IEC 61300-3-47

Edition 1.0 2014-07

INTERNATIONAL STANDARD

colour inside

Fibre optic interconnecting devices and passive components – Basic test and measurement procedures –
Part 3-47: Examinations and measurements – End face geometry of PC/APC spherically polished ferrules using interferometry

IEC 61300-3-47:2014-07(en)

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CONTENTS

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FIBRE OPTIC INTERCONNECTING DEVICES AND PASSIVE COMPONENTS – BASIC TEST AND MEASUREMENT PROCEDURES –

Part 3-47: Examinations and measurements – End face geometry of PC/APC spherically polished ferrules using interferometry

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

FDIS	Report on voting
86B/3773/FDIS	86B/3805/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.

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Part 3-47: Examinations and measurements – End face geometry of PC/APC spherically polished ferrules using interferometry

1 Scope

This part of IEC 61300 describes a procedure to measure the end face geometry of a spherically polished ferrule or connector. Within this standard the words “ferrule” and “connector” can be used interchangeably.

2 Terms and definitions

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

2.1
radius of curvature
B
radius of curvature of the portion of the spherically polished ferrule end face which is domed for physical contact

Note 1 to entry: It is assumed that the end face is spherical, although in practice the end face is often aspherical (see Figure 1).

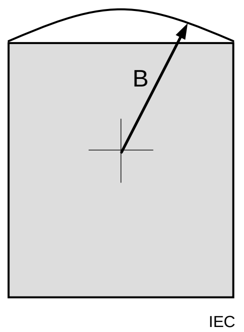

Figure 1 – Radius of curvature of a spherically polished ferrule end face

2.2
apex offset
C
distance between the axis of the ferrule and the line parallel to the axis which passes through the vertex (or highest point on the dome), formed by spherically polishing the ferrule, as shown in Figure 2

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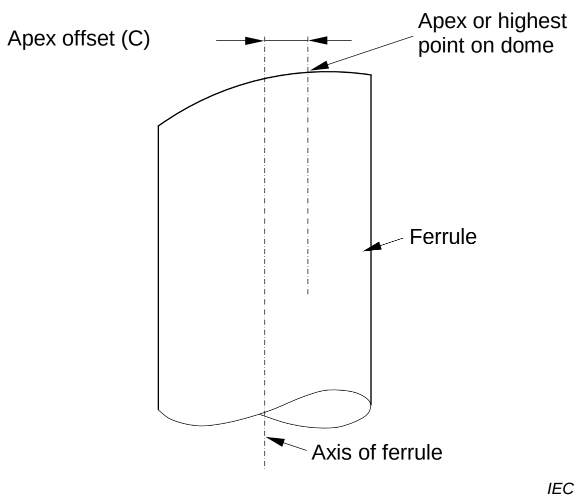

Figure 2 – Apex offset of a spherically polished ferrule end face

2.3
fibre height
average distance between the fibre end face and a virtual spherical surface which is fitted to the spherically polished ferrule end face (see Annex C)

Note 1 to entry: It is assumed that a circular region of the ferrule end face, which is centred to the ferrule axis, is spherical although in practice the end face is often aspherical. A positive value indicates fibre undercut (see Figure 3a). A negative value indicates fibre protrusion (see Figure 3b).

