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Fibre optic communication subsystem test procedures – Part 1-3: General communication subsystems – Central wavelength and spectral width measurement

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FIBRE OPTIC COMMUNICATION SUBSYSTEM TEST PROCEDURES –

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FOREWORD

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

This second edition cancels and replaces the first edition published in 1998. This edition constitutes a technical revision with changes reflecting new laser technology and includes a second method modified for state of the art instrumentation.

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

CDV	Report on voting
86C/ 887/CDV	86C/ 937/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 61280 series can be found, under the general title *Fibre optic communication subsystem test procedures*, on the IEC website.

The committee has decided that the contents of this amendment and the base publication will remain unchanged until the stability 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- withdrawn,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.

A bilingual version of this publication may be issued at a later date.

FIBRE OPTIC COMMUNICATION SUBSYSTEM TEST PROCEDURES –

Part 1-3: General communication subsystems – Central wavelength and spectral width measurement

1 Scope

This part of IEC 61280 provides definitions and measure 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.

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 may be appropriate to different spectral types, such as continuous spectra characteristic of light-emitting diodes (LEDs), and multilongitudinal-mode (MLM), multitransverse-mode (MTM) and single-longitudinal mode (SLM) spectra, characteristic of laser diodes (LDs).

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

IEC 62129, *Calibration of optical spectrum analyzers*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1 Wavelength

NOTE The following wavelength terms provide quantitative definitions for the describing the central wavelength of a spectrum. In this standard, “central wavelength” is a general category label for these terms.

3.1.1
centre wavelength
λ_0
also called “half-power mid-point”, the mean of the closest spaced half-power wavelengths in an optical spectrum, one above and one below the peak wavelength

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

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

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

3.2 Spectral width

3.2.1
root-mean-square (rms) width
$\Delta\lambda_{rms}$
the square root of the second moment of the power distribution about the centroidal wavelength

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

3.2.3
full-width at half-maximum
$\Delta\lambda_{fwhm}$
a special case of n-dB-down width with n = 3

3.3 Additional spectral characteristics

3.3.1
side-mode suppression ratio
SMSR
the ratio of the largest peak of the optical spectrum to the second largest peak, for a nominally SLM spectrum (see 8.8)

4 Apparatus

4.1 Calibrated optical spectrum analyzer

This special-purpose test equipment uses a dispersive spectrophotometric method to resolve and record the optical spectral distribution. The required wavelength resolution and range depends 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 of 1 nm or narrower are recommended. Laser sources have much narrower spectra and may be used in wavelength-domain multiplexing (WDM) applications, where more accurate determination of the wavelength is required. A wavelength resolution 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 in accordance with IEC 62129. 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 Power supplies

As required for the device under test.

4.3 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.

4.4 Test cord

Unless otherwise specified, the physical and optical properties of the test cords shall match to 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 width 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) and due to chirp that may be measurable by this method.

WARNING – Exercise care to avoid possible eye damage from looking into the end of an energized fibre from any light source. Most importantly, avoid looking into any energized fibre using any type of magnification device.

The requirements in IEC 60825-1 shall be followed.

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 allows 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 standard. Method A has the advantage of easier simpler automated analysis and better representation of complex but narrow spectra, such as multitransverse-mode vertical cavity surface emitting lasers (VCSELs). Due to its convenience and prevalence in the industry, Method A is considered the reference test method.

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 (per 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 analyzer on, and allow the recommended warm-up and settling time to achieve 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 analyzer. 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 control, select an appropriate resolution (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 4 times the sample resolution times the total measured width. For example, a 10 nm measurement span, using 0,1 nm resolution, requires a minimum of 400 points in the measurement (4 × (total span)/resolution).

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.

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 (per 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 analyzer on, and allow the recommended warm-up and settling time to achieve 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 analyzer. 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.

7.2 Adjustment of spectrum analyzer controls

7.2.1 Using the resolution control, select an appropriate resolution (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 Continuous LED and SLM spectra

7.3.1 General

Refer to Figures 1 and 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).

