp}} \text{ (dB)} \quad (1)$$

Refer to Figure 3.

The gain variation with temperature can depend on the signal wavelength, owing to its active fibre characteristics. The wavelength at which the parameter is specified and measured should be stated.

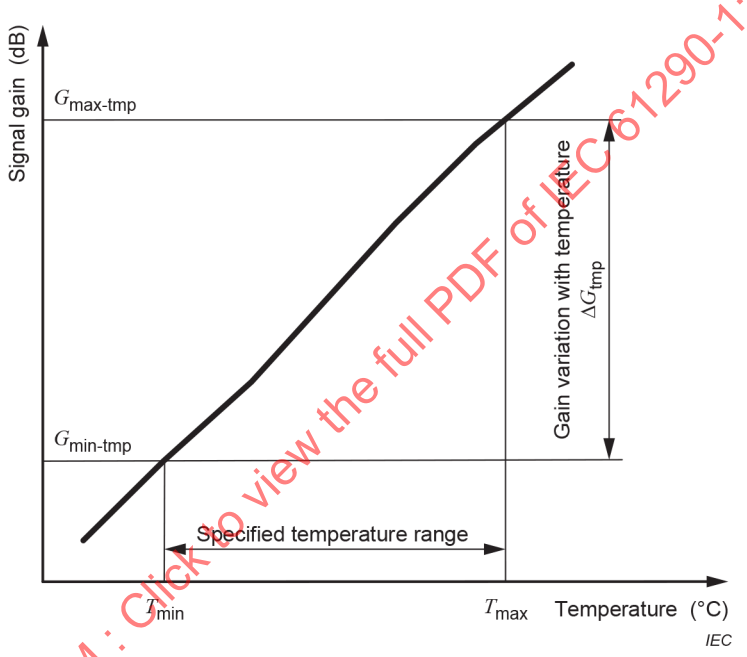

Figure 3 – Typical behaviour of the gain as a function of temperature

g) Gain wavelength band: Measure the maximum gain as described in d). Identify those wavelengths at which the gain is N dB below the maximum gain. The gain wavelength band shall be given by the wavelength interval(s) that comprise(s) those wavelengths at which the gain is between the maximum gain value and the value N dB below the maximum gain. Calculations are processed according to the following procedure:

1) plot the gain at each wavelength as a function of wavelength, as shown in Figure 2;
2) draw a horizontal line N dB below the maximum gain value;
3) the two or more intersection points of this line with the gain profile plotted in 1) yield two (or more) N dB-down wavelengths, which define the range of the gain wavelength band. The wavelength interval with the minimum difference in N dB-down wavelengths is the gain wavelength band.

NOTE 2 A value of N = 3 is typically applied.

h) Gain wavelength variation: Measure the maximum gain and minimum gain over the specified measurement wavelength range as described in d). The gain variation shall be the difference between the maximum and the minimum gain values. Calculations are processed according to the following procedure:

1) plot the gain of each wavelength as shown in Figure 4;

2) find the maximum gain, $G_{\text{max-}\lambda}$ (dB) within the specified wavelength band;

3) find the minimum gain, $G_{\text{min-}\lambda}$ (dB) within the specified wavelength band;

4) calculate the gain wavelength variation, ΔG_{λ} (dB) from Formula (2):

$$\Delta G_{\lambda} = G_{\text{max-}\lambda} - G_{\text{min-}\lambda} \text{ (dB)} \quad (2)$$

