IEC 61290-1-1

Edition 3.0 2015-05

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

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

IEC 61290-1-1:2015-05(en-fr)

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INTERNATIONAL
ELECTROTECHNICAL
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ICS 33.180.30

ISBN 978-2-8322-3742-7

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OPTICAL AMPLIFIERS – TEST METHODS –

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FOREWORD

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

This bilingual version (2016-11) corresponds to the monolingual English version, published in 2015-05.

This third edition cancels and replaces the second edition published in 2006 and constitutes a technical revision.

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

a) updates on the characteristics of measurement apparatus;

b) revised list of addressed optical amplifier parameters.

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

FDIS	Report on voting
86C/1309/FDIS	86C/1328/RVD

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

The French version of this standard has not been voted upon.

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

This standard shall be used in conjunction with IEC 61290-1 and IEC 61291-1.

A list of all parts of the IEC 61290 series, published under the general title *Optical amplifiers – Test methods*[1] 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 website 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- withdrawn,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.

1 The first editions of some of these parts were published under the general title *Optical fibre amplifiers – Basic specification* or *Optical amplifier test methods*.

OPTICAL AMPLIFIERS – TEST METHODS –

Part 1-1: Power and gain parameters – Optical spectrum analyzer method

1 Scope

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

The object of this standard is to establish uniform requirements for accurate and reliable measurements, by means of the optical spectrum analyzer test method, of the following OA parameters, as defined in IEC 61291-1:

a) nominal output signal power;
b) gain;
c) polarization-dependent gain;
d) maximum output signal power;
e) maximum total output power.

NOTE All numerical values followed by (‡) are suggested values for which the measurement is assured.

The object of this standard is specifically directed to single-channel amplifiers. For multichannel amplifiers, one should refer to the IEC 61290-10 series [1][2].

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, *Optical amplifiers - Test methods - Part 1: Power and gain parameters*

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

3 Terms, definitions and abbreviations

3.1 Terms and definitions

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

3.2 Abbreviations

ASE amplified spontaneous emission

DBR distributed Bragg reflector (laser diode)

DFB distributed feed-back (laser diode)

2 Numbers in square brackets refer to the Bibliography

ECL	external cavity laser (diode)
LED	light emitting diode
OA	optical amplifier
OFA	optical fibre amplifier
POWA	planar optical waveguide amplifier
SOA	semiconductor optical amplifier

4 Apparatus

A diagram of the measurement set-up is given in Figure 1.

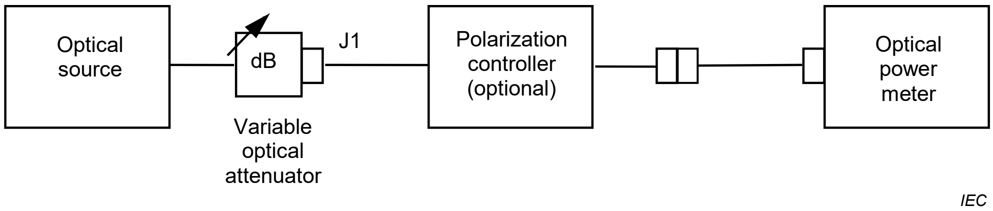

Figure 1a – Calibration

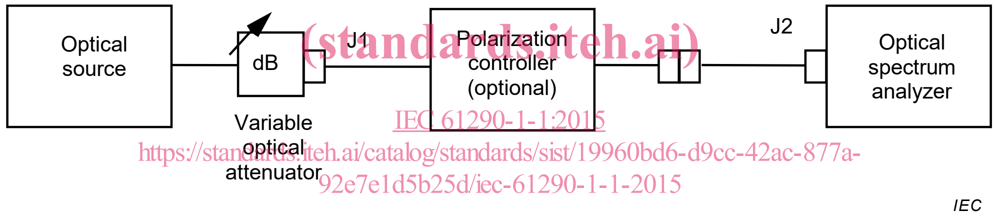

Figure 1b – Input signal power measurement

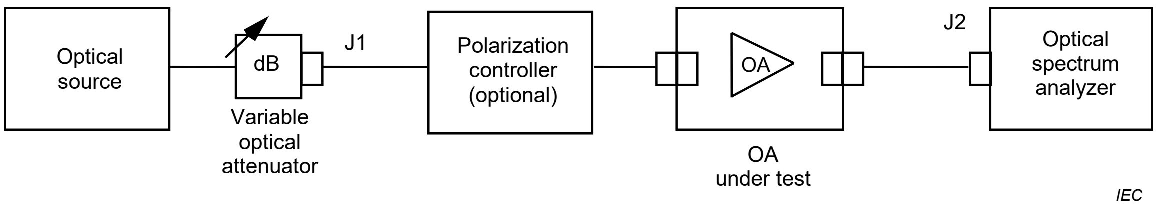

Figure 1c – Output power measurement

Figure 1 – Typical arrangement of the optical spectrum analyzer test apparatus for gain and power measurements

The test equipment listed below, with the required characteristics, is needed.

a) *optical source:*

The optical source shall be either at fixed wavelength or wavelength-tuneable.