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

7.3.3 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), and the wavelength λ_i and the amplitude p_i for each point i in the displayed spectrum as follows.

7.3.4 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.

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

7.3.6 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 7.3.4). Record the wavelengths in Table 2, Column 2.

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

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

7.4 Discrete MLM spectra

7.4.1 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.

7.4.2 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 7.4.1, calculate the average of the 10 measured wavelengths and the corresponding average of the 10 amplitude readings. Record these average values in Table 2.

7.4.3 Compare the readings of 7.4.1 and 7.4.2 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.

7.5 Continuous SLM spectra

7.5.1 Measure and record the amplitude (M1) at the peak wavelength and the amplitude (M2) of the strongest side-mode.

7.5.2 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.

8 Calculation

8.1 General

Many optical spectrum analyzers calculate some or all of the following parameters internally. Note that for Method A, there will be N points corresponding to all of 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 in 7.3.3 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:

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

where

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

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

P_0 is the total power summed for all points:

$$P_0 = \sum_{i=1}^{N} P_i$$

N is the number of points.

Refer to Table 1 for a calculation example.

8.4 Peak wavelength

8.4.1 Continuous LED and SLM spectra

Use the value measured in 7.3.2 for Method B or the wavelength of the maximum power in the spectrum of 6.3.5 for Method A as the peak wavelength.

8.4.2 Discrete MLM spectra

The peak wavelength can be obtained directly the wavelength corresponding to maximum power in the spectrum from 6.3.5 for Method A or from Table 2 (log or linear scale), representing the average of 10 readings, by reading the wavelength corresponding to the peak power level for Method B. If the maximum power occurs in more than one mode, take the average of the wavelength of all modes with the maximum power. Use the average value as the peak wavelength.

8.5 RMS spectral width ($\Delta\lambda_{rms}$)

Using the wavelengths and corresponding linear power (nW), in the spectrum from 6.3.5 for Method A or from Table 2 (single or average values) for Method B, calculate the rms spectral width as:

$$\Delta\lambda_{\text{rms}} = \left[\frac{1}{P_0} \sum_{i=1}^{N} P_i (\lambda_i - \lambda_c)^2 \right]^{\frac{1}{2}}$$

Refer to Table 1 for a calculation example. Note that $\Delta\lambda_{\text{rms}}$ does not apply to SLM sources. As mentioned at the beginning of Clause 8, a documented method for limiting the range of the data points should be used, such as a cutoff of 20 dB from the peak power.

8.6 n-dB spectral width ($\Delta\lambda_{n\text{-dB}}$)

The difference in wavelengths recorded in 7.5.2 for Method B, or which are n dB below the peak in the spectrum from 6.3.5 from Method A, is $\Delta\lambda_{\text{n-dB}}$ (see Figure 5). This $\Delta\lambda_{\text{n-dB}}$ applies to SLM lasers, but does not apply to MLM lasers or to LEDs.

8.7 Full-width half-maximum spectral width ($\Delta\lambda_{fwhm}$)

8.7.1 Continuous LED spectra

The difference of the half-power wavelengths recorded in 7.3.3 from Method B or determined from the spectra of 6.3.5 for Method A is $\Delta\lambda_{\text{fwhm}}$.

8.7.2 Discrete MLM spectra

This is the difference 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 and draw a horizontal line 3 dB down from the peak power point. The two or more intersection points between these lines define the half-power wavelengths. The maximum difference in half-power wavelengths is $\Delta\lambda_{fwhm}$.

NOTE The procedure of 8.7.2 uses interpolation based on a segmented linear fit. In many cases, the spectrum can also be well represented by a Gaussian fit. In this case, the FWHM spectral width can also be calculated on the basis of the RMS spectral width. For a Gaussian distribution, $\Delta\lambda_{fwhm} = 2{,}355 \times \Delta\lambda_{rms}$.

