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INTERNATIONAL STANDARD

colour inside

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

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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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CONTENTS

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OPTICAL AMPLIFIERS – TEST METHODS –

Part 1-3: Power and gain parameters – Optical power meter 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 IEC 61290-1-3:2015. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

IEC 61290-1-3 has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics. It is an International Standard.

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

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

a) harmonization with IEC 61290-1-1;
b) use of the term "measurement uncertainty" instead of "measurement accuracy".

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

Draft	Report on voting
86C/1671/CDV	86C/1698/RVC

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

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

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

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

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "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 1-3: Power and gain parameters – Optical power meter method

1 Scope

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

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

The object of this document is to establish uniform requirements for accurate and reliable measurements, by means of the optical power meter 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 2 All numerical values followed by (‡) are suggested values for which the measurement is assured. Other values ~~may~~ can be acceptable ~~but should be verified~~ upon verification.

This document applies to single-channel amplifiers. For multichannel amplifiers, IEC 61290-10 (all parts) applies.

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

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*

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:

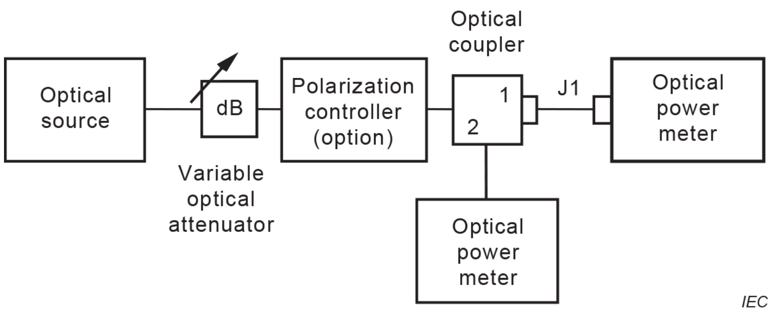
- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.2 Abbreviated terms

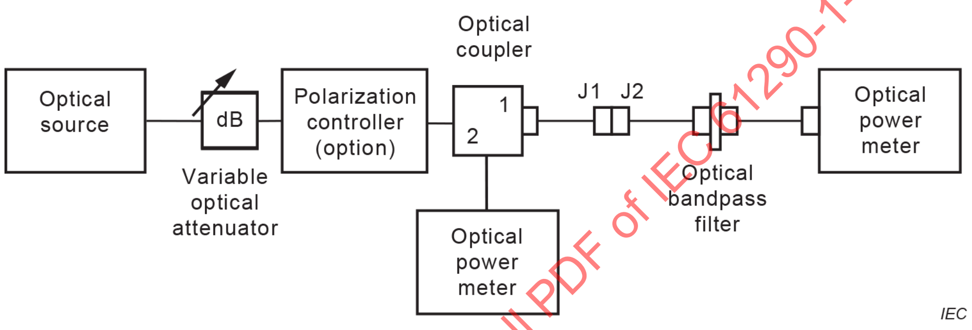
ASE amplified spontaneous emission
DBR distributed Bragg reflector (laser diode)
DFB distributed feedback (laser diode)
ECL external cavity laser (diode)
FWHM full width at half maximum
LED light emitting diode
OA optical amplifier
OFA optical fibre amplifier
OSA optical spectrum analyzer
PDL polarization dependent loss
POWA planar optical waveguide amplifier
SOA semiconductor optical amplifier

4 Apparatus

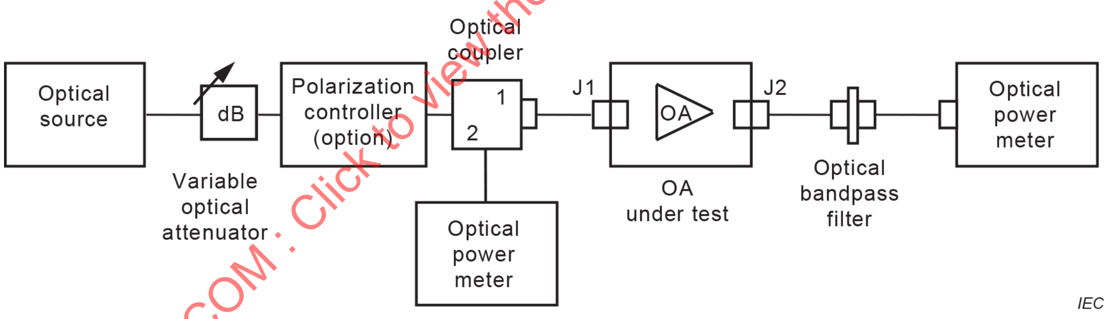
A diagram of the measurement set-up is given in Figure 1 a), Figure 1 b), Figure 1 c) and Figure 1 d).



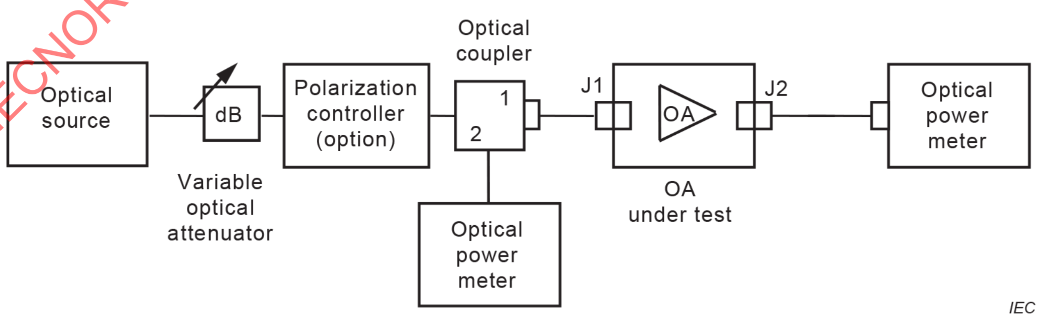
a) Measurement of input signal power



b) Measurement of optical bandpass filter loss and jumper loss



c) Measurement of output signal power and gain



d) Measurement of total output power

Key

J1, J2 optical connector

Figure 1 – Typical arrangement of optical power meter test apparatus for measurement

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. Unless otherwise specified, the optical source shall emit a continuous wave with FWHM of the spectrum narrower than 1 nm (‡). A distributed feedback (DFB) laser, a distributed Bragg reflector (DBR) laser, an external cavity laser (ECL) diode, a light emitting diode (LED) with a narrow-band filter and a single line laser 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~~ can be ~~better~~ 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 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. Its optical power shall be specified in the relevant ~~detail~~ product specification. Unless otherwise specified, the optical source shall emit a continuous wave with the full width at half maximum (FWHM) 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~~ can be ~~better~~ 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 laser sources, and the ratio of the source power to total spontaneous emission power of the laser shall be more than 30 dB.

b) Optical power meter: It shall have a measurement ~~accuracy better~~ uncertainty of less than ~~±~~0,2 dB, irrespective of the state of polarization, within the operational wavelength bandwidth of the OA. A maximum optical input power shall be large enough [e.g. +20 dBm (‡)]. Sensitivity shall be high enough [e.g. −40 dBm (‡)]. A dynamic range exceeding the measured gain is required (e.g. 40 dB).

