

# INTERNATIONAL STANDARD



**Fibre optic interconnecting devices and passive components – Basic test and measurement procedures –  
Part 3-35: Examinations and measurements – Fibre optic connector endface visual and automated inspection**



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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

## **Part 3-35: Examinations and measurements – Fibre optic connector endface visual and automated inspection**

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This standard replaces IEC/PAS 61300-3-35 which was published in 2002.

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

FDIS	Report on voting
86B/2909/FDIS	86B/2947/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.

A list of all parts of IEC 61300 series, published under the general title, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures* can be found on the IEC website.

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

## Part 3-35: Examinations and measurements – Fibre optic connector endface visual and automated inspection

### 1 Scope

This part of IEC 61300 describes methods for quantitatively assessing the endface quality of a polished fibre optic connector. The information is intended for use with other standards which set requirements for allowable surface defects such as scratches, pits and debris which may affect optical performance. In general, the methods described in this standard apply to 125 µm cladding fibres contained within a ferrule and intended for use with sources of  $\leq 2$  W of input power. However, portions are applicable to non-ferruled connectors and other fibre types. Those portions are identified where appropriate.

### 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.

None.

### 3 Measurement

#### 3.1 General

The objective of this standard is to prescribe methods for quantitatively inspecting fibre optic endfaces to determine if they are suitable for use. Three methods are described: A: direct view optical microscopy, B: video microscopy, C: automated analysis microscopy. Within each method, there are hardware requirements and procedures for both low resolution and high resolution systems. High resolution systems are to be utilized for critical examination of the glass fibre after polishing and upon incoming quality assurance. High resolution systems are typically not used during field polishing or in conjunction with multimode connectors. Low resolution systems are to be utilized prior to mating connectors for any purpose. All methods require a means for measuring and quantifying defects.

There are many types of defects. Commonly used terminology would include: particles, pits, chips, scratches, embedded debris, loose debris, cracks, etc. For practical purposes, all defects will be categorized in one of two groups. They are defined as follows:

**scratches:** permanent linear surface features;

**defects:** all non-linear features detectable on the fibre. This includes particulates, other debris, pits, chips, edge chipping, etc.

All defects and scratches are surface anomalies. Sub-surface cracks and fractures are not reliably detectable with a light microscope in all situations and are therefore not covered within this standard. Cracks and fractures to the fibre may be detected with a light microscope and are generally considered a catastrophic failure.

Differentiating between a scratch and all other defects is generally intuitive to a human being. However, to provide clarity, and for automated systems, scratches are defined as being less than 4  $\mu\text{m}$  wide, linear in nature, and with a length that is at least 30 times their width. As the width dimension is not practical to visually measure below 3  $\mu\text{m}$ , these figures can be grossly estimated.

Defects size is defined for methods A and B as the diameter of the smallest circle that can encompass the entire defect. Defect size for method C can be either the actual measured surface area or the diameter of the smallest circle than can encompass the entire defect.

Some fibre types have structural features potentially visible on the fibre endface. Fibres that use microstructures to contain the light signal, such as photonic band-gap and hole-assisted fibres, can have an engineered or random pattern of structures surrounding the core. These features are not defects.

For methods A and B below, it is recommended that visual gauge tools be developed to facilitate the measurement procedure. For method A, an eyepiece reticule is recommended. For method B, an overlay is recommended.

### **3.2 Measurement conditions**

No restrictions are placed on the range of atmospheric conditions under which the test can be conducted. It may be performed in controlled or uncontrolled environments

### **3.3 Pre-conditioning**

No minimum pre-conditioning time is required.

### **3.4 Recovery**

Since measurements are to be made at standard test conditions, no minimum recovery time is required.

## **4 Apparatus**

### **4.1 Method A: direct view optical microscopy**

This method utilizes a light microscope in which a primary objective lens forms a first image that is then magnified by an eyepiece that projects the image directly to the user's eye. It shall have the following features and capabilities:

- a suitable ferrule or connector adapter;
- a light source and focusing mechanism;
- a means to measure defects observed in the image.

### **4.2 Method B: video microscopy**

This method utilizes a light microscope in which a lens system forms an image on a sensor that, in turn, transfers the image to a display. The user views the image on the display. It shall have the following features and capabilities:

- a suitable ferrule or connector adapter;
- a light source and focusing mechanism;
- a means to measure defects observed in the image.



### 4.3 Method C: automated analysis microscopy

This method utilizes a light microscope in which a digital image is acquired or created and subsequently analyzed via an algorithmic process. The purpose of such a system is to reduce the effects of human subjectivity in the analysis process and, in some cases, to improve cycle times. It shall have the following features and capabilities:

- a suitable ferrule or connector adapter;
- a means for acquiring or creating a digital image;
- algorithmic analysis of the digital image.

A means to compare the analyzed image to programmable acceptance criteria in such a manner that a result of “pass” or “fail” is provided.

### 4.4 Calibration requirements for low and high resolution systems

#### 4.4.1 General

Microscope systems for any of the methods above shall be calibrated for use in either low or high resolution applications. It is suggested that this calibration be conducted with a purpose-built calibration artefact that can serve to validate a system's ability to detect defects of relevant size. Such an artefact shall be provided with instructions on its use and shall be manufactured in a method such that it can be measured in a traceable manner. Details on the manufacture of such artefacts can be found in Annex B.

For reference, a system's optical resolution may be calculated using the formula below. Optical resolution is not equivalent to the system's detection capability. In most cases, the system will be able to detect defects smaller than its optical resolution.

Optical resolution =  $(0,61 \times \text{wavelength of illumination source}) / \text{system's numerical aperture}$

#### 4.4.2 Requirements for low resolution microscope systems

Minimum total magnification offering a field of view of at least 250  $\mu\text{m}$  (for methods B and C, this dimension is to be measured in the vertical, or most constrained, axis) capable of detecting low-contrast defects of 2  $\mu\text{m}$  in diameter or width.

#### 4.4.3 Requirements for high resolution microscope systems

Minimum total magnification offering a field of view of at least 120  $\mu\text{m}$  (for methods B and C, this dimension shall be measured in the vertical, or most constrained, axis) capable of detecting low contrast scratches of 0,2  $\mu\text{m}$  in width and 0,003  $\mu\text{m}$  in depth.

