

INTERNATIONAL STANDARD



**Optical fibres –
Part 2-40: Product specifications – Sectional specification for category A4
multimode fibres**

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multimode fibres**

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OPTICAL FIBRES –

**Part 2-40: Product specifications –
Sectional specification for category A4 multimode fibres**

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC 60793-2-40:2015. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

International Standard IEC 60793-2-40 has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

This fifth edition cancels and replaces the fourth edition published in 2015. This edition constitutes a technical revision.

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

- a) revision of NA range of A4a.2;
- b) addition of a new subcategory A4i;
- c) deletion of the subcategory A4f and of Annex F.

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

CDV	Report on voting
86A/1943/CDV	86A/1981/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.

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- withdrawn,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.

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OPTICAL FIBRES –

Part 2-40: Product specifications – Sectional specification for category A4 multimode fibres

1 Scope

This part of IEC 60793 is applicable to category A4 optical multimode fibres and the related subcategories A4a, A4b, A4c, A4d, A4e, ~~A4f~~, A4g, A4h and A4i. These fibres have a plastic core and plastic cladding and may have step-index, multi-step index or graded-index profiles. The fibres are used in information transmission equipment and other applications employing similar light transmitting techniques, and ~~finally~~ in fibre optic cables. Table 1 summarizes some of the salient characteristics and applications of these fibres.

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Table 1 – Characteristics and applications of category A4 fibres

Sub-category	A4a	A4b	A4c	A4d	A4e	A4f	A4g	A4h
Core diameter (µm)	See Note 1	See Note 1	See Note 1	See Note 1	≥ 500	200	120	62,5
Cladding diameter (µm)	1 000	750	500	1 000	750	490	490	245
Numerical aperture Na_{ff}	0,50	0,50	0,50	0,30	0,25	0,190	0,190	0,190
Operating wave-length (s) (nm)	650 See Note 2	650	650	650	650	650 850 1 300	650 850 1 300	850 1 300
Applications	Digital audio interface, automobile, industrial, sensor and data transmission	Industrial and sensor	Sensor	Digital audiovisual interface and data transmission	Digital audiovisual interface and data transmission	Industrial and mobile; compatible with A3 transmission equipment	Data transmission	Data transmission; primarily used in ribbon structures
NOTE 1 – Typically 15 µm to 35 µm smaller than the cladding diameter.								
NOTE 2 – Other potential wavelengths for A4a fibre are described in Annex J.								

Sub-category	A4a		A4b	A4c	A4d	A4e	A4f	A4g	A4h	A4i
	A4a.1	A4a.2								
Core diameter (µm)	a		a	a	a	≥ 500	c	120	62,5	55
Cladding diameter (µm)	1 000		750	500	1 000	750	c	490	245 ^d	490
Numerical aperture Na_{ff}	0,50	0,53	0,50	0,50	0,30	0,25	c	0,190	0,190	0,24
Operating wave-length(s) (nm)	650 ^b		650	650	650	650	c	650 850 1 300	850 1 300	850
Applications	Digital audio interface, automobile, industrial, sensor and data transmission		Industrial and sensor	Sensor	Digital audio-visual interface and data transmission	Digital audio-visual interface and data transmission	c	Data transmission	Data transmission; primarily used in ribbon structures	Industrial data transmission

^a Typically 15 µm to 35 µm smaller than the cladding diameter.

^b Other potential wavelengths for A4a fibre are described in Annex K.

^c This sub-category is outdated and therefore no more specified.

^d Cladding diameters of 490 µm and 750 µm are also possible.

^e Na_{ff} is numerical aperture measured by far field pattern method.

In addition to the applications shown in Table 1, other applications for A4 fibres include, but are not restricted to, the following: support for short reach, high bit-rate systems in telephony, distribution and local networks, carrying data, voice and/or video services and on-premises intrabuilding and interbuilding fibre installations, including local area networks (LANs), private branch exchanges (PBXs), video, various multiplexing uses and miscellaneous related uses, such as consumer electronics and industrial and mobile networks.

Three types of requirements apply to A4 fibres:

- general requirements, as defined in IEC 60793-2;
- specific requirements common to category A4 multimode fibres covered in this document and which are given in Clause 4;
- particular requirements applicable to individual fibre sub-categories and implementations or specific applications which are defined in this document, in the normative family specification annexes.

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 60068-1, *Environmental testing – Part 1: General and guidance*

IEC 60793-1-20:2004, *Optical fibres – Part 1-20: Measurement methods and test procedures – Fibre geometry*

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

IEC 60793-1-40:2004/2019, *Optical fibres – Part 1-40: Attenuation measurement methods and test procedures – Attenuation*

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

IEC 60793-1-46, *Optical fibres – Part 1-46: Measurement methods and test procedures – Monitoring of changes in optical transmittance*

IEC 60793-1-47:2009, *Optical fibres – Part 1-47: Measurement methods and test procedures – Macrobending loss*

IEC 60793-1-50, *Optical fibres – Part 1-50: Measurement methods and test procedures – Damp heat (steady state) tests*

IEC 60793-1-51, *Optical fibres – Part 1-51: Measurement methods and test procedures – Dry heat (steady state) tests*

IEC 60793-1-52, *Optical fibres – Part 1-52: Measurement methods and test procedures – Change of temperature tests*

3 Terms and definitions

No terms and definitions are listed in this document.

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>

4 Specifications

4.1 Dimensional requirements

Relevant dimensional attributes and measurement methods are given in Table 2.

Requirements common to all category A4 fibres are indicated in Table 3.

Additional attributes that shall be specified in the family specifications for subcategories ~~A4f~~ A4g through ~~A4h~~ A4i are given in Table 4.

Table 2 – Dimensional attributes and measurement methods

Attribute	Measurement method
Cladding diameter	IEC 60793-1-20 ^a
Cladding non-circularity	IEC 60793-1-20 ^a
Core diameter ^b	IEC 60793-1-20
Fibre length	IEC 60793-1-22
Core-cladding concentricity error	IEC 60793-1-20
Core non-circularity	IEC 60793-1-20
^a Mechanical methods are also applicable to cladding diameter and cladding non-circularity measurements if they provide the same measurement uncertainty.	
^b Core diameter is specified at 650 nm ± 10 nm with a test specimen length of 2,0 m ± 0,2 m and a threshold value k_{CORE} of 2,5 % (IEC 60793-1-20:2001, method B) for A4 fibres.	

Table 3 – Requirements common to all category A4 fibres

Attribute	Unit	Limit
Cladding diameter	µm	a
Cladding non-circularity	%	≤ 6 ^b
Core diameter	µm	c
Fibre length	km	d
^a The cladding diameter varies and is listed in the family specification. ^b Unless otherwise specified in the family specification. ^c For A4a, A4b, A4c and A4d fibre, the core diameter is typically 15 µm to 35 µm smaller than the cladding diameter. For A4e, ~~A4f~~ , A4g, A4h and A4i fibre, the core diameter varies and is listed in the relevant family specification (in the annexes to this document). ^d Length requirements vary and should be agreed between supplier and customer.		

Table 4 – Additional attributes required in ~~A4f~~ A4g through ~~A4h~~ A4i family specifications

Attribute
Core non-circularity
Core-cladding concentricity error

4.2 Mechanical requirements

4.2.1 General

Mechanical attributes, test methods, and requirements for buffered fibres can be found in IEC 60794-2-41.

Relevant mechanical attributes and test methods are given in Table 5.

Requirements common to all category A4 fibres are indicated in Table 6.

Additional attributes that shall be specified in the family specifications for subcategories ~~A4f~~ A4g through ~~A4h~~ A4i are given in Table 7.

Table 5 – Mechanical attributes and test methods

Attribute	Test method
Tensile performance	4.2.2

Table 6 – Requirements common to category A4 fibres

Attribute	Unit	Limit
Elongation at yield peak	%	≥ 4,0
Tensile load at yield peak	N	a
^a Tensile load at yield peak varies and is listed in the family specification (see annexes to this document).		

Table 7 – Additional attributes required in family specification for subcategory ~~A4f~~ A4g through ~~A4h~~ A4i fibres

Attribute
Tensile load to induce 4 % elongation

4.2.2 Tensile load test

4.2.2.1 Object

The purpose of this test is to characterize the ability of the fibre to support a load during handling. Its purpose is to obtain values of the fibre's tensile strength.

~~The fibre samples are subjected to a mechanical environment as specified below.~~ The test shall be carried out at the standard test conditions in compliance with IEC 60068-1.

4.2.2.2 Definition of yield peak

Figure 1 shows a typical load versus elongation curve for a plastic optical fibre. The curve exhibits an initial monotonic increase in tensile load with applied elongation that goes through a load peak. The peak is followed by a decrease in load as the sample begins to undergo a ductile, irreversible elongation. Localized necking and drawing of the sample may accompany the process. This phenomenon is known as yielding and the peak is termed a yield peak.

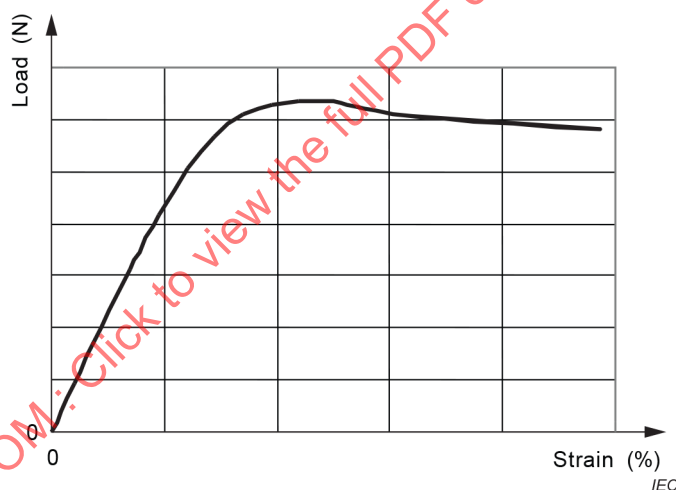


Figure 1 – Tensile load versus elongation for a plastic optical fibre

4.2.2.3 Test apparatus

The length of the sample between two clamping devices shall be between 100 mm and 200 mm.

The tensile strength measuring apparatus shall be a device, for example a vertical tensile tester, which provides relative motion to the test fibre. The apparatus shall be capable of imparting constant motion without jerking the fibre under test. The apparatus shall have the ability to simultaneously measure and record the resulting tensile force or load. To prevent fibre breakage, the means used to secure the fibre ends at the clamping points shall not stress the fibre excessively.

4.2.2.4 Procedure

The tensile speed shall be 100 mm/min $\pm$ 10 %. Yield strength and yield elongation are obtained from the load-elongation curve described in 4.2.2.2. Unless otherwise specified, tensile load at the yield peak and tensile load to induce 4 % elongation shall be recorded.

NOTE Elongation to breaking point is not applicable to category A4 fibres.

4.2.2.5 Requirements

The requirements are stated in the family specifications found in Annex A to Annex J. If the fibre sample breaks at a clamping point, the test shall be regarded as invalid and another test shall be carried out. The number of samples tested shall be sufficient to allow for a statistical analysis.

4.3 Transmission requirements

Relevant transmission attributes and measurement methods are given in Table 8.

Additional attributes required in the family specifications are indicated in Table 9.

Table 8 – Transmission attributes and measurement methods

Attribute	Measurement method
Attenuation ^a	IEC 60793-1-40
Modal bandwidth ^a	IEC 60793-1-41
Modal bandwidth with RML	IEC 60793-1-41
Numerical aperture ^{b,c,d}	IEC 60793-1-43
Chromatic dispersion	IEC 60793-1-42
Macrobending loss	IEC 60793-1-47:2009, method B
^a When measuring attenuation and modal bandwidth, the appropriate launching conditions should be applied as specified in IEC 60793-1-40 and IEC 60793-1-41 or as stated in the family specification. Bandwidth is not necessarily linear with regard to length. The value of bandwidth is referenced to 100 m of fibre. ^b Numerical aperture is specified at 650 nm ± 10 nm with a test specimen length of 2,0 m ± 0,2 m and a threshold value k_{NA} of 50 % for A4a to A4c and A4e fibres. ^c Numerical aperture is specified at 650 nm ± 10 nm with a test specimen length of 2,0 m ± 0,2 m and by the local minimums and related angles in the farfield intensity pattern for A4d fibres (IEC 60793-1-43:2014, Technique 4, inverse far-field measurement). ^d Numerical aperture is specified at 850 nm ± 10 nm with a test specimen length of 6,0 m ± 0,6 m and a threshold value k_{NA} of 5 % for A4f A4g to A4h A4i fibres.	

Table 9 – Attributes required in family specifications

Attribute
Attenuation
Modal bandwidth
Numerical aperture
Chromatic dispersion
Macrobending loss

4.4 Environmental requirements

4.4.1 General

Environmental exposure tests and measurement methods are documented in two forms:

- relevant environmental attributes, test methods and test conditions given in Table 10;
- measurements of a particular mechanical and transmission attribute that may change during exposure to the environmental test listed in Table 11.

