PUBLICLY AVAILABLE SPECIFICATION

IEC PAS 62129

Pre-Standard

First edition
2004-03

Calibration of optical spectrum analyzers

Reference number
IEC/PAS 62129:2004(E)

Publication numbering

As from 1 January 1997 all IEC publications are issued with a designation in the 60000 series. For example, IEC 34-1 is now referred to as IEC 60034-1.

Consolidated editions

The IEC is now publishing consolidated versions of its publications. For example, edition numbers 1.0, 1.1 and 1.2 refer, respectively, to the base publication, the base publication incorporating amendment 1 and the base publication incorporating amendments 1 and 2.

Further information on IEC publications

The technical content of IEC publications is kept under constant review by the IEC, thus ensuring that the content reflects current technology. Information relating to this publication, including its validity, is available in the IEC Catalogue of publications (see below) in addition to new editions, amendments and corrigenda. Information on the subjects under consideration and work in progress undertaken by the technical committee which has prepared this publication, as well as the list of publications issued, is also available from the following:

- **IEC Web Site (www.iec.ch)**

- **Catalogue of IEC publications**

  The on-line catalogue on the IEC web site (www.iec.ch/searchpub) enables you to search by a variety of criteria including text searches, technical committees and date of publication. On-line information is also available on recently issued publications, withdrawn and replaced publications, as well as corrigenda.

- **IEC Just Published**

  This summary of recently issued publications (www.iec.ch/online_news/ justpub) is also available by email. Please contact the Customer Service Centre (see below) for further information.

- **Customer Service Centre**

  If you have any questions regarding this publication or need further assistance, please contact the Customer Service Centre:

  Email: custserv@iec.ch
  Tel: +41 22 919 02 11
  Fax: +41 22 919 03 00

PUBLICLY AVAILABLE SPECIFICATION

IEC PAS 62129

Pre-Standard

First edition
2004-03

Calibration of optical spectrum analyzers

International Electrotechnical Commission, 3, rue de Varembé, PO Box 131, CH-1211 Geneva 20, Switzerland
Telephone: +41 22 919 02 11 Telefax: +41 22 919 03 00 E-mail: inmail@iec.ch Web: www.iec.ch

Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

PRICE CODE X

For price, see current catalogue

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

CALIBRATION OF OPTICAL SPECTRUM ANALYZERS

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.

2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.

3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.

4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.

5) IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with an IEC Publication.

6) All users should ensure that they have the latest edition of this publication.

7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.

8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

A PAS is a technical specification not fulfilling the requirements for a standard but made available to the public.

IEC-PAS 62129 has been prepared by IEC technical committee 86: Fibre optics.

The text of this PAS is based on the following document:	This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document
Draft PAS	**Report on voting**
86/202/NP	86/214/RVN

Following publication of this PAS, which is a pre-standard publication, the technical committee or subcommittee concerned will transform it into an International Standard.

CALIBRATION OF OPTICAL SPECTRUM ANALYZERS

1 Scope

This document provides procedures for calibrating an optical spectrum analyzer designed to measure the power distribution of an optical spectrum; this analyzer is equipped with an input port for use with a fibre-optic connector.

An optical spectrum analyzer is equipped with the following minimum features:

a) the ability to present a display of an optical spectrum with respect to absolute wavelength;

b) a marker/cursor that displays the optical power and wavelength at a point on the spectrum display.

NOTE This specification applies to optical spectrum analyzers developed for use in fibre-optic communications and is limited to equipment that can directly measure the optical spectrum output from an optical fibre, where the optical fibre is connected to an input port installed in the optical spectrum analyzer through a fibre-optic connector.

In addition, an optical spectrum analyzer can measure the spectral power distribution with respect to the absolute wavelength of the tested light and display the results of such measurements; it will not include an optical wavelength meter that measures only centre wavelengths, a Fabry-Perot interferometer or a monochromator that has no display unit.

The procedures outlined in this document are considered to be mainly performed by users of optical spectrum analyzers. The document, therefore, does not include correction using the calibration results in the main body. The correction procedures are described in Annex C. Of course, this document will be useful in calibration laboratories and for manufacturers of optical spectrum analyzers.

