



BSI Standards Publication

Optical fibres

Part 1-49: Measurement methods and test procedures - Differential mode delay

National foreword

This British Standard is the UK implementation of EN IEC 60793-1-49:2018. It is identical to IEC 60793-1-49:2018. It supersedes BS EN 60793-1-49:2006, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/86/1, Optical fibres and cables.

A list of organizations represented on this committee can be obtained on request to its secretary.

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English Version

**Optical fibres - Part 1-49: Measurement methods and test
procedures - Differential mode delay
(IEC 60793-1-49:2018)**

Fibres optiques - Partie 1-49: Méthodes de mesure et
procédures d'essai - Retard différentiel de mode
(IEC 60793-1-49:2018)

Lichtwellenleiter - Teil 1-49: Messmethoden und
Prüfverfahren - Gruppenlaufzeitdifferenz
(IEC 60793-1-49:2018)

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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European foreword

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- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2021-09-19

This document supersedes EN 60793-1-49:2006.

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Endorsement notice

The text of the International Standard IEC 60793-1-49:2018 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60793-2-10 NOTE Harmonized as EN 60793-2-10

IEC 60793-1-42 NOTE Harmonized as EN 60793-1-42

Annex ZA

(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60793-1-1	2017	Optical fibres - Part 1-1: Measurement methods and test procedures - General and guidance	EN 60793-1-1	2017
IEC 60793-1-22	-	Optical fibres - Part 1-22: Measurement methods and test procedures - Length measurement	EN 60793-1-22	-
IEC 60793-1-41	-	Optical fibres - Part 1-41: Measurement methods and test procedures - Bandwidth	-	-
IEC 60793-1-45	-	Optical fibres - Part 1-45: Measurement methods and test procedures - Mode field diameter	EN IEC 60793-1-45	-
IEC 60825-1	-	Safety of laser products - Part 1: Equipment classification and requirements	EN 60825-1	-
IEC 60825-2	-	Safety of laser products - Part 2: Safety of optical fibre communication systems (OFCS)	EN 60825-2	-
IEC 61280-1-4	-	Fibre optic communication subsystem test procedures - Part 1-4: General communication subsystems - Light source encircled flux measurement method	EN 61280-1-4	-

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

OPTICAL FIBRES –

**Part 1-49: Measurement methods and test procedures –
Differential mode delay**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60793-1-49 has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

This third edition cancels and replaces the second edition published in 2006. This edition constitutes a technical revision.

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

- a) better alignment with original intent by filling some omissions and therefore improving measurement rigor;

- b) the measurement of fibres with smaller differential mode delay (and higher modal bandwidth) such as type A1a.3 fibres of IEC 60793-2-10 [1]¹ that are used in constructing OM4 performance category cables; new requirements on specifying detector amplitude and temporal response, specimen deployment conditions, four-quadrant scanning, and uniformity of radial locations for calculating bandwidth.

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

CDV	Report on voting
86A/1812/CDV	86A/1860/RVC

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 International Standard is to be used in conjunction with IEC 60793-1-1:2017.

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 "<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.

¹ Numbers in square brackets refer to the Bibliography.

OPTICAL FIBRES –

Part 1-49: Measurement methods and test procedures – Differential mode delay

1 Scope

This part of IEC 60793 applies only to multimode, graded-index glass-core (category A1) fibres. The test method is commonly used in production and research facilities, but is not easily accomplished in the field.

This document describes a method for characterizing the modal structure of a graded-index multimode fibre. This information is useful for assessing the bandwidth performance of a fibre especially when the fibre is intended to support a range of launch conditions, for example, those produced by standardized laser transmitters.

With this method, the output from a probe fibre that is single-moded at the test wavelength excites the multimode fibre under test. The probe spot is scanned across the end-face of the fibre under test at specified radial positions, and a set of response pulses are acquired at these positions.

Three specifiable parameters can be derived from the collected set of data.

- The first parameter, differential modal delay (*DMD*), is the difference in optical pulse delay time between the fastest and slowest mode groups of the fibre under test. *DMD* specifications place limits on modal delay over a specified range of probe fibre radial offset positions. *DMD* specifications are determined by modeling and experimentation to correspond to a minimum effective modal bandwidth (*EMB*) for the expected range of transmitters used in a link at a given performance level.
- The second specifiable parameter is derived by combining the pulses using sets of specific radial weights to determine an approximation of a set of pulses from typical transmitters. Using Fourier transforms, the calculated effective modal bandwidth (*EMB_c*) is determined for each weight set. The minimum of these *EMB_c* values (*minEMB_c*) is the specifiable parameter.
- The third specifiable parameter, the computed overfilled launch bandwidth, *OMB_c*, is determined in a manner similar to *EMB_c*, but by applying just one weight set to the set of pulses; this weight set corresponds to the overfilling condition, where all mode groups are equally excited.