## 5 Procedure

### 5.1 Measurement regions

For the purposes of setting requirements on endface quality, the polished endface of a connector is divided into measurement regions defined as follows (see Table 1 and Table 2).

**Table 1 – Measurement regions for single fibre connectors**

Zone	Diameter for single mode	Diameter for multimode
A: core	0 µm to 25 µm	0 µm to 65 µm
B: cladding	25 µm to 120 µm	65 µm to 120 µm
C: adhesive	120 µm to 130 µm	120 µm to 130 µm
D: contact	130 µm to 250 µm	130 µm to 250 µm
NOTE 1 All data above assumes a 125 µm cladding diameter.		
NOTE 2 Multimode core zone diameter is set at 65 µm to accommodate all common core sizes in a practical manner.		
NOTE 3 A defect is defined as existing entirely within the inner-most zone which it touches.		

**Table 2 – Measurement regions for multiple fibre rectangular ferruled connectors**

Zone	Diameter for single mode	Diameter for multimode
A: Core	0 µm to 25 µm	0 µm to 65 µm
B: Cladding	25 µm to 115 µm	65 µm to 115 µm
NOTE 1 All data above assumes a 125 µm cladding diameter.		
NOTE 2 Multimode core zone diameter is set at 65 µm to accommodate all common core sizes in a practical manner.		
NOTE 3 A defect is defined as existing entirely within the inner-most zone which it touches.		
NOTE 4 Criteria should be applied to all fibres in the array for functionality of any fibres in the array.		

### 5.2 Calibration procedure

On commissioning, and periodically during its life, the microscope system shall be calibrated.

Fix the artefact(s) on the microscope system, focus the image.

Follow manufacturer's instructions on how to calibrate the system using the artefact. Generally, this should entail viewing the artefact and verifying that the small features and contrast targets are "reliably detectable"; and that the region of interest can be fully viewed or scanned. Reliably detectable is defined as sufficient clear and visible so that a typical technician of average training would recognize the feature at least 98 % of the time.

For automated systems, software utilities to perform this calibration shall be provided. In any event, those systems shall be able to perform the same calibration to validate that they can reliably detect the features of the artefact.

### 5.3 Inspection procedure

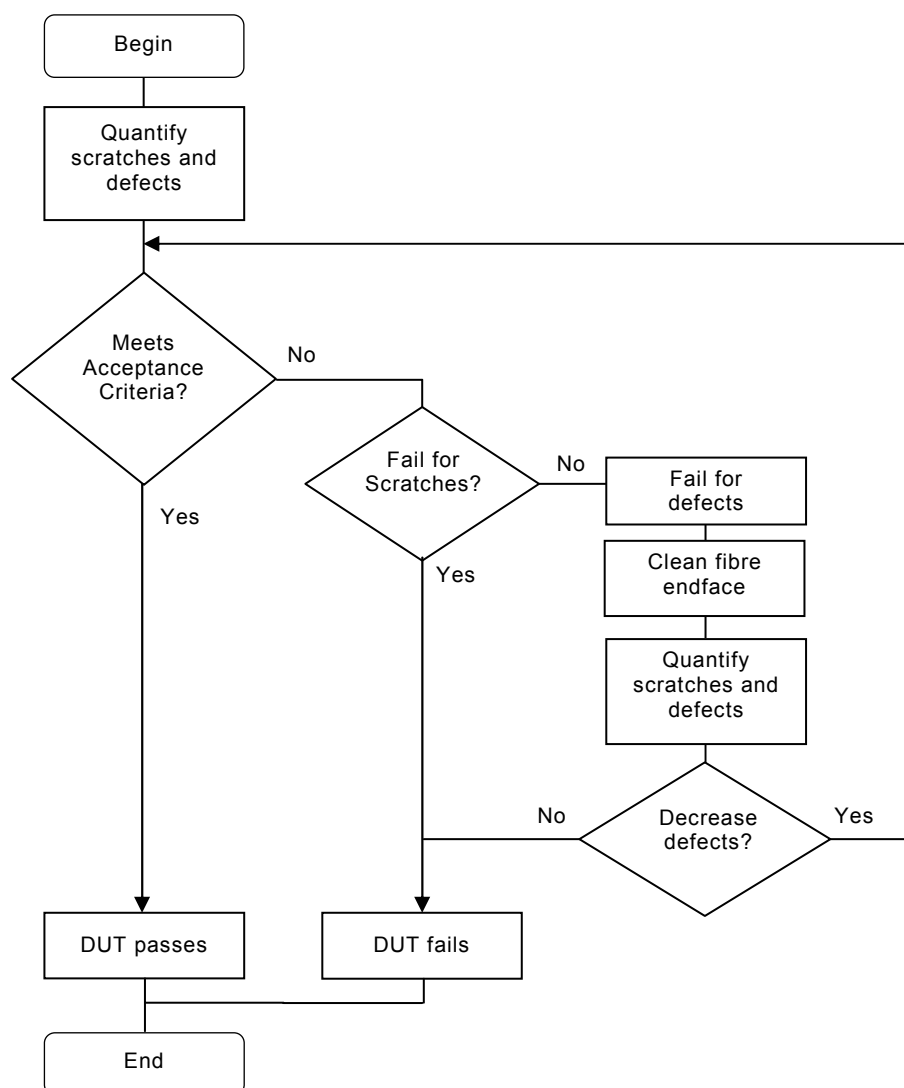
Focus the microscope so that a crisp image can be seen.

Locate all defects and scratches within the zones prescribed in the acceptance criteria. Count and measure defects and count scratches within each zone. Scratches that are extremely wide may be judged to be too large, per the acceptance criteria and result in immediate failure of the DUT.

Once all defects and scratches have been quantified, the results should be totalled by zone and compared to the appropriate acceptance criteria. Such criteria can be found in 5.4.

Any endface with quantified defects or scratches in excess of the values shown in any given zone on the table are determined to have failed.

If the fibre fails inspection for defects, the user shall clean the fibre and repeat the inspection process. In this way, loose debris can be removed and the fibre may be able to pass a subsequent inspection without rework or scrap. Cleaning shall be repeated a number of times consistent with the cleaning procedure being used.



IEC 2214/09

**Figure 1 – Inspection procedure flow**

## 5.4 Visual requirements

Visual requirements for each connector are shown in Table 3, Table 4, Table 5 and Table 6.

