

Optical fibres —

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

The European Standard EN 60793-1-49:2006 has the status of a British Standard

ICS 33.180.10

National foreword

This British Standard was published by BSI. It is the UK implementation of EN 60793-1-49:2006. It is identical with IEC 60793-1-49:2006. It supersedes BS EN 60793-1-49:2003 which is withdrawn.

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

A list of organizations represented on GEL/86/1 can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 29 September 2006

© BSI 2006

ISBN 0 580 49288 5

Amendments issued since publication

Amd. No.	Date	Comments

English version

Optical fibres
Part 1-49: Measurement methods and test procedures -
Differential mode delay
(IEC 60793-1-49:2006)

Fibres optiques
Partie 1-49: Méthodes de mesure et
procédures d'essai -
Retard différentiel de mode
(CEI 60793-1-49:2006)

Lichtwellenleiter
Teil 1-49: Messmethoden und
Prüfverfahren -
Gruppenlaufzeitdifferenz
(IEC 60793-1-49:2006)

This European Standard was approved by CENELEC on 2006-07-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

CENELEC

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

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Foreword

The text of document 86A/1061/FDIS, future edition 2 of IEC 60793-1-49, prepared by SC 86A, Fibres and cables, of IEC TC 86, Fibre optics, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60793-1-49 on 2006-07-01.

This European Standard supersedes EN 60793-1-49:2003.

It adds minimum calculated effective modal bandwidth (EMBc) to the test procedures, supporting EN 60793-2-10.

This standard is to be read in conjunction with EN 60793-1-1 and EN 60793-2-10.

The following dates were fixed:

- | | | |
|--|-------|------------|
| – latest date by which the EN has to be implemented
at national level by publication of an identical
national standard or by endorsement | (dop) | 2007-04-01 |
| – latest date by which the national standards conflicting
with the EN have to be withdrawn | (dow) | 2009-07-01 |

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60793-1-49:2006 was approved by CENELEC as a European Standard without any modification.

CONTENTS

1	Scope	4
2	Normative references	4
3	Terms and definitions	5
4	Apparatus	6
4.1	Optical source	6
4.2	Stability	6
4.3	Launch system	6
4.4	Detection system	7
4.5	Computational equipment	8
5	Sampling and specimens	8
5.1	Test sample	8
5.2	Specimen endfaces	8
5.3	Specimen length	8
5.4	Specimen packaging	8
5.5	Specimen positioning	8
6	Procedure	8
6.1	Adjust and measure system response	8
6.2	Adjust detection system	9
6.3	Measure the test sample	9
7	Calculations and interpretation of results	10
7.1	Differential mode delay (DMD)	10
7.2	Minimum calculated effective modal bandwidth	10
7.3	Length normalization	12
8	Documentation	12
8.1	Report the following information for each test:	12
8.2	The following information shall be available upon request:	12
9	Specification information	12
	Annex A (normative) Source spectral width limitation	14
	Annex B (informative) Discussion of measurement details	17
	Annex C (informative) Determining DMD weights for EMBc calculation	21
	Annex D (informative) EMBc calculation information	24
	Annex E (informative) Comparison between this standard and ITU recommendations	27
	Bibliography	28
	Figure B.1 – Idealized DMD data	17
	Table A.1 – Highest expected dispersion for any of the commercially available Category A1 fibres	16
	Table D.1 – DMD weightings – Example set 1	24
	Table D.2 – DMD weightings – Example set 2	25

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 standard 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 variety of launch conditions such as those produced by standardized laser transmitters.

With this method, the output from a fibre that is single-mode at the test wavelength excites the multimode fibre under test. The probe spot is scanned across the endface of the fibre under test, and the optical pulse delay is determined at specified offset positions.

Two results can be produced from the same data. First, the difference in optical pulse delay time between the fastest and slowest mode groups of the fibre under test can be determined. The user specifies the upper and lower limits of radial offset positions over which the probe fibre is scanned in order to specify desired limits of modal structure. The DMD data is then compared to DMD specifications that have been determined by modeling and experimentation to correspond to a minimum EMB for a range of transmitters. Second, the optical pulse shapes can be combined using specific weights to determine a calculated effective modal bandwidth (EMBc), and by calculating a sequence of EMBc values with different sets of weights, a minimum EMBc can be calculated, corresponding to a range of transmitters.

The test quantifies the effects of interactions of the fibre modal structure and the source modal characteristics excluding the source spectral interactions with fibre chromatic dispersion. Adding the effects of chromatic dispersion and source spectral width will reduce the overall transmission bandwidth, but this is a separate calculation in most transmission models. In this test, the effects of non-zero spectral width are minimized but any residual effects will tend to increase the DMD value and decrease the EMBc value.

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.

IEC 60793-1-1: *Optical fibres – Part 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 60793-1-42: *Optical fibres – Part 1-42: Measurement methods and test procedures – Chromatic dispersion*

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

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 – Collection and reduction of two-dimensional nearfield data for multimode fibre laser transmitters*

3 Terms and definitions

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

NOTE The user of this standard specifies either the maximum DMD for the outer (R_{OUTER}) and inner (R_{INNER}) limits of radial offset position over which the probe spot is scanned, or the minimum EMBc among the EMBc values calculated from a sequence of DMD weightings.