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 60050-731:1991, *International Electrotechnical Vocabulary (IEV) – Chapter 731: Optical fibre communication*

IEC 60359:2001, *Electrical and electronic measurement equipment – Expression of performance*

IEC 60793-1(all parts), *Optical fibres – Part 1: Measurement methods and test procedures*

IEC 60825-1:1993, *Safety of laser products – Part 1: Equipment classification, requirements and user's guide*

IEC 60825-2:2000, *Safety of laser products – Part 2: Safety of optical fibre communication systems*

IEC 61290-3-1:2003, *Optical amplifiers – Test methods – Part 3-1: Noise figure parameters – Optical spectrum analyzer method*

ISO 9000*: Quality management systems – Fundamentals and vocabulary*

ISO:1995, *Guide to the expression of uncertainty in measurement*

ISO:1993, *International vocabulary of basic and general terms in metrology*

3 Definitions

For the purposes of this document, the definitions contained in IEC 60050-731 and the following definitions apply.

3.1
calibration
set of operations which establishes, under specified conditions, the relationship between the values indicated by the measuring instrument and the corresponding known values of that quantity (see also ISO International vocabulary of basic and general terms in metrology, definition 6.11)

3.2
calibration under reference conditions
calibration which includes the evaluation of the test analyzer uncertainty under **reference conditions** (3.17)

3.3
calibration for operating conditions
calibration for operating conditions of an **optical spectrum analyzer** (3.16) including the evaluation of the test analyzer operational uncertainty

3.4
centre wavelength
$\boldsymbol{\lambda_{centre}}$
power-weighted mean wavelength of a light source in a vacuum, in nanometers (nm)

For a continuous spectrum, the centre wavelength is defined as

$$\lambda_{centre} = (1 / P_{total}) \int \rho(\lambda)\, \lambda \, d\lambda \qquad (1)$$

For a spectrum consisting of discrete lines, the centre wavelength is defined as

$$\lambda_{centre} = \sum_i P_i \lambda_i \, / \sum_i P_i \qquad (2)$$

where

$\rho(\lambda)$ is the power spectral density of the source, for example in W/nm;

λ_i is the i^{th} discrete wavelength;

P_i is the power at λ_i, for example, in watts;

P_{total} is ΣP_i = total power, for example, in watts.

NOTE The above integrals and summations theoretically extend over the entire spectrum of the light source.

3.5
confidence level
estimation of the probability that the true value of a measured parameter lies in the given range (see **expanded uncertainty** (3.11))

3.6
coverage factor
k
coverage factor, k, is used to calculate the **expanded uncertainty** (3.11) U from the **standard uncertainty** (3.21), σ (see 3.11)

3.7
displayed power level
DPL
power level indicated by an **optical spectrum analyzer** (3.16) undergoing **calibration** (3.1) at a specified wavelength resolution setting

NOTE With an **optical spectrum analyzer**, the power level for a set resolution is measured and displayed.

3.8
displayed power level deviation
ΔP
difference between the displayed power level measured by the test analyzer, P_{OSA}, and the corresponding reference power, P_{ref}, divided by the reference power

$$\Delta P = (P_{OSA} - P_{ref}) / P_{ref} = P_{OSA} / P_{ref} - 1 \qquad (3)$$

3.9
displayed power level uncertainty, symbol $\sigma_{\Delta P}$
standard uncertainty (3.21) of the displayed power level deviation

$$\sigma_{\Delta P} = \sigma(P_{OSA} / P_{ref} - 1) \qquad (4)$$

NOTE In the above formula, σ is to be understood as the **standard uncertainty** (3.21).

3.10
displayed wavelength range
complete wavelength range shown in an **optical spectrum analyzer** (3.16) display for a particular **instrument state** (3.12)

3.11
expanded uncertainty
U
expanded uncertainty, U (also called the confidence interval) is the range of values within which the measurement parameter, at the stated **confidence level** (3.5), can be expected to lie. It is equal to the **coverage factor** (3.6), k, times the combined **standard uncertainty** (3.21) σ:

$$U = k\,\sigma \qquad (5)$$

NOTE When the distribution of uncertainties is assumed to be normal and a large number of measurements are made, then **confidence levels** (3.5) of 68,3 %, 95,5 % and 99,7 % correspond to k values of 1, 2 and 3 respectively.

The measurement uncertainty of an **optical spectrum analyzer** (3.16) should be specified in the form of expanded uncertainty, U.

3.12
instrument state
complete description of the measurement conditions and state of an **optical spectrum analyzer** (3.16) during the calibration process

NOTE Typical parameters of the instrument state are the **displayed wavelength range** (3.10) in use, the **resolution bandwidth (spectral resolution)** (3.18), the display mode (watt or dBm), warm-up time and other instrument settings.