**Table 3 – Visual requirements for PC polished connectors, single mode fibre, RL ≥ 45 dB**

Zone name	Scratches	Defects
A: core	None	None
B: cladding	No limit ≤3 µm None >3 µm	No limit <2 µm 5 from 2 µm to 5 µm None >5 µm
C: adhesive	No limit	No limit
D: contact	No limit	None =>10 µm
<p>NOTE 1 For scratches, the requirement refers to width.</p> <p>NOTE 2 No visible subsurface cracks are allowed in the core or cladding zones.</p> <p>NOTE 3 All loose particles should be removed. If defect(s) are non-removable, it should be within the criteria above to be acceptable for use.</p> <p>NOTE 4 There are no requirements for the area outside the contact zone since defects in this area have no influence on the performance. Cleaning loose debris beyond this region is recommended good practice.</p> <p>NOTE 5 Structural features that are part of the functional design of the optical fibre, such as microstructures, are not considered defects.</p>		

**Table 4 – Visual requirements for angle polished connectors (APC), single mode fibre**

Zone name	Scratches	Defects
A: core	≤4	None
B: cladding	No limit	No limit <2 µm 5 from 2 µm to 5 µm None >5 µm
C: adhesive	No limit	No limit
D: contact	No limit	None ≥10 µm
<p>NOTE 1 For scratches, the requirement refers to width.</p> <p>NOTE 2 No visible subsurface cracks are allowed in the core or cladding zones.</p> <p>NOTE 3 All loose particles should be removed. If defect(s) are non-removable, it should be within the criteria above to be acceptable for use.</p> <p>NOTE 4 There are no requirements for the area outside the contact zone since defects in this area have no influence on the performance. Cleaning loose debris beyond this region is recommended good practice.</p> <p>NOTE 5 Structural features that are part of the functional design of the optical fibre, such as microstructures, are not considered defects.</p>		

**Table 5 – Visual requirements for PC polished connectors, single mode fibre, RL ≥ 26 dB**

Zone name	Scratches	Defects
A: core	2 ≤ 3 μm None >3 μm	2 ≤ 3 μm None >3 μm
B: cladding	No limit ≤3 μm 3 > 3 μm	No limit <2 μm 5 from 2 μm to 5 μm None >5 μm
C: adhesive	No limit	No limit
D: contact	No limit	No ≥10 μm
<p>NOTE 1 For scratches, the requirement refers to width.</p> <p>NOTE 2 No visible subsurface cracks are allowed in the core or cladding zones.</p> <p>NOTE 3 All loose particles should be removed. If defect(s) are non-removable, it should be within the criteria above to be acceptable for use.</p> <p>NOTE 4 There are no requirements for the area outside the contact zone since defects in this area have no influence on the performance. Cleaning loose debris beyond this region is recommended good practice.</p> <p>NOTE 5 Criteria should be applied to all fibre pairs in the array for functionality of any fibre pairs in the array.</p> <p>NOTE 6 Structural features that are part of the functional design of the optical fibre, such as microstructures, are not considered defects.</p>		

**Table 6 – Visual requirements for PC polished connectors, multimode fibres**

Zone name	Scratches	Defects
A: core	No limit ≤3 μm 0 > 5 μm	4 ≤ 5 μm None >5 μm
B: cladding	No limit ≤5 μm 0 > 5 μm	No limit <2 μm 5 from 2 μm to 5 μm None >5 μm
C: adhesive	No limit	No limit
D: contact	No limit	None ≥10 μm
<p>NOTE 1 For scratches, the requirement refers to width.</p> <p>NOTE 2 No visible subsurface cracks are allowed in the core or cladding zones.</p> <p>NOTE 3 All loose particles should be removed. If defect(s) are non-removable, it should be within the criteria above to be acceptable for use.</p> <p>NOTE 4 There are no requirements for the area outside the contact zone since defects in this area have no influence on the performance. Cleaning loose debris beyond this region is recommended good practice.</p> <p>NOTE 5 The zone size for multimode fibres has been set at 65 μm to accommodate both 50 μm and 62,5 μm core size fibres. This is done to simplify the grading process.</p> <p>NOTE 6 Structural features that are part of the functional design of the optical fibre, such as microstructures, are not considered defects.</p>		

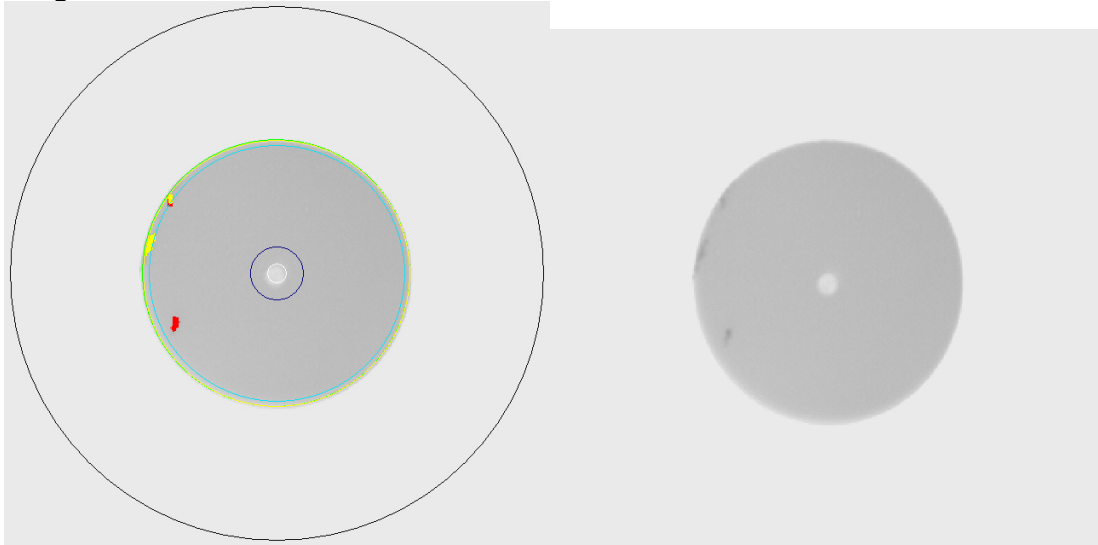
## Annex A (informative)

### Examples of inspected end-faces with defects

Images below are shown on the left with a computer overlay highlighting where the scratch or defect was found, and then at right without the overlay.

