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REDLINE VERSION

INTERNATIONAL STANDARD

Calibration of fibre-optic power meters

colour inside

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Calibration of fibre-optic power meters

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CONTENTS

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CALIBRATION OF FIBRE-OPTIC POWER METERS

FOREWORD

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International Standard IEC 61315 has been prepared by IEC technical committee 86: Fibre optics.

This third edition cancels and replaces the second edition published in 2005. It constitutes a technical revision.

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

a) update of terms and definitions;
b) update of 5.1, including Table 1 (new type of source);
c) update of Annex A;
d) addition of Annex B on dB conversion.

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

CDV	Report on voting
86/533/CDV	86/540A/RVC

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

In this document, the following print types are used:

– *terms defined in the document: in italic type.*

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Fibre-optic power meters are designed to measure optical power from fibre-optic sources as accurately as possible. This capability depends largely on the quality of the *calibration* process. In contrast to other types of measuring equipment, the *measurement results* of *fibre-optic power meters* usually depend on many conditions of measurement. The conditions of measurement during the *calibration* process are called *calibration conditions*. Their precise description ~~must~~ is therefore ~~be~~ an integral part of the *calibration*.

This document defines all of the steps involved in the *calibration* process: establishing the *calibration conditions*, carrying out the *calibration*, calculating the uncertainty, and reporting the uncertainty, the *calibration conditions* and the *traceability*.

The absolute power *calibration* describes how to determine the ratio between the value of the input power and the power meter's result. This ratio is called *correction factor*. The measurement uncertainty of the *correction factor* is combined following Annex A from uncertainty contributions from the *reference meter*, the *test meter*, the setup and the procedure.

The calculations go through detailed characterizations of individual uncertainties. It is important to know that

a) ~~estimations of the individual uncertainties are acceptable~~ some uncertainties are type B estimations, experience-based,

b) a detailed uncertainty analysis is usually only ~~necessary~~ done once for each power meter type under test, and all subsequent *calibrations* ~~can be~~ are usually based on this one-time analysis, using the appropriate type A measurement contributions evaluated at the time of the *calibration*, and

c) some of the individual uncertainties ~~can~~ are simply ~~be~~ considered to be part of a checklist, with an actual value which can be neglected.

~~Calibration according to~~ Clause 5 defines absolute power *calibration*, which is mandatory for *calibration* reports referring to this document.

Clause 6 describes the evaluation of the measurement uncertainty of a calibrated power meter operated within *reference conditions* or within *operating conditions*. It depends on the *calibration* uncertainty of the power meter as calculated in 5.4, the conditions and its dependence on the conditions. It is usually performed by manufacturers in order to establish specifications and is not mandatory for reports referring to this document. One of these dependences, the *nonlinearity*, is determined in a separate *calibration* (Clause 7).

~~NOTE Fibre-optic power meters measure and indicate the optical power in the air, at the end of an optical fibre. It is about 3,6 % lower than in the fibre due to Fresnel reflection at the glass-air boundary (with *N* = 1,47). This should be kept in mind when the power in the fibre has to be known.~~

CALIBRATION OF FIBRE-OPTIC POWER METERS

1 Scope

This document is applicable to instruments measuring *radiant power* emitted from sources that are typical for the fibre-optic communications industry. These sources include laser diodes, light emitting diodes (LEDs) and fibre-type sources. ~~The radiation may be divergent or collimated.~~ Both divergent and collimated radiations are covered. This document ~~describes~~ defines the *calibration* of power meters to be performed by *calibration* laboratories or by power meter manufacturers.

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 60050-300, *International Electrotechnical Vocabulary – Electrical and electronic measurements and measuring instruments – Part 311: General terms relating to measurements – Part 312: General terms relating to electrical measurements – Part 313: Types of electrical measuring instruments – Part 314: Specific terms according to the type of instrument*~~

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

IEC 60793-2, *Optical fibres – Part 2: Product specifications – General*

~~IEC 61300-3-12, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-12: Examinations and measurements – Polarization dependence of attenuation of a single-mode fibre optic component: Matrix calculation method*~~

~~IEC 61930, *Fibre optic graphical symbology*~~

IEC TR 61931:1998, *Fibre optic – Terminology*

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

~~ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*~~

~~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:1995, *Guide to the expression of uncertainty in measurement (GUM)*~~

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TR 61931 and the following 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
accredited calibration laboratory
calibration laboratory authorized by the appropriate national organization to issue *calibration* certificates with a minimum specified uncertainty, which demonstrate *traceability* to *national standards* (3.14)

3.2
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: When the instrument is made to give a null indication corresponding to a null value of the measurand, the set of operations is called zero adjustment.

Note 2 to entry: For more information, see ISO/IEC Guide 99:2007, 3.11.

