IEC 62129-2

Edition 1.0 2011-05

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Calibration of wavelength/optical frequency measurement instruments –
Part 2: Michelson interferometer single wavelength meters

Étalonnage des appareils de mesure de longueur d'onde/appareil de mesure de la fréquence optique –
Partie 2: Appareils de mesure de longueur d'onde unique à interféromètre de Michelson

IEC 62129-2:2011

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

- Catalogue of IEC publications: www.iec.ch/searchpub

The IEC on-line Catalogue enables you to search by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, withdrawn and replaced publications.

- IEC Just Published: www.iec.ch/online_news/justpub

Stay up to date on all new IEC publications. Just Published details twice a month all new publications released. Available on-line and also by email.

- Electropedia: www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 20 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary online.

- Customer Service Centre: www.iec.ch/webstore/custserv

If you wish to give us your feedback on this publication or need further assistance, please visit the Customer Service Centre FAQ or contact us:
Email: csc@iec.ch
Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00

A propos de la CEI

La Commission Electrotechnique Internationale (CEI) est la première organisation mondiale qui élabore et publie des normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications CEI

Le contenu technique des publications de la CEI est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

- Catalogue des publications de la CEI: www.iec.ch/searchpub/cur_fut-f.htm

Le Catalogue en-ligne de la CEI vous permet d'effectuer des recherches en utilisant différents critères (numéro de référence, texte, comité d'études,…). Il donne aussi des informations sur les projets et les publications retirées ou remplacées.

- Just Published CEI: www.iec.ch/online_news/justpub

Restez informé sur les nouvelles publications de la CEI. Just Published détaille deux fois par mois les nouvelles publications parues. Disponible en-ligne et aussi par email.

- Electropedia: www.electropedia.org

Le premier dictionnaire en ligne au monde de termes électroniques et électriques. Il contient plus de 20 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans les langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International en ligne.

- Service Clients: www.iec.ch/webstore/custserv/custserv_entry-f.htm

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions, visitez le FAQ du Service clients ou contactez-nous:
Email: csc@iec.ch
Tél.: +41 22 919 02 11
Fax: +41 22 919 03 00

IEC 62129-2

Edition 1.0 2011-05

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Calibration of wavelength/optical frequency measurement instruments – Part 2: Michelson interferometer single wavelength meters

Étalonnage des appareils de mesure de longueur d’onde/appareil de mesure de la fréquence optique – Partie 2: Appareils de mesure de longueur d'onde unique à interféromètre de Michelson

INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

PRICE CODE
CODE PRIX X

ICS 33.180.30

ISBN 978-2-88912-523-4

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

CALIBRATION OF WAVELENGTH/OPTICAL FREQUENCY MEASUREMENT INSTRUMENTS –

Part 2: Michelson interferometer single wavelength meters

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 62129-2 has been prepared by IEC technical committee 86: Fibre optics.

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

FDIS	Report on voting
86/395/FDIS	86/399/RVD

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.

The list of all parts in the IEC 62129 series, published under the general title, *Calibration of wavelength/optical frequency – Measurement instruments*, can be found on the IEC website.

The committee has decided that the contents of this 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.

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

Wavelength meters, often based on the Michelson interferometer, are designed to measure the wavelength of an optical source as accurately as possible. Although the wavelength meters contain an internal absolute reference, typically a Helium-Neon laser, calibration is required to achieve the highest accuracies. The instrument is typically used to measure wavelengths other than that of the internal reference. Corrections are made within the instrument for the refractive index of the surrounding air. A precise description of the calibration conditions must therefore be an integral part of the calibration.

This international standard 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 calibration procedure describes how to determine the ratio between the value of the input reference wavelength (or the optical frequency) and the wavelength 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 characterization of individual uncertainties. It is important to know that:

a) estimations of the individual uncertainties are acceptable;

b) a detailed uncertainty analysis is only necessary once for each wavelength meter type under test, and that all subsequent calibrations can be based on this one-time analysis;

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

A number of optical frequency references can be used to provide a traceable optical frequency. These are based on absorption by gas molecules under low pressure and using excited-state opto-galvanic transitions in atoms. Annex E lists the lines.

