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INTERNATIONAL STANDARD

colour inside

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

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CONTENTS

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OPTICAL AMPLIFIERS – TEST METHODS –

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

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

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

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

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

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

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

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

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

This document is to be used in conjunction with IEC 61290-1 and IEC 61291-1.

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

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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- withdrawn,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

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OPTICAL AMPLIFIERS – TEST METHODS –

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

1 Scope

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

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

a) nominal output signal power;

b) gain;

c) polarization-dependent gain (PDG);

d) maximum output signal power;

e) maximum total output power.

In addition, this document provides the test method of:

f) gain ripple (for SOAs).

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

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

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

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

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

3 Terms, definitions, and abbreviated terms

3.1 Terms and definitions

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

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

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

3.2 Abbreviated terms

ASE amplified spontaneous emission

DBR distributed Bragg reflector (laser diode)

DFB distributed feed-back (laser diode)

ECL external cavity laser (diode)

LED light emitting diode

OA optical amplifier

OFA optical fibre amplifier

OSA optical spectrum analyzer

PDG polarization-dependent gain

POWA planar optical waveguide amplifier

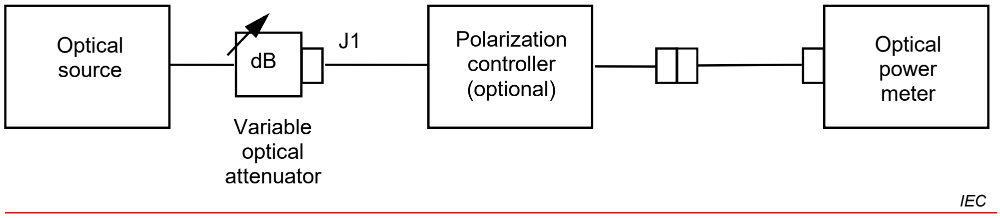
SOA semiconductor optical amplifier

4 Apparatus

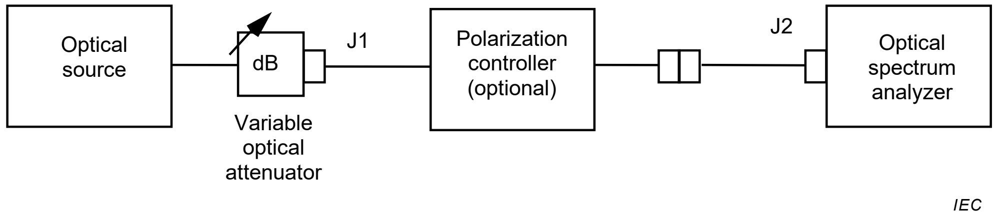
4.1 Test setup

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

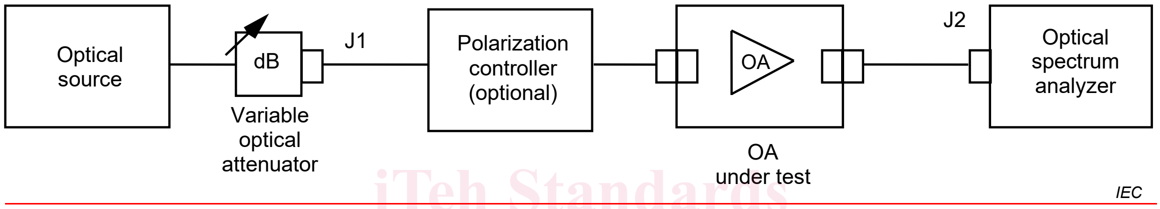
The test set-up for gain ripple measurements is displayed in Figure 2, showing the set-up for calibration in Figure 2 a), the set-up for input signal power measurement in Figure 2 b), and two different set-ups for gain ripple measurement in Figure 2 c) and Figure 2 d).



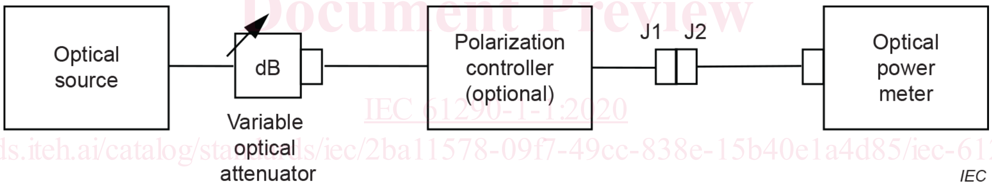
~~Figure 1a – Calibration~~



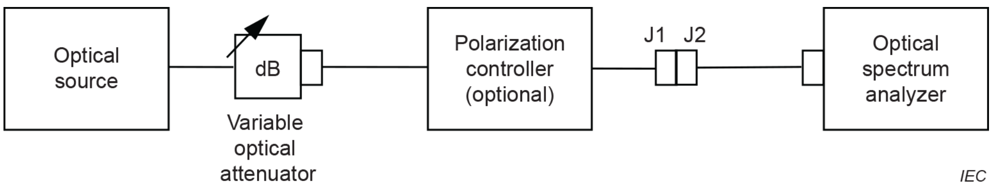
~~Figure 1b – Input signal power measurement~~