Examples of low resolution graded images:

**Image 1**

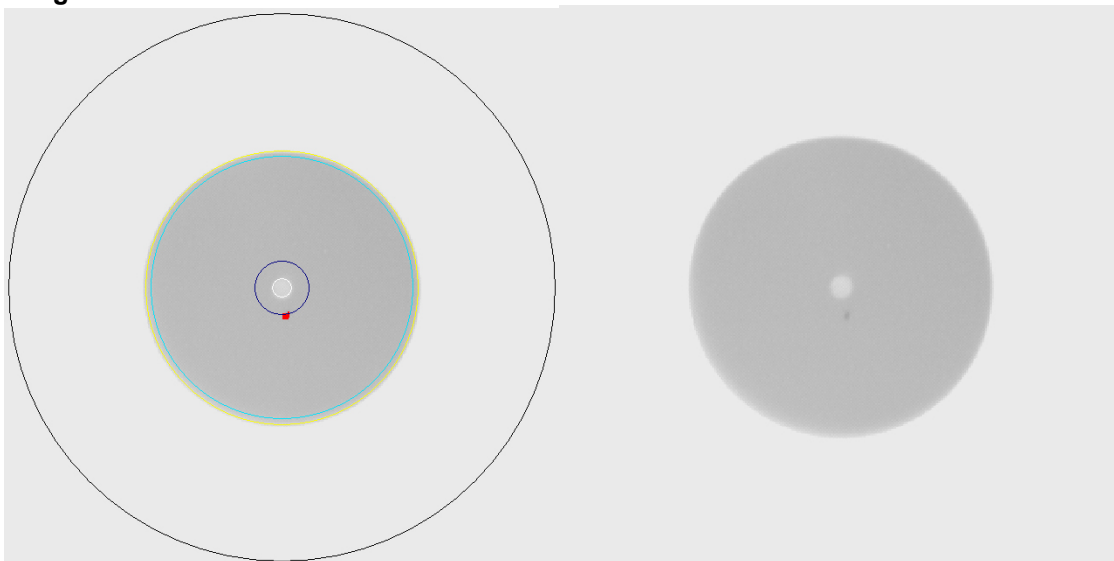


**Fibre/connector type:** SM,  $RL \geq 45$  dB (Table 3).

**Result:** rejected.

**Reason:** 3 defects in the cladding zone. Those highlighted in red are over  $5 \mu\text{m}$  in diameter and a failure condition per Table 3.

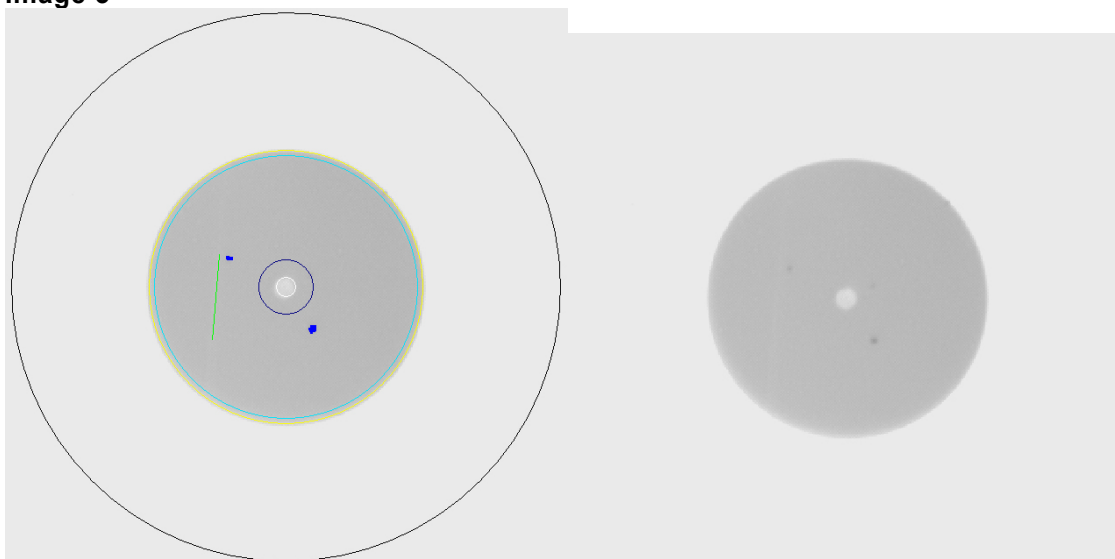
**Image 2**



**Fibre/connector type:** SM,  $RL \geq 45$  dB (Table 3).

**Result:** rejected.

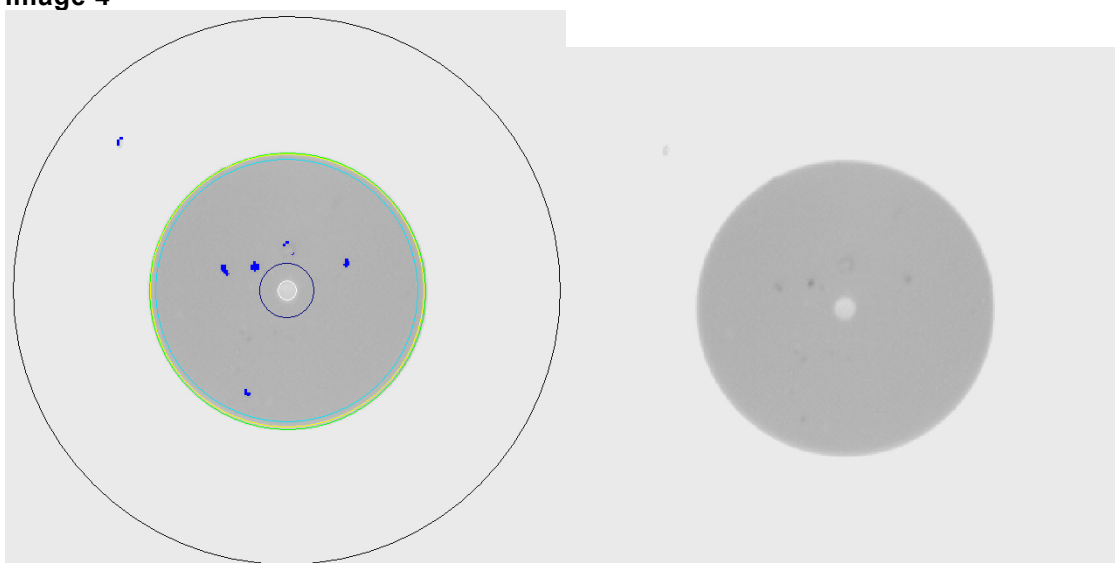
**Reason:** 1 defect touching the core zone. Per Table 1, since it touches the core zone, it is judged to exist entirely in the core zone. Per Table 3, no defects are allowed in the core zone.

