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INTERNATIONAL STANDARD

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

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FOREWORD

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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- withdrawn,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.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

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.

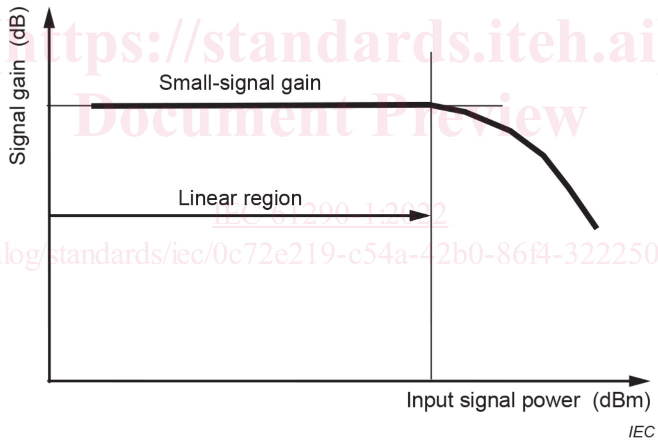

Figure 1 – Typical behaviour of the gain as a function of input signal power

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.

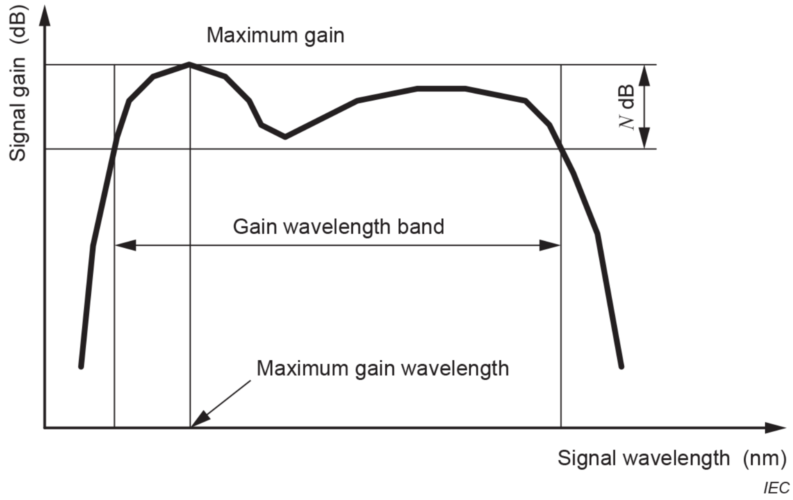

Figure 2 – Typical behaviour of the gain as a function of wavelength

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):

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

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.

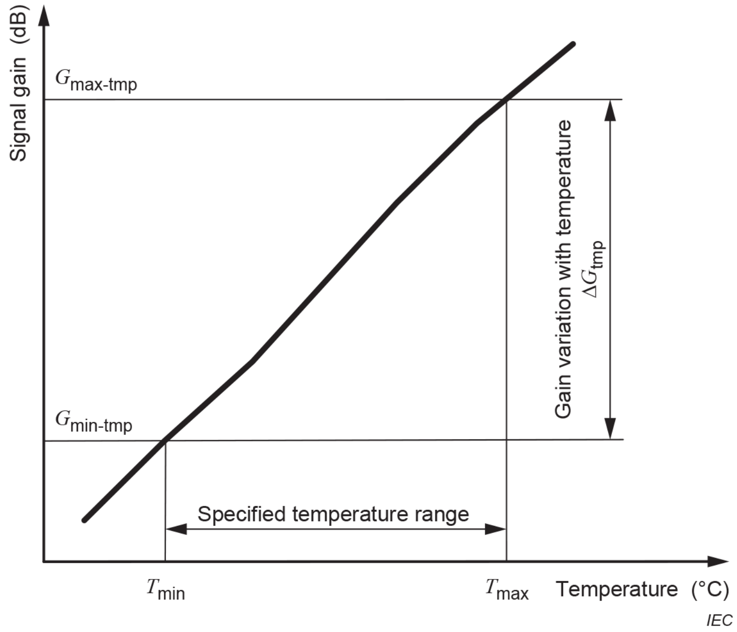

Figure 3 – Typical behaviour of the gain as a function of temperature

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, $G_{max-\lambda}$ (dB) within the specified wavelength band;

