

Optical fibres —

Part 1-45: Measurement methods and test procedures — Mode field diameter

The European Standard EN 60793-1-45:2003 has the status of a
British Standard

ICS 33.180.10

National foreword

This British Standard is the official English language version of EN 60793-1-45:2003. It was derived by CENELEC from IEC 60793-1-45:2001. It partly supersedes BS EN 188000:1994 which will be withdrawn on publication of the full BS EN 60793-1 series.

The CENELEC common modifications have been implemented at the appropriate places in the text and are indicated by common modification tags Ⓒ Ⓓ.

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

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the *BSI Catalogue* under the section entitled “International Standards Correspondence Index”, or by using the “Search” facility of the *BSI Electronic Catalogue* or of British Standards Online.

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Optical fibres
Part 1-45: Measurement methods and test procedures –
Mode field diameter
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Fibres optiques
Partie 1-45: Méthodes de mesure
et procédures d'essai –
Diamètre du champ de mode
(CEI 60793-1-45:2001 +
corrigendum 2002, modifiée)

Lichtwellenleiter
Teil 1-45: Messmethoden und
Prüfverfahren –
Modenfelddurchmesser
(IEC 60793-1-45:2001 +
Corrigendum 2002, modifiziert)

This European Standard was approved by CENELEC on 2003-11-01. 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.

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CENELEC

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

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Foreword

The text of document 86A/674/FDIS, future edition 1 of IEC 60793-1-45, 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 60793-1-45 on 2001-10-01.

A draft amendment, prepared by the Technical Committee CENELEC TC 86A, Optical fibres and optical fibre cables, was submitted to the Unique Acceptance Procedure and was approved by CENELEC for inclusion into EN 60793-1-45 on 2003-11-01.

This European Standard supersedes subclause 4.24 (test method 314) and subclause 4.25 (test method 315) of EN 188000:1992.

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) 2004-11-01
- latest date by which the national standards conflicting
with the EN have to be withdrawn (dow) 2006-11-01

Annexes designated "normative" are part of the body of the standard.

In this standard, Annexes A, B, C, D and ZA are normative and annex E is informative.

Annex ZA has been added by CENELEC.

Compared to IEC 60793-1:1989 and IEC 60793-2:1992, IEC/SC 86A has adopted a revised structure of the new IEC 60793 series: The individual measurement methods and test procedures for optical fibres are published as "Part 1-XX"; the product standards are published as "Part 2-XX".

The general relationship between the new series of EN 60793 and the superseded European Standards of the EN 188000 series is as follows:

EN	Title	supersedes
EN 60793-1-XX	Optical fibres -- Part 1-XX: Measurement methods and test procedures	Individual subclauses of EN 188000:1992
EN 60793-2-XX	Optical fibres -- Part 2-XX: Product specifications	EN 188100:1995 EN 188101:1995 EN 188102:1995 EN 188200:1995 EN 188201:1995 EN 188202:1995

EN 60793-1-4X consists of the following parts, under the general title: Optical fibres:

- Part 1-40: Measurement methods and test procedures – Attenuation
- Part 1-41: Measurement methods and test procedures – Bandwidth
- Part 1-42: Measurement methods and test procedures – Chromatic dispersion
- Part 1-43: Measurement methods and test procedures – Numerical aperture
- Part 1-44: Measurement methods and test procedures – Cut-off wavelength
- Part 1-45: Measurement methods and test procedures – Mode field diameter
- Part 1-46: Measurement methods and test procedures – Monitoring of changes in optical transmittance
- Part 1-47: Measurement methods and test procedures – Macrobending loss
- Part 1-48: Measurement methods and test procedures – Polarization mode dispersion
- Part 1-49: Measurement methods and test procedures – Differential mode delay

The contents of the corrigendum of April 2004 have been included in this copy.

Endorsement notice

The text of the International Standard IEC 60793-1-45:2001 was approved by CENELEC as a European Standard with agreed common modifications.

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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, 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 1-45: Measurement methods and test procedures – Mode field diameter

1 Scope

This part of IEC 60793 establishes uniform requirements for measuring the mode field diameter (MFD) of optical fibre, thereby assisting in the inspection of fibres and cables for commercial purposes.

The MFD represents a measure of the transverse extent of the electromagnetic field intensity of the mode in a fibre cross section, and it is defined from the far-field intensity distribution as a ratio of integrals known as the Petermann II definition. See equation (1).

The definitions of MFD are strictly related to the measurement configurations. The mathematical equivalence of these definitions results from transform relationships between measurement results obtained by different implementations summarized in figure 1 as follows:

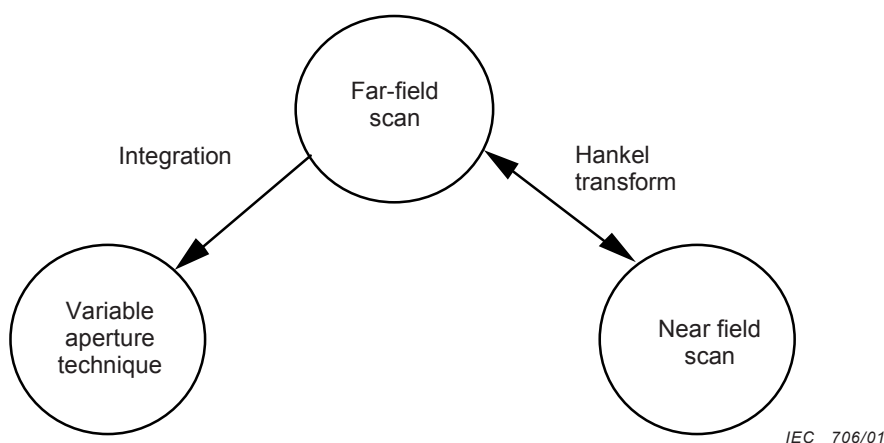


Figure 1 – Transform relationships between measurement results

Four methods are described for measuring MFD:

- method A: direct far-field scan;
- method B: variable aperture in the far field;
- method C: near-field scan;
- method D: bi-directional backscatter using an optical time domain reflectometer (OTDR).

