IEC 60793-1-47

Edition 4.0 2017-10

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Optical fibres –
Part 1-47: Measurement methods and test procedures – Macrobending loss

Fibres optiques –
Partie 1-47: Méthodes de mesure et procédures d'essai – Pertes par macrocourbures

IEC 60793-1-47:2017-10(en-fr)

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FOREWORD

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International Standard IEC 60793-1-47 has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

This fourth edition cancels and replaces the third edition published in 2009. It constitutes a technical revision.

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

a) former Annex A has been renumbered to Annex D;
b) introduction of new Annex A on the transmitted power monitoring technique;
c) introduction of Annex B on the cut-back technique;
d) introduction of Annex C on the requirements for the optical source characteristics of A1 multimode measurement;
e) introduction of Annex E on parallel plate (2-point) macrobend loss approximation.

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

FDIS	Report on voting
86A/1823/FDIS	86A/1828/RVD

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.

This standard is to be read in conjunction with IEC 60793-1-1:2017.

A list of all parts of 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 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- withdrawn,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.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Publications in the IEC 60793-1 series concern measurement methods and test procedures as they apply to optical fibres.

Within the same series, several different areas are grouped, but all numbers are possibly not used, as follows:

Parts 1-10 to 1-19:	General
Parts 1-20 to 1-29:	Measurement methods and test procedures for dimensions
Parts 1-30 to 1-39:	Measurement methods and test procedures for mechanical characteristics
Parts 1-40 to 1-49:	Measurement methods and test procedures for transmission and optical characteristics
Parts 1-50 to 1-59:	Measurement methods and test procedures for environmental characteristics

OPTICAL FIBRES –

Part 1-47: Measurement methods and test procedures – Macrobending loss

1 Scope

This part of IEC 60793 establishes uniform requirements for measuring the macrobending loss of single-mode fibres (class B) at 1 550 nm or 1 625 nm, category A1 multimode fibres at 850 nm or 1 300 nm, and category A3 and A4 multimode fibres at 650 nm, 850 nm or 1 300 nm, thereby assisting in the inspection of fibres and cables for commercial purposes.

This document gives two methods for measuring macrobending sensitivity:

- Method A – Fibre winding, pertains to class B single-mode fibres and category A1 multimode fibres.
- Method B – Quarter circle bends, pertains to category A3 and A4 multimode fibres.

For both of these methods, the macrobending loss can be measured utilizing general fibre attenuation techniques, for example the power monitoring technique (see Annex A) or the cut-back technique (see Annex B). Methods A and B are expected to produce different results if they are applied to the same fibre. This is because the key difference between the two methods is the deployment, including the bend radius and length of fibre that is bent. The reason for the difference is that A3 and A4 multimode fibres are expected to be deployed in short lengths with a smaller number of bends per unit fiber length compared to single-mode and category A1 multimode fibres.

In this document, the "curvature radius" is defined as the radius of the suitable circular shaped support (e.g. mandrel or guiding groove on a flat surface) on which the fibre can be bent.

In addition, informative Annex E has been added to approximate bend loss for class B single-mode fibres across a broad wavelength range at various effective bends.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 (all parts), *Optical fibres – Measurement methods and test procedures*

IEC 60793-1-1:2017, *Optical fibres – Part 1-1: Measurement methods and test procedures – General and guidance*

IEC 60793-2, *Optical fibres – Part 2: Product specifications – General*

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

IEC 61280-1-4, *Fibre optic communication subsystem test procedures – Part 1-4: General communication subsystems – Light source encircled flux measurement method*

IEC 61280-4-1, *Fibre-optic communication subsystem test procedures – Part 4-1: Installed cable plant– Multimode attenuation measurement*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60793-2, IEC 60793-1 (all parts) and IEC 60793-1-1 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

NOTE General definitions for fibres are provided in IEC 60793-2, definitions of the specified attributes are contained in the relevant test methods standard of IEC 60793-1 (all parts), and general definitions for testing are provided in IEC 60793-1-1.

4 Apparatus

4.1 Method A – Fibre winding

The apparatus consists of a tool (e.g. a mandrel or a guiding groove on a flat surface) able to hold the sample bent with a radius as stated in the appropriate optical fibre sectional product specification and a loss measurement instrument. Determine the macrobending loss at the wavelength as stated in the appropriate sectional product specification by using either the transmitted power monitoring technique (Annex A) or the cut-back technique (Annex B), taking care of the appropriate launch condition for the specific fibre type.