Table 10 – Environmental exposure tests

Test condition ^a	Environment	Test method ^b	Test condition ^c
A	Damp heat	IEC 60793-1-50	+75 °C, 85 % RH, 30 days
	Dry heat	IEC 60793-1-51	+85 °C, 30 days
	Change of temperature	IEC 60793-1-52	T_A : -40 °C, T_B : +85 °C
B	Damp heat	IEC 60793-1-50	+60 °C, 85 % RH, 30 days
	Dry heat	IEC 60793-1-51	+70 °C, 30 days
	Change of temperature	IEC 60793-1-52	T_A : -20 °C, T_B : +70 °C
^a Test condition A or B should be agreed between supplier and customer. ^b Although these test methods do not specifically mention their applicability to A4 fibres, the test methods should be used. The test specimen length shall be agreed between supplier and customer. ^c These test conditions supersede any that might be specified in the indicated test methods.			

Table 11 – Attributes measured

Attribute	Measurement method
Change in optical transmission	IEC 60793-1-46
Tensile load	4.2.2

These tests are normally conducted periodically as type-tests for a fibre design. Unless otherwise specified:

- the specimen shall be pre-conditioned by keeping it at standard atmospheric conditions for at least 24 h, and
- the recovery period allowed between the completion of the environmental exposure and measuring the attributes shall be as stated in the particular environmental test method.

Environmental exposure testing of subcategory A4a to A4e fibres are usually performed after the fibres are buffered (refer to IEC 60794-2-41 for environmental requirements on buffered fibres). Environmental exposure testing of unbuffered fibre is only required when the fibres are sold in unbuffered form.

4.4.2 Mechanical environmental requirements

Tensile strength shall be verified according to Table 12 following removal of the fibre from the environment but only after cooling down the specimen at standard atmospheric conditions.

Table 12 – Requirement for tensile strength

Environment	Elongation at yield peak
Damp heat	≥ 4,0 %

4.4.3 Transmission environmental requirements

Change in attenuation from the initial value shall be less than the values in Table 13 and Table 14. The requirements differ for the two groups of fibres because of their different application environments.

Table 13 – Requirement for change in attenuation for A4a through A4e fibre

Environment	Attribute	Unit	Limits
Damp heat	Attenuation increase at 650 nm	dB/100 m	≤ 5 (includes attenuation due to water absorption)
Dry heat	Attenuation increase at 650 nm	dB/100 m	≤ 2
Change of temperature	Attenuation increase at 650 nm	dB/100 m	≤ 2

Table 14 – Requirement for change in attenuation for ~~A4f~~ A4g through ~~A4h~~ A4i fibre

Environment	Attribute	Unit	Limits
Damp heat	Attenuation increase at 650 nm, 850 nm and/or 1 300 nm ^a	dB/100 m	≤ 1,0 (includes attenuation due to water absorption)
Dry heat	Attenuation increase at 650 nm, 850 nm and/or 1 300 nm	dB/100 m	≤ 0,5
Change of temperature	Attenuation increase at 650 nm, 850 nm and/or 1 300 nm	dB/100 m	≤ 0,5
^a Because the effect of absorbed water can be significant at 1 300 nm, attenuation increase is specified only after the sample has recovered for at least 24 h under standard room temperature atmospheric conditions.			

Annex A (normative)

Family specifications for subcategory A4a multimode fibres

A.1 General

The clauses and tables in this Annex A contain particular requirements applicable to subcategory A4a fibres. Common requirements, from the main body text of this document and repeated here for ease of reference ~~from this sectional specification~~, are noted by an entry in the "Reference" column.

Subcategory A4a fibre is a 1 000 µm cladding diameter step-index fibre.

A.2 Dimensional requirements

Table A.1 contains dimensional requirements specific to A4a fibres.

Table A.1 – Dimensional requirements specific to A4a fibres

Attribute	Unit	Limit	Reference
Cladding diameter	µm	1 000 ± 60	4.1
Cladding non-circularity	%	≤ 6	4.1
Core diameter	µm	See 4.1	4.1 Table 2
Fibre length	km	See 4.1	4.1

A.3 Mechanical requirements

Table A.2 contains mechanical requirements specific to A4a fibres.

Table A.2 – Mechanical requirements specific to A4a fibres

Attribute	Unit	Limit	Reference
Tensile load at yield peak	N	≥ 56	4.2.2
Elongation at yield peak	%	≥ 4,0	4.2.2

A.4 Transmission requirements

Table A.3 contains transmission requirements specific to A4a fibres.

Implementation A4a.1 corresponds to subcategory A4a fibre specified in the second edition of this document, IEC 60793-2-40:2006. Implementation A4a.2 is a higher grade of subcategory A4a fibre in terms of attenuation and bandwidth, to achieve longer distance transmission than implementation A4a.1 (see Annex J for information about 520 nm transmission over A4a.2 fibres).

Table A.3 – Transmission requirements specific to A4a fibres

Attribute	Unit	Limit		Reference
		A4a.1	A4a.2	
Attenuation at 650 nm when using an overfilled launch	dB/100 m ^a	≤ 40	≤ 40	4.3
Attenuation at 650 nm when using an equilibrium mode distribution launch ^c	dB/100 m ^a	≤ 30	≤ 18	4.3
Minimum modal bandwidth at 650 nm	MHz over 100 m ^b	10	–	4.3
Minimum modal bandwidth at 650 nm using RML	MHz over 100 m ^b	–	40	4.3
Numerical aperture	Unitless	0,50 ± 0,15	0,485 ± 0,045 0,53 ± 0,07	4.3 Table 8
Macrobending loss at 650 nm (10 turns around a 25 mm radius quarter circle)	dB	≤ 0,5	≤ 0,5	4.3
^a The unit of 100 m is used because this is typical of the fibre length actually used. Attenuation values expressed in dB/100 m can be approximately compared to values stated in dB/km by multiplying the dB/100 m values by 10. ^b The unit of MHz over 100 m is used because this is typical of the fibre length actually used. Bandwidth values expressed in MHz over 100 m can be approximately compared to values stated in MHz·km by dividing the MHz over 100 m values by 10. ^c See Annex J.				

A.5 Environmental requirements

The requirements of 4.4 shall be met.

Annex B (normative)

Family specifications for subcategory A4b multimode fibres

B.1 General

The clauses and tables in this Annex B contain particular requirements applicable to subcategory A4b fibres. Common requirements, from the main body text of this document and repeated here for ease of reference ~~from this sectional specification~~, are noted by an entry in the "Reference" column.

Subcategory A4b fibre is a 750 µm cladding diameter step-index fibre.

B.2 Dimensional requirements

Table B.1 contains dimensional requirements specific to A4b fibres.

Table B.1 – Dimensional requirements specific to A4b fibres

Attribute	Unit	Limit	Reference
Cladding diameter	µm	750 ± 45	4.1
Cladding non-circularity	%	≤ 6	4.1
Core diameter	µm	See 4.1	4.1 Table 2
Fibre length	km	See 4.1	4.1

B.3 Mechanical requirements

Table B.2 contains mechanical requirements specific to A4b fibres.

Table B.2 – Mechanical requirements specific to A4b fibres

Attribute	Unit	Limit	Reference
Tensile load at yield peak	N	≥ 32	4.2.2
Elongation at yield peak	%	≥ 4,0	4.2.2

B.4 Transmission requirements

Table B.3 contains transmission requirements specific to A4b fibres.

Table B.3 – Transmission requirements specific to A4b fibres

Attribute	Unit	Limit	Reference
Attenuation at 650 nm when using an overfilled launch	dB/100 m ^a	≤ 40	4.3
Attenuation at 650 nm when using an equilibrium mode distribution launch ^c	dB/100 m ^a	≤ 30	4.3
Minimum modal bandwidth at 650 nm	MHz over 100 m ^b	10	4.3
Numerical aperture	Unitless	0,50 ± 0,15	4.3 Table 8
Macrobending loss at 650 nm (10 turns around a 25 mm radius quarter circle)	dB	≤ 0,5	4.3
^a The unit of 100 m is used because this is typical of the fibre length actually used. Attenuation values expressed in dB/100 m can be approximately compared to values stated in dB/km by multiplying the dB/100 m values by 10. ^b The unit of MHz over 100 m is used because this is typical of the fibre length actually used. Bandwidth values expressed in MHz over 100 m can be approximately compared to values stated in MHz·km by dividing the MHz over 100 m values by 10. ^c See Annex J.			

B.5 Environmental requirements

The requirements of 4.4 shall be met.

Annex C (normative)

Family specifications for subcategory A4c multimode fibres

C.1 General

The clauses and tables in this Annex C contain particular requirements applicable to subcategory A4c fibres. Common requirements, from the main body text of this document and repeated here for ease of reference ~~from this sectional specification~~, are noted by an entry in the "Reference" column.

Sub-category A4c fibre is a 500 µm cladding diameter step-index fibre.

C.2 Dimensional requirements

Table C.1 contains dimensional requirements specific to A4c fibres.

Table C.1 – Dimensional requirements specific to A4c fibres

Attribute	Unit	Limit	Reference
Cladding diameter	µm	500 ± 30	4.1
Cladding non-circularity	%	≤ 6	4.1
Core diameter	µm	See 4.1	4.1 Table 2
Fibre length	km	See 4.1	4.1

C.3 Mechanical requirements

Table C.2 contains mechanical requirements specific to A4c fibres.

Table C.2 – Mechanical requirements specific to A4c fibres

Attribute	Unit	Limit	Reference
Tensile load at yield peak	N	≥ 14	4.2.2
Elongation at yield peak	%	≥ 4,0	4.2.2

C.4 Transmission requirements

Table C.3 contains transmission requirements specific to A4c fibres.

Table C.3 – Transmission requirements specific to A4c fibres

Attribute	Unit	Limit	Reference
Attenuation at 650 nm when using an overfilled launch	dB/100 m ^a	≤ 40	4.3
Attenuation at 650 nm when using an equilibrium mode distribution launch ^c	dB/100 m ^a	≤ 30	4.3
Minimum modal bandwidth at 650 nm	MHz over 100 m _b	10	4.3
Numerical aperture	Unitless	0,50 ± 0,15	4.3 Table 8
Macrobending loss at 650 nm (10 turns around a 25 mm radius quarter circle)	dB	≤ 0,5	4.3
^a The unit of 100 m is used because this is typical of the fibre length actually used. Attenuation values expressed in dB/100 m can be approximately compared to values stated in dB/km by multiplying the dB/100 m values by 10. ^b The unit of MHz over 100 m is used because this is typical of the fibre length actually used. Bandwidth values expressed in MHz over 100 m can be approximately compared to values stated in MHz·km by dividing the MHz over 100 m values by 10. ^c See Annex J.			

C.5 Environmental requirements

The requirements of 4.4 shall be met.

Annex D (normative)

Family specifications for subcategory A4d multimode fibres

D.1 General

The clauses and tables in this Annex D contain particular requirements applicable to subcategory A4d fibres. Common requirements, from the main body text of this document and repeated here for ease of reference ~~from this sectional specification~~, are noted by an entry in the "Reference" column.

Subcategory A4d fibre is a 1 000 µm cladding diameter double step-index fibre.

D.2 Dimensional requirements

Table D.1 contains dimensional requirements specific to A4d fibres.

Table D.1 – Dimensional requirements specific to A4d fibres

Attribute	Unit	Limit	Reference
Cladding diameter	µm	1 000 ± 60	4.1
Cladding non-circularity	%	≤ 6	4.1
Core diameter	µm	See 4.1	4.1
Fibre length	km	See 4.1	4.1

D.3 Mechanical requirements

Table D.2 contains mechanical requirements specific to A4d fibres.

Table D.2 – Mechanical requirements specific to A4d fibres

Attribute	Unit	Limit	Reference
Tensile load at yield peak	N	≥ 56	4.2.2
Elongation at yield peak	%	≥ 4,0	4.2.2

D.4 Transmission requirements

Table D.3 contains transmission requirements specific to A4d fibres.

Table D.3 – Transmission requirements specific to A4d fibres

Attribute	Unit	Limit	Reference
Attenuation at 650 nm when using an overfilled launch	dB/100 m ^a	≤ 40	4.3
Attenuation at 650 nm using a launch NA = 0,3	dB/100 m ^a	≤ 18	4.3
Minimum modal bandwidth at 650 nm using launch NA = 0,3 (RML)	MHz over 100 m ^b	100	4.3
Numerical aperture	Unitless	0,30 ± 0,05	4.3 Table 8
Macrobending loss at 650 nm (10 turns around a 25 mm radius quarter circle)	dB	≤ 0,5	4.3
^a The unit of 100 m is used because this is typical of the fibre length actually used. Attenuation values expressed in dB/100 m can be approximately compared to values stated in dB/km by multiplying the dB/100 m values by 10. ^b The unit of MHz over 100 m is used because this is typical of the fibre length actually used. Bandwidth values expressed in MHz over 100 m can be approximately compared to values stated in MHz·km by dividing the MHz over 100 m values by 10.			

D.5 Environmental requirements

The requirements of 4.4 shall be met.

Annex E (normative)

Family specifications for subcategory A4e multimode fibres

E.1 General

The clauses and tables in this Annex E contain particular requirements applicable to subcategory A4e fibres. Common requirements, from the main body text of this document and repeated here for ease of reference ~~from this sectional specification~~, are noted by an entry in the "Reference" column.

