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Edition 2.0 2017-07

INTERNATIONAL STANDARD

NORME INTERNATIONALE

End-face image analysis procedure for the calibration of optical fibre geometry test sets

Procédure d'analyse d'image d'extrémité pour l'étalonnage de dispositifs d'essais de géométrie des fibres optiques

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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END-FACE IMAGE ANALYSIS PROCEDURE FOR THE CALIBRATION OF OPTICAL FIBRE GEOMETRY TEST SETS

FOREWORD

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International Standard IEC 61745 has been prepared by IEC technical committee 86: Fibre optics.

This second edition cancels and replaces the first edition, published in 1998, and constitutes a technical revision.

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

a) removal of the limitation of single mode optical fibre geometry test sets to include multimode;
b) addition of a new annex as mathematical basis.

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

CDV	Report on voting
86/510/CDV	86/516/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.

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- withdrawn,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.

INTRODUCTION

In the research and production environments, there exists a range of test methods for characterizing the geometry of optical fibres. Furthermore, each test method may determine one or more of the many parameters required for complete geometrical characterization. IEC 61745 describes the calibration of test sets that perform end-face image analysis, also known as "near-field" or "grey-scale" analysis. The principles, however, may be applied to test sets of a different type.

END-FACE IMAGE ANALYSIS PROCEDURE FOR THE CALIBRATION OF OPTICAL FIBRE GEOMETRY TEST SETS

1 Scope

This document describes the calibration of test sets that perform end-face image analysis, also known as "near-field" or "grey-scale" analysis. The principles, however, can be applied to test sets of a different type.

The procedures outlined are performed by calibration laboratories and by the manufacturers or users of geometry test sets, for the purpose of calibrating geometry test sets and for evaluating the uncertainties in measurements made on calibrated test sets. The calibration of fibre coating or cable measurement test sets is not covered by this document.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purpose of this International Standard, the following definitions 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 an appropriate national organization to issue calibration certificates that demonstrates traceability to national standards

3.2
artefact
object that is measured on or used to calibrate a geometry test set

EXAMPLE An optical fibre and a chromium-on-glass pattern are examples of artefacts.

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

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 may also determine other metrological properties such as the effects of influence quantities.

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

3.4
calibration chain
chain of transfers from a national standard to the geometry test set through intermediate or working standards

Note 1 to entry: See $U = k \times u$.

3.5
calibration checking
establishing that a geometry test set that has been previously calibrated but has reached its calibration due date remains within specified uncertainty limits

Note 1 to entry: If the geometry test set has drifted outside these limits, then re-calibration is required. Otherwise, the re-checking period can be extended for a stated period.

Note 2 to entry: The test set may be checked using a working standard.

3.6
calibration standard
artefact that is calibrated against a reference standard and is used to calibrate test sets

Note 1 to entry: The artefact may be a fibre or a chromium-on-glass pattern.

Note 2 to entry: Proper use of a calibration standard ensures traceability.

Note 3 to entry: The term includes the reference standard, the transfer standard and the working standard(s), in descending order of metrological uncertainty.

3.7
combined standard uncertainty
combination of a number of individual standard uncertainties

Note 1 to entry: The term "accuracy" should be avoided in this context.

Note 2 to entry: In calibration reports and technical data sheets, the combined standard uncertainty in the geometry test set measurement is reported as an overall expanded uncertainty with the applicable confidence level, for example 95,5% or 99,7 %.

3.8
confidence level
estimation of the probability that the true value of a measured parameter lies within a given range (expanded uncertainty)

3.9
correction offset
number that is added to or subtracted from the measurement result of a test set to correct for a known physical effect

3.10
coverage factor
k
factor used to calculate the expanded uncertainty, U, from the standard uncertainty, u

3.11
expanded uncertainty
U
range of values within which the measurement parameter, at the stated confidence level, can be expected to lie

Note 1 to entry: It is equal to the coverage factor, k, times the combined standard uncertainty u

$$U = k \times u \tag{1}$$

Note 2 to entry: When the distribution of uncertainties is assumed to be normal and a large number of measurements are made, then confidence levels of 68,3 %, 95,5 % and 99,7 % correspond to k values of 1, 2 and 3 respectively.

3.12
geometry test set
instrument used to measure the geometrical parameters of an optical fibre

Note 1 to entry: The parameters measured will depend on the type of geometry test set.

