

Calibration of optical spectrum analyzers

ICS 33.180.30

National foreword

This British Standard is the UK implementation of EN 62129:2006, incorporating corrigendum December 2006. It is identical with IEC 62129:2006. It supersedes PD IEC/PAS 62129:2004 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/86, Fibre optics.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 May 2006

© BSI 2008

ISBN 978 0 580 60811 7

Amendments/corrigenda issued since publication

Amd No.	Date	Comments
16488 Corrigendum No.1	30 June 2006	Correction to formatting errors at printing stage
	31 March 2008	Implementation of CENELEC corrigendum December 2006 (change to EN Foreword and addition of Annex ZA)

English version

**Calibration of optical spectrum analyzers
(IEC 62129:2006)**

Etalonnage des analyseurs
de spectre optique
(CEI 62129:2006)

Kalibrierung von optischen
Spektrumanalysatoren
(IEC 62129:2006)

This European Standard was approved by CENELEC on 2006-02-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

© 2006 CENELEC - All rights of exploitation in any form and by any means reserved worldwide for CENELEC members.

Ref. No. EN 62129:2006 E



Documents

Document Sharing Hub

Foreword

The text of document 86/245/FDIS, future edition 1 of IEC 62129, prepared by IEC TC 86, Fibre optics, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 62129 on 2006-02-01.

The following dates were fixed:

- latest date by which the EN has to be implemented
at national level by publication of an identical
national standard or by endorsement (dop) 2006-11-01
- latest date by which the national standards conflicting
with the EN have to be withdrawn (dow) 2009-02-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 62129:2006 was approved by CENELEC as a European Standard without any modification.

CONTENTS

FOREWORD	2
1 Scope	5
2 Normative references	5
3 Terms and definitions	6
4 Calibration test requirements	10
4.1 Preparation	10
4.2 Reference test conditions	10
4.3 Traceability	10
5 Resolution bandwidth (spectral resolution) test	11
5.1 Overview	11
5.2 Resolution bandwidth (spectral resolution) test	11
6 Displayed power level calibration	13
6.1 Overview	13
6.2 Displayed power level (DPL) calibration under reference conditions	14
6.3 Displayed power level (DPL) calibration for operating conditions	16
6.4 Calculation of expanded uncertainty in displayed power level	21
7 Wavelength calibration	22
7.1 Overview	22
7.2 Wavelength calibration under reference conditions	23
7.3 Wavelength calibration for operating conditions	24
7.4 Calculation of expanded uncertainty in wavelength	26
8 Documentation	27
8.1 Measurement data and uncertainty	27
8.2 Measurement conditions	27
Annex A (normative) Mathematical basis for calculation of calibration uncertainty	28
Annex B (informative) Examples of calculation of calibration uncertainty	32
Annex C (informative) Using the calibration results	40
Annex D (informative) Wavelength references	45
Annex E (informative) Further reading and references for calibration of wavelength scale ..	50
Annex ZA (normative) Normative references to international publications with their corresponding European publications	51
Figure 1 – Setup using a gas laser whose wavelength is known	11
Figure 2 – Setup using a broadband source with a transmission device	11
Figure 3 – Setup using an LD with an unknown wavelength	12
Figure 4 – Setup for calibration of displayed power level under reference conditions	14
Figure 5 – Test configuration for determining the wavelength dependence of displayed power level uncertainty	16

Figure 6 – Test configuration for determining the polarization dependence of displayed power level uncertainty	18
Figure 7 – Configuration for testing linearity error of displayed power level uncertainty	19
Figure 8 – Test configuration for determining the temperature dependence of displayed power level uncertainty	20
Figure 9 – Test configuration for determining the temperature dependence of wavelength uncertainty	26
Figure A.1 – Deviation and uncertainty type B, and how to replace both with an appropriately larger uncertainty.....	29
Figure C.1 – Calibration of OSA wavelength scale using krypton emission lines	44
Figure D.1 – Absorption of LED light by acetylene ($^{12}\text{C}_2\text{H}_2$)	47
Figure D.2 – Absorption of LED light by hydrogen cyanide ($\text{H}^{13}\text{C}^{14}\text{N}$)	48
Table 1 – Recommended light sources.....	12
Table C.1 – OSA calibration results	43
Table C.2 – Summary of OSA calibration parameters	44
Table D.1 – Vacuum wavelengths (nm) of selected gas laser lines	45
Table D.2 – Vacuum wavelengths (nm) of noble gas reference lines.....	45
Table D.3 – Vacuum wavelengths (nm) for the $\nu_1+\nu_3$ band of acetylene $^{12}\text{C}_2\text{H}_2$ absorption lines [11]	46
Table D.4 – Vacuum wavelengths (nm) for the $\nu_1+\nu_3$ band of acetylene $^{13}\text{C}_2\text{H}_2$ absorption lines [11]	47
Table D.5 – Vacuum wavelengths (nm) of selected hydrogen cyanide ($\text{H}^{13}\text{C}^{14}\text{N}$) absorption lines [12]	48