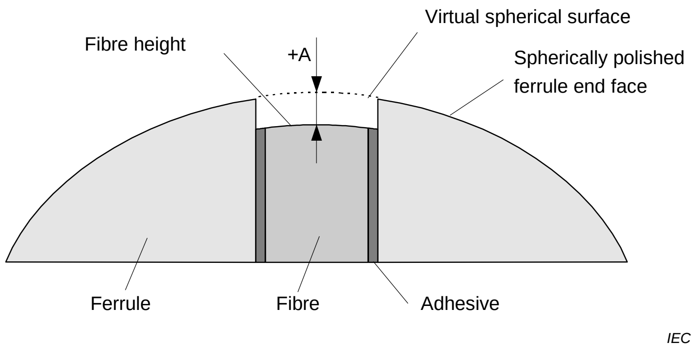

Figure 3a – Fibre height +A

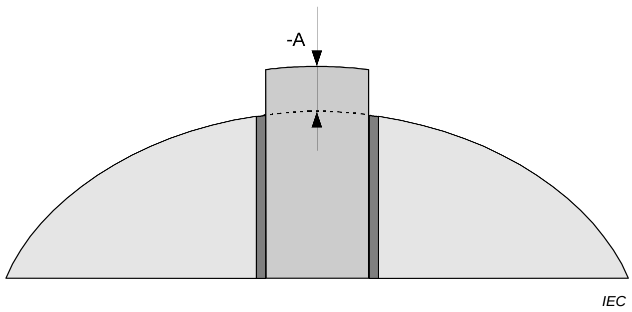

Figure 3b – Fibre height –A (protrusion)

Figure 3 – Fibre height of a spherically polished ferrule end face

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2.4
end face angle
angle (θ) between the plane perpendicular to the axis of the ferrule, and the straight line tangent to the polished surface at the fibre centre in the direction of the nominal angle (see Figure 4)

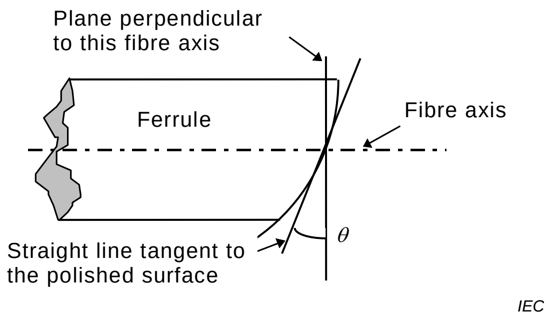

Figure 4 – Ferrule end face angle for spherically polished ferrules

3 Measurement by interferometer

3.1 General

A typical interferometer configuration is shown in Figure 5. The apparatus consists of a suitable ferrule/connector holder, an optical interferometric system combined with a microscope and a camera.

