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Optical fibres — Measurement methods — Microbending sensitivity

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National foreword

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CONTENTS

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OPTICAL FIBRES – MEASUREMENT METHODS – MICROBENDING SENSITIVITY

FOREWORD

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IEC 62221, which is a technical report, has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

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

Enquiry draft	Report on voting
86A/652/CDV	86A/721/RVC

Full information on the voting for the approval of this technical report 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 3.

The committee has decided that the contents of this publication will remain unchanged until 2004. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

This document, which is purely informative, is not to be regarded as an International Standard.

OPTICAL FIBRES – MEASUREMENT METHODS – MICROBENDING SENSITIVITY

1 Scope and object

This technical report describes four techniques for the measurement of microbending sensitivity of optical fibre.

Methods A and B may also be used to measure the microbending sensitivity of optical fibre ribbons.

Methods A, B, C and D are distinguished by the equipment used for measurements and their applications:

- method A uses an expandable drum and applies to class B fibres;
- method B uses a fixed diameter drum and applies to category A1 and class B fibres;
- method C uses a wire mesh and applied loads and applies to category A1 and class B fibres;
- method D uses a "basketweave" wrap on a fixed diameter drum, and applies to class B fibres.

Methods A and C offer the capability to measure the microbending sensitivity over a wide range of applied linear pressure or loads. Method B may be used to determine the microbending sensitivity for a fixed linear pressure.

The results from the four methods can only be compared qualitatively.

These methods do not constitute a routine test used in the general evaluation of optical fibre. This parameter is not generally specified within a detail specification.

2 Reference documents

NOTE 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.

IEC 60793-1-1:1995, *Optical fibres – Part 1-1: Generic specification – General*

IEC 60793-1-22:2001, *Optical fibres – Part 1-22: Measurement methods and test procedures – Length measurement*

IEC 60793-1-40:2001, *Optical fibres – Part 1-40: Measurement methods and test procedures – Attenuation*

IEC 60793-1-46:2001, *Optical fibres – Part 1-46: Measurement and test procedures – Monitoring of changes in optical transmittance*

3 Test procedures

3.1 Method A: expandable drum

3.1.1 General

This subclause describes a technique for the measurement of the loss increase due to microbending effects induced by the application of linear pressure to a single-mode optical fibre. This method may also be used to measure the microbending sensitivity of optical fibre ribbons.

3.1.2 Apparatus

The apparatus is an expandable drum, the diameter of which can be changed continuously. In order to avoid any loss contribution due to macrobending effects, a minimum drum diameter of 200 mm is recommended. The curvature at any edges of the expanded segments of the drum also exceeds 200 mm diameter. The drum surface is coated with a material of fixed roughness, e.g. a sandpaper/lapping film PSA – grade 40 µm – mineral Al_2O_3. It is possible to wind at least 400 m of the fibre or ribbon to be tested onto the rough surface. The winding pitch is controlled to prevent the fibre/ribbon turns from overlapping.

While expanding the drum, the fibre elongation is measured using the phase-shift method (Method E of IEC 60793-1-22). The attenuation measurement is conducted using either the cut-back technique (method A of IEC 60793-1-40), the backscatter technique (method C of IEC 60793-1-40) or by the direct transmitted power measurement technique (method A of IEC 60793-1-46).

3.1.3 Procedure

The fibre to be tested is carefully wound onto the coated drum with minimal tension (e.g. 40 g to 50 g) in one single layer avoiding any crossing or overlapping. The fibre is fixed to avoid any relative slipping. While expanding the drum the changes in attenuation coefficient and phase are recorded.

3.1.4 Calculations.

The fibre elongation (ε) can be found from:

$$\varepsilon = \frac{\Delta\theta}{f \cdot L} \cdot V \quad (1)$$

where

$\Delta\theta$ is the phase shift (degrees);

f is the modulation frequency (Hz);

L is the length of the sample (km);

V is the constant depending on the photo-elastic coefficient (k), of the speed of light in a vacuum (c) and the group index (N):

$$V = \frac{k \cdot c}{360\ N} \quad (2)$$

For category B1 fibres, V is typically 726 km/s/degree.

From this the linear pressure *P* can be calculated:

$$P = \frac{T}{R} = \frac{EA\varepsilon}{R} \qquad (3)$$

where

T is the tension applied to the fibre (N);

R is the radius of the expandable drum in rest condition (mm);

E is the Young's modulus of the fibre (N/mm^2);

A is the cross-sectional area of the fibre (glass part) (mm^2).