8.8 Side-mode suppression ratio (*SMSR*)

From the power of the highest signal peak of an SLM, M1, and the power of the highest sidemode, M2, as determined in 7.5.1 from Method B or from the spectrum of 6.3.5 from Method A, calculate the ratio (in dB) as:

$$SMSR = 10 \log_{10}\left(\frac{M1}{M2}\right)$$

9 Test results

9.1 Required information

The required information shall include :

a) Date, title of test, and procedures used
b) Identification of the fibre optic transmitter (terminal device) or the optical source to be tested, together with applicable data
c) Reference point temperature
d) Results of the examination.

9.2 Information to be available on request

Information to be available on request is as followings:

a) Test equipment used and the latest date of calibration
b) Names of test personnel
c) The measurement uncertainty due to measurement inaccuracy and display resolution
d) Data rate and input signal characteristics, including modulation depth and pulse shape
e) Supply voltage(s) and/or current(s)
f) Bias circuit configuration for discrete optical source
g) Optical output measurement conditions, including details of fibre test cords, pigtail and standard coupling means, where applicable
h) Optical output measurement conditions, including details of fibre test cords, pigtail and standard coupling means, where applicable
i) Recommended warm-up time for temperature stabilization.

10 Example results

The output power spectrum (in dBm) of a single-mode fibre coupled, high power, InGaAsP edge-emitting LED is shown in Figure 1. Columns 1 to 3 in Table 1 show the 11 points selected from the spectrum according to 7.3. Column 4 shows the power converted from logarithmic to linear units. The products shown in Columns 5 and 6, and the summations shown in the row labeled “SUM”, are used to calculate the centroidal wavelength λ_c, and rms spectral width, $\Delta\lambda_{rms}$, according to 8.3 and 8.5, respectively. The bottom two rows show the calculated centroidal wavelength and rms spectral width for this LED.

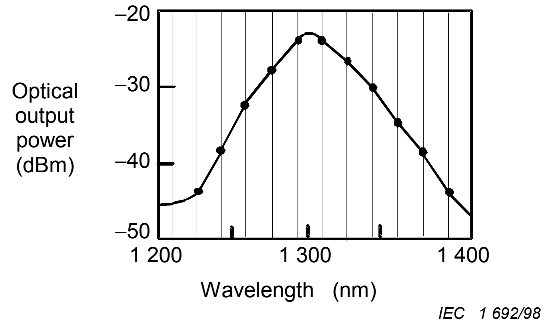


Figure 1 – Example of a LED optical spectrum

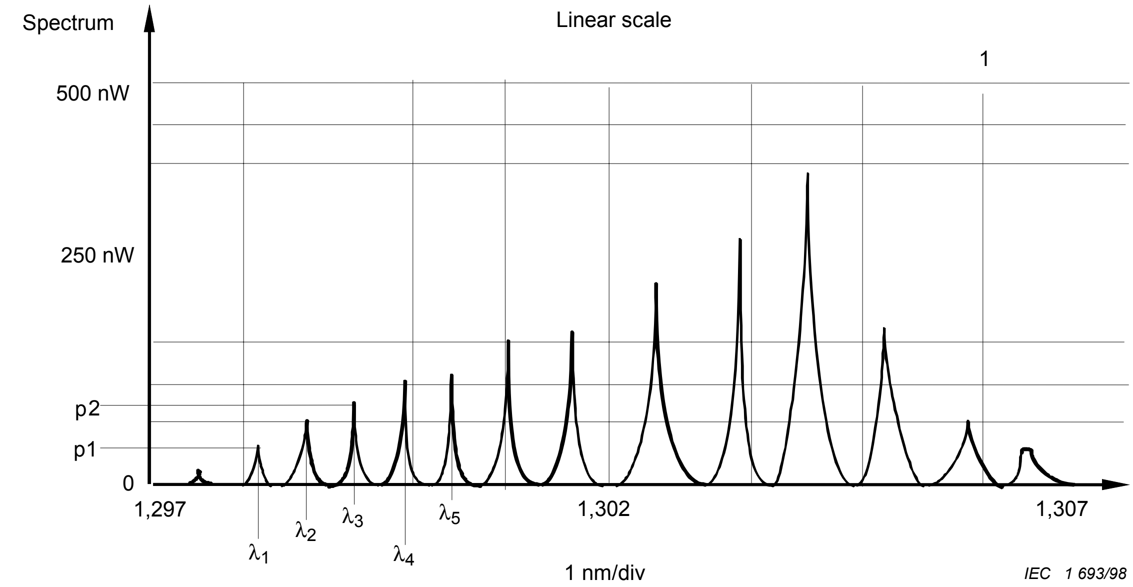
Table 1 – Measurement points for LED spectrum from Figure 1