CALIBRATION OF OPTICAL SPECTRUM ANALYZERS

1 Scope

This International Standard 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 standard 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 standard 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 standard 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, *International Electrotechnical Vocabulary (IEV) – Chapter 731: Optical fibre communication*

IEC 60359, *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, *Safety of laser products – Part 1: Equipment classification, requirements and user's guide*

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

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

BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, and OIML:1993, *International vocabulary of basic terms in metrology (VIM)*

BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, and OIML, *Guide to the expression of uncertainty in measurement (GUM)*

3 Terms and definitions

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

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

3.4 centre wavelength

λ_{centre}

the power-weighted mean wavelength of a light source in a vacuum, in nanometers (nm)

For a continuous spectrum the centre wavelength is defined as:

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

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

$$\lambda_{\text{centre}} = \sum_i P_i \lambda_i / \sum_i P_i \quad (2)$$

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 $\sum P_i$ = 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

an 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

the 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

the 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

the 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

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

3.9 displayed power level uncertainty

σ_{ΔP}

the **standard uncertainty** (3.21) of the displayed power level deviation

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

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

3.10 displayed wavelength range

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

3.11 expanded uncertainty

U

confidence interval

the expanded uncertainty, *U*, 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*:

$$U = k \sigma \quad (5)$$

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

a 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**

the 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**

the 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

[VIM, definition 5.5 modified]

3.16**optical spectrum analyzer****OSA**

an 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**

an appropriate set of influencing parameters, their nominal values and their tolerance bands, with respect to which the uncertainty at reference conditions is specified

[IEC 60359, definition 3.3.10 modified]

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-adaptor combination, reference wavelength, reference (spectral) bandwidth and **resolution bandwidth (spectral resolution)** (3.18) set.

3.18**resolution bandwidth****R**

spectral resolution

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**

the 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 standard, 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):

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

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/IEC Guide to the Expression of Uncertainty in Measurement (ISO/IEC GUIDE EXPRES).

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/IEC GUIDE EXPRES)

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/IEC GUIDE EXPRES)

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

$\Delta\lambda$

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

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

3.25

wavelength uncertainty

$\sigma_{\Delta\lambda}$

the **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 (refer to IEC 60825-1).

Perform all tests at an ambient room temperature of $(23 \pm 3)^\circ\text{C}$ with a relative humidity of $(50 \pm 20)\%$ 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 the IEC 60793-1 series, 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 analyzer's accuracy and resolution capabilities, as specified by the manufacturer's operating procedures.

Document the conditions as specified in Clause 8.

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

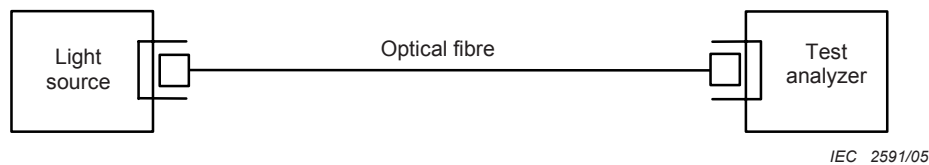
5.1 Overview

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. Calibration of optical bandwidth is described in IEC 61290-3-1.

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.

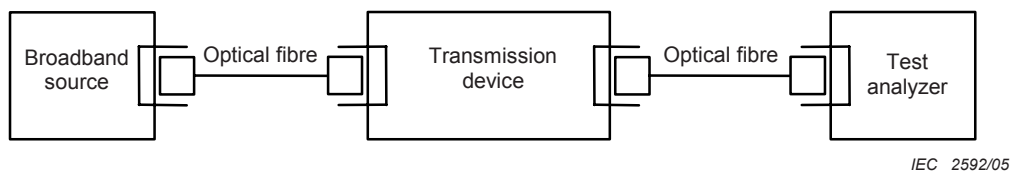
5.2 Resolution bandwidth (spectral resolution) test

Alternative setups for the resolution bandwidth are shown in Figures 1, 2, and 3. In the Figure 1 setup, a gas laser whose wavelength is known is used as the light source. Figure 2 shows a setup 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 setup in which a laser diode (LD) whose wavelength is unknown is used for the light source.