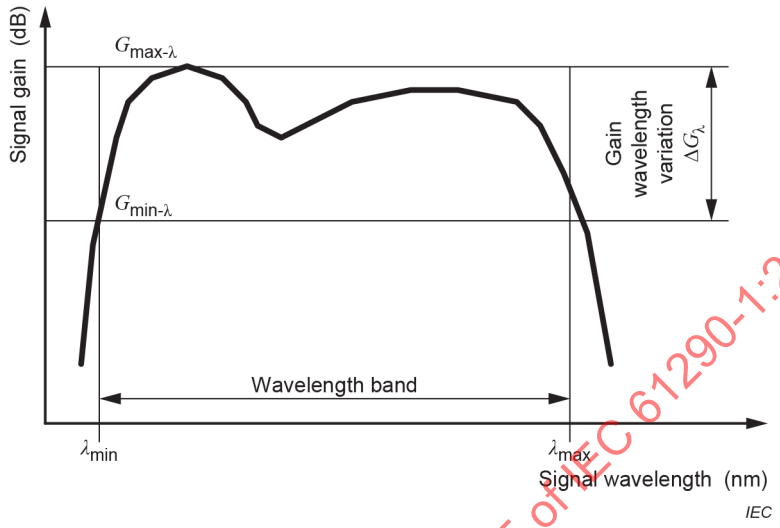

Figure 4 – Typical behaviour of the gain as a function of wavelength

i) Gain stability: The maximum degree of gain fluctuation of the maximum and minimum signal gain for a certain specified test period, as specified in the relevant detail specification. The measurement procedure and calculations described below shall be followed with reference to the measurement set-up for each test method. Refer to Figure 5 for typical behaviour of the gain fluctuation:

1) as for b), measure the maximum gain $G_{\text{max-stability}}$ for a certain specified test period, as specified in the relevant detail specification;

2) as for b), measure the minimum gain $G_{\text{min-stability}}$ for a certain specified test period, as specified in the relevant detail specification;

3) the gain stability $\Delta G_{\text{stability}}$ (dB) is given by Formula (3):

$$\Delta G_{\text{stability}} = G_{\text{max-stability}} - G_{\text{min-stability}} \text{ (dB)} \quad (3)$$

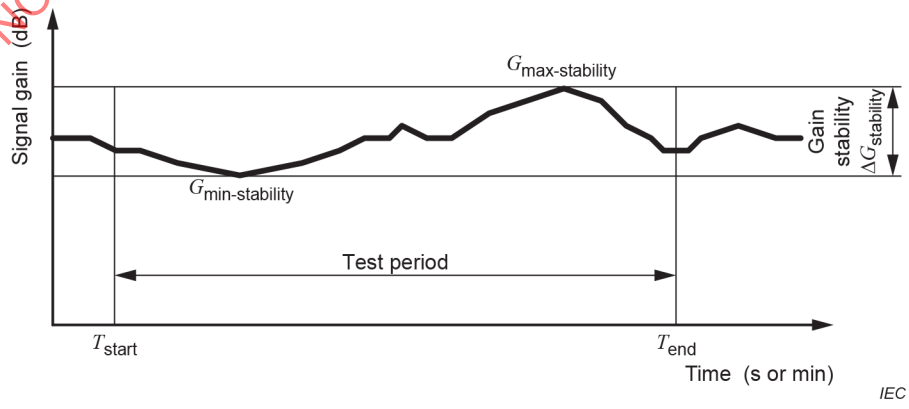

Figure 5 – Typical behaviour of the gain fluctuation as a function of time

j) Polarization-dependent gain: Gain values at the different states of polarization as described in b). The procedure and calculations are described in each test method.

k) Gain ripple: Details of the measurement procedures and calculations are described in IEC 61290-1-1.

l) Large-signal output stability: The maximum degree of gain fluctuation of the maximum and minimum output optical power for a certain specified test period, as specified in the relevant detail specification. The measurement procedure and calculations described below shall be followed, with reference to the measurement set-up for each test method. Refer to Figure 6 for typical behaviour of the output power fluctuation:

1) as described in a), measure the maximum output signal power $P_{\text{max-stability}}$ for a certain specified test period at a given wavelength and maximum signal input power, as specified in the relevant detail specification;

2) as described in a), measure the minimum output signal power $P_{\text{min-stability}}$ for a certain specified test period at a given wavelength and maximum signal input power, as specified in the relevant detail specification;

3) compare $P_{\text{max-stability}}$ with $P_{\text{min-stability}}$, and subtract $P_{\text{min-stability}}$ from $P_{\text{max-stability}}$ to obtain the large signal output stability;