4.2 Method B – Quarter circle bends

The apparatus consists of one or more plates, each containing one or more "guide grooves", and a loss measurement instrument. The plates shall be designed to be stacked during the test without contacting the sample fibre in a lower or higher plate; such contact will affect the measurement results. Each guide groove shall have a quarter circle segment (i.e. 90°) as shown in Figure 1. The bend radius r, i.e. the radius of the quarter circle segment, shall be stated in the detail specification. The width of each guide groove is recommended to be 40 % broader than the outer fibre diameter.

Determine the macrobending loss at the wavelength as stated in the appropriate sectional product specification by using either the transmitted power monitoring technique (Annex A) or the cut-back technique (Annex B), taking care of the appropriate launch condition for the specific fibre type.

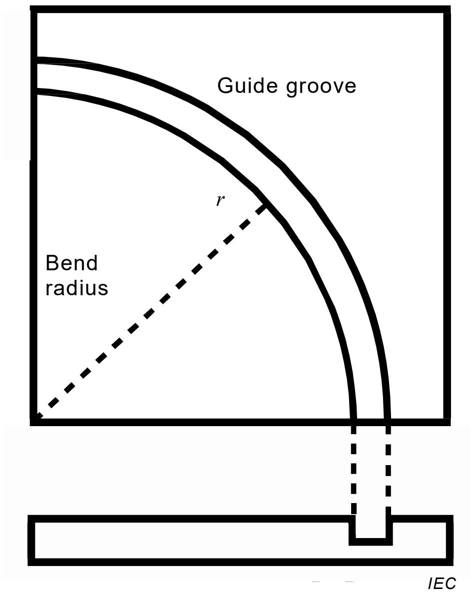

Figure 1 – Quarter circle guide groove in plate

4.3 Input system

4.3.1 Optical source

Use a suitable radiation source, such as a lamp, laser or light emitting diode. The choice of source depends upon the type of measurement. The source shall be stable in position, intensity and wavelength over a time period sufficiently long to complete the measurement procedure. Specify the spectral line width (between the 50 % optical intensity power points of the sources used) such that the line width is narrow, for example less than 10 nm, compared with any features of the fibre spectral attenuation. Align the fibre to the launch cone, or connect it coaxially to a launch fibre.

4.3.2 Optical launch arrangement

4.3.2.1 General

Figure 2 shows the general launch arrangement used for all fibres. Apply the appropriate launch arrangement to produce a full or restricted launch, depending on the parameter being measured. See 4.3.2.3 to 4.3.2.4 for further details as they apply to specific categories of single-mode and multimode fibres.

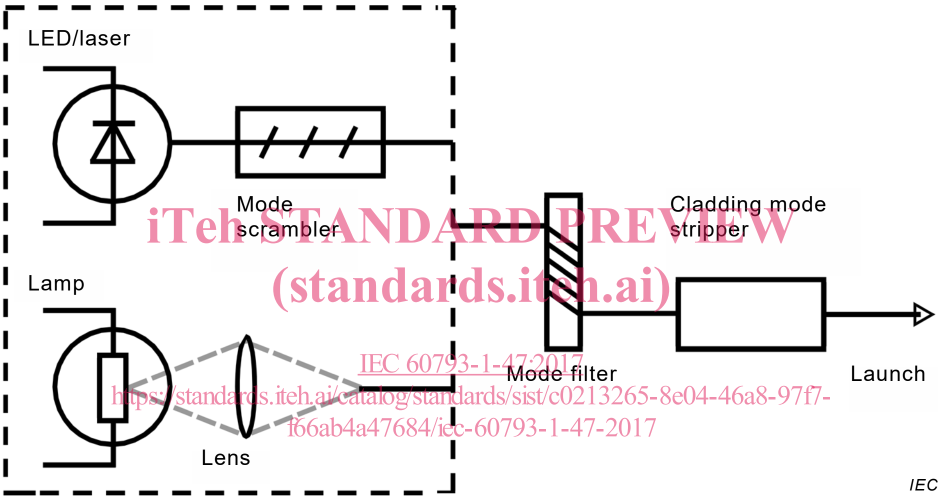

Figure 2 – General launch arrangement

4.3.2.2 Launch arrangement for single-mode fibres

4.3.2.2.1 General

An optical lens system or fibre pigtail may be employed to excite the test fibre. The power coupled into the fibre shall be stable for the duration of the measurement (see Figure A.1 or Figure B.1).