The changes in attenuation coefficient (dB/km) are plotted as a function of the linear pressure *P* (N/mm) or the elongation ε (%). The points obtained are interpolated by a straight line passing through the origin, the slope of which gives the microbending sensitivity (dB/km)/(N/mm) or (dB/km/%) of the tested fibre.

3.1.5 Results

The following information should be reported for each test:

- test apparatus arrangement;
- minimum diameter of the expandable drum;
- roughness and type of material used to cover the drum;
- fibre identification;
- length of fibre wound onto the expandable drum;
- wavelength of optical source;
- plot of measured change in attenuation coefficient as a function of the calculated linear pressure or of the elongation;
- microbending sensitivity [(dB/km)/(N/mm)] or (dB/km/%);
- relative humidity and ambient temperature during the test.

3.2 Method B: fixed diameter drum

3.2.1 General

This subclause describes a procedure to measure the microbending sensitivity of category A1 and class B fibres. This technique gives the loss increase due to microbending effects for a fixed linear pressure applied to the fibre. This method may also be used to measure the microbending sensitivity of optical fibre ribbons.

3.2.2 Apparatus.

The apparatus consists of a fixed diameter drum. In order to avoid macrobending effects the minimum drum diameter is 200 mm.

The surface of the drum is coated with a material of fixed roughness (for example: sandpaper – lapping film PSA – grade 40 µm – mineral Al_2O_3). It is possible to wind at least 400 m of the fibre/ribbon to be tested onto the coated surface of the drum.

The attenuation measurement is performed using the cut-back technique (method A of IEC 60793-1-40) or by the backscatter technique (method C of IEC 60793-1-40).

3.2.3 Procedure

The fibre to be tested is wound onto the coated surface of the drum in one single layer, i.e. avoiding crossovers. The winding tension is 3 N.

Measure the attenuation coefficient of the fibre under test. Calculate the attenuation increase due to microbending by subtracting the intrinsic attenuation coefficient of the fibre.

3.2.4 Calculations

The microbending sensitivity is found from the following relationship:

$$\text{Microbending sensitivity} = \frac{\alpha R}{T} = \frac{\alpha}{P} \ [(\text{dB/km})/(\text{N/mm})] \qquad (4)$$

where

α is the attenuation increase due to the microbending sensitivity (dB/km);

P is the linear pressure (N/mm), see equation (3);

R is the radius of the fixed drum (mm);

T is the winding tension applied to the fibre (N).

The complete procedure may be repeated using different winding forces.

3.2.5 Results

The following information should be reported for each test:

- date of test;
- test apparatus arrangement;
- diameter of drum;
- roughness and type of material used;
- fibre identification;
- length of fibre wound onto the coated surface of the drum;
- wavelength of the optical source;
- microbending sensitivity [(dB/km)/(N/mm)].

3.3 Method C: wire mesh

3.3.1 General

This subclause describes a procedure to measure the microbending sensitivity of category A1 and class B fibres. This technique gives the loss increase due to microbending effects caused by the application of a wire mesh (under load) to the fibre under test.

3.3.2 Apparatus

The apparatus comprises:

- the microbend inducing equipment is shown in figure 1.