i	**Wavelength λ_i** m	**Power (log)** dBm	**Power (linear) p_i nW**	$p_i\ \lambda_i$	$p_i\ (\lambda_i - \lambda_c)^2$
1	1 226	–44	40	49 040	256 000
2	1 243	–39	126	156 618	500 094
3	1 260	–33	501	631 260	1 060 116
4	1 277	–28	1 585	2 024 045	1 332 985
5	1 294	–24	3 981	5 151 414	573 264
6	1 311	–24	3 981	5 219 091	99 525
7	1 328	–27	1 995	2 649 360	965 580
8	1 345	–31	794	1 067 930	1 207 674
9	1 362	–35	316	430 392	990 976
10	1 379	–39	126	173 754	671 454
11	1 396	–44	40	55 840	324 000
SUM	–	–	13 485	17 608 744	7 981 668
λ_c	1 306	–	–		
$\Delta\lambda_{rms}$	24	–	–		

Table 2 – RMS spectral characterization

i	**Wavelength** λ_i nm	**Power (log)** dBm	**Power (linear)** p_i **nW**	$p_i \lambda_i$	$p_i (\lambda_i - \lambda_c)^2$
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
SUM	–	–			
λ_c		–	–	–	–
$\Delta\lambda_{rms}$		–	–	–	–

The table contains the average wavelength power readings for each point, where *i* corresponds to mode number for discrete MLM spectra and to wavelength point for continuous LED and SLM spectra.