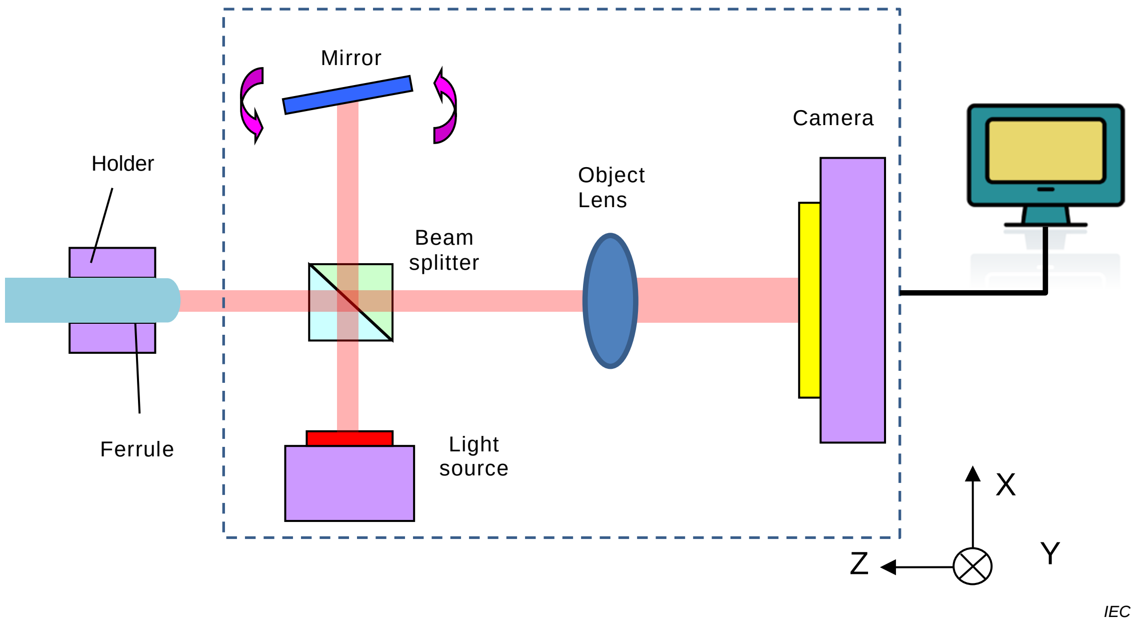

Figure 5 – Interferometer

3.2 Ferrule/connector holder

This is a suitable device to hold the ferrule/connector in a fixed alignment position with respect to the optical axis of the interferometer. The holder is designed such that the portion of the ferrule closest to the end face is secured by the holder. The ferrule shall be aligned by holding it over a distance of at least twice the ferrule diameter. The ferrules axis should be adjustable in order to make it parallel to the optical axis of the interferometer. Alternatively,

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this can be carried out by positioning the reference mirror of the interferometer. For angled polished ferrules adjustments are necessary to align the polish angle axis with the optical axis of the interferometer.

3.3 Optical interferometric system

A suitable optical interferometric system (for example a Michelson interferometer) displays an image with interference fringes of the ferrule's end face.

3.4 Microscope with camera

The image of the end face is projected on to the camera with a minimum field of view of 250 μm. Software processes the image(s) and calculates the required parameters.

4 Requirements for the interferometer

4.1 XY calibration (radius of curvature)

The interferometer shall have the ability to measure the radius of curvature with measurement uncertainty better than ±0,1 mm for radii from 5 mm to 30 mm. See Annex A.

4.2 Z calibration (fibre height)

The interferometer shall have the ability to measure the fibre height with measurement uncertainty better than ±10 nm. See Annex A.

4.3 Alignment of ferrule axis with the interferometer's optical axis (apex offset calibration)

The interferometer shall have the ability to measure the apex offset with a maximum difference of less than 5 μm between two measurements where the second measurement is made after rotating the ferrule by 180°. See Annex A.

NOTE This test is only possible with non-angled ferrules.

4.4 Tilt and key angle

When measuring angled connectors, calibration of the holder position is required. Measurement of a flat polished ferrule should have a measurement uncertainty better than ±0,1° for the key angle and ±0,03° for the tilt angle.

NOTE The key angle is the angular rotational misalignment between the ferrule mating surface of an angled end face connector, and its design orientation angle with respect to its key (see Annex B).

5 Measurement method

5.1 General

For all measurements, the instrument should be adjusted such that

a) a sample is placed in the measurement holder,

b) the image of the ferrule end face in the fibre zone is seen on the monitor,

c) the interference fringes appear on the ferrule end face,

d) the ferrule axis is correctly aligned with the optical axis of the interferometer ("apex offset calibration"),

e) all other instrument calibrations have been performed,

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f) the system is configured according to the type of measurement to be performed (e.g. PC or APC ferrule/connector).

5.2 Measurement regions

Three regions shall be defined on the ferrule end face for the measurement (see Figure 6).

a) Fitting region: the fitting region is set on the ferrule surface, and defined by a circular region having a diameter, D, minus a circular region having a diameter, E, (the extracting region). The fitting region shall be defined in order to cover the contact zone of the ferrule end face when the ferrule is mated.

b) Extracting region: the extracting region, which includes the fibre end face region and the adhesive region, is defined by a circle having a diameter E.

c) Averaging region: the averaging region is set on the fibre surface, and defined by a circular region “having a diameter F”. This region is used for fibre height A averaging.

