IEC 60793-1-40

Edition 3.0 2024-11

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Optical fibres –
Part 1-40: Attenuation measurement methods

Fibres optiques –
Partie 1-40: Méthodes de mesure de l'affaiblissement

IEC 60793-1-40:2024-11(en-fr)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 33.180.10

ISBN 978-2-8327-0026-6

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OPTICAL FIBRES –

Part 1-40: Attenuation measurement methods

FOREWORD

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IEC 60793-1-40 has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics. It is an International Standard.

This third edition cancels and replaces the second edition published in 2019. This edition constitutes a technical revision.

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

a) modifying the definition of attenuation to be compatible with the definition in electropedia.org

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

Draft	Report on voting
86A/2355/CDV	86A/2446/RVC

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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 document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

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OPTICAL FIBRES –

Part 1-40: Attenuation measurement methods

1 Scope

This part of IEC 60793 establishes uniform requirements for measuring the attenuation of optical fibre, thereby assisting in the inspection of fibres and cables for commercial purposes.

Four methods are described for measuring attenuation, one being that for modelling spectral attenuation:

– method A: cut-back;
– method B: insertion loss;
– method C: backscattering;
– method D: modelling spectral attenuation.

Methods A to C apply to the measurement of attenuation for all categories of the following fibres:

- class A multimode fibres;
- class B single-mode fibres.

Method C, backscattering, also covers the location, losses and characterization of point discontinuities.

Method D is applicable only to class B fibres.

Information common to all four methods appears in Clause 1 to Clause 11, and information pertaining to each individual method appears in Annex A, Annex B, Annex C, and Annex D, respectively.

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

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

IEC 60793-1-43, *Optical fibres – Part 1-43: Measurement methods and test procedures – Numerical aperture measurement*

IEC 61746-1, *Calibration of optical time-domain reflectometers (OTDR) – Part 1: OTDR for single mode fibres*

IEC 61746-2, *Calibration of optical time-domain reflectometers (OTDR) – Part 2: OTDR for multimode fibres*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60793-1-1 and the following 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

3.1.1
attenuation
optical power reduction along a fibre at wavelength λ between two cross-sections, 1 and 2, separated by a distance and defined as

$$A(\lambda) = 10\log_{10}\frac{P_1(\lambda)}{P_2(\lambda)} \quad (1)$$

where

$A(\lambda)$ is the attenuation, in dB, at wavelength λ;

$P_1(\lambda)$ is the optical power traversing the first cross-section;

$P_2(\lambda)$ is the optical power traversing the second cross-section.

Note 1 to entry: Attenuation is a measure of the decreasing optical power in a fibre at a given wavelength. It depends on the nature and length of the fibre and is also affected by measurement conditions.

3.1.2
attenuation coefficient
attenuation per unit length for a uniform fibre under steady-state conditions

Note 1 to entry: It is possible to define the attenuation per unit length or the attenuation coefficient as follows:

$$\alpha(\lambda) = \frac{A(\lambda)}{L} \quad (2)$$

which is independent of the chosen length of the fibre,

where

$\alpha(\lambda)$ is the attenuation coefficient;

$A(\lambda)$ is the attenuation at wavelength λ;

L is the length, in kilometres.

Note 2 to entry: Uncontrolled launching conditions normally excite higher order lossy modes that produce transient losses and result in attenuation that is not proportional to the length of the fibre. A controlled, steady-state launching condition yields attenuation that is proportional to the fibre's length. Under steady-state conditions, an attenuation coefficient of a fibre can be determined and the attenuation of concatenated fibres added linearly.

3.1.3
spectral attenuation modelling
technique that predicts the attenuation coefficients across a spectrum of wavelengths from a small number (three to five) of discrete values measured directly at different wavelengths

3.1.4
point discontinuity
temporary or permanent local deviation of the continuous optical time-domain reflectometer (OTDR) signal in the upward or downward direction

Note 1 to entry: The nature of the deviation can vary with test conditions (e.g. pulse duration, wavelength, and direction of the OTDR signal). Although a point discontinuity can have a length greater than the corresponding displayed pulse duration (including transmitter and receiver effects), the length is usually about equal to the pulse duration. For a correct interpretation, the guidelines in IEC 60793-1-22 should be followed for measuring length.

3.2 Abbreviated terms

FWHM	full width at half maximum
LPS	limited phase space
OTDR	optical time-domain reflectometer
RMSW	root-mean-squared width
RTM	reference test method

4 Calibration requirements

See Annex A, Annex B, and Annex C for methods A, B, and C, respectively.

5 Reference test method

Method A, cut-back, is the reference test method (RTM), which shall be the one used to settle disputes.

6 Apparatus

Annex A, Annex B, Annex C, and Annex D include layout drawings and other equipment requirements for each of the methods, respectively.

7 Sample preparation

7.1 Sample length

The sample shall be a known length of fibre on a reel, or within a cable, as specified in the relevant specification.

7.2 Sample end face

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

8 Procedure

See Annex A, Annex B, Annex C, and Annex D for methods A, B, C and D, respectively.