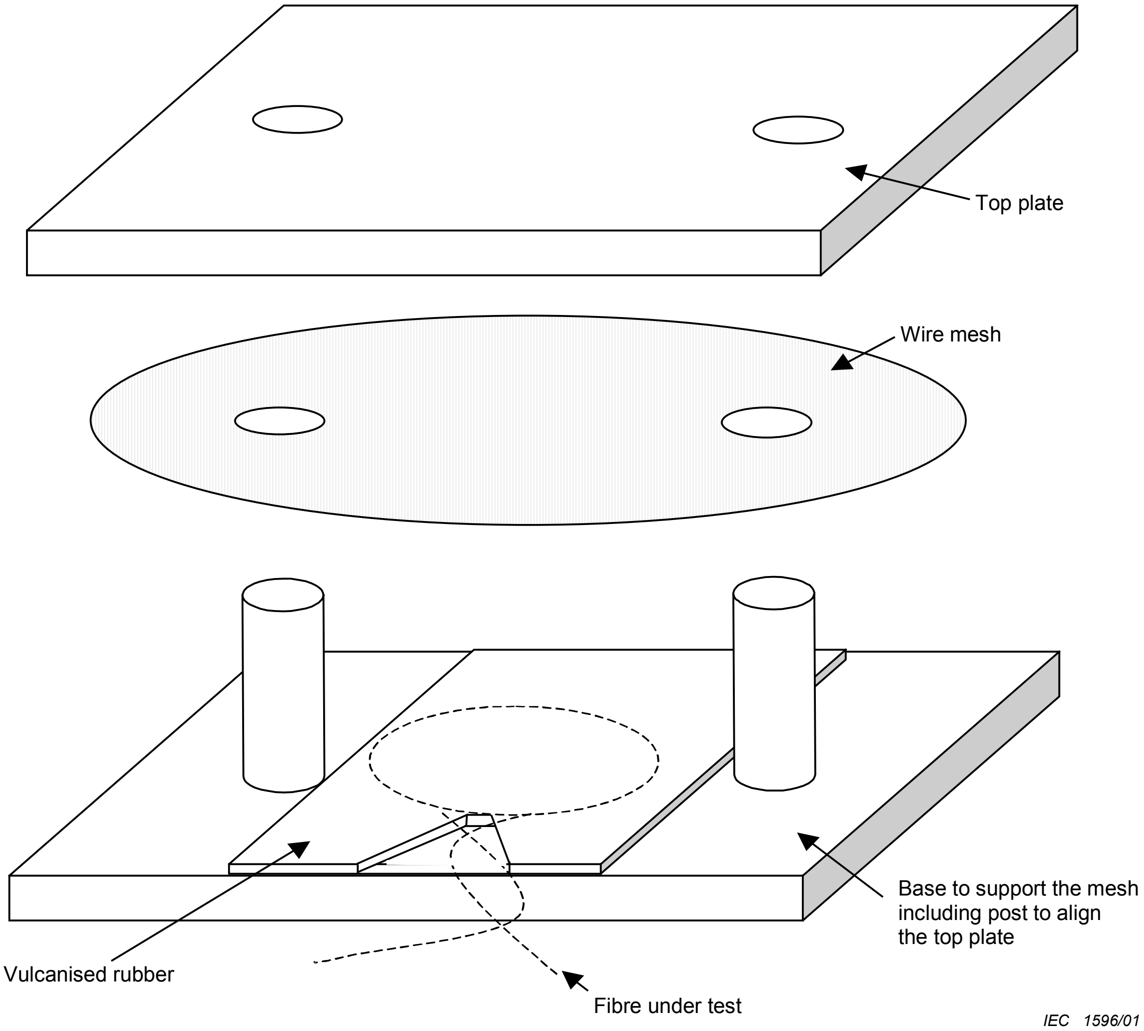

Figure 1 – Microbend-inducing equipment

3.3.2.1 Microbend-inducing equipment

An arrangement as shown in figure 1 is used to produce the microbend losses. The metal base plate acts as a location and smooth surface for the upper layers of the equipment. Use dowels or other devices to both align the plates and allow the top plate to compress onto the lower plate.

It is critical that all the surfaces should be flat and smooth so that the load is borne only by the fibre. This can also be facilitated by reducing the surfaces to an area as small as possible – whilst still covering the fibre.

A sheet of vulcanised rubber, having a Shore A hardness of 73 to 78, is fixed securely to the upper surface of the base plate. Deploy the fibre in a single circular loop with a diameter of 98 mm by laying it onto a pre-marked circle or by the use of a temporary deployment mandrel. As can be seen in figure 1, a section of the rubber is cut away, thus preventing fibre crossover at the point where the fibre enters and exits the test apparatus. This cut-out reduces the length of fibre under test by approximately 8 mm. In order to avoid any spurious microbending effects it is important that the rubber sheet is smooth and flat.

The wire mesh is constructed from woven stainless steel wire. The mesh is plain woven with a mesh number of 70. If greater discrimination is required, then the use of a coarser mesh, e.g. mesh number 20, is appropriate. Direct comparisons cannot be made between the results obtained using different mesh sizes, the mesh number will affect the microbend sensitivity.

The wire mesh has holes drilled into it to enable repeated accurate location onto the dowels (or other alignment devices) in the base plate.

The top plate, of nominal mass 1 kg has two location holes which have a sliding fit with the dowels (or other alignment devices) in the base plate. A set of 1 kg weights is employed to provide the additional load required to induce additional microbending losses. Alternatively, use a controlled loading machine to achieve the required compression.