**Image 3**

**Fibre/connector type:** SM,  $RL \geq 45$  dB (Table 3)

**Result:** accepted.

**Reason:** 1 fine scratch and 2 particles  $< 5 \mu\text{m}$  in the cladding zone. Per Table 3, acceptable.

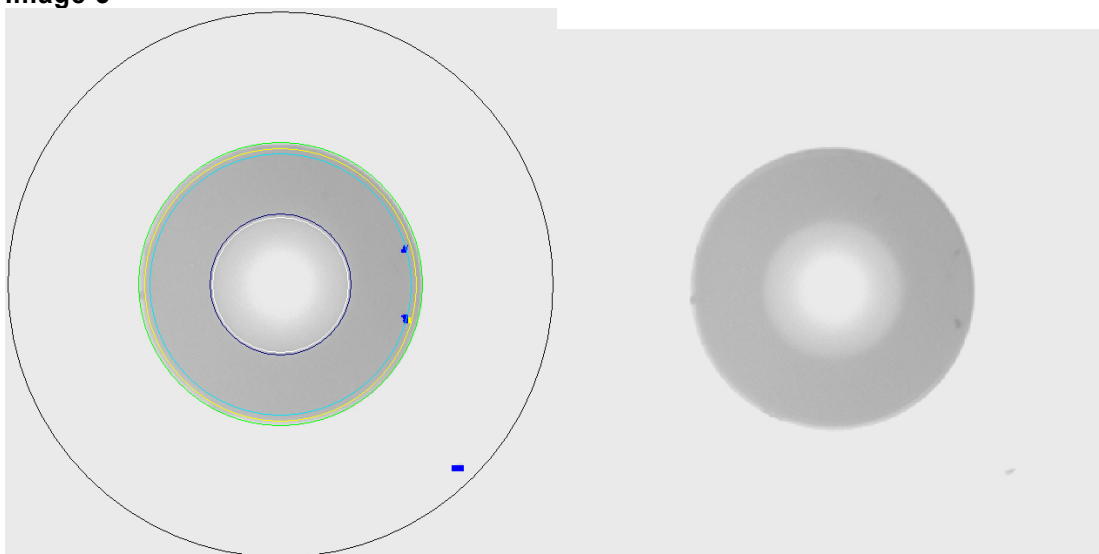
**Image 4**

**Fibre/connector type:** SM,  $RL \geq 45$  dB (Table 3).

**Result:** accepted.

**Reason:** observed defects: 6 defects in the cladding zone. One defect is  $< 2 \mu\text{m}$  and can be ignored; the other 5 are below  $5 \mu\text{m}$  in diameter. In the contact zone, 1 defect  $< 10 \mu\text{m}$ . Per Table 3, acceptable.

**Image 5**

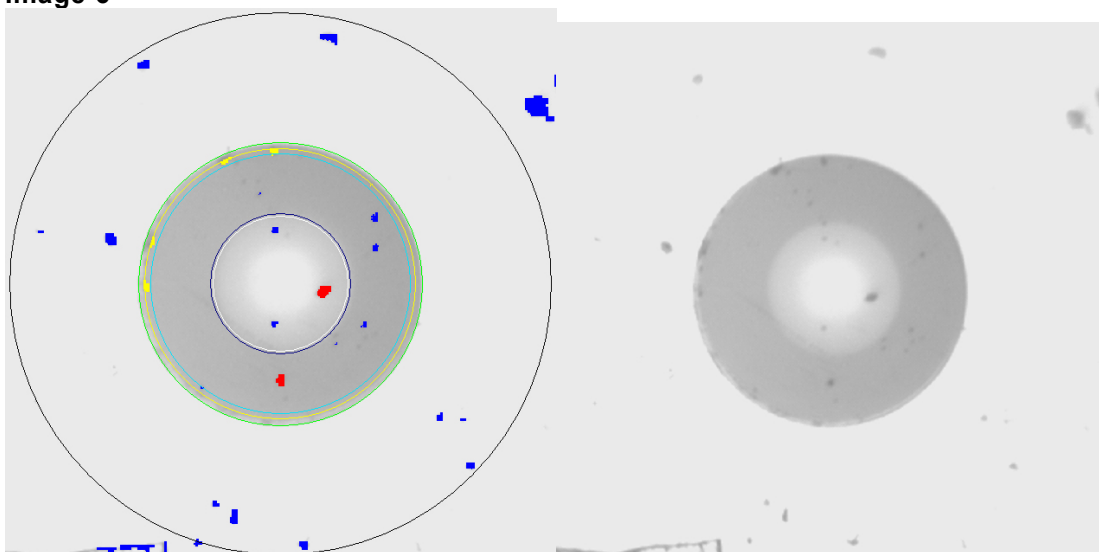


**Fibre/connector type:** MM, (Table 6).

**Result:** accepted.

**Reason:** 2 defects < 5  $\mu\text{m}$  in the cladding zone (1 defect of 4,8  $\mu\text{m}$  and 1 defect of 4,9  $\mu\text{m}$ ); 1 defect in the contact zone. Per Table 6; acceptable.