CALIBRATION OF WAVELENGTH/OPTICAL FREQUENCY MEASUREMENT INSTRUMENTS –

Part 2: Michelson interferometer single wavelength meters

1 Scope

This part of IEC 62129 is applicable to instruments measuring the vacuum wavelength or optical frequency emitted from sources that are typical for the fibre-optic communications industry. These sources include Distributed Feedback (DFB) laser diodes, External Cavity lasers and single longitudinal mode fibre-type sources. It is assumed that the optical radiation will be coupled to the wavelength meter by a single-mode optical fibre. The standard describes the calibration of wavelength meters to be performed by calibration laboratories or by wavelength meter manufacturers. This standard is part of the IEC 62129 series on the calibration of wavelength/optical frequency measurement instruments. Refer to IEC 62129 for the calibration 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 60050-300:2001, International *Electrotechnical Vocabulary – Electrical and electronic measurements and measuring instruments – Part 311: General terms relating to measurements – Part 312: General terms relating to electrical instruments – Part 313: Types of electrical measuring instruments – Part 314: Specific terms according to the type of instrument*

IEC 61315 :2005, *Calibration of fibre-optic power meters*

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

ISO/IEC 17025:2005, *General requirements for the competence of testing and calibration laboratories*

ISO/IEC Guide 99:2007, *International vocabulary of metrology – Basic and general concepts and associated terms (VIM)*

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

3 Terms and definitions

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

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*

3.2
adjustment
set of operations carried out on an instrument in order that it provides given indications corresponding to given values of the measurand

[IEC 60050-300:2001 (311-03-16); see also ISO/IEC Guide 99:2007, 3.11, modified]

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 standards

[ISO/IEC Guide 99:2007, 2.39, modified]

NOTE 1 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 A calibration may also determine other metrological properties such as the effect of influence quantities.

NOTE 3 The result of a calibration may be recorded in a document, sometimes called a calibration certificate or a calibration report.

3.4
calibration conditions
conditions of measurements in which the calibration is performed

3.5
correction factor
CF
numerical factor by which the uncorrected result of a measurement is multiplied to compensate for systematic error

[ISO/IEC Guide 99:2007, 2.53, modified]

3.6
detector
the element of the wavelength meter that transduces the radiant optical power into a measurable, usually electrical quantity

[IEC/TR 61931 and ISO/IEC Guide 99:2007, 3.9, modified]

3.7
deviation
value minus its reference value

NOTE In this standard, the deviation is the difference between the indication of the test meter and the indication of the reference meter when excited under the same conditions.

3.8
excitation (fibre-)
description of the distribution of optical power between the modes in the fibre

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

3.9
instrument state
complete description of the state of the meter during the calibration

3.10
measuring range
set of values of measurands for which the error of a measuring instrument is intended to lie within specified limits

[ISO/IEC Guide 99:2007, 4.7, modified]

NOTE In this standard, 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.

3.11
national (measurement) 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

[ISO/IEC Guide 99:2007, 5.3, modified]

3.12
national standards laboratory
laboratory which maintains the *national standard*

3.13
natural standard
atomic or molecular transition that can be used to realise a reference standard

3.14
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

[ISO/IEC Guide 99:2007, 4.9, modified]

NOTE The operating conditions and uncertainty at operating conditions are usually specified by manufacturer for the convenience of the user.

3.15
operating range
specified range of values of one of a set of *operating conditions*

3.16
optical input port
physical input of the wavelength meter (or standard) to which the radiant power is to be applied or to which the optical fibre end is to be connected. An optical path (path of rays with or without optical elements like lenses, diaphragms, light guides, etc.) is assumed to connect the optical input port with the detector

3.17
reference conditions
conditions of use prescribed for testing the performance of a measuring instrument or for intercomparison of results of measurements

[ISO/IEC Guide 99:2007, 4.11, modified]

NOTE The reference conditions generally include reference values or reference ranges for the influence quantities affecting the measuring instrument.