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

d) 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.

e) 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~~ can be necessary to achieve the desired accuracy for OA devices exhibiting significant polarization dependent gain.

f) Optical fibre jumpers: ~~The mode field diameter of the optical fibre jumpers used should 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 defined in IEC 60793-2-50, B1 are recommended. However, other fiber type may be used as input/output fiber. In this case, the type of fibre will be considered.~~

The optical fibre jumpers used 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.

g) Optical connectors: The connection loss repeatability shall be ~~better~~ less than ~~±~~ 0,2 dB. The reflectance from this device shall be smaller than −40 dB (‡).

h) Optical bandpass filter: The optical bandwidth (FWHM) of this device shall be less than 3 nm (‡). It shall be either wavelength-tuneable or an appropriate set of fixed bandpass filters. During measurement, the difference between the centre wavelength of this bandwidth and the optical source centre wavelength shall be no more than 1,5 nm (‡). The PDL of the bandpass filter shall be less than 0,2 dB (‡). The reflectance from this device shall be smaller than −40 dB (‡).

NOTE 1 Optimization of optical band pass filter spectral width is discussed in Annex A.

i) Optical coupler: The polarization dependence of the branching ratio of the coupler shall be less than 0,1 dB (‡). Any unconnected port of the coupler shall be properly terminated, in such a way as to decrease the reflectance below −40 dB (‡).

NOTE 2 The change of the state of polarization of the input light is typically negligible.

j) Wavelength meter: It shall have a wavelength measurement ~~accuracy better~~ uncertainty of less than 0,1 nm (‡). If the optical source is so calibrated that the ~~accuracy~~ uncertainty of the wavelength is ~~better~~ less than 0,1 nm (‡), the wavelength meter is not necessary.

5 Test sample

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

Standard optical fibres type B-652.B or B-652.D as defined in IEC 60793-2-50 are recommended. Even if fibre type other than B-652.B or B-652.D is used as input/output fibre, the mode field diameter of the optical fibre jumpers closely matches those of the input and output fibres of the OA [see Clause 4 f)].

For all parameter measurements except polarization-dependent gain, 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, thus leading to measurement ~~errors~~ uncertainty.

6 Procedure

a) Nominal output signal power: The nominal output signal power is given by the minimum output signal optical power, for an input signal optical power specified in the relevant ~~detail~~ product specification, and under nominal operating conditions, given in the relevant ~~detail~~ product specification. To find this minimum value, input and output signal power levels shall be continuously monitored for a given duration of time and in presence of changes in the state of polarization and other instabilities, as specified in the relevant ~~detail~~ product specification. The measurement procedures described below shall be followed, with reference to Figure 1.

   In order to minimize the amplified spontaneous emission (ASE) power contribution to the signal power output from the OA, several methods may be used. The optical bandpass filter method is given below.

   1) Set the optical source at the test wavelength specified in the relevant ~~detail~~ product specification, measuring the input signal wavelength (e.g. with a wavelength meter).

2) Measure the branching ratio of the optical coupler through the signal power levels exiting the two output ports with an optical power meter.

3) Measure the loss L_{bj} of the optical bandpass filter and the optical fibre jumper between the OA and the optical power meter [see Figure 1 b)] by the insertion loss technique [see method B (insertion loss) in IEC 60793-1-40].

4) Activate the OA under test and evaluate the ASE power level passed through the optical filter, P_{ASE}, by measuring the optical output power from the OA, as shown in Figure 1 c), without input signal.

NOTE 1 ~~In large-signal conditions, the measurement of the ASE power is sometimes omitted.~~

The small-signal regime is when the OA under test operates in the linear regime, whereas the large-signal regime is when it operates in the saturated regime. The distinction between small-signal and large-signal regimes can be made by plotting G versus the input signal power with a constant pump drive. The linear regime requires the time-averaged input signal power to be in the range in which the gain is quite independent of the input signal power (see IEC 61290-1). An input signal power ranging from −30 dBm to −40 dBm is generally well within this range. In the saturated regime, the signal power is large enough to well suppress the ASE, so that the measurement of the ASE power is sometimes omitted.

NOTE 2 For consideration of measurement uncertainty, refer to the last paragraph of Annex A, which concerns the optimization of the optical band pass filter spectral width.

5) Set the optical source and the variable optical attenuator in such a way as to provide, at the input port of the OA, the input optical signal power (P_{in}) specified in the relevant ~~detail~~ product specification. Record the optical power (P_o) measured with an optical power meter at the other (second) output port of the optical coupler, as shown in Figure 1 a).

~~Instantly applying signal light into the active OA can cause the generation of an optical surge which may damage the optical components.~~ Applying signal light with short rise time into the OA operating without signal light can cause the generation of an optical surge which can damage the optical components. The input signal shall have sufficiently small power to prevent the optical surge, when it is launched to the OA initially. The input power shall be gradually increased to the specified level.

6) Keep the optical signal power at the OA input constant (P_{in}) during the following measurements, by monitoring the second output port of the coupler and, if necessary, setting the variable optical attenuator in such a way that the optical power (P_o) exiting the second output port of the optical coupler remains constant.

7) Connect the fibre jumpers to the input and output port of the OA under test, as shown in Figure 1 c) and evaluate the optical output power (P_{out}) with input signal.

If the polarization controller is used, the following procedure shall be adapted.

8) Set the polarization controller at a given state of polarization as specified in the relevant ~~detail~~ product specification; activate the OA, and monitor, by means of the optical power meter, the optical signal power at the output of the OA, for the specified period of time, recording the minimum value.

9) Change the state of polarization of the input signal by means of the polarization controller, trying to measure maximum and minimum output optical signal powers with the optical power meter, and repeat procedure 8).

10) Repeat procedure step 9) for the different states of polarization indicated in the relevant ~~detail~~ product specification and, finally, take the absolute minimum and maximum output optical signal powers recorded in the various conditions: $P_{out\text{-}min}$ and $P_{out\text{-}max}$.

Optical connectors J1 and J2 shall not be removed during the measurement to avoid measurement ~~errors~~ uncertainty due to reconnection.

The measurement ~~error~~ uncertainty shall be reduced by eliminating the effect of the ASE simultaneously detected with the signal. This is better attainable by placing an optical bandpass filter having the narrower passband at the output of the OA under test, as it has been discussed in ~~the main text~~ Clause 6 a). For large optical signal power levels, the optical bandpass filter ~~may not be~~ is often not necessary to achieve an accurate measurement. The use of the optical bandpass filter is ~~important,~~ especially important when the input signal to the OA is small. This is because the ASE power increases as the input signal decreases. However, if this kind of optical filter is already built in the OA, the external optical filter is not needed. The effectiveness of the optical band pass filter is further discussed in Annex A.

b) Gain ~~and polarization dependent gain~~:

1) to 7) As in procedures 1) to 7) in a), but this method permits determination of the gain through the measurements of the OA input signal power P_{in} and the OA output power P_{out}, taking into account the OA amplified spontaneous emission (ASE) power P_{ASE} at the signal wavelength.

~~11~~ 8) Repeat procedures 5) to 7) in a), with increasing input signal power gradually to the maximum input signal power given in the relevant ~~detail~~ product specification. Maintain the pump power or pump current with the firstly set point.

c) Polarization-dependent gain: as in a), but this parameter is determined through the measurements of the OA input signal power, Pin, the OA output power, Pout-min and Pout-max, taking into account the OA amplified spontaneous emission (ASE) power, PASE at the signal wavelength, by repeating all procedures at different states of polarization as specified in the relevant ~~detail~~ product specification.

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~~ product specification. 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~~ continuously.

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 PDL of the optical connector shall be less than 0,2 dB (‡).

c) Maximum output signal power: As in a), but this parameter is determined by repeating all procedures at different wavelengths specified in the detailed specification, and replace procedures 1), 4), 5) with the following.