**Image 6**

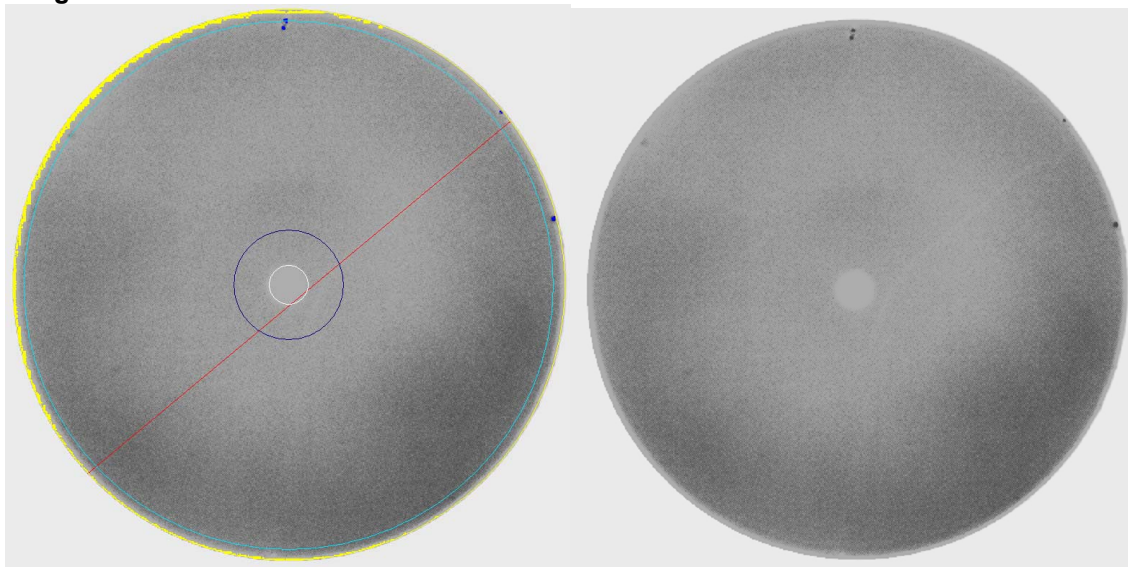


**Fibre/connector type:** MM (Table 6).

**Result:** rejected.

**Reason:** 3 defects in the core zone, 1 of which measures 6,0 $\mu\text{m}$  (highlighted in red); 7 defects in the cladding zone, 1 of which measures 7,0  $\mu\text{m}$ . Both red particles exceed thresholds established in Table 6.

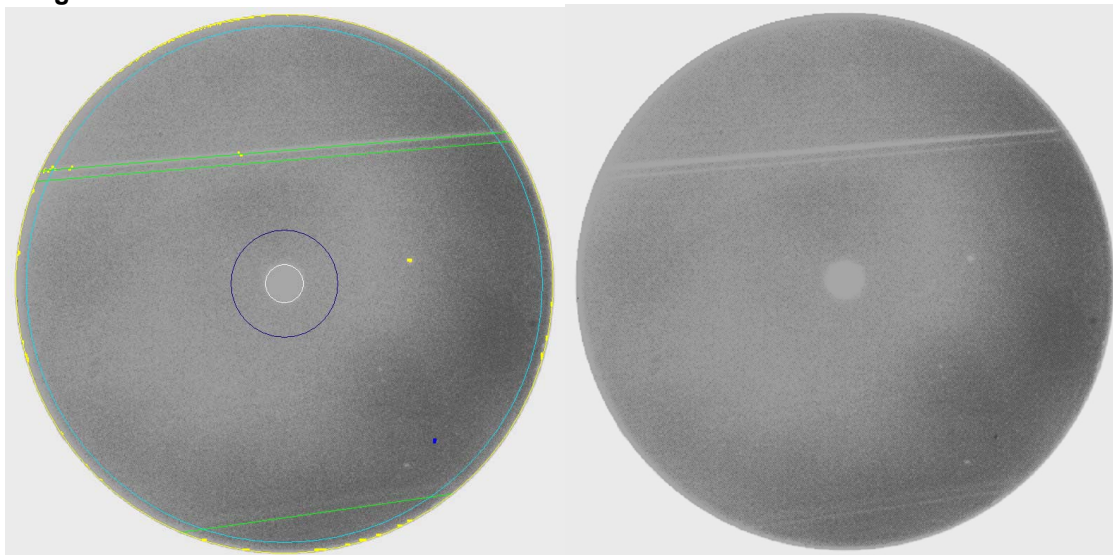


**Examples of high resolution graded images:****Image 7**

**Fibre/connector type:** SM,  $RL \geq 45$  dB (Table 3).

**Result:** rejected.

**Reason:** 1 scratch in the core zone (highlighted in red, failure), 2 small defects in the cladding zone that are both  $< 2 \mu\text{m}$  and can be ignored. Several small defects in the adhesive zone.