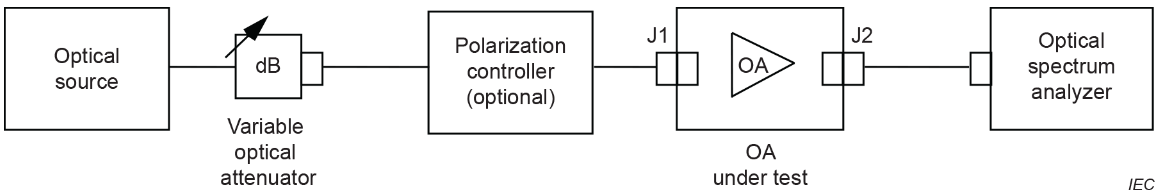
~~Figure 1c – Output power measurement~~



a) – Calibration



b) – Input signal power measurement

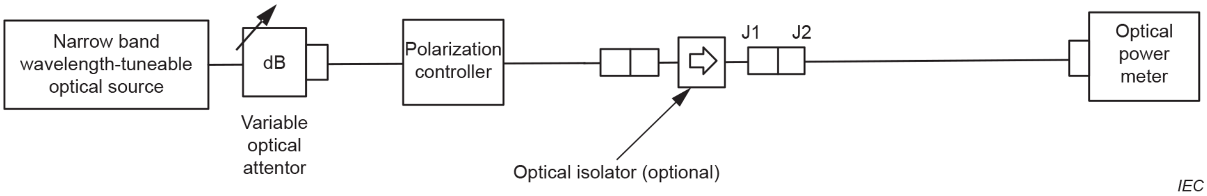


c) – Output power measurement

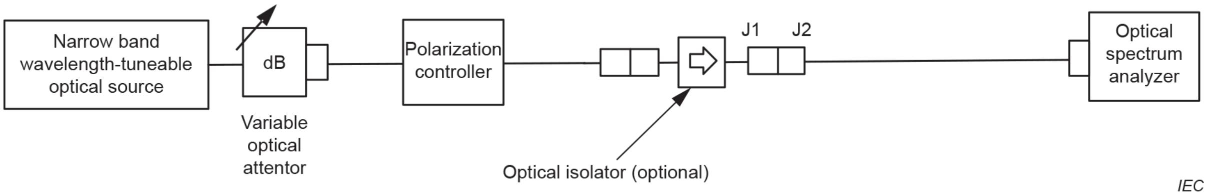
Key

J1, J2 optical connector

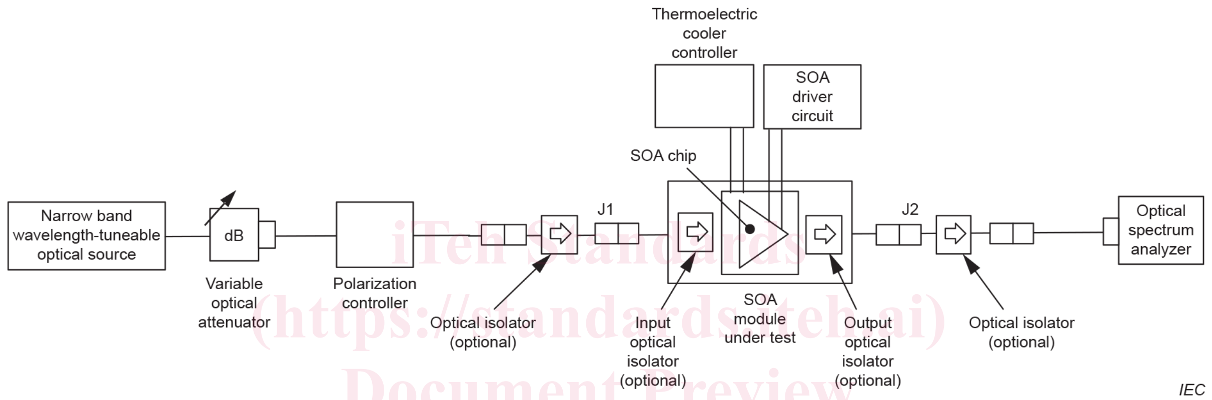
Figure 1 – Typical arrangement of optical spectrum analyzer test apparatus for gain and power measurements