3.13
measurement result
displayed or electrical output of any **optical spectrum analyzer** (3.16) in wavelength, in units of nm or µm, and in power level, in units of mW or dBm, after completing all operations suggested by the operating instructions, for example warm-up

3.14
measurement wavelength range
wavelength range of injected light over which an **optical spectrum analyzer** (3.16) performance is specified

3.15
operating conditions
all conditions of the measured and influential qualities, and other important requirements which the **expanded uncertainty** (3.11) of an **optical spectrum analyzer** (3.16) is intended to be met (modified from ISO International vocabulary of basic and general terms in metrology, definition 5.5)

3.16
optical spectrum analyzer
OSA
optical instrument for measuring the power distribution of a spectrum with respect to wavelength (frequency)

NOTE An OSA is equipped with an input port for use with a fibre-optic connector, and the spectrum is obtained from light injected into the input port; the instrument also includes a screen-display function.

3.17
reference conditions
appropriate set of influencing parameters, their nominal values and their tolerance bands, with respect to which the uncertainty at reference conditions is specified (modified from IEC 60359, 3.3.10)

NOTE Each tolerance band includes both the possible uncertainty of the condition and the uncertainty in measuring the condition.

The reference conditions normally include the following parameters and, if necessary, their tolerance bands: reference date, reference temperature, reference humidity, reference atmospheric pressure, reference light source, reference **displayed power level** (3.7), reference fibre, reference connector-adapter combination, reference wavelength, reference (spectral) bandwidth and **resolution bandwidth (spectral resolution)** (3.18) set.

3.18
resolution bandwidth (spectral resolution)
R
full width at half maximum (FWHM) of the displayed spectrum obtained by the test analyzer when using a source whose **spectral bandwidth** (3.20) is sufficiently narrow, that is, very much less than the resolution bandwidth being measured

3.19
side-mode suppression ratio
SMSR
peak power ratio between the main mode spectrum and the largest side mode spectrum in a single-mode laser diode such as a DFB-LD

NOTE The side-mode suppression ratio is usually described in dB.

3.20
spectral bandwidth
B
for the purpose of this document, the FWHM of the spectral width of the source.

If the source exhibits a continuous spectrum, then the spectral bandwidth, *B*, is the FWHM of the spectrum.

If the source is a laser diode with a multiple-longitudinal mode spectrum, then the FWHM spectral bandwidth B is the RMS spectral bandwidth, multiplied by 2,35 (assuming the source has a Gaussian envelope):

$$B = 2{,}35\ [\{(1\ /\ P_{\text{total}}) \times \left[\sum_i P_i \lambda_i^2\right]\} - \lambda_{\text{centre}}^2]^{1/2} \qquad (6)$$

where

λ_{centre} is the **centre wavelength** (3.4) of laser diode, in nm;

P_{total} is $\sum P_i$ = total power, in watts;

P_i is the power of i^{th} longitudinal mode, in watts;

λ_i is the wavelength of i^{th} longitudinal mode, in nm.

3.21
standard uncertainty
σ
uncertainty of a measurement result expressed as a standard deviation

NOTE For further information, see Annex A and the ISO Guide to the expression of uncertainty in measurement.

3.22
uncertainty type A
type of uncertainty obtained by a statistical analysis of a series of observations, such as when evaluating certain random effects of measurement (see ISO Guide to the expression of uncertainty in measurement)

3.23
uncertainty type B
type of uncertainty obtained by means other than a statistical analysis of observations, for example an estimation of probable sources of uncertainty, such as when evaluating systematic effects of measurement (see ISO Guide to the expression of uncertainty in measurement)

NOTE Other means may include previous measurement data, experience with or general knowledge of the behaviour and properties of relevant materials, instruments, manufacturers' specifications, data provided in calibration and other certificates, and uncertainties assigned to reference data taken from handbooks.

3.24
wavelength deviation
$\Delta\lambda$
difference between the **centre wavelength** (3.4) measured by the test analyzer, λ_{OSA}, and the reference wavelength, λ_{ref}, in nm or µm

$$\Delta\lambda = \lambda_{OSA} - \lambda_{ref} \qquad (7)$$

3.25
wavelength uncertainty
$\sigma_{\Delta\lambda}$
standard uncertainty (3.21) of the **wavelength deviation** (3.24), in nm or µm

4 Calibration test requirements

4.1 Preparation

The following recommendations apply.

Calibrations should be carried out in facilities that are separate from other functions of the organization. This separation should include laboratory accommodation and measurement equipment.