The attenuation measurement is conducted using either the cut-back technique (method A of IEC 60793-1-40), the backscatter technique (method C of IEC 60793-1-40) or the direct transmitted power measurement technique (method A of IEC 60793-1-46).

3.3.3 Procedure

The test is typically conducted on a 2 m to 3 m length of fibre.

Place the fibre in a loop in order to follow the circle on the rubber sheet. The fibre may be held into position by no more than three small (≤3 mm wide) pieces of tape. In order to avoid crossovers ensure that the fibre enters and exits the apparatus at the point where the rubber sheet is cut away.

Power readings is taken at each required wavelength prior to the application of the wire mesh or any load.

Gently apply the wire mesh to the fibre under test followed by the top plate (1 kg).

Take power readings at each required wavelength.

Apply further loads in 1 kg increments taking power readings between each successive loading. Wait approximately 60 s after the application of any load prior to taking power readings.

Optionally, upon completion of the test carefully remove all of the weights and the wire mesh. Take a further set of power readings. This data can be used to establish whether there is any permanent effect due to the test.

3.3.4 Calculations

The microbending sensitivity is calculated from the following:

$$\text{Microbending sensitivity} = \frac{\alpha}{P} \ [(\text{dB/km})/(\text{N/mm})] \qquad (5)$$

or

$$\text{Microbending sensitivity} = \frac{\alpha}{W} \ (\text{dB/kg}) \qquad (6)$$

where

α is the attenuation increase due to the microbending sensitivity (dB/km);

P is the linear pressure (N/mm), N being the load applied to the length of fibre beneath the mesh;

W is weight in kg.

3.3.5 Results

The following information should be reported for each test:

- date of test;
- test apparatus arrangement;
- wire mesh specification;
- fibre identification;
- length of fibre under test;
- length of fibre subjected to load;
- wavelength of the optical source;
- microbending sensitivity [(dB/km)/(N/mm)] or dB/kg.

3.4 Method D: basketweave

3.4.1 General

This subclause describes a procedure to measure the microbending sensitivity of class B fibres as a function of temperature. This technique gives the attenuation loss increase over a wide temperature range.

3.4.2 Apparatus

3.4.2.1 The fixed diameter quartz drum

The apparatus consists of a fixed diameter, silica drum. The drum composition is necessary to match the expansion coefficient of the fibre. In order to minimise macrobending effects and maximise microbending effects, the minimum drum diameter is 111 mm. An example of the drum dimensions is found in Figure 2.

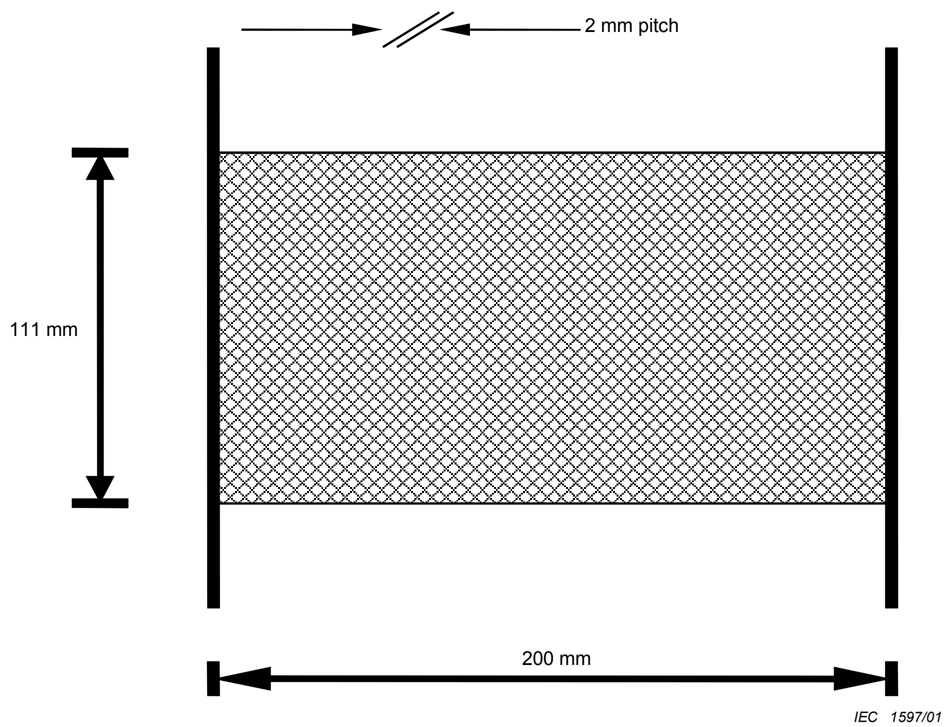

Figure 2 – Quartz drum

3.4.2.2 Temperature controlled test chamber

This test is conducted in an environmental test chamber with inside dimensions capable of accommodating the sample and allowing unrestricted air flow around the test sample. The chamber should have an operational range sufficient to cover the temperature extremes and maintain the specified temperature within ±2 °C throughout the test duration. There should be an access port or ports through which the fibre ends may extend allowing measurements to be taken while maintaining a sufficient seal such that the specified temperatures may be maintained.

