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INTERNATIONAL STANDARD

colour inside

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

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OPTICAL AMPLIFIERS – TEST METHODS –

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

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. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

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 fourth edition cancels and replaces the third edition published in 2015 and constitutes a technical revision.

This edition includes the following significant technical change with respect to the previous edition: addition of techniques to test gain ripple of SOAs.

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

FDIS	Report on voting
86C/1673/FDIS	86C/1687/RVD

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

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

This document is to 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* 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 "http://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- withdrawn,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 1-1: 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~~ optical fibre amplifiers (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 document is to establish uniform requirements for accurate and reliable measurements, by means of the optical spectrum analyzer (OSA) test method, of the following OA parameters, as defined in IEC 61291-1:

a) nominal output signal power;

b) gain;

c) polarization-dependent gain (PDG);

d) maximum output signal power;

e) maximum total output power.

In addition, this document provides the test method of:

f) gain ripple (for SOAs).

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

The object of this document is specifically directed to single-channel amplifiers. Test methods for multichannel amplifiers~~, one should refer to the~~ are standardized in IEC 61290-10 (all parts) [1][1].

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 60793-2-50, *Optical fibres – Part 2-50: Product specifications – Sectional specification for class B single-mode fibres*

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

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

[1] Numbers in square brackets refer to the Bibliography.

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

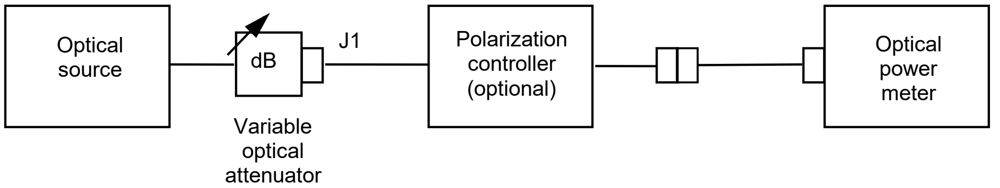
ASE amplified spontaneous emission
DBR distributed Bragg reflector (laser diode)
DFB distributed feed-back (laser diode)
ECL external cavity laser (diode)
LED light emitting diode
OA optical amplifier
OFA optical fibre amplifier
OSA optical spectrum analyzer
PDG polarization-dependent gain
POWA planar optical waveguide amplifier
SOA semiconductor optical amplifier

4 Apparatus

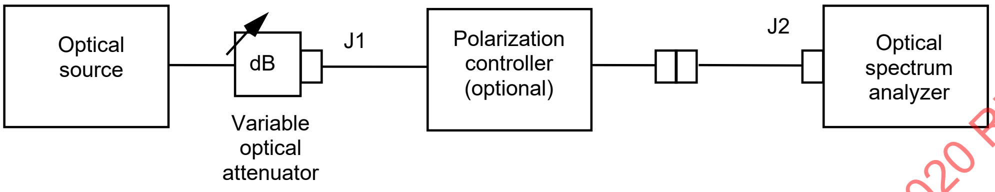
4.1 Test setup

A diagram of the ~~measurement~~ test set-up for gain and power measurements is given in Figure 1, showing the set-up for calibration in Figure 1 a), the set-up for input signal power measurement in Figure 1 b), and the set-up for output power measurement in Figure 1 c).

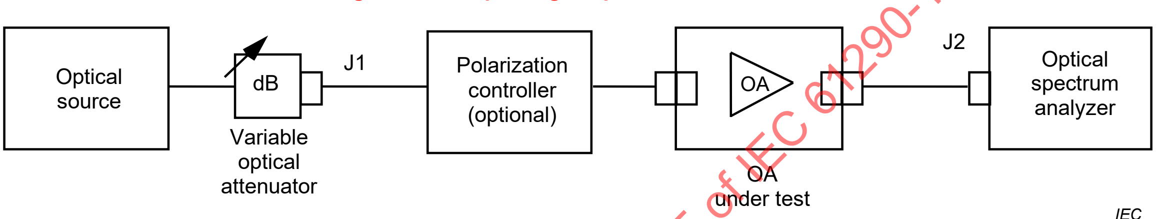
The test set-up for gain ripple measurements is displayed in Figure 2, showing the set-up for calibration in Figure 2 a), the set-up for input signal power measurement in Figure 2 b), and two different set-ups for gain ripple measurement in Figure 2 c) and Figure 2 d).



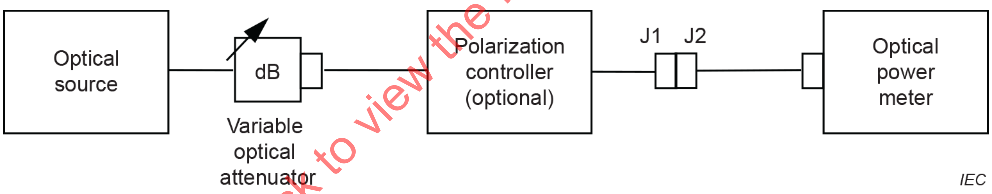
~~Figure 1a – Calibration~~



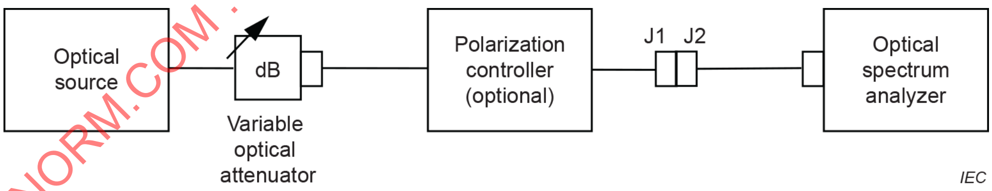
~~Figure 1b – Input signal power measurement~~



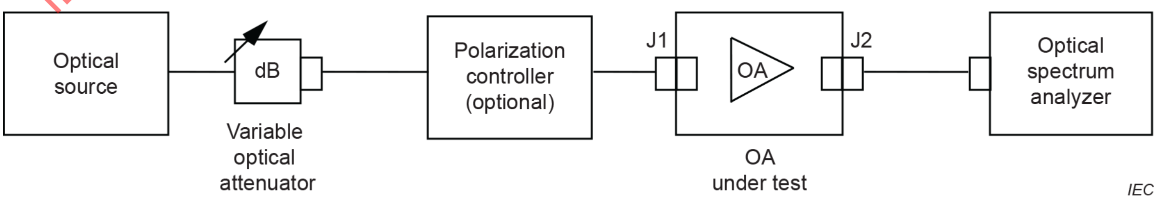
~~Figure 1c – Output power measurement~~



a) – Calibration



b) – Input signal power measurement

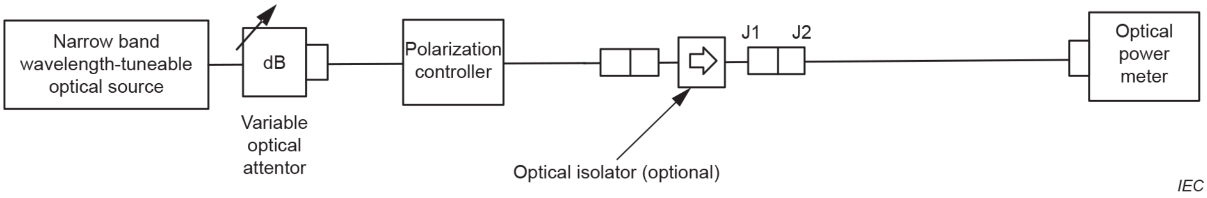


c) – Output power measurement

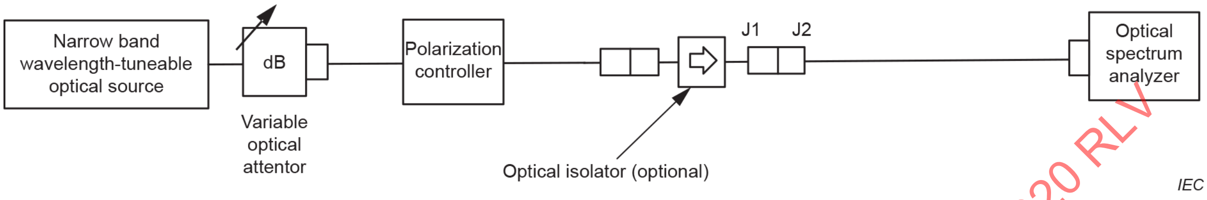
Key

J1, J2 optical connector

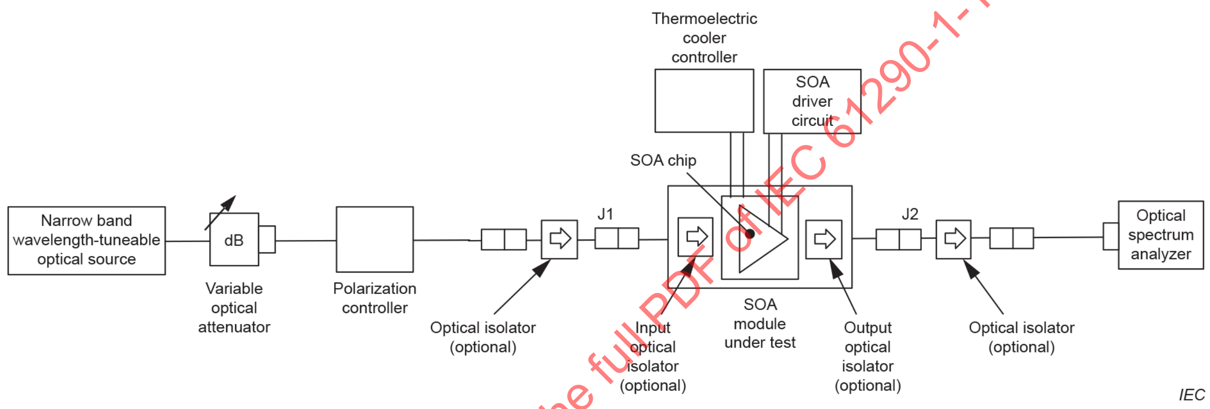
Figure 1 – Typical arrangement of optical spectrum analyzer test apparatus for gain and power measurements