The calibration laboratory should operate a quality control system appropriate to the range of measurement it performs (for example, ISO 9000), when the calibration is performed in calibration laboratories. There should be independent scrutiny of the measurement results, intermediary calculations and preparation of calibration certificates.

The environmental conditions shall be commensurate with the degree of uncertainty that is required for calibration:

a) the environment shall be clean;

b) temperature monitoring and control is required;

c) all laser sources shall be safely operated (see IEC 60825-1).

Perform all tests at an ambient room temperature of 23 °C ± 3 °C with a relative humidity of (50 ± 20) % unless otherwise specified. Give the test equipment a minimum of 2 h prior to testing to reach equilibrium with its environment. Allow the optical spectrum analyzer a warm-up period in accordance with the manufacturer's instructions.

4.2 Reference test conditions

The reference test conditions usually include the following parameters and, if necessary, their tolerance bands: date, temperature, relative humidity, displayed power level, wavelength, light source, fibre, connector-adapter combination, (spectral) bandwidth and resolution bandwidth (spectral resolution) set. Unless otherwise specified, use a single-mode optical fibre input pigtail as prescribed by IEC 60793-1, having a length of at least 2 m.

Operate the optical spectrum analyzer in accordance with the manufacturer's specifications and operating procedures. Where practical, select a range of test conditions and parameters which emulate the actual field operating conditions of the analyzer under test. Choose these parameters so as to optimize the accuracy of the analyzer and resolution capabilities, as specified by the manufacturer's operating procedures.

Document the conditions as specified in Clause 8.

NOTE 1 The calibration results only apply to the set of test conditions used in the calibration process.

NOTE 2 Because of the potential for hazardous radiation, be sure to establish and maintain conditions of laser safety. Refer to IEC 60825-1 and IEC 60825-2.

4.3 Traceability

Make sure that any test equipment which has a significant influence on the calibration results is calibrated in an unbroken chain to the appropriate national standard or natural physical constant. Upon request, specify this test equipment and its calibration chain(s). The re-calibration period(s) shall be defined and documented.

5 Resolution bandwidth (spectral resolution) test

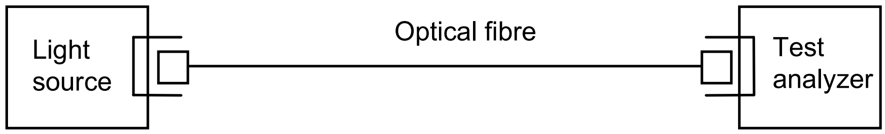
5.1 Overview

The resolution bandwidth (spectral resolution) of the test analyzer should be tested prior to displayed power level and wavelength calibration because the resolution bandwidth influences their calibration. This test is performed under reference calibration conditions. Wavelength is shown in a vacuum.

NOTE The result of the resolution bandwidth (spectral resolution) test described here should be employed as the optical bandwidth (in wavelength units) for the measurement of optical-amplifier noise-figure. The calibration of optical bandwidth is described in IEC 61290-3-1.

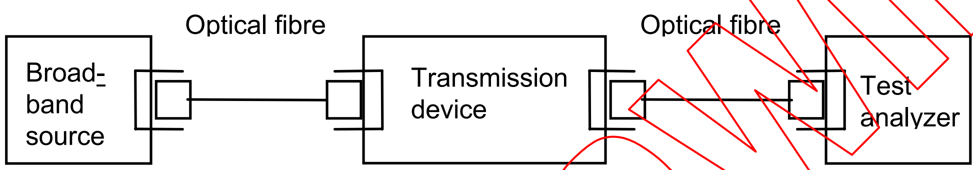
5.2 Resolution bandwidth (spectral resolution) test

Alternative set-ups for the resolution bandwidth are shown in Figures 1, 2, and 3. In the Figure 1 set-up, a gas laser whose wavelength is known is used as the light source. Figure 2 shows a set-up in which a broadband source is used in conjunction with a transmission device with known (traceable) wavelengths of peak (or null) transmission. Figure 3 shows a set-up in which a laser diode (LD) whose wavelength is unknown is used for the light source.