[SOURCE: IEC 60050-311:2001, 311-03-16, modified – The words "of a measuring instrument" have been deleted from the term, and Note 2 to entry has been added. ~~see also VIM 4.30~~]

3.3
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 measurement standards

Note 1 to entry: The result of a *calibration* permits either the assignment of values of measurands to the indications or the determination of corrections with respect to indications.

Note 2 to entry: A *calibration* may also determine other metrological properties such as the effect of influence quantities.

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

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

~~[VIM, 6.11, modified]~~

3.4
calibration conditions
conditions of measurement in which the *calibration* is performed

3.5
~~**centre**~~ **centroidal wavelength**
$\lambda_{\mathrm{c}\cancel{\mathrm{entre}}}$
power-weighted mean wavelength of a light source in vacuum

Note 1 to entry: For a continuous spectrum, the ~~centre~~ *centroidal wavelength* is defined as:

$$\cancel{\lambda_{\mathrm{centre}} =} \frac{1}{P_{\mathrm{total}}} \int p(\lambda) \times \lambda \times d\lambda$$

~~and the total power is:~~

$$\cancel{P_{\mathrm{total}} =} \int p(\lambda) \times d\lambda$$

~~where $p(\lambda)$ is the power spectral density of the source, for example in W/nm.~~

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

$$\cancel{\lambda_{\text{centre}} = \frac{\sum P_i \times \lambda_i}{\sum P_i}}$$

~~where~~

~~P_i is the power of the i^{th} discrete line, for example in W, and~~

~~λ_i is the vacuum wavelength of the i^{th} discrete line.~~

$$\lambda_c = \frac{\int p(\lambda)\lambda d\lambda}{P_{\text{total}}} \quad (1)$$

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

$$\lambda_c = \frac{\sum_i P_i \lambda_i}{\sum_i P_i} \quad (2)$$

where

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

λ_i is the vacuum wavelength of the i^{th} discrete line;

P_i is the power of the i^{th} discrete line, for example, in W;

P_{total} is the total power, for example, in W.

Note 2 to entry: The above integrals and summations theoretically extend over the entire spectrum of the light source. However, it is usually sufficient to perform the integral or summation over the spectrum where the spectral density $p(\lambda)$ or power P_i is higher than 0,1 % of the maximum spectral density $p(\lambda)$ or power P_i.

3.6
correction factor
CF
numerical factor by which the uncorrected result of a measurement is multiplied to compensate for systematic error

Note 1 to entry: This note applies to the French language only.

~~[VIM, 3.16]~~

~~**3.7**~~
~~**decibel**~~
~~**dB**~~
~~submultiple of the bel (1 dB = 0,1 B), unit used to express values of power level on a logarithmic scale. The **power level** is always relative to a reference power P_0:~~

$$\cancel{L_{P/P_0} = 10 \times \log_{10}\left(\frac{P}{P_0}\right) \text{ (dB)}}$$

~~where P and P_0 are expressed in the same linear units.~~

~~The reference power must always be reported, for example, the power level of 200 µW relative to 1 mW can be noted $L_{P/1\,mW}$ = –7 dB or L_P(re 1 mW) = –7 dB.~~

~~The linear ratio, R_{lin}, of two radiant powers, P_1 and P_2, can alternatively be expressed as a **power level difference** in decibels (dB):~~

$$\cancel{\Delta L_P = 10\log_{10}(R_{lin}) = 10\log_{10}(P_1/P_2) = 10\log_{10}(P_1) - 10\log_{10}(P_2).}$$

~~Similarly, relative uncertainties, U_{lin}, or relative deviations, can be alternatively expressed in decibels:~~

$$U_{dB} = \frac{10}{\ln 10} U_{lin} \cong 4{,}34 \times U_{lin} \ \cancel{(dB)}$$

~~NOTE ISO 31-2 and IEC 60027-3 should be consulted for further details. The rules of IEC 60027-3 do not permit attachments to unit symbols. However, the unit symbol dBm is widely used to indicate power levels relative to 1 mW and often displayed by fibre-optic power meters.~~

3.7
detector
element of the power meter that transduces the radiant optical power into a measurable, usually electrical, quantity

Note 1 to entry: In this document, the *detector* is assumed to be connected with the *optical input port* by an optical path.

Note 2 to entry: For more information, see ISO/IEC Guide 99:2007, 3.9.

~~[see IEC 61931 and VIM, 4.15]~~

3.8
deviation
D
~~for the purpose of this standard, the~~ relative difference between the power measured by the *test meter* (3.32) P_{DUT} and the reference power P_{ref}:

$$D = \frac{P_{DUT} - P_{ref}}{P_{ref}} \quad (3)$$

Note 1 to entry: This note applies to the French language only.