9 Calculations

9.1 Methods A and B

Methods A and B, cut-back and insertion loss use Formula (1) and Formula (2) respectively, which appear in 3.1.1 and 3.1.2.

9.2 Method C

See Annex C.

9.3 Method D

See Annex D.

10 Results

10.1 Information available with each measurement

Report the following information with each measurement:

- date and title of measurement;
- identification of specimen;
- optical source wavelength;
- specimen length;
- spectral attenuation, in dB, or attenuation coefficient, in dB/km, versus wavelength or at specific wavelength(s), as required by the relevant specification.

10.2 Information available upon request

The following information shall be available upon request:

- measurement method used: A, B, C, or D;
- type of optical source used: centroidal wavelength(s) and spectral width(s);
- launching technique and conditions used;

- indication if a dead-zone fibre was used (for method C only);
- description of all key equipment;
- for type B fibres – dimensions and number of turns of the mode filter or mode scrambler;
- pulse duration(s), scale range(s), and signal-averaging details;
- details of computation technique (calculation method);
- any deviations to the procedure that were made;
- date of latest calibration of measurement equipment.

10.3 Method-specific additional information

For methods C and D, see the additional requirements in Clause C.6 and Clause D.6, respectively. This particularly applies when using method C for measuring point discontinuities.

11 Specification information

The relevant specification shall specify the following information:

- type of fibre (or cable) to be measured;
- failure or acceptance criteria at the wavelength or wavelength range;
- any deviations to the procedure that apply;
- information to be reported.

Annex A
(normative)

Requirements specific to method A – Cut-back

A.1 General

The cut-back technique is the only method directly derived from the definition of fibre attenuation, in which the power levels, $P_1(\lambda)$ and $P_2(\lambda)$, are measured at two points of the fibre without change of input conditions. $P_2(\lambda)$ is the power emerging from the end of the fibre, and $P_1(\lambda)$ is the power emerging from a point near the input after cutting the fibre. This explains its wide acceptance as the reference test method for attenuation.

This measurement principle does not permit information to be obtained on the attenuation behaviour over the length of the fibre, nor is it easy to measure the change of attenuation under changing conditions. In some situations, its destructive nature is a disadvantage.

A.2 Apparatus

A.2.1 General apparatus for all fibres

A.2.1.1 General

See Figure A.1 and Figure A.2 for diagrams of suitable test set-ups.

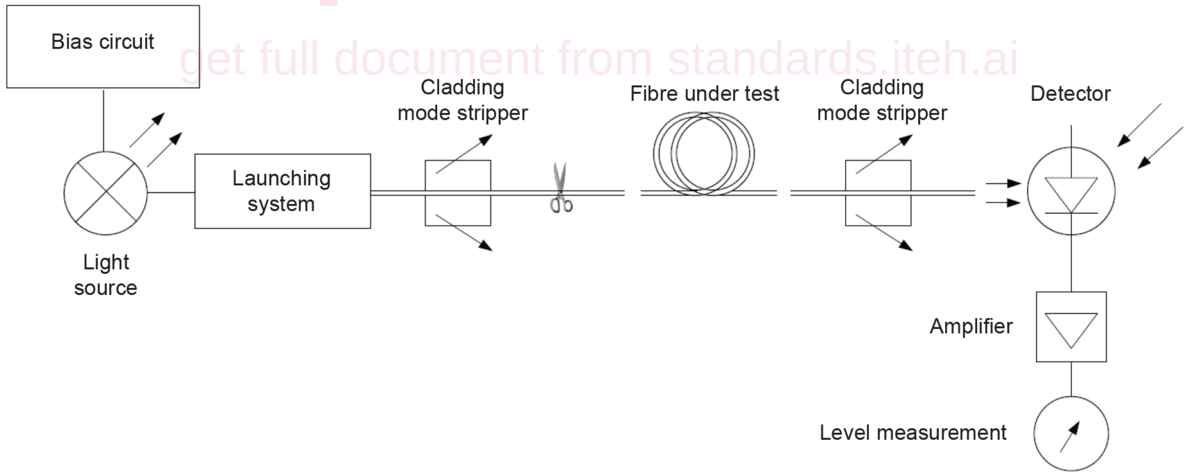

Figure A.1 – Arrangement of equipment for loss measurement at a specified wavelength