– *fixed-wavelength optical source:* This optical source shall generate a light with a wavelength and optical power specified in the relevant detail specification. Unless otherwise specified, the optical source shall emit a continuous wave with the full width at half maximum of the spectrum narrower than 1 nm (‡). A distributed feed-back (DFB) laser, a distributed Bragg reflector (DBR) laser, an external cavity laser (ECL) diode and a light emitting diode (LED) with a narrow-band filter are applicable, for example. The suppression ratio for the side modes for the DFB laser, the DBR laser or the ECL shall be higher than 30 dB (‡). The output power fluctuation shall be less than 0,05 dB (‡), which may be better attainable with an optical isolator at the output port of the optical source. Spectral broadening at the foot of the lasing spectrum shall be minimal for laser sources and the ratio of the source power to total spontaneous emission power of the laser shall be more than 30 dB;

– *wavelength-tuneable optical source*: This optical source shall be able to generate a wavelength-tunable light within the range specified in the relevant detail specification. Its optical power shall be specified in the relevant detail specification. Unless otherwise specified, the optical source shall emit a continuous wave with the full width at half maximum of the spectrum narrower than 1 nm (‡). An ECL or an LED with a narrow bandpass optical filter is applicable, for example. The suppression ratio of side modes for the ECL shall be higher than 30 dB (‡). The output power fluctuation shall be less than 0,05 dB, which may be more easily attainable with an optical isolator at the output port of the optical source. Spectral broadening at the foot of the lasing spectrum shall be minimal for the ECL. Spectral broadening at the foot of the lasing spectrum shall be minimal for laser sources and the ratio of the source power to total spontaneous emission power of the laser shall be more than 30 dB.

The use of an LED shall be limited to small-signal gain measurements.

b) *optical power meter:*

It shall have a measurement uncertainty better than ±0,2 dB, irrespective of the state of polarization, within the operational wavelength bandwidth of the OA. A dynamic range exceeding the measured gain is required (e.g. 40 dB);

c) *optical spectrum analyzer:*

Within the operational wavelength bandwidth of the OA, the linearity of the spectral power measurement shall be better than the desired gain uncertainty and at most ±0,5 dB, and the amplitude stability of the spectral power measurement shall be better than the desired power uncertainty and at least better than ±0,2 dB over the duration of the measurement. Polarization dependence of the spectral power measurement shall be better than ±0,5 dB. The wavelength measurement uncertainty shall be better than ±0,5 nm. A dynamic range exceeding the measured gain is required (e.g. 40 dB). The spectral resolution shall be equal or better than 1 nm;

d) *optical isolator:*

Optical isolators may be used to bracket the OA. The polarization-dependent loss variation of the isolator shall be better than 0,2 dB (‡). Optical isolation shall be better than 40 dB (‡). The reflectance from this device shall be smaller than –40 dB (‡) at each port;

e) *variable optical attenuator:*

The attenuation range and stability shall be over 40 dB (‡) and better than ±0,1 dB (‡), respectively. The reflectance from this device shall be smaller than –40 dB (‡) at each port;

f) *polarization controller:*

This device shall be able to provide as input signal light all possible states of polarization (e.g. linear, elliptical and circular). For example, the polarization controller may consist of a linear polarizer followed by an all-fibre-type polarization controller, or by a linear polarizer followed by a quarter-wave plate rotatable by minimum of 90°, and a half wave plate rotatable by minimum of 180°. The loss variation of the polarization controller shall be less than 0,2 dB (‡). The reflectance from this device shall be smaller than –40 dB (‡) at each port. The use of a polarization controller is considered optional, except for the measurement of polarization dependent gain, but may also be necessary to achieve the desired uncertainty of other power and gain parameters for OA devices exhibiting significant polarization dependent gain;

g) *optical fibre jumpers:*

The mode field diameter of the optical fibre jumpers used shall be as close as possible to that of fibres used as input and output ports of the OA. The reflectance from this device shall be smaller than –40 dB (‡) at each port, and the length of the jumper shall be shorter than 2 m;

Standard optical fibres type B1 as defined in IEC 60793-2-50 [2] are recommended. However, other fibre types may be used as input/output fibre. In this case, type of fibre will be considered.

h) *optical connectors, J1 and J2:*

The connection loss repeatability shall be better than ±0,2 dB.