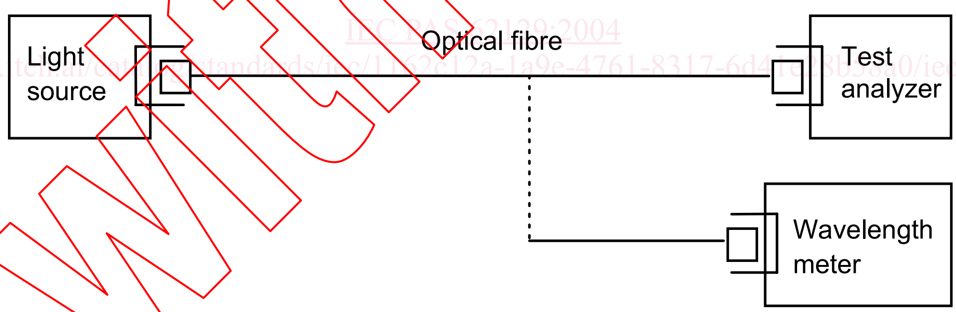
a) for resolution bandwidth test,
b) for wavelength calibration under reference conditions, and
c) for determining the wavelength dependence of wavelength uncertainty.

Figure 1 – Set-up using a gas laser whose wavelength is known



a) for resolution bandwidth test,
b) for wavelength calibration under reference conditions, and
c) for determining the wavelength dependence of wavelength uncertainty.

Figure 2 – Set-up using a broadband source with a transmission device



a) for resolution bandwidth test,
b) for wavelength calibration under reference conditions, and
c) for determining the wavelength dependence of wavelength uncertainty.

Figure 3 – Set-up using an LD with an unknown wavelength

5.2.1 Equipment for resolution bandwidth (spectral resolution) test

a) **Light source:** use the light source prescribed for calibrating the test analyzer; if a light source is not prescribed, use one with a spectral bandwidth and wavelength stability sufficient for the minimum resolution bandwidth prescribed for the test analyzer.

Recommended light sources are lasers such as those listed in Table 1, a laser diode (LD) or other laser (which may be tunable) having a spectral bandwidth much narrower than the resolution bandwidth of the test analyzer. Also, a broadband source may be used in conjunction with a transmission device with known (traceable) wavelengths of peak (or null) transmission. The transmission device may be, for example, a series of fixed narrowband filters, absorption lines in gaseous media, or Fabry-Perot interferometers. Annex D tabulates many stable wavelength references. The reference used should have a wavelength stability, spectral bandwidth, and power stability sufficient for the resolution bandwidth test.

Table 1 – Recommended light sources

Light source	Wavelength (nm) [vac]
Ar laser	488,122
	514,673
He-Ne laser	632,991
	1152,590
	1523,488

b) **Wavelength meter:** an instrument for measuring the wavelength of a light source. Its precision must be sufficiently better than the precision required in the wavelength test. This instrument is used when a laser diode (LD) with an unknown wavelength is used as the light source.

c) **Optical fibre:** single-mode optical fibre as prescribed by IEC 60793-1.

5.2.2 Test procedure for resolution bandwidth (spectral resolution)

Using the test set-up shown in Figure 1, 2 or 3, set the wavelength measurement range of the test analyzer so that it includes the wavelength of the light source.

a) Set the resolution bandwidth of the test analyzer to its specified value. Let the specified value be R_{set}.

b) Measure the resolution of the displayed spectral bandwidth, that is, the wavelength interval 3 dB below the peak value, as R_{OSAi}. Repeat this measurement at least ten times and calculate the average resolution.

$$R_{OSA} = \sum_{i=1}^{m} R_{OSAi} \ / \ m \qquad (8)$$

where m is the number of measurements.

c) Calculate the difference ratio of the OSA value from the resolution bandwidth setting using equation (9).

$$\Delta r_{diff} = R_{OSA} \ / \ R_{set} - 1 \qquad (9)$$

d) If necessary, repeat this procedure with different resolution bandwidth settings.

NOTE 1 When the test analyzer has a wavelength span linearity error, it is necessary to tune the light source slightly around the wavelength of interest, while making multiple measurements of the displayed 3 dB bandwidth to obtain an accurate measurement of the true resolution bandwidth at a given wavelength. The required tuning range is of the order of ±1 nm, so this measurement can be made with a temperature-tuned DFB laser, an external cavity laser or a tunable fibre laser. By averaging the resolution bandwidth readings, a more accurate measurement of the true resolution bandwidth can be obtained.

NOTE 2 If the resolution bandwidth should be corrected on the basis of the calibration results, this is typically implemented by making software corrections to the instrument, mathematical corrections to the results, or instrument hardware adjustments. Once the adjustments have been made, it is advisable to repeat the test to verify that the correction has operated correctly. See Annex C.