1) Set the wavelength-tuneable optical source at a test wavelength within the specified wavelength range, measuring the input signal wavelength (e.g. with a wavelength meter).

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~~ product 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.

5) 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 signal power $P_{in\text{-}max}$ specified in the relevant ~~detail~~ product specification. Record the optical power P_o measured with an optical power meter at the other (second) output port of the optical coupler, as shown in Figure 1 a).

Instantly applying signal light into the active OA can cause the generation of an optical surge which ~~may~~ can damage the optical components. The input signal shall have sufficiently small power to prevent the optical surge, when it is launched into the OA initially. The input power shall be gradually increased to the specified level.

d) Maximum total output power: The maximum total output power is given by the highest optical power level at the output port of the OA operating within the absolute maximum ratings. To find this maximum value, input and output ~~signal~~ power levels shall be continuously monitored for a given duration of time and in presence of changes in the state of polarization and other instabilities, as specified in the relevant ~~detail~~ product specification. The measurement procedures described below shall be followed, with reference to Figure 1.

~~12~~ 1) Measure the branching ratio of the optical coupler through the signal power levels exiting the two output ports with an optical power meter.

~~13~~ 2) 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 signal power $P_{\text{in-max}}$ specified in the relevant ~~detail~~ product specification. Record the optical power P_{o} measured with an optical power meter at the other (second) output port of the optical coupler, as shown in Figure 1 a).

Putting signal light into the active OA can cause the generation of optical surge which ~~may~~ can damage the optical components. Input signal shall have sufficiently small power to prevent the optical surge, when it is launched to the OA in the beginning. And the input power shall be gradually increased to a certain level.

~~14~~ 3) Keep the optical signal power at the OA input constant ($P_{\text{in-max}}$) during the following measurements by monitoring the second output port of the coupler and, if necessary, setting the variable optical attenuator in such a way that the optical power (P_{o}) exiting the second output port of the optical coupler remains constant.

~~15~~ 4) Connect the fibre jumpers to the input and output port of the OA under test, as shown in Figure 1 d) and activate OA and adjust the maximum pump power or maximum pump current of OA to the absolute maximum ratings, given in the relevant ~~detail~~ product 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 evaluate the optical output power ($P_{\text{total-out}}$) with input signal.

If the polarization controller is used, procedures 5), 6), 7) shall be followed.

~~16~~ 5) Set the polarization controller at a given state of polarization as specified in the relevant ~~detail~~ product specification; activate the OA, and monitor, by means of the optical power meter, the optical ~~signal~~ power at the output of the OA, for the specified period of time, recording the ~~minimum~~ maximum value.

~~17~~ 6) Change the state of polarization of the input signal by means of the polarization controller, trying to measure maximum and minimum output optical powers with the optical power meter, and repeat procedure 5).

~~18~~ 7) Repeat procedure 5) and 6) for the different states of polarization indicated in the relevant ~~detail~~ product specification, and finally take the absolute minimum and maximum output optical powers recorded in the various conditions: $P_{\text{total-out-min}}$ and $P_{\text{total-out-max}}$.

Optical connectors J1 and J2 shall not be removed during the measurement to avoid measurement ~~errors~~ uncertainty due to reconnection.

~~The measurement error shall be reduced by eliminating the effect of the ASE simultaneously detected with the signal. This is better attainable by placing an optical bandpass filter having the narrower passband at the output of the OA under test, as it has been discussed in the main text. For large optical signal power levels, the optical bandpass filter may not be necessary to achieve an accurate measurement. The use of the optical bandpass filter is important, especially when the input signal to the OA is small. This is because the ASE power increases as the input signal decreases. However, if this kind of optical filter is already built in the OA, the external optical filter is not needed. The effectiveness of the optical band pass filter is further discussed in Annex A.~~

7 Calculation

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

$$P_{\text{sig-out-nom}} = 10 \log_{10} (P_{\text{out}} - P_{\text{ASE}}) + L_{\text{bj}} \quad \text{(dBm)} \tag{1}$$

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 optical bandpass filter and fibre jumper placed between the OA and the optical power meter (in dB).

NOTE 1 If optical bandpass filter is already built in the OA, the external optical filter is not needed. In this case, the insertion loss L_{bj} is equal to that of the fibre jumper.

NOTE 2 A comparison of the measured values obtained with OSA, with the calculated values with optical power meter using various band pass filters, is referred to in Annex A.

b) Gain: the gain G at the signal wavelength shall be calculated as

~~$G = (P_{out} - P_{ASE})/P_{in}$ (linear units) (2)~~

~~or as~~

~~$G = 10 \log_{10} [(P_{out} - P_{ASE})/P_{in}]$ (dB) (3)~~

$$G = 10 \log_{10} [(P_{out} - P_{ASE})/P_{in}] \text{ (dB)} \quad (2)$$

If the FWHM of the filter is very narrow so that the detected P_{ASE} is sufficiently small, P_{ASE} could be omitted in the above calculation. In large-signal regime, if P_{out} is sufficiently larger than P_{ASE}, P_{ASE} could be negligible with respect to P_{out}. A comparison of the measured values obtained with OSA, with the calculated values with optical power meter using various band pass filters, is referred to in Annex A.

~~NOTE 3 The small-signal regime is when the OA under test operates in the linear regime, while the large-signal regime is in the saturated regime. The distinction between small-signal and large-signal regimes can be confirmed by plotting G versus the input signal power. The linear regime demands the time-averaged input signal power to be in the range in which the gain is quite independent from it (see IEC 61290-1). An input signal power ranging from –30 dBm to –40 dBm is generally well within this range. In the saturated regime, the signal power is large enough to well suppress the ASE.~~

NOTE ~~4~~3 The measurement ~~error can be better than ±~~ uncertainly can be less than 0,2 dB (‡), depending mainly on the uncertainty of the optical power meter.

c) Polarization-dependent gain: Calculate the gain values at the different states of polarization as described in b). Calculations are processed using the following procedure.

1) Calculate the gain values at the different states of polarization, as in b).

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.

3) The polarization-dependent gain ΔG_{pol} shall be calculated as follows

$$\Delta G_{pol} = G_{max\text{-}pol} - G_{min\text{-}pol} \text{ (dB)} \quad (~~4~~3)$$

NOTE ~~5~~4 $G_{min\text{-}pol}$ is defined as the same as G in b). $G_{max\text{-}pol}$ is defined as G in which $P_{out\text{-}min}$ is replaced by $P_{out\text{-}max}$.

NOTE ~~6~~5 ΔG_{pol} does not necessarily indicate the possible maximum variation of the polarization dependency. This is because 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 76 The measurement error can be better than ± uncertainly can be less than 0,5 dB (‡), depending mainly on the optical power meter polarization dependency.

The input signal power at which the parameter is specified and measured should be stated. Larger input power is recommended considering the ASE factor contained in the output power.

d) Maximum output signal power: Calculate the maximum output signal power $P_{sig\text{-}out\text{-}max}$ (in dBm) as in a).