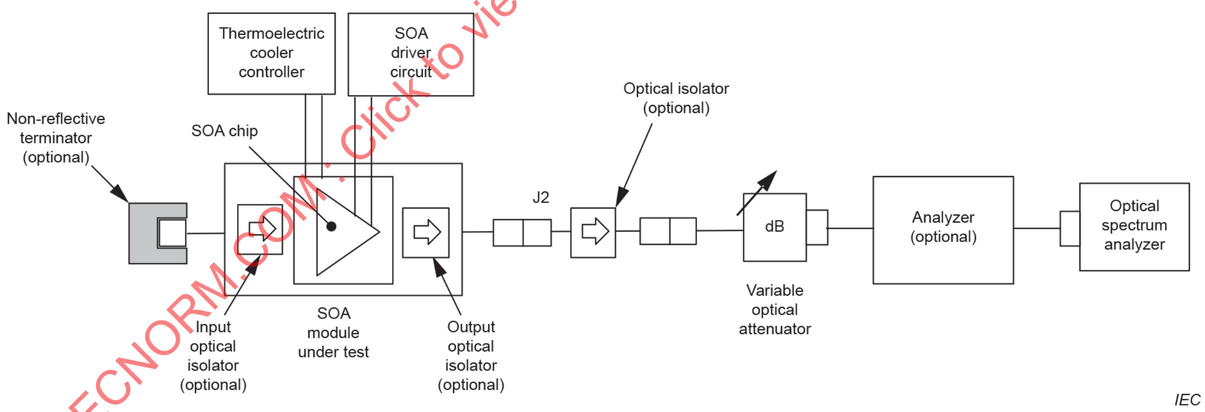
a) – Calibration



b) – Input signal power measurement



c) – Gain ripple measurement (signal gain method)



d) – Gain ripple measurement (ASE method)

Key

J1, J2 optical connector

Figure 2 – Typical arrangement of optical spectrum analyzer test apparatus for gain ripple measurements

4.2 Characteristics of test equipment

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~~ product specification or equivalent. 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-tuneable light within the range specified in the ~~relevant detail~~ product specification or equivalent. Its optical power shall be specified in the ~~relevant detail~~ product specification or equivalent. 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.

– Narrow band wavelength-tuneable optical source

This optical source shall be able to generate wavelength-tuneable light within the range specified in the product specification or equivalent. Its optical power shall be specified in the product specification or equivalent. Unless otherwise specified, the optical source shall emit a continuous wave with the full width at half maximum of the spectrum narrower (for example, one tenth) than the gain ripple period to be measured. 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~~ less than ~~±~~0,2 dB, irrespective of the state of polarization, within the operational wavelength bandwidth of the OA. A dynamic range ~~exceeding~~ 10 dB higher than the measured gain ~~is~~ shall be required (e.g. 40 dB).

c) Optical spectrum analyzer (OSA)

Within the operational wavelength bandwidth of the OA, the linearity of the spectral power measurement shall be ~~better~~ less than the desired gain uncertainty and at most ~~±~~0,5 dB, and the amplitude stability of the spectral power measurement shall be ~~better~~ less than the desired power uncertainty and at least ~~better~~ less than ~~±0,2~~ 0,4 dB over the duration of the measurement. Polarization dependence of the spectral power measurement shall be ~~better~~

less than ~~±0,5~~ 1,0 dB. The wavelength measurement uncertainty shall be ~~better~~ less than ~~±~~0,5 nm. A dynamic range ~~exceeding~~ 10 dB higher than the measured gain ~~is~~ shall be required (e.g. 40 dB). The spectral resolution shall be equal or ~~better~~ less than 1 nm.

The amplifier stability is the maximum degree of amplitude fluctuation expressed by the ratio of the maximum and minimum optical power over the duration of the measurement.

d) Optical isolator

Optical isolators may be used to bracket the OA. The polarization-dependent loss variation of the isolator shall be ~~better~~ less than 0,2 dB (‡). Small wavelength dependent loss is recommended. Optical isolation shall be ~~better~~ more 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~~ less than ~~±0,1~~ 0,2 dB (‡), respectively. The reflectance from this device shall be smaller than −40 dB (‡) at each port.

The attenuation stability is the maximum degree of attenuation fluctuation expressed by the ratio of the maximum and minimum optical attenuation over the duration of the measurement after setting a certain attenuation setpoint.

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 PDG, but may also be necessary to achieve the desired uncertainty of other power and gain parameters for OA devices exhibiting significant PDG.

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.~~

The optical fibre jumpers shall be of the same fibre category defined in IEC 60793-2-50 as the fibres used as input and output ports of the OA, so that the mode field diameters of the optical fibre jumpers closely match those of the input and output fibres 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. Polarization maintaining fibre shall be used for the input fibre jumper when testing gain ripple in an SOA, if the gain ripple of the SOA is sensitive to the state of polarization.

h) Optical connectors, J1 and J2

The connection loss repeatability shall be ~~better~~ less than ~~±0,2~~ 0,4 dB. The repeatability of the connection loss, ΔL is defined as the range of 3σ of the distribution of measured values expressed in Formula (1):

$$\Delta L = 3\,\sigma \quad \text{(dB)} \tag{1}$$

where σ is the standard deviation of the measurements calculated by Formula (2):

$$\sigma^2 = \frac{1}{m}\sum_{j=1}^{m}\left[L(j)-\bar{L}\right]^2 \quad \text{(dB)} \tag{2}$$

where

m is the number of measurements;

$L(j)$ is the measurement value of the connector loss;

$\bar{L}$ is the mean value of the measurement value of the connector loss.

A minimum of ten times (m = 10) is recommended to provide a reasonable estimate of σ.

i) Analyzer

This device shall be able to provide linear polarized light from the power emitted from the DUT and adjust to an arbitrary polarization axis. The polarization extinction ratio shall be more than 20 dB.

j) Non-reflective terminator

A non-reflective terminator shall be used for the ASE method of gain ripple measurement when the SOA module does not have an isolator at the input side. The reflectance from this device shall be smaller than −40 dB (‡) at each port.

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~~ reduce signal instability and 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.~~ Except for the SOA, standard optical fibres type B-652.B or B-652.D, as defined in IEC 60793-2-50, are recommended. However, other fibre types may be used as input/output fibre. If fibre types other than B-652.B or B-652.D are used as input/output fibre, the mode field diameter of the optical fibre jumpers shall closely match those of the input and output fibres of the OA (see 4.2 g)). For measurements of the parameters of Clause 1, care shall be taken to maintain the state of polarization of the input light during the measurement. Changes in the polarization state of the input light ~~may~~ can result in input optical power changes because of the slight polarization dependency expected from all the optical components used, ~~this~~ thus leading to increased measurement ~~errors~~ uncertainty.

6 Procedure

~~The procedure is as follows:~~

6.1 Gain and nominal output signal power

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

a) set the optical source ~~at~~ to the test wavelength specified in the ~~relevant detail~~ product specification or equivalent; set the optical source and the variable optical attenuator in such a way as to provide, at the input port of the OA, the optical power P_{in} specified in the ~~relevant detail~~ product specification or equivalent;

b) measure P_{in} with the optical power meter, as shown in Figure 1 a), to calibrate the OSA;

c) measure P_{in} with the OSA, as shown in Figure 1 b);

d) measure P_{out} with the OSA, as shown in Figure 1 c);

e) measure P_{ASE} with the OSA, as shown in Figure 1 c), according to the technique specified in the ~~relevant detail~~ product specification or equivalent.

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

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

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 the wavelength offset to both sides of the signal wavelength on the OSA 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~~ more than 30 dB (‡), and P_{out} shall be calculated as an average value over all 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~~ disconnected during the measurement ~~to avoid~~ except between measurement ~~errors~~ steps c) and d) to avail measurement uncertainty due to reconnection.

6.2 PDG variation

As in 6.1, 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~~ product specification or equivalent, and replace procedure a) with the following:

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

6.3 Maximum output signal power

As in 6.1, but this parameter is determined by repeating all steps at different wavelengths specified in detailed specification, and replace steps a), d), and f) with the following:

a) set the wavelength-tuneable optical source ~~at~~ to the test wavelength specified in the ~~relevant detail~~ product specification or equivalent; set the optical source and the variable optical attenuator in such a way as to provide, at the input port of the OA, the maximum input optical power $P_{in\ max}$ specified in the ~~relevant detail~~ product specification or equivalent;

d) activate the OA and adjust the maximum pump power or maximum pump current of the OA to the nominal condition as specified in the ~~relevant detail~~ product specification or equivalent; 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 OSA, as shown in Figure 1 c);

f) measure maximum output signal power by adjusting the polarization controller until a maximum P_{out} is achieved and repeat step e) in 6.1.

6.4 Maximum total output power

Same procedure as for 6.3.

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.

6.5 Gain ripple

6.5.1 General

This document provides two test methods for measuring the gain ripple of SOAs:

– method 1 – signal gain method;

– method 2 – ASE method.

The signal gain method is the way to measure the gain spectrum directly under the condition of an actual signal input, whereas the ASE method is the way to measure the ASE spectrum without any input signal. It should be noted that the gain ripple result in an SOA that is measured by the ASE method is theoretically equal to that which is measured by the signal gain method only in the case when the gain in the medium is considered to be uniform throughout the gain medium. High input power or high bias current could lead to inaccurate results.

To measure the gain ripple, both methods can be done under a small signal condition. In addition, the signal gain method is sensitive to a stability of wavelength and power of the input signal. On the other hand, the bias condition of SOAs should be carefully chosen in the ASE method, because high bias conditions may lead to gain non-uniformity.

6.5.2 Method 1 – Signal gain method

This method permits determination of the gain ripple 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:

a) set the optical source to the test wavelength specified in the product specification or equivalent;

b) set the variable optical attenuator in a such a way as to provide, at the input port of the OA, optical power P_{in} less than −20 dBm (‡);

c) measure P_{out} by adjusting the polarization controller until a maximum P_{out} is achieved and repeat step b).

d) measure P_{in} with the optical power meter, as shown in Figure 2 a), to calibrate the OSA;

e) measure P_{in} with the OSA, as shown in Figure 2 b);

f) measure P_{out} with the OSA, as shown in Figure 2 c);

g) measure P_{ASE} with the OSA, as shown in Figure 2 c), according to the technique specified in the product specification or equivalent.