The 3 regions should be concentric on the ferrule axis. For connectors with 125 μm nominal fibre diameter and a radius of curvature of nominally 5 mm to 30 mm, the values of the diameters D, E and F are as follows:

D = 250 μm

E = 140 μm

F = 50 μm

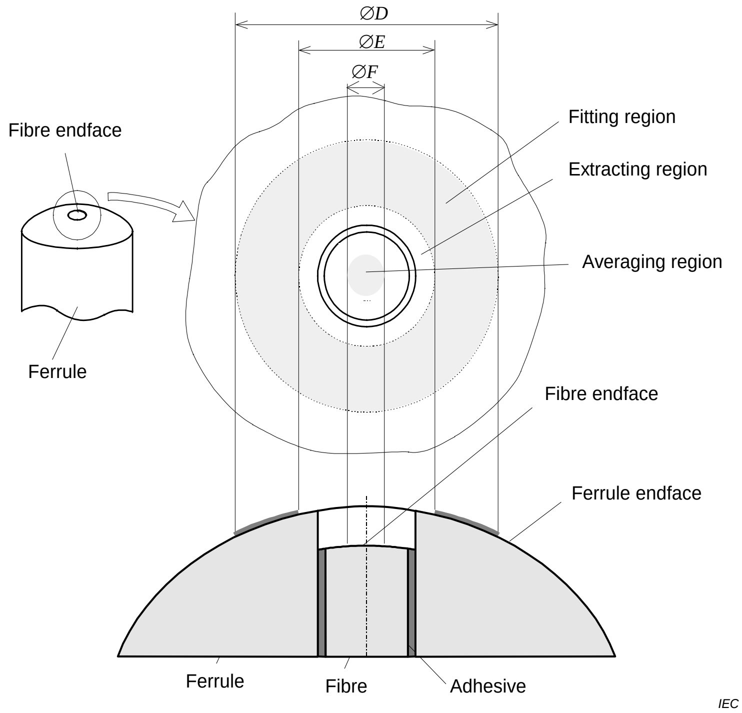

Figure 6 – Ferrule end face and measurement regions

5.3 Measurement procedure for the radius of curvature

The following steps shall be taken:

a) Measure the surface of the end face with the interferometer, recording the three-dimensional surface measurement data on its surface data processing unit (see Figure 7).

b) Correct the surface data, taking into account the refractive indices and the absorption coefficients of the fibre and the ferrule.

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c) Using the data from the fitting regions, calculate the “best fit” radius of curvature (Annex C).

5.4 Measurement procedure for the dome eccentricity (apex offset)

The following steps shall be taken:

a) Measure the surface of the end face with the interferometer, recording the three-dimensional surface measurement data on its surface data processing unit (see Figure 7).

b) Correct the surface data, taking into account the refractive indices and the absorption coefficients of the fibre and the ferrule.

c) From the analysis of the interference image(s) the normal distance between the centre of the sphere (Annex C) fitted to the surface over the fitting region and the fibre axis shall be measured. This value corresponds to the apex offset.

5.5 Measurement procedure for fibre height

The following steps shall be taken:

a) Measure the surface of the end face with the interferometer, recording the three-dimensional surface measurement data on its surface data processing unit (see Figure 7).

b) Correct the surface data, taking into account the refractive indices and the absorption coefficients of the fibre and the ferrule.

c) Using only the data within the averaging region and the fitting region evaluate A (see Figure 7 to Figure 10 and Annex C).

The calculation shall be as follows:

1) Create a converted surface from the corrected surface data by subtracting the “best fit” radius of curvature from the spherical surface data between the fitting region. The fitting region of the converted surface may be flat when the ferrule end face has an ideal spherical surface (See Figure 9).

2) Calculate an average surface height on the fibre averaging region and an average surface height on the fitted ferrule portion from the converted surface. The fibre height, A, is measured as the difference between the two average surface heights, as shown in Figure 10. A positive value indicates fibre undercut. A negative value indicates fibre protrusion.