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

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

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

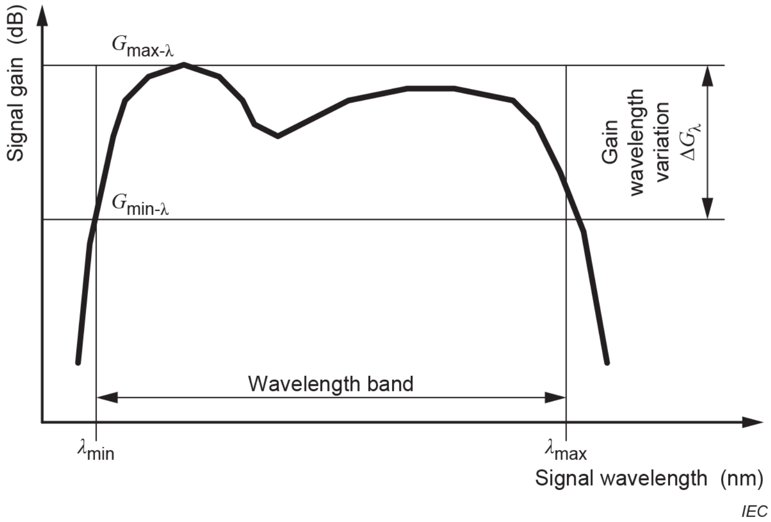

Figure 4 – Typical behaviour of the gain as a function of wavelength

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):