Subcategory A4e fibre is a 750 µm cladding diameter, either multi-step-index or graded-index fibre.

E.2 Dimensional requirements

Table E.1 contains dimensional requirements specific to A4e fibres.

Table E.1 – Dimensional requirements specific to A4e fibres

Attribute	Unit	Limit	Reference
Cladding diameter	µm	750 ± 45	4.1
Cladding non-circularity	%	≤ 6	4.1
Core diameter	µm	≥ 500	4.1
Length	km	See 4.1	4.1

E.3 Mechanical requirements

Table E.2 contains the mechanical requirements specific to A4e fibres.

Table E.2 – Mechanical requirements specific to A4e fibres

Attribute	Unit	Limit	Reference
Tensile load at yield peak	N	≥ 32	4.2.2
Elongation at yield peak	%	≥ 4,0	4.2.2

E.4 Transmission requirements

Table E.3 contains transmission requirements specific to A4e fibres.

Table E.3 – Transmission requirements specific to A4e fibres

Attribute	Unit	Limit	Reference
Attenuation coefficient at 650 nm using a launch NA = 0,3	dB/100 m ^a	≤ 18	4.3
Minimum modal bandwidth at 650 nm using a launch NA = 0,3	MHz over 100 m ^b	200	4.3
Numerical aperture	Unitless	0,25 ± 0,07	4.3 Table 8
Macrobending loss at 650 nm (10 turns around a 25 mm radius quarter circle)	dB	≤ 0,5	4.3
^a The unit of 100 m is used because this is typical of the fibre length actually used. Attenuation values expressed in dB/100 m can be approximately compared to values stated in dB/km by multiplying the dB/100 m values by 10. ^b The unit of MHz over 100 m is used because this is typical of the fibre length actually used. Bandwidth values expressed in MHz over 100 m can be approximately compared to values stated in MHz·km by dividing the MHz over 100 m values by 10.			

E.5 Environmental requirements

The requirements of 4.4 shall be met.

Annex F (normative)

Family specifications for subcategory A4f multimode fibres

F.1 General

The clauses and tables in Annex F contain particular requirements applicable to sub-category A4f fibres. Common requirements, repeated here for ease of reference from this sectional specification, are noted by an entry in the "Reference" column.

Sub-category A4f fibre is a 200/490 μm graded-index fibre.

F.2 Dimensional requirements

Table F.1 contains dimensional requirements specific to A4f fibres.

Table F.1 — Dimensional requirements specific to A4f fibres

Attribute	Unit	Limit	Reference
Cladding diameter	μm	490 ± 10	3.1
Cladding non-circularity	%	≤ 4	3.1
Core-cladding concentricity error	μm	≤ 6	3.1
Core diameter	μm	200 ± 10	3.1
Core non-circularity	%	≤ 6	3.1
Length	km	See 3.1	3.1

F.3 Mechanical requirements

Table F.2 contains the mechanical requirements specific to A4f fibres.

Table F.2 — Mechanical requirements specific to A4f fibres

Attribute	Unit	Limit	Reference
Tensile load at yield peak	N	≥ 7	3.2.2
Tensile load to induce 4 % elongation	N	≥ 7	3.2.2
Elongation at yield peak	%	≥ 4	3.2.2

F.4 Transmission requirements

Table F.3 contains transmission requirements specific to A4f fibres.

Table F.3 — Transmission requirements specific to A4f fibres

Attribute	Unit	Limit	Reference
Attenuation at 650 nm ^a	dB/100 m ^f	≤ 10	3.3
Attenuation at 850 nm ^a	dB/100 m ^f	≤ 4	3.3
Attenuation at 1300 nm ^a	dB/100 m ^f	≤ 4	3.3
Minimum modal bandwidth at 650 nm ^b	MHz over 100 m ^c	800	3.3
Minimum modal bandwidth at 850 nm ^b	MHz over 100 m ^c	$\geq 1\,500^d$	3.3
Minimum modal bandwidth at 1300 nm ^b	MHz over 100 m ^c	$\geq 1\,500^d$	3.3
Numerical aperture	Unitless	$0,190 \pm 0,015$	3.3 Table 8
Macrobending loss at 850 nm (10 turns around a 25 mm radius quarter circle) ^e	dB	$\leq 1,25$	3.3
Zero dispersion wavelength, λ_0	nm	$1\,200 \pm \lambda_0 \leq 1\,650$	3.3
Zero dispersion slope, S_0	ps/(nm ² ·km)	$\leq 0,06$	3.3

^a — 60 mm is a common mandrel diameter when using Method A in IEC 60793-1-40:2001.

^b — Measured using the overfilled launch condition in IEC 60793-1-41 for A3 and A4 fibres.

^c — Measured on 100 through 500 m length. The method used to scale from the measurement length to the 100 m reference length should be available on request. The unit of MHz over 100 m is used because this is typical of the fibre length actually used. Bandwidth values expressed in MHz over 100 m can be approximately compared to values stated in MHz·km by dividing the MHz over 100 m values by 10.

^d — The specific value shall be agreed by the supplier and the customer.

^e — Measured with a 60 mm diameter mandrel launch.

^f — The unit of 100 m is used because this is typical of the fibre length actually used. Attenuation values expressed in dB/100 m can be approximately compared to values stated in dB/km by multiplying the dB/100 m values by 10.

F.5 — Environmental requirements

The requirements of 3.4 shall be met.

This annex has been removed.

Annex G (normative)

Family specifications for subcategory A4g multimode fibres

G.1 General

The clauses and tables in this Annex G contain particular requirements applicable to subcategory A4g fibres. Common requirements, from the main body text of this document and repeated here for ease of reference ~~from this sectional specification~~, are noted by an entry in the "Reference" column.

Subcategory A4g fibre is a 120/490 µm graded-index fibre.

G.2 Dimensional requirements

Table G.1 contains dimensional requirements specific to A4g fibres.

Table G.1 – Dimensional requirements specific to A4g fibres

Attribute	Unit	Limit	Reference
Cladding diameter	µm	490 ± 10	4.1
Cladding non-circularity	%	≤ 4	4.1
Core-cladding concentricity error	µm	≤ 6	4.1
Core diameter	µm	120 ± 10	4.1
Core non-circularity	%	≤ 6	4.1
Length	km	See 4.1	4.1

G.3 Mechanical requirements

Table G.2 contains the mechanical requirements specific to A4g fibres.

Table G.2 – Mechanical requirements specific to A4g fibres

Attribute	Unit	Limit	Reference
Tensile load at yield peak	N	≥ 7	4.2.2
Tensile load to induce 4 % elongation	N	≥ 7	4.2.2
Elongation at yield peak	%	≥ 4	4.2.2

G.4 Transmission requirements

Table G.3 contains transmission requirements specific to A4g fibres.

Table G.3 – Transmission requirements specific to A4g fibres

Attribute	Unit	Limit	Reference
Attenuation at 650 nm ^a	dB/100 m ^f	≤ 10	4.3
Attenuation at 850 nm ^a	dB/100 m ^f	$\leq 3,3$	4.3
Attenuation at 1 300 nm ^a	dB/100 m ^f	$\leq 3,3$	4.3
Minimum modal bandwidth at 650 nm ^b	MHz over 100 m ^c	800	4.3
Minimum modal bandwidth at 850 nm ^b	MHz over 100 m ^c	$\geq 1\,880$ ^d	4.3
Minimum modal bandwidth at 1 300 nm ^b	MHz over 100 m ^c	$\geq 1\,880$ ^d	4.3
Numerical aperture	Unitless	$0,190 \pm 0,015$	4.3 Table 8
Macrobending loss at 850 nm (10 turns around a 25 mm radius quarter circle) ^e	dB	$\leq 0,6$	4.3
Zero dispersion wavelength, λ_0	nm	$1\,200 \leq \lambda_0 \leq 1\,650$	4.3
Zero dispersion slope, S_0	ps/(nm ² · km)	$\leq 0,06$	4.3

^a 60 mm is a common mandrel diameter when using Method A in IEC 60793-1-40:2004.
^b Measured using the overfilled launch condition in IEC 60793-1-41 for A3 and A4 fibres.
^c Measured on 100 m through 500 m length. The method used to scale from the measurement length to the 100 m reference length should be available on request. The unit of MHz over 100 m is used because this is typical of the fibre length actually used. Bandwidth values expressed in MHz over 100 m can be approximately compared to values stated in MHz·km by dividing the MHz over 100 m values by 10.
^d The specific value shall be agreed by the supplier and the customer.
^e Measured with a 60 mm diameter mandrel launch.
^f The unit of 100 m is used because this is typical of the fibre length actually used. Attenuation values expressed in dB/100 m can be approximately compared to values stated in dB/km by multiplying the dB/100 m values by 10.

G.5 Environmental requirements

The requirements of 4.4 shall be met.

Annex H (normative)

Family specifications for subcategory A4h multimode fibres

H.1 General

The clauses and tables in this Annex H contain particular requirements applicable to subcategory A4h fibres. Common requirements, from the main body text of this document and repeated here for ease of reference ~~from this sectional specification~~, are noted by an entry in the "Reference" column.

Subcategory A4h fibre is a 62,5/245 µm graded-index fibre.

H.2 Dimensional requirements

Table H.1 contains dimensional requirements specific to A4h fibres.

Table H.1 – Dimensional requirements specific to A4h fibres

Attribute	Unit	Limit	Reference
Cladding diameter	µm	245 ± 5	4.1
Cladding non-circularity	%	≤ 4	4.1
Core-cladding concentricity error	µm	≤ 3	4.1
Core diameter	µm	62,5 ± 5	4.1
Core non-circularity	%	≤ 6	4.1
Length	km	(see 4.1)	4.1

H.3 Mechanical requirements

Table H.2 contains the mechanical requirements specific to A4h fibres.

Table H.2 – Mechanical requirements specific to A4h fibres

Attribute	Unit	Limit	Reference
Tensile load at yield peak	N	≥ 1,75	4.2.1
Tensile load to induce 4 % elongation	N	≥ 1,75	4.2.1
Elongation at yield peak	%	≥ 4	4.2.1

H.4 Transmission requirements

Table H.3 contains transmission requirements specific to A4h fibres.

Table H.3 – Transmission requirements specific to A4h fibres

Attribute	Unit	Limit	Reference
Attenuation at 850 nm ^a	dB/100 m ^f	$\leq 3,3$	4.3
Attenuation at 1 300 nm ^a	dB/100 m ^f	$\leq 3,3$	4.3
Minimum modal bandwidth at 850 nm ^b	MHz over 100 m ^c	$\geq 1\,880$ ^d	4.3
Minimum Modal bandwidth at 1 300 nm ^b	MHz over 100 m ^c	$\geq 1\,880$ ^d	4.3
Numerical aperture	Unitless	$0,190 \pm 0,015$	4.3 Table 8
Macrobending loss at 850 nm (10 turns around a 25 mm radius quarter circle) ^e	dB	$\leq 0,25$	4.3
Zero dispersion wavelength, λ_0	nm	$1\,200 \leq \lambda_0 \leq 1\,650$	4.3
Zero dispersion slope, S_0	ps/(nm ² · km)	$\leq 0,06$	4.3
^a 20 mm is a common mandrel diameter when using Method A in IEC 60793-1-40:2004. ^b Measured using the overfilled launch condition in IEC 60793-1-41 for A3 and A4 fibres. ^c Measured on 100 m through 500 m length. The method used to scale from the measurement length to the 100 m reference length should be available on request. The unit of MHz over 100 m is used because this is typical of the fibre length actually used. Bandwidth values expressed in MHz over 100 m can be approximately compared to values stated in MHz·km by dividing the MHz over 100 m values by 10. ^d The specific value shall be agreed by the supplier and the customer. ^e Measured with a 20 mm diameter mandrel launch. ^f The unit of 100 m is used because this is typical of the fibre length actually used. Attenuation values expressed in dB/100 m can be approximately compared to values stated in dB/km by multiplying the dB/100 m values by 10.			

H.5 Environmental requirements

The requirements of 4.4 shall be met.

Annex I (normative)

Family specifications for subcategory A4i multimode fibres

I.1 General

The clauses and tables in this Annex I contain particular requirements applicable to subcategory A4i fibres. Common requirements, from the main body text of this document and repeated here for ease of reference, are noted by an entry in the "Reference" column.

Subcategory A4i fibre is a 55/490 µm graded-index fibre.

I.2 Dimensional requirements

Table I.1 contains dimensional requirements specific to A4i fibres.

Table I.1 – Dimensional requirements specific to A4i fibres

Attribute	Unit	Limit	Reference
Cladding diameter	µm	490 ± 5	4.1
Cladding non-circularity	%	≤ 4	4.1
Core-cladding concentricity error	µm	≤ 6	4.1
Core diameter	µm	55 ± 5	4.1
Core non-circularity	%	≤ 6	4.1
Length	km	(see 4.1)	4.1

I.3 Mechanical requirements

Table I.2 contains the mechanical requirements specific to A4i fibres.