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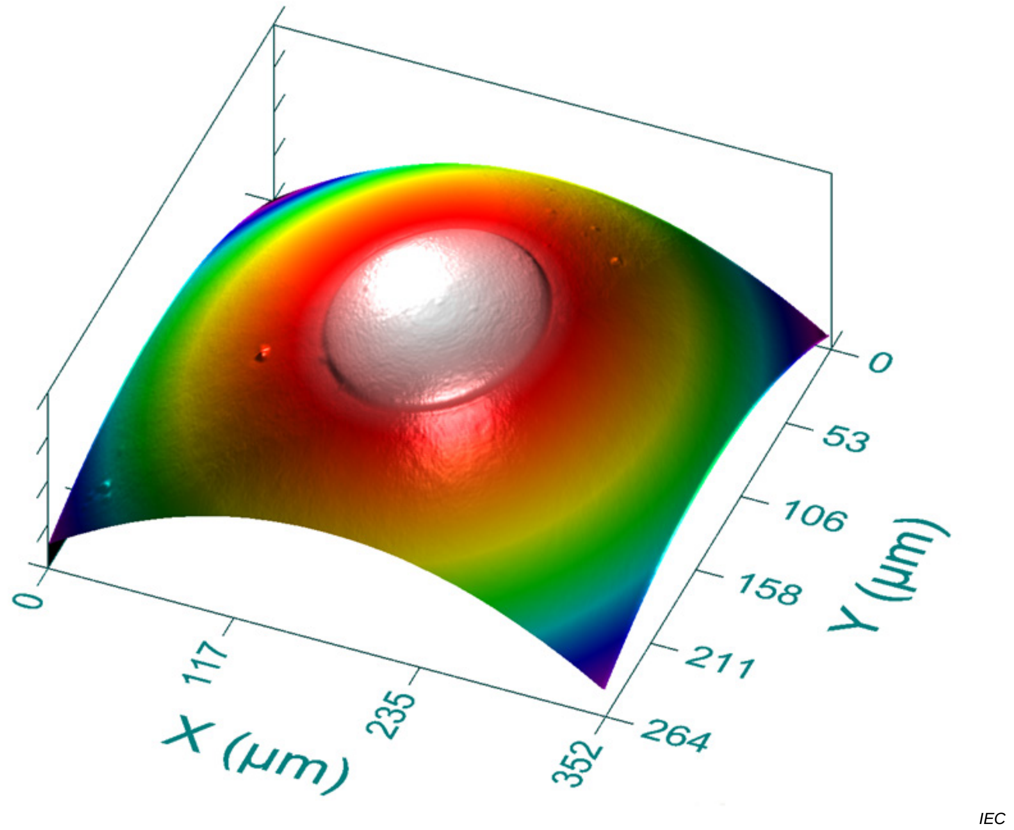

