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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Calibration of tuneable laser sources

Étalonnage des sources laser accordables

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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CALIBRATION OF TUNEABLE LASER SOURCES

FOREWORD

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IEC 62522 has been prepared by IEC technical committee 86: Fibre optics. It is an International Standard.

This second edition cancels and replaces the first edition published in 2014. This edition constitutes a technical revision.

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

a) addition of references to IEC 61315;
b) addition of Table 1 and Table 2 on uncertainties;
c) clarification of the reference power meter settings in 6.2.3 and 6.3.2.3.

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

Draft	Report on voting
86/639/FDIS	86/643/RVD

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/publications.

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

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

Wavelength-division multiplexing (WDM) transmission systems have been deployed in optical trunk lines. ITU-T Recommendations in the G.694 series describe the frequency and wavelength grids for WDM applications. For example, the frequency grid of ITU-T Recommendation G.694.1 supports a variety of channel spacing ranging from 12,5 GHz to 100 GHz and wider. WDM devices, such as arrayed waveguide grating (AWG), thin film filter or grating based multiplexers (MUX), and demultiplexers (DMUX) with narrow channel spacing are incorporated in the WDM transmission systems. When measuring the characteristics of such devices, wavelength tuneable laser sources are commonly used and are required to have well-calibrated performances; wavelength uncertainty, wavelength tuning repeatability, wavelength stability, and output optical power stability are important parameters.

The tuneable laser source (TLS) is generally equipped with the following features:

a) the output wavelength is continuously tuneable in a wavelength range starting at 1 260 nm or higher and ending at less than 1 675 nm (the output should excite only the fundamental LP01 fibre mode);

b) an output port for optical fibre connectors.

The envelope of the spectrum is a single longitudinal mode with a full-width at half-maximum (FWHM) of at most 0,1 nm. Any adjacent modes are at least 20 dB lower than the main spectral mode (for example, a distributed feedback laser diode (DFB-LD), external cavity laser, etc.).

CALIBRATION OF TUNEABLE LASER SOURCES

1 Scope

This document provides a stable and reproducible procedure to calibrate the wavelength and power output of a tuneable laser against reference instrumentation such as optical power meters and optical wavelength meters (including optical frequency meters) that have been previously traceably calibrated.

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 60793-2-50, *Optical fibres – Part 2-50: Product specifications – Sectional specification for class B single-mode fibres*

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

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

IEC 61315, *Calibration of fibre-optic power meters*

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

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

3 Terms, definitions, and abbreviated terms

3.1 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1.1
accredited calibration laboratory
calibration laboratory authorized by an appropriate national organization to issue calibration certificates that demonstrates traceability to national standards

3.1.2
adjustment
set of operations carried out on an instrument in order that it provides given indications corresponding to given values of the measurand

Note 1 to entry: For more information, see ISO/IEC Guide 99:2007, 3.11.

[SOURCE: IEC 60050-311:2001, 311-03-16, modified – Domain deleted, words "measuring instrument" deleted in the definition, and omission of the Note to entry therein.]

3.1.3
calibration
set of operations that establish, under specified conditions, the relationship between the values of quantities indicated by a measuring instrument and the corresponding values realized by standards

Note 1 to entry: The results of a calibration permit either the assignment of measurand values to the indications or the determination of corrections with respect to the indications.

Note 2 to entry: A calibration can also determine other metrological properties such as the effects of influence quantities.

Note 3 to entry: The result of a calibration can be recorded in a document, called a calibration certificate or a calibration report.

Note 4 to entry: See also ISO/IEC Guide 99:2007, 2.39.