Table I.2 – Mechanical requirements specific to A4i fibres

Attribute	Unit	Limit	Reference
Tensile load at yield peak	N	≥ 6	4.2.1
Tensile load to induce 4 % elongation	N	≥ 6	4.2.1
Elongation at yield peak	%	≥ 4	4.2.1

I.4 Transmission requirements

Table I.3 contains transmission requirements specific to A4i fibres.

Table I.3 – Transmission requirements specific to A4i fibres

Attribute	Unit	Limit	Reference
Attenuation at 850 nm ^a	dB/100 m ^f	≤ 10	4.3
Minimum modal bandwidth at 850 nm ^b	MHz over 100 m ^c	$\geq 3\,500$ ^d	4.3
Numerical aperture	Unitless	$0,24 \pm 0,025$	4.3 Table 8
Macrobending loss at 850 nm (10 turns around a 25 mm radius quarter circle) ^e	dB	$\leq 0,1$	4.3
Zero dispersion wavelength, λ_0	nm	$1\,200 \leq \lambda_0 \leq 1\,650$	4.3
Zero dispersion slope, S_0	ps/(nm ² · km)	$\leq 0,06$	4.3
^a 10 mm is a common mandrel diameter when using Method A in IEC 60793-1-40. ^b Measured using the overfilled launch condition in IEC 60793-1-41 for A3 and A4 fibres. ^c Measured on 100 m through 500 m length. The method used to scale from the measurement length to the 100 m reference length should be available on request. The unit of MHz over 100 m is used because this is typical of the fibre length actually used. Bandwidth values expressed in MHz over 100 m can be approximately compared to values stated in MHz·km by dividing the MHz over 100 m values by 10. ^d The specific value shall be agreed by the supplier and the customer. ^e Measured with a 10 mm diameter mandrel launch. ^f The unit of 100 m is used because this is typical of the fibre length actually used. Attenuation values expressed in dB/100 m can be approximately compared to values stated in dB/km by multiplying the dB/100 m values by 10.			

I.5 Environmental requirements

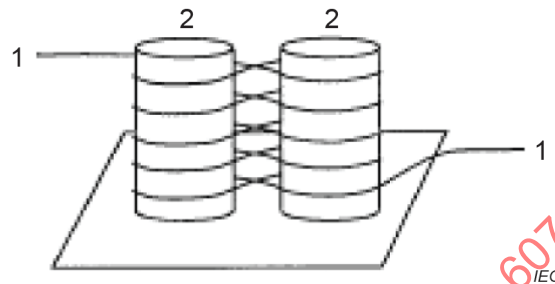
The requirements of 4.4 shall be met.

Annex J (normative)

Mode scramblers for subcategory A4a to ~~A4d~~ A4c fibres

J.1 General

When measuring the equilibrium mode launch attenuation of subcategory A4a, A4b, and A4c fibres, use a figure 8-shaped mode scrambler (Figure J.1), such as that described in IEC 60793-1-40:20012019, Figure ~~A.1.4~~ A.8.



Key

- 1 fibre under test
- 2 cylinders

Figure J.1 – Mode scrambler for category A4 fibre

J.2 Specification for mode scramblers

The mode scrambler shall be made with buffered A4 fibre of the same subcategory as the fibre under test. Parameters for the mode scrambler shall be as shown in Table J.1.

Table J.1 – Mode scrambler parameters

Fibre subcategory	Fibre length m	Diameter of cylinders mm	Distance between the two cylinders mm	Number of "figure-8" turns
A4a	20	42	3	10
A4b	15	35	3	20
A4c	10	32	2	40

Annex K (informative)

Additional transmission requirements for subcategory A4a multimode fibres for wavelengths below 650 nm

K.1 General

This Annex K contains additional transmission requirements according to Annex A applicable to implementation A4a.2 of subcategory A4a fibres, which are intended to be used with wavelengths below 650 nm. PMMA based fibres have the lowest attenuation at wavelengths around 520 nm and 560 nm. The market availability of powerful transceivers based on GaN-LEDs makes it more and more attractive to use the optical window around 520 nm for the design of improved transmission systems. The following requirements should be fulfilled in order to support the design and use of such systems.

K.2 Transmission requirements

Table K.1 contains additional transmission requirements specific to A4a.2 fibres.

Table K.1 – Transmission requirements specific to A4a.2 fibre

Attribute	Unit	Limit	Reference
		A4a.2	
Attenuation at 520 nm when using an equilibrium mode distribution launch ^c	dB/100 m ^a	≤ 10	4.3
Minimum modal bandwidth at 520 nm when using an equilibrium mode distribution launch ^c	MHz over 100 m ^b	40	4.3
Macrobending loss at 520 nm (10 turns around a 25 mm radius quarter circle)	dB	≤ 0,5	4.3
^a The unit of 100 m is used because this is typical of the fibre length actually used. Attenuation values expressed in dB/100 m can be approximately compared to values stated in dB/km by multiplying the dB/100 m values by 10. ^b The unit of MHz over 100 m is used because this is typical of the fibre length actually used. Bandwidth values expressed in MHz over 100 m can be approximately compared to values stated in MHz · km by dividing the MHz over 100 m values by 10. ^c See Annex J.			

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IEC 60794-2-41, *Optical fibre cables – Part 2-41: Indoor cables – Product specification for simplex and duplex buffered A4 fibres*

¹ This document has been withdrawn.

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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Optical fibres –

Part 2-40: Product specifications – Sectional specification for category A4 multimode fibres

Fibres optiques –

Partie 2-40: Spécifications de produits – Spécification intermédiaire pour les fibres multimodales de catégorie A4

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

OPTICAL FIBRES –

**Part 2-40: Product specifications –
Sectional specification for category A4 multimode fibres**

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International Standard IEC 60793-2-40 has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

This fifth edition cancels and replaces the fourth edition published in 2015. This edition constitutes a technical revision.

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

- a) revision of NA range of A4a.2;
- b) addition of a new subcategory A4i;
- c) deletion of the subcategory A4f and of Annex F.

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

CDV	Report on voting
86A/1943/CDV	86A/1981/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.

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.

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OPTICAL FIBRES –

Part 2-40: Product specifications – Sectional specification for category A4 multimode fibres

1 Scope

This part of IEC 60793 is applicable to category A4 optical multimode fibres and the related subcategories A4a, A4b, A4c, A4d, A4e, A4g, A4h and A4i. These fibres have a plastic core and plastic cladding and may have step-index, multi-step index or graded-index profiles. The fibres are used in information transmission equipment and other applications employing similar light transmitting techniques, and in fibre optic cables. Table 1 summarizes some of the salient characteristics and applications of these fibres.

Table 1 – Characteristics and applications of category A4 fibres

Sub-category	A4a		A4b	A4c	A4d	A4e	A4f	A4g	A4h	A4i
	A4a.1	A4a.2								
Core diameter (µm)	a		a	a	a	≥ 500	c	120	62,5	55
Cladding diameter (µm)	1 000		750	500	1 000	750	c	490	245 ^d	490
Numerical aperture Na _{ff} e	0,50	0,53	0,50	0,50	0,30	0,25	c	0,190	0,190	0,24
Operating wave-length(s) (nm)	650 ^b		650	650	650	650	c	650 850 1 300	850 1 300	850
Applications	Digital audio interface, automobile, industrial, sensor and data transmission		Industrial and sensor	Sensor	Digital audio-visual interface and data transmission	Digital audio-visual interface and data transmission	c	Data transmission	Data transmission; primarily used in ribbon structures	Industrial data transmission

^a Typically 15 µm to 35 µm smaller than the cladding diameter.

^b Other potential wavelengths for A4a fibre are described in Annex K.

^c This sub-category is outdated and therefore no more specified.

^d Cladding diameters of 490 µm and 750 µm are also possible.

^e Na_{ff} is numerical aperture measured by far field pattern method.

In addition to the applications shown in Table 1, other applications for A4 fibres include, but are not restricted to, the following: support for short reach, high bit-rate systems in telephony, distribution and local networks, carrying data, voice and/or video services and on-premises intrabuilding and interbuilding fibre installations, including local area networks (LANs), private branch exchanges (PBXs), video, various multiplexing uses and miscellaneous related uses, such as consumer electronics and industrial and mobile networks.

Three types of requirements apply to A4 fibres:

- general requirements, as defined in IEC 60793-2;
- specific requirements common to category A4 multimode fibres covered in this document and which are given in Clause 4;

- particular requirements applicable to individual fibre sub-categories and implementations or specific applications which are defined in this document, in the normative family specification annexes.

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 60068-1, *Environmental testing – Part 1: General and guidance*

IEC 60793-1-20, *Optical fibres – Part 1-20: Measurement methods and test procedures – Fibre geometry*

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

IEC 60793-1-40:2019, *Optical fibres – Part 1-40: Attenuation measurement methods*

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

IEC 60793-1-46, *Optical fibres – Part 1-46: Measurement methods and test procedures – Monitoring of changes in optical transmittance*

IEC 60793-1-47, *Optical fibres – Part 1-47: Measurement methods and test procedures – Macrobending loss*

IEC 60793-1-50, *Optical fibres – Part 1-50: Measurement methods and test procedures – Damp heat (steady state) tests*

IEC 60793-1-51, *Optical fibres – Part 1-51: Measurement methods and test procedures – Dry heat (steady state) tests*

IEC 60793-1-52, *Optical fibres – Part 1-52: Measurement methods and test procedures – Change of temperature tests*

3 Terms and definitions

No terms and definitions are listed in this document.

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>

4 Specifications

4.1 Dimensional requirements

Relevant dimensional attributes and measurement methods are given in Table 2.

Requirements common to all category A4 fibres are indicated in Table 3.

Additional attributes that shall be specified in the family specifications for subcategories A4g through A4i are given in Table 4.

Table 2 – Dimensional attributes and measurement methods

Attribute	Measurement method
Cladding diameter	IEC 60793-1-20 ^a
Cladding non-circularity	IEC 60793-1-20 ^a
Core diameter ^b	IEC 60793-1-20
Fibre length	IEC 60793-1-22
Core-cladding concentricity error	IEC 60793-1-20
Core non-circularity	IEC 60793-1-20
^a Mechanical methods are also applicable to cladding diameter and cladding non-circularity measurements if they provide the same measurement uncertainty. ^b Core diameter is specified at $650 \text{ nm} \pm 10 \text{ nm}$ with a test specimen length of $2,0 \text{ m} \pm 0,2 \text{ m}$ and a threshold value k_{CORE} of 2,5 % (IEC 60793-1-20, method B) for A4 fibres.	

Table 3 – Requirements common to all category A4 fibres

Attribute	Unit	Limit
Cladding diameter	μm	^a
Cladding non-circularity	%	≤ 6 ^b
Core diameter	μm	^c
Fibre length	km	^d
^a The cladding diameter varies and is listed in the family specification. ^b Unless otherwise specified in the family specification. ^c For A4a, A4b, A4c and A4d fibre, the core diameter is typically $15 \mu\text{m}$ to $35 \mu\text{m}$ smaller than the cladding diameter. For A4e, A4g, A4h and A4i fibre, the core diameter varies and is listed in the relevant family specification (in the annexes to this document). ^d Length requirements vary and should be agreed between supplier and customer.		

Table 4 – Additional attributes required in A4g through A4i family specifications

Attribute
Core non-circularity
Core-cladding concentricity error

4.2 Mechanical requirements

4.2.1 General

Mechanical attributes, test methods, and requirements for buffered fibres can be found in IEC 60794-2-41.

Relevant mechanical attributes and test methods are given in Table 5.

Requirements common to all category A4 fibres are indicated in Table 6.

Additional attributes that shall be specified in the family specifications for subcategories A4g through A4i are given in Table 7.

Table 5 – Mechanical attributes and test methods

Attribute	Test method
Tensile performance	4.2.2

Table 6 – Requirements common to category A4 fibres

Attribute	Unit	Limit
Elongation at yield peak	%	≥ 4,0
Tensile load at yield peak	N	a
^a Tensile load at yield peak varies and is listed in the family specification (see annexes to this document).		

Table 7 – Additional attributes required in family specification for subcategory A4g through A4i fibres

Attribute
Tensile load to induce 4 % elongation

4.2.2 Tensile load test

4.2.2.1 Object

The purpose of this test is to characterize the ability of the fibre to support a load during handling. Its purpose is to obtain values of the fibre's tensile strength.

The test shall be carried out at the standard test conditions in compliance with IEC 60068-1.

4.2.2.2 Definition of yield peak

Figure 1 shows a typical load versus elongation curve for a plastic optical fibre. The curve exhibits an initial monotonic increase in tensile load with applied elongation that goes through a load peak. The peak is followed by a decrease in load as the sample begins to undergo a ductile, irreversible elongation. Localized necking and drawing of the sample may accompany the process. This phenomenon is known as yielding and the peak is termed a yield peak.

