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INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

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

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Part 1: Power and gain parameters

FOREWORD

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

The text of this standard is based on the following documents:

CDV	Report on voting
86C/1188/CDV	86C/1258/RVC

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

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

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 publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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- withdrawn,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

OPTICAL AMPLIFIERS –
TEST METHODS –

Part 1: Power and gain parameters

1 Scope and object

This part of 61290 applies to all commercially available optical amplifiers (OAs) and optically amplified subsystems. It applies to OAs using optically pumped fibres (OFAs based on either rare-earth doped fibres or on the Raman effect), semiconductors (SOAs), and waveguides (POWAs).

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

The object of this standard is to establish uniform requirements for accurate and reliable measurements of the following OA parameters, as defined in Clause 3 of IEC 61291-1:2012:

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) large-signal output stability;
l) saturation output power;
m) maximum output signal power;
n) maximum total output power.

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, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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, *Optical amplifiers – Part 1: Generic specification*

3 Acronyms and abbreviations

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

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.

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

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

The aim of the third procedure (see IEC 61290-1-3) is to determine 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 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 output port and vice-versa.

d) *Maximum gain:* As in b), but use a wavelength-tuneable optical source, repeat all procedures at different wavelengths in a way 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 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 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.

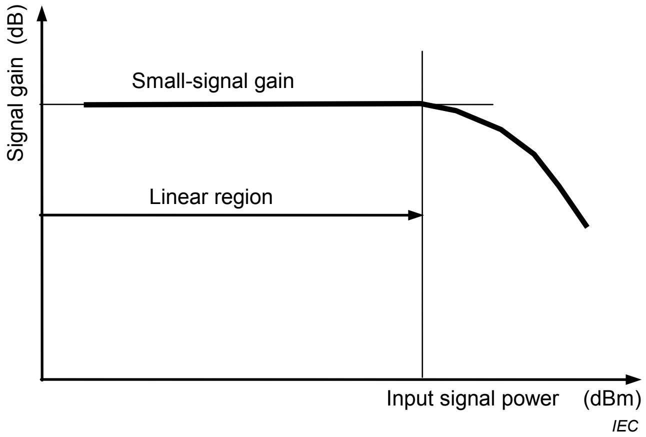

Figure 1 – Typical behaviour of the gain as a function of the input signal power

e) *Maximum gain wavelength:* As in d) above, 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.

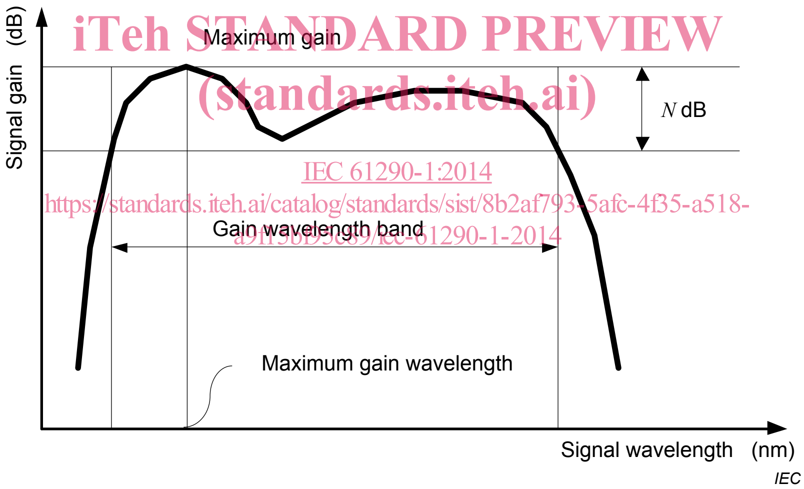

Figure 2 – Typical behaviour of the gain as a function of the wavelength

f) *Maximum gain variation with temperature:* The maximum change of signal gain for a certain specified temperature range. The measurement procedures and calculations are 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) Maximum gain variation with temperature ΔG_{tmp} is given by the following formula:

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

Refer to Figure 3.

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

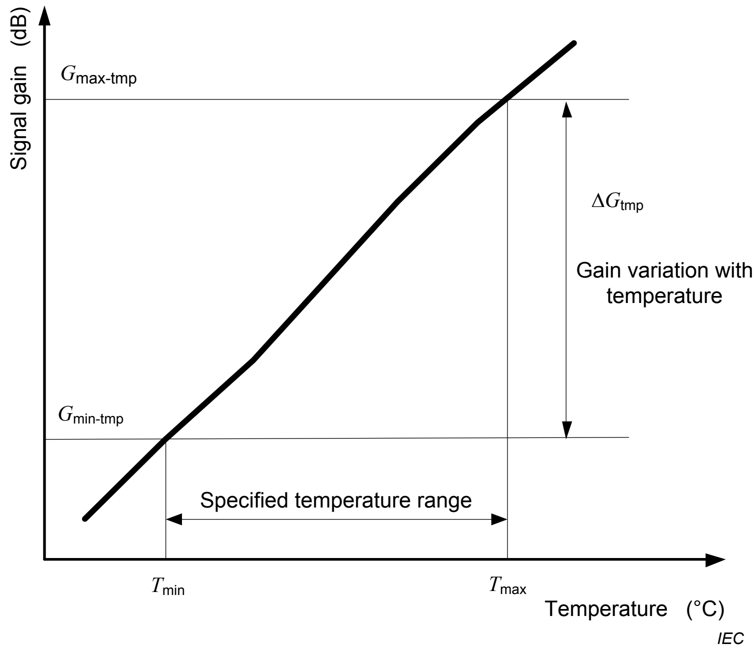

Figure 3 – Typical behaviour of the gain as a function of the temperature

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) comprised between those wavelengths within which the gain is comprised between the maximum gain value and a value N dB below the maximum gain. Calculations are processed according to the following procedure.

