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Optical amplifiers – Test methods –

Part 10-4: Multichannel parameters – Interpolated source subtraction method using an optical spectrum analyzer

Amplificateurs optiques – Méthodes d'essais –

Partie 10-4: Paramètres à canaux multiples – Méthode par soustraction de la source interpolée en utilisant un analyseur de spectre optique

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OPTICAL AMPLIFIERS – TEST METHODS –

Part 10-4: Multichannel parameters – Interpolated source subtraction method using an optical spectrum analyzer

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 61290-10-4 has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics.

This standard shall be used in conjunction with IEC 61291-1. It was established on the basis of the second (2006) edition of that standard.

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

CDV	Report on voting
86C/724/CDV	86C/742/RVC

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

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

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 publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

INTRODUCTION

This International Standard is devoted to the subject of optical amplifiers. The technology of optical amplifiers is still rapidly evolving, hence amendments and new additions to this standard can be expected.

OPTICAL AMPLIFIERS – TEST METHODS –

Part 10-4: Multichannel parameters – Interpolated source subtraction method using an optical spectrum analyzer

1 Scope and object

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

The object of this standard is to establish uniform requirements for accurate and reliable measurements, by means of the interpolated source subtraction method using an optical spectrum analyzer. The following OA parameters, as defined in Clause 3 of IEC 61291-1, are determined:

- channel gain, and
- channel signal-spontaneous noise figure.

This method is called *interpolated source subtraction* (ISS) because the amplified spontaneous emission (ASE) at each channel is obtained by interpolating from measurements at a small wavelength offset around each channel. To minimize the effect of source spontaneous emission, the effect of source noise is subtracted from the measured noise.

The accuracy of the ISS technique degrades at high input power level due to the spontaneous emission from the laser source(s). Annex A provides guidance on the limits of this technique for high input power.

An additional source of inaccuracy is due to interpolation error. Annex A provides guidance on the magnitude of interpolation error for a typical amplifier ASE versus wavelength characteristic.

NOTE 1 All numerical values followed by (‡) are suggested values for which the measurement is assured. Other values may be acceptable but should be verified.

NOTE 2 General aspects of noise figure test methods are reported in IEC 61290-3.

2 Normative references

The following referenced documents are indispensable for the application 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 61291-1:2006, *Optical amplifiers – Part 1: Generic specification*

IEC 61291-4: *Optical amplifiers – Part 4: Multichannel applications – Performance specification template*

3 Abbreviated terms

Each abbreviation introduced in this standard is explained in the text at least the first time it appears. However, for an easier understanding of the whole text, the following is a list of all abbreviations used in this standard:

ASE	Amplified spontaneous emission
DI	Direct interpolation (technique)
FWHM	Full-width half-maximum
ISS	Interpolated source subtraction
NF	Noise figure
RBW	Resolution bandwidth
OA	Optical amplifier
OFA	Optical fibre amplifier
OSA	Optical spectrum analyzer
POWA	Planar optical waveguide amplifier
PCF	Power correction factor
SOA	Semiconductor optical amplifier
SSE	Source spontaneous emission

4 Apparatus

4.1 Multichannel source

This optical source consists of *n* laser sources where *n* is the number of channels for the test configuration. The full width at half maximum (FWHM) of the output spectrum of the laser sources shall be narrower than 0,1 nm (‡) so as not to cause any interference to adjacent channels. The suppression ratio of the side modes of the single-line laser shall be higher than 35 dB (‡). The output power fluctuation shall be less than 0,05 dB (‡), which is more easily attainable with an optical isolator placed at the output port of each source. The wavelength accuracy shall be better than ±0,1 nm (‡) with stability better than ±0,01 nm (‡). The spontaneous emission level must be less than -43 dB/nm with respect to the total input power for 0 dBm total input power and less than -48 dB/nm with respect to the total input power for 5 dBm total input power (‡). See Annex A for a discussion of the impact of the spontaneous emission level on the accuracy of noise figure measurements.