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

$$P_{out\text{-}max} = 10 \log_{10} (P_{out\text{-}max}) \quad \text{(dBm)} \tag{5}$$

where

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

$$P_{out\text{-}max} = 10 \log_{10} P_{out\text{-}max}^{linear} \quad \text{(dBm)} \tag{4}$$

where

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

8 Test results

The following parameters shall be recorded in the test reports unless otherwise stated in the relevant product specification.

a) Nominal optical signal power

The following details shall be presented:

1) arrangement of the test set-up;
2) spectral linewidth (FWHM) of the optical source;
3) indication of the optical pump power and possibly driving current of pump lasers for OFAs, and injection current for SOAs (if applicable);
4) operating temperature (if required);
5) input signal optical power P_{in};
6) FWHM of the optical bandpass filter;
7) central wavelength of the optical bandpass filter;
8) wavelength of the measurement;
9) nominal optical signal power levels $P_{sig\text{-}out\text{-}nom}$;
10) change in the state of polarization given to the input signal light.

b) Gain: The details 1) to 8) previously listed for the nominal optical signal power levels shall be presented and, in addition:

11 9) gain:

Parameters 5) and 9) may be replaced with the gain versus input optical signal power curve.

Parameters 8) and 10 9) may be replaced with the gain versus input signal wavelength curve.

c) Polarization-dependent gain: The details 1) to 8) previously listed for the gain shall be presented and, in addition:

~~12~~ 9) polarization dependency of the optical power meter uncertainty;

~~13~~ 10) the maximum and minimum gain, $G_{\text{max-pol}}$ and $G_{\text{min-pol}}$;

~~14~~ 11) polarization-dependent gain;

~~15~~ 12) change in the state of polarization given to the input signal light.

d) Maximum output signal power: The details 1) to 8) previously listed for the gain shall be presented and, in addition:

~~16~~ 9) maximum output signal power $P_{\text{sig-out-max}}$.

e) Maximum total output power: The details 1) to 8) previously listed for the gain shall be presented and, in addition:

~~17~~ 9) maximum total output power $P_{\text{out-max}}$.

Annex A
(informative)

Optimization of optical bandpass filter spectral width

The measurement uncertainty of this method depends on the choice of the band pass filter, ~~e.g.~~ in terms of ~~the~~ its spectral width (FWHM). ~~In fact, as mentioned,~~ The purpose of this filter is to ~~cancel~~ remove the ASE contribution from the measurement. As such, it is intuitive that the smaller the filter FWHM is chosen, the greater is the ASE cancellation and, hence, the smaller is the measurement uncertainty. However, if the filter spectral width is excessively narrow, problems of alignment between the filter central frequency and the signal frequency can arise, leading to stability problems which can be detrimental to measurement uncertainty. These considerations indicate that an optimal spectral width of the filter should be chosen to minimize the measurement uncertainty.

A possible procedure to determine such an optimal filter is to calibrate this optical power meter ~~(OPM)~~ method with the OSA technique (see IEC 61290-1-1), which is intrinsically more accurate. For a given OA typology, ~~OPM~~ optical power meter measurements using successively different filters (with FWHM e.g. from 1 nm to 5 nm) can be compared with an OSA measurement. The optimal band pass filter ~~to be chosen will be~~ is the one which minimizes the difference between the results from the two measurement methods.

For example, applying this calibration procedure in a numerically simulated case, the use of a band pass filter of Lorentzian type with FWHM of 2 nm demonstrated to sufficiently cancel the effect of ASE and achieve a difference with respect to OSA measurements result less than only 0,05 dB. This difference increased to approximately 0,15 dB for a filter with FWHM of 5 nm. It should be noted that, while the effect of ASE can be accurately evaluated in small-signal regime, even in large-signal regime, notwithstanding less accurate evaluation of ASE power, the portion of ASE power becomes less significant with respect to the signal power. As a result, an accurate ~~OPM~~ optical power meter measurement can be maintained over entire input signal levels by choosing an optimally narrow FWHM of band pass filter.

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

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

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

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

IEC TR 61931, *Fibre optic – Terminology*

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INTERNATIONAL STANDARD

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

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

IEC 61290-1-3:2021-03(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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OPTICAL AMPLIFIERS – TEST METHODS –

Part 1-3: Power and gain parameters – Optical power meter 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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IEC 61290-1-3 has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics. It is an International Standard.

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

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

a) harmonization with IEC 61290-1-1;
b) use of the term "measurement uncertainty" instead of "measurement accuracy".

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

Draft	Report on voting
86C/1671/CDV	86C/1698/RVC

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

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

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

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

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "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 1-3: Power and gain parameters – Optical power meter method

1 Scope

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

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

The object of this document is to establish uniform requirements for accurate and reliable measurements, by means of the optical power meter 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 2 All numerical values followed by (‡) are suggested values for which the measurement is assured. Other values can be acceptable upon verification.

This document applies to single-channel amplifiers. For multichannel amplifiers, IEC 61290-10 (all parts) applies.

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

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

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

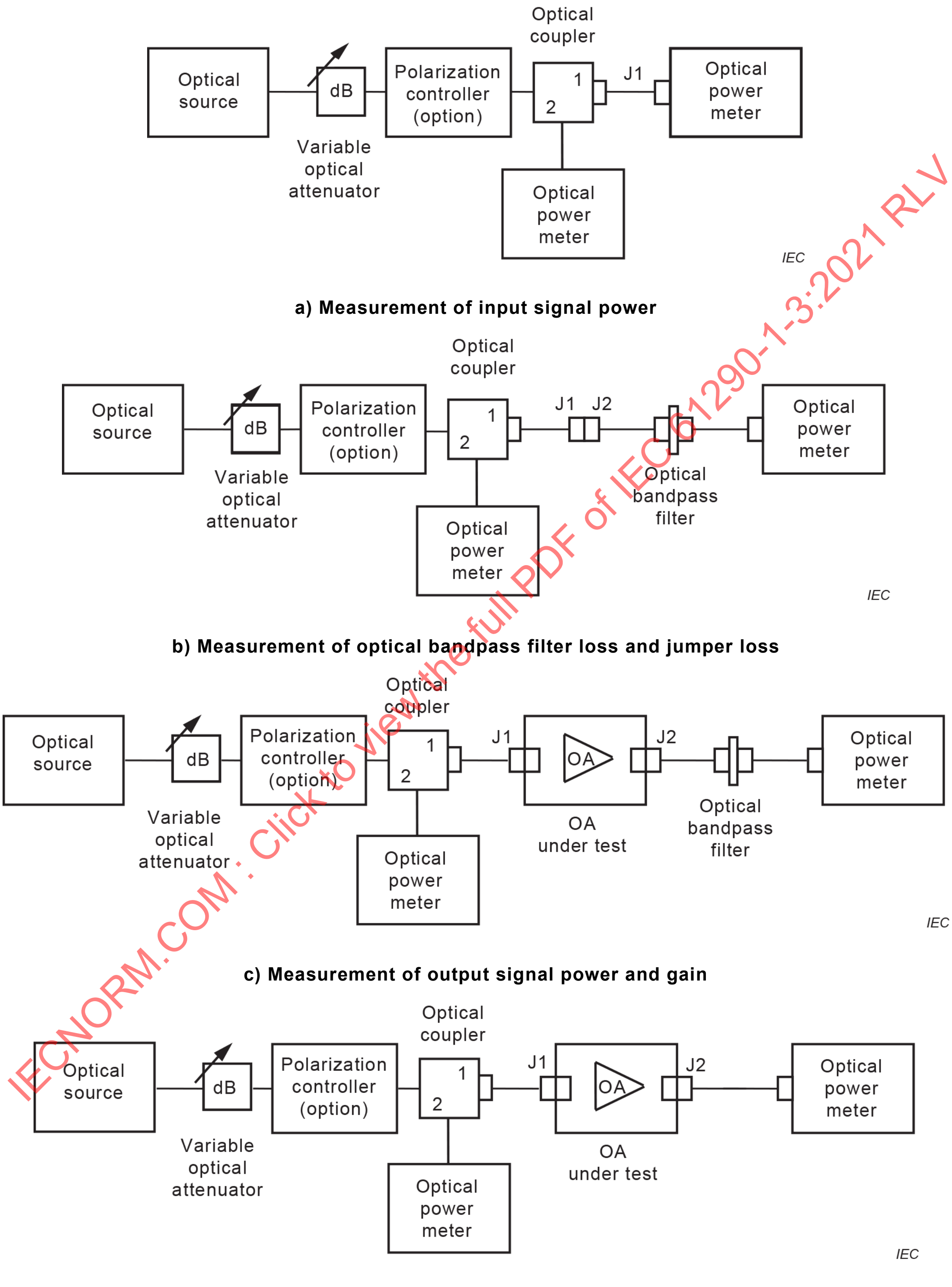
- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.2 Abbreviated terms