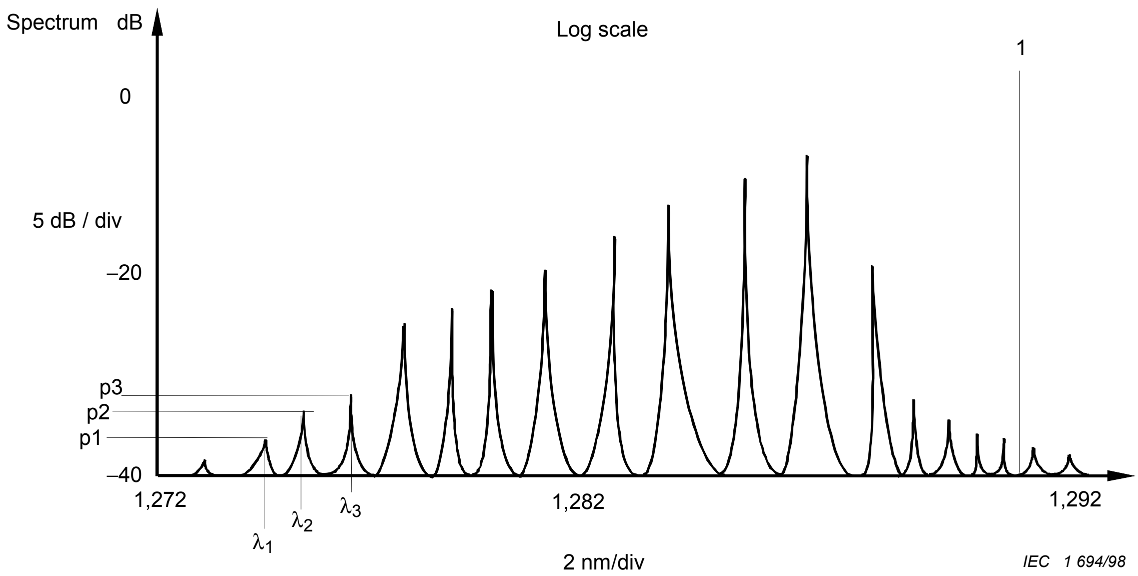


Figure 2 – Typical spectrum analyzer output for an MLM laser

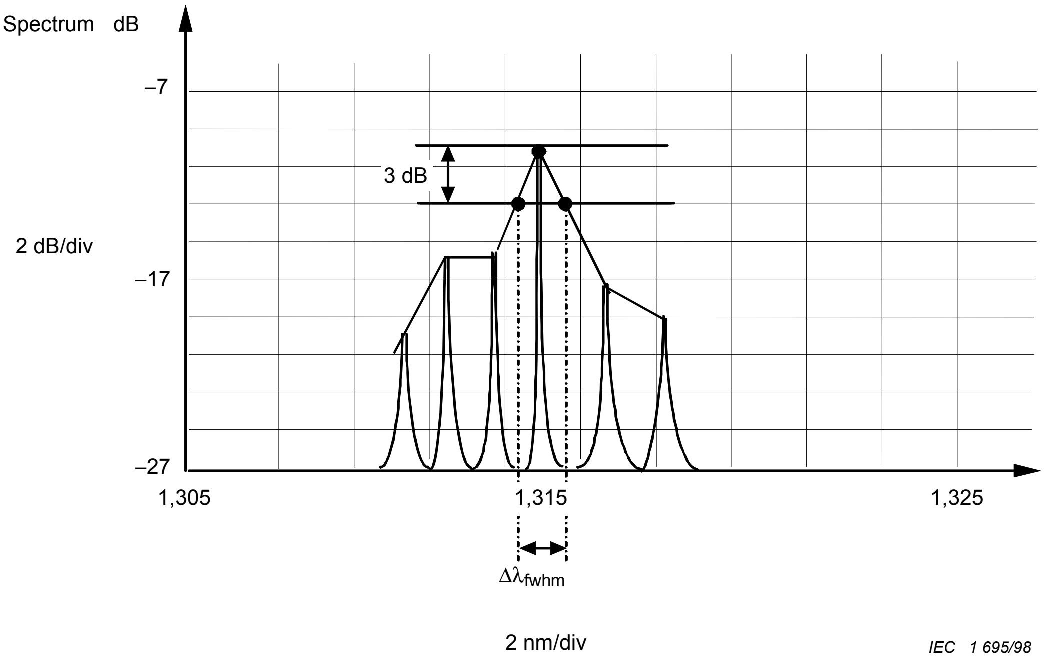


Figure 3 – $\Delta\lambda_{fwhm}$ spectral width measurement for MLM laser

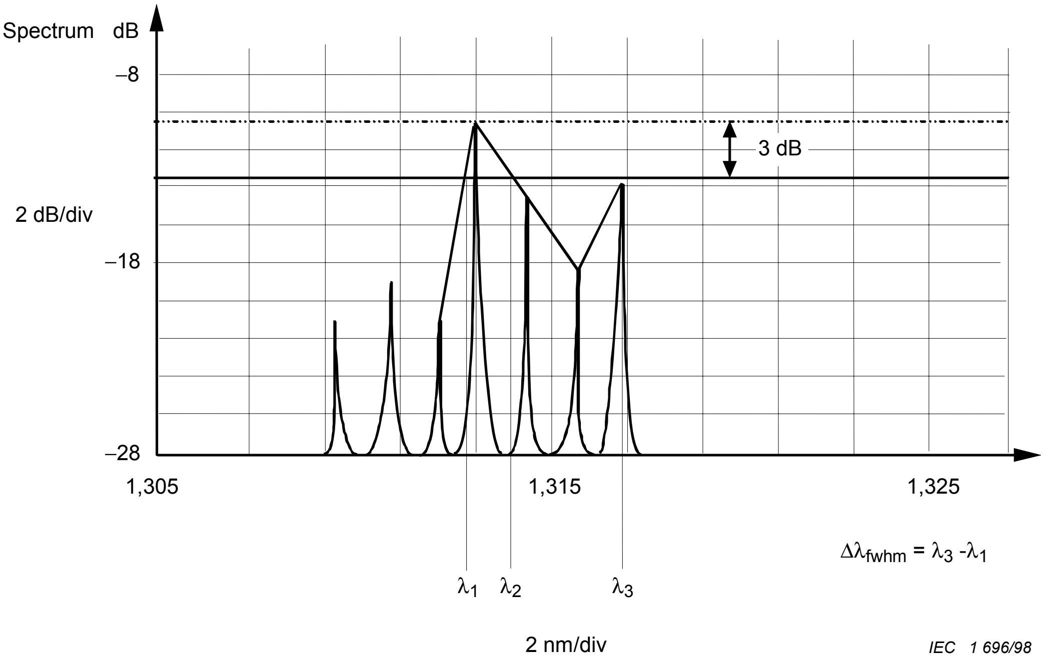