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 wavelengths that are offset in both directions from the signal wavelength on the OSA 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 (‡). If the polarizer technique cannot sufficiently eliminate the signal power, the interpolation technique may be used in addition to the polarizer technique.

Optical connectors J1 and J2 shall not be disconnected during the measurement except between measurement steps e) and f) to avail measurement uncertainty due to reconnection.

6.5.3 Method 2 – ASE method

a) Set the operating injection current to the value specified in the product specification or equivalent.

b) Measure P_{ASE} with the OSA, as shown in Figure 2 d).

If the analyzer is used, procedures c) and d) shall be followed:

c) set the polarization controller to a given state of polarization as specified in the product specification or equivalent;

d) change the state of polarization of the input signal by means of the polarization controller and repeat procedure b).

The wavelength resolution of the OSA should be at least 1/10 of the ripple period to be measured.

6.6 Detail requirements of apparatus

The polarization controller shall be operated as specified in the ~~relevant detail specifications~~ product specification or equivalent. 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~~ continuously. 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 PDG.

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:~~

7.1 Nominal output signal power

The nominal output signal power $P_{sig\text{-}out\text{-}nom}$ (in dBm) shall be calculated as in Formula (3):

$$P_{sig\text{-}out\text{-}nom} = 10 \log_{10} (P_{out} - P_{ASE}) + L_{bj} \quad \text{(dBm)} \tag{3}$$

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 The measurement ~~error~~ uncertainty can be ~~better~~ less than 1,5 dB (‡), depending on the OSA uncertainty.

7.2 Gain

The gain G at the signal wavelength shall be calculated as in Formula (4):

~~$G = (P_{out} - P_{ASE}) / P_{in}$ (linear units)~~

~~or~~

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

$$G = 10 \log_{10} [(P_{out} - P_{ASE}) / P_{in}] \text{ (dB)} \quad (4)$$

NOTE 1 The small-signal regime is a 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 a 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 2 The measurement ~~error~~ uncertainty can be ~~better~~ less than ~~±~~1,5 dB (‡), depending on the OSA 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~~ uncertainty can be much reduced by adjusting the state of polarization of the input signal to the OA so that the OSA 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 OSA ~~error to ±~~ uncertainty 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.

7.3 Polarization-dependent gain

Calculate the gain values at the different states of polarization, as in 7.2. Identify the maximum, $G_{max\text{-}pol}$, and the minimum, $G_{min\text{-}pol}$, gain as the highest and the lowest of all these gain values, respectively. The PDG variation ΔG_p shall be calculated as in Formula (5):

$$\Delta G_p = G_{max\text{-}pol} - G_{min\text{-}pol} \text{ (dB)} \quad (5)$$

NOTE 1 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 2 The measurement ~~error~~ uncertainty can be ~~better~~ less than ~~±~~1 dB (‡), depending on the OSA uncertainty, mainly in terms of its polarization dependency.

7.4 Maximum output signal power

The maximum output signal power $P_{sig\text{-}out\text{-}max}$ (in dBm) shall be calculated as in Formula (6):

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

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

~~where~~

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

$$P_{sig\text{-}out\text{-}max} = 10 \log_{10}(P_{out\text{-}max}^{linear} - P_{ASE}) \text{ (dBm)} \quad (6)$$

where

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

7.5 Maximum total output power

The maximum total output power $P_{out\text{-}max}$ (in dBm) shall be calculated as in Formula (7):

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

~~where~~

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

$$P_{\text{out-max}} = 10\log_{10}\left(P_{\text{out-max}}^{\text{linear}}\right)\ (\text{dBm}) \quad (7)$$

where

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

7.6 Gain ripple

7.6.1 Method 1 – Signal gain test method

Calculate the gain values at the specified wavelength range, as in 7.2. The gain ripple is the maximum difference in gain between adjacent peaks and valleys in the specified wavelength range (see Figure 3).

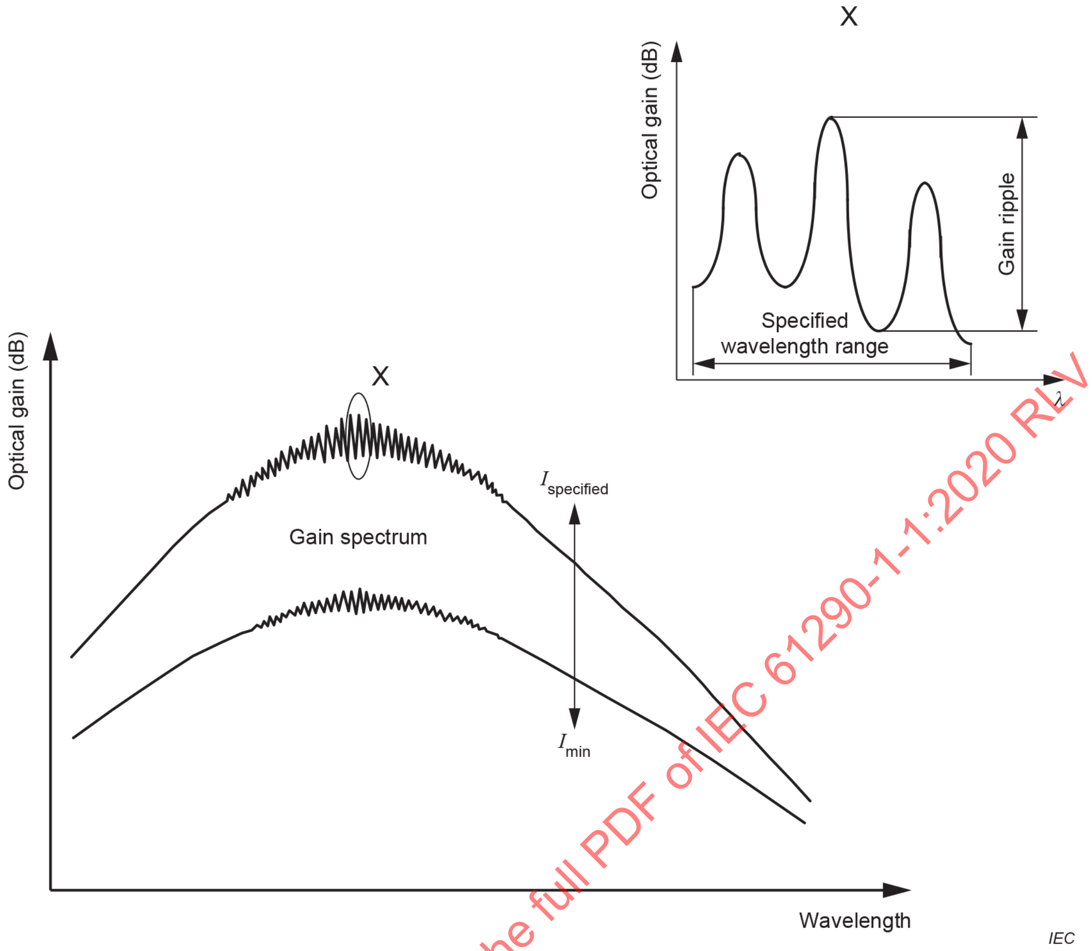


Figure 3 – Example of gain ripple spectrum with the signal gain method

Ripples in the gain spectrum (gain ripples) can be expressed as in Formula (8) (ΔG_j (λ), j-th gain peak channel, j = 1, 2, ..., n; n total number of gain peak):

$$\Delta G_j(\lambda) = G_{j\text{-peak}}(\lambda) - G_{j\text{-valley}}(\lambda) \tag{8}$$

The gain ripple $\Delta G_{\text{ripple}}(\lambda)$ is defined as in Formula (9) and is expressed in dB:

$$\Delta G_{\text{ripple}}(\lambda) = \text{MAX}_j \{\Delta G_j(\lambda)\} \tag{9}$$

7.6.2 Method 2 – ASE method

The gain ripple is the maximum difference in power between adjacent peaks and valleys in a specified wavelength range (see Figure 4).

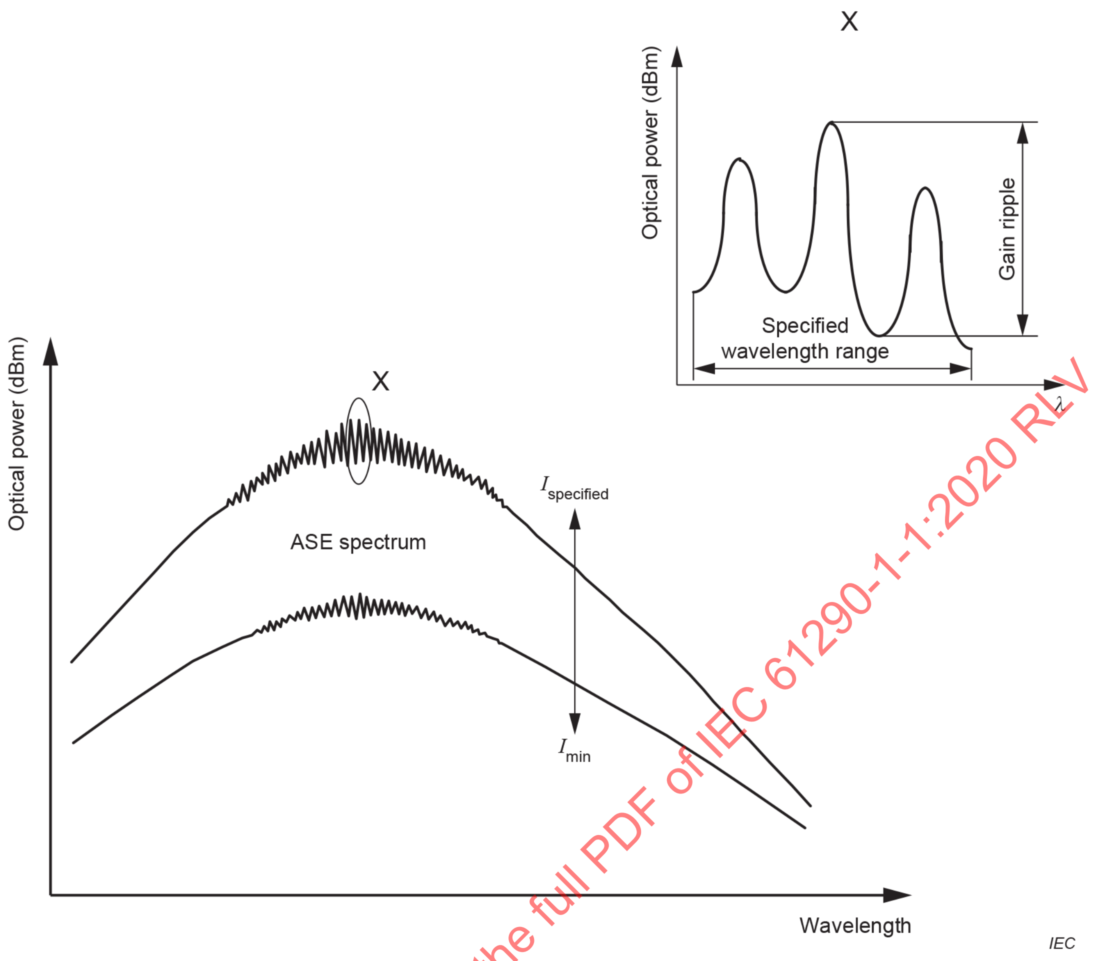


Figure 4 – Example of gain ripple spectrum with ASE method

Multiple gain ripple can be expressed as in Formula (10) (ΔP_j (λ), j-th ASE power peak channel, j = 1, 2, . . . n; n total number of gain peak):