ASE	amplified spontaneous emission
DBR	distributed Bragg reflector (laser diode)
DFB	distributed feedback (laser diode)
ECL	external cavity laser (diode)
FWHM	full width at half maximum
LED	light emitting diode
OA	optical amplifier
OFA	optical fibre amplifier
OSA	optical spectrum analyzer
PDL	polarization dependent loss
POWA	planar optical waveguide amplifier
SOA	semiconductor optical amplifier

4 Apparatus

A diagram of the measurement set-up is given in Figure 1 a), Figure 1 b), Figure 1 c) and Figure 1 d).



a) Measurement of input signal power

b) Measurement of optical bandpass filter loss and jumper loss

c) Measurement of output signal power and gain

d) Measurement of total output power

Key

J1, J2 optical connector

Figure 1 – Typical arrangement of optical power meter test apparatus for measurement

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 product specification. Unless otherwise specified, the optical source shall emit a continuous wave with FWHM of the spectrum narrower than 1 nm (‡). A distributed feedback (DFB) laser, a distributed Bragg reflector (DBR) laser, an external cavity laser (ECL) diode, a light emitting diode (LED) with a narrow-band filter and a single line laser 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 can 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 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 product specification. Its optical power shall be specified in the relevant product specification. Unless otherwise specified, the optical source shall emit a continuous wave with the full width at half maximum (FWHM) 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 can 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 laser sources, and the ratio of the source power to total spontaneous emission power of the laser shall be more than 30 dB.

b) Optical power meter*:* It shall have a measurement uncertainty of less than 0,2 dB, irrespective of the state of polarization, within the operational wavelength bandwidth of the OA. A maximum optical input power shall be large enough [e.g. +20 dBm (‡)]. Sensitivity shall be high enough [e.g. −40 dBm (‡)]. A dynamic range exceeding the measured gain is required (e.g. 40 dB).

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

d) 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.

e) 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 can be necessary to achieve the desired accuracy for OA devices exhibiting significant polarization dependent gain.

f) Optical fibre jumpers: The optical fibre jumpers used 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.

g) Optical connectors: The connection loss repeatability shall be less than 0,2 dB. The reflectance from this device shall be smaller than −40 dB (‡).

h) Optical bandpass filter: The optical bandwidth (FWHM) of this device shall be less than 3 nm (‡). It shall be either wavelength-tuneable or an appropriate set of fixed bandpass filters.

During measurement, the difference between the centre wavelength of this bandwidth and the optical source centre wavelength shall be no more than 1,5 nm (‡). The PDL of the bandpass filter shall be less than 0,2 dB (‡). The reflectance from this device shall be smaller than −40 dB (‡).

NOTE 1 Optimization of optical band pass filter spectral width is discussed in Annex A.

i) Optical coupler: The polarization dependence of the branching ratio of the coupler shall be less than 0,1 dB (‡). Any unconnected port of the coupler shall be properly terminated, in such a way as to decrease the reflectance below −40 dB (‡).

NOTE 2 The change of the state of polarization of the input light is typically negligible.

j) Wavelength meter: It shall have a wavelength measurement uncertainty of less than 0,1 nm (‡). If the optical source is so calibrated that the uncertainty of the wavelength is less than 0,1 nm (‡), the wavelength meter is not necessary.

5 Test sample

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

Standard optical fibres type B-652.B or B-652.D as defined in IEC 60793-2-50 are recommended. Even if fibre type other than B-652.B or B-652.D is used as input/output fibre, the mode field diameter of the optical fibre jumpers closely matches those of the input and output fibres of the OA [see Clause 4 f)].

For all parameter measurements except polarization-dependent gain, 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 measurement uncertainty.

6 Procedure

a) Nominal output signal power: The nominal output signal power is given by the minimum output signal optical power, for an input signal optical power specified in the relevant product specification, and under nominal operating conditions, given in the relevant product specification. To find this minimum value, input and output signal power levels shall be continuously monitored for a given duration of time and in presence of changes in the state of polarization and other instabilities, as specified in the relevant product specification. The measurement procedures described below shall be followed, with reference to Figure 1.

   In order to minimize the amplified spontaneous emission (ASE) power contribution to the signal power output from the OA, several methods may be used. The optical bandpass filter method is given below.

   1) Set the optical source at the test wavelength specified in the relevant product specification, measuring the input signal wavelength (e.g. with a wavelength meter).

   2) Measure the branching ratio of the optical coupler through the signal power levels exiting the two output ports with an optical power meter.

   3) Measure the loss L_{bj} of the optical bandpass filter and the optical fibre jumper between the OA and the optical power meter [see Figure 1 b)] by the insertion loss technique [see method B (insertion loss) in IEC 60793-1-40].

   4) Activate the OA under test and evaluate the ASE power level passed through the optical filter, P_{ASE}, by measuring the optical output power from the OA, as shown in Figure 1 c), without input signal.

   NOTE 1 The small-signal regime is when the OA under test operates in the linear regime, whereas the large-signal regime is when it operates in the saturated regime. The distinction between small-signal and large-signal regimes can be made by plotting G versus the input signal power with a constant pump drive. The linear regime requires the time-averaged input signal power to be in the range in which the gain is quite independent of the input signal power (see IEC 61290-1). An input signal power ranging from −30 dBm to −40 dBm is generally well within this range. In the saturated regime, the signal power is large enough to well suppress the ASE, so that the measurement of the ASE power is sometimes omitted.

NOTE 2 For consideration of measurement uncertainty, refer to the last paragraph of Annex A, which concerns the optimization of the optical band pass filter spectral width.

5) Set the optical source and the variable optical attenuator in such a way as to provide, at the input port of the OA, the input optical signal power (P_{in}) specified in the relevant product specification. Record the optical power (P_o) measured with an optical power meter at the other (second) output port of the optical coupler, as shown in Figure 1 a).

   Applying signal light with short rise time into the OA operating without signal light can cause the generation of an optical surge which can damage the optical components. The input signal shall have sufficiently small power to prevent the optical surge, when it is launched to the OA initially. The input power shall be gradually increased to the specified level.

6) Keep the optical signal power at the OA input constant (P_{in}) during the following measurements, by monitoring the second output port of the coupler and, if necessary, setting the variable optical attenuator in such a way that the optical power (P_o) exiting the second output port of the optical coupler remains constant.

7) Connect the fibre jumpers to the input and output port of the OA under test, as shown in Figure 1 c) and evaluate the optical output power (P_{out}) with input signal.