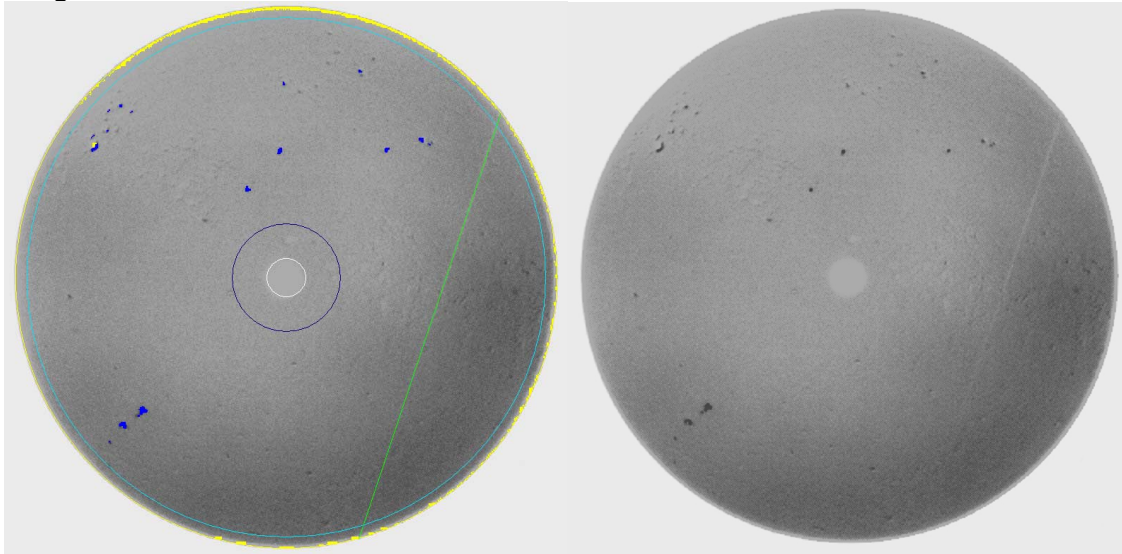
**Image 8**

**Fibre/connector type:** SM,  $RL \geq 45$  dB (Table 3).

**Result:** accepted.

**Reason:** several defects  $< 2 \mu\text{m}$  which can be ignored, 3 scratches in the cladding zone.

**Image 9**

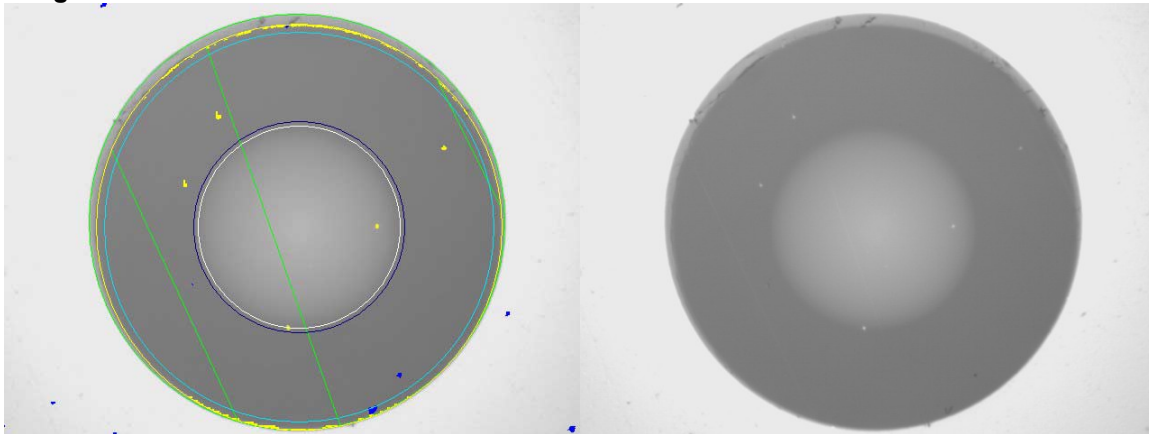


**Fibre/connector type:** SM,  $RL \geq 45$  dB (Table 3).

**Result:** accepted.

**Reason:** multiple defects in the cladding zone that are  $< 2 \mu\text{m}$  and can be ignored (per procedure in this standard, assumes cleaning attempts did not remove and these are fixed particles). 2 defects in the cladding zone that are  $< 5 \mu\text{m}$  diameter. 1 scratch in the cladding zone.

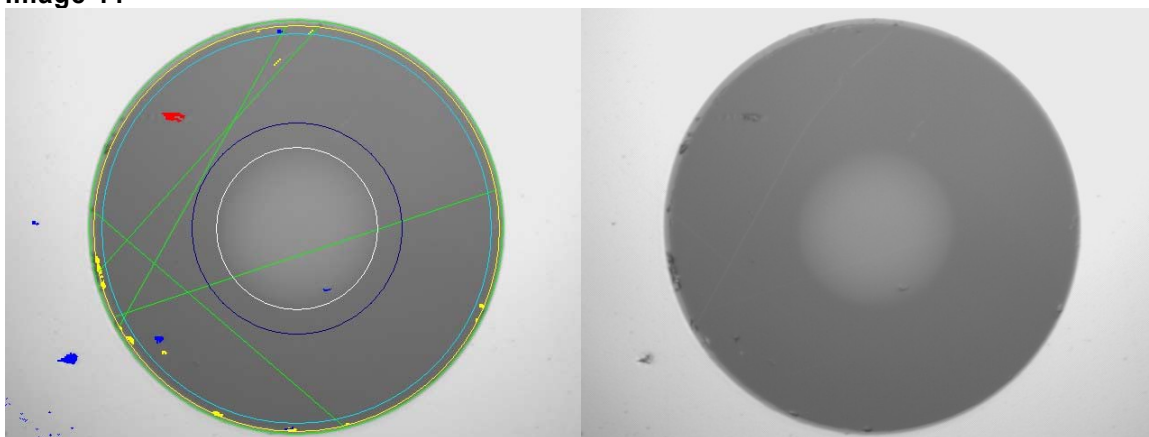
**Image 10**



**Fibre/connector type:** MM (Table 6).

**Result:** accepted.

**Reason:** 1 fine scratch (less than  $2 \mu\text{m}$  wide), and 2 defects  $< 5 \mu\text{m}$  in core zone; 2 fine scratches and 4 defects  $< 5 \mu\text{m}$  in the cladding zone; multiple defects in the contact zone that fall below the  $10 \mu\text{m}$  failure threshold, per Table 6.

**Image 11**

**Fibre/connector type:** MM (Table 6).

**Result:** rejected.

**Reason:** one particle  $>5\ \mu\text{m}$  diameter in the cladding zone produced failure. Other observed defects that did not create a failure condition: 1 fine scratch ( $<2\ \mu\text{m}$  wide) and 1 defect  $<5\ \mu\text{m}$  ( $2,6\ \mu\text{m}$ ) in the core zone; 3 fine scratches, 3 defects  $<5\ \mu\text{m}$  in the cladding zone.

## Annex B (normative)

### Diagram of calibration artefact and method of manufacture

#### B.1 High resolution artefact

The artefact is constructed by inducing a series of scratches into an otherwise pristine endface. The scratches should be cut into a simple, but recognizable pattern to ensure the user can differentiate them from scratches that may be created through normal use and cleaning during the artefact's life. This is done using a device commonly referred to as a nanoindentation test system (ISO 14577-2). There are several manufacturers throughout the world that can supply such a device.

A nano-indenter is similar to a hardness tester, but uses much smaller indentation tips with less force. The operating principle of a nano-indenter is quite simple. A tip is brought into contact with the sample, a small force is applied and the tip compresses the sample and indents itself into the material. Based on the depth to which the tip indents, one can determine the hardness of the sample.

To create the high resolution artefact, the device is used in a slightly different manner. The sample is a pristine fibre end face. For practical purposes, a common 1,25 mm or 2,5 mm PC polished ferrule with  $RL \geq 45$  dB is recommended. The tip shall be a  $90^\circ$  cone type with  $1,0 \mu\text{m}$  radius. The tip is brought into contact with the cladding and a force of  $450 \mu\text{N}$  is applied. This will allow the tip to indent approximately 4 nm into the surface of the cladding. Then the tip is translated across the surface of the cladding so that it scratches the glass. The result will be a scratch that is approximately 4 nm deep and 200 nm to 400 nm wide. Of key importance is that the scratch is created with a means that does not produce a square "trench" type of scratch that will be high contrast. This is the purpose of the radius shaped tip.