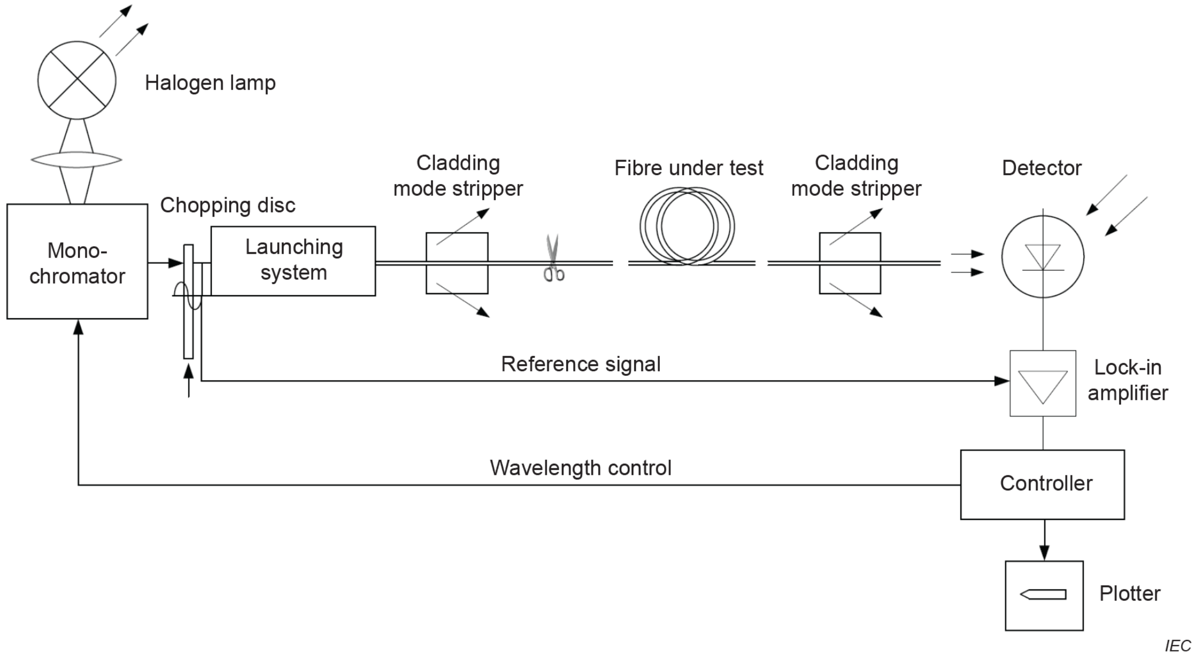

Figure A.2 – Arrangement of equipment used to obtain loss spectrum

A.2.1.2 General launch arrangement

Figure A.3 shows the general launch arrangement used for all fibres. See A.2.2 to A.2.4 for further details as they apply to specific categories of single-mode and multimode fibres.

A.2.1.3 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 <10 nm, compared with any features of the fibre spectral attenuation. Align the fibre to the launch cone or connect it to a launch fibre.

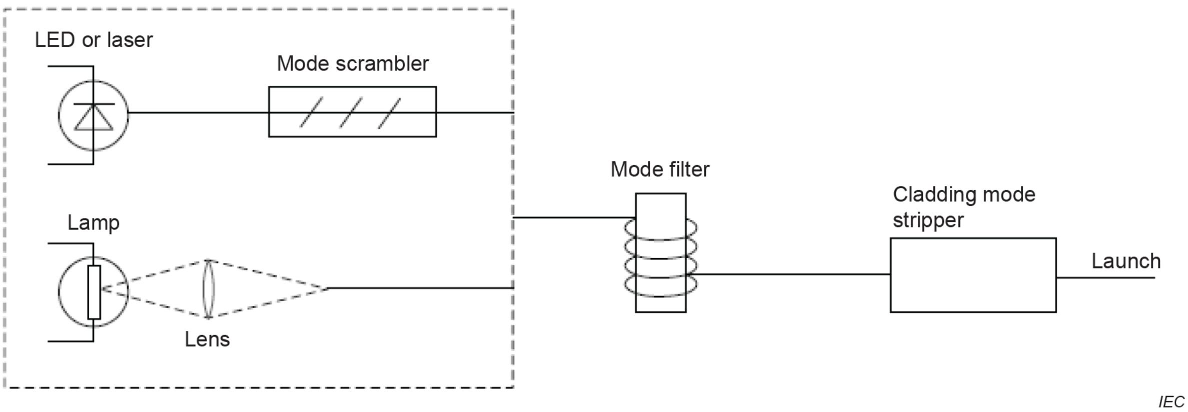

Figure A.3 – General launch arrangement

A.2.1.4 Source wavelength

Measurements can be made at one or more wavelengths. Alternatively, a spectral response can be obtained over a range of wavelengths.

A.2.1.5 Optical detection assembly

Means shall be provided to couple all power emitted from the specimen to the active region of the detector. For example, an optical lens system, a butt spliced to a fibre pigtail, or a coupling directly to the detector can 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 might include a photovoltaic mode photodiode amplified by a current input amplifier, with synchronous detection by a lock-in amplifier.

A.2.1.6 Signal processing

It is customary to modulate the light source to improve the signal to noise ratio 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 been fully characterized with a response function.

A.2.1.7 Cladding mode stripper

Use suitable techniques to remove optical power propagating in the cladding where this would significantly influence the received signal.

A.2.2 Launch apparatus for all single-mode fibres

A.2.2.1 General

An optical lens system or fibre pigtail can 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.

A.2.2.2 Fibre pigtail

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

A.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.

A.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. For bending loss insensitive single-mode fibres, multiple loops with smaller radius or longer cut-back specimen length can be applied. Care should be taken that the radius is not too small as to induce wavelength-dependent oscillations. Increase of the cut-back specimen length should be accounted for in the attenuation computation.