If the polarization controller is used, the following procedure shall be adapted.

8) Set the polarization controller at a given state of polarization as specified in the relevant product specification; activate the OA, and monitor, by means of the optical power meter, the optical signal power at the output of the OA, for the specified period of time, recording the minimum value.

9) Change the state of polarization of the input signal by means of the polarization controller, trying to measure maximum and minimum output optical signal powers with the optical power meter, and repeat procedure 8).

10) Repeat procedure step 9) for the different states of polarization indicated in the relevant product specification and, finally, take the absolute minimum and maximum output optical signal powers recorded in the various conditions: $P_{out\text{-}min}$ and $P_{out\text{-}max}$.

   Optical connectors J1 and J2 shall not be removed during the measurement to avoid measurement uncertainty due to reconnection.

The measurement uncertainty shall be reduced by eliminating the effect of the ASE simultaneously detected with the signal. This is better attainable by placing an optical bandpass filter having the narrower passband at the output of the OA under test, as it has been discussed in Clause 6 a). For large optical signal power levels, the optical bandpass filter is often not necessary to achieve an accurate measurement. The use of the optical bandpass filter is especially important when the input signal to the OA is small. This is because the ASE power increases as the input signal decreases. However, if this kind of optical filter is already built in the OA, the external optical filter is not needed. The effectiveness of the optical band pass filter is further discussed in Annex A.

b) Gain:

   1) to 7) As in procedures 1) to 7) in a), but this method permits determination of the gain through the measurements of the OA input signal power P_{in} and the OA output power P_{out}, taking into account the OA amplified spontaneous emission (ASE) power P_{ASE} at the signal wavelength.

   8) Repeat procedures 5) to 7) in a), with increasing input signal power gradually to the maximum input signal power given in the relevant product specification. Maintain the pump power or pump current with the firstly set point.

c) Polarization-dependent gain: as in a), but this parameter is determined through the measurements of the OA input signal power, Pin, the OA output power, Pout-min and

Pout-max, taking into account the OA amplified spontaneous emission (ASE) power, PASE at the signal wavelength, by repeating all procedures at different states of polarization as specified in the relevant product specification.

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 product specification. 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° continuously.

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 PDL of the optical connector shall be less than 0,2 dB (‡).

d) Maximum output signal power: As in a), but this parameter is determined by repeating all procedures at different wavelengths specified in the detailed specification, and replace procedures 1), 4), 5) with the following.

   1) Set the wavelength-tuneable optical source at a test wavelength within the specified wavelength range, measuring the input signal wavelength (e.g. with a wavelength meter).

   4) Activate OA and adjust the maximum pump power or maximum pump current of OA to the nominal condition as specified in the relevant product 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.

   5) 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 signal power $P_{in\text{-}max}$ specified in the relevant product specification. Record the optical power P_o measured with an optical power meter at the other (second) output port of the optical coupler, as shown in Figure 1 a).

   Instantly applying signal light into the active OA can cause the generation of an optical surge which can damage the optical components. The input signal shall have sufficiently small power to prevent the optical surge, when it is launched into the OA initially. The input power shall be gradually increased to the specified level.

e) Maximum total output power: The maximum total output power is given by the highest optical power level at the output port of the OA operating within the absolute maximum ratings. To find this maximum value, input and output power levels shall be continuously monitored for a given duration of time and in presence of changes in the state of polarization and other instabilities, as specified in the relevant product specification. The measurement procedures described below shall be followed, with reference to Figure 1.

   1) Measure the branching ratio of the optical coupler through the signal power levels exiting the two output ports with an optical power meter.

   2) 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 signal power $P_{in\text{-}max}$ specified in the relevant product specification. Record the optical power P_o measured with an optical power meter at the other (second) output port of the optical coupler, as shown in Figure 1 a).

   Putting signal light into the active OA can cause the generation of optical surge which can damage the optical components. Input signal shall have sufficiently small power to prevent the optical surge, when it is launched to the OA in the beginning. And the input power shall be gradually increased to a certain level.

   3) Keep the optical signal power at the OA input constant ($P_{in\text{-}max}$) during the following measurements by monitoring the second output port of the coupler and, if necessary,

setting the variable optical attenuator in such a way that the optical power (P_o) exiting the second output port of the optical coupler remains constant.

4) Connect the fibre jumpers to the input and output port of the OA under test, as shown in Figure 1 d) and activate OA and adjust the maximum pump power or maximum pump current of OA to the absolute maximum ratings, given in the relevant product 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 evaluate the optical output power ($P_{total\text{-}out}$) with input signal.

If the polarization controller is used, procedures 5), 6), 7) shall be followed.

5) Set the polarization controller at a given state of polarization as specified in the relevant product specification; activate the OA, and monitor, by means of the optical power meter, the optical power at the output of the OA, for the specified period of time, recording the maximum value.
6) Change the state of polarization of the input signal by means of the polarization controller, trying to measure maximum and minimum output optical powers with the optical power meter, and repeat procedure 5).
7) Repeat procedure 5) and 6) for the different states of polarization indicated in the relevant product specification, and finally take the absolute minimum and maximum output optical powers recorded in the various conditions: $P_{total\text{-}out\text{-}min}$ and $P_{total\text{-}out\text{-}max}$.

Optical connectors J1 and J2 shall not be removed during the measurement to avoid measurement uncertainty due to reconnection.

7 Calculation

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

$$P_{sig\text{-}out\text{-}nom} = 10 \log_{10} (P_{out} - P_{ASE}) + L_{bj} \quad \text{(dBm)} \tag{1}$$

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 optical bandpass filter and fibre jumper placed between the OA and the optical power meter (in dB).

NOTE 1 If optical bandpass filter is already built in the OA, the external optical filter is not needed. In this case, the insertion loss L_{bj} is equal to that of the fibre jumper.

NOTE 2 A comparison of the measured values obtained with OSA, with the calculated values with optical power meter using various band pass filters, is referred to in Annex A.

b) Gain: the gain G at the signal wavelength shall be calculated as

$$G = 10 \log_{10} [(P_{out} - P_{ASE})/P_{in}] \quad \text{(dB)} \tag{2}$$

If the FWHM of the filter is very narrow so that the detected P_{ASE} is sufficiently small, P_{ASE} could be omitted in the above calculation. In large-signal regime, if P_{out} is sufficiently larger than P_{ASE}, P_{ASE} could be negligible with respect to P_{out}. A comparison of the measured values obtained with OSA, with the calculated values with optical power meter using various band pass filters, is referred to in Annex A.

NOTE 3 The measurement uncertainly can be less than 0,2 dB (‡), depending mainly on the uncertainty of the optical power meter.

c) Polarization-dependent gain: Calculate the gain values at the different states of polarization as described in b). Calculations are processed using the following procedure.
   1) Calculate the gain values at the different states of polarization, as in b).
   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.
   3) The polarization-dependent gain ΔG_{pol} shall be calculated as follows

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

NOTE 4 $G_{\text{min-pol}}$ is defined as the same as G in b). $G_{\text{max-pol}}$ is defined as G in which $P_{\text{out-min}}$ is replaced by $P_{\text{out-max}}$.

NOTE 5 ΔG_{pol} does not necessarily indicate the possible maximum variation of the polarization dependency. This is because 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 6 The measurement uncertainly can be less than 0,5 dB (‡), depending mainly on the optical power meter polarization dependency.