$$\Delta P_j\ (\lambda) = P_{j\text{-peak}}(\lambda) - P_{j\text{-valley}}(\lambda) \tag{10}$$

where

$P_{j\text{-peak}}(\lambda)$ is the optical power at j-th ASE power peak channel (in dBm);

$P_{j\text{-valley}}(\lambda)$ is the optical power at adjacent valleys to j-th ASE power peak channel (in dBm).

The gain ripple ΔG_{ripple} (λ) is defined as in Formula (11) and is expressed in dB:

$$\Delta G_{\text{ripple}}\ (\lambda) = \text{MAX}_j\ \{\Delta P_j\ (\lambda)\} \tag{11}$$

NOTE Gain ripple in an SOA is uncertain in cases where the gain in the medium is non-uniform. Therefore, high input power could be a factor leading to uncertain results.

8 Test results

~~Test results are as follows:~~

The following test setting conditions shall be recorded.

a) Nominal output signal power

The following details shall be presented:

1) arrangement of the test set-up;
2) type of optical source;
3) indication of the optical pump power (if applicable);
4) ~~operating~~ ambient temperature (when required);
5) case temperature (when required);
6) input signal optical power, P_{in};
7) resolution bandwidth of the OSA;
8) wavelength of the measurement.

b) Gain

Details 1) to 8) listed for nominal output signal power shall be presented and, in addition:

1) gain.

c) Polarization-dependent gain (PDG)

Details 1) to 8) listed for nominal output signal power shall be presented and, in addition:

1) polarization dependency of ~~the optical spectrum analyzer power uncertainty~~ optical power for the OSA;
2) the maximum and minimum gain, $G_{max-pol}$ and $G_{min-pol}$;
3) PDG variation;
4) change in the state of polarization given to the input signal light.

d) Maximum output signal power

Details 1) to 8) listed for nominal output signal power shall be presented and, in addition:

1) maximum output signal power $P_{sig-out-max}$.

e) Maximum total output power:

Details 1) to 8), listed for nominal output signal power, shall be presented and, in addition:

1) maximum total output power $P_{out-max}$.

f) Gain ripple

The following details 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 SOA).

Bibliography

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

~~[2] IEC 60793-2-50, *Optical fibres – Part 2-50: Product specifications – Sectional specification for class B single-mode fibres*~~

[2] IEC TR 61292-9, *Optical amplifiers – Part 9: Semiconductor optical amplifiers (SOAs)*

IEC

IEC 61290-1-1

Edition 4.0 2020-09

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 61290-1-1:2020-09(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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OPTICAL AMPLIFIERS – TEST METHODS –

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

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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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 fourth edition cancels and replaces the third edition published in 2015 and constitutes a technical revision.

This edition includes the following significant technical change with respect to the previous edition: addition of techniques to test gain ripple of SOAs.

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

FDIS	Report on voting
86C/1673/FDIS	86C/1687/RVD

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

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

This document is to 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* 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 "http://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 1-1: 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 optical fibre amplifiers (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 document is to establish uniform requirements for accurate and reliable measurements, by means of the optical spectrum analyzer (OSA) test method, of the following OA parameters, as defined in IEC 61291-1:

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

In addition, this document provides the test method of:

f) gain ripple (for SOAs).

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

The object of this document is specifically directed to single-channel amplifiers. Test methods for multichannel amplifiers are standardized in IEC 61290-10 (all parts) [1][1].

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 60793-2-50, *Optical fibres – Part 2-50: Product specifications – Sectional specification for class B single-mode fibres*

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

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

[1] Numbers in square brackets refer to the Bibliography.

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

DBR distributed Bragg reflector (laser diode)

DFB distributed feed-back (laser diode)

ECL external cavity laser (diode)

LED light emitting diode

OA optical amplifier

OFA optical fibre amplifier

OSA optical spectrum analyzer

PDG polarization-dependent gain

POWA planar optical waveguide amplifier

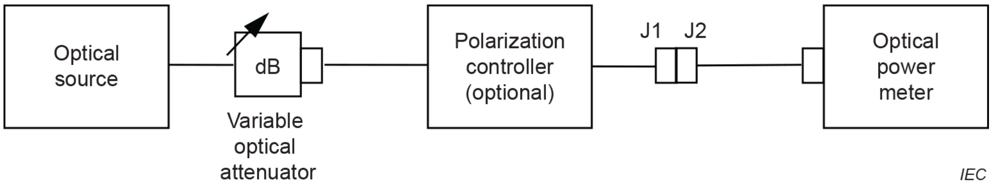
SOA semiconductor optical amplifier

4 Apparatus

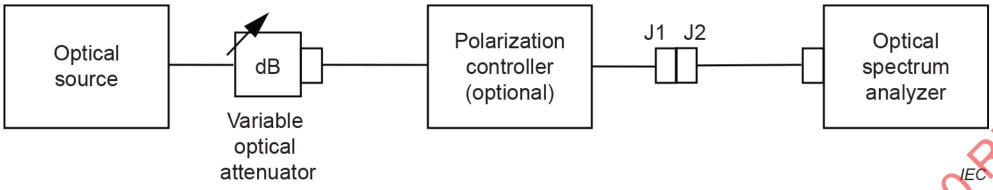
4.1 Test setup

A diagram of the test set-up for gain and power measurements is given in Figure 1, showing the set-up for calibration in Figure 1 a), the set-up for input signal power measurement in Figure 1 b), and the set-up for output power measurement in Figure 1 c).

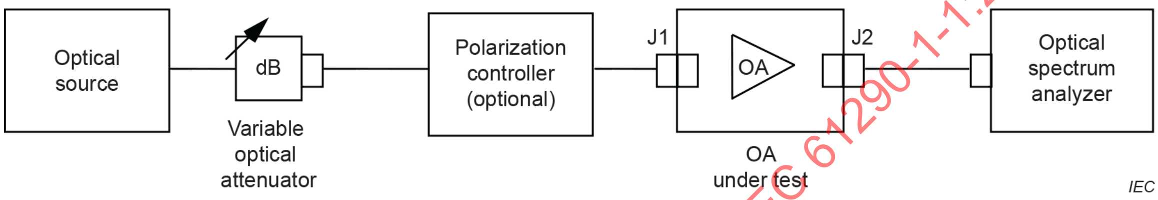
The test set-up for gain ripple measurements is displayed in Figure 2, showing the set-up for calibration in Figure 2 a), the set-up for input signal power measurement in Figure 2 b), and two different set-ups for gain ripple measurement in Figure 2 c) and Figure 2 d).



a) – Calibration



b) – Input signal power measurement

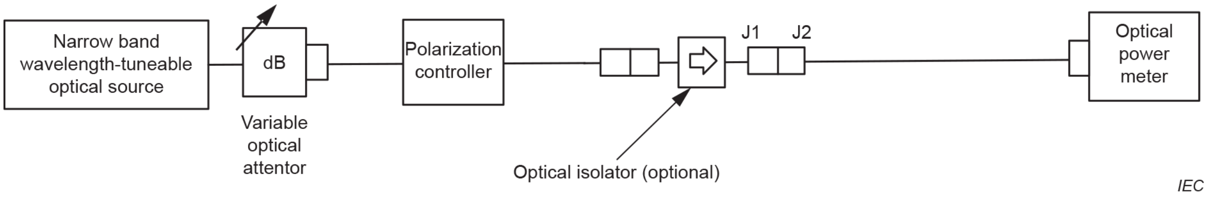


c) – Output power measurement

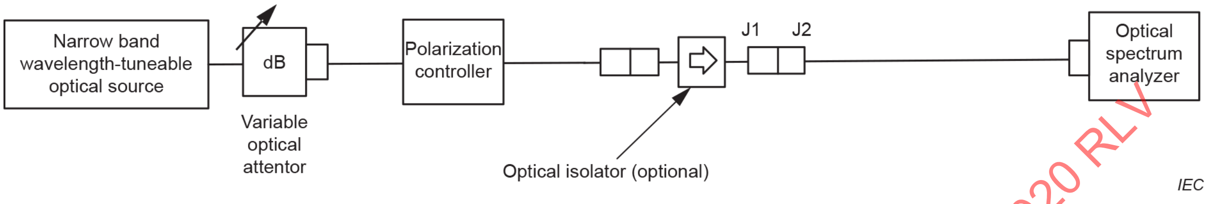
Key

J1, J2 optical connector

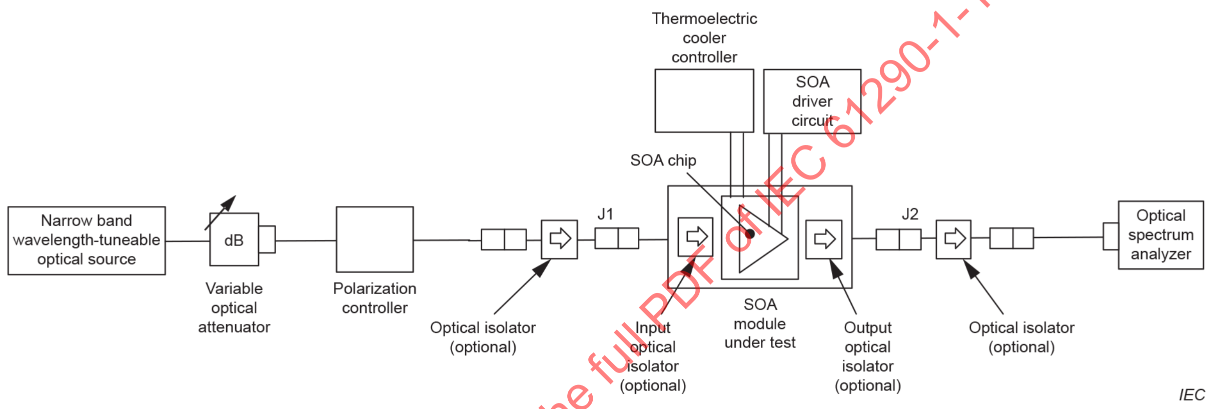
Figure 1 – Typical arrangement of optical spectrum analyzer test apparatus for gain and power measurements



