SLOVENSKI STANDARD

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Optična vlakna - 1-48. del: Metode merjenja in preskusni postopki - disperzija z načinom polarizacije (IEC 60793-1-48:2007)

Optical fibres - Part 1-48: Measurement methods and test procedures - Polarization mode dispersion (IEC 60793-1-48:2007)

Lichtwellenleiter - Teil 1-48: Messmethoden und Prüfverfahren - Polarisationsmodendispersion (IEC 60793-1-48:2007)

Fibres optiques - Partie 1-48: Méthodes de mesure et procédures d'essai - Dispersion du mode de polarisation (IEC 60793-1-48:2007)

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English version

Optical fibres -
Part 1-48: Measurement methods and test procedures -
Polarization mode dispersion
(IEC 60793-1-48:2007)

Fibres optiques -
Partie 1-48: Méthodes de mesure
et procédures d'essai -
Dispersion du mode de polarisation
(CEI 60793-1-48:2007)

Lichtwellenleiter -
Teil 1-48: Messmethoden
und Prüfverfahren -
Polarisationsmodendispersion
(IEC 60793-1-48:2007)

This European Standard was approved by CENELEC on 2007-09-01. 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.

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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/1038/CDV, future edition 2 of IEC 60793-1-48, prepared by SC 86A, Fibres and cables, of IEC TC 86, Fibre optics, was submitted to the IEC-CENELEC parallel Unique Acceptance Procedure and was approved by CENELEC as EN 60793-1-48 on 2007-09-01.

This European Standard supersedes EN 60793-1-48:2003.

In EN 60793-1-48:2007, reference to IEC/TR 61282-9 has resulted in the removal of Annexes E, F, G and H as well as the creation of a new Annex E.

This standard is to be used in conjunction with EN 60793-1-1.

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)	2008-06-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2010-09-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60793-1-48:2007 was approved by CENELEC as a European Standard without any modification.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60793-1-1	– [1]	Optical fibres - Part 1-1: Measurement methods and test procedures - General and guidance	EN 60793-1-1	2003 [2]
IEC 60793-1-44	– [1]	Optical fibres - Part 1-44: Measurement methods and test procedures - Cut-off wavelength	EN 60793-1-44	2002 [2]
IEC 60793-2-50	– [1]	Optical fibres - Part 2-50: Product specifications - Sectional specification for class B single-mode fibres	EN 60793-2-50 + corr. July	2004 [2] 2004
IEC 60794-3	– [1]	Optical fibres cables - Part 3: Sectional specification - Outdoor cables	EN 60794-3	2002 [2]
IEC 61280-4-4	– [1]	Fibre optic communication subsystem test procedures - Part 4-4: Cable plants and links - Polarization mode dispersion measurement for installed links	EN 61280-4-4	2006 [2]
IEC/TR 61282-3	– [1]	Fibre optic communication system design guides - Part 3: Calculation of link polarization mode dispersion	–	–
IEC/TR 61282-9	– [1]	Fibre optic communication system design guides - Part 9: Guidance on polarization mode dispersion measurements and theory	–	–
IEC 61290-11-1	– [1]	Optical amplifier test methods - Part 11-1: Polarization mode dispersion - Jones matrix eigenanalysis method (JME)	EN 61290-11-1	2003 [2]
IEC 61290-11-2	– [1]	Optical amplifiers - Test methods - Part 11-2: Polarization mode dispersion parameter - Poincaré sphere analysis method	EN 61290-11-2	2005 [2]

[1] Undated reference.

[2] Valid edition at date of issue.

Publication	Year	Title	EN/HD	Year
IEC/TR 61292-5	– [1)]	Optical amplifiers - Part 5: Polarization mode dispersion parameter - General information	–	–
IEC 61300-3-32	– [1)]	Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 3-32: Examinations and measurements - Polarisation mode dispersion measurement for passive optical components	EN 61300-3-32	2006 [2)]
ITU-T Recommendation G.650.2	– [1)]	Definitions and test methods for statistical and non-linear related attributes of single-mode fibre and cable	–	–

INTERNATIONAL STANDARD

NORME INTERNATIONALE

IEC
CEI
60793-1-48

Second edition
Deuxième édition
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Optical fibres –

Part 1-48:
Measurement methods and test procedures – Polarization mode dispersion

Fibres optiques –

Partie 1-48:
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Pour prix, voir catalogue en vigueur

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

OPTICAL FIBRES –

Part 1-48: Measurement methods and test procedures – Polarization mode dispersion

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 60793-1-48 has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

This second edition cancels and replaces the first edition published in 2003. It constitutes a technical revision. In this edition, reference to IEC 61282-9 has resulted in the removal of Annexes E, F, G and H as well as the creation of a new Annex E.

The text of this standard is based on the following documents:

CDV	Report on voting
86A/1038/CDV	86A/1078/RVC

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

This publication 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.