4.3.2.2.2 Fibre pigtail

If using a pigtail, it may be necessary to use index-matching material between the source pigtail and test fibre to eliminate interference effects.

4.3.2.2.3 Optical lens system

If using an optical lens system, provide a means of stably supporting the input end of the fibre, such as a vacuum chuck. Mount this support on a positioning device so that the fibre end can be repeatedly positioned in the input beam. A method of making the positioning of the fibre less sensitive is to overfill the fibre end spatially and angularly.

4.3.2.2.4 High-order mode filter

Use a method to remove high-order propagating modes in the wavelength range of interest.

An example of such a high-order mode filter is a single loop of radius sufficiently small to shift the cut-off wavelength below the minimum wavelength of interest, but not so small as to induce wavelength-dependent oscillations.

Another option commonly employed on bend insensitive single mode fibres and other single mode fibres with little or no cut-off response to bend is the use of a standard single mode fibre as a mode filter.

4.3.2.2.5 Cladding mode stripper

Use suitable techniques to remove optical power propagating in the cladding where this would significantly influence the received signal. The cladding mode stripper ensures that no radiation modes, propagating in the cladding region, will be detectable after a short distance along the fibre. The cladding mode stripper often consists of a material having a refractive index equal to or greater than that of the fibre cladding. This may be an index-matching fluid applied directly to the uncoated fibre near its ends; under some circumstances, the fibre coating itself will perform this function.

4.3.2.3 Launch arrangement for A1 multimode fibres

The required launch for measuring the macrobending loss of A1 multimode fibres shall be an encircled flux launch. The requirements for the optical source characteristics for A1 multimode measurement are included in Annex C.

The encircled flux emitted by the launching cord depends on the characteristic of the light source emerging from the face of the socket, the connection of the launching cord to the socket, the optical fibre within the launch cord, and any applied mode conditioning.

The test equipment manufacturer should provide specifications for the test cord that are compatible with the particular source implementation used. When the specification on the cord is met and used with the test equipment, the encircled flux (EF) requirements should be assured.

4.3.2.4 Launch arrangements for A2 to A4 multimode fibres

Below are some examples of generic launching arrangements for short-distance fibres described in Figure 3, Figure 4 and Figure 5.

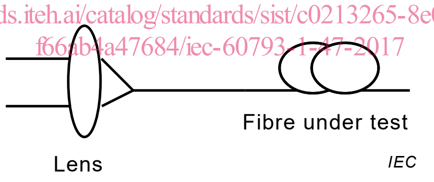

Figure 3 – Lens system

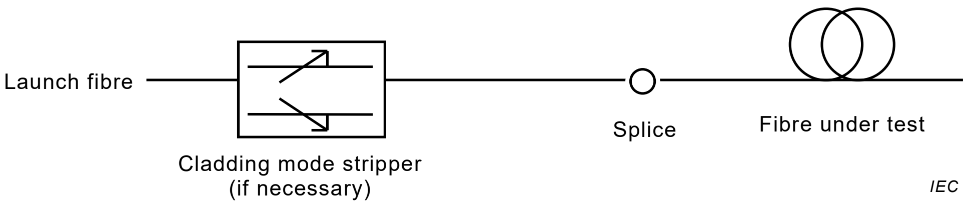

Figure 4 – Launch fibre

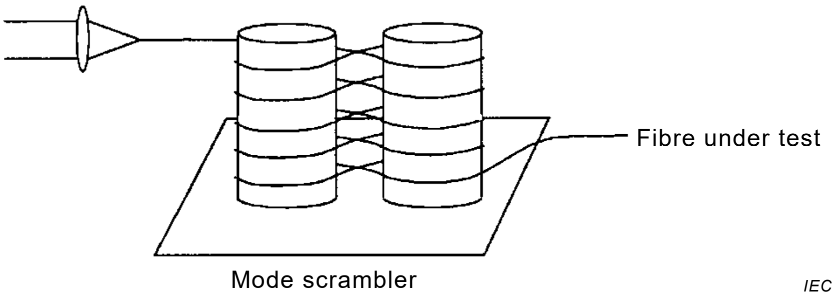

Figure 5 – Mode scrambler (for A4 fibre)

The reproducibility of the attenuation measurements of step-index fibres is critical. Therefore, a well-defined launching set-up description is necessary. Such a set-up can be achieved by using commercially available optical components and shall be able to provide spot sizes and launch numerical apertures (NAs) as given in Table 1. In addition, the measurement wavelength shall be calibrated to within ±10 nm.