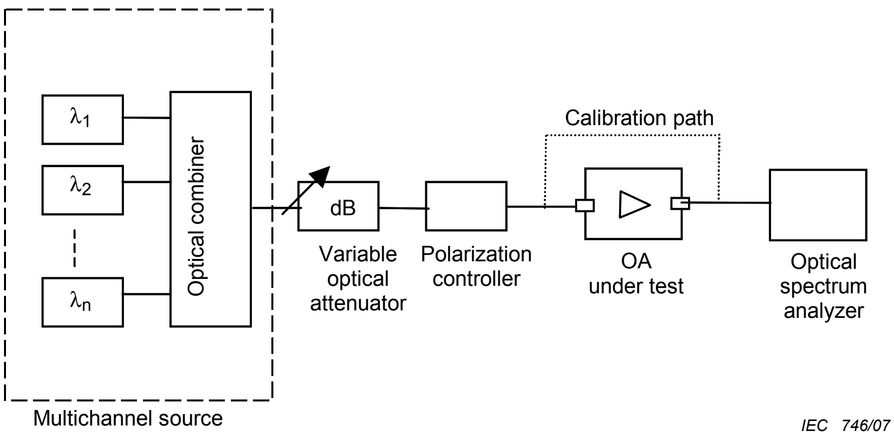

Figure 1 – Apparatus for gain and noise figure measurement

4.2 Polarization controller

This device shall be able to convert any state of polarization of a signal to any other state of polarization. The polarization controller may consist of an all-fibre polarization controller or a quarter-wave plate rotatable by a minimum of 90° followed by a half-wave plate rotatable by a minimum of 180°. The reflectance of this device shall be smaller than –50 dB (‡) at each port. The insertion loss variation of this device shall be less than 0,2 dB (‡). The use of a polarization controller is considered optional, but may be necessary to achieve the desired accuracy for OA devices exhibiting significant polarization dependent gain.

4.3 Variable optical attenuator

The attenuation range and stability shall be over 40 dB (‡) and better than 0,1 dB (‡), respectively. The reflectance from this device shall be smaller than –50 dB (‡) at each port. The wavelength flatness over the full range of attenuation shall be less than 0,2 dB (‡).

4.4 Optical spectrum analyzer

The optical spectrum analyzer (OSA) shall have polarization sensitivity less than 0,1 dB (‡), stability better than 0,1 dB (‡), and wavelength accuracy better than 0,05 nm (‡). The linearity should be better than 0,2 dB (‡) over the device dynamic range. The reflectance from this device shall be smaller than –50 dB (‡) at its input port. The OSA shall have sufficient dynamic range to measure the noise between channels. For 100 GHz (0,8 nm) channel spacing, the dynamic range shall be greater than 55 dB at 50 GHz (0,4 nm) from the signal.

4.5 Optical power meter

This device shall have a measurement accuracy better than 0,2 dB (‡), irrespective of the state of polarization, within the operational wavelength bandwidth of the OA and within the power range from –40 dBm to +20 dBm (‡).

4.6 Broadband optical source

This device shall provide broadband optical power over the operational wavelength bandwidth of the OA (for example, 1 530 nm to 1 565 nm). The output spectrum shall be flat with less than a 0,1 dB (‡) variation over the measurement bandwidth range (typically 10 nm). For example, the ASE generated by an OA with no signal applied could be used.

4.7 Optical connectors

The connection loss repeatability shall be better than 0,1 dB (‡). The reflectance from this device shall be smaller than –50 dB (‡).

4.8 Optical fibre jumpers

The mode field diameter of the optical fibre jumpers shall be as close as possible to that of the fibres used as input and output ports of the OA. The reflectance from this device shall be smaller than –50 dB (‡), and the device length shall be short (< 2m). The jumpers between the source and the device under test should remain undisturbed during the duration of the measurements in order to minimize state of polarization changes.

Subsequently, the combination of the multichannel optical source, the variable optical attenuator, and the input polarization controller shall be referred to as the *source module.* The polarization controller of the source module is optional and is required only when polarization dependent performances are to be measured.

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, use of optical isolators is recommended to bracket the OA under test. This will minimize the signal instability and the measurement inaccuracy.

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

6 Procedure

This method is based on the optical measurement of the following parameters:

- the signal power level for each channel at the input of the OA under test;
- the signal power level for each channel at the output of the OA under test;
- the ASE power level for each channel at the output of the OA under test;
- the SSE power level for each channel at the input of the OA under test; and
- the optical bandwidth of the OSA.

The noise-equivalent bandwidth of the OSA is required for the calculation of ASE power density. If not specified by the manufacturer to sufficient accuracy, it may be calibrated using one of the two methods below. The noise-equivalent bandwidth of a wavelength filter is the bandwidth of a theoretical filter with rectangular pass-band and the same transmission at the centre wavelength that would pass the same total noise power as the actual filter when the source power density is constant versus wavelength.