Figure 4 – $\Delta\lambda_{fwhm}$ spectral width calculation for MLM laser

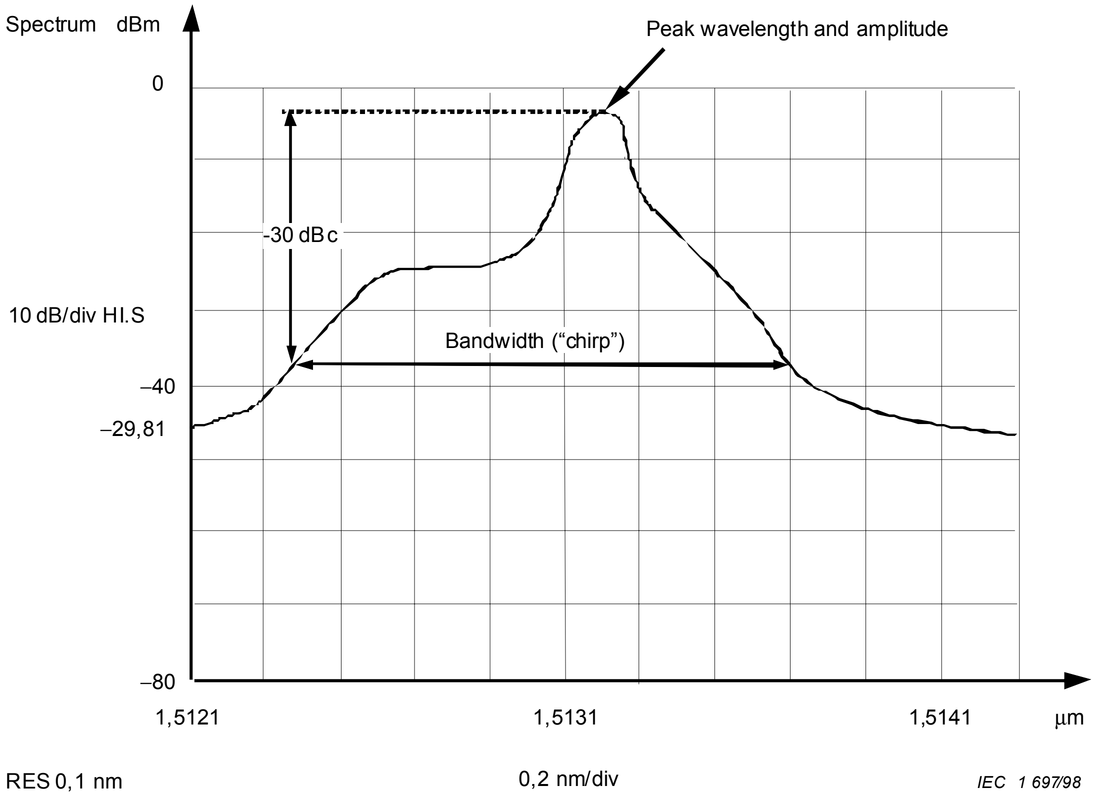


Figure 5 – Peak emission wavelength and $\Delta\lambda_{30-dB}$ measurement for SLM laser

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