Table 1 – Launch conditions for A2 to A4 fibres

Attribute	Fibre category		
	A2 **Glass core/glass cladding**	**A3** **Glass core/plastic cladding**	**A4** **Plastic core/plastic cladding**
Spot size	= fibre core size	= fibre core size	= fibre core size with full mode launch (or use mode scrambler with equilibrium mode launch)
Numerical aperture (NA)	= fibre max NA[a]	= fibre max NA[b]	= fibre max NA, with full mode launch[b]

[a] This launch condition can be produced by overfilling a mode filter made from 2 m of fibre identical to the fibre under test (FUT), with appropriate cladding mode stripping and using the output from this mode filter to launch into the FUT.

[b] This launch condition can be produced in the same manner as described in Note a. However, some types of A3 and A4 fibre will not require cladding mode stripping for the mode filter.

4.4 Output system and detection

4.4.1 Optical divider

When an optical divider is required, it shall have a splitting ratio that remains constant during the test. The splitting ratio and temperature stability shall be as shown in the relevant detail specification. Commercially available or custom built devices may be used.

4.4.2 Optical detector

The optical detector shall be of sufficient area to intercept all of the radiated power in the output cone and shall be sufficiently linear over the optical powers encountered.

The optical detector shall have a sufficiently uniform response over the active area and range of incidence angle at the measurement wavelength to ensure the movement of the output cone in position or angle relative to the detector. This shall be within the limits determined by the mechanical design of the measurement equipment and shall not significantly affect the results.

Where more than one detector is used, as in the arrangement shown in Figure A.1, the detectors shall be of the same manufacturer and model and be of comparable linearity.

4.4.3 Optical detection assembly

All power emitted from the specimen should be coupled to the active region of the detector by an appropriate means. For example, an optical lens system, a butt spliced fibre pigtail, or direct coupling to the detector may be used. If the detector is already pigtailed, the pigtail fibre shall have sufficiently large core diameter and numerical aperture to capture all of the light exiting the reference and specimen fibres.

Use an optical detector that is linear and stable over the range of intensities and measurement times that are encountered in performing this measurement. A typical system can include a photovoltaic mode photodiode amplified by a current input amplifier, with synchronous detection by a lock-in amplifier.

4.4.4 Signal processing

It is customary to modulate the light source in order to improve the signal-to-noise ratio (SNR) at the receiver. If such a procedure is adopted, link the detector to a signal processing system synchronous with the source modulation frequency. The detecting system should be substantially linear or have known characteristics.

When low loss is expected, more test bends may be added provided there are separate grooves for each additional bend to improve the SNR; however, the approximation of the bend diameter along with the bend control may be further degraded.

5 Specimen

5.1 Specimen length

5.1.1 Method A – Fibre winding

The specimen shall be a known length of fibre, as specified in the detail specification. In particular, the length of the sample tested for loss is determined by the measurement set-up, i.e. curvature radius (R) and number of turns (N); any further fibre length does not affect the measurement results, provided that the SNR is optimised.

5.1.2 Method B – Quarter circle bends

The specimen length shall be determined according to the details shown in 6.2.

5.2 Specimen end face

Prepare a flat end face, orthogonal to the fibre axis, at the input and output ends of each test specimen.

6 Procedure

6.1 Method A – Fibre winding

6.1.1 General consideration

Loosely wind the fibre on the tool, avoiding excessive fibre twist. The number of turns, curvature radius and wavelength at which loss is to be measured are discussed below in 6.1.1 and in 6.1.2 and 6.1.3.

Since the actual curvature radius is critical, a maximum tolerance of ±0,1 mm (for radii lower than or equal to 15 mm) or ±1,0 mm (for larger radii) is accepted: a tighter tolerance on small radii is required for higher measurement sensitivity.

Both for single-mode and for multimode fibres, two optical powers can be measured using

– the power-monitoring technique, which measures the fibre attenuation increase due to a change from the straight condition to a bent condition, or
– the cut-back technique, which measures the total attenuation of the fibre in the bent condition. In order to determine the induced attenuation due to macrobending, this value should be corrected for the intrinsic attenuation of the fibre.

The fibre length outside the mandrel and the reference cut-back length shall be free of bends that can introduce a significant change in the measurement result. It is also possible to rewind