3.1

differential mode delay

DMD

the 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}

3.2

effective modal bandwidth

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

3.3

inner limit

R_{INNER}

outer limit

R_{OUTER}

limits of radial offset positions on the endface of the fibre under test over which the probe spot is scanned

4 Apparatus

4.1 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, 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, and a pulse of duration less than ~110 ps is needed. Testing to the same DMD limit in a 10 000 m length of fibre requires measuring a DMD of 2 000 ps, and 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.

Chromatic dispersion induced broadening resulting from source spectral width shall be within the limits indicated 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.

The centre wavelength shall be within ± 10 nm of the nominal specified wavelength.

A mode locked titanium-sapphire laser is an example of a source usable for this application.

4.2 Stability

Devices shall be available to position the input and output ends of the test specimen with sufficient stability and reproducibility to meet the conditions of 4.3 and 4.4.

4.3 Launch system

The probe fibre between the light source and test sample shall propagate only a single mode at the measurement wavelength. The mode field diameter of the probe fibre at λ shall be $(8,7\lambda - 2,39) \pm 0,5 \mu\text{m}$, where λ is the measurement wavelength in micrometers, 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-mode. One method to do this is to strip higher order modes by wrapping the probe fibre three turns around a 25-mm diameter mandrel.

The output spot of the probe fibre shall be scanned across the endface of the test sample with a positional accuracy less than or equal to $\pm 0,5 \mu\text{m}$.

The output beam from the probe fibre shall be perpendicular to the endface of the test sample to within an angular tolerance of less than or equal to 1,0 degree.

The launch system shall be capable of reproducibly centring the output spot of the probe fibre to within $\pm 1,0 \mu\text{m}$.

If directly coupled to the test sample, the gap between the output end of the probe fibre and the endface of the test sample shall be no more than 10 µm.

A free space optics system of lenses or mirrors may be used to image the output spot of the probe fibre onto the endface of the test sample. When using this type of launch system, care should be taken to ensure that 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. For example, a system of lenses or mirrors may be used to image the output of a single-mode fibre onto the end face of the test sample.

Provide 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.

4.4 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, such that the detection sensitivity is not significantly mode dependent. The detector, along with any signal preamplifier, shall respond linearly (within $\pm 5\%$) over the range of power detected.

The temporal response of the detector system, including any optional optical attenuator, shall not be significantly mode dependent.

A specific test for mode dependence is given in 6.1. Alternatively, the detector's temporal response may be a function of offset as long as it is stable over the course of the measurement (i.e. $\Delta T_{\text{PULSE}}(r)$ shall fulfil the $\pm 5\%$ requirement of 6.1).

Ringings of the detector system shall be limited such that maximum overshoot or undershoot shall be less than 5 % of the peak amplitude of the detected optical signal as measured on the reference.

The waveform of the detected optical signal shall be recorded and displayed on a suitable instrument, such as a high-speed sampling oscilloscope with calibrated time sweep. The recording system should be capable of averaging the detected waveform for multiple optical pulses.

Use a delay device, such as a digital delay generator, to provide a means of triggering the detection electronics at the correct time. The delay device may trigger the optical source, or be triggered by it. The delay device may be internal or external to the recording instrument.

The combined effect of timing jitter and noise in the detection system shall be small enough that the difference between successive measurements of optical delay times for any fixed launch used in the measurement shall be less than 5 % of the measured value of DMD. Averaging the detected waveform for multiple optical pulses may be used to reduce the effects of timing jitter and noise. If averaging is used, each waveform shall be recorded using at least the number of averages used when determining ΔT_{PULSE} in 6.1. The system shall maintain this level of stability over the course of the measurement.

4.5 Computational equipment

This test method generally requires a computer to store the intermediate data and calculate the test results.

5 Sampling and specimens

5.1 Test sample

The test sample shall be graded-index glass-core (category A1) multimode fibre.

5.2 Specimen endfaces

Prepare flat endfaces at the input and output ends of the specimen.

5.3 Specimen length

The length of the fibre shall be measured using a suitably accurate method such as that of IEC 60793-1-22.

5.4 Specimen packaging

Support the test fibre in a manner that relieves tension and minimizes microbending.

5.5 Specimen positioning

Position the input end of the test sample such that it is aligned to the output end of the launch system as described in 4.3.

Position the output end of the test sample such that it is aligned with the detection system, as described in 4.4.

6 Procedure

6.1 Adjust and measure system response

Couple the output of the probe fibre into the detection apparatus. This may be accomplished by mounting the probe fibre in the detection apparatus, or by using a short (<10 m) length of fibre mounted between the launch system and the detection system, or by directly coupling the probe output to the detector via a system of lenses and mirrors. If using a short fibre, it shall be of the same type fibre as the test fibre.

Adjust the amplitude of the optical pulse to match the smallest peak amplitude expected from the test fibre during the measurement. The smallest peak amplitude from the test fibre will usually occur for the largest radial offset.

Adjust the time scale of the detection system to match the time scale used in acquiring data from the test sample to ensure that the entire pulse is captured (see 6.2).

Measure the waveform of the optical pulse, and determine its temporal width at 25 % of the peak amplitude. This value will be used to calculate the test results, and will be called ΔT_{PULSE} . Linear interpolation may be used between successive time points to calculate ΔT_{PULSE} for improved accuracy.