Figure 7 – Ferrule end face surface

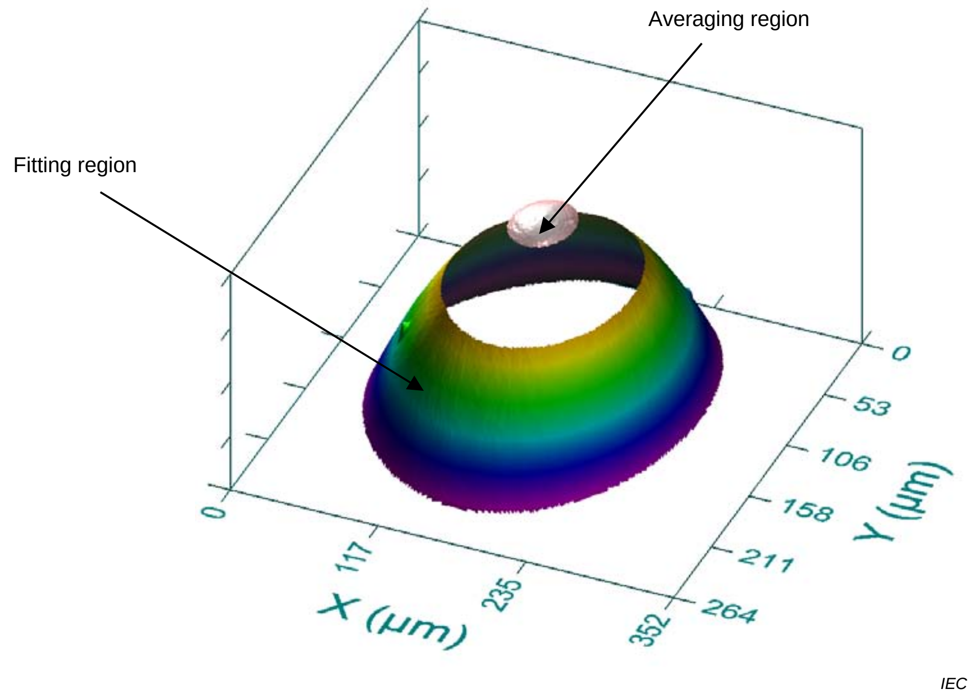

Figure 8 – Fitting region and averaging region of the ferrule end face surface

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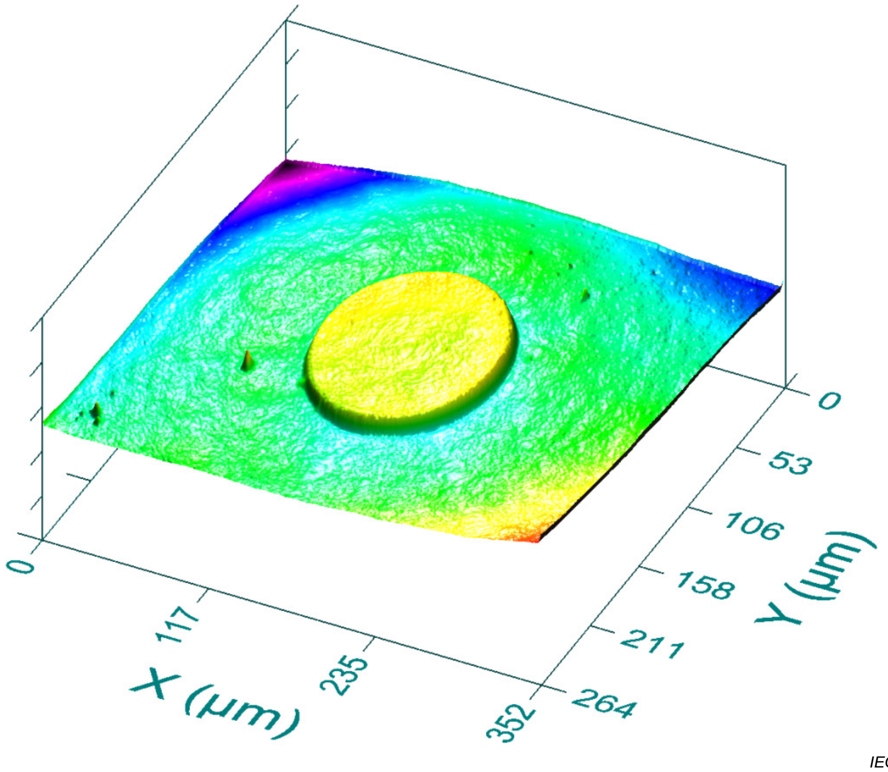