3.1.4
calibration conditions
conditions of measurement in which the calibration is performed

3.1.5
calibration at reference conditions
calibration which includes the evaluation of the uncertainty at reference conditions of the light source under calibration

3.1.6
calibration at operating conditions
calibration which includes the evaluation of the uncertainty at operating conditions of the light source under calibration

3.1.7
level of confidence
estimated probability that the true value of a measured parameter lies in the given range

3.1.8
coverage factor
k
factor used to calculate the expanded uncertainty U from the standard uncertainty u

3.1.9
optical power deviation
D_P
difference between the set power of the light source under calibration, P_{TLS}, and the corresponding reference power, P_{meas}, measured by the reference power meter

$$D_P = \frac{P_{TLS} - P_{meas}}{P_{meas}}$$

Note 1 to entry: Power P is expressed in linear units, for example W.

Note 2 to entry: This deviation is relative, it has no unit (it can be expressed in %).

3.1.10
operating conditions
appropriate set of specified ranges of values with influence quantities usually wider than the reference conditions for which the uncertainties of a measuring instrument are specified

Note 1 to entry: Operating conditions and the uncertainty at operating conditions are usually specified by the manufacturer for the convenience of the user.

3.1.11
reference conditions
conditions used for testing the performance of a measuring instrument or for the intercomparison of the measurement results

Note 1 to entry: Reference conditions generally include reference values or reference ranges for the quantities influencing and affecting the measuring instrument.

3.1.12
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 1 to entry: Side-mode suppression ratio is usually expressed in dB.

3.1.13
wavelength
wavelength (in a vacuum) of a light source

3.1.14
wavelength deviation
D_λ
difference between the target wavelength, set on the light source under calibration, λ_{TLS}, and the measured wavelength, λ_{meas}, in nm or µm

$$D_\lambda = \lambda_{TLS} - \lambda_{meas}$$

3.2 Abbreviated terms

APC	angled physical contact
AWG	arrayed waveguide grating
DFB-LD	distributed feedback laser diode
DMUX	demultiplexers
FWHM	full-width at half-maximum
MUX	multiplexers
O/E	optical-electrical
OSA	optical spectrum analyser
RIN	relative intensity noise
SMSR	side-mode suppression ratio
TLS	tuneable laser source
WDM	wavelength-division multiplexing

4 Preparation for calibration

4.1 Organization

The calibration laboratory should ensure that suitable requirements for calibration are followed.

NOTE Guidance about good practices for calibration can be found in ISO/IEC 17025.

There should be a documented measurement procedure for each type of calibration performed, giving step-by-step operating instructions and equipment to be used.

4.2 Traceability

The calibration laboratory should ensure that suitable requirements are followed.

NOTE Guidance about good practices for calibration can be found in ISO/IEC 17025.

All standards used in the calibration process shall be calibrated according to a documented program with traceability to national standards laboratories or to accredited calibration laboratories.

It is advisable to maintain more than one standard on each hierarchical level, so that the performance of the standard can be verified by comparisons on the same level. Make sure that any other calibration equipment which have a significant influence on the calibration results are calibrated.

4.3 Preparation

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

a) calibrations shall be carried out in a clean environment;
b) temperature monitoring and control is required;
c) all laser sources shall be safely operated (according to IEC 60825-1 and IEC 60825-2);
d) the output of the TLS should be examined with an optical spectrum analyser (OSA) having sufficient resolution to resolve the longitudinal mode structure to check for single mode operation.

The recommended temperature is 23 °C, for example, (23 ± 2) °C. Give the calibration equipment enough time prior to testing (2 h is recommended) to reach equilibrium within its environment. Allow the TLS a warm-up period in accordance with the manufacturer's instructions.

4.4 Reference calibration conditions

The reference calibration conditions usually include the following parameters and, if necessary, their tolerance bands: date, temperature, relative humidity, atmospheric pressure, displayed optical power, displayed wavelength, fibre, connector-adapter combination, (spectral) bandwidth and resolution bandwidth (spectral resolution) set. Unless otherwise specified, use a single-mode optical fibre category B1.1 or B1.3 pigtail as specified in IEC 60793-2-50, having a length of at least 2 m. It is desirable to perform all the calibration in a situation where back-reflections are negligible. Thus, angled connectors and isolators should be used wherever the situation permits.