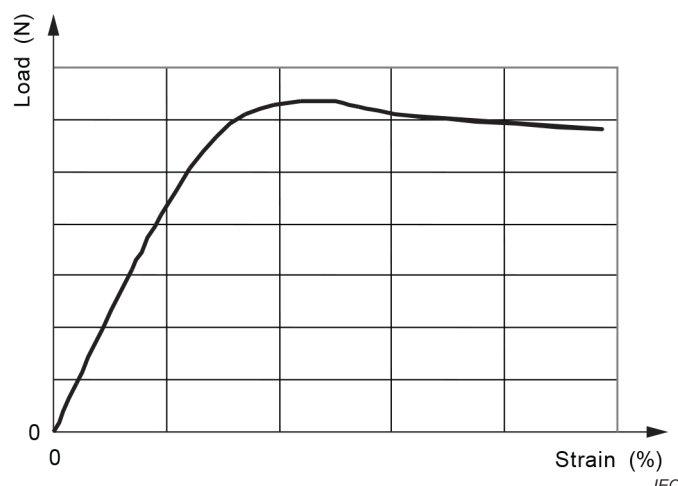


Figure 1 – Tensile load versus elongation for a plastic optical fibre

4.2.2.3 Test apparatus

The length of the sample between two clamping devices shall be between 100 mm and 200 mm.

The tensile strength measuring apparatus shall be a device, for example a vertical tensile tester, which provides relative motion to the test fibre. The apparatus shall be capable of imparting constant motion without jerking the fibre under test. The apparatus shall have the ability to simultaneously measure and record the resulting tensile force or load. To prevent fibre breakage, the means used to secure the fibre ends at the clamping points shall not stress the fibre excessively.

4.2.2.4 Procedure

The tensile speed shall be $100 \text{ mm/min} \pm 10 \%$. Yield strength and yield elongation are obtained from the load-elongation curve described in 4.2.2.2. Unless otherwise specified, tensile load at the yield peak and tensile load to induce 4 % elongation shall be recorded.

NOTE Elongation to breaking point is not applicable to category A4 fibres.

4.2.2.5 Requirements

The requirements are stated in the family specifications found in Annex A to Annex J. If the fibre sample breaks at a clamping point, the test shall be regarded as invalid and another test shall be carried out. The number of samples tested shall be sufficient to allow for a statistical analysis.

4.3 Transmission requirements

Relevant transmission attributes and measurement methods are given in Table 8.

Additional attributes required in the family specifications are indicated in Table 9.

Table 8 – Transmission attributes and measurement methods

Attribute	Measurement method
Attenuation ^a	IEC 60793-1-40
Modal bandwidth ^a	IEC 60793-1-41
Modal bandwidth with RML	IEC 60793-1-41
Numerical aperture ^{b,c,d}	IEC 60793-1-43
Chromatic dispersion	IEC 60793-1-42
Macrobending loss	IEC 60793-1-47, method B
^a When measuring attenuation and modal bandwidth, the appropriate launching conditions should be applied as specified in IEC 60793-1-40 and IEC 60793-1-41 or as stated in the family specification. Bandwidth is not necessarily linear with regard to length. The value of bandwidth is referenced to 100 m of fibre. ^b Numerical aperture is specified at 650 nm ± 10 nm with a test specimen length of 2,0 m ± 0,2 m and a threshold value k_{NA} of 50 % for A4a to A4c and A4e fibres. ^c Numerical aperture is specified at 650 nm ± 10 nm with a test specimen length of 2,0 m ± 0,2 m and by the local minimums and related angles in the farfield intensity pattern for A4d fibres (IEC 60793-1-43, Technique 4, inverse far-field measurement). ^d Numerical aperture is specified at 850 nm ± 10 nm with a test specimen length of 6,0 m ± 0,6 m and a threshold value k_{NA} of 5 % for A4g to A4i fibres.	

Table 9 – Attributes required in family specifications

Attribute
Attenuation
Modal bandwidth
Numerical aperture
Chromatic dispersion
Macrobending loss

4.4 Environmental requirements

4.4.1 General

Environmental exposure tests and measurement methods are documented in two forms:

- relevant environmental attributes, test methods and test conditions given in Table 10;
- measurements of a particular mechanical and transmission attribute that may change during exposure to the environmental test listed in Table 11.

Table 10 – Environmental exposure tests

Test condition ^a	Environment	Test method ^b	Test condition ^c
A	Damp heat	IEC 60793-1-50	+75 °C, 85 % RH, 30 days
	Dry heat	IEC 60793-1-51	+85 °C, 30 days
	Change of temperature	IEC 60793-1-52	T_A : -40 °C, T_B : +85 °C
B	Damp heat	IEC 60793-1-50	+60 °C, 85 % RH, 30 days
	Dry heat	IEC 60793-1-51	+70 °C, 30 days
	Change of temperature	IEC 60793-1-52	T_A : -20 °C, T_B : +70 °C
^a Test condition A or B should be agreed between supplier and customer. ^b Although these test methods do not specifically mention their applicability to A4 fibres, the test methods should be used. The test specimen length shall be agreed between supplier and customer. ^c These test conditions supersede any that might be specified in the indicated test methods.			

Table 11 – Attributes measured

Attribute	Measurement method
Change in optical transmission	IEC 60793-1-46
Tensile load	4.2.2

These tests are normally conducted periodically as type-tests for a fibre design. Unless otherwise specified:

- the specimen shall be pre-conditioned by keeping it at standard atmospheric conditions for at least 24 h, and
- the recovery period allowed between the completion of the environmental exposure and measuring the attributes shall be as stated in the particular environmental test method.

Environmental exposure testing of subcategory A4a to A4e fibres are usually performed after the fibres are buffered (refer to IEC 60794-2-41 for environmental requirements on buffered fibres). Environmental exposure testing of unbuffered fibre is only required when the fibres are sold in unbuffered form.

4.4.2 Mechanical environmental requirements

Tensile strength shall be verified according to Table 12 following removal of the fibre from the environment but only after cooling down the specimen at standard atmospheric conditions.

Table 12 – Requirement for tensile strength

Environment	Elongation at yield peak
Damp heat	≥ 4,0 %

4.4.3 Transmission environmental requirements

Change in attenuation from the initial value shall be less than the values in Table 13 and Table 14. The requirements differ for the two groups of fibres because of their different application environments.

Table 13 – Requirement for change in attenuation for A4a through A4e fibre

Environment	Attribute	Unit	Limits
Damp heat	Attenuation increase at 650 nm	dB/100 m	≤ 5 (includes attenuation due to water absorption)
Dry heat	Attenuation increase at 650 nm	dB/100 m	≤ 2
Change of temperature	Attenuation increase at 650 nm	dB/100 m	≤ 2

Table 14 – Requirement for change in attenuation for A4g through A4i fibre

Environment	Attribute	Unit	Limits
Damp heat	Attenuation increase at 650 nm, 850 nm and/or 1 300 nm ^a	dB/100 m	≤ 1,0 (includes attenuation due to water absorption)
Dry heat	Attenuation increase at 650 nm, 850 nm and/or 1 300 nm	dB/100 m	≤ 0,5
Change of temperature	Attenuation increase at 650 nm, 850 nm and/or 1 300 nm	dB/100 m	≤ 0,5
^a Because the effect of absorbed water can be significant at 1 300 nm, attenuation increase is specified only after the sample has recovered for at least 24 h under standard room temperature atmospheric conditions.			

Annex A (normative)

Family specifications for subcategory A4a multimode fibres

A.1 General

The clauses and tables in this Annex A contain particular requirements applicable to subcategory A4a fibres. Common requirements, from the main body text of this document and repeated here for ease of reference, are noted by an entry in the "Reference" column.

Subcategory A4a fibre is a 1 000 µm cladding diameter step-index fibre.

A.2 Dimensional requirements

Table A.1 contains dimensional requirements specific to A4a fibres.

Table A.1 – Dimensional requirements specific to A4a fibres

Attribute	Unit	Limit	Reference
Cladding diameter	µm	1 000 ± 60	4.1
Cladding non-circularity	%	≤ 6	4.1
Core diameter	µm	See 4.1	4.1 Table 2
Fibre length	km	See 4.1	4.1

A.3 Mechanical requirements

Table A.2 contains mechanical requirements specific to A4a fibres.

Table A.2 – Mechanical requirements specific to A4a fibres

Attribute	Unit	Limit	Reference
Tensile load at yield peak	N	≥ 56	4.2.2
Elongation at yield peak	%	≥ 4,0	4.2.2

A.4 Transmission requirements

Table A.3 contains transmission requirements specific to A4a fibres.

Implementation A4a.1 corresponds to subcategory A4a fibre specified in the second edition of this document, IEC 60793-2-40:2006. Implementation A4a.2 is a higher grade of subcategory A4a fibre in terms of attenuation and bandwidth, to achieve longer distance transmission than implementation A4a.1 (see Annex J for information about 520 nm transmission over A4a.2 fibres).

Table A.3 – Transmission requirements specific to A4a fibres

Attribute	Unit	Limit		Reference
		A4a.1	A4a.2	
Attenuation at 650 nm when using an overfilled launch	dB/100 m ^a	≤ 40	≤ 40	4.3
Attenuation at 650 nm when using an equilibrium mode distribution launch ^c	dB/100 m ^a	≤ 30	≤ 18	4.3
Minimum modal bandwidth at 650 nm	MHz over 100 m ^b	10	–	4.3
Minimum modal bandwidth at 650 nm using RML	MHz over 100 m ^b	–	40	4.3
Numerical aperture	Unitless	0,50 ± 0,15	0,53 ± 0,07	4.3 Table 8
Macrobending loss at 650 nm (10 turns around a 25 mm radius quarter circle)	dB	≤ 0,5	≤ 0,5	4.3
^a The unit of 100 m is used because this is typical of the fibre length actually used. Attenuation values expressed in dB/100 m can be approximately compared to values stated in dB/km by multiplying the dB/100 m values by 10. ^b The unit of MHz over 100 m is used because this is typical of the fibre length actually used. Bandwidth values expressed in MHz over 100 m can be approximately compared to values stated in MHz·km by dividing the MHz over 100 m values by 10. ^c See Annex J.				

A.5 Environmental requirements

The requirements of 4.4 shall be met.

Annex B (normative)

Family specifications for subcategory A4b multimode fibres

B.1 General

The clauses and tables in this Annex B contain particular requirements applicable to subcategory A4b fibres. Common requirements, from the main body text of this document and repeated here for ease of reference, are noted by an entry in the "Reference" column.

Subcategory A4b fibre is a 750 µm cladding diameter step-index fibre.

B.2 Dimensional requirements

Table B.1 contains dimensional requirements specific to A4b fibres.

Table B.1 – Dimensional requirements specific to A4b fibres

Attribute	Unit	Limit	Reference
Cladding diameter	µm	750 ± 45	4.1
Cladding non-circularity	%	≤ 6	4.1
Core diameter	µm	See 4.1	4.1 Table 2
Fibre length	km	See 4.1	4.1

B.3 Mechanical requirements

Table B.2 contains mechanical requirements specific to A4b fibres.

Table B.2 – Mechanical requirements specific to A4b fibres

Attribute	Unit	Limit	Reference
Tensile load at yield peak	N	≥ 32	4.2.2
Elongation at yield peak	%	≥ 4,0	4.2.2

B.4 Transmission requirements

Table B.3 contains transmission requirements specific to A4b fibres.

Table B.3 – Transmission requirements specific to A4b fibres

Attribute	Unit	Limit	Reference
Attenuation at 650 nm when using an overfilled launch	dB/100 m ^a	≤ 40	4.3
Attenuation at 650 nm when using an equilibrium mode distribution launch ^c	dB/100 m ^a	≤ 30	4.3
Minimum modal bandwidth at 650 nm	MHz over 100 m ^b	10	4.3
Numerical aperture	Unitless	0,50 ± 0,15	4.3 Table 8
Macrobending loss at 650 nm (10 turns around a 25 mm radius quarter circle)	dB	≤ 0,5	4.3
^a The unit of 100 m is used because this is typical of the fibre length actually used. Attenuation values expressed in dB/100 m can be approximately compared to values stated in dB/km by multiplying the dB/100 m values by 10. ^b The unit of MHz over 100 m is used because this is typical of the fibre length actually used. Bandwidth values expressed in MHz over 100 m can be approximately compared to values stated in MHz·km by dividing the MHz over 100 m values by 10. ^c See Annex J.			

B.5 Environmental requirements

The requirements of 4.4 shall be met.

Annex C (normative)

Family specifications for subcategory A4c multimode fibres

C.1 General

The clauses and tables in this Annex C contain particular requirements applicable to subcategory A4c fibres. Common requirements, from the main body text of this document and repeated here for ease of reference, are noted by an entry in the "Reference" column.

Sub-category A4c fibre is a 500 µm cladding diameter step-index fibre.

C.2 Dimensional requirements

Table C.1 contains dimensional requirements specific to A4c fibres.

Table C.1 – Dimensional requirements specific to A4c fibres

Attribute	Unit	Limit	Reference
Cladding diameter	µm	500 ± 30	4.1
Cladding non-circularity	%	≤ 6	4.1
Core diameter	µm	See 4.1	4.1 Table 2
Fibre length	km	See 4.1	4.1

C.3 Mechanical requirements

Table C.2 contains mechanical requirements specific to A4c fibres.