4) large-signal output stability $\Delta P_{\text{stability}}$ (dB) is given by Formula (4):

$$\Delta P_{\text{stability}} = P_{\text{max-stability}} - P_{\text{min-stability}} \text{ (dB)} \quad (4)$$

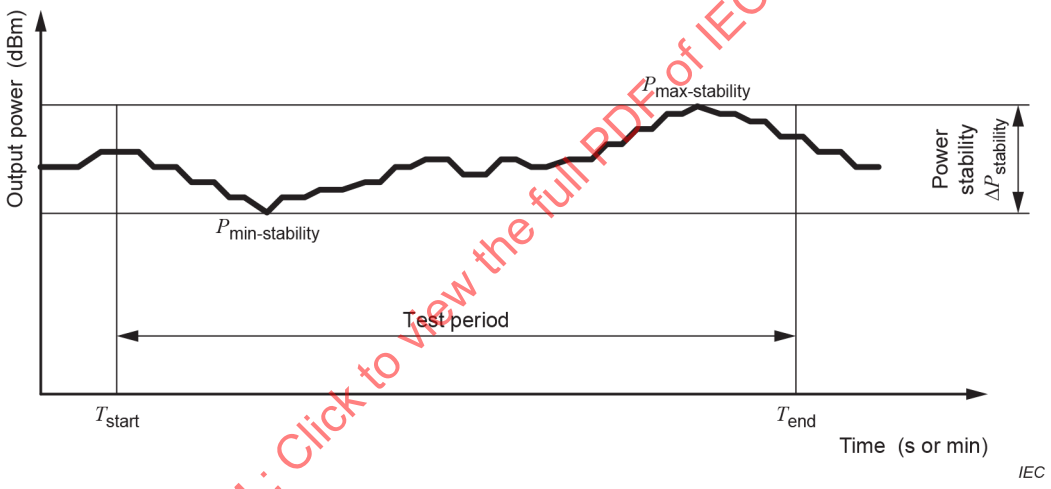

Figure 6 – Typical behaviour of the output power fluctuation as a function of time

m) Saturation output power: The measurement procedure described below shall be followed with reference to the measurement set-up for each test method. The saturation output power shall be given by the output power at which the gain is reduced by N dB (typically N = 3) with respect to the small-signal gain at the same signal wavelength. Calculations are processed according to the following procedure:

1) plot the gain versus input power as described in d). Refer to Figure 7 for typical behaviour of the gain;

2) plot the output power versus input power. Refer to Figure 8 for typical behaviour of the output power;

3) find the gain G_{sat} (dB) which is N dB smaller than the small signal gain G_{max} in the linear gain region (see Figure 7);

4) find the input power $P_{\text{in-sat}}$ (dBm) that produces the gain G_{sat};

5) find the output power $P_{\text{out-sat}}$ (dBm) at the input power $P_{\text{in-sat}}$ (see Figure 8);

6) $P_{\text{out-sat}}$ is the saturation output power.

NOTE 3 A value of N = 3 is typically applied.