3.18
reference wavelength meter
standard which is used as the reference to calibrate a test wavelength meter

3.19
reference source
laser stabilized by reference to an atomic or molecular transition, or a stabilized frequency comb, of known frequency/wavelength

3.20
reference standard
standard, generally having the highest metrological quality available at a given location or in a given organization, from which measurements made there are derived

[ISO/IEC Guide 99:2007, 5.6, modified]

3.21
test meter
wavelength meter (or standard) to be calibrated by comparison with the *reference wavelength meter or the reference standard*

3.22
traceability
property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties

[ISO/IEC Guide 99:2007, 2.41, modified]

3.23
traceability chain
unbroken chain of comparison (see Figure 1)

[ISO/IEC Guide 99:2007, 2.41 and 2.42, modified]

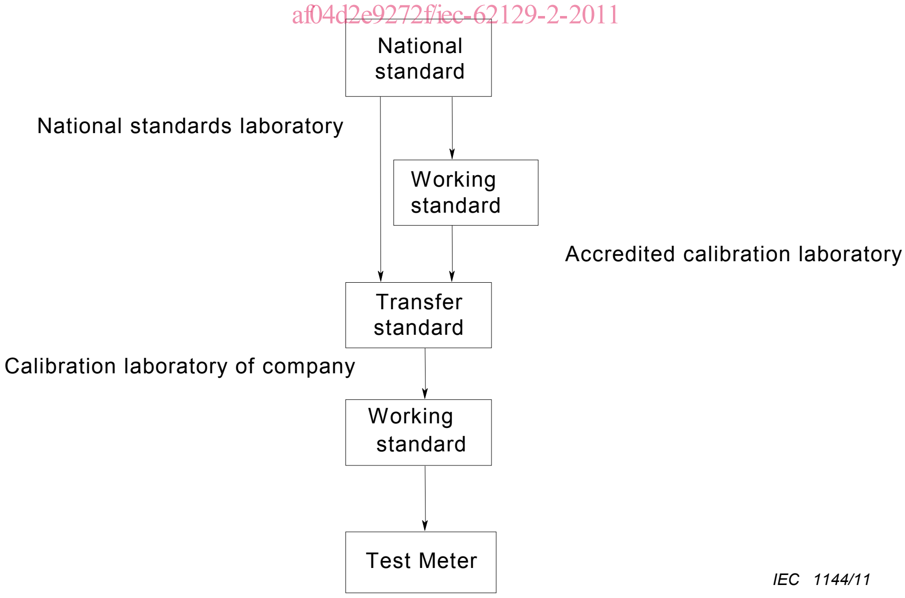

Figure 1 – Example of a traceability chain

3.24
wavelength meter (Michelson interferometer single-)
instrument, based on a Michelson interferometer, capable of measuring the wavelength of one source

NOTE Certain instrument designs can also measure the input power but with a larger uncertainty than most power meters.

3.25
working standard
standard that is used routinely to calibrate measuring instruments

[ISO/IEC Guide 99:2007, 5.7, modified]

NOTE A working standard is usually calibrated against a reference standard.

4 Preparation for calibration

4.1 Organization

The calibration laboratory should satisfy requirements of ISO/IEC 17025.

There shall 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 requirements of ISO/IEC 17025 should be met.

All standards used in the calibration process shall be calibrated according to a documented programme 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 test equipment which has a significant influence on the calibration results is calibrated. Upon request, specify this test equipment and its *traceability chain*(s). The re-calibration period(s) shall be defined and documented.

4.3 Advice for measurements and calibrations

This subclause gives general advice for all measurements and calibrations of wavelength meters.

The calibration should be made in a temperature-controlled environment. The recommended temperature is 23 °C. Depending on the desired uncertainty, the temperature, atmospheric pressure and humidity may need to be monitored during the measurement, as the air refractive index is a function of these parameters. Humidity control may be necessary to ensure that the environment is within the operating specification of the instrument.

The laboratory should be kept clean. Connectors and optical input ports should always be cleaned before measurement. The quality and cleanness of the connector in front of the wavelength meter should be checked. The wavelength meter is a precision mechanical instrument and so the fibre should be moved to the instrument rather than the other way round as required for power meter calibrations.

Laser diodes are sensitive to back reflections. To improve stability, it is advisable to use an optical isolator between the laser diode and the test meter.

For instruments that also report optical power, refer to IEC 61315 for calibration procedures. It is important to note that optical sources such as extended cavity laser diodes that may have a narrow linewidth (e.g. 50 kHz) and therefore give rise to a long coherence length. Coherent reflections will add as the vector sum of the electric fields rather than the sum of the optical powers.