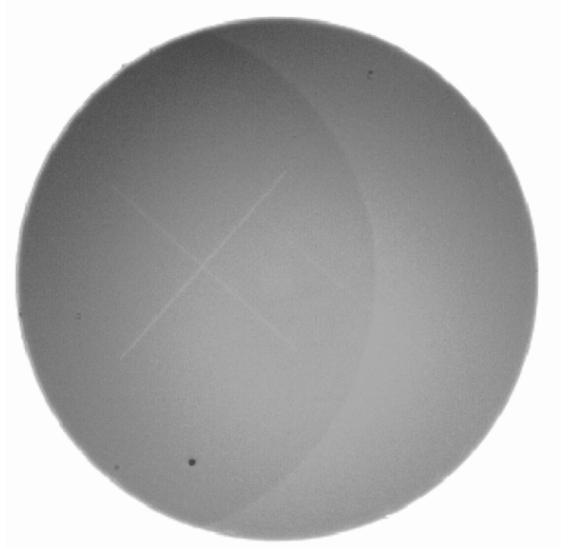
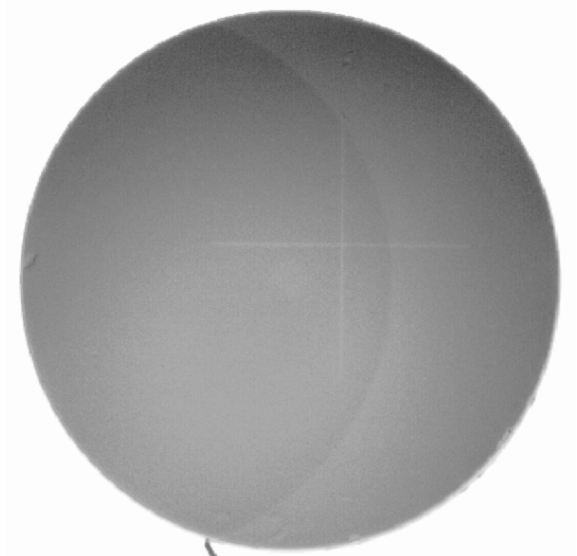
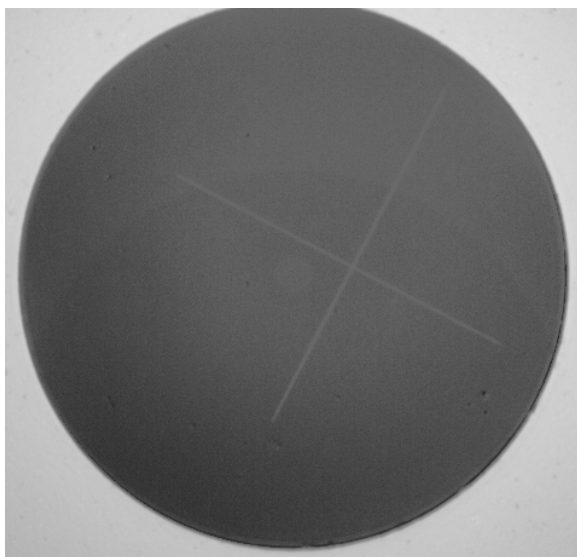
Each artefact shall be measured using a method traceable to a national standards body. Two suitable means are by scanning electron microscope or atomic force microscope. The width of the scratch shall be within 200 nm to 400 nm and the depth of the scratch shall be within 3 nm to 6 nm. The edges of the scratch cannot be quantitatively measured, but they should be viewed with a high resolution microscope to ensure the scratch is very low in contrast.

#### Example of nanoindentation test system



**Example of high resolution artefact**

Samples of pattern cut into a 125 µm cladding on the end of a polished SC connector

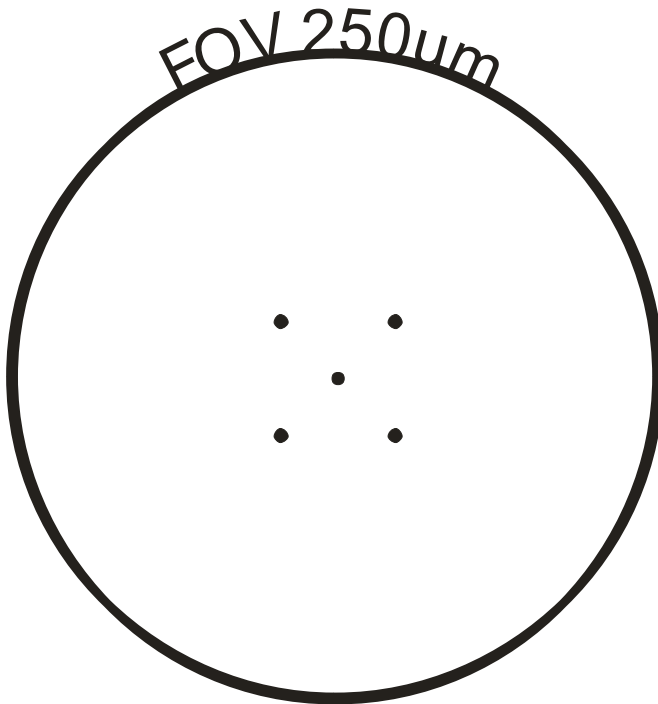


## B.2 Low resolution artefact

This artefact can be constructed as either deposited chrome on glass, or by some other means. The contrast level for this is less critical. Recommended construction is as follows:

- flat glass substrate with deposited chrome (<15 % transmittance);
- five detection targets (solid circles) near the center arranged in a star pattern as shown below;
- each target measuring 2,0  $\mu\text{m}$  in diameter;
- the outer 4 targets shall be 50  $\mu\text{m}$  apart from one another;
- a large field-of-view circle measuring 250  $\mu\text{m}$  in diameter and 5  $\mu\text{m}$  in line width (unfilled circle);
- field of view circle labelled with “FOV 250  $\mu\text{m}$ ”.

### Example of low resolution artefact pattern



## **Bibliography**

ISO 5807: *Documentation symbols and conventions for data, program and system flowcharts, program network charts and system resource charts*

ISO 14577-2:2002, *Metallic materials – Instrumented indentation test for hardness and materials parameters – Part 2: Verification and calibration of testing machines*

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