The test's intent is to quantify the effects of interactions of the fibre modal structure and the source modal characteristics excluding the source's spectral interaction with fibre chromatic dispersion. Adding the effects of fibre chromatic dispersion and the source spectral characteristics will reduce the overall transmission bandwidth, but this is a separate calculation in most transmission models. In this test, the contribution of chromatic dispersion is controlled by limiting the spectral width of usable test sources. Practical test sources will have non-zero spectral width and will thus slightly distort the *DMD*, *minEMB_c* and *OMB_c* values. These chromatic dispersion effects are considered in Annex A.

NOTE Comparison between IEC 60793-1-49 and ITU recommendations: ITU-T Recommendation G.650.1 [2] contains no information on how to measure the *DMD* of a graded-index multimode fibre.

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 60793-1-1:2017, *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 60793-1-41, *Optical fibres – Part 1-41: Measurement methods and test procedures – Bandwidth*

IEC 60793-1-45, *Optical fibres – Part 1-45: Measurement methods and test procedures – Mode field diameter*

IEC 60825-1, *Safety of laser products – Part 1: Equipment classification and requirements*

IEC 60825-2, *Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCS)*

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

3 Terms and definitions

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

maximum *DMD*

maximum *DMD* occurring between the outer (R_{OUTER}) and inner (R_{INNER}) limits of radial offset position over which the probe spot is scanned for one or more sets of R_{OUTER} and R_{INNER}

3.2

minimum EMB_c

$minEMB_c$

minimum EMB_c among the EMB_c values calculated from a sequence of *DMD* weightings

Note 1 to entry: The user of this document may also specify the calculated overfilled modal bandwidth (OMB_c).

3.3

differential mode delay

DMD

estimated difference in optical pulse delay time between the fastest and slowest modes excited for all radial offset positions between and including R_{INNER} and R_{OUTER}

Note 1 to entry: This note applies to the French language only.

3.4 effective modal bandwidth

EMB

bandwidth associated with the transfer function, $H(f)$, of a particular laser/fibre combination

Note 1 to entry: This note applies to the French language only.

3.5 calculated overfilled modal bandwidth

OMB_c

bandwidth associated with the transfer function, $H(f)$, when the fibre is overfilled

3.6 quadrant

radial section at one of four possible azimuthal angles over which a radial set of pulse data can be collected

Note 1 to entry: For example, a radial section may be taken from one of the sets x -positive, x -negative, y -positive or y -negative.

3.7 mode field diameter

MFD

diameter of the mode emanating from the end-face of a single-mode fibre, as determined by IEC 60793-1-45

Note 1 to entry: This note applies to the French language only.

3.8 reference test method

RTM

test method in which a given characteristic of a specified class of optical fibres or optical cables (and associated components) is measured strictly according to the definition of this characteristic, and which gives results that are accurate, reproducible and relatable to practical use

Note 1 to entry: This note applies to the French language only.

3.9 full width quarter maximum

FWQM

full width at 25 % of maximum amplitude of an optical pulse

Note 1 to entry: This note applies to the French language only.

4 Apparatus

4.1 Overview

The apparatus shall provide a means to inject and detect short-duration pulses of light of a small spot size launched into known locations of the core of the multimode fibre to be measured. An example is diagrammed in Figure 1.