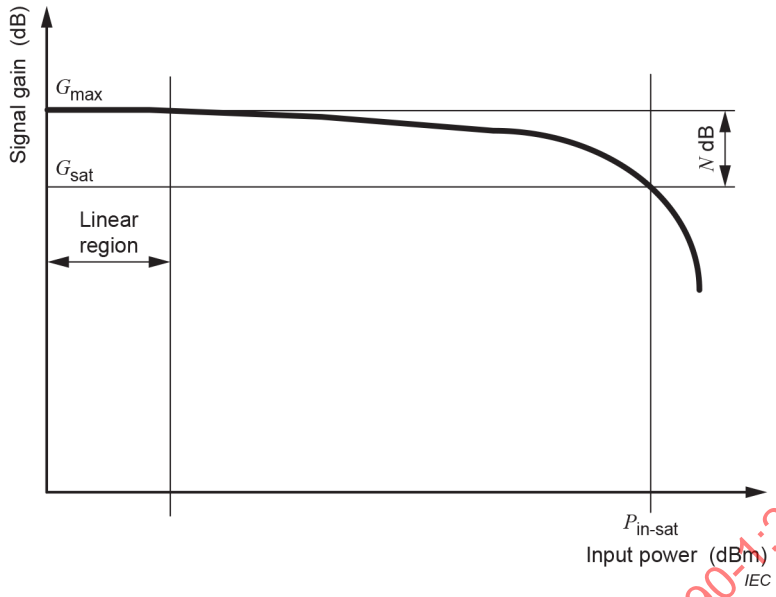

Figure 7 – Typical behaviour of the gain as a function of input signal power

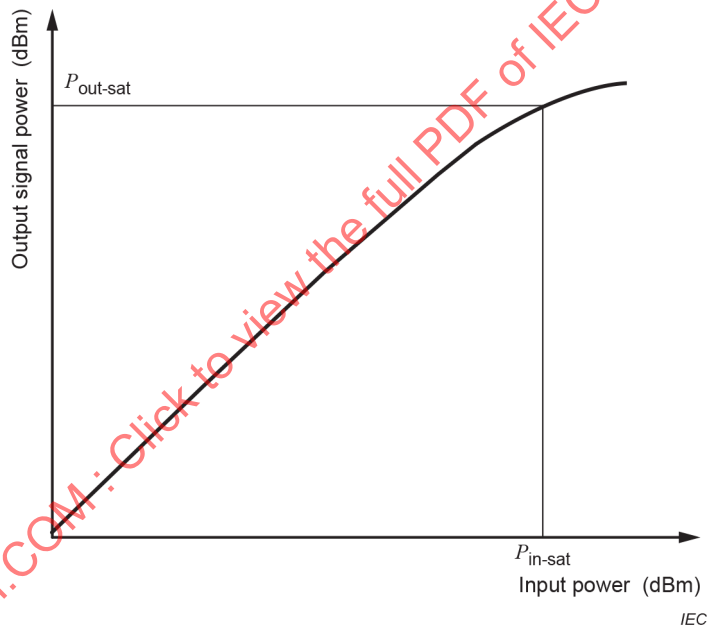

Figure 8 – Typical behaviour of the output power as a function of input signal power

n) Maximum output signal power: The measurement procedure and calculations are described in each test method.

o) Maximum total output power: The measurement procedure and calculations are described in each test method.

6 Test results

The following information and data shall be recorded in the test results.

a) Nominal optical signal power:

   1) arrangement of the test set-up;

   2) spectral linewidth (FWHM) of the optical source;

3) indication of the optical pump power and possibly driving current of pump lasers for OFAs, and injection current for SOAs (if applicable);
4) operating temperature (if required);
5) input signal optical power, P_{in};
6) time-averaged input signal power (if applicable);
7) resolution bandwidth of the optical spectrum analyzer (if applicable);
8) resolution bandwidth of the electrical spectrum analyzer (if applicable);
9) FWHM of the optical bandpass filter (if applicable);
10) central wavelength of the optical bandpass filter (if applicable);
11) wavelength of the measurement;
12) nominal optical signal power levels, P;
13) change in the state of polarization given to the input signal light.

b) Gain: Items 1) to 11) listed for nominal optical signal power levels shall be presented and:

12) gain.

Items 5) and 12) may be replaced with the gain versus input optical signal power curve.

c) Reverse gain: Items 1) to 11) listed for gain shall be presented and:

12) reverse gain.

Items 5) and 12) may be replaced with the reverse gain versus input optical signal power curve.

d) Maximum gain: Items 1) to 11) listed for gain shall be presented and:

12) wavelength range of the measurement;
13) maximum gain.

Items 5) and 13) may be replaced with the maximum gain versus input optical signal power curve.

e) Maximum gain wavelength: Items 1) to 11) listed for gain shall be presented and:

12) wavelength range of the measurement;
13) wavelength measurement uncertainty;
14) maximum gain wavelength.

