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INTERNATIONAL STANDARD

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Fibre optic communication subsystem test procedures – Part 1-3: General communication subsystems – Measurement of central wavelength, spectral width and additional spectral characteristics

Procédures d'essai des sous-systèmes de télécommunication fibroniques – Partie 1-3: Sous-systèmes généraux de télécommunication – Mesure de la longueur d'onde centrale, de la largeur spectrale et des caractéristiques spectrales supplémentaires

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FIBRE OPTIC COMMUNICATION SUBSYSTEM TEST PROCEDURES –

Part 1-3: General communication subsystems – Measurement of central wavelength, spectral width and additional spectral characteristics

FOREWORD

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IEC 61280-1-3 has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics. It is an International Standard.

This third edition cancels and replaces the second edition published in 2010. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) addition of measurement of signal-to-source spontaneous emission ratio in 8.9;

b) change of document title to reflect the additional measurement;

c) additional information on the resolution bandwidth used in the measurement of the side-mode suppression ratio in 8.8;

d) use of a calibrated optical wavelength meter for accurate wavelength measurements of single-longitudinal mode lasers.

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

Draft	Report on voting
86C/1701/CDV	86C/1717/RVC

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts in the IEC 61280 series, published under the general title *Fibre optic communication subsystem test procedures*, 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 webstore.iec.ch in the data related to the specific document. At this date, the document will be

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- replaced by a revised edition, or
- amended.

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FIBRE OPTIC COMMUNICATION SUBSYSTEM TEST PROCEDURES –

Part 1-3: General communication subsystems – Measurement of central wavelength, spectral width and additional spectral characteristics

1 Scope

This part of IEC 61280 provides definitions and measurement procedures for several wavelength and spectral width properties of an optical spectrum associated with a fibre optic communication subsystem, an optical transmitter, or other light sources used in the operation or test of communication subsystems. This document also provides definitions and measurement procedures for side-mode suppression ratio and signal-to-source spontaneous emission ratio.

The measurement is done for the purpose of system construction and/or maintenance. In the case of communication subsystem signals, the optical transmitter is typically under modulation.

NOTE Different properties can be appropriate to different spectral types, such as continuous spectra characteristics of light-emitting diodes (LEDs), as well as multilongitudinal-mode (MLM), multitransverse-mode (MTM) and single-longitudinal mode (SLM) spectra, which are characteristic of laser diodes (LDs).

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 60825-1, *Safety of laser products – Part 1: Equipment classification and requirements*

IEC 62129-1, *Calibration of wavelength/optical frequency measurement instruments – Part 1: Optical spectrum analyzers*

IEC 62129-2, *Calibration of wavelength/optical frequency measurement instruments – Part 2: Michelson interferometer single wavelength meters*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms, definitions and abbreviated terms 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

3.1 Wavelength

NOTE The following wavelength terms provide quantitative definitions for the description of the central wavelength of a spectrum. In this document, "central wavelength" is a general category label for these terms.

3.1.1
centre wavelength
λ_0
mean of the closest spaced half-power wavelengths in an optical spectrum, one above and one below the peak wavelength

Note 1 to entry: Centre wavelength is also called "half-power mid-point".

3.1.2
half-power wavelength
λ_{3dB}
wavelength corresponding to a half-peak power value of the optical spectrum

3.1.3
peak wavelength
λ_p
wavelength corresponding to the maximum power value of the optical spectrum

3.1.4
centroidal wavelength
λ_c
mean or average wavelength of an optical spectrum

3.2 Spectral width

3.2.1
RMS spectral width
$\Delta\lambda_{rms}$
square root of the second moment of the power distribution about the centroidal wavelength

3.2.2
***n*-dB-down spectral width**
$\Delta\lambda_{n\text{-}dB}$
positive difference of the closest spaced wavelengths, one above and one below the peak wavelength λ_p, at which the spectral power density determined in a specified resolution bandwidth is n dB down from its peak value