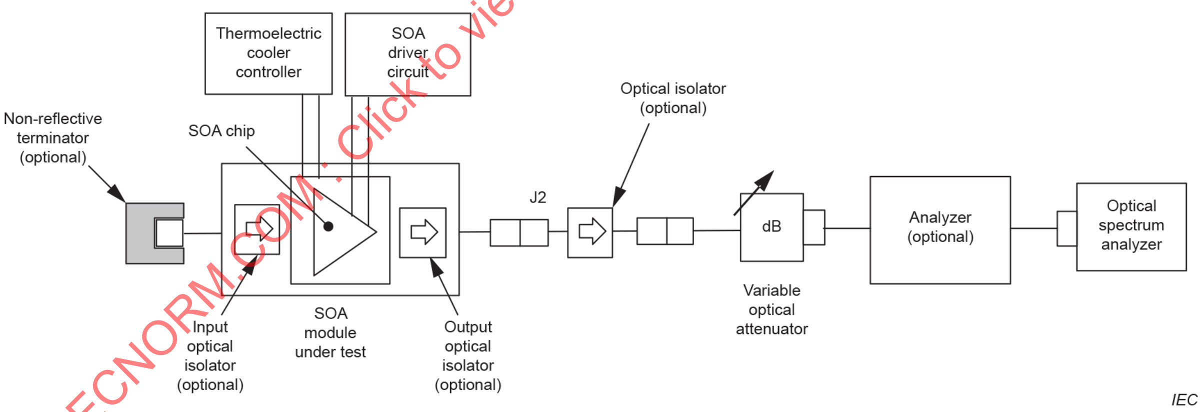
a) – Calibration



b) – Input signal power measurement



c) – Gain ripple measurement (signal gain method)



d) – Gain ripple measurement (ASE method)

Key

J1, J2 optical connector

Figure 2 – Typical arrangement of optical spectrum analyzer test apparatus for gain ripple measurements

4.2 Characteristics of test equipment

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

a) Optical source

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

– Fixed-wavelength optical source

This optical source shall generate light with a wavelength and optical power specified in the product specification or equivalent. 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 wavelength-tuneable light within the range specified in the product specification or equivalent. Its optical power shall be specified in the product specification or equivalent. 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.

– Narrow band wavelength-tuneable optical source

This optical source shall be able to generate wavelength-tuneable light within the range specified in the product specification or equivalent. Its optical power shall be specified in the product specification or equivalent. Unless otherwise specified, the optical source shall emit a continuous wave with the full width at half maximum of the spectrum narrower (for example, one tenth) than the gain ripple period to be measured. 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 less than 0,2 dB, irrespective of the state of polarization, within the operational wavelength bandwidth of the OA. A dynamic range 10 dB higher than the measured gain shall be required (e.g. 40 dB).

c) Optical spectrum analyzer (OSA)

Within the operational wavelength bandwidth of the OA, the linearity of the spectral power measurement shall be less than the desired gain uncertainty and at most 0,5 dB, and the amplitude stability of the spectral power measurement shall be less than the desired power uncertainty and at least less than 0,4 dB over the duration of the measurement. Polarization dependence of the spectral power measurement shall be less than 1,0 dB. The wavelength measurement uncertainty shall be less than 0,5 nm. A dynamic range 10 dB higher than the measured gain shall be required (e.g. 40 dB). The spectral resolution shall be equal or less than 1 nm.

The amplifier stability is the maximum degree of amplitude fluctuation expressed by the ratio of the maximum and minimum optical power over the duration of the measurement.

d) Optical isolator

Optical isolators may be used to bracket the OA. The polarization-dependent loss variation of the isolator shall be less than 0,2 dB (‡). Small wavelength dependent loss is recommended. Optical isolation shall be more 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 less than 0,2 dB (‡), respectively. The reflectance from this device shall be smaller than −40 dB (‡) at each port.

The attenuation stability is the maximum degree of attenuation fluctuation expressed by the ratio of the maximum and minimum optical attenuation over the duration of the measurement after setting a certain attenuation setpoint.

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 PDG, but may also be necessary to achieve the desired uncertainty of other power and gain parameters for OA devices exhibiting significant PDG.

g) Optical fibre jumpers

The optical fibre jumpers shall be of the same fibre category defined in IEC 60793-2-50 as the fibres used as input and output ports of the OA, so that the mode field diameters of the optical fibre jumpers closely match those of the input and output fibres 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. Polarization maintaining fibre shall be used for the input fibre jumper when testing gain ripple in an SOA, if the gain ripple of the SOA is sensitive to the state of polarization.

h) Optical connectors, J1 and J2

The connection loss repeatability shall be less than 0,4 dB. The repeatability of the connection loss, ΔL is defined as the range of 3σ of the distribution of measured values expressed in Formula (1):

$$\Delta L = 3\,\sigma \qquad \text{(dB)} \tag{1}$$

where σ is the standard deviation of the measurements calculated by Formula (2):

$$\sigma^2 = \frac{1}{m}\sum_{j=1}^{m}\left[L(j) - \bar{L}\right]^2 \qquad \text{(dB)} \tag{2}$$

where

m is the number of measurements;

$L(j)$ is the measurement value of the connector loss;

$\bar{L}$ is the mean value of the measurement value of the connector loss.

A minimum of ten times (m = 10) is recommended to provide a reasonable estimate of σ.

i) Analyzer

This device shall be able to provide linear polarized light from the power emitted from the DUT and adjust to an arbitrary polarization axis. The polarization extinction ratio shall be more than 20 dB.

j) Non-reflective terminator

A non-reflective terminator shall be used for the ASE method of gain ripple measurement when the SOA module does not have an isolator at the input side. The reflectance from this device shall be smaller than −40 dB (‡) at each port.

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 reduce signal instability and measurement uncertainty.

Except for the SOA, standard optical fibres type B-652.B or B-652.D, as defined in IEC 60793-2-50, are recommended. However, other fibre types may be used as input/output fibre. If fibre types other than B-652.B or B-652.D are used as input/output fibre, the mode field diameter of the optical fibre jumpers shall closely match those of the input and output fibres of the OA (see 4.2 g)). For measurements of the parameters of Clause 1, care shall be taken to maintain the state of polarization of the input light during the measurement. Changes in the polarization state of the input light can result in input optical power changes because of the slight polarization dependency expected from all the optical components used, thus leading to increased measurement uncertainty.

6 Procedure

6.1 Gain and nominal output signal power

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

a) set the optical source to the test wavelength specified in the product specification or equivalent; set the optical source and the variable optical attenuator in such a way as to provide, at the input port of the OA, the optical power P_{in} specified in the product specification or equivalent;

b) measure P_{in} with the optical power meter, as shown in Figure 1 a), to calibrate the OSA;

c) measure P_{in} with the OSA, as shown in Figure 1 b);

d) measure P_{out} with the OSA, as shown in Figure 1 c);

e) measure P_{ASE} with the OSA, as shown in Figure 1 c), according to the technique specified in the product specification or equivalent.

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

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

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 the wavelength offset to both sides of the signal wavelength on the OSA 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 more than 30 dB (‡), and P_{out} shall be calculated as an average value over all 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 disconnected during the measurement except between measurement steps c) and d) to avail measurement uncertainty due to reconnection.

6.2 PDG variation

As in 6.1, 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 product specification or equivalent, and replace procedure a) with the following:

a) set the optical source to the test wavelength specified in the product specification or equivalent; set the polarization controller to a given state of polarization as specified in the product specification or equivalent; set the optical source and the variable optical attenuator in such a way as to provide, at the input port of the OA, the optical power P_{in} specified in the product specification or equivalent.

6.3 Maximum output signal power

As in 6.1, but this parameter is determined by repeating all steps at different wavelengths specified in detailed specification, and replace steps a), d), and f) with the following:

a) set the wavelength-tuneable optical source to the test wavelength specified in the product specification or equivalent; set the optical source and the variable optical attenuator in such a way as to provide, at the input port of the OA, the maximum input optical power $P_{in\ max}$ specified in the product specification or equivalent;

d) activate the OA and adjust the maximum pump power or maximum pump current of the OA to the nominal condition as specified in the product specification or equivalent; 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 OSA, as shown in Figure 1 c);

f) measure maximum output signal power by adjusting the polarization controller until a maximum P_{out} is achieved and repeat step e) in 6.1.

6.4 Maximum total output power

Same procedure as for 6.3.

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.

6.5 Gain ripple

6.5.1 General

This document provides two test methods for measuring the gain ripple of SOAs:

– method 1 – signal gain method;

– method 2 – ASE method.

The signal gain method is the way to measure the gain spectrum directly under the condition of an actual signal input, whereas the ASE method is the way to measure the ASE spectrum without any input signal. It should be noted that the gain ripple result in an SOA that is measured by the ASE method is theoretically equal to that which is measured by the signal gain method only in the case when the gain in the medium is considered to be uniform throughout the gain medium. High input power or high bias current could lead to inaccurate results.

To measure the gain ripple, both methods can be done under a small signal condition. In addition, the signal gain method is sensitive to a stability of wavelength and power of the input signal. On the other hand, the bias condition of SOAs should be carefully chosen in the ASE method, because high bias conditions may lead to gain non-uniformity.