All four methods apply to all categories of type B single-mode fibre shown in IEC 60793-2 and operating near 1 310 nm or 1 550 nm. Method D is not recommended for the measurement of fibres of unknown type or design.

Information common to all four methods is contained in clauses 1 to 8, and information pertaining to each individual method appears in annexes A, B, C and D, respectively.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 60793. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of IEC 60793 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

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

IEC 60793-2:1998, *Optical fibres – Part 2: Product specifications*

3 Reference test method

Method A, direct far-field scan, is the reference test method (RTM), which shall be the one used to settle disputes.

4 Apparatus

The following apparatus is common to all measurement methods. Annexes A, B, C and D include layout drawings and other equipment requirements for each of the four methods, respectively.

4.1 Light source

For methods A, B and C, use a suitable coherent or non-coherent light source such as a semiconductor laser or a sufficiently powerful filtered white light source. The source shall produce sufficient radiation at the intended wavelength(s) and be stable in intensity over a time period sufficient to perform the measurement.

A monochromator or interference filter(s) may be used, if required, for wavelength selection. The detail specification shall specify the wavelength of the source. The FWHM (full width half maximum) spectral line width of the source shall be less than or equal to 10 nm, unless otherwise specified.

See annex D for method D.

4.2 Input optics

For method A, B, and C, an optical lens system or fibre pigtail may be employed to excite the specimen. It is recommended that the power coupled into the specimen be relatively insensitive to the position of its input end face. This can be accomplished by using a launch beam that spatially and angularly overfills the input end face.

If using a butt splice, employ index-matching material between the fibre pigtail and the specimen to avoid interference effects. The coupling shall be stable for the duration of the measurement.

See annex D for method D.

4.3 Input positioner

Provide means of positioning the input end of the specimen to the light source. Examples include the use of x-y-z micropositioner stages, or mechanical coupling devices such as connectors, vacuum splices, three-rod splices, etc. The position of the fibre shall remain stable over the duration of the measurement.

4.4 Cladding mode stripper

Use a device that extracts cladding modes. Under some circumstances the fibre coating will perform this function.

4.5 High-order mode filter

Use a means to remove high-order propagating modes in the wavelength range that is greater than or equal to the cut-off wavelength of the specimen. For example, a one-turn bend with a radius of 30 mm on the fibre is generally sufficient.

4.6 Output positioner

Provide a suitable means for aligning the fibre output end face in order to allow an accurate axial adjustment of the output end, such that, at the measurement wavelength, the scan pattern is suitably focused on the plane of the scanning detector. Such coupling may include the use of lenses, or may be a mechanical connector to a detector pigtail.

Provide means such as a side-viewing microscope or camera with a crosshair to locate the fibre at a fixed distance from the apertures or detectors. It may be sufficient to provide only longitudinal adjustment if the fibre is constrained in the lateral plane by a device such as a vacuum chuck. (This depends mainly upon the size of the light detector.)

4.7 Output optics

See the appropriate annex: A, B, C or D.

4.8 Detector

See the appropriate annex: A, B, C or D.

4.9 Computer

Use a computer to perform operations such as controlling the apparatus, taking intensity measurements, and processing the data to obtain the final results. For individual details, see the appropriate annex: A, B, C or D.

5 Sampling and specimens

5.1 Specimen length

For methods A, B and C, the specimen shall be a known length, typically $2\text{ m} \pm 0,2\text{ m}$ of single-mode fibre.

NOTE For method D, OTDR, the sample must be long enough to exceed (or be positioned beyond) the dead zone of the OTDR, with both ends accessible, as described in the backscatter test method IEC 60793-1-40.

5.2 Specimen end face

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

6 Procedure

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

7 Calculations

The basic equations for calculating MFD by methods A, B and C are given below. For additional calculations, see the appropriate annex: A, B, C or D. Sample data sets for methods A, B and C are included in annex E.

7.1 Method A – Direct far-field scan

The following equation defines the MFD for method A in terms of the electromagnetic field emitted from the end of the specimen.

Calculate the MFD by scanning the far-field data and evaluating the Petermann II integral, which is defined from the far-field intensity distribution:

$$2W_0 = \frac{\lambda\sqrt{2}}{\pi} \left[\frac{\int_0^{\pi/2} P_F(\theta) \sin(\theta) \cos(\theta) d\theta}{\int_0^{\pi/2} P_F(\theta) \sin^3(\theta) \cos(\theta) d\theta} \right] \quad (1)$$

where

$2W_0$ is the MFD in μm ;

$P_F(\theta)$ is the far-field intensity distribution;

λ is the wavelength of measurement in μm ;

θ is the angle in the far-field measurement from the axis of the fibre.

NOTE 1 The integration limits are shown to be from zero to $\pi/2$, but it is understood that the integrands approach zero with increasing argument so that, in practice, the integrals can be truncated.

NOTE 2 P_F is the $F^2(\theta)$ in ITU-T publications.

The far-field method for obtaining the MFD of a single-mode fibre is a two-step procedure. First, measure the far-field radiation pattern of the fibre. Second, use a mathematical procedure based on the Petermann II far-field definition to calculate the mode field from far-field data, as described in equation (1) above.

Annex E provides sample data and calculated values for $2W_0$ to enable one to check the numerical evaluation of the Petermann II Integral. The sample data are in the form of the folded power, $P_F(\theta)$, as a function of the angle, θ .