Figure 9 – Converted end face surface of the ferrule

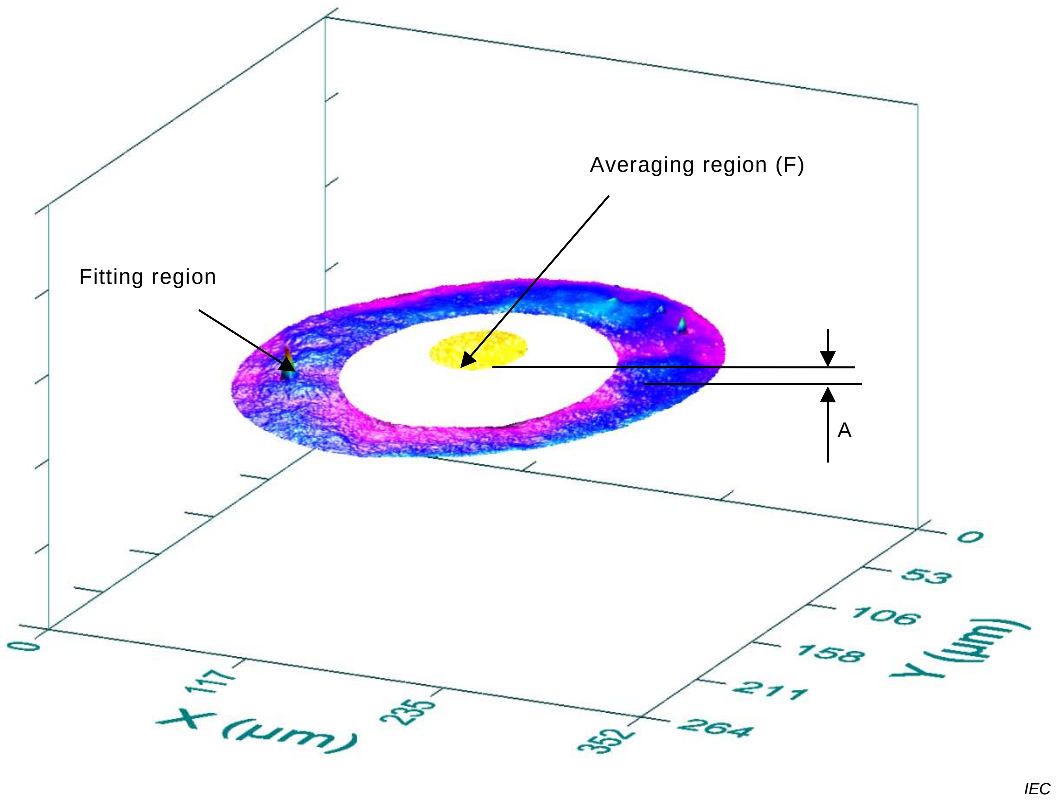

Figure 10 – Converted ferrule end face surface without the extracting region

The difference in refractive indices and the absorption coefficients between the ferrule and the fibre should be taken into account when processing the measured surface data. If the

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procedure is done without consideration of the difference, the procedure described in this clause may not accurately show the fibre undercut or protrusion.

6 Details to be specified

The following details, as applicable, shall be specified in the relevant specification:

– Type of interferometry;
– Nominal angle of tilt, e.g. PC/APC;
– Instrument configuration (keying adapter, ferrule holder etc.);
– Rotational tolerance of the ferrule position in the holder (key angular error);
– Any deviation from this method;
– Measurement uncertainty.

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Annex A
(normative)

Calibration for the interferometer

A.1 XY calibration

An XY calibration is required when the requirements of Clause 4 cannot be met.

The interferometer shall be calibrated in XY directions (if a Z calibration has already been performed beforehand), by measuring an artifact with a spherical surface – previously measured with a mechanical method. Example: contact gauge.

Alternatively an etched wafer with a calibrated grid pattern for the XY calibration can be used.

A.2 Z calibration

If the interferometer is based on the monochromatic phase-shifting method: use a step height artifact with a nominal step height less than one-quarter of the wavelength of the light source used in the interferometer.

If the interferometer uses the white-light interferometry method, use step height artifact with a nominal step height of approximately one-quarter to three-quarters of the Z scanning range of the interferometer.

A.3 Alignment of the ferule axis with the optical axis of the interferometer ("apex offset calibration")

The calibration for non-angled PC connectors is to measure the apex offset positions while rotating the ferrule by (for example) 60° steps and calculating the centre made by the 6 apex offset measurements by fitting a circle using the least-square fit method. Once calculated, translate this point to the centre of the fibre by aligning the ferrule/connector holder or the reference mirror of the interferometer. For angled connectors, see Clause A.4.

A.4 Tilt and key angle

Tilt and key angle calibration is required when angled connectors are measured and the requirements of 4.4 cannot be met.

Two methods are used (reference procedure is b):

a) Calibrate the instrument as per Clause A.3 then rotate the connector holder or the optical system by a calibrated nominal angle (e.g. 8°).

b) Calibrate the holder or mirror orientation with an artifact measured with a mechanical method. Example: contact gauge. This artifact should simulate a connector with its orientation key and compose of a flat tilted surface. For the key error compensation, a software based compensation may be used.