1) Plot the gain of each wavelength to the gains of adjacent wavelengths as shown in Figure 2.
2) Draw a horizontal line N -dB down from the maximum gain point.
3) The two or more intersection points define the gain wavelength band. The minimum difference in N -dB down wavelengths is 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 wavelength band.
3) Find the minimum gain, $G_{min-\lambda}$ (dB) within wavelength band.
4) Calculate the gain wavelength variation, ΔG_{λ} (dB) by the following formula:

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

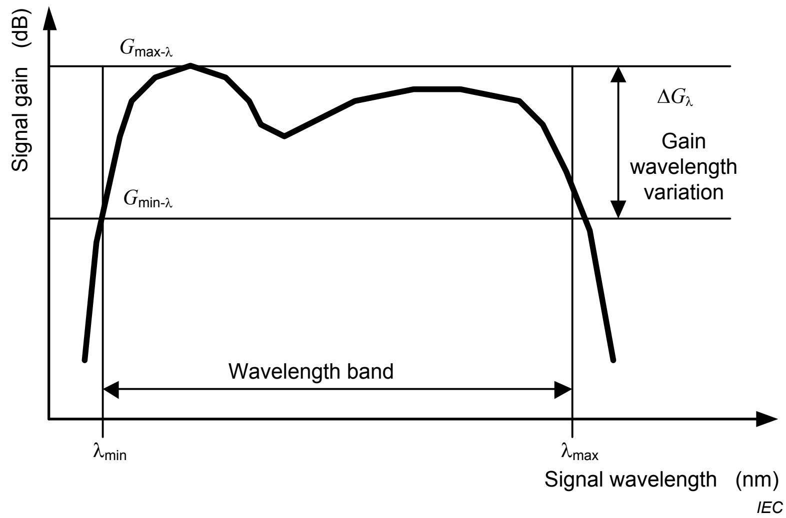

Figure 4 – Typical behaviour of the gain as a function of the wavelength

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) Gain stability $\Delta G_{stability}$ (dB) is given by the following formula:

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

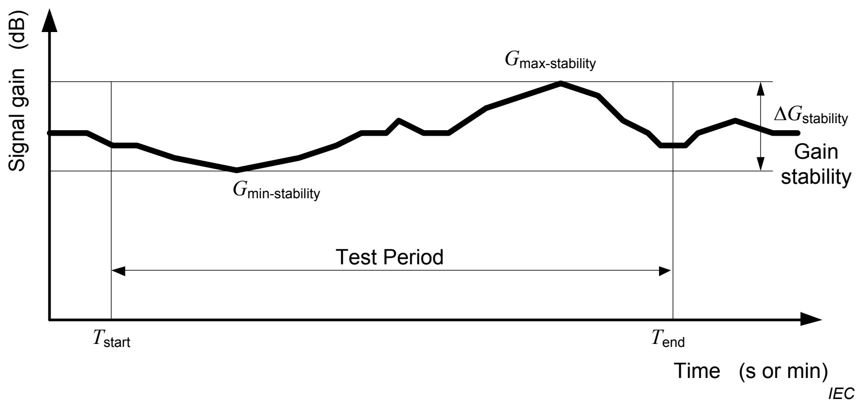

Figure 5 – Typical behaviour of the gain fluctuation as a function of time

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

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) above, 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) above, 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 large signal output stability.

4) Large-signal output stability $\Delta P_{stability}$ (dB) is given by the following formula:

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

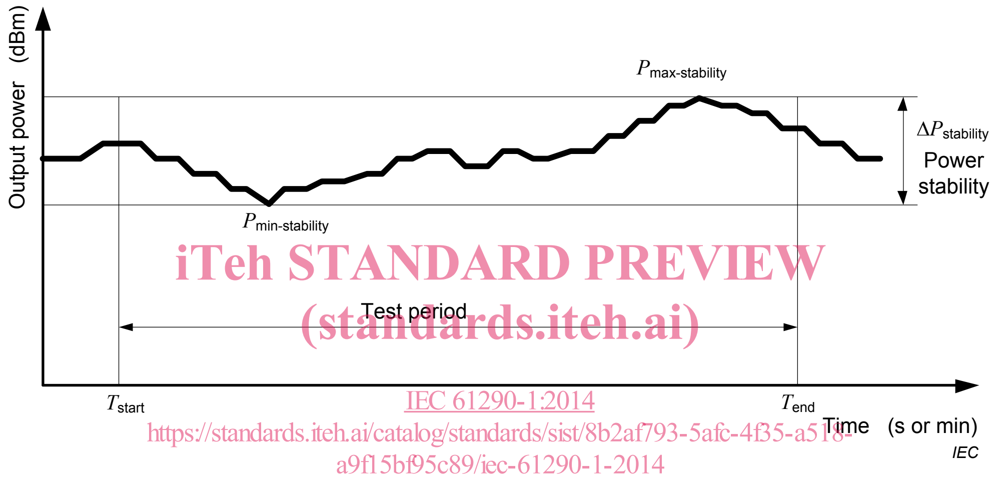

Figure 6 – Typical behaviour of the output power fluctuation as a function of time

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 above which the gain is reduced by N dB (typically N = 3) with respect to the small-signal gain at the signal wavelength. Calculations are processed according to the following procedure.

1) Plot gain vs. input power as described in d). Refer to Figure 7 for typical behaviour of the gain.

2) Plot the output power vs. 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 small signal gain under linear gain region.

4) Find the input power $P_{in\text{-}sat}$ (dBm) which produce the gain G_{sat}.

5) Find the output power $P_{out\text{-}sat}$ (dBm) at the input power $P_{in\text{-}sat}$.

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

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