6.5.2 Method 1 – Signal gain method

This method permits determination of the gain ripple 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:

a) set the optical source to the test wavelength specified in the product specification or equivalent;

b) set the variable optical attenuator in a such a way as to provide, at the input port of the OA, optical power P_{in} less than −20 dBm (‡);

c) measure P_{out} by adjusting the polarization controller until a maximum P_{out} is achieved and repeat step b).

d) measure P_{in} with the optical power meter, as shown in Figure 2 a), to calibrate the OSA;

e) measure P_{in} with the OSA, as shown in Figure 2 b);

f) measure P_{out} with the OSA, as shown in Figure 2 c);

g) measure P_{ASE} with the OSA, as shown in Figure 2 c), according to the technique specified in the product specification or equivalent.

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 wavelengths that are offset in both directions from the signal wavelength on the OSA 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 (‡). If the polarizer technique cannot sufficiently eliminate the signal power, the interpolation technique may be used in addition to the polarizer technique.

Optical connectors J1 and J2 shall not be disconnected during the measurement except between measurement steps e) and f) to avail measurement uncertainty due to reconnection.

6.5.3 Method 2 – ASE method

a) Set the operating injection current to the value specified in the product specification or equivalent.

b) Measure P_{ASE} with the OSA, as shown in Figure 2 d).

If the analyzer is used, procedures c) and d) shall be followed:

c) set the polarization controller to a given state of polarization as specified in the product specification or equivalent;

d) change the state of polarization of the input signal by means of the polarization controller and repeat procedure b).

The wavelength resolution of the OSA should be at least 1/10 of the ripple period to be measured.

6.6 Detail requirements of apparatus

The polarization controller shall be operated as specified in the product specification or equivalent. 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° continuously. 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 PDG.

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

7.1 Nominal output signal power

The nominal output signal power $P_{\text{sig-out-nom}}$ (in dBm) shall be calculated as in Formula (3):

$$P_{\text{sig-out-nom}} = 10 \log_{10} (P_{\text{out}} - P_{\text{ASE}}) + L_{\text{bj}} \text{ (dBm)} \tag{3}$$

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 The measurement uncertainty can be less than 1,5 dB (‡), depending on the OSA uncertainty.

7.2 Gain

The gain G at the signal wavelength shall be calculated as in Formula (4):

$$G = 10 \log_{10} [(P_{\text{out}} - P_{\text{ASE}}) / P_{\text{in}}] \text{ (dB)} \tag{4}$$

NOTE 1 The small-signal regime is a 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 a 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 2 The measurement uncertainty can be less than 1,5 dB (‡), depending on the OSA 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 uncertainty can be much reduced by adjusting the state of polarization of the input signal to the OA so that the OSA 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 OSA uncertainty 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.

7.3 Polarization-dependent gain

Calculate the gain values at the different states of polarization, as in 7.2. Identify the maximum, $G_{\text{max-pol}}$, and the minimum, $G_{\text{min-pol}}$, gain as the highest and the lowest of all these gain values, respectively. The PDG variation ΔG_{p} shall be calculated as in Formula (5):

$$\Delta G_p = G_{max\text{-}pol} - G_{min\text{-}pol} \text{ (dB)} \quad (5)$$

NOTE 1 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 2 The measurement uncertainty can be less than 1 dB (‡), depending on the OSA uncertainty, mainly in terms of its polarization dependency.

7.4 Maximum output signal power

The maximum output signal power $P_{sig\text{-}out\text{-}max}$ (in dBm) shall be calculated as in Formula (6):

$$P_{sig\text{-}out\text{-}max} = 10 \log_{10}(P_{out\text{-}max}^{linear} - P_{ASE}) \text{ (dBm)} \quad (6)$$

where

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

7.5 Maximum total output power

The maximum total output power $P_{out\text{-}max}$ (in dBm) shall be calculated as in Formula (7):

$$P_{out\text{-}max} = 10 \log_{10} (P_{out\text{-}max}^{linear}) \text{ (dBm)} \quad (7)$$

where

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

7.6 Gain ripple

7.6.1 Method 1 – Signal gain test method

Calculate the gain values at the specified wavelength range, as in 7.2. The gain ripple is the maximum difference in gain between adjacent peaks and valleys in the specified wavelength range (see Figure 3).

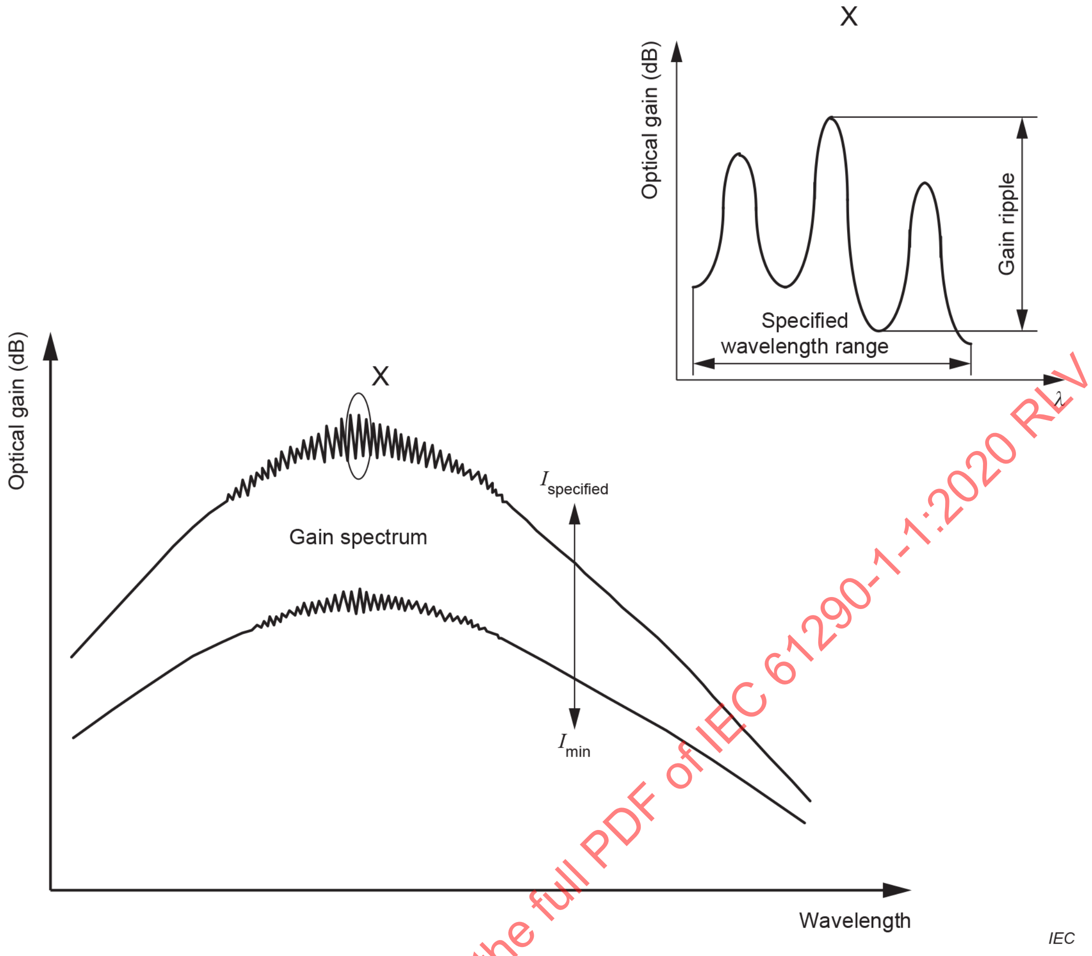


Figure 3 – Example of gain ripple spectrum with the signal gain method

Ripples in the gain spectrum (gain ripples) can be expressed as in Formula (8) (ΔG_j (λ), j-th gain peak channel, j = 1, 2, ..., n; n total number of gain peak):

$$\Delta G_j\ (\lambda) = G_{j\text{-peak}}(\lambda) - G_{j\text{-valley}}(\lambda) \tag{8}$$

The gain ripple $\Delta G_{\text{ripple}}(\lambda)$ is defined as in Formula (9) and is expressed in dB:

$$\Delta G_{\text{ripple}}(\lambda) = \text{MAX}_j\ \{\Delta G_j\ (\lambda)\} \tag{9}$$

7.6.2 Method 2 – ASE method

The gain ripple is the maximum difference in power between adjacent peaks and valleys in a specified wavelength range (see Figure 4).

