IEC 60793-1-20

Edition 2.0 2014-10

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Optical fibres –
Part 1-20: Measurement methods and test procedures – Fibre geometry

Fibres optiques –
Partie 1-20: Méthodes de mesure et procédures d'essai – Géométrie de la fibre

IEC 60793-1-20:2014-10(en-fr)

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OPTICAL FIBRES –

Part 1-20: Measurement methods and test procedures – Fibre geometry

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International Standard IEC 60793-1-20 has been prepared by subcommittee SC86A: Fibre and cables, of IEC technical committee TC86: Fibre optics.

This second edition cancels and replaces the first edition, published in 2001, and constitutes a technical revision.

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

- the reference test method for all fibre types is changed to the video grey scale transmitted near field method from the refracted near field method;
- the test lengths for all fibre types are now to be specified in the fibre's detail specification;
- the core illumination wavelength for all multimode fibre types may now to be specified in the fibre's detail specification although defaults are given;

- the core k-factor (decision level) is now to be specified in the detail specification for all multimode fibre types;
- this edition is substantially more specific in describing the measurement; data reduction and transformation is fully described;
- the data reduction methodology for both refracted near-field and transmitted near-field methods are now unified and consistent.

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

CDV	Report on voting
86A/1562/CDV	86A/1623/RVC

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.

A list of all parts in the IEC 60793 series, published under the general title *Optical fibres*, 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 website 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- withdrawn,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.

The contents of the corrigendum of March 2016 have been included in this copy.

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INTRODUCTION

This standard gives two methods for measuring fibre geometry characteristics:

– Method A: Refracted near-field, described in Annex A;

– Method B: Transmitted near-field, described in Annex B.

Methods A and B apply to the geometry measurement of all class A multimode fibres, class B single-mode fibres and class C single-mode interconnection fibres. The fibre’s applicable product specifications, IEC 60793-2-10, IEC 60793-2-20, IEC 60793-2-30, IEC 60793-2-40, IEC 60793-2-50 and IEC 60793-2-60, provide relevant measurement details, including sample lengths and k factors.

The geometric parameters measurable by the methods described in this standard are as follows:

– cladding diameter;

– cladding non-circularity;

– core diameter (class A fibre only);

– core non-circularity (class A fibre only);

– core-cladding concentricity error.

NOTE 1 The core diameter of class B and class C fibres is not specified. The equivalent parameter is mode field diameter, determined by IEC 60793-1-45.

NOTE 2 These methods specify both one-dimensional (1-D) and two-dimensional (2-D) data collection techniques and data analyses. The 1-D methods by themselves cannot detemine non-circularity nor concentricity error. When non-circular bodies are measured with 1-D methods, body diameters suffer additional uncertainties. These limitations may be overcome by scanning and analysing multiple 1-D data sets. Clause 5 provides further information.

Information common to both methods appears in Clauses 2 through 10, and information pertaining to each individual method appears in Annexes A and B, respectively. Annex C describes normative methods used to find the optical boundaries of the core and the cladding, Annex D describes normative procedures to fit ellipses to sets of detected boundaries. Annex E provides an informative fitting procedure of power-law models to graded-index core profiles. Annex F describes an informative methodology relating to the transformation of core diameter measurements determined with methods other than the reference method to approximate reference method values.

OPTICAL FIBRES –

Part 1–20: Measurement methods and test procedures – Fibre geometry

1 Scope

This part of IEC 60793 establishes uniform requirements for measuring the geometrical characteristics of uncoated optical fibres.

The geometry of uncoated optical fibres directly affect splicing, connectorization and cabling and so are fundamental parameters requiring careful specification, quality control, and thus measurement.