The input signal power at which the parameter is specified and measured should be stated. Larger input power is recommended considering the ASE factor contained in the output power.

d) Maximum output signal power: Calculate the maximum output signal power $P_{\text{sig-out-max}}$ (in dBm) as in a).

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

$$P_{\text{out-max}} = 10 \log_{10} P_{\text{out-max}}^{\text{linear}} \text{ (dBm)} \quad (4)$$

where

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

8 Test results

The following parameters shall be recorded in the test reports unless otherwise stated in the relevant product specification.

a) Nominal optical signal power

   The following details shall be presented:
   1) arrangement of the test set-up;
   2) spectral linewidth (FWHM) of the optical source;
   3) indication of the optical pump power and possibly driving current of pump lasers for OFAs, and injection current for SOAs (if applicable);
   4) operating temperature (if required);
   5) input signal optical power P_{in};
   6) FWHM of the optical bandpass filter;
   7) central wavelength of the optical bandpass filter;

8) wavelength of the measurement;

9) nominal optical signal power levels $P_{sig-out-nom}$;

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

b) Gain: The details 1) to 8) previously listed for the nominal optical signal power levels shall be presented and, in addition:

9) gain:

Parameters 5) and 9) may be replaced with the gain versus input optical signal power curve.

Parameters 8) and 9) may be replaced with the gain versus input signal wavelength curve.

c) Polarization-dependent gain: The details 1) to 8) previously listed for the gain shall be presented and, in addition:

9) polarization dependency of the optical power meter uncertainty;

10) the maximum and minimum gain, $G_{max-pol}$ and $G_{min-pol}$;

11) polarization-dependent gain;

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

d) Maximum output signal power: The details 1) to 8) previously listed for the gain shall be presented and, in addition:

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

e) Maximum total output power: The details 1) to 8) previously listed for the gain shall be presented and, in addition:

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

Annex A
(informative)

Optimization of optical bandpass filter spectral width

The measurement uncertainty of this method depends on the choice of the band pass filter, in terms of its spectral width (FWHM). The purpose of this filter is to remove the ASE contribution from the measurement. As such, it is intuitive that the smaller the filter FWHM is chosen, the greater is the ASE cancellation and, hence, the smaller is the measurement uncertainty. However, if the filter spectral width is excessively narrow, problems of alignment between the filter central frequency and the signal frequency can arise, leading to stability problems which can be detrimental to measurement uncertainty. These considerations indicate that an optimal spectral width of the filter should be chosen to minimize the measurement uncertainty.

A possible procedure to determine such an optimal filter is to calibrate this optical power meter method with the OSA technique (see IEC 61290-1-1), which is intrinsically more accurate. For a given OA typology, optical power meter measurements using successively different filters (with FWHM e.g. from 1 nm to 5 nm) can be compared with an OSA measurement. The optimal band pass filter is the one which minimizes the difference between the results from the two measurement methods.

For example, applying this calibration procedure in a numerically simulated case, the use of a band pass filter of Lorentzian type with FWHM of 2 nm demonstrated to sufficiently cancel the effect of ASE and achieve a difference with respect to OSA measurements result less than only 0,05 dB. This difference increased to approximately 0,15 dB for a filter with FWHM of 5 nm. It should be noted that, while the effect of ASE can be accurately evaluated in small-signal regime, even in large-signal regime, notwithstanding less accurate evaluation of ASE power, the portion of ASE power becomes less significant with respect to the signal power. As a result, an accurate optical power meter measurement can be maintained over entire input signal levels by choosing an optimally narrow FWHM of band pass filter.

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

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

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

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

IEC TR 61931, *Fibre optic – Terminology*

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SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

AMPLIFICATEURS OPTIQUES – MÉTHODES D'ESSAI –

Partie 1-3: Paramètres de puissance et de gain – Méthode par appareil de mesure de la puissance optique

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La Norme internationale IEC 61290-1-3 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. Cette édition constitue une révision technique.

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

a) harmonisation avec l'IEC 61290-1-1;
b) utilisation du terme "incertitude de mesure" au lieu de "précision de mesure".

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

Projet	Rapport de vote
86C/1671/CDV	86C/1698/RVC

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.

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

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2 et élaboré selon les directives ISO/IEC, Partie 1 et les directives ISO/IEC, Supplément IEC disponible à l'adresse suivante www.iec.ch/members_experts/refdocs. Les principaux types de documents élaborés par l'IEC sont décrits de façon plus détaillée à l'adresse www.iec.ch/standardsdev/publications.

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

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AMPLIFICATEURS OPTIQUES – MÉTHODES D'ESSAI –

**Partie 1-3: Paramètres de puissance et de gain –
Méthode par appareil de mesure de la puissance optique**

1 Domaine d’application

La présente partie de l'IEC 61290 s’applique à tous les amplificateurs optiques (AO) et sous-systèmes à amplification optique, disponibles sur le marché. Elle s’applique aux AO utilisant des fibres pompées optiquement (AFO basé sur des fibres dopées aux terres rares ou sur l’effet Raman), des semiconducteurs (AOS), et des guides d’ondes (POWA).

NOTE 1 L’applicabilité des méthodes d’essai décrites dans le présent document à des amplificateurs Raman répartis est destinée à une étude ultérieure.

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 par appareil de mesure de la puissance optique, des paramètres d’AO donnés ci-dessous, tels qu’ils sont définis dans l'IEC 61291-1:

a) puissance nominale du signal de sortie;

b) gain;

c) gain en fonction de la polarisation;

d) puissance maximale du signal de sortie;

e) puissance totale de sortie maximale

NOTE 2 Toutes les valeurs numériques suivies de (‡) sont des valeurs suggérées, pour lesquelles le mesurage est assuré. D’autres valeurs peuvent être acceptables après vérification.

Le présent document s'applique aux amplificateurs à un seul canal. Pour les amplificateurs à canaux multiples, l’IEC 61290-10 (toutes les parties) s'applique.

2 Références normatives

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

IEC 60793-2-50, Fibres optiques – Partie 2-50: *Spécifications de produits – Spécification intermédiaire pour les fibres unimodales de classe B*

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

3 Termes, définitions et termes abrégés

3.1 Termes et définitions

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

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

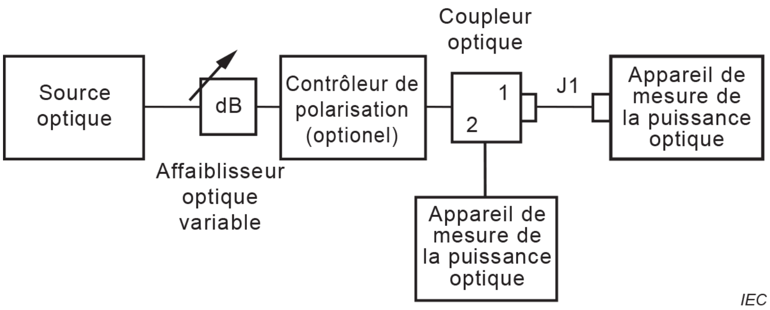
- IEC Electropedia: disponible à l'adresse http://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obp