Items 12) and 14) may be replaced with the gain versus input signal wavelength curve.

f) Maximum gain variation with temperature: Items 1) to 11) listed for gain shall be presented and:

12) the maximum and minimum gain with temperature, $G_{max\text{-}tmp}$ and $G_{min\text{-}tmp}$;
13) maximum gain variation with temperature.

g) Gain wavelength band: Items 1) to 11) listed for gain shall be presented and:

12) wavelength range of the measurement;
13) wavelength measurement uncertainty;
14) gain wavelength band;
15) N value chosen for the determination of the wavelength bandwidth.

Items 12), 14) and 15) may be replaced with the gain versus input signal wavelength curve.

h) Gain wavelength variation: Items 1) to 11) listed for gain shall be presented and:

12) wavelength range of the measurement;
13) wavelength measurement uncertainty of the optical spectrum analyzer;
14) gain variation.

Items 12) and 14) may be replaced with the gain versus input signal wavelength curve.

i) Gain stability: Items 1) to 11) listed for gain shall be presented and:

12) the maximum and minimum gain, $G_{\text{max-stability}}$ and $G_{\text{min-stability}}$;

13) gain stability.

j) Polarization-dependent gain: Items 1) to 11) listed for gain shall be presented and:

12) polarization dependency of the apparatus for detecting optical power for each test method;

13) maximum and minimum gain, $G_{\text{max-pol}}$ and $G_{\text{min-pol}}$;

14) polarization-dependent gain;

15) change in the state of polarization given to the input signal light.

k) Gain ripple:

The following items shall be presented:

1) arrangement of the test set-up;

2) type of optical source;

3) operating temperature (when required);

4) case temperature;

5) input signal optical power, P_{in} (if applicable);

6) resolution bandwidth of the OSA;

7) wavelength of the measurement;

8) injection current (only for SOAs).

l) Large-signal output stability: Items 1) to 11) listed for gain shall be presented and:

12) the maximum and minimum output power $P_{\text{max-stability}}$ and $P_{\text{min-stability}}$;

13) large-signal output stability.

m) Saturation output power: Items 1) to 11) listed for gain shall be presented and:

12) saturation figure N;

13) saturation gain G_{sat};

14) saturation input power $P_{\text{in-sat}}$;

15) saturation output power $P_{\text{out-sat}}$.

n) Maximum output signal power: Items 1) to 11) listed for gain shall be presented and:

12) maximum output signal power $P_{\text{sig-out-max}}$.

o) Maximum total output power: Items 1) to 11) listed for gain shall be presented and:

12) maximum total output power $P_{\text{out-max}}$.

Bibliography

IEC 60793-1-1, *Optical fibres – Part 1-1: Measurement methods and test procedures – General and guidance*

IEC 60793-1-40, *Optical fibres – Part 1-40: Attenuation measurement methods*

IEC 60825-1, *Safety of laser products – Part 1: Equipment classification and requirements*

IEC 60825-2, *Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCSs)*

IEC 61290-10 (all parts), *Optical amplifiers – Test methods – Part 10-X: Multichannel parameters*

IEC TR 61931, *Fibre optic – Terminology*

SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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AMPLIFICATEURS OPTIQUES – MÉTHODES D'ESSAI –

Partie 1: Paramètres de puissance et de gain

AVANT-PROPOS

1) La Commission Electrotechnique Internationale (IEC) est une organisation mondiale de normalisation composée de l'ensemble des comités électrotechniques nationaux (Comités nationaux de l'IEC). L'IEC a pour objet de favoriser la coopération internationale pour toutes les questions de normalisation dans les domaines de l'électricité et de l'électronique. À cet effet, l'IEC – entre autres activités – publie des Normes internationales, des Spécifications techniques, des Rapports techniques, des Spécifications accessibles au public (PAS) et des Guides (ci-après dénommés "Publication(s) de l'IEC"). Leur élaboration est confiée à des comités d'études, aux travaux desquels tout Comité national intéressé par le sujet traité peut participer. Les organisations internationales, gouvernementales et non gouvernementales, en liaison avec l'IEC, participent également aux travaux. L'IEC collabore étroitement avec l'Organisation Internationale de Normalisation (ISO), selon des conditions fixées par accord entre les deux organisations.
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8) L'attention est attirée sur les références normatives citées dans cette publication. L'utilisation de publications référencées est obligatoire pour une application correcte de la présente publication.
9) L'attention est attirée sur le fait que certains des éléments du présent document de l'IEC peuvent faire l'objet de droits de brevet. L'IEC ne saurait être tenue pour responsable de ne pas avoir identifié de tels droits de brevets.