A list of all parts of 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 publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

INTRODUCTION

Polarization mode dispersion (PMD) causes an optical pulse to spread in the time domain. This dispersion could impair the performance of a telecommunications system. The effect can be related to differential phase and group velocities and corresponding arrival times $\delta\tau$ of different polarization components of the signal. For a sufficiently narrow band source, the effect can be related to a differential group delay (DGD), $\Delta\tau$, between pairs of orthogonally polarized principal states of polarization (PSP) at a given wavelength. For broadband transmission, the delays bifurcate and result in an output pulse that is spread out in the time domain. In this case, the spreading can be related to the average of DGD values.

In long fibre spans, DGD is random in both time and wavelength since it depends on the details of the birefringence along the entire fibre length. It is also sensitive to time-dependent temperature and mechanical perturbations on the fibre. For this reason, a useful way to characterize PMD in long fibres is in terms of the expected value, $\langle\Delta\tau\rangle$, or the mean DGD over wavelength. In principle, the expected value $\langle\Delta\tau\rangle$ does not undergo large changes for a given fibre from day to day or from source to source, unlike the parameters $\delta\tau$ or $\Delta\tau$. In addition, $\langle\Delta\tau\rangle$ is a useful predictor of lightwave system performance.

The term "PMD" is used both in the general sense of two polarization modes having different group velocities, and in the specific sense of the expected value $\langle\Delta\tau\rangle$. The DGD $\Delta\tau$ or pulse broadening $\delta\tau$ can be averaged over wavelength, yielding $\langle\Delta\tau\rangle_\lambda$, or time, yielding $\langle\Delta\tau\rangle_t$, or temperature, yielding $\langle\Delta\tau\rangle_T$. For most purposes, it is not necessary to distinguish between these various options for obtaining $\langle\Delta\tau\rangle$.

The coupling length l_c is the length of fibre or cable at which appreciable coupling between the two polarization states begins to occur. If the fibre length L satisfies the condition $L << l_c$, mode coupling is negligible and $\langle\Delta\tau\rangle$ scales with fibre length. The corresponding PMD coefficient is

$$\text{"short-length" PMD coefficient} = \langle\Delta\tau\rangle/L.$$

Fibres in practical systems are nearly always in the $L >> l_c$, regime and mode coupling is random. If mode coupling is also found to be random, $\langle\Delta\tau\rangle$ scales with the square root of fibre length, and

$$\text{"long-length" PMD coefficient} = \langle\Delta\tau\rangle/\sqrt{L}$$

OPTICAL FIBRES –

Part 1-48: Measurement methods and test procedures – Polarization mode dispersion

1 Scope

This part of IEC 60793 applies to three methods of measuring polarization mode dispersion (PMD), which are described in Clause 4. It establishes uniform requirements for measuring the PMD of single-mode optical fibre, thereby assisting in the inspection of fibres and cables for commercial purposes.

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 1-1: Measurement methods and test procedures – General and guidance*

IEC 60793-1-44, *Optical fibres – Part 1-44: Measurement methods and test procedures – Cut-off wavelength*

IEC 60793-2-50, *Optical fibres – Part 2-50: Product specifications – Sectional specification for class B single-mode fibres*

IEC 60794-3, *Optical fibre cables – Part 3: Sectional specification – Outdoor cables*

IEC 61280-4-4, *Fibre optic communication subsystem test procedures – Part 4-4: Cable plants and links – Polarization mode dispersion measurement for installed links*

IEC/TR 61282-3, *Fibre optic communication system design guides – Part 3: Calculation of link polarization mode dispersion*

IEC/TR 61282-9, *Fibre optic communication system design guides – Part 9: Guidance on polarization mode dispersion measurements and theory*

IEC 61290-11-1, *Optical amplifier test methods – Part 11-1: Polarization mode dispersion – Jones matrix eigenanalysis method (JME)*

IEC 61290-11-2, *Optical amplifiers – Test methods – Part 11-2: Polarisation mode dispersion parameter – Poincaré sphere analysis method*

IEC/TR 61292-5, *Optical amplifiers – Part 5: Polarization mode dispersion parameter – General information*

IEC 61300-3-32, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-32: Examinations and measurements – Polarization mode dispersion measurement for passive optical components*

ITU-T Recommendation G.650.2, *Definitions and test methods for statistical and non-linear related attributes of single-mode fibre and cable*

3 Terms and definitions

For the purposes of this document, the terms and definitions contained in ITU-T Recommendation G.650.2 apply.

NOTE Further explanation of their use in this document is provided in IEC 61282-9.

4 General

4.1 Methods for measuring PMD

Three methods are described for measuring PMD (see Annexes A, B and C for more details). The methods are listed below in the order of their introduction. For some methods, multiple approaches of analyzing the measured results are also provided.