3.2.3
full-width at half-maximum
$\Delta\lambda_{fwhm}$
positive difference of the closest spaced wavelengths, one above and one below the peak wavelength λ_p, at which the spectral power density determined in a specified resolution bandwidth is 3 dB down from its peak value

3.3 Additional spectral characteristics

3.3.1
side-mode suppression ratio
SMSR
ratio of the largest peak of the optical spectrum to the second largest peak under non-modulated (continuous wave) operating condition, which is determined in a specified wavelength resolution bandwidth (RBW), for a nominally single-longitudinal mode (SLM) spectrum

Note 1 to entry: See 8.8.

3.3.2
signal-to-source spontaneous emission ratio
SSER
ratio between the signal power and maximum source spontaneous emission (SSE) power under the non-modulated (CW) condition which is determined in a specified bandwidth

3.4 Abbreviated terms

CW	continuous wave
DFB	distributed feedback
ESD	electrostatic discharge
InGaAsP	indium gallium arsenide phosphide
LD	laser diode
LED	light-emitting diode
MLM	multi-longitudinal mode
MTM	multi-transverse mode
OSA	optical spectrum analyzer
OWM	optical wavelength meter
RBW	resolution bandwidth
RMS	root-mean-square
SLM	single-longitudinal mode
SMSR	side-mode suppression ratio
SSE	source spontaneous emission
SSER	signal-to-source spontaneous emission ratio
TLA	tuneable laser assembly
VCSEL	vertical cavity surface emitting lasers
WDM	wavelength-division multiplexing

4 Apparatus

4.1 Calibrated optical spectrum analyzer (OSA)

This special-purpose test equipment uses a dispersive spectrophotometric method to resolve and record the optical spectral distribution. The required wavelength resolution bandwidth and range depend on the type and variety of signals to be measured. Generally, LED sources have wide spectra with little structure, so a range of at least 200 nm and resolution bandwidth of 1 nm or narrower are recommended. Laser sources have much narrower spectra and can be used in wavelength-division multiplexing (WDM) applications, where more accurate determination of the wavelength is required. A resolution bandwidth of 0,1 nm or narrower is recommended, and the actual requirement is determined by the application. In any case, the sensitivity and wavelength range of the spectrum analyzer shall be sufficient to measure all of the spectrum within at least −20 dB from the peak power. For measurement of SMSR, a larger dynamic range is typically required.

OSA equipment shall be calibrated for vacuum wavelengths in order to be consistent with the calibration processes and results of IEC 62129-1. The equipment used shall have a valid calibration certificate, in accordance with the applicable quality system for the period over which the testing is done.

4.2 Calibrated optical wavelength meter (OWM)

For central wavelength measurements of SLM lasers, such as distributed feedback (DFB) lasers or tuneable laser assemblies (TLAs) for dense WDM applications, sufficient measurement accuracy is required. In this case, an optical wavelength meter based on interferometric spectroscopy can be used. The accuracy of the central wavelength measurement is generally specified for non-modulated (CW) lasers. When the SLM laser is modulated, the uncertainty of the central wavelength measurement increases with the increasing modulation frequency or symbol rate.

OWM equipment shall be calibrated in accordance with IEC 62129-2. The equipment used shall have a valid calibration certificate, in accordance with the applicable quality system for the period over which the testing is done.

4.3 Power supplies

As required for the device under test.

4.4 Input signal source or modulator

The input signal source is a signal generator or modulator with the appropriate digital or analogue signal of the system.

4.5 Test cord

Unless otherwise specified, the physical and optical properties of the test cords shall match the cable plant with which the equipment is intended to operate. The cords shall be 2 m to 5 m long and shall contain fibres with coatings which remove cladding light. Appropriate connectors shall be used. Single-mode cords shall be deployed with two 90 mm diameter loops or otherwise assure rejection of cladding modes. If the equipment is intended for multimode operation and the intended cable plant is unknown, the fibre size shall be 50/125 µm.