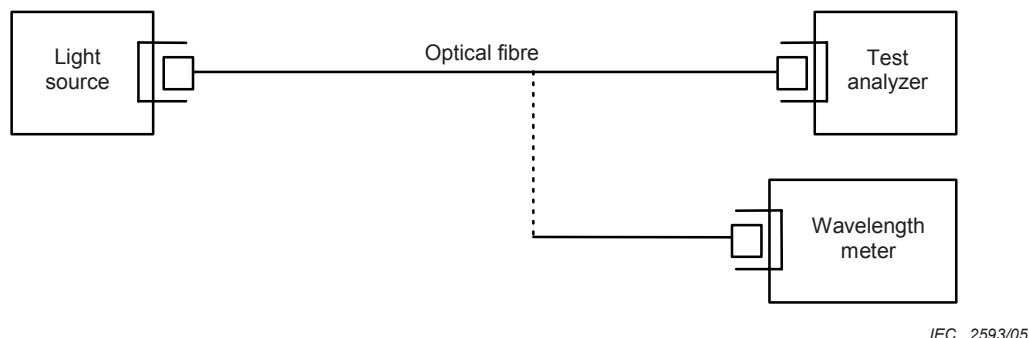
- a) For resolution bandwidth test,
- b) for wavelength calibration under reference conditions, and
- c) for determining the wavelength dependence of wavelength uncertainty.

Figure 1 – Setup 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 – Setup 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 – Setup 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
	1 152,590
	1 523,488

- 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 the IEC 60793-1 series.

5.2.2 Test procedure for resolution bandwidth (spectral resolution)

Using the test setup 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} .
- d) Measure the resolution of the displayed spectral bandwidth, i.e. the wavelength interval 3 dB below the peak value, as $R_{\text{OSA}i}$. Repeat this measurement at least ten times and calculate the average resolution.

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

where m is the number of measurements.

- e) Calculate the difference ratio of the OSA value from the resolution bandwidth setting using Equation (9).

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

- f) 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 must be corrected based on 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.

6 Displayed power level calibration

6.1 Overview

The factors making up uncertainty in the displayed power level of the test analyzer consist of

- a) the intrinsic uncertainty of the test analyzer as found in the test under reference conditions, and
- b) partial uncertainties due to wavelength dependence, polarization dependence, linearity and temperature dependence as found in tests under operating conditions.

If the test analyzer is used beyond the reference conditions, it is necessary to obtain the partial uncertainties.

The intrinsic uncertainty under the reference conditions is obtained by the calibration procedure described in 6.2. The partial uncertainties are obtained by the calibration procedure described in 6.3.1 to 6.3.4 in compliance with the individual factor, i.e. wavelength, polarization, linearity and temperature. When the test analyzer is only used under reference conditions, the calibration procedures described in 6.3 are not essential, that is, they are not mandatory.

NOTE 1 Since the unit generally used for measurement values, dBm, is not appropriate for uncertainty accumulation, linear units (mW, μ W) are used. Results of such accumulations can be converted back to dB to express overall uncertainty when needed.

NOTE 2 A power meter or a reference power meter will be needed to check the light source power each time a new source wavelength is used.

NOTE 3 The state of polarization should not be changed during calibration except controlling by an optional polarization controller.

6.2 Displayed power level (DPL) calibration under reference conditions

Figure 4 shows the test configuration for determining the uncertainty in the displayed power level (DPL). This test is performed under reference calibration conditions.

NOTE The light source used for the displayed power level calibration should be depolarized, or else a polarization controller should be used. This will calibrate the test analyzer at the mid-point of its variation due to polarization

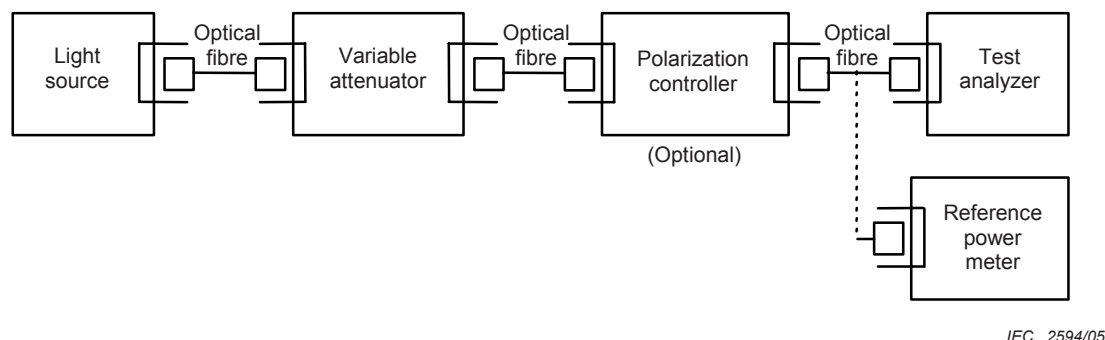


Figure 4 – Setup for calibration of displayed power level under reference conditions