– Method A
  - Fixed analyser (FA)
  - Extrema counting (EC)
  - Fourier transform (FT)
  - Cosine Fourier transform (CFT)
– Method B
  - Stokes parameter evaluation (SPE)
  - Jones matrix eigenanalysis (JME)
  - Poincaré sphere analysis (PSA)
  - State of polarization (SOP)
– Method C
  - Interferometry (INTY)
  - Traditional analysis (TINTY)
  - General analysis (GINTY)

The PMD value is defined in terms of the differential group delay (DGD), $\Delta\tau$, which usually varies randomly with wavelength, and is reported as one or another statistical metric. Equation (1) is a linear average value and is used for the specification of optical fibre cable. Equation (2) is the root mean square value which is reported by some methods. Equation (3) can be used to convert one value to the other if the DGDs are assumed to follow a Maxwell random distribution.

$$PMD_{\mathrm{AVG}} = \langle \Delta\tau \rangle \qquad (1)$$

$$PMD_{\mathrm{RMS}} = \langle \Delta\tau^2 \rangle^{1/2} \qquad (2)$$

$$\langle \Delta\tau \rangle = \left(\frac{8}{3\pi} \right)^{1/2} \langle \Delta\tau \rangle^{1/2} \qquad (3)$$

NOTE Equation (3) applies only when the distribution of DGDs is Maxwellian, for instance when the fibre is randomly mode coupled. The generalized use of Equation (3) can be verified by statistical analysis. A Maxwell distribution may not be the case if there are point sources of elevated birefringence (relative to the rest of the fibre), such as a tight bend, or other phenomena that reduce the mode coupling, such as a continual reduced bend radius with fibre in tension. In these cases, the distribution of the DGDs will begin to resemble the square root of a non-central Chi-square distribution with three degrees of freedom. For these cases, the PMD_{RMS} value will generally be larger relative to the PMD_{AVG} that is indicated in Equation (3). Time domain methods such as Method C and Method A, cosine Fourier transform, which are based on PMD_{RMS}, can use Equation (3) to convert to PMD_{AVG}. If mode coupling is reduced, the resultant reported PMD value from these methods may exceed those that can be reported by the frequency domain measurements that report PMD_{AVG}, such as Method B.

The PMD coefficient is the PMD value normalized to the fibre length. For normal transmission fibre, for which random mode coupling occurs and for which the DGDs are distributed as Maxwell random variables, the PMD value is divided by the square root of the length and the PMD coefficient is reported in units of ps/km$^{1/2}$. For some fibres with negligible mode coupling, such as polarization maintaining fibre, the PMD value is divided by the length and the PMD coefficient is reported in units of ps/km.

All methods are suitable for laboratory measurements of factory lengths of optical fibre and optical fibre cable. For all methods, changes in the deployment of the specimen can alter the results. For installed lengths of optical fibre cable that may be moving or vibrating, either Method C or Method B (in an implementation capable of millisecond measurement time scales) is appropriate.

All methods require light sources that are controlled at one or more states of polarization (SOPs). All methods require injecting light across a broad spectral region (i.e. 50 nm to 200 nm wide) to obtain a PMD value that is characteristic of the region (i.e. 1 300 nm or 1 550 nm). The methods differ in:

a) the wavelength characteristics of the source;

b) the physical characteristics that are actually measured;

c) the analysis methods.

Method A measures PMD by measuring a response to a change of narrowband light across a wavelength range. At the source, the light is linearly polarized at one or more SOPs. For each SOP, the change in output power that is filtered through a fixed polarization analyser, relative to the power detected without the analyser, is measured as a function of wavelength. The resulting measured function can be analysed in one of three ways.

– By counting the number of peaks and valleys (EC) of the curve and application of a formula that has been shown [1][1)] to agree with the average of DGD values, when the DGDs are distributed as Maxwellian. This analysis is considered as a frequency domain approach.

– By taking the FT of the measured function. This FT is equivalent to the pulse spreading obtained by the broadband transmission of Method C. Appropriate characterisation of the width of the FT function agrees with the average of DGD values, when the DGDs are distributed as Maxwellian.

– By taking the cosine Fourier transform of the difference of the normalized spectra from two orthogonal analyzer settings and calculating the RMS of the squared envelope. The PMD_{RMS} value is reported. This is equivalent to simulating the fringe pattern of the cross-correlation function that would result from interferometric measurements.

Method B measures PMD by measuring a response to a change of narrowband light across a wavelength range. At the source, the light is linearly polarized at one or more SOPs. The Stokes vector of the output light is measured for each wavelength. The change of these Stokes vectors with angular optical frequency, ω and with the (optional) change in input SOP yields the DGD as a function of wavelength through relationships that are based on the following definitions:

$$\frac{\mathrm{d}s(\omega)}{\mathrm{d}\omega} = \Omega(\omega) \times s(\omega) \tag{4}$$

$$\Delta\tau(\omega) = \left|\Omega(\omega)\right| \tag{5}$$

where

s is the normalized output Stokes vector;

[1)] Figures in square brackets refer to the Bibliography.