Table C.2 – Mechanical requirements specific to A4c fibres

Attribute	Unit	Limit	Reference
Tensile load at yield peak	N	≥ 14	4.2.2
Elongation at yield peak	%	$\geq 4,0$	4.2.2

C.4 Transmission requirements

Table C.3 contains transmission requirements specific to A4c fibres.

Table C.3 – Transmission requirements specific to A4c fibres

Attribute	Unit	Limit	Reference
Attenuation at 650 nm when using an overfilled launch	dB/100 m ^a	≤ 40	4.3
Attenuation at 650 nm when using an equilibrium mode distribution launch ^c	dB/100 m ^a	≤ 30	4.3
Minimum modal bandwidth at 650 nm	MHz over 100 m _b	10	4.3
Numerical aperture	Unitless	0,50 ± 0,15	4.3 Table 8
Macrobending loss at 650 nm (10 turns around a 25 mm radius quarter circle)	dB	≤ 0,5	4.3
^a The unit of 100 m is used because this is typical of the fibre length actually used. Attenuation values expressed in dB/100 m can be approximately compared to values stated in dB/km by multiplying the dB/100 m values by 10. ^b The unit of MHz over 100 m is used because this is typical of the fibre length actually used. Bandwidth values expressed in MHz over 100 m can be approximately compared to values stated in MHz·km by dividing the MHz over 100 m values by 10. ^c See Annex J.			

C.5 Environmental requirements

The requirements of 4.4 shall be met.

Annex D (normative)

Family specifications for subcategory A4d multimode fibres

D.1 General

The clauses and tables in this Annex D contain particular requirements applicable to subcategory A4d fibres. Common requirements, from the main body text of this document and repeated here for ease of reference, are noted by an entry in the "Reference" column.

Subcategory A4d fibre is a 1 000 µm cladding diameter double step-index fibre.

D.2 Dimensional requirements

Table D.1 contains dimensional requirements specific to A4d fibres.

Table D.1 – Dimensional requirements specific to A4d fibres

Attribute	Unit	Limit	Reference
Cladding diameter	µm	1 000 ± 60	4.1
Cladding non-circularity	%	≤ 6	4.1
Core diameter	µm	See 4.1	4.1
Fibre length	km	See 4.1	4.1

D.3 Mechanical requirements

Table D.2 contains mechanical requirements specific to A4d fibres.

Table D.2 – Mechanical requirements specific to A4d fibres

Attribute	Unit	Limit	Reference
Tensile load at yield peak	N	≥ 56	4.2.2
Elongation at yield peak	%	≥ 4,0	4.2.2

D.4 Transmission requirements

Table D.3 contains transmission requirements specific to A4d fibres.

Table D.3 – Transmission requirements specific to A4d fibres

Attribute	Unit	Limit	Reference
Attenuation at 650 nm when using an overfilled launch	dB/100 m ^a	≤ 40	4.3
Attenuation at 650 nm using a launch NA = 0,3	dB/100 m ^a	≤ 18	4.3
Minimum modal bandwidth at 650 nm using launch NA = 0,3 (RML)	MHz over 100 m ^b	100	4.3
Numerical aperture	Unitless	0,30 ± 0,05	4.3 Table 8
Macrobending loss at 650 nm (10 turns around a 25 mm radius quarter circle)	dB	≤ 0,5	4.3
^a The unit of 100 m is used because this is typical of the fibre length actually used. Attenuation values expressed in dB/100 m can be approximately compared to values stated in dB/km by multiplying the dB/100 m values by 10. ^b The unit of MHz over 100 m is used because this is typical of the fibre length actually used. Bandwidth values expressed in MHz over 100 m can be approximately compared to values stated in MHz·km by dividing the MHz over 100 m values by 10.			

D.5 Environmental requirements

The requirements of 4.4 shall be met.

Annex E (normative)

Family specifications for subcategory A4e multimode fibres

E.1 General

The clauses and tables in this Annex E contain particular requirements applicable to subcategory A4e fibres. Common requirements, from the main body text of this document and repeated here for ease of reference, are noted by an entry in the "Reference" column.

Subcategory A4e fibre is a 750 µm cladding diameter, either multi-step-index or graded-index fibre.

E.2 Dimensional requirements

Table E.1 contains dimensional requirements specific to A4e fibres.

Table E.1 – Dimensional requirements specific to A4e fibres

Attribute	Unit	Limit	Reference
Cladding diameter	µm	750 ± 45	4.1
Cladding non-circularity	%	≤ 6	4.1
Core diameter	µm	≥ 500	4.1
Length	km	See 4.1	4.1

E.3 Mechanical requirements

Table E.2 contains the mechanical requirements specific to A4e fibres.

Table E.2 – Mechanical requirements specific to A4e fibres

Attribute	Unit	Limit	Reference
Tensile load at yield peak	N	≥ 32	4.2.2
Elongation at yield peak	%	≥ 4,0	4.2.2

E.4 Transmission requirements

Table E.3 contains transmission requirements specific to A4e fibres.

Table E.3 – Transmission requirements specific to A4e fibres

Attribute	Unit	Limit	Reference
Attenuation coefficient at 650 nm using a launch NA = 0,3	dB/100 m ^a	≤ 18	4.3
Minimum modal bandwidth at 650 nm using a launch NA = 0,3	MHz over 100 m ^b	200	4.3
Numerical aperture	Unitless	0,25 ± 0,07	4.3 Table 8
Macrobending loss at 650 nm (10 turns around a 25 mm radius quarter circle)	dB	≤ 0,5	4.3
^a The unit of 100 m is used because this is typical of the fibre length actually used. Attenuation values expressed in dB/100 m can be approximately compared to values stated in dB/km by multiplying the dB/100 m values by 10. ^b The unit of MHz over 100 m is used because this is typical of the fibre length actually used. Bandwidth values expressed in MHz over 100 m can be approximately compared to values stated in MHz·km by dividing the MHz over 100 m values by 10.			

E.5 Environmental requirements

The requirements of 4.4 shall be met.

Annex F
(normative)

Family specifications for subcategory A4f multimode fibres

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Annex G (normative)

Family specifications for subcategory A4g multimode fibres

G.1 General

The clauses and tables in this Annex G contain particular requirements applicable to subcategory A4g fibres. Common requirements, from the main body text of this document and repeated here for ease of reference, are noted by an entry in the "Reference" column.

Subcategory A4g fibre is a 120/490 µm graded-index fibre.

G.2 Dimensional requirements

Table G.1 contains dimensional requirements specific to A4g fibres.

Table G.1 – Dimensional requirements specific to A4g fibres

Attribute	Unit	Limit	Reference
Cladding diameter	µm	490 ± 10	4.1
Cladding non-circularity	%	≤ 4	4.1
Core-cladding concentricity error	µm	≤ 6	4.1
Core diameter	µm	120 ± 10	4.1
Core non-circularity	%	≤ 6	4.1
Length	km	See 4.1	4.1

G.3 Mechanical requirements

Table G.2 contains the mechanical requirements specific to A4g fibres.

Table G.2 – Mechanical requirements specific to A4g fibres

Attribute	Unit	Limit	Reference
Tensile load at yield peak	N	≥ 7	4.2.2
Tensile load to induce 4 % elongation	N	≥ 7	4.2.2
Elongation at yield peak	%	≥ 4	4.2.2

G.4 Transmission requirements

Table G.3 contains transmission requirements specific to A4g fibres.

Table G.3 – Transmission requirements specific to A4g fibres

Attribute	Unit	Limit	Reference
Attenuation at 650 nm ^a	dB/100 m ^f	≤ 10	4.3
Attenuation at 850 nm ^a	dB/100 m ^f	≤ 3,3	4.3
Attenuation at 1 300 nm ^a	dB/100 m ^f	≤ 3,3	4.3
Minimum modal bandwidth at 650 nm ^b	MHz over 100 m ^c	800	4.3
Minimum modal bandwidth at 850 nm ^b	MHz over 100 m ^c	≥ 1 880 ^d	4.3
Minimum modal bandwidth at 1 300 nm ^b	MHz over 100 m ^c	≥ 1 880 ^d	4.3
Numerical aperture	Unitless	0,190 ± 0,015	4.3 Table 8
Macrobending loss at 850 nm (10 turns around a 25 mm radius quarter circle) ^e	dB	≤ 0,6	4.3
Zero dispersion wavelength, λ_0	nm	1 200 ≤ λ_0 ≤ 1 650	4.3
Zero dispersion slope, S_0	ps/(nm ² · km)	≤ 0,06	4.3
^a 60 mm is a common mandrel diameter when using Method A in IEC 60793-1-40. ^b Measured using the overfilled launch condition in IEC 60793-1-41 for A3 and A4 fibres. ^c Measured on 100 m through 500 m length. The method used to scale from the measurement length to the 100 m reference length should be available on request. The unit of MHz over 100 m is used because this is typical of the fibre length actually used. Bandwidth values expressed in MHz over 100 m can be approximately compared to values stated in MHz·km by dividing the MHz over 100 m values by 10. ^d The specific value shall be agreed by the supplier and the customer. ^e Measured with a 60 mm diameter mandrel launch. ^f The unit of 100 m is used because this is typical of the fibre length actually used. Attenuation values expressed in dB/100 m can be approximately compared to values stated in dB/km by multiplying the dB/100 m values by 10.			

G.5 Environmental requirements

The requirements of 4.4 shall be met.

Annex H (normative)

Family specifications for subcategory A4h multimode fibres

H.1 General

The clauses and tables in this Annex H contain particular requirements applicable to subcategory A4h fibres. Common requirements, from the main body text of this document and repeated here for ease of reference, are noted by an entry in the "Reference" column.

Subcategory A4h fibre is a 62,5/245 µm graded-index fibre.

H.2 Dimensional requirements

Table H.1 contains dimensional requirements specific to A4h fibres.

Table H.1 – Dimensional requirements specific to A4h fibres

Attribute	Unit	Limit	Reference
Cladding diameter	µm	245 ± 5	4.1
Cladding non-circularity	%	≤ 4	4.1
Core-cladding concentricity error	µm	≤ 3	4.1
Core diameter	µm	$62,5 \pm 5$	4.1
Core non-circularity	%	≤ 6	4.1
Length	km	(see 4.1)	4.1

H.3 Mechanical requirements

Table H.2 contains the mechanical requirements specific to A4h fibres.

Table H.2 – Mechanical requirements specific to A4h fibres

Attribute	Unit	Limit	Reference
Tensile load at yield peak	N	$\geq 1,75$	4.2.1
Tensile load to induce 4 % elongation	N	$\geq 1,75$	4.2.1
Elongation at yield peak	%	≥ 4	4.2.1

H.4 Transmission requirements

Table H.3 contains transmission requirements specific to A4h fibres.

Table H.3 – Transmission requirements specific to A4h fibres

Attribute	Unit	Limit	Reference
Attenuation at 850 nm ^a	dB/100 m ^f	$\leq 3,3$	4.3
Attenuation at 1 300 nm ^a	dB/100 m ^f	$\leq 3,3$	4.3
Minimum modal bandwidth at 850 nm ^b	MHz over 100 m ^c	$\geq 1\,880$ ^d	4.3
Minimum Modal bandwidth at 1 300 nm ^b	MHz over 100 m ^c	$\geq 1\,880$ ^d	4.3
Numerical aperture	Unitless	$0,190 \pm 0,015$	4.3 Table 8
Macrobending loss at 850 nm (10 turns around a 25 mm radius quarter circle) ^e	dB	$\leq 0,25$	4.3
Zero dispersion wavelength, λ_0	nm	$1\,200 \leq \lambda_0 \leq 1\,650$	4.3
Zero dispersion slope, S_0	ps/(nm ² · km)	$\leq 0,06$	4.3
^a 20 mm is a common mandrel diameter when using Method A in IEC 60793-1-40. ^b Measured using the overfilled launch condition in IEC 60793-1-41 for A3 and A4 fibres. ^c Measured on 100 m through 500 m length. The method used to scale from the measurement length to the 100 m reference length should be available on request. The unit of MHz over 100 m is used because this is typical of the fibre length actually used. Bandwidth values expressed in MHz over 100 m can be approximately compared to values stated in MHz·km by dividing the MHz over 100 m values by 10. ^d The specific value shall be agreed by the supplier and the customer. ^e Measured with a 20 mm diameter mandrel launch. ^f The unit of 100 m is used because this is typical of the fibre length actually used. Attenuation values expressed in dB/100 m can be approximately compared to values stated in dB/km by multiplying the dB/100 m values by 10.			

H.5 Environmental requirements

The requirements of 4.4 shall be met.

Annex I (normative)

Family specifications for subcategory A4i multimode fibres

I.1 General

The clauses and tables in this Annex I contain particular requirements applicable to subcategory A4i fibres. Common requirements, from the main body text of this document and repeated here for ease of reference, are noted by an entry in the "Reference" column.

Subcategory A4i fibre is a 55/490 µm graded-index fibre.

I.2 Dimensional requirements

Table I.1 contains dimensional requirements specific to A4i fibres.