The use of a reference source based on a natural standard will yield lower uncertainties than calibrations made using a reference wavelength meter.

4.4 Recommendations to customers

A single wavelength meter calibration within an ITU band (see Annex D) is expected to be sufficient for that band. The increase in uncertainties due to extrapolation of the calibration to adjacent bands must be determined for each design of instrument.

5 Single wavelength calibration

5.1 General

The wavelength calibration of the wavelength meter is based on a comparison with a reference standard and the uncertainty comprises the contribution of the stability of the instrument under test, its "On/Off repeatability," its wavelength dependence and the optical connector repeatability.

The correction is based on the calibration result.

The "On/Off repeatability" measurement provides a contribution to the instrument uncertainty calculation. The repeatability of the stabilization of the internal wavelength reference and the stability of the optical alignment are the main contributors to this uncertainty contribution.

The measurement of the wavelength dependence also provides a contribution to the instrument uncertainty calculation. This measurement has several purposes.

a) To verify that the correction for the air refractive index has been correctly implemented within the instrument.
b) To determine the uncertainty contributions caused by numerical truncation errors.
c) To determine the uncertainty contributions caused by the finite optical path length within the test instrument.
d) To determine systematic alignment effects such as wavelength dependent beam steering.

The calibration can be performed either using a reference source with a lock quality monitor or using a reference wavelength meter.

Acquiring the measurement results under computer control is highly recommended.

5.2 Establishing calibration conditions

Establishing and maintaining the calibration conditions is an important part of the calibration, because any change in these conditions is capable of producing erroneous measurement results. The calibration conditions should be a close approximation to the intended operating conditions. This ensures that the (additional) uncertainty in the operating environment is as small as possible. The calibration conditions should be specified in the form of nominal values with uncertainties when applicable. In order to meet the requirements of this standard, the calibration conditions shall at least consist of

a) the date of calibration,
b) the ambient temperature, with uncertainty, for example 23 °C ± 1 °C. The temperature may need to be monitored continuously to ensure that it remains within the prescribed limits,
c) the atmospheric pressure, for example 1020 hPa to1025 hPa. The atmospheric pressure may need to be monitored continuously to ensure that it remains within the prescribed limits,

d) the ambient relative humidity, for example 30 % to 50 %. The ambient relative humidity may need to be monitored continuously to ensure that it remains within the prescribed limits. A relative humidity below the condensation point is assumed by default,

e) the input optical power (that must fall within the allowable specification for the instruments),

f) the connector and polishing type,

g) details of the reference material or its identification number. Examples have been taken for a gas absorption cell:

   1) gas and isotope, e.g. $^{13}C_2H_2$

   2) path length, e.g. 15 cm

   3) pressure within the vessel, e.g. 1 000 Pa

   4) transition, e.g. R(21)

h) the centre vacuum wavelength or frequency of the exciting source with its uncertainty,

i) if a transition locked source is used then the quality of the lock must be continuously monitored during the measurements; a lock indicator can be sufficient.

NOTE The above conditions may not be exhaustive. There may be other parameters that have a significant influence on the measurement uncertainty and therefore should also be reported.

5.3 Calibration procedure

5.3.1 General

a) Establish and record the appropriate calibration conditions (see 5.2). Switch on all instrumentation and wait for enough time to stabilize.

b) Set up the reference source.

c) In some of the older instrument designs a connector-adapter combination is used to couple light from the optical fibre into the instrument. A fraction of the light from the reference signal, typically a helium-neon laser, is emitted from the instrument. This beam defines the optical axis for the interferometer. Maximizing the residual reference signal from the test wavelength meter optimises the alignment of the connector-adapter. The optical power must be measured using a linear power meter.

d) Set up the instrument state of the test wavelength meter according to the instruction manual. Select appropriate units.

e) Record the instrument states of the wavelength meter.

5.3.2 Measurement configuration

Figure 2 shows the configuration using a reference source S with a lock-quality monitor Q. The temperature, pressure and humidity of the environment may need to be monitored. The refractive index change due to humidity is less than $\pm 4 \times 10^{-7}$ at 1 550 nm. Monitoring of the relative humidity is optional and is required only to achieve the best specification.