Operate the TLS in accordance with the manufacturer's specifications and operating procedures. Where practical, select a range of calibration conditions and parameters that emulate the actual field operating conditions of the TLS under calibration. Choose these parameters to optimize the tuneable laser source's accuracy, as specified by the manufacturer's operating procedures.

Document the conditions as specified in Clause 7.

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

5 Wavelength calibration

5.1 Overview

The factors making up the uncertainty in the wavelength of the light source under calibration consist of:

a) the intrinsic uncertainty of the light source under calibration as found in the calibration at reference conditions, including temperature and time dependences for these tight conditions, and;

b) the uncertainties due to dependences on optical power, temperature and time as found in the calibrations at broader operating conditions.

The list of the source of uncertainty is summarized in Table 1.

Table 1 – Source of uncertainty for wavelength calibration

Source of uncertainty	Type of origin	Symbol
Repeatability	Measurement	s_{λ_j}
Temperature	Environment	$u_{\lambda_j,\Delta\Theta}$
Stability	Light source under calibration	$u_{\lambda_j,\Delta t}$
Wavelength resolution	Reference wavelength meter	$u_{\lambda_j,\mathrm{res}}$
Wavelength meter calibration	Reference wavelength meter	$u_{\mathrm{WM}_{\lambda_j}}$
Optical power	Light source under calibration	$u_{\lambda_j,P}$

The wavelength calibration at reference conditions for discrete wavelengths, as described in 5.2, is mandatory. The calibration at operating conditions, described in 5.3, is optional.

5.2 Wavelength calibration at reference conditions

5.2.1 Set-up

Figure 1 shows a system for wavelength calibration. The calibration is performed under the given reference conditions.

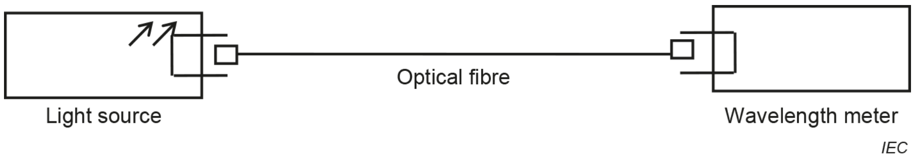

Figure 1 – Measurement set-up for wavelength calibration

5.2.2 Calibration equipment

A wavelength meter shall be used for the calibration. The wavelength meter shall be calibrated according to IEC 62129-2.

5.2.3 Procedure for wavelength calibration

The calibration procedure is as follows:

a) Regarding the calibration system shown in Figure 1, the set wavelength of the light source is given by $\lambda_{\text{TLS}\ j}$ and the measured values are given by $\lambda_{\text{meas}\ i,j}$. The uncertainty of the wavelength measurement takes into account the tuning repeatability and hysteresis of the TLS. Hysteresis is defined as the deviation resulting from tuning the desired wavelength from both the shorter and the longer wavelengths.

b) It is recommended to repeat the wavelength measurement ten (m) times. Ensure that the TLS is tuned to $\lambda_{\text{TLS}\ j}$ prior to each measurement. The target wavelength (j) should be approached in such a way that tuning occurs from both longer and shorter wavelengths.

c) Calculate the average measured wavelength $\overline{\lambda}_{\text{meas}\ j}$:

$$\overline{\lambda}_{\text{meas},\ j} = \frac{1}{m}\sum_{i=1}^{m}\lambda_{\text{meas}\,i,j} \tag{1}$$

where

m	is the number of measurements performed.
Each $\lambda_{\text{meas}\ i,j}$	is suggested to be an averaged value from the wavelength meter.

d) Calculate the wavelength deviation D_{λ_j}:

$$D_{\lambda_j} = \lambda_{\text{TLS}\,j} - \overline{\lambda}_{\text{meas}\ j} \tag{2}$$

where $\lambda_{\text{TLS}\ j}$ is the tuned wavelength of the TLS.