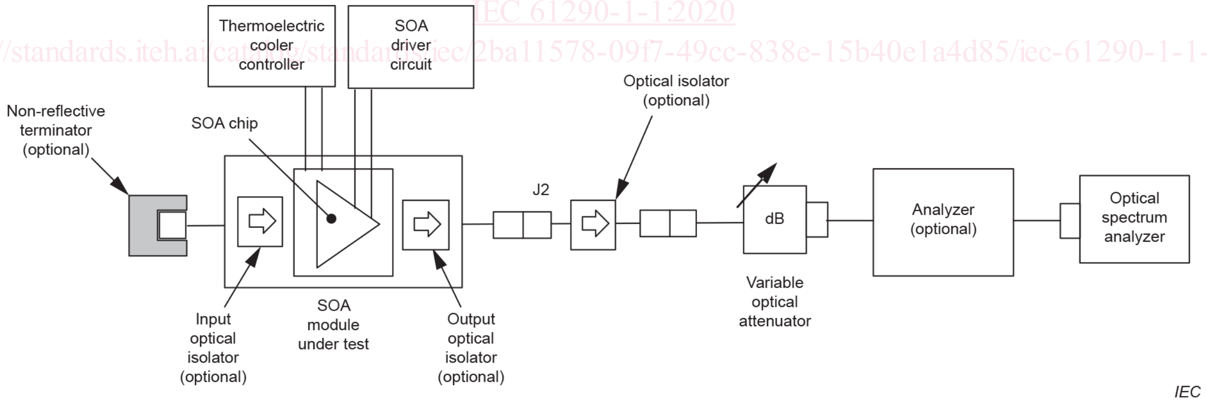
a) – Calibration



b) – Input signal power measurement



c) – Gain ripple measurement (signal gain method)



d) – Gain ripple measurement (ASE method)

Key

J1, J2 optical connector

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

4.2 Characteristics of test equipment

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

a) Optical source

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

– Fixed-wavelength optical source

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

– Wavelength-tuneable optical source

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

– Narrow band wavelength-tuneable optical source

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

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

b) Optical power meter

It shall have a measurement uncertainty ~~better~~ less than ~~±~~0,2 dB, irrespective of the state of polarization, within the operational wavelength bandwidth of the OA. A dynamic range ~~exceeding~~ 10 dB higher than the measured gain ~~is~~ shall be required (e.g. 40 dB).

c) Optical spectrum analyzer (OSA)

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

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

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

d) Optical isolator

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

e) Variable optical attenuator

The attenuation range and stability shall be over 40 dB (‡) and ~~better~~ less than ~~±0,1~~ 0,2 dB (‡), respectively. The reflectance from this device shall be smaller than −40 dB (‡) at each port.

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

f) Polarization controller

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

g) Optical fibre jumpers

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

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

The optical fibre jumpers shall be of the same fibre category defined in IEC 60793-2-50 as the fibres used as input and output ports of the OA, so that the mode field diameters of the optical fibre jumpers closely match those of the input and output fibres of the OA. The reflectance from this device shall be smaller than −40 dB (‡) at each port, and the length of the jumper shall be shorter than 2 m. Polarization maintaining fibre shall be used for the input fibre jumper when testing gain ripple in an SOA, if the gain ripple of the SOA is sensitive to the state of polarization.

h) Optical connectors, J1 and J2

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

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

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

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

where

m is the number of measurements;

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

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

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

i) Analyzer

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

j) Non-reflective terminator

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

5 Test sample

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

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

6 Procedure

~~The procedure is as follows:~~

6.1 Gain and nominal output signal power

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

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

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

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

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

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

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

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

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

Optical connectors J1 and J2 shall not be ~~removed~~ disconnected during the measurement ~~to avoid~~ except between measurement ~~errors~~steps c) and d) to avail measurement uncertainty due to reconnection.

6.2 PDG variation

As in 6.1, but use a polarization controller between the variable optical attenuator and the connector J1 (see Figure 1), repeat all procedures at different states of polarization as specified in the ~~relevant detail~~ product specification or equivalent, and replace procedure a) with the following:

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

6.3 Maximum output signal power

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

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

d) activate the OA and adjust the maximum pump power or maximum pump current of the OA to the nominal condition as specified in the ~~relevant detail~~ product specification or equivalent; when the OA under test is integrated with control circuitry, the OA shall be tested with constant pump power mode or constant pump current mode and measure P_{out} with the OSA, as shown in Figure 1 c);

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

6.4 Maximum total output power

Same procedure as for 6.3.

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