6.1 Calibration

6.1.1 Calibration of optical bandwidth

The noise-equivalent bandwidth, B_o, can be determined with the following methods. The calibration can be performed using one of the following two methods, based on the use of either a tuneable narrowband or a broadband optical source, respectively.

6.1.1.1 Calibration using a narrowband optical source

The steps listed below shall be followed.

a) Connect the output of a tuneable narrowband optical source directly to the OSA.

b) Set the OSA centre wavelength to the signal wavelength to be calibrated, λ_S.

c) Set the OSA span to zero (fixed wavelength).

d) Set the OSA resolution bandwidth to the desired value, RBW.

e) Set the narrowband optical source wavelength to λ_i, within the range from $\lambda_S - RBW - \delta$ to $\lambda_S + RBW + \delta$, choosing δ large enough to ensure that the end wavelengths fall out of the OSA filter pass-band.

f) Record the OSA signal level, $P(\lambda_i)$, in linear units.

g) Repeat steps e) and f), incrementing the narrowband optical source wavelength through the wavelength range by the tuning interval, $\Delta\lambda$, selected according to the accuracy requirements as described below.

h) Determine the optical bandwidth according to the following equation:

$$\Delta\lambda_{BW}(\lambda_S) = \sum_i \frac{P(\lambda_i)}{P(\lambda_S)} \Delta\lambda \qquad (1)$$

The procedure may be repeated for different signal wavelengths, or for each wavelength of the multichannel source.

The accuracy of this measurement is related to the tuning interval of the narrowband optical source ($\Delta\lambda$) and power flatness over the wavelength range. A tuning interval smaller than 0,1 nm is advisable. The optical power should not vary more than 0,4 dB over the wavelength range.

6.1.1.2 Calibration using a broadband optical source

This method requires that the OSA have a rectangular shape bandwidth-limiting filter, when the resolution bandwidth is at the maximum value. The steps listed below shall be followed.

a) Connect the output of a narrowband optical source directly to the OSA. If adjustable, as in the case of a tuneable laser, set the wavelength of the source to a specific wavelength, λ_S.

b) Set the OSA resolution bandwidth to the maximum value, preferably not larger than 10 nm.

c) Using the OSA, measure the FWHM by scanning over the narrowband signal, $\Delta\lambda_{RBWmax}$.

d) Connect the output of a broadband optical source directly to the OSA.

e) Keep the OSA resolution bandwidth at the maximum value.

f) Using the OSA, measure the output power level, P_{RBWmax} (in linear units), at the given wavelength, λ_S.

g) Set the OSA resolution bandwidth to the desired value.

h) Using the OSA, measure the output power level, P_{RBW} (in linear units), at the given wavelength, λ_S.

i) Determine the optical bandwidth according to the following equation:

$$\Delta\lambda_{BW}(\lambda_S) = \frac{P_{RBW}}{P_{RBWmax}} \Delta\lambda_{RBW}(\lambda_S) \quad (2)$$

j) The procedure may be repeated for different signal wavelengths, or for each wavelength of the multichannel source.

For both methods, the following approximate equation permits converting the optical bandwidth from the wavelength domain, $\Delta\lambda_{BW}(\lambda_S)$, to the frequency domain, $B_o(\lambda_S)$:

$$B_o(\lambda_S) = c\left[(\lambda_s - \Delta\lambda_{BW}(\lambda_s)/2)^{-1} - (\lambda_s + \Delta\lambda_{BW}(\lambda_s)/2)^{-1}\right] \quad (3)$$

where c is the speed of light in free space.

NOTE 1 Once this value is determined, all OSA measurements are made with the same resolution bandwidth setting as calibrated above, taking into consideration the optical filter in the OSA, if present. A resolution bandwidth must be chosen such that the dynamic range is adequate to measure ASE between channels.

NOTE 2 If a narrow optical filter is included in the OA, then the OA should be included in the path between the source and the OSA when calibrating $B_o(\lambda_s)$. The resolution bandwidth setting must be smaller than the optical filter bandwidth.

NOTE 3 It is assumed that the measurement at the maximum resolution bandwidth, $\Delta\lambda_{RBWmax}$, is accurate.

6.1.2 Calibration of OSA power correction factor

Follow the steps listed below to calibrate the OSA power correction factor (PCF). The power correction factor calibrates the OSA for absolute power.

a) Adjust the source module for a single channel at signal wavelength, λ_S. Connect the output of the source module directly to the input of the optical power meter, and measure P_{PM} (in dBm).