5 Test sample

The test sample shall be a specified fibre optic subsystem, transmitter, or light source. The system inputs and outputs shall be those normally seen by the user. The spectral width parameters are typically used for characterizing MLM and LED transmitters. The widths of MTM and SLM lasers without modulation are normally too narrow to measure with the dispersive spectral instruments used with this method. Modulated SLM transmitters have broadened linewidths for high data rates (above about 2,5 Gb/s) caused by chirp that can be measurable by this method.

Because of the potential for hazardous radiation, conditions of laser safety shall be established and maintained. Refer to IEC 60825-1.

6 Procedure (method A)

6.1 General

Method A is designed for the use of typical commercial optical spectrum analyzer instruments that allow quick measurement of spectra with 1 000 wavelength samples or more and allow for the analysis of such spectra based on all of the samples, rather than selecting for example only the samples at the peaks of mode wavelengths. The previous method using a smaller number of discrete wavelength points is included in Clause 7 as method B, for compatibility with the first edition of this document. Method A has the advantage of easier, simpler automated analysis and better representation of complex but narrow spectra, such as multi-transverse-mode vertical cavity surface emitting lasers (VCSELs). Due to its convenience and prevalence in the industry, method A is considered the reference test method.

For measurements of the central wavelength of SLM lasers, a commercial optical wavelength meter can also be used. These instruments typically allow the user to specify whether the optical signal is a continuous wave (CW) signal or a modulated communication signal. An appropriate mode should be selected according to the condition of the light signal under test. In the case of modulated SLM lasers, the uncertainty of the central wavelength measurement typically increases with increasing modulation frequency or symbol rate.

6.2 Setup

6.2.1 Use appropriate handling procedures to prevent damage from electrostatic discharge (ESD), which can cause opto-electronic devices to fail.

6.2.2 With the exception of ambient temperature, standard ambient conditions shall be used, unless otherwise specified. The ambient or reference point temperature shall be 23 °C ± 2 °C, unless otherwise specified.

6.2.3 Unless otherwise specified, apply a modulated input signal to the optical source. Allow sufficient time (according to the manufacturer's recommendation or as specified in the detail specification) for the optical source/transmitter to reach a steady-state temperature.

6.2.4 Turn the optical spectrum measuring instruments, such as the OSA or the OWM, on and allow the recommended warm-up and settling time to achieve the rated measurement performance level.

6.2.5 Connect the optical output of the optical source under test to the optical input connector of the optical spectrum measuring instrument. If the transmitter under test does not include isolation from back-reflections, as often the case at 850 nm, these reflections can cause the spectrum to be unstable and should be reduced with high return-loss connections and possibly external isolation or attenuation at the transmitter output.

6.3 Adjustment of spectrum analyzer controls

6.3.1 Using the resolution bandwidth control, select an appropriate resolution bandwidth (see 4.1). Typically, less than 1/10 of the spectral width to be measured or the finest available resolution bandwidth (0,1 nm or narrower) should be used. Set the number of data points in the acquired signal to be sure to adequately sample the detail of the optical spectrum. Typically, this is set to at least four times the sample resolution times the total measured width. For example, a 10 nm measurement span using 0,1 nm resolution bandwidth requires a minimum of 400 points in the measurement, which is given by four times the total measurement span divided by the resolution bandwidth.

6.3.2 Using the span control, select an appropriate span of wavelength range on the display section of the spectrum analyzer. Initially, select a sufficiently wide span to determine the appropriate position of the peak wavelength; then reduce and adjust the span again to fit all of the source spectrum or at least all that is within at least 20 dB of the peak power. For SLM lasers, the span may need to be changed, typically from 2 nm to 20 nm full scale, to determine the spectral width and SMSR.

6.3.3 Using the gain or reference level control, select a gain or reference level so that the amplitude of the peak output extends over the entire screen vertical scale.