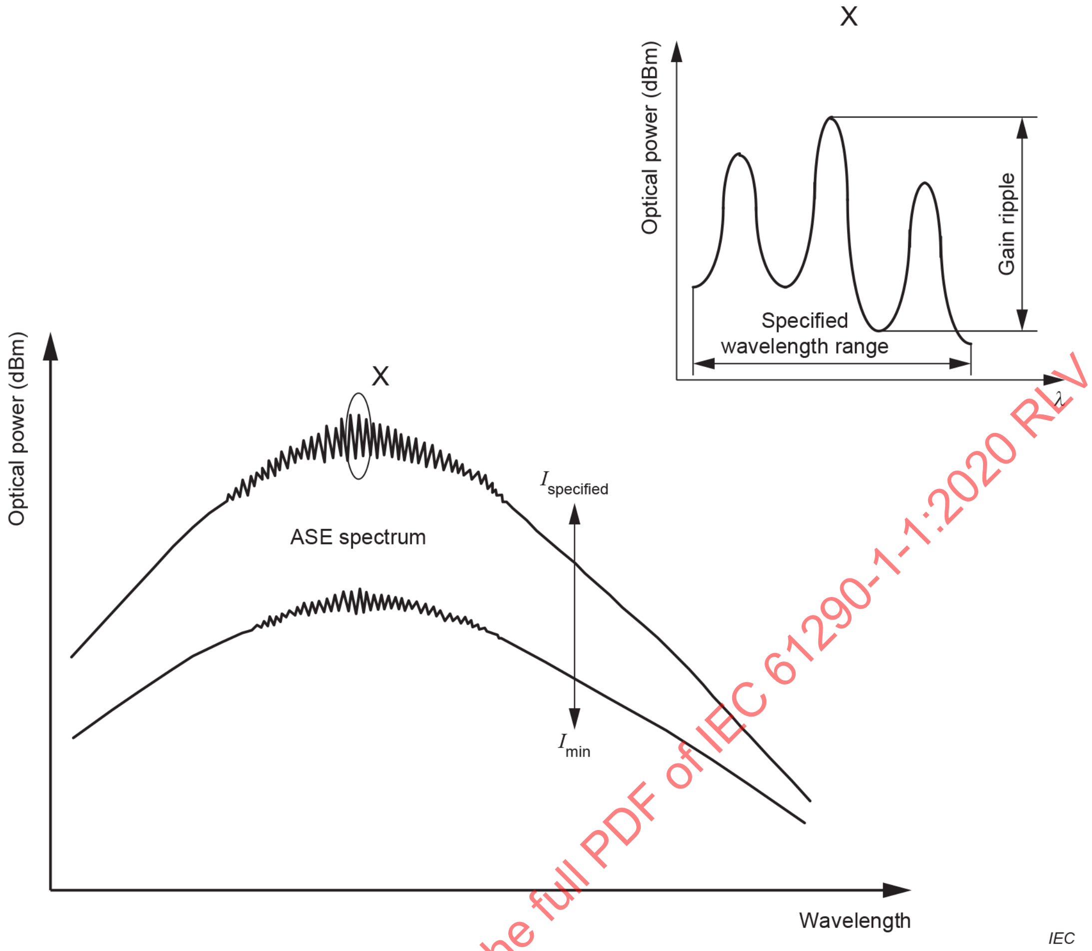


Figure 4 – Example of gain ripple spectrum with ASE method

Multiple gain ripple can be expressed as in Formula (10) ($\Delta P_j\ (\lambda)$, j-th ASE power peak channel, j = 1, 2, . . . n; n total number of gain peak):

$$\Delta P_j\ (\lambda) = P_{j\text{-peak}}(\lambda) - P_{j\text{-valley}}(\lambda) \tag{10}$$

where

$P_{j\text{-peak}}(\lambda)$ is the optical power at j-th ASE power peak channel (in dBm);

$P_{j\text{-valley}}(\lambda)$ is the optical power at adjacent valleys to j-th ASE power peak channel (in dBm).

The gain ripple $\Delta G_{\text{ripple}}\ (\lambda)$ is defined as in Formula (11) and is expressed in dB:

$$\Delta G_{\text{ripple}}\ (\lambda) = \text{MAX}_j\ \{\Delta P_j\ (\lambda)\} \tag{11}$$

NOTE Gain ripple in an SOA is uncertain in cases where the gain in the medium is non-uniform. Therefore, high input power could be a factor leading to uncertain results.

8 Test results

The following test setting conditions shall be recorded.

a) Nominal output signal power

The following details shall be presented:

1) arrangement of the test set-up;
2) type of optical source;
3) indication of the optical pump power (if applicable);
4) ambient temperature (when required);
5) case temperature (when required);
6) input signal optical power, P_{in};
7) resolution bandwidth of the OSA;
8) wavelength of the measurement.

b) Gain

Details 1) to 8) listed for nominal output signal power shall be presented and, in addition:

1) gain.

c) Polarization-dependent gain (PDG)

Details 1) to 8) listed for nominal output signal power shall be presented and, in addition:

1) polarization dependency of optical power for the OSA;
2) the maximum and minimum gain, $G_{max-pol}$ and $G_{min-pol}$;
3) PDG variation;
4) change in the state of polarization given to the input signal light.

d) Maximum output signal power

Details 1) to 8) listed for nominal output signal power shall be presented and, in addition:

1) maximum output signal power $P_{sig-out-max}$.

e) Maximum total output power:

Details 1) to 8), listed for nominal output signal power, shall be presented and, in addition:

1) maximum total output power $P_{out-max}$.

f) Gain ripple

The following details 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 SOA).

Bibliography

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

[2] IEC TR 61292-9, *Optical amplifiers – Part 9: Semiconductor optical amplifiers (SOAs)*

SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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AMPLIFICATEURS OPTIQUES – MÉTHODES D'ESSAI –

Partie 1-1: Paramètres de puissance et de gain – Méthode de l'analyseur de spectre optique

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La Norme internationale IEC 61290-1-1 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.

Cette quatrième édition annule et remplace la troisième édition parue en 2015, dont elle constitue une révision technique.

La présente édition inclut la modification technique majeure suivante par rapport à l'édition précédente: ajout de techniques pour soumettre aux essais l'ondulation du gain des amplificateurs optiques à semiconducteurs.

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

FDIS	Rapport de vote
86C/1673/FDIS	86C/1687/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette Norme internationale.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2.

Le présent document doit être utilisé conjointement avec l'IEC 61290-1 et l'IEC 61291-1.

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.

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- supprimé,
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- amendé.

AMPLIFICATEURS OPTIQUES – MÉTHODES D'ESSAI –

Partie 1-1: Paramètres de puissance et de gain – Méthode de l'analyseur de spectre optique

1 Domaine d'application

La présente partie de l'IEC 61290 s'applique à tous les amplificateurs optiques (OA: *optical amplifier*) et modules à amplification optique. Elle s'applique aux amplificateurs optiques utilisant des amplificateurs à fibres optiques (OFA: *optical fibre amplifier*) composés de fibres dopées aux terres rares ou utilisant l'effet Raman, des amplificateurs optiques à semiconducteurs (SOA: *semiconductor optical amplifier*) et des amplificateurs à guide d'onde optique plan (POWA: *planar optical waveguide amplifier*).

L'objet du présent document est d'établir des exigences uniformes pour des mesurages précis et fiables, par le biais de la méthode d'essai de l'analyseur de spectre optique (OSA: *optical spectrum analyzer*), des paramètres d'amplificateurs optiques donnés ci-dessous, tels qu'ils sont définis dans l'IEC 61291-1:

a) puissance nominale du signal de sortie;

b) gain;

c) gain dépendant de la polarisation (PDG: *polarization-dependent gain*);

d) puissance maximale du signal en sortie;

e) puissance totale de sortie maximale.

En outre, la présente norme fournit la méthode d'essai suivante:

f) essai d'ondulation du gain (pour amplificateurs optiques à semiconducteurs).

NOTE Toutes les valeurs numériques suivies de (‡) sont des valeurs suggérées pour lesquelles le mesurage est assuré.

L'objet du présent document est spécifiquement centré sur les amplificateurs à un seul canal. Les méthodes d'essai pour les amplificateurs à canaux multiples sont normalisées dans la série IEC 61290-10 (toutes les parties) [1][1].

2 Références normatives

Les documents suivants cités dans le texte 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 60793-2-50, *Fibres optiques – Partie 2-50: Spécifications de produits – Spécification intermédiaire pour les fibres unimodales de classe B*

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

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

[1] Les nombres entre crochets font référence à la Bibliographie.

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)

DBR distributed bragg reflector (réflecteur de Bragg distribué) (laser diode)

DFB distributed feed-back (rétroaction distribuée) (laser diode)

ECL external cavity laser (laser à cavité externe) (diode)

LED light emitting diode (diode électroluminescente)

OA optical amplifier (amplificateur optique)

OFA optical fibre amplifier (amplificateur à fibres optiques)

OSA optical spectrum analyser (analyseur de spectre optique)

PDG polarization-dependent gain (gain dépendant de la polarisation)

POWA planar optical waveguide amplifier (amplificateur à guide d'onde optique plan)

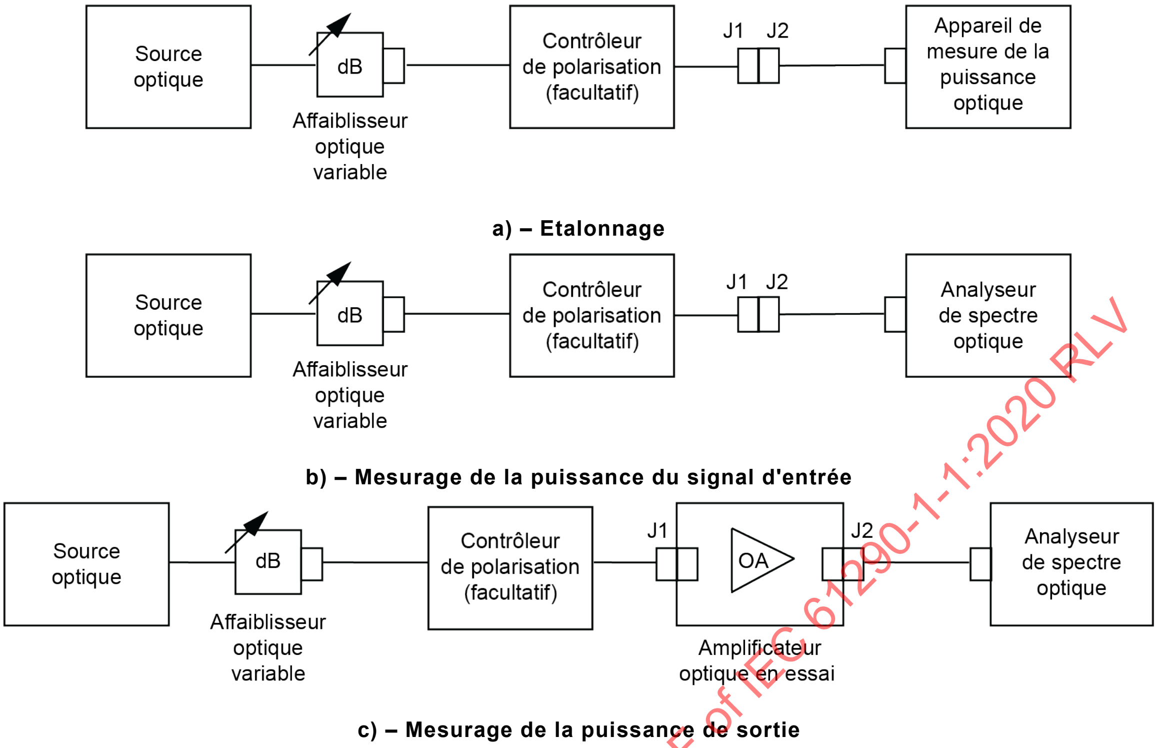
SOA semiconductor optical amplifier (amplificateur optique à semiconducteurs)

4 Appareillage

4.1 Montage d'essai

Un schéma du montage d'essai pour les mesurages du gain et de la puissance est donné à la Figure 1. La Figure 1 a) présente le montage pour effectuer l'étalonnage, la Figure 1 b) le montage pour effectuer le mesurage de la puissance du signal d'entrée et la Figure 1 c) le montage pour effectuer le mesurage de la puissance du signal de sortie.