5 Test sample

The OA under test shall operate at nominal operating conditions. If the OA is likely to cause laser oscillations due to unwanted reflections, optical isolators shall be used to bracket the OA under test. This will minimize the signal instability and the measurement uncertainty.

For measurements of the parameters of Clause 1, care shall be taken in maintaining the state of polarization of the input light during the measurement. Changes in the polarization state of the input light may result in input optical power changes because of the slight polarization dependency expected from all the optical components used, this leading to measurement errors.

6 Procedure

The procedure is as follows:

a) *Gain and nominal output signal power:*

This method permits determination of the gain through the measurements of the OA input signal power, P_{in}, the OA output power, P_{out}, and the OA amplified spontaneous emission (ASE) power, P_{ASE} at the signal wavelength. The measurement procedures described below shall be followed:

1) set the optical source at the test wavelength specified in the relevant detail specification. Set the optical source and the variable optical attenuator in a way to provide, at the input port of the OA, the optical power P_{in} specified in the relevant detail specification;
2) measure P_{in} with the optical power meter, as shown in Figure 1a, to calibrate the optical spectrum analyzer;
3) measure P_{in} with the optical spectrum analyzer, as shown in Figure 1b;
4) measure P_{out} with the optical spectrum analyzer, as shown in Figure 1c;
5) measure P_{ASE} with the optical spectrum analyzer, as shown in Figure 1c, according to the technique specified in the relevant detail specification;

   In cases using a polarization controller, the following procedure shall be used:

6) measure P_{out} by adjusting the polarization controller until a minimum P_{out} is achieved and repeat step 5).

Various techniques for P_{ASE} measurements are applicable. One technique makes use of an interpolation procedure to evaluate the ASE level at the signal wavelength by measuring the ASE level at wavelength offset to both side of signal wavelength on the optical spectrum analyzer display. Another technique employs a polarizer, placed between the variable optical attenuator and the OA under test, to eliminate the signal component from the OA output to measure the ASE level without being affected by the amplified signal spectrum. In the latter case, the input optical signal shall be linearly polarized with an extinction ratio better than 30 dB (‡), and P_{out} shall be calculated as an averaged value overall the polarization states. If the polarizer technique cannot sufficiently eliminate the signal power, the interpolation technique can be used in addition to the polarizer technique.

Optical connectors J1 and J2 shall not be removed during the measurement to avoid measurement errors due to re-connection.

b) *Polarization-dependent gain variation:*

As in a), but use a polarization controller between the variable optical attenuator and the connector J1 (see Figure 1), repeat all procedures at different states of polarization as specified in the relevant detail specification, and replace procedure 1) with the following:

1) set the optical source to the test wavelength specified in the relevant detail specification. Set the polarization controller at a given state of polarization as specified in the relevant detail specification. Set the optical source and the variable optical attenuator in a way to provide, at the input port of the OA, the optical power P_{in} specified in the relevant detail specification.

c) *Maximum output signal power:*

As in a), but this parameter is determined by repeating all steps at different wavelengths specified in detailed specification, and replace steps 1), 4), and 6) with the following:

1) set the wavelength-tuneable optical source at the test wavelength specified in the relevant detail specification. Set the optical source and the variable optical attenuator in a way to provide, at the input port of the OA, the maximum input optical power $P_{in\ max}$ specified in the relevant detail specification;
4) activate OA and adjust the maximum pump power or maximum pump current of OA to the nominal condition as specified in the relevant detail specification. When the OA under test is integrated with control circuitry, the OA shall be tested with constant pump power mode or constant pump current mode and measure P_{out} with the optical spectrum analyzer, as shown in Figure 1c;
6) measure maximum output signal power by adjusting the polarization controller until a maximum P_{out} is achieved, and repeat 6 a), step 5).

d) *Maximum total output power:*

Same procedure as for c).

The state of polarization of the input signal shall be changed after each measurement of P_{in}, P_{out} and P_{ASE} by means of the polarization controller, so that substantially all the states of polarization, in principle, are successively launched into the input port of the OA under test.