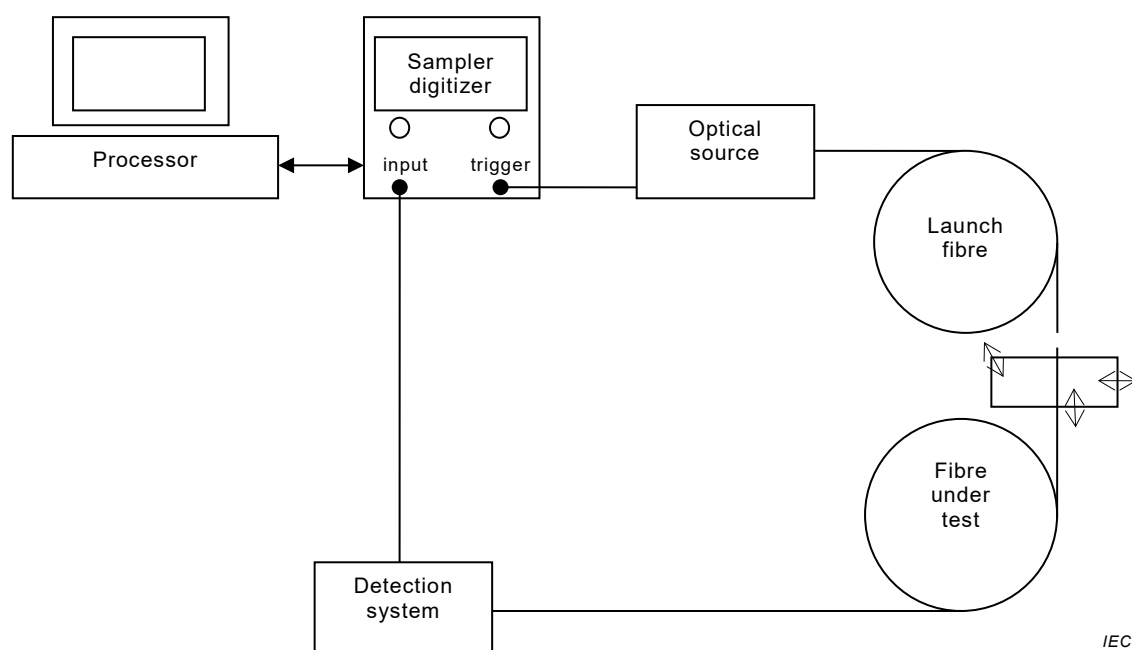


Figure 1 – Example apparatus

4.2 Optical source

Use an optical source that introduces short duration, narrow spectral width pulses into the probe fibre.

The temporal duration of the optical pulse shall be short enough to measure the intended differential delay time. The maximum duration allowed for the optical pulse, characterized as full width at 25 % of maximum amplitude (*FWQM*), will depend both on the value of *DMD* to be determined and the sample length. For example, if the desired length-normalized *DMD* limit is 0,20 ps/m over a sample of length 500 m, the *DMD* to be measured is 100 ps, so the maximum allowable *FWQM* of the probe pulse is ~110 ps. Testing to the same *DMD* limit in a 10 000 m length of fibre requires measuring a *DMD* of 2 000 ps, therefore a pulse as wide as ~2 200 ps may be used. Detailed limits are given in 6.1, and may depend on the source spectral width.

Source spectral width shall meet the requirements of Annex A. Chromatic dispersion induced broadening resulting from source spectral width is limited through the methodologies described in Annex A. The requirement on spectral width may be met either by using a spectrally narrow source, or alternatively by the use of appropriate optical filtering at either the source or detection end. This requirement is challenging when measuring the highest performance fibres (whose *DMD* can be as low as 0,1 ps/m). In these circumstances, the pulse source's spectrum may be transform limited, in which case, no improvement can be made.

The source centre wavelength requirement is given by the product specification documents, which may require measurements at more than one wavelength. Each wavelength is considered in this document as a single measurement (if no default wavelength specification is defined for the product to be measured, the default of 850 nm ± 10 nm shall be used).

A mode-locked titanium-sapphire laser, pulsed semiconductor laser or mode-locked fibre laser are examples of sources suitable for this application.

Reference shall be made to IEC 60825-1 and to IEC 60825-2 for an explanation of the safe usage of these sources.

4.3 Probe fibre

The optical source shall be coupled to a fibre which is single-moded at the wavelength of measurement. It is required that this fibre be nominally of step-index design, and so shall have a mode field diameter (*MFD*) satisfying the following equation:

$$MFD = (8,7\lambda - 2,39) \pm 0,5 \mu\text{m} \quad (1)$$

where

λ is the source wavelength in μm ;

and the mode field diameter is determined using IEC 60793-1-45.

This equation produces a mode field diameter of 5 μm at 850 nm and 9 μm at 1 310 nm, which corresponds to commercially available single-mode fibres.

Ensure that the output of the probe fibre is single-moded by limiting the ability for higher-order modes to propagate. Winding the probe fibre around a mandrel of a given diameter is an example mode control device; a common example is three turns around a 25 mm diameter mandrel.

4.4 Scanning stage

Either the probe fibre or the test sample shall be mounted to a scanning stage capable of scanning the test sample relative to the probe fibre over the entire diameter of the test sample's core in both *x*- and *y*-direction. The scanning stage *x*- and *y*-actuators shall be capable of positioning the probe fibre to within 0,5 μm of the desired position. Often, the scanning stage is used to adjust the gap between the probe fibre and the test sample's end-face or, when an optical system is employed, to focus the probe spot image onto the sample end-face.

The probe fibre output beam's angle of propagation shall be aligned with the test sample's axis of propagation to within 1°.

The apparatus shall employ algorithms to reproducibly centre (with respect to the test sample's core) the output spot of the probe fibre to within $\pm 1,0 \mu\text{m}$. Refer to Annex B for a discussion of end-face centring.

4.5 Probe to test sample coupling

If directly coupled to the test sample, the gap between the output end of the probe fibre and the end-face of the test sample shall be no more than 10 μm . Alternatively, a free-space optics system of lenses or mirrors may be used to image the output spot of the probe fibre onto the end-face of the test sample. When optics are employed, it is required that at each radial scan position of the measurement, substantially the same modes are excited in the test fibre as would be if the beam were coupled directly from the output of the single-mode probe fibre.

4.6 Cladding mode stripper

A cladding mode stripper provides means to remove cladding light from the test sample. Often, the fibre coating is sufficient to perform this function. Otherwise, use cladding mode strippers near both ends of the test sample. If the fibre is retained on the cladding mode stripper(s) with small weights, care shall be taken to avoid microbending at these sites.

4.7 Detection system

Use an optical detection apparatus suitable for the test wavelength. The detection apparatus shall couple all of the guided modes from the test sample onto the detector's active area.