6.2.1 Equipment for DPL calibration under reference conditions

- a) **Light source:** use a light source which can emit stable optical-fibre light with an output from 0,1 mW (–10 dBm) to 1 mW (0 dBm), and which offers good suppression of side-modes and optical noise (>40 dB, when measured with a resolution bandwidth which is the same as that of the test analyzer) outside its spectral bandwidth. The source spectral bandwidth should be in turn sufficiently narrower than the resolution prescribed for the test analyzer. The light sources shown in Table 1, a laser diode (LD) (SMSR > 40 dB: see 3.19) or a fibre laser (also with SMSR > 40 dB) are recommended.

NOTE The wavelength of the light source should be measured in advance by using a wavelength meter if a laser diode (LD) or a fibre laser is used.

- b) **Variable attenuator:** use a variable attenuator that can be adjusted over the optical power range used in the test.
- c) **Reference optical power meter:** either of the following operated under reference calibration conditions:
- 1) an optical power meter calibrated by an official institution that performs calibration services with a stated uncertainty; or
 - 2) an optical power meter calibrated according to standards specified by such an official institution with a stated uncertainty.

Namely the uncertainty of the reference power meter, σ_{PPM} , is already known and is described in its certification.

- d) **Optional polarization controller:** a polarization controller is used which controls the state of polarization of incident light to obtain an optical fibre output with an extinction ratio of 20 dB or more. The level variation when the state of polarization is changed should be far smaller than the polarization dependence of the test analyzer. Some polarization controllers are combinations of a polarizer, a 1/2-wavelength plate and a 1/4-wavelength plate; some rotate two fibre loops.

6.2.2 Test procedure for DPL calibration under reference conditions

Using the test configuration shown in Figure 5, set the resolution of the test analyzer sufficiently larger than the spectral bandwidth of the light source. Adjust the variable attenuator so that the power level of the outgoing light to the test analyzer is optimized. If the wavelength of the light source is not already known, it should be measured by using a wavelength meter.

The measurement sequence is as follows.

- a) Measure the value of the outgoing optical-fibre light as $P_{REF,i}$ using a reference optical power meter. If a polarization controller is used, measure multiple times at different states of polarization and average these values.
- b) After this, connect the outgoing optical-fibre light to the test analyzer and read the peak power level measured by the test analyzer as P_{OSAi} ; use a linear scale (in units of mW or μ W) to read the value. If a polarization controller is used, measure multiple times at different states of polarization and average these values.
- c) Calculate the difference ratio of the OSA value from the power meter measurement using Equation (10).

$$\Delta P_{diff,i} = P_{OSAi} / P_{REF,i} - 1 \quad (10)$$

- d) Repeat this measurement at least ten times.

6.2.3 Calculation of DPL uncertainty under reference conditions

Calculate the mean and standard deviation of the difference ratio using the following equations.

$$\Delta P_{diff} = \sum_{i=1}^m (\Delta P_{diff,i}) / m \quad (11)$$

$$\sigma_{\Delta P_{diff}} = \left[\sum_{i=1}^m (\Delta P_{diff,i} - \Delta P_{diff})^2 / (m - 1) \right]^{1/2} \quad (12)$$

where m is the number of measurements used.

The uncertainty $\sigma_{\Delta P_{ref}}$ with respect to the displayed power level for the test analyzer operated under reference calibration conditions is given by Equation (13).

$$\sigma_{\Delta P_{ref}} = (\sigma_{PPM}^2 + \sigma_{\Delta P_{diff}}^2)^{1/2} \quad (13)$$

where

σ_{PPM} is the uncertainty of the reference optical power meter described in its certification;

$\sigma_{\Delta P_{diff}}$ is the standard deviation of the values measured during the test.

The displayed power level deviation ΔP_{ref} is given by Equation (14), which is the same as the mean value of the difference ratio.

$$\Delta P_{ref} = \Delta P_{diff} \quad (14)$$