3.2 Termes abrégés

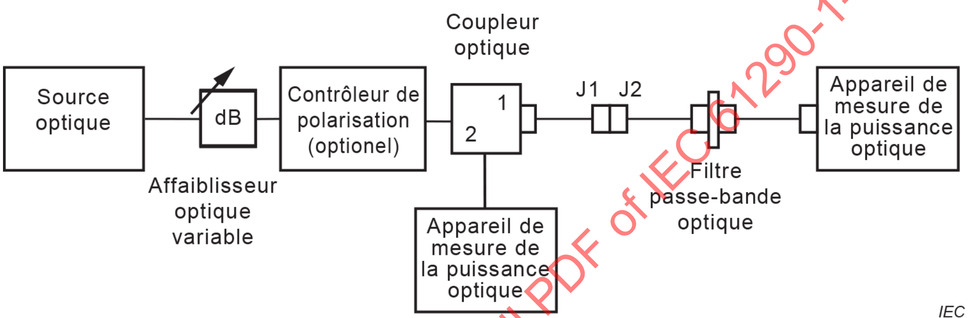
ESA	émission spontanée amplifiée
DBR	distributed bragg reflector (réflecteur de Bragg distribué) (diode laser)
DFB	distributed feedback (rétroaction distribuée) (diode laser)
ECL	external cavity laser (laser à cavité externe) (diode)
FWHM	full width at half maximum (largeur à mi-hauteur)
LED	light emitting diode (diode électroluminescente)
AO	amplificateur optique
AFO	amplificateur à fibres optiques
ASO	analyseur de spectre optique
PDL	polarization dependent loss (perte dépendant de la polarisation)
POWA	planar optical waveguide amplifier (amplificateur à guide d'onde optique plan)
AOS	amplificateur optique à semiconducteur

4 Appareillage

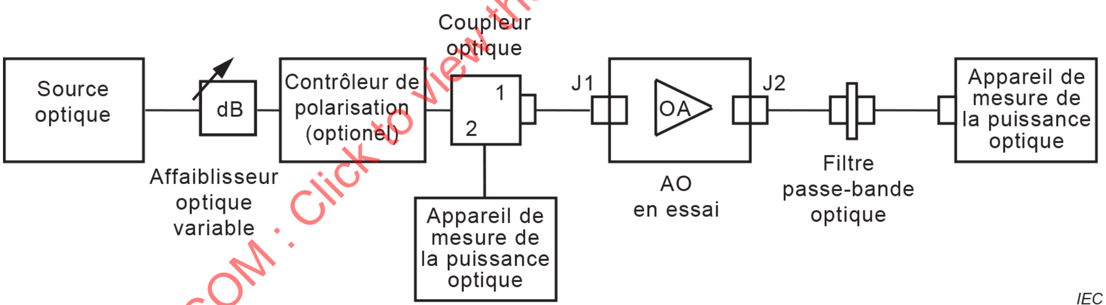
Un schéma du montage de mesure est fourni aux Figure 1 a), Figure 1 b), Figure 1 c) et Figure 1 d).



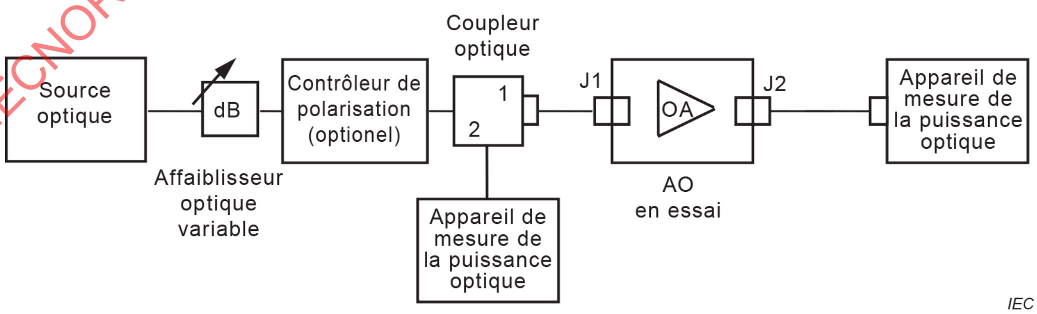
a) Mesurage de la puissance du signal d'entrée



b) Mesurage des pertes du filtre passe-bande optique et des pertes des jarretières



c) Mesurage de la puissance du signal de sortie et du gain



d) Mesurage de la puissance totale de sortie

Légende

J1, J2 connecteurs optiques

Figure 1 – Configuration typique de l'appareillage d'essai de mesure de la puissance optique pour les mesurages

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

a) Source optique: la source optique doit être de longueur d'onde fixe, ou 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 applicable. Sauf spécification contraire, la source optique doit émettre une onde continue avec une largeur spectrale à mi-hauteur (FWHM) inférieure à 1 nm (‡). Une diode laser à rétroaction distribuée (DFB), un laser à réflecteur de Bragg distribué (DBR), une diode laser à cavité externe (ECL), une diode électroluminescente (LED) avec un filtre à bande étroite et un laser à raie unique sont appropriés, par exemple.

     Le taux de suppression des modes latéraux pour le laser DFB, le laser DBR ou l'ECL doit être supérieur à 30 dB (‡). La variation 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 spécifiée dans la spécification de produit applicable. Sa puissance optique doit être indiquée dans la spécification de produit applicable. Sauf spécification contraire, la source optique doit émettre une onde continue avec une largeur spectrale à mi-hauteur (FWHM) inférieure à 1 nm (‡). Un ECL ou une LED avec un filtre optique passe-bande étroit est approprié(e), par exemple. Le taux de suppression des modes latéraux pour l'ECL doit être supérieur à 30 dB (‡). La variation 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.

b) Appareil de mesure de la puissance optique: il doit avoir une incertitude de mesure inférieure à 0,2 dB, sans tenir compte de l'état de polarisation dans la largeur de bande de longueurs d'onde opérationnelle de l'AO. La puissance d'entrée optique maximale doit être suffisamment élevée [par exemple, +20 dBm (‡)]. La sensibilité doit être suffisamment élevée [par exemple, –40 dBm (‡)]. Une plage dynamique dépassant le gain mesuré est exigée (par exemple, 40 dB).

c) Isolateur optique: des isolateurs optiques peuvent être utilisés en entrée et en sortie de l'AO. La variation des pertes dépendant de la polarisation (PDL) de l'isolateur doit être inférieure à 0,2 dB (‡). L'isolation optique doit être supérieure à 40 dB (‡). La réflectance de ce dispositif doit être inférieure à –40 dB (‡) à chaque port.

d) Affaiblisseur optique variable: la plage d'affaiblissement et la stabilité doivent être respectivement supérieure à 40 dB (‡) et inférieure à 0,2 dB (‡). La réflectance de ce dispositif doit être inférieure à –40 dB (‡) à chaque port.

e) Contrôleur de polarisation: ce dispositif doit être capable de fournir un signal lumineux d'entrée à tous les états de polarisation possibles (par exemple, les états linéaire, elliptique et circulaire). Par exemple, le contrôleur de polarisation peut consister soit en un polariseur linéaire suivi d'un contrôleur de polarisation pour tout type de fibre, soit en un polariseur linéaire suivi d'une lame quart d'onde orientable à 90° au minimum et d'une lame demi-onde orientable à 180° au minimum. La variation des pertes du contrôleur de polarisation doit être inférieure à 0,2 dB (‡). La réflectance de ce dispositif doit être inférieure à –40 dB (‡) à chaque port. L'utilisation d'un contrôleur de polarisation est considérée comme facultative, excepté pour le mesurage du gain dépendant de la polarisation, mais peut être nécessaire pour obtenir l'exactitude souhaitée pour les dispositifs d'AO présentant un gain dépendant de la polarisation significatif.

f) Jarretières de fibres optiques: les jarretières de fibres optiques utilisées doivent être constituées des mêmes fibres de la catégorie définie dans l'IEC 60793-2-50 que celles