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Calibration of wavelength/optical frequency measurement instruments

Part 3: Optical frequency meters using optical frequency combs

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CONTENTS

FOREWORD ... 3
INTRODUCTION ... 5
1 Scope ... 6
2 Normative references ... 6
3 Terms and definitions ... 6
4 Calibration test requirements ... 7
4.1 Preparation ... 7
4.2 Reference test conditions ... 8
4.3 Traceability ... 8
4.3.1 General ... 8
4.3.2 National standard ... 8
4.3.3 Transfer standard ... 9
4.3.4 Working standard ... 9
5 Optical frequency calibration ... 9
5.1 General ... 9
5.2 Establishing the calibration conditions ... 11
5.3 Calibration procedure ... 11
5.3.1 General ... 11
5.3.2 Measurement configuration ... 11
5.3.3 Detailed procedure ... 13
5.4 Calibration uncertainty ... 13
5.5 Reporting the results ... 13
Annex A (normative) Mathematical basis ... 14
A.1 General ... 14
A.2 Type A evaluation of uncertainty ... 14
A.3 Type B evaluation of uncertainty ... 15
A.4 Determining the combined standard uncertainty ... 15
A.5 Reporting ... 16
Annex B (informative) References of optical frequency comb source ... 17
B.1 Method A (mode-locked fibre laser + carrier-envelope phase lock) ... 17
B.2 Method B (stabilized laser + electro-optical modulator) ... 17
B.3 Method C (stabilized laser + supercontinuum source) ... 18
Annex C (informative) Frequency-dependence of uncertainty ... 19
Bibliography ... 20

Figure 1 – Traceability chain using optical frequency measurement scheme ... 9
Figure 2 – Schematic configuration of optical frequency measurement technique that uses optical comb ... 10
Figure 3 – Optical spectra of lasers and optical frequency combs ... 11
Figure 4 – Optical frequency meter measurement using a reference source ... 12
Figure 5 – Optical frequency meter measurement using a reference optical frequency meter ... 12
Figure B.1 – Mode-locked laser + nonlinear optical effect ... 17
Figure B.2 – Electro-optical modulator type comb source ... 18
Figure B.3 – Supercontinuum source ... 18

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

CALIBRATION OF WAVELENGTH/OPTICAL FREQUENCY MEASUREMENT INSTRUMENTS –

Part 3: Optical frequency meters using optical frequency combs

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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC/TS 62129-3, which is a technical specification, has been prepared by IEC technical committee 86: Fibre optics.

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The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
86/461/DTS	86/465/RVC

Full information on the voting for the approval of this technical specification 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 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

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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

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INTRODUCTION

It is essential for realizing fibre optic systems that optical channels are defined in the optical frequency domain, not the wavelength domain. One example, the anchor frequency of the ITU-T grid is 193,1 THz, and the channel spacings of the ITU-T grid are 12,5 GHz, 25 GHz, 50 GHz, and 100 GHz [2][1].

ITU-T has also discussed λ-interface systems such as “black link” [3]. “Black link” includes WDM MUX/DEMUX and a transmission fibre, and provides λ-interfaces. Especially in DWDM systems (channel spacing <100 GHz), the uncertainty in specifying optical frequency needs to be minimized.

To implement future telecom systems, it is expected that optical frequency measurements will need to be extremely precise. For example, to achieve the channel spacing of 25 GHz, signal optical frequency uncertainty (Uf_{sig}) and required measurement uncertainty (Uf_{meas}) need to be 2 GHz to 200 MHz ($Uf_{\mathrm{sig}} / f = 10^{-5}$ to 10^{-6}) and 200 MHz to 2 MHz ($Uf_{\mathrm{meas}} / f = 10^{-6}$ to 10^{-8}), respectively. Unfortunately, conventional wavelength meters have measurement uncertainties of 10^{-6} to 10^{-7}. The solution is to use optical frequency measurements since measurement uncertainties can be as small as 10^{-15} to 10^{-16}, which satisfies the above telecom requirement ($Uf_{\mathrm{meas}} / f = 10^{-6}$ to 10^{-8}). Therefore, an optical frequency measurement scheme is necessary for the calibration of future telecom systems.

Optical frequency measurement technology is progressing rapidly. Many fundamental papers have examined the use of equally-spaced “optical frequency comb” lines (spacing of up to 50 GHz) from an optical frequency comb as a “ruler” for optical frequency measurement [4-15]. For example, mode-locked lasers with carrier-envelope phase locked enable ultra-low measurement uncertainties of 10^{-15} to 10^{-16}. Some examples of practical optical frequency combs are shown in Annex B (mode-locked fibre laser + carrier-envelope phase lock, stabilized laser + electro-optical modulator, and stabilized laser + supercontinuum source). Frequency measurements provide more accurate values than interferometric wavelength measurements in air by eliminating the effects of refractive indices. Furthermore, they allow the measurement devices to be significantly smaller than wavelength meters.

[1] Numbers between square brackets refer to the Bibliography.

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CALIBRATION OF WAVELENGTH/OPTICAL FREQUENCY MEASUREMENT INSTRUMENTS –

Part 3: Optical frequency meters using optical frequency combs

1 Scope

This part of IEC 62129, which is a technical specification, describes the calibration of optical frequency meters. It is applicable to instruments measuring the optical frequency emitted from sources that are typical for the fibre-optic communications industry. It is assumed that the optical radiation will be coupled to the optical frequency meter by a single-mode optical fibre.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 (OFCS)*

IEC/TR 61931, *Fibre optic – Terminology*

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

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

3 Terms and definitions

For the purposes of this document, the terms and definitions contained in IEC/TR 61931, as well as 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 measurement standards

3.2
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

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