L'IEC 61290-1 a été établie par le sous-comité 86C: Systèmes et dispositifs actifs à fibres optiques, du comité d'études 86 de l'IEC: Fibres optiques. Il s'agit d'une Norme internationale.

Cette deuxième édition annule et remplace la première édition parue en 2014. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) spécification de l'ondulation du gain en tant que nouveau paramètre;
b) spécification de la méthode d'essai et du rapport d'essai pour les mesures d'ondulation du gain;
c) utilisation du terme "incertitude de mesure" au lieu de "précision de mesure".

Le texte de cette Norme internationale est issu des documents suivants:

Projet	Rapport de vote
86C/1746/FDIS	86C/1783/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à son approbation.

La langue employée pour l'élaboration de cette Norme internationale est l'anglais.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2, il a été développé selon les Directives ISO/IEC, Partie 1 et les Directives ISO/IEC, Supplément IEC, disponibles sous www.iec.ch/members_experts/refdocs. Les principaux types de documents développés par l'IEC sont décrits plus en détail sous www.iec.ch/publications/.

Une liste de toutes les parties de la série IEC 61290, publiées sous le titre général *Amplificateurs optiques – Méthodes d'essai*, peut être consultée sur le site web de l'IEC.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous webstore.iec.ch dans les données relatives au document recherché. À cette date, le document sera

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- remplacé par une édition révisée, ou
- amendé.

AMPLIFICATEURS OPTIQUES – MÉTHODES D'ESSAI –

Partie 1: Paramètres de puissance et de gain

1 Domaine d'application

La présente partie de l'IEC 61290 s'applique à tous les amplificateurs optiques (AO) et sous-systèmes à amplification optique, disponibles sur le marché. Elle s'applique aux AO utilisant des fibres pompées optiquement (amplificateurs à fibres optiques (AFO) basés sur des fibres dopées aux terres rares ou sur l'effet Raman), des semiconducteurs (amplificateurs optiques à semiconducteurs (SOA)), et des guides d'ondes (amplificateurs à guide d'ondes optiques planaires (POWA)). Elle est spécifiquement centrée sur les amplificateurs à un seul canal. Les méthodes d'essai pour les amplificateurs à canaux multiples sont définies dans la série IEC 61290-10.

Le présent document établit des exigences uniformes pour des mesures précises et fiables des paramètres d'AO donnés ci-dessous, tels qu'ils sont définis dans l'IEC 61291-1:2018, Article 3:

a) puissance nominale du signal de sortie;
b) gain;
c) gain inverse;
d) gain maximal;
e) longueur d'onde du gain maximal;
f) variation maximale du gain en fonction de la température;
g) bande de longueur d'onde du gain;
h) variation du gain en fonction de la longueur d'onde;
i) stabilité du gain;
j) gain dépendant de la polarisation;
k) ondulation du gain (SOA uniquement);
l) stabilité de sortie grands signaux;
m) puissance de sortie en saturation;
n) puissance maximale du signal de sortie;
o) puissance de sortie totale maximale.

NOTE 1 L'applicabilité des méthodes d'essai décrites dans le présent document à des amplificateurs à effet Raman répartis est toujours à l'étude.