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 60793-2-10, *Optical fibres – Part 2-10: Product specifications – Sectional specification for category A1 multimode fibres*

IEC 60793-2-20, *Optical fibres – Part 2-20: Product specifications – Sectional specification for category A2 multimode fibres*

IEC 60793-2-30, *Optical fibres – Part 2-30: Product specifications – Sectional specification for category A3 multimode fibres*

IEC 60793-2-40, *Optical fibres – Part 2-40: Product specifications – Specification for category A4 multimode fibres*

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

IEC 60793-2-60, *Optical fibres – Part 2-60: Product specifications – Sectional specification for category C single-mode intraconnection fibres*

IEC 61745, *End-face image analysis procedure for the calibration of optical fibre geometry test sets*

3 Terms, definitions and symbols

3.1 Terms and definitions

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

3.1.1
body
general term describing an entity whose geometry is measured (i.e. cladding or core)

3.1.2
reference point
fixed coordinate in the scan's plane

Note 1 to entry: This point is arbitrary (say the lower left corner of a video image, or the rough centre of the fibre after the fibre is located in a scanning apparatus).

3.1.3
centre
centre of a body in the measurement plane with respect to the reference point, expressed in micrometres

3.1.4
diameter
average diameter, in micrometres, of a nearly circular body

3.1.5
non-circularity
difference between the maximum and minimum radial deviation from the body's centre, normalized to the body's diameter, expressed as a per cent

3.1.6
concentricity error
scalar distance, in micrometres between two body centres

3.1.7
scan
term used to define the collection of data along one axis of the Cartesian coordinate plane, at a fixed angular orientation and a fixed offset from the reference point

3.1.8
scan set or set
one or more scans used together to determine the fibre's geometry

Note 1 to entry: The set can be one scan (see limitations below), a set of scans at different angular orientations with respect to the fibre, or a raster scan (like a video image).

3.1.9
edge table
set of number pairs representing a set of points in the scanning plane which define a closed curve line of delineation between the cladding and the surrounding media (the cladding edge table) or the core and the cladding (the core edge table)

3.1.10
elliptical model
ellipse fit
best fit ellipse to an edge table

3.2 Symbols

The symbols defined below are used to indicate various aspects of a scanned data set. Scans can be one-dimensional, or two-dimensional raster scans (where the scan axes are orthogonal on a Cartesian plane), or a set of one-dimensional scans at a set of angles.

i The index used for the scanning axis or the 'fast' axis in the case of a raster scan.

j The index used for the 'slow' axis in a raster scan.

k The index used for the angle in a multi-angular scan set.

I The set of data from one-dimensional or two-dimensional scanning. The data can be near-field intensity data (from Method B) or index of refraction (Method A); in this standard, no delineation is made as either type of data is intermediate and is further analysed to extract the fibre's geometry. A single datum from a set is indicated by subscript in a manner consistent with the nature of the data set: I_i for the ith point of the scan in a single scan set; $I_{j,i}$ for a raster data point at the jth location on the slow axis and the ith position on the fast axis; $I_{k,I}$ for the i^{th} point at the k^{th} angle.

x The positional data, in micrometres, of the set. For a single scan set, the meaning of x is clear. For a raster scan set or a multi-angle set, x refers to the positional data of the 'fast' axis (raster) or scan positions (for each angle). (Raster sets whose individual lines have different fast-axis positions or multi-angle sets where each angle uses a different set of positions are allowed by this standard, but this complication is ignored in the forthcoming analytical development).

y The positional data, in micrometres, of the raster lines (the slow-axis locations) in a raster scan set.

φ The angles in a multi-angle set. The k^{th} angle in the set is indicated by subscript: φ_k.

nS The number of points in a single scan. In the case of raster scan sets n_S is the number of points of the fast axis. In multi-angular scan sets, nS is the number of points in any scan. (This standard's nomenclature ignores cases where the number of points varies between raster lines or angles, although such data sets are allowed.)

nR The number of raster rows (slow axis scans) in a raster set.

$n\varphi$ The number of angles in a multi-angle set.

NOTE The following symbols are used to describe an edge table.

X, Y A set of locations in the X-Y scan plane of the fibre which delineate a body from its surroundings.

n_e The number of edge points in an edge table.

4 Overview of method

4.1 General

In essence, each method (A or B) defined herein describes a way of producing an image of the fibre in a plane normal to its axis of propagation. This resultant image is then further analysed (as described in Annexes C, D and E) to reduce the image to an expression of the fibre's geometry. Methods A and B can produce images which are one-dimensional (i.e. along only one axis in the plane of the image), or two-dimensional. It is obvious that a two-dimensional image is more information rich, and thus these images produce more complete geometric information; the non-circularity of a body cannot be determined from a one-dimensional scan, nor can concentricity errors be determined with any certainty.