3.13
infant fibre
fibre whose geometry is to be measured on a calibrated geometry test set

3.14
instrument state
description of the measurement conditions of the geometry test set during calibration and measurement

Note 1 to entry: The measurements conditions are for instance form-fits used, data filtering schemes employed and other important information concerning the test set such as warm-up time and date of calibration.

3.15
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

[SOURCE: ISO/IEC Guide 99:2007, 5.3, modified – The first preferred term "national measurement standard" has been deleted, and the definition has been rephrased.]

3.16
national standards laboratory
laboratory which maintains the national standard

3.17
operating range
range of conditions under which the geometry test set is designed to perform within the stated expanded uncertainty

Note 1 to entry: Such conditions include the diameter of the fibre being measured and environmental conditions, such as temperature.

3.18
reference standard
artefact measured at a calibration laboratory, with the measurement traceable to national standards

3.19
scaling factor
ratio of the known standard values for a calibration standard to the values indicated by the geometry test set when no correction offsets are applied

3.20
standard uncertainty
u
uncertainty of a measurement result expressed as a standard deviation

Note 1 to entry: For further information, see Annex A and ISO/IEC Guide 98-3.

3.21
traceability
ability to demonstrate, for a measurement result or a geometry test set, a calibration chain originating from a national standard

Note 1 to entry: Geometry test sets calibrated by the procedures in this document are traceable. Direct traceability of the measurement results either to a national standards laboratory or to an accredited calibration laboratory need to be demonstrated. Such traceability includes the calibration schedules of all artefacts in the calibration chain and detailed calculations of all (cumulative) transfer uncertainties in the calibration chain.

Note 2 to entry: The use of a working standard alone to compare or monitor geometry test set calibration cannot establish or re-establish traceability, but can only extend the duration of the traceability certification if no change is found.

3.22
transfer standard
standard that is calibrated against a reference standard and is used for calibrating geometry test sets

3.23
transfer uncertainty
estimate characterizing the uncertainty of a measurement caused by uncertainties in the transfer process, at the given confidence level (such as changes in environmental conditions)

Note 1 to entry: These uncertainties may arise from the calibration standards used as well as from the geometry test set.

3.24
working standard
standard that is used on a routine basis to calibrate or check measuring instruments

4 General information and preparation for calibration

4.1 Geometrical parameters of optical fibres

It is necessary to characterize the geometrical properties of optical fibres in order to ensure satisfactory mechanical and optical performance. The geometrical parameters measured by the types of test sets consist of the following:

a) cladding (reference surface) diameter;

b) cladding non-circularity;

c) core/cladding concentricity error.

4.2 Description of geometry test sets

End face image, or grey-scale, test sets usually comprise an optical microscope, an illumina-tion source, an electronic image recording device, such as a camera, and a means of storing image data for processing by digital computer. A second illumination source is usually employed to launch light into the other end of the fibre. This enables the position of the fibre core also to be measured. A typical measurement sequence is as follows: a cleaved fibre end is positioned in the measurement port of the instrument and an image of the fibre end is formed on the camera. The image of the fibre is focused, usually under automatic computer control, digitized, and then transferred to a computer, which determines the geometrical parameters of the fibre.

The quality of the fibre end is critical in this method, and the presence of cleave damage, such as chips or edge roughness, can seriously affect the measurement. It is thus usual to employ data-filtering methods to reduce the sensitivity of the measured result to the presence of cleave damage.

4.3 Calibration standard requirements

The calibration procedure detailed in this document requires the use of traceable calibration artefacts. These artefacts consist of a calibrated fibre end and a chromium-on-glass mask. Their nominal dimensions are discussed in 5.3.3 and 5.5.

5 Calibration

5.1 General

The calibration procedure comprises the following two operations.

a) The magnification, or scaling factor, of the imaging system is calibrated. This is a similar process to conventional calibration methods for optical microscopes, except that, in this case, a two-dimensional calibration is required.

b) A correction offset is determined. This offset is required to correct for systematic effects such as diffraction at the fibre edge, differences between the way the calibration artefact is calibrated and the method of measurement in the test set, and distortion of the image of the fibre edge by camera sampling.

Worked examples for the determination of calibration factors are given in Annex B.

The calibration will be valid when applied to measurements in the following way:

– the scaling factors are applied multiplicatively to the raw data from the camera, before applying form-fits and computing the cladding diameter of the fibre under test;

– the correction offset is applied additively to the computed cladding diameter of the fibre under test.

NOTE 1 The choice of an edge-setting criterion defining the position of the cladding edge is important, and calibration applies only to measurements using the same criterion as that used at the time of calibration.