Table I.1 – Dimensional requirements specific to A4i fibres

Attribute	Unit	Limit	Reference
Cladding diameter	µm	490 ± 5	4.1
Cladding non-circularity	%	≤ 4	4.1
Core-cladding concentricity error	µm	≤ 6	4.1
Core diameter	µm	55 ± 5	4.1
Core non-circularity	%	≤ 6	4.1
Length	km	(see 4.1)	4.1

I.3 Mechanical requirements

Table I.2 contains the mechanical requirements specific to A4i fibres.

Table I.2 – Mechanical requirements specific to A4i fibres

Attribute	Unit	Limit	Reference
Tensile load at yield peak	N	≥ 6	4.2.1
Tensile load to induce 4 % elongation	N	≥ 6	4.2.1
Elongation at yield peak	%	≥ 4	4.2.1

I.4 Transmission requirements

Table I.3 contains transmission requirements specific to A4i fibres.

Table I.3 – Transmission requirements specific to A4i fibres

Attribute	Unit	Limit	Reference
Attenuation at 850 nm ^a	dB/100 m ^f	≤ 10	4.3
Minimum modal bandwidth at 850 nm ^b	MHz over 100 m ^c	$\geq 3\,500$ ^d	4.3
Numerical aperture	Unitless	$0,24 \pm 0,025$	4.3 Table 8
Macrobending loss at 850 nm (10 turns around a 25 mm radius quarter circle) ^e	dB	$\leq 0,1$	4.3
Zero dispersion wavelength, λ_0	nm	$1\,200 \leq \lambda_0 \leq 1\,650$	4.3
Zero dispersion slope, S_0	ps/(nm ² · km)	$\leq 0,06$	4.3
^a 10 mm is a common mandrel diameter when using Method A in IEC 60793-1-40. ^b Measured using the overfilled launch condition in IEC 60793-1-41 for A3 and A4 fibres. ^c Measured on 100 m through 500 m length. The method used to scale from the measurement length to the 100 m reference length should be available on request. The unit of MHz over 100 m is used because this is typical of the fibre length actually used. Bandwidth values expressed in MHz over 100 m can be approximately compared to values stated in MHz·km by dividing the MHz over 100 m values by 10. ^d The specific value shall be agreed by the supplier and the customer. ^e Measured with a 10 mm diameter mandrel launch. ^f The unit of 100 m is used because this is typical of the fibre length actually used. Attenuation values expressed in dB/100 m can be approximately compared to values stated in dB/km by multiplying the dB/100 m values by 10.			

I.5 Environmental requirements

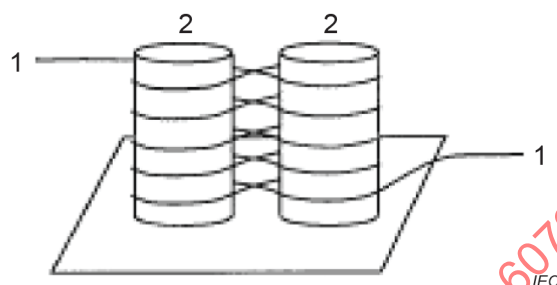
The requirements of 4.4 shall be met.

Annex J (normative)

Mode scramblers for subcategory A4a to A4c fibres

J.1 General

When measuring the equilibrium mode launch attenuation of subcategory A4a, A4b, and A4c fibres, use a figure 8-shaped mode scrambler (Figure J.1), such as that described in IEC 60793-1-40:2019, Figure A.8.



Key

- 1 fibre under test
- 2 cylinders

Figure J.1 – Mode scrambler for category A4 fibre

J.2 Specification for mode scramblers

The mode scrambler shall be made with buffered A4 fibre of the same subcategory as the fibre under test. Parameters for the mode scrambler shall be as shown in Table J.1.

Table J.1 – Mode scrambler parameters

Fibre subcategory	Fibre length m	Diameter of cylinders mm	Distance between the two cylinders mm	Number of "figure-8" turns
A4a	20	42	3	10
A4b	15	35	3	20
A4c	10	32	2	40

Annex K (informative)

Additional transmission requirements for subcategory A4a multimode fibres for wavelengths below 650 nm

K.1 General

This Annex K contains additional transmission requirements according to Annex A applicable to implementation A4a.2 of subcategory A4a fibres, which are intended to be used with wavelengths below 650 nm. PMMA based fibres have the lowest attenuation at wavelengths around 520 nm and 560 nm. The market availability of powerful transceivers based on GaN-LEDs makes it more and more attractive to use the optical window around 520 nm for the design of improved transmission systems. The following requirements should be fulfilled in order to support the design and use of such systems.

K.2 Transmission requirements

Table K.1 contains additional transmission requirements specific to A4a.2 fibres.

Table K.1 – Transmission requirements specific to A4a.2 fibre

Attribute	Unit	Limit	Reference
		A4a.2	
Attenuation at 520 nm when using an equilibrium mode distribution launch ^c	dB/100 m ^a	≤ 10	4.3
Minimum modal bandwidth at 520 nm when using an equilibrium mode distribution launch ^c	MHz over 100 m ^b	40	4.3
Macrobending loss at 520 nm (10 turns around a 25 mm radius quarter circle)	dB	≤ 0,5	4.3
^a The unit of 100 m is used because this is typical of the fibre length actually used. Attenuation values expressed in dB/100 m can be approximately compared to values stated in dB/km by multiplying the dB/100 m values by 10. ^b The unit of MHz over 100 m is used because this is typical of the fibre length actually used. Bandwidth values expressed in MHz over 100 m can be approximately compared to values stated in MHz · km by dividing the MHz over 100 m values by 10. ^c See Annex J.			

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IEC 60794-2-41, *Optical fibre cables – Part 2-41: Indoor cables – Product specification for simplex and duplex buffered A4 fibres*

¹ This document has been withdrawn.

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FIBRES OPTIQUES –

**Partie 2-40: Spécifications de produits –
Spécification intermédiaire pour les fibres multimodales de catégorie A4**

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Cette cinquième édition annule et remplace la quatrième édition parue en 2015 dont elle constitue une révision technique.

La présente édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

- a) révision de la plage d'ouvertures numériques des fibres A4a.2;
- b) ajout d'une nouvelle sous-catégorie A4i;
- c) suppression de la sous-catégorie A4f et de l'Annexe F.

Le texte de cette Norme internationale est issu des documents suivants:

CDV	Rapport de vote
86A/1943/CDV	86A/1981/RVC

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette Norme internationale.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2.

Une liste de toutes les parties de la série IEC 60793, publiées sous le titre général *Fibres optiques*, peut être consultée sur le site web de l'IEC.

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FIBRES OPTIQUES –

Partie 2-40: Spécifications de produits – Spécification intermédiaire pour les fibres multimodales de catégorie A4

1 Domaine d'application

La présente partie de l'IEC 60793 s'applique à la catégorie de fibres optiques multimodales A4 et à ses sous-catégories A4a, A4b, A4c, A4d, A4e, A4g, A4h et A4i. Ces fibres possèdent un cœur et une gaine en plastique et elles peuvent avoir des profils de type en saut d'indice, en sauts multiples d'indice ou en gradient d'indice. Les fibres sont utilisées dans les équipements destinés à la transmission de l'information et dans d'autres applications utilisant des techniques similaires de transmission du rayonnement lumineux, et dans des câbles fibroniques. Le Tableau 1 résume certaines des caractéristiques et applications principales de ces fibres.

Tableau 1 – Caractéristiques et applications des fibres de catégorie A4

Sous-catégorie	A4a		A4b	A4c	A4d	A4e	A4f	A4g	A4h	A4i
	A4a.1	A4a.2								
Diamètre du cœur (µm)	a		a	a	a	≥ 500	c	120	62,5	55
Diamètre de la gaine (µm)	1 000		750	500	1 000	750	c	490	245 ^d	490
Ouverture numérique Na _{ff} ^e	0,50	0,53	0,50	0,50	0,30	0,25	c	0,190	0,190	0,24
Longueur(s) d'onde de fonctionnement (nm)	650 ^b		650	650	650	650	c	650 850 1 300	850 1 300	850
Applications	Interface audionumérique, automobile, industrie, capteur et transmission de données		Industrie et capteur	Capteur	Interface audio-visuelle numérique et transmission de données	Interface audio-visuelle numérique et transmission de données	c	Transmission de données	Transmission de données; essentiellement dans les structures en rubans	Transmission de données industrielles

^a Typiquement de 15 µm à 35 µm plus petit que le diamètre de la gaine.

^b Les autres longueurs d'onde possibles pour la fibre A4a sont décrites dans l'Annexe K.

^c Cette sous-catégorie n'étant pas à jour, elle n'est plus spécifiée.

^d Des diamètres de gaine de 490 µm et 750 µm sont également possibles.

^e Na_{ff} est l'ouverture numérique mesurée par la méthode du diagramme en champ lointain.

En plus des applications indiquées dans le Tableau 1, les fibres A4 sont utilisées dans d'autres applications, entre autres et sans caractère exhaustif: les supports pour des systèmes faiblement étendus de réseaux téléphoniques à haut débit, les réseaux de distribution et les réseaux locaux transportant des données, des services de communication vocale et/ou vidéo, les installations de fibres à l'intérieur de bâtiments et entre bâtiments, y compris les réseaux locaux (LAN: *local area network*), les commutateurs téléphoniques d'abonné (PBX: *private branch exchanges*), la vidéo et différentes utilisations de multiplexage, ainsi que diverses autres utilisations liées, comme l'électronique grand public et les réseaux industriels et mobiles.

Trois types d'exigences s'appliquent aux fibres A4:

- les exigences générales qui sont définies dans l'IEC 60793-2;
- des exigences spécifiques communes aux fibres multimodales de catégorie A4 couvertes par le présent document et qui sont données à l'Article 4;
- des exigences particulières applicables à des sous-catégories et à des mises en œuvre particulières de fibres ou à des applications spécifiques, qui sont définies dans le présent document, dans les spécifications de famille normatives figurant en annexe.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60068-1, *Essais d'environnement – Partie 1: Généralités et lignes directrices*

IEC 60793-1-20, *Fibres optiques – Partie 1-20: Méthodes de mesure et procédures d'essai – Géométrie de la fibre*

IEC 60793-1-22, *Fibres optiques – Partie 1-22: Méthodes de mesure et procédures d'essai – Mesure de la longueur*

IEC 60793-1-40:2019, *Fibres optiques – Partie 1-40: Méthodes de mesurage de l'affaiblissement*

IEC 60793-1-41, *Fibres optiques – Partie 1-41: Méthodes de mesure et procédures d'essai – Largeur de bande*

IEC 60793-1-42, *Fibres optiques – Partie 1-42: Méthodes de mesure et procédures d'essai – Dispersion chromatique*

IEC 60793-1-43, *Fibres optiques – Partie 1-43: Méthodes de mesure et procédures d'essai – Mesure de l'ouverture numérique*

IEC 60793-1-46, *Fibres optiques – Partie 1-46: Méthodes de mesure et procédures d'essai – Contrôle des variations du facteur de transmission optique*

IEC 60793-1-47, *Fibres optiques – Partie 1-47: Méthodes de mesure et procédures d'essai – Pertes par macrocourbures*

IEC 60793-1-50, *Fibres optiques – Partie 1-50: Méthodes de mesure et procédures d'essai – Essais de chaleur humide (état continu)*

IEC 60793-1-51, *Fibres optiques – Partie 1-51: Méthodes de mesure et procédures d'essai – Essais de chaleur sèche (état continu)*

IEC 60793-1-52, *Fibres optiques – Partie 1-52: Méthodes de mesure et procédures d'essai – Essais de variations de température*

3 Termes et définitions

Aucun terme n'est défini dans le présent document.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse <http://www.electropedia.org/>
- ISO Online browsing platform: disponible à l'adresse <http://www.iso.org/obp>

4 Spécifications

4.1 Exigences dimensionnelles

Les attributs dimensionnels et les méthodes de mesure applicables sont donnés dans le Tableau 2.

Les exigences communes à toutes les fibres de catégorie A4 sont données dans le Tableau 3.

Des attributs supplémentaires qui doivent être indiqués dans les spécifications de famille pour les sous-catégories A4g à A4i sont donnés dans le Tableau 4.

Tableau 2 – Attributs dimensionnels et méthodes de mesure

Attribut	Méthode de mesure
Diamètre de la gaine	IEC 60793-1-20 ^a
Non-circularité de la gaine	IEC 60793-1-20 ^a
Diamètre du cœur ^b	IEC 60793-1-20
Longueur de fibre	IEC 60793-1-22
Erreur de concentricité entre le cœur et la gaine	IEC 60793-1-20
Non-circularité du cœur	IEC 60793-1-20
^a Les méthodes mécaniques sont aussi applicables aux mesurages du diamètre de la gaine et de la non-circularité de la gaine si elles offrent la même incertitude de mesure.	
^b Le diamètre du cœur est spécifié à $650 \text{ nm} \pm 10 \text{ nm}$ avec une longueur du spécimen d'essai de $2,0 \text{ m} \pm 0,2 \text{ m}$ et une valeur de seuil k_{CORE} de 2,5 % (IEC 60793-1-20, méthode B) pour les fibres A4.	