6.3.4 If available, use the spectrum analyzer log-scale for amplitude measurement to achieve the maximum dynamic range

6.3.5 For OSAs that are not capable of performing the subsequent calculations in Clause 8 internally, download the measured optical spectra data to a computer for further analysis in a format that contains both the wavelength and amplitude of all points in the measurement.

6.4 Setting of optical wavelength meter

6.4.1 The optical wavelength meter is implemented with a longitudinal mode detecting function. The appropriate parameters should be set, such as threshold from the peak and excursion from the peak.

6.4.2 Generally, the optical wavelength meter is also implemented with a light signal condition setting function. The appropriate condition should be set, such as continuous wave (CW) or modulated signal.

7 Procedure (method B)

7.1 Setup

7.1.1 Use appropriate handling procedures to prevent damage from electrostatic discharge (ESD), which can cause opto-electronic devices to fail.

7.1.2 With the exception of ambient temperature, standard ambient conditions shall be used, unless otherwise specified. The ambient or reference point temperature shall be 23 °C ± 2 °C, unless otherwise specified.

7.1.3 Unless otherwise specified, apply a modulated input signal to the optical source. Allow sufficient time (according to the manufacturer's recommendation or as specified in the detail specification) for the optical source/transmitter to reach a steady-state temperature.

7.1.4 Turn the optical spectrum measuring instruments, such as the OSA or the OWM, on and allow the recommended warm-up and settling time to achieve the rated measurement performance level.

7.1.5 Connect the optical output of the optical source under test to the optical input connector of the optical spectrum measuring instrument. If the transmitter under test does not include isolation from back-reflections, as is often the case at 850 nm, these reflections can cause the spectrum to be unstable and should be reduced with high return-loss connections and possibly external isolation or attenuation at the transmitter output.

7.2 Adjustment of spectrum analyzer controls

7.2.1 Using the resolution bandwidth control, select an appropriate resolution bandwidth (see 4.1).

7.2.2 Using the span control, select an appropriate span of wavelength range on the display section of the spectrum analyzer. Initially, select the maximum span to obtain the appropriate position of the peak wavelength; then adjust the span again so that, at the selected gain, the smallest detectable output power level occupies the extreme edges of the screen horizontal scale. For SLM lasers, the span may need to be changed, typically from 2 nm to 20 nm full scale, to determine the spectral width and SMSR.

7.2.3 Using the gain or reference level control, select a gain or reference level so that the amplitude of the peak output extends over the entire screen vertical scale. If available, use the spectrum analyzer log-scale for amplitude measurement to achieve the maximum dynamic range.

7.3 Setting of optical wavelength meter

7.3.1 The optical wavelength meter is implemented with a longitudinal mode detecting function, and appropriate parameters should be set, such as threshold from the peak and excursion from the peak.

7.3.2 Generally, the optical wavelength meter is also implemented with a light signal condition setting function, and the appropriate conditions should be set, such as continuous wave (CW) or modulated signal.

7.4 Continuous LED and SLM spectra

7.4.1 Refer to Figure 1 and Figure 5 for samples of LED and SLM-LD spectrum analyzer outputs. At the end of several single measurement sweeps, ensure that the output spectrum is stable (power variation at any wavelength is ≤ 10 % or ~0,5 dB between sweeps).

7.4.2 Determine the peak wavelength, λ_p. (Most optical spectrum analyzers have a peak-search button that automatically performs this function.)

7.4.3 For LEDs, record the two half-power wavelengths on both sides of the peak wavelength that are 3 dB down from the peak amplitude. Determine the number of points to record (minimum 11), the wavelength λ_i, and the amplitude p_i for each point i in the displayed spectrum as follows.

7.4.4 On both sides of the peak, find the wavelengths closest to the peak, corresponding to the two points n dB down from the peak (see example in Figure 1), where n is typically 20.

7.4.5 To find 11 equally spaced points, subtract these two wavelengths and divide the result by 10. This gives the spacing between points.