The analysis of the image consists of two steps. The first step is to quantify where in the image the body of interest is delineated (see Annex C). The second step reduces the ensemble of these points of delineation to one or more geometric parameters: diameter, non-circularity and centre (if both, the cladding and core are measured and their centres determined then concentricity error may also be determined). Annex D describes methods which can be used on both the cladding and core of all fibre types and Annex E describes a method that may be used for the core body of class A fibres.

This standard addresses a range of needs, and as such, allows for a range of for data collection and reduction. The specific limitations and uses of these approaches are discussed below.

4.2 Scanning methods

4.2.1 General

As noted above, sampling a two-dimensional body in only one-dimension has limitations. Ideal fibres are perfectly circular and the core and cladding are concentric; real fibres are noncircular and have concentricity errors. Non-circularity and concentricity cannot be measured by a one-dimensional scan and one-dimensional scanning may under- or over-estimate the average diameter of a noncircular body. One-dimensional scanning may be useful for fibres whose non-circularity and concentricity errors are known to be small and one-dimensional scans are commonly used to determine the core diameter of class A fibres.

4.2.2 One-dimensional scan sources of error

4.2.2.1 Scanning a chord

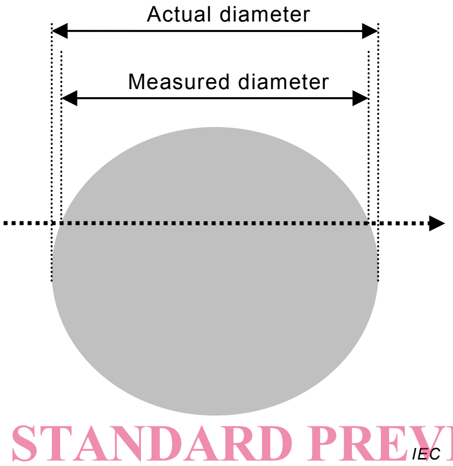
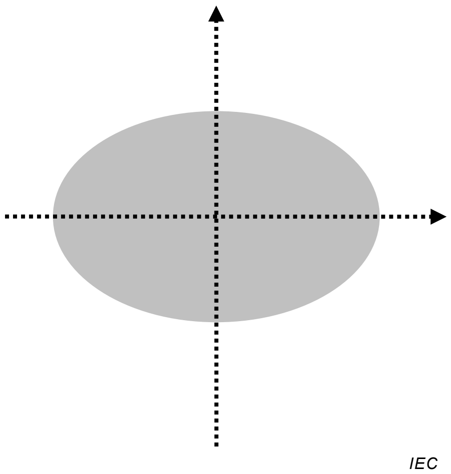


Figure 1 – Sampling on a chord

Figure 1 illustrates the error that occurs when the sampling axis is not co-linear with the centre of the body. When the sampling axis misses the body's centre, the body's diameter is underestimated. This is a second order error.

4.2.2.2 Scanning non-circular bodies

If a body is non-circular, a one-dimensional scan will not fully describe the body's shape. Sampling a body in one dimension will generally under-estimate or over-estimate the average diameter of the body. It may be assumed that this problem can be rectified by sampling the body in two orthogonal axes (i.e. X and Y), but in general, this is not sufficient. Consider Figure 2:



Figre 2a – Major diameter

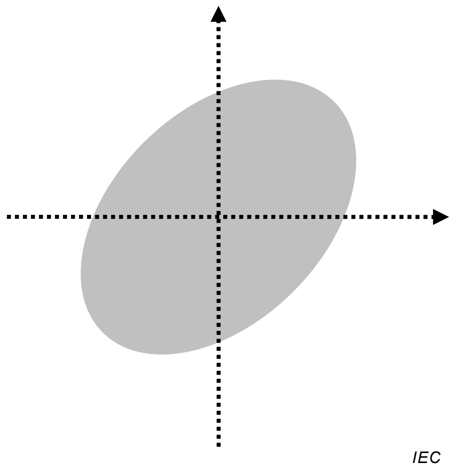


Figure 2b – Average diameter

Figure 2 – Scan of a non-circular body

Figure 2 illustrates errors that occur when an elliptical body is sampled on one or two axes. In the major diameter example (Figure 2a), the ellipse's major diameter is aligned with the X axis. In this case, sampling only in X will over-estimate the body's average diameter; the fact that the body is non-circular will be missed (likewise, sampling the body only in Y will underestimate the body's diameter). In this orientation, if the body is sampled on both axes the body will be completely characterized: both its average diameter and non-circularity are discovered. However, in the 'average diameter' case, sampling on either axes gives the same, approximately correct diameter for both axes; if both axes are sampled it would appear that the body is perfectly circular. Analysing ±45 ° scans will give the correct non-circularity and diameter, but there is no way to know the proper angular scan angles beforehand. At orientations other than –45 ° and +45 °, the body's average diameter will be measured correctly, but the body's circularity will be underestimated.

4.2.2.3 Concentricity indeterminacy

If a single axis is scanned, the core's centre relative to the cladding centre cannot be known. Scanning two orthogonal axes can provide a reasonable estimate of the core's centre. This estimate will degrade if the core is scanned on a chord far from the core's centre. If the core is substantially smaller than the cladding and is significantly non-concentric, then one or more scans may miss the core entirely.

4.2.3 Multidimensional scanning

4.2.3.1 Multi-angle scanning

As suggested in 5.2.2.2 and 5.2.2.3, the estimation of the geometry of the fibre can be improved by scanning on two orthogonal axes. Combining scans over more than two angles (for example at 0 °, 45 °, 90 ° and 135 °) will improve these estimates further. Acquiring data at multiple angles can be accomplished by rotating the fibre in its holding chuck, or, if the scanner is so designed, by the mechanics of the scanner itself. Note that all angular scans shall share a single frame of reference (a common origin) or errors will be introduced.

4.2.3.2 Raster scanning

If the scanner is capable of motion on two orthogonal axes, then it is possible that a two-dimensional image of the fibre may be constructed by performing a raster scan.

Measurement of the transmitted near-field using grey-scale video is inherently a raster scan.

4.3 Data reduction

4.3.1 Simple combination of few-angle scan sets

When reducing data sets where only a few angular orientations are measured, it is generally sufficient to employ simple data reduction. For each body, the diameter can be determined by averaging the diameters of each angular scan; the non-circularity by using the maximum and minimum diameters from the set of angles. When both cladding and core are measured, the concentricity error can be determined simply from the angle showing the worst-case centration error. See Annex D for more information.

4.3.2 Ellipse fitting of several-angle or raster data sets

When many data points may be extracted from the scan set, as is the case when many angles are scanned or when raster scanning is employed, the edge tables may be fit to elliptical models. Annex E describes the methodology to fit a body's edge table (determined as described in Annex D).

For both the cladding and the core for all fibre categories, ellipse fitting is the reference method.

5 Reference test method

The reference test method (RTM) is the video grey-scale transmitted near-field method described in Annex B for all fibre categories. Data analysis shall employ boundary detection as described in Annex C, and ellipse fitting to reduce the edge tables to geometry, as described in Annex D. See Annexes A and B for a discussion of reference sample lengths for all fibre classes, and refer to Annex C for a discussion of the decision threshold factor k for class A fibres.

6 Apparatus

Annexes A and B include layout drawings and other equipment requirements for each of the Methods A and B, respectively.

7 Sampling and specimens

7.1 Specimen length

Annexes A and B specify the required sample lengths for their respective methods.

7.2 Specimen end face

Prepare a clean, flat end face, perpendicular to the fibre axis, at the input and output ends of each specimen. The accuracy of measurements is affected by a non-perpendicular end face. End angles less than 1 ° are recommended.

See Clause B.2 for the tighter requirements on end faces when using Method B.

8 Procedure

Use the procedures given in IEC 61745 for calibration. Annexes A and B document the procedures for Methods A and B, respectively.