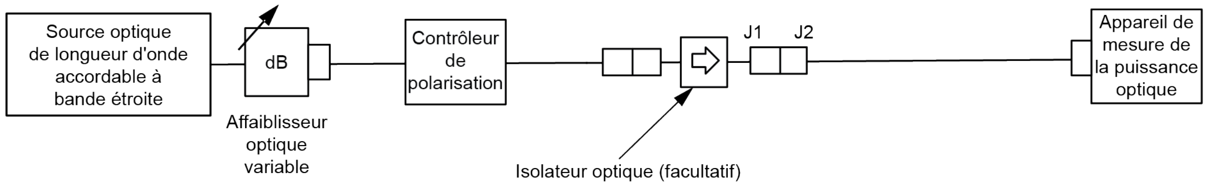
Le montage d'essai pour les mesurages de l'ondulation du gain est donné à la Figure 2. La Figure 2 a) présente le montage pour effectuer l'étalonnage, la Figure 2 b) le montage pour effectuer le mesurage de la puissance du signal d'entrée et les Figure 2 c) et Figure 2 d) deux différents montages pour effectuer le mesurage de l'ondulation du gain.



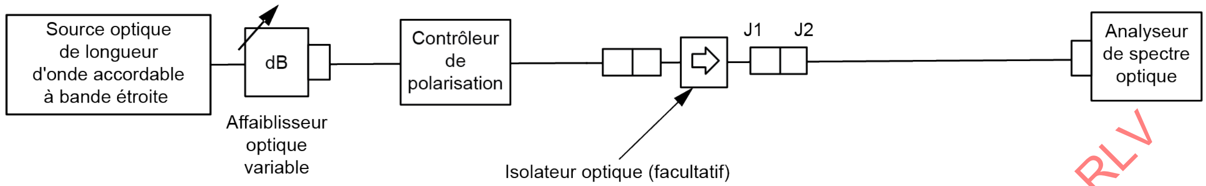
Légende

J1, J2 connecteurs optiques

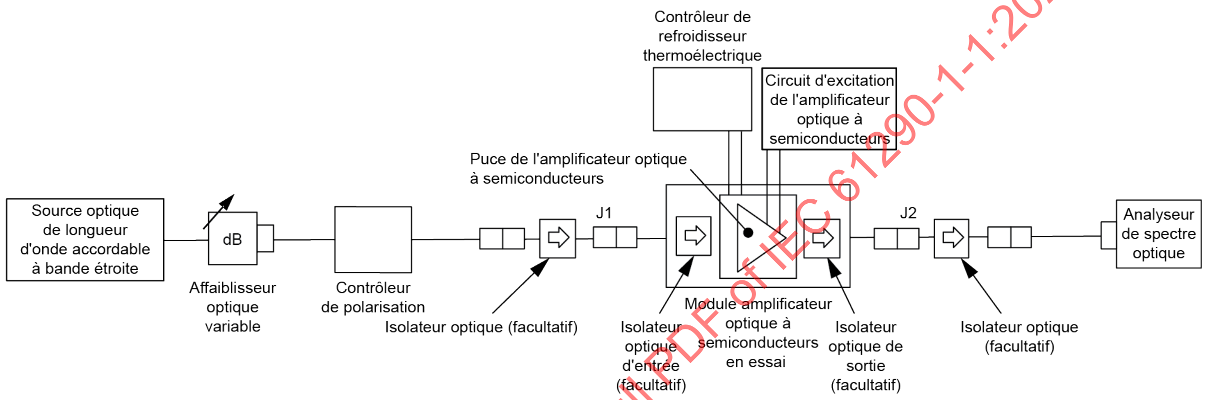
Figure 1 – Organisation typique de l'appareillage d'essai de l'analyseur de spectre optique pour les mesurages du gain et de la puissance



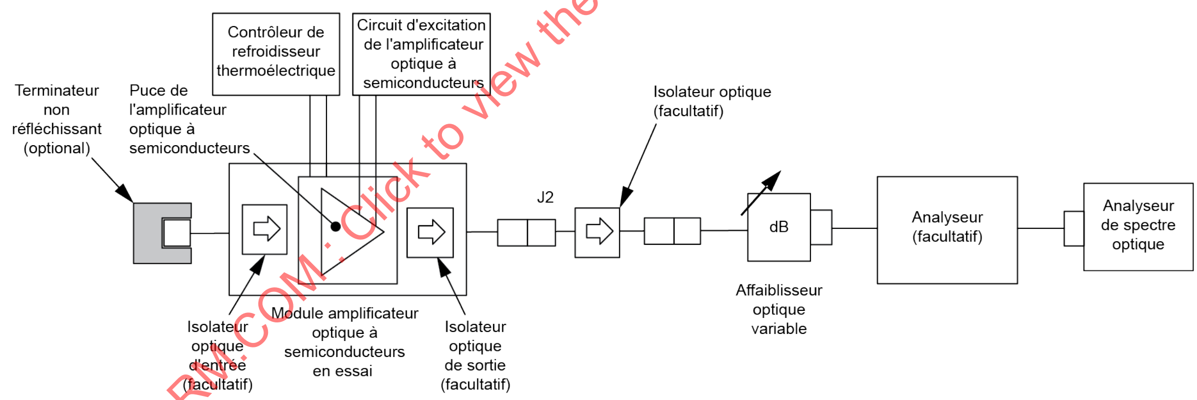
a) – Etalonnage



b) – Mesurage de la puissance du signal d'entrée



c) – Mesurage de l'ondulation du gain (méthode du gain du signal)



d) – Mesurage de l'ondulation du gain (méthode de l'émission spontanée amplifiée)

Légende

J1, J2 connecteurs optiques

Figure 2 – Organisation typique de l'appareillage d'essai de l'analyseur de spectre optique pour les mesurages de l'ondulation du gain

4.2 Caractéristiques du matériel d'essai

Le matériel d'essai énuméré ci-dessous est nécessaire avec les caractéristiques exigées.

a) Source optique

La source optique doit être soit de longueur d'onde fixe, soit de longueur d'onde accordable.

– Source optique de longueur d'onde fixe

Cette source optique doit générer un rayonnement lumineux avec une longueur d'onde et une puissance optique indiquées dans la spécification de produit ou un document équivalent. Sauf spécification contraire, la source optique doit émettre une onde continue avec une largeur spectrale à mi-hauteur inférieure à 1 nm (‡). Un laser à rétroaction distribuée (DFB), un laser à réflecteur de Bragg distribué (DBR), une diode laser à cavité externe (ECL) ou une diode électroluminescente (LED) avec un filtre à bande étroite, par exemple, sont applicables. Le taux de suppression des modes latéraux pour le laser DFB, le laser DBR ou l'ECL doit être supérieur à 30 dB (‡). La fluctuation de la puissance de sortie doit être inférieure à 0,05 dB (‡), ce qui peut être plus facilement réalisable avec un isolateur optique placé au niveau du port de sortie de la source optique. L'élargissement spectral au pied du spectre de l'émission laser doit être minimal pour les sources laser, et le rapport de la puissance de la source sur la puissance due à l'émission spontanée totale du laser doit être supérieur à 30 dB.

– Source optique de longueur d'onde accordable

Cette source optique doit pouvoir générer un rayonnement lumineux de longueur d'onde accordable dans la plage indiquée dans la spécification de produit ou un document équivalent. Sa puissance optique doit être indiquée dans la spécification de produit ou un document équivalent. Sauf spécification contraire, la source optique doit émettre une onde continue avec une largeur spectrale à mi-hauteur inférieure à 1 nm (‡). Une ECL ou une LED, par exemple, avec un filtre optique passe-bande étroit, est applicable. Le taux de suppression des modes latéraux pour l'ECL doit être supérieur à 30 dB (‡). La fluctuation de la puissance de sortie doit être inférieure à 0,05 dB, ce qui peut être plus facilement réalisable avec un isolateur optique placé au niveau du port de sortie de la source optique. L'élargissement spectral au pied du spectre de l'émission laser doit être minimal pour l'ECL. L'élargissement spectral au pied du spectre de l'émission laser doit être minimal pour les sources laser, et le rapport de la puissance de la source sur la puissance due à l'émission spontanée totale du laser doit être supérieur à 30 dB.

– Source optique de longueur d'onde accordable à bande étroite

Cette source optique doit pouvoir générer un rayonnement lumineux de longueur d'onde accordable dans la plage indiquée dans la spécification de produit ou un document équivalent. Sa puissance optique doit être indiquée dans la spécification de produit ou un document équivalent. Sauf spécification contraire, la source optique doit émettre une onde continue avec une largeur spectrale à mi-hauteur inférieure à la période d'ondulation du gain à mesurer (par exemple un dixième). Une ECL ou une LED, par exemple, avec un filtre optique passe-bande étroit, est applicable. Le taux de suppression des modes latéraux pour l'ECL doit être supérieur à 30 dB (‡). La fluctuation de la puissance de sortie doit être inférieure à 0,05 dB, ce qui peut être plus facilement réalisable avec un isolateur optique placé au niveau du port de sortie de la source optique. L'élargissement spectral au pied du spectre de l'émission laser doit être minimal pour l'ECL. L'élargissement spectral au pied du spectre de l'émission laser doit être minimal pour les sources laser, et le rapport de la puissance de la source sur la puissance due à l'émission spontanée totale du laser doit être supérieur à 30 dB.

L'utilisation d'une LED doit être limitée aux mesurages de gain en petits signaux.

b) Appareil de mesure de la puissance optique

Il doit avoir une incertitude de mesurage inférieure à 0,2 dB, sans tenir compte de l'état de polarisation, dans la largeur de bande de longueurs d'onde de fonctionnement de l'amplificateur optique. Une plage dynamique supérieure de 10 dB par rapport au gain mesuré doit être exigée (par exemple 40 dB).