3.4.3 Procedure

3.4.3.1 Sample preparation

The fibre to be tested is carefully wound onto the glass drum with a winding tension of 70 g ± 5 g and a pitch (distance between adjacent wraps of fibre) of 2 mm. The fibres in the next layer are wrapped at the opposite angle. Every second layer, the angle reverses. The crossover of the tensioned fibres from the adjacent layers creates the microbend mechanism. It is recommended that 2,5 km of fibre be tested, as shorter lengths give unrepeatable results and longer lengths do not improve the measurement. To achieve accurate and repeatable results, the following wind conditions are recommended:

- winding force ≤ 0,7 N ± 0,05 N;
- take-up width ≥200 mm;
- take-up pitch 2,0 mm;
- tapered stack 0,5 mm/pass;
- wind speed 1 m/s to 2 m/s.

3.4.3.2 Sample preconditioning

The sample needs to be preconditioned for a minimum of 12 h at standard atmospheric conditions as specified in IEC 60793-1-1 (temperature 23 °C ± 5 °C, relative humidity 45 % ± 25 %). After placing the sample in the chamber, the fibre ends extending from the chamber ports do not exceed 10 % of the fibre length inside the chamber. The fibre ends should be prepared for transmittance or attenuation measurement as recommended in the measurement technique used.

The attenuation measurement is conducted using either the cut-back technique (method A of IEC 60793-1-40), the backscatter technique (method C of IEC 60793-1-40) or by the direct transmitted power measurement technique (method A of IEC 60793-1-46).

3.4.3.3 Temperature cycling

Measure the attenuation as the sample is cycled to low temperatures. An example temperature cycle is shown in figure 3. Alternative cycles may include lower temperatures such as –60 °C.

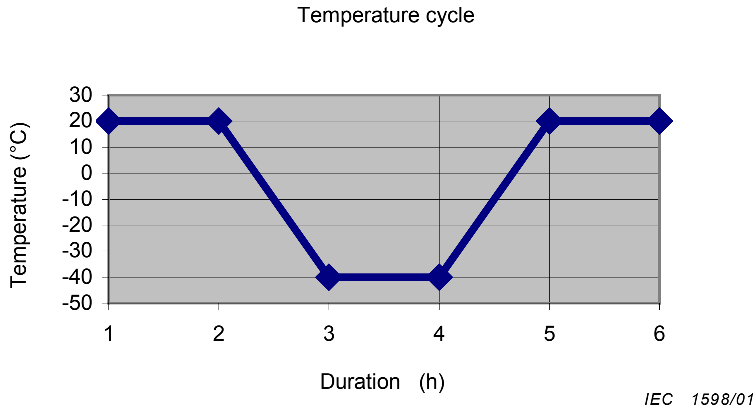

Figure 3 – Temperature cycle inside chamber

The measurements may be continuously monitored or are recorded at the end of each constant temperature phase.

3.4.4 Calculations or interpretation of results

The microbend sensitivity at a given temperature shows an increase of fibre attenuation or transmittance above its inherent attenuation or transmittance determined at room temperature prior to any thermal excursions.

Data may be reported as either absolute attenuation or as a change in attenuation or transmittance from baseline. Determine the attenuation change (dB/km) between the room temperature attenuation and each low temperature attenuation.

Performance of fibre in a given cable structure can be predicted by comparing the microbend performance of the test fibre and a reference fibre. The fibre of known performance in a particular cable structure should be used as a reference. The fibre showing lower microbend sensitivity on the glass drum is predicted to perform better inside the cable.

3.4.5 Results

The following information should be reported for each test:

- date of test;
- test apparatus arrangement;
- fibre identification;
- length of fibre under test;
- length of fibre subjected to load;
- environmental test conditions;
- wind test conditions;
- wavelength of the optical source;
- microbending sensitivity (dB/km).

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