7.4.6 Starting with the minimum wavelength as the first point, add the wavelength spacing to find the next point. Continue until 11 points are found (the 11th point should correspond to the maximum wavelength from 7.4.4). Record the wavelengths in Table 2, column 2.

7.4.7 Find the output power (in dBm) corresponding to each wavelength point and record in Table 2, column 3.

7.4.8 Convert the power in dBm to nanowatts (nW) using P(nW) = $10^{[0{,}1\ P\ (\text{dBm})\ +6]}$ and record in Table 2, column 4.

7.5 Discrete MLM spectra

7.5.1 At the end of a single measurement sweep, measure and record the wavelength and the amplitude, for all the modes displayed, in Table 2. The display at the end of the measurement sweep will determine the number of modes and the reference nominal wavelength for each mode. Refer to Figure 2 for a sample spectrum analyzer output.

7.5.2 Measure and record the wavelength and the amplitude for each mode displayed for each of the 10 single measurement sweeps. Include modes at least n dB below the peak mode, where n is typically 20 to 25. For each mode at nominal wavelengths measured and recorded in 7.5.1, calculate the average of the 10 measured wavelengths and the corresponding average of the 10 amplitude readings. Record these average values in Table 2.

7.5.3 Compare the readings of 7.5.1 and 7.5.2 for each mode. For any mode, if the difference in wavelength readings is more than 0,2 nm, or the difference in amplitude readings is more than 10 %, this indicates mode instability, and the calculations may not be accurate.

7.6 SLM spectra

7.6.1 Measure and record the power (M_1) at the peak wavelength and the power (M_2) of the strongest side-mode under the non-modulated (CW) condition.

7.6.2 Measure and record the two wavelengths on both sides of the peak wavelength that are n dB down from the peak amplitude, where n is typically 20 or 30.

7.6.3 Measure and record the optical signal power (P_1) and the maximum value (P_2) of the optical power level of source spontaneous emission (SSE) under non-modulated (CW) operating condition. The SSE power level shall be determined over the entire wavelength range where the laser (TLA) can oscillate, with the exclusion of typically ±1 nm around the optical signal wavelength (see Figure 7). The resolution bandwidth of OSA is usually set to 0,1 nm. The actual resolution bandwidth (B_r) should be calibrated.

8 Calculation

8.1 General

Many optical spectrum analyzers calculate some or all the following parameters internally. Note that for method A, there will be N points corresponding to all the data points taken. Before beginning calculations, it is recommended that any power data points that are more than 20 dB (or another chosen and documented range) below the maximum power reading not be used in the calculations. This will especially prevent the user from overestimating the RMS spectral width. For method B, the total number of data points N will be the number of recorded mode peaks.

8.2 Centre wavelength

8.2.1 Continuous LED spectra

This is the average of the half-power wavelengths determined from the result of 6.3.5 for method A or 7.4.3 for method B.

8.2.2 Discrete MLM spectra

This is the average of the half-power wavelengths that can be determined as follows by interpolation, since the laser may not have modes at these wavelengths.

Connect the tip of each mode to the tips of adjacent modes as shown in Figure 3; draw a horizontal line 3 dB down from the peak power point. The two or more intersection points of the horizontal line with the tip-connecting lines define the half-power wavelengths. The average of the half-power wavelengths that are furthest separated is λ_0.

8.3 Centroidal wavelength

Using the wavelengths and corresponding linear power (nW) in Table 2 for method B or the result of 6.3.5 for method A, calculate the centroidal wavelength as follows:

$$\lambda_c = \left(\frac{1}{P_0}\right)\sum_{i=1}^{N} P_i\,\lambda_i \qquad (1)$$

where

λ_i is the wavelength of the i^{th} point;

P_i is the power of the i^{th} point;

P_0 is the total power summed for all points: $P_0 = \sum_{i=1}^{N} P_i$