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Annex B
(informative)

Measurement procedure for end face "angle error" of angled convex polished ferrules

For a convex polished ferrule, the radius of curvature, B, and the apex offset component in the direction of the angle K are calculated from the analysis of the interferometric fringes (see Figure B.1). The value of the angle error is calculated from the value of B and K_x (Equation [B.1]). The value of the key error is calculated from the values of B and K_y (Equation [B.2]). When measuring angled convex polished ferrules, in addition to tilting the connector with respect to the interferometer, an adapter or keying mechanism should also be installed on the interferometer. This keying mechanism is designed to constrain the rotational orientation of the ferrule with respect to its key.

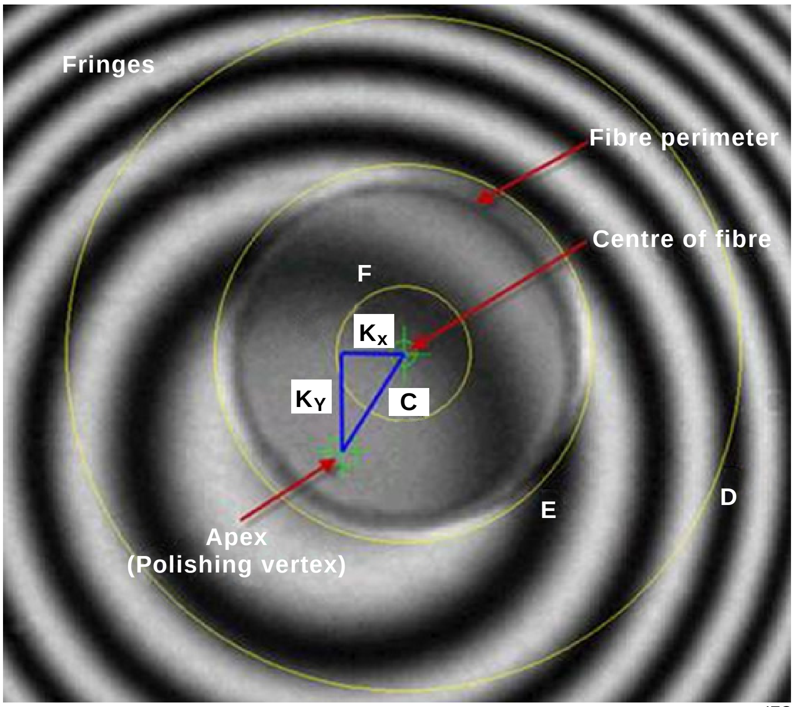

Figure B.1 – Example of key error calculated from interference pattern for a convex polished ferrule

From the analysis of the image(s) the component in the angle direction K_x, which is the distance between the apex and the fibre centre shall be calculated (see Figure B.1). The value of the angle, also called "angle error" shall be:

$$\theta = \text{arctan}\left(\frac{K_x}{R}\right) + \theta_0 \qquad [B.1]$$

From the analysis of the image(s) the component in the angle direction K_y, which is the distance between the apex and the fibre centre shall be calculated (see Figure B.1). The value of the angle, also called "key error" shall be:

$$\alpha = \text{arctan}\left(\frac{K_y}{R}\right) \qquad [B.2]$$

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It is important to understand that key error is calculated from the vertical component of the apex offset (K_y in Figure B.1) using Equation [B.2]. Although related, it should not be confused with the physical rotational degrees of the ferrule. Due to the mechanical advantage created by tilting the connector (or interferometer), repeatability of this measurement will be determined by how accurately the key can be constrained and other factors, such as the tolerances of the inner key components. This is especially true for “floating ferrule” connector designs.

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Annex C
(informative)

Formula for calculating ferrule end face geometry

The ideal spherical surface being calculated for single fibre connectors is described by the following formula:

$$(X-X_0)^2 + (Y-Y_0)^2 + (Z-Z_0)^2 = B^2 \quad [C.1]$$

where (X_0, Y_0, Z_0) is the set of coordinates of the centre of the sphere and B is its radius.

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