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

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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- withdrawn,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 (OPA 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.

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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

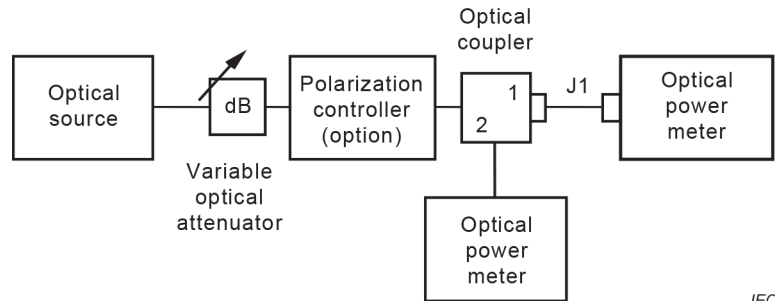
ASE	amplified spontaneous emission
DBR	distributed Bragg reflector (laser diode)
DFB	distributed feedback (laser diode)
ECL	external cavity laser (diode)
FWHM	full width at half maximum
LED	light emitting diode
OA	optical amplifier
OFA	optical fibre amplifier
OSA	optical spectrum analyzer
PDL	polarization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

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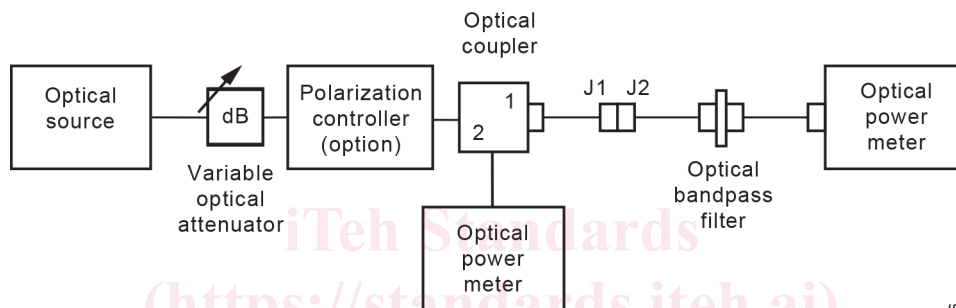
4 Apparatus

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



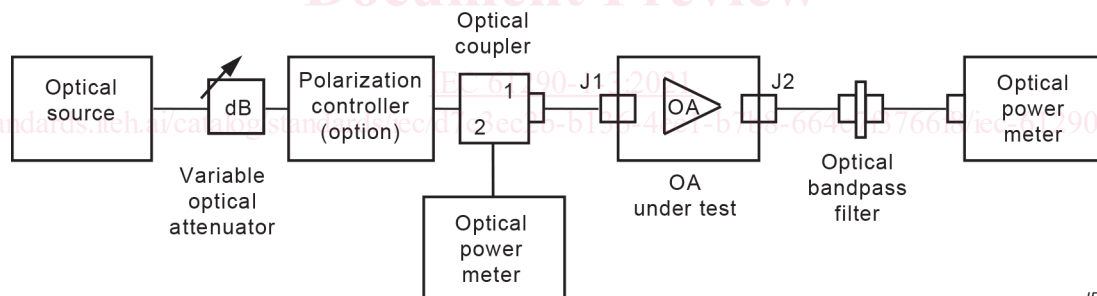
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a) Measurement of input signal power



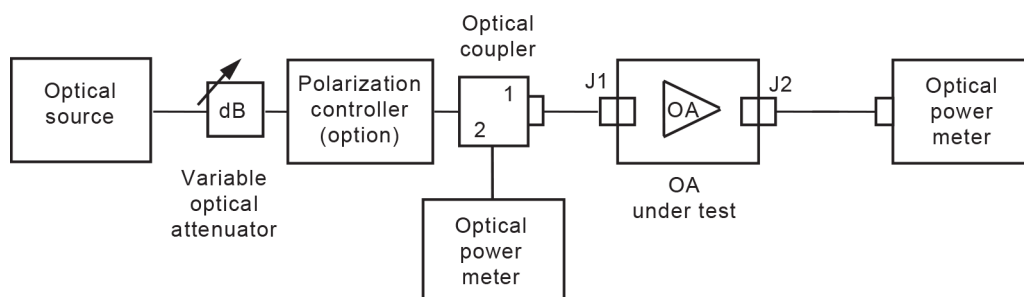
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b) Measurement of optical bandpass filter loss and jumper loss



IEC

c) Measurement of output signal power and gain



IEC

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 (\pm). 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 (\pm). The output power fluctuation shall be less than 0,05 dB (\pm), 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 (\pm). 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 (\pm). 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 $\pm 0,2$ 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 (\pm)]. Sensitivity shall be high enough [e.g. -40 dBm (\pm)]. 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 (\pm). Optical isolation shall be ~~better~~ more than 40 dB (\pm). The reflectance from this device shall be smaller than -40 dB (\pm) at each port.
- d) Variable optical attenuator: The attenuation range and stability shall be over 40 dB (\pm) and ~~better~~ less than ~~$\pm 0,1$~~ 0,2 dB (\pm), respectively. The reflectance from this device shall be smaller than -40 dB (\pm) 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 (\pm). The reflectance from this device shall be smaller than -40 dB (\pm) 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 (\pm) 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 (\pm) 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 $\pm 0,2$ dB. The reflectance from this device shall be smaller than -40 dB (\pm).
- h) Optical bandpass filter: The optical bandwidth (FWHM) of this device shall be less than 3 nm (\pm). 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 (\pm). The PDL of the bandpass filter shall be less than 0,2 dB (\pm). The reflectance from this device shall be smaller than -40 dB (\pm).

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 (\pm). Any unconnected port of the coupler shall be properly terminated, in such a way as to decrease the reflectance below -40 dB (\pm).

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 (\pm). If the optical source is so calibrated that the ~~accuracy~~ uncertainty of the wavelength is ~~better~~ less than 0,1 nm (\pm), 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: $P_{out-min}$ and $P_{out-max}$.

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

The measurement ~~error~~ 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.

14 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, P_{in} , the OA output power, $P_{out-min}$ and $P_{out-max}$, taking into account the OA amplified spontaneous emission (ASE) power, P_{ASE} 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 (\pm).

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-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_{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_{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 ($P_{total-out}$) 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: $P_{total-out-min}$ and $P_{total-out-max}$.

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 $P_{sig-out-nom}$ (in dBm) shall be calculated as

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