NOTE 2 In certain circumstances, it has been found sufficient to calibrate only the scaling factor using a fibre or chromium-on-glass standard. This approach, however, can lead to increased uncertainties when measuring fibres that are of significantly different diameter from the calibration standard used.

5.2 Rationale for calibration of geometry test sets

5.2.1 General

The measurement of cladding diameter is common to most types of geometry test sets, so calibration of this parameter is very important in comparing test sets of different types. This document, however, details only the calibration of test sets that perform end-face image analysis.

Basically, calibration is achieved by exposing the test set to independent geometrical calibration standards. It is these standards that form the calibration chain and, therefore, contribute to the transfer uncertainty.

The procedure is detailed in 5.3. The complete calibration chain is illustrated in Figure 1.

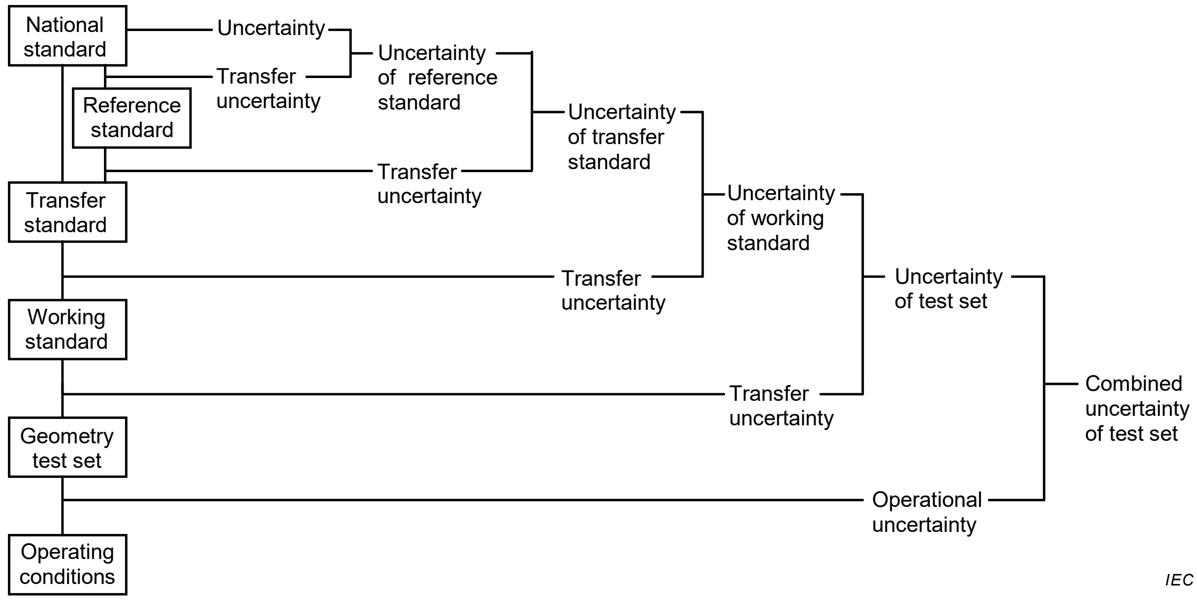

Figure 1 – Example of a calibration chain and the accumulation of uncertainties

Calibration of the core/cladding concentricity error and non-circularity measurement is not described, as there are no suitable standard reference materials available at the time of writing. However, procedures enabling estimation of the uncertainties obtained in the measurement of these parameters are given in Annex G and Annex H respectively.

5.2.2 Verification of calibration state

For routine verification, such as may frequently be carried out on geometry test sets in use, it is sufficient to check (but not to reset) the state of calibration of the geometry test sets using a working standard. The working standard may be a fibre or a chrome-on-glass mask.

A procedure for generation of a working standard is given in Annex F.

The distinction between checking the state of calibration and the calibration itself shall be clearly made. While it is sufficient to establish stability of the geometry test set using the working standard, this is not a substitute for full calibration.

The use of a working standard allows continued traceability to national standards to be claimed, if it can be satisfactorily established that the existing instrument state, correction factors, and so on, are sufficient to provide geometry results within a specified uncertainty and without alteration. This simply means that the geometry test set has remained stable since the last calibration.

Continued traceability can be claimed on a calibrated test set provided that the measured values for the working standard agree with its calibrated values within the uncertainties.

Calibration is essential in the commissioning of geometry test sets, whereas a working standard is used for routine calibration checking.

The procedure for calibration checking is described in 5.4.