Tableau 3 – Exigences communes à toutes les fibres de catégorie A4

Attribut	Unité	Limite
Diamètre de la gaine	μm	^a
Non-circularité de la gaine	%	≤ 6 ^b
Diamètre du cœur	μm	^c
Longueur de fibre	km	^d
^a Le diamètre de la gaine varie et il est indiqué dans la spécification de famille.		
^b Sauf indication contraire dans la spécification de famille.		
^c Pour les fibres A4a, A4b, A4c et A4d, le diamètre du cœur est normalement de $15 \mu\text{m}$ à $35 \mu\text{m}$ inférieur au diamètre de la gaine. Pour les fibres A4e, A4g, A4h et A4i, le diamètre du cœur varie et il est indiqué dans la spécification de famille applicable (dans les annexes du présent document).		
^d Les exigences de longueur sont variables et il convient qu'elles fassent l'objet d'un accord entre le fournisseur et le client.		

Tableau 4 – Attributs supplémentaires exigés dans les spécifications de famille A4g à A4i

Attribut
Non-circularité du cœur
Erreur de concentricité entre le cœur et la gaine

4.2 Exigences mécaniques

4.2.1 Généralités

Les attributs mécaniques, les méthodes d'essai et les exigences pour les fibres sous revêtement protecteur peuvent être consultés dans l'IEC 60794-2-41.

Les attributs mécaniques et les méthodes d'essai applicables sont donnés dans le Tableau 5.

Les exigences communes à toutes les fibres de catégorie A4 sont données dans le Tableau 6.

Des attributs supplémentaires qui doivent être indiqués dans les spécifications de famille pour les sous-catégories A4g à A4i sont donnés dans le Tableau 7.

Tableau 5 – Attributs mécaniques et méthodes d'essai

Attribut	Méthode d'essai
Performance à la traction	4.2.2

Tableau 6 – Exigences communes aux fibres de catégorie A4

Attribut	Unité	Limite
Allongement à la limite d'élasticité	%	≥ 4,0
Charge de traction à la limite d'élasticité	N	^a
^a La charge de traction à la limite d'élasticité varie et elle est indiquée dans la spécification de famille (voir les annexes du présent document).		

Tableau 7 – Attributs supplémentaires exigés dans la spécification de famille pour les fibres des sous-catégories A4g à A4i

Attribut
Charge de traction pour induire un allongement de 4 %

4.2.2 Essai de la charge de traction

4.2.2.1 Objet

L'objet de cet essai est de caractériser l'aptitude de la fibre à supporter une charge au cours des manipulations. Il est destiné à obtenir les valeurs de la résistance à la traction de la fibre.

L'essai doit être réalisé dans les conditions d'essai normalisées conformément à l'IEC 60068-1.

4.2.2.2 Définition de la limite d'élasticité

La Figure 1 présente une courbe typique d'allongement en fonction de la charge pour une fibre optique plastique. La courbe présente une augmentation initiale régulière de l'allongement en fonction de la charge de traction appliquée, puis elle atteint une valeur de pointe. La valeur de pointe est suivie d'une diminution de charge lorsque l'échantillon commence à subir un allongement ductile irréversible. Une striction et un étirage localisés de l'échantillon peuvent accompagner le processus. Ce phénomène est connu sous le terme d'élasticité et la valeur de pointe est désignée comme limite d'élasticité.

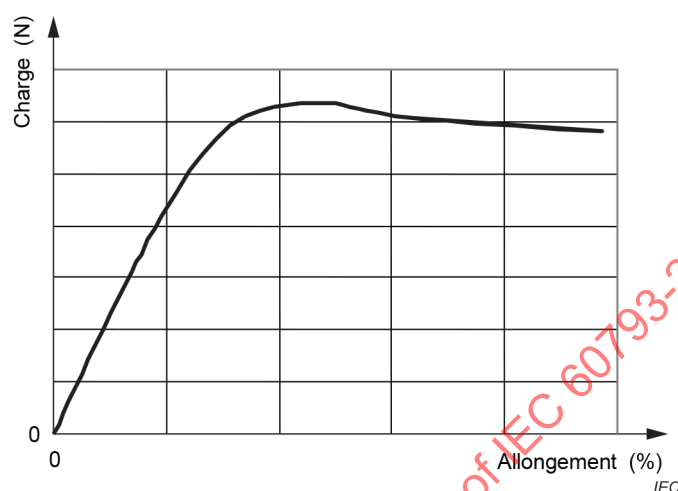


Figure 1 – Allongement en fonction de la charge de traction pour une fibre optique plastique

4.2.2.3 Appareillage d'essai

La longueur de l'échantillon entre deux dispositifs d'accrochage doit être comprise entre 100 mm et 200 mm.

L'appareillage de mesure de la résistance à la traction doit être un dispositif, par exemple une machine de traction verticale, assurant un déplacement relatif de la fibre soumise à l'essai. L'appareillage doit pouvoir exercer sur la fibre soumise à l'essai un mouvement constant, sans secousse. L'appareillage doit être capable de mesurer et d'enregistrer simultanément la force ou la charge de traction obtenue. Pour éviter la rupture de la fibre, les dispositifs utilisés pour fixer les extrémités des fibres au niveau des points d'accrochage ne doivent pas exercer une contrainte excessive sur la fibre.

4.2.2.4 Procédure

La vitesse de traction doit être de 100 mm/min $\pm$ 10 %. La charge et l'allongement correspondant à la limite d'élasticité sont obtenus à partir de la courbe charge-allongement décrite en 4.2.2.2. Sauf spécification contraire, la charge de traction à la limite d'élasticité et la charge de traction induisant un allongement de 4 % doivent être enregistrées.

NOTE L'allongement jusqu'au point de rupture n'est pas applicable aux fibres de catégorie A4.

4.2.2.5 Exigences

Les exigences sont indiquées dans les spécifications de famille figurant dans les Annexes A à J. Si l'échantillon de fibre se rompt au point d'accrochage, l'essai doit être considéré comme non valable et un autre essai doit être réalisé. Le nombre d'échantillons soumis à l'essai doit être suffisant pour permettre une analyse statistique.

4.3 Exigences de transmission

Les attributs de transmission et les méthodes de mesure applicables sont donnés dans le Tableau 8.

Les attributs supplémentaires exigés dans les spécifications de famille sont indiqués dans le Tableau 9.

Tableau 8 – Attributs de transmission et méthodes de mesure

Attribut	Méthode de mesure
Affaiblissement ^a	IEC 60793-1-40
Largeur de bande modale ^a	IEC 60793-1-41
Largeur de bande modale avec injection en mode restreint (RML, <i>Restricted Mode Launch</i>)	IEC 60793-1-41
Ouverture numérique ^{b,c,d}	IEC 60793-1-43
Dispersion chromatique	IEC 60793-1-42
Pertes par macrocourbures	IEC 60793-1-47, méthode B
^a Pour mesurer l'affaiblissement et la largeur de bande modale, il convient d'appliquer les conditions d'injection appropriées comme cela est spécifié dans l'IEC 60793-1-40 et dans l'IEC 60793-1-41, ou comme indiqué dans la spécification de famille. La largeur de bande n'est pas nécessairement linéaire par rapport à la longueur. La valeur de la largeur de bande est donnée avec pour référence une longueur de fibre de 100 m. ^b L'ouverture numérique est spécifiée à $650 \text{ nm} \pm 10 \text{ nm}$ avec une longueur du spécimen d'essai de $2,0 \text{ m} \pm 0,2 \text{ m}$ et une valeur de seuil k_{NA} de 50 % pour les fibres A4a à A4c et A4e. ^c L'ouverture numérique est spécifiée à $650 \text{ nm} \pm 10 \text{ nm}$ avec une longueur du spécimen d'essai de $2,0 \text{ m} \pm 0,2 \text{ m}$ et par le diagramme d'intensité en champ lointain des minimums locaux et des angles liés pour les fibres A4d (IEC 60793-1-43, Technique 4: mesure en champ lointain inverse). ^d L'ouverture numérique est spécifiée à $850 \text{ nm} \pm 10 \text{ nm}$ avec une longueur du spécimen d'essai de $6,0 \text{ m} \pm 0,6 \text{ m}$ et une valeur de seuil k_{NA} de 5 % pour les fibres A4g à A4i.	

Tableau 9 – Attributs exigés dans les spécifications de famille

Attribut
Affaiblissement
Largeur de bande modale
Ouverture numérique
Dispersion chromatique
Pertes par macrocourbures

4.4 Exigences environnementales

4.4.1 Généralités

Les essais d'exposition à l'environnement et les méthodes de mesure correspondantes sont documentés sous deux formes:

- attributs d'environnement, méthodes d'essai et conditions d'essai applicables, donnés dans le Tableau 10;
- mesurages d'un attribut mécanique et d'un attribut de transmission spécifiques, pouvant varier au cours de l'exposition à l'essai d'environnement, énumérés dans le Tableau 11.

Tableau 10 – Essais d'exposition à l'environnement

Conditions d'essai ^a	Environnement	Méthode d'essai ^b	Condition d'essai ^c
A	Chaleur humide	IEC 60793-1-50	+75 °C, HR 85 %, 30 jours
	Chaleur sèche	IEC 60793-1-51	+85 °C, 30 jours
	Variations de température	IEC 60793-1-52	$T_A: -40\text{ °C}$, $T_B: +85\text{ °C}$
B	Chaleur humide	IEC 60793-1-50	+60 °C, HR 85 %, 30 jours
	Chaleur sèche	IEC 60793-1-51	+70 °C, 30 jours
	Variations de température	IEC 60793-1-52	$T_A: -20\text{ °C}$, $T_B: +70\text{ °C}$
^a Il convient que la condition d'essai A ou B fasse l'objet d'un accord entre le fournisseur et le client. ^b Bien que ces méthodes d'essai ne mentionnent pas de manière spécifique leur applicabilité aux fibres A4, il convient de les utiliser. La longueur de du spécimen d'essai doit faire l'objet d'un accord entre le fournisseur et le client. ^c Ces conditions d'essai remplacent toute condition qui pourrait avoir été spécifiée dans les méthodes d'essai indiquées.			

Tableau 11 – Attributs mesurés

Attribut	Méthode de mesure
Variations du facteur de transmission optique	IEC 60793-1-46
Charge de traction	4.2.2

Ces essais sont normalement effectués de manière périodique comme essais de type pour une conception de fibre donnée. Sauf spécification contraire:

- le spécimen doit être pré conditionné en le maintenant dans des conditions atmosphériques normalisées pendant au moins 24 h, et
- la période de rétablissement autorisée entre la fin de l'exposition à l'environnement et la réalisation des mesures des attributs doit être celle spécifiée dans la méthode d'essai d'environnement spécifique.

L'essai d'exposition à l'environnement des fibres des sous-catégories A4a à A4e est généralement réalisé après avoir recouvert les fibres d'un revêtement protecteur (voir l'IEC 60794-2-41 pour les exigences d'environnement relatives aux fibres avec revêtement protecteur). L'essai d'exposition à l'environnement des fibres sans revêtement protecteur n'est exigé que lorsque ces fibres sont vendues dans cet état.

4.4.2 Exigences d'environnement mécanique

La résistance à la traction doit être vérifiée conformément au Tableau 12 après le retrait de la fibre de l'environnement, mais seulement après avoir laissé refroidir le spécimen dans des conditions atmosphériques normalisées.

Tableau 12 – Exigence pour la résistance à la traction

Environnement	Allongement à la limite d'élasticité
Chaleur humide	≥ 4,0 %

4.4.3 Exigences d'environnement pour la transmission

La variation d'affaiblissement par rapport à la valeur initiale doit être inférieure aux valeurs du Tableau 13 et du Tableau 14. Les exigences diffèrent pour les deux groupes de fibres parce que leurs environnements d'application sont différents.

Tableau 13 – Exigences pour la variation d'affaiblissement pour les fibres A4a à A4e

Environnement	Attribut	Unité	Limites
Chaleur humide	Augmentation de l'affaiblissement à 650 nm	dB/100 m	≤ 5 (inclut l'affaiblissement dû à l'absorption d'eau)
Chaleur sèche	Augmentation de l'affaiblissement à 650 nm	dB/100 m	≤ 2
Variations de température	Augmentation de l'affaiblissement à 650 nm	dB/100 m	≤ 2

Tableau 14 – Exigences pour la variation d'affaiblissement pour les fibres A4g à A4i

Environnement	Attribut	Unité	Limites
Chaleur humide	Augmentation de l'affaiblissement à 650 nm, 850 nm et/ou 1 300 nm ^a	dB/100 m	≤ 1,0 (inclut l'affaiblissement dû à l'absorption d'eau)
Chaleur sèche	Augmentation de l'affaiblissement à 650 nm, 850 nm et/ou 1 300 nm	dB/100 m	≤ 0,5
Variations de température	Augmentation de l'affaiblissement à 650 nm, 850 nm et/ou 1 300 nm	dB/100 m	≤ 0,5
^a Étant donné que l'effet de l'eau absorbée peut être important à 1 300 nm, l'augmentation de l'affaiblissement est spécifiée uniquement après une période de rétablissement de l'échantillon d'au moins 24 h dans des conditions atmosphériques normalisées à température ambiante.			