NOTE 2 Toutes les valeurs numériques suivies de (‡) sont des valeurs suggérées, pour lesquelles la mesure est assurée. D'autres valeurs sont acceptables, à condition d'être vérifiées.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 61290-1-1, *Amplificateurs optiques – Méthodes d'essai – Partie 1-1: Paramètres de puissance et de gain – Méthode de l'analyseur de spectre optique*

IEC 61290-1-2, *Amplificateurs optiques – Méthodes d'essai – Partie 1-2: Paramètres de puissance et de gain – Méthode de l'analyseur de spectre électrique*

IEC 61290-1-3, *Amplificateurs optiques – Méthodes d'essai – Partie 1-3: Paramètres de puissance et de gain – Méthode par appareil de mesure de la puissance optique*

IEC 61291-1:2018, *Amplificateurs optiques – Partie 1: Spécification générique*

3 Termes, définitions et termes abrégés

3.1 Termes et définitions

Pour les besoins du présent document, les termes et définitions de l'IEC 61291-1 s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse http://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obp

3.2 Termes abrégés

ASE (*amplified spontaneous emission*) émission spontanée amplifiée

FWHM (*full width at half maximum*) largeur à mi-hauteur

AO amplificateur optique

AFO amplificateur à fibres optiques

OSA (*optical spectrum analyzer*) analyseur de spectre optique

POWA *(planar optical waveguide amplifier*) amplificateur à guide d'ondes optique planaire

SOA (*semiconductor optical amplifier*) amplificateur optique à semiconducteurs

4 Méthode d'essai de puissance optique et de gain

Une des méthodes d'essai décrites dans l'IEC 61290-1-1, l'IEC 61290-1-2 et l'IEC 61290-1-3, en vue de quantifier la puissance optique et le gain d'un AO, doit être suivie dans le présent document.

La méthode d'essai décrite dans l'IEC 61290-1-1 détermine la puissance optique et le gain au moyen d'un analyseur de spectre optique.

La méthode d'essai décrite dans l'IEC 61290-1-2 détermine la puissance optique et le gain au moyen d'un détecteur optique et d'un analyseur de spectre électrique.

La méthode d'essai décrite dans l'IEC 61290-1-3 détermine la puissance optique et le gain au moyen d'un appareil de mesure de la puissance optique et d'un filtre passe-bande optique.

5 Paramètres de puissance optique et de gain

Les paramètres énumérés ci-dessous sont exigés quant au gain et à la puissance:

a) Puissance nominale du signal de sortie. La puissance nominale du signal de sortie est donnée par la puissance optique minimale du signal de sortie, pour une puissance optique du signal d'entrée spécifiée dans la spécification particulière applicable, et dans des conditions de fonctionnement nominales, données dans la spécification particulière applicable. Pour trouver cette valeur minimale, les niveaux de puissance du signal d'entrée et du signal de sortie doivent être contrôlés continuellement pendant une durée donnée et

en présence de variations de l'état de polarisation et d'autres instabilités, comme cela est spécifié dans la spécification particulière applicable. Les procédures de mesure et les calculs sont décrits dans chaque méthode d'essai.

b) Gain: Les procédures de mesure et les calculs sont décrits dans chaque méthode d'essai.

c) Gain inverse: Comme en b), mais avec l'AO fonctionnant avec le port d'entrée utilisé comme port de sortie et vice versa.

d) Gain maximal. Comme en b), mais utiliser une source optique de longueur d'onde accordable et répéter toutes les étapes à différentes longueurs d'onde de manière à couvrir toute la plage de longueurs d'onde indiquée dans la spécification particulière applicable.

Sauf spécification contraire, il convient que la longueur d'onde soit modifiée par pas inférieurs à 1 nm (‡), autour de la longueur d'onde à laquelle le profil du spectre d'ASE, observé (par exemple avec un analyseur de spectre optique ou un monochromateur) sans le signal d'entrée, prend sa valeur maximale.

NOTE 1 Une incertitude de mesure de la longueur d'onde de 0,01 nm, dans la plage de longueurs d'onde de fonctionnement de l'AO, peut être obtenue avec des appareils de mesure de la longueur d'onde disponibles dans le commerce, basés sur des techniques de comptage de franges d'interférence. Certains appareils de mesure avec diode laser à cavité externe accordable fournissent une incertitude de mesure de la longueur d'onde de 0,2 nm.

Les valeurs de gain sont mesurées à différentes valeurs de longueurs d'onde telles que décrites en b) ci-dessus. Le gain maximal doit être donné par la plus grande de ces valeurs de gain aux conditions de fonctionnement nominales. La Figure 1 représente le comportement typique du gain en fonction de la puissance du signal d'entrée.