The polarization controller shall be operated as specified in the relevant detail specifications. A possible way, when using a linear polarizer followed by a quarter-wave rotatable plate, is the following: the linear polarizer is adjusted so that the OA output power is maximized; the quarter-wave plate is then rotated by a minimum of 90° step-by-step. At each step, the half-wave plate is rotated by a minimum of 180° step-by-step. Another possible way is to select four known and specified states of polarization to allow matrix calculation of the resulting polarization dependent gain.

A short optical jumper at the OA input, kept as straight as possible, shall be used, in order to minimize the change of the state of polarization induced in it by possible stress and anisotropy.

The polarization-dependent loss variation of the optical connector shall be less than 0,2 dB (‡).

7 Calculation

The calculations shall be made as follows:

a) *Nominal output signal power:*

The nominal output signal power $P_{sig\text{-}out\text{-}nom}$ (in dBm) shall be calculated as:

$$P_{sig\text{-}out\text{-}nom} = 10 \log (P_{out} - P_{ASE}) + L_{bj} \quad \text{(dBm)}$$

where

P_{out} is the recorded absolute value of output optical signal power (in mW);

P_{ASE} is the recorded absolute value of output ASE power through the optical bandpass filter (in mW);

L_{bj} is the insertion loss of the fibre jumper placed between the OA and the optical power meter (in dB).

NOTE 1 The measurement error can be better than 1,5 dB (‡), depending on the optical spectrum analyzer uncertainty.

b) *Gain:*

The gain G at the signal wavelength shall be calculated as:

$$G = (P_{out} - P_{ASE}) / P_{in} \qquad \text{(linear units)}$$

or

$$G = 10 \log [(P_{out} - P_{ASE}) / P_{in}] \qquad \text{(dB)}$$

NOTE 2 The small-signal regime is the range of input signal power sufficiently small so that the OA under test operates in the linear regime. This regime can be established by plotting G versus P_{in}. The linear regime demands P_{in} to be in the range where the gain is quite independent from P_{in}. An input signal power ranging from –30 dBm to –40 dBm generally is well within this range.

NOTE 3 The measurement error can be better than ±1,5 dB (‡), depending on the optical spectrum analyzer uncertainty, mainly in terms of its polarization dependency. If linearly polarized light (i.e. light generated by a laser) and a polarization controller are used, the measurement error can be much reduced by adjusting the state of polarization of the input signal to the OA so that the optical spectrum analyzer always indicates the minimum (or maximum) signal power in each measurement. On the other hand, an LED and a monochromator can be used as an optical source to reduce the optical spectrum analyzer error to ±0,2 dB, since LEDs emit unpolarized light. However, it is to be noted that the optical power level obtainable from such a source is much lower than that of a laser.

c) *Polarization-dependent gain:*

Calculate the gain values at the different states of polarization, as in 7, point b) above. Identify the maximum, G_{max}, and the minimum, G_{min}, gain as the highest and the lowest of all these gain values, respectively. The polarization-dependent gain variation ΔG_p shall be calculated as follows:

$$\Delta G_p = G_{max\text{-}pol} - G_{min\text{-}pol} \qquad \text{(dB)}$$

NOTE 4 ΔG_p does not necessarily indicate the possible maximum variation of the polarization dependency. In fact, the evolution of the state of polarization inside the OA depends on temperature and other parameters, and the attenuation through the OA under test is maximum only when each input state of polarization simultaneously yields maximum attenuation for each component in the OA under test.

NOTE 5 The measurement error can be better than ±1 dB (‡), depending on the optical spectrum analyzer uncertainty, mainly in terms of its polarization dependency.

d) *Maximum output signal power:*

The maximum output signal power $P_{sig\text{-}out\text{-}max}$ (in dBm) shall be calculated as:

$$P_{sig\text{-}out\text{-}max} = P_{out\text{-}max} - P_{ASE} \qquad \text{(linear units)}$$

$$P_{sig\text{-}out\text{-}max} = 10 \log (P_{out\text{-}max} - P_{ASE}) \qquad \text{(dBm)}$$

where

$P_{out\text{-}max}$ is the recorded absolute maximum value of output optical power (in mW);

e) *Maximum total output power:*

The maximum total output power $P_{out\text{-}max}$ (in dBm) shall be calculated as:

$$P_{out\text{-}max} = 10 \log (P_{out\text{-}max}) \qquad \text{(dBm)}$$