3.9
excitation
<fibre> description of the distribution of optical power between the modes in the fibre

Note 1 to entry: In context with multimode fibres, the fibre *excitation* is described by

a) the *spot diameter* (3.31) on the surface of the fibre end, and

b) the *numerical aperture* (3.17) of the radiation emitted from the fibre.

~~Full excitation means radiation characterized by a spot diameter which is approximately equal to the fibre's core diameter, and by a numerical aperture which is approximately equal to the fibre's numerical aperture.~~

Single-mode fibres are generally assumed to be excited by only one mode (the fundamental mode).

3.10
instrument state
set of parameters that can be chosen on an instrument

Note 1 to entry: Typical parameters of the *instrument state* are the optical power range, the wavelength setting, the display measurement unit and the output from which the *measurement result* is obtained (for example, display, interface bus, analogue output).

3.11
irradiance
quotient of the incremental *radiant power* ∂P incident on an element of the reference plane by the incremental area ∂A of that element:

$$E = \frac{\partial P}{\partial A} \quad \left(\mathrm{W/m^2}\right) \tag{4}$$

Note 1 to entry: For more information, see IEC TR 61931:1998, 2.1.15.

3.12
measurement result
y
(displayed or electrical) output of a power meter (or standard), after completing all actions suggested by the operating instructions, for example warm-up, ~~zeroing~~ zero adjustment and wavelength-correction

Note 1 to entry: *Measurement result* is expressed in watts (W). For the purposes of uncertainty ~~analysis~~, *measurement results* in other units, for example volts, should be converted to watts. *Measurement results* in decibels (dB) should also be converted to watts, because the entire uncertainty accumulation is based on measurement results expressed in watts. See Annex B.

3.13
measuring range
set of values of measurands for which the error of a measuring instrument is intended to lie within specified limits

Note 1 to entry: In this document, the *measuring range* is the range of *radiant power* (part of the *operating range*), for which the uncertainty at *operating conditions* is specified. The term "dynamic range" should be avoided in this context.

Note 2 to entry: For more information, see ISO/IEC Guide 99:2007, 4.7.

~~[VIM, 5.4]~~

3.14
national measurement standard
national standard
standard recognized by a national decision to serve in a country as the basis for assigning values to other standards of the quantity concerned

Note 1 to entry: For more information, see ISO/IEC Guide 99:2007, 5.3.

~~[VIM, 6.3]~~

3.15
national standards laboratory
laboratory which maintains the *national standard* (3.14)

3.16
nonlinearity
NL
relative difference between the *response* (3.28) at a given power P and the *response* at a reference power P_0:

$$nl_{\mathrm{P/P_0}} = \frac{r(P)}{r(P_0)} - 1 \tag{5}$$

If expressed in decibels, the *nonlinearity* is:

$$NL_{\mathrm{P/P_0}} = 10 \times \log_{10} \frac{r(P)}{r(P_0)} \text{ (dB)} \tag{6}$$

Note 1 to entry: The *nonlinearity* is equal to zero at the reference power.

Note 2 to entry: The term "local *nonlinearity*" is used for the relative difference between the *responses* at two different power levels (separated by 3,01 dB) obtained during the *nonlinearity calibration*. The term "global *nonlinearity*" is used for the result of summing ~~up~~ the local nonlinearities (in dB); it is identical to the *nonlinearity* defined here.

3.17
numerical aperture
description of the beam divergence of an optical source

Note 1 to entry: In this document, the *numerical aperture* is the sine of the (linear) half-angle at which the *irradiance* is 5 % of the maximum *irradiance*.

Note 2 to entry: Adapted from the definition of the *numerical aperture* of multimode graded-index fibres in IEC 60793-1-43:2015, Clause 3; in this document, the definition is used to describe the divergence of all divergent beams.

3.18
operating conditions
appropriate set of specified ranges of values of influence quantities usually wider than the *reference conditions* for which the uncertainties of a measuring instrument are specified ~~(see VIM, 5.5)~~

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

3.19
operating range
specified range of values of one of a set of *operating conditions* (3.18)

3.20
optical input port
physical input of the power meter (or standard) to which the *radiant power* is to be applied or to which the optical fibre end is to be connected

Note 1 to entry: An optical path (path of rays with or without optical elements, such as lenses, diaphragms, light guides, etc.) is assumed to connect the *optical input port* with the power meter's *detector*.

3.21
optical reference plane
plane on or near the *optical input port* (3.20) which is used to define the beam's *spot diameter* (3.31)

Note 1 to entry: The *optical reference plane* is usually assumed to be perpendicular to the beam propagation, and it should be described by appropriate mechanical dimensions relative to the power meter's *optical input port*.

3.22
polarization dependent response
PDR
variation in *response* of a power meter with respect to all possible polarization states of the input light:

$$PDR = 10 \times \log_{10}\left(\frac{r_{\mathrm{max}}}{r_{\mathrm{min}}}\right) \text{ (dB)} \tag{7}$$