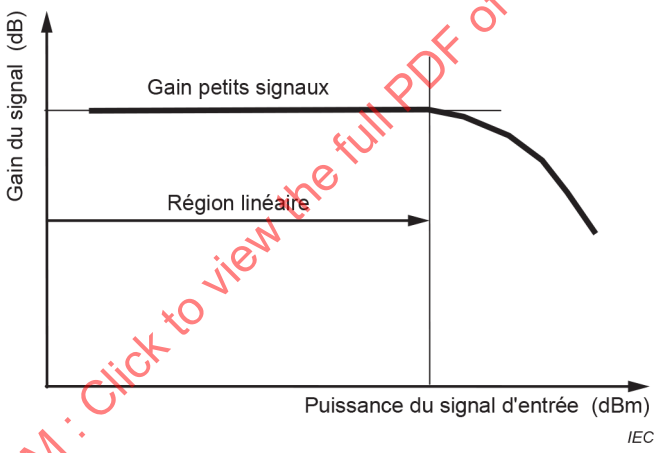

Figure 1 – Comportement typique du gain en fonction de la puissance du signal d'entrée

e) Longueur d'onde du gain maximal: Comme en d), la longueur d'onde du gain maximal doit être la longueur d'onde à laquelle le gain maximal se produit. Se reporter à la Figure 2 pour le comportement du gain typique pour différentes longueurs d'onde.

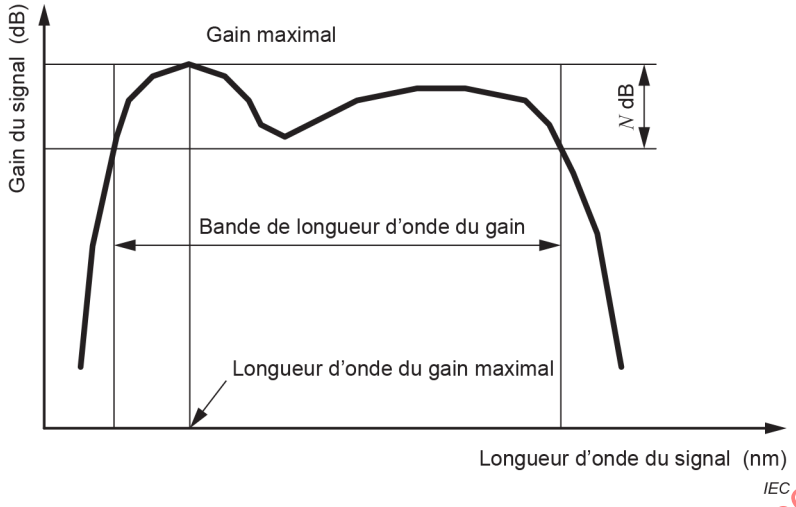

Figure 2 – Comportement typique du gain en fonction de la longueur d'onde

f) Variation maximale du gain en fonction de la température: Variation maximale du gain du signal pour une certaine plage de températures spécifiée. Les procédures de mesure et les calculs décrits ci-dessous doivent être suivis, en se référant au montage de mesure et à la procédure de mesure pour chaque méthode d'essai:

1) comme cela est décrit en b), mesurer le gain maximal $G_{\text{max-tmp}}$ dans les limites de la variation de température, telle que stipulée dans la spécification particulière applicable;
2) comme cela est décrit en b), mesurer le gain minimal $G_{\text{min-tmp}}$ dans les limites de la variation de température, telle que stipulée dans la spécification particulière applicable;
3) la variation maximale du gain en fonction de la température ΔG_{tmp} est donnée par la Formule (1):

$$\Delta G_{\text{tmp}} = G_{\text{max-tmp}} - G_{\text{min-tmp}} \text{ (dB)} \quad (1)$$

Se reporter à la Figure 3.

La variation du gain en fonction de la température peut dépendre de la longueur d'onde du signal en raison de ses caractéristiques de fibres actives. Il convient d'établir la longueur d'onde à laquelle le paramètre est spécifié et mesuré.