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

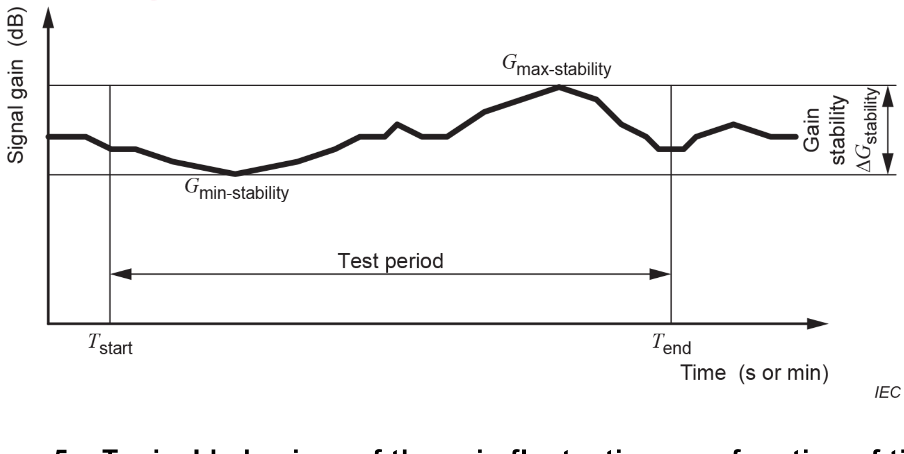

Figure 5 – Typical behaviour of the gain fluctuation as a function of time

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

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

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

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

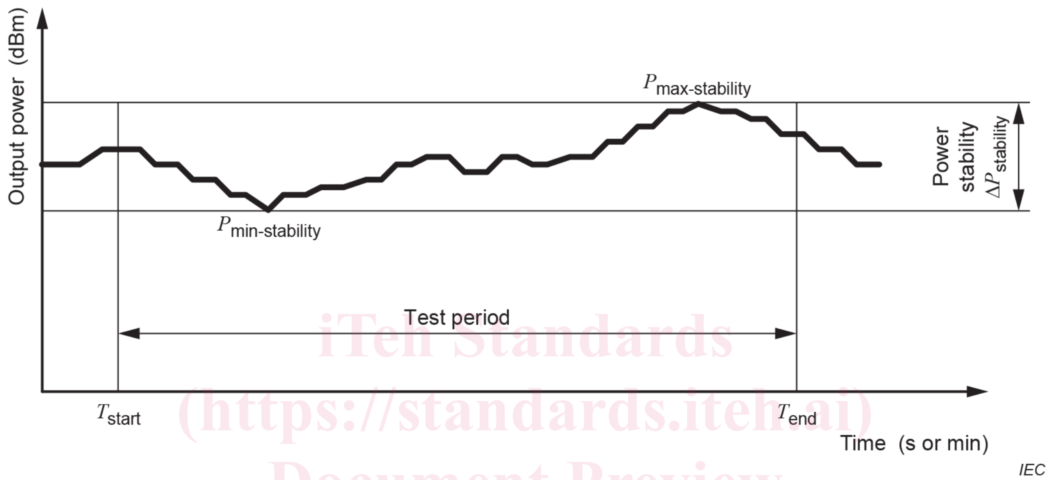

Figure 6 – Typical behaviour of the output power fluctuation as a function of time

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

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

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

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

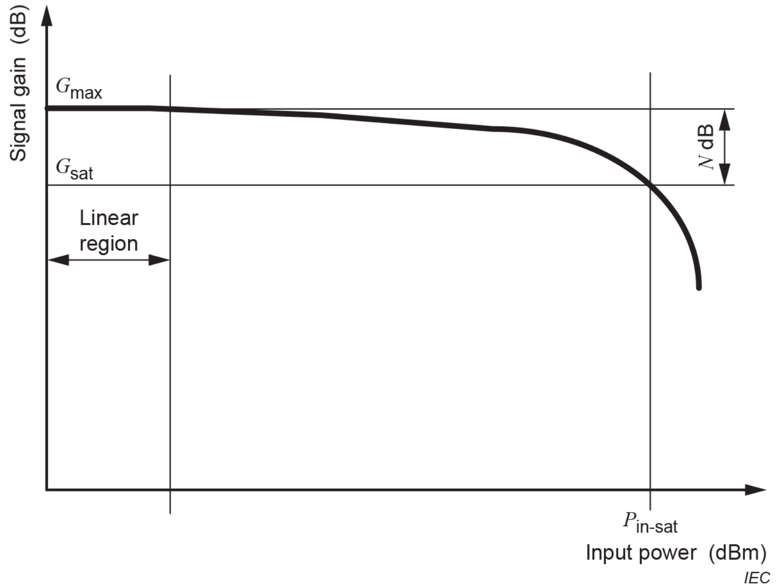

Figure 7 – Typical behaviour of the gain as a function of input signal power

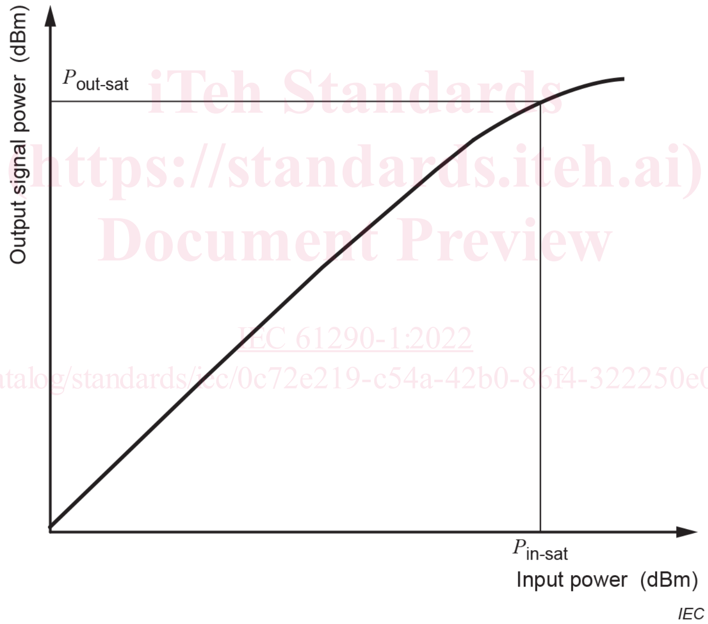

Figure 8 – Typical behaviour of the output power as a function of input signal power

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:~~