INTERNATIONAL STANDARD

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

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ICS 33.180.10

ISBN 978-2-8322-7323-4

Warning! Make sure that you obtained this publication from an authorized distributor.
# CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOREWORD</td>
<td>5</td>
</tr>
<tr>
<td>1 Scope</td>
<td>7</td>
</tr>
<tr>
<td>2 Normative references</td>
<td>7</td>
</tr>
<tr>
<td>3 Terms and definitions</td>
<td>8</td>
</tr>
<tr>
<td>4 Background</td>
<td>8</td>
</tr>
<tr>
<td>5 Overview of methods</td>
<td>8</td>
</tr>
<tr>
<td>6 Reference test method</td>
<td>9</td>
</tr>
<tr>
<td>7 Apparatus</td>
<td>9</td>
</tr>
<tr>
<td>7.1 Light source</td>
<td>9</td>
</tr>
<tr>
<td>7.2 Modulation</td>
<td>10</td>
</tr>
<tr>
<td>7.3 Launch optics</td>
<td>10</td>
</tr>
<tr>
<td>7.4 Support and positioning apparatus</td>
<td>10</td>
</tr>
<tr>
<td>7.5 Deployment mandrel</td>
<td>10</td>
</tr>
<tr>
<td>7.5.1 General</td>
<td>10</td>
</tr>
<tr>
<td>7.5.2 Cable cut-off wavelength deployment, method A</td>
<td>10</td>
</tr>
<tr>
<td>7.5.3 Cable cut-off wavelength deployment, method B</td>
<td>11</td>
</tr>
<tr>
<td>7.5.4 Fibre cut-off wavelength deployment, method C</td>
<td>12</td>
</tr>
<tr>
<td>7.6 Detection optics</td>
<td>13</td>
</tr>
<tr>
<td>7.7 Detector assembly and signal detection electronics</td>
<td>14</td>
</tr>
<tr>
<td>7.8 Cladding mode stripper</td>
<td>14</td>
</tr>
<tr>
<td>8 Sampling and specimens</td>
<td>14</td>
</tr>
<tr>
<td>8.1 Specimen length</td>
<td>14</td>
</tr>
<tr>
<td>8.2 Specimen end face</td>
<td>14</td>
</tr>
<tr>
<td>9 Procedure</td>
<td>14</td>
</tr>
<tr>
<td>9.1 Positioning of specimen in apparatus</td>
<td>14</td>
</tr>
<tr>
<td>9.1.1 General requirements for all methods</td>
<td>14</td>
</tr>
<tr>
<td>9.1.2 Deployment requirements for each method</td>
<td>14</td>
</tr>
<tr>
<td>9.2 Measurement of output power</td>
<td>14</td>
</tr>
<tr>
<td>9.2.1 Overview</td>
<td>14</td>
</tr>
<tr>
<td>9.2.2 Bend-reference technique</td>
<td>15</td>
</tr>
<tr>
<td>9.2.3 Multimode-reference technique</td>
<td>16</td>
</tr>
<tr>
<td>10 Calculations</td>
<td>16</td>
</tr>
<tr>
<td>10.1 Bend-reference technique</td>
<td>16</td>
</tr>
<tr>
<td>10.2 Multimode-reference technique</td>
<td>16</td>
</tr>
<tr>
<td>10.3 Curve-fitting technique for improved precision (optional)</td>
<td>14</td>
</tr>
<tr>
<td>10.3.1 General</td>
<td></td>
</tr>
<tr>
<td>10.3.2 Step 1, define the upper wavelength region</td>
<td></td>
</tr>
<tr>
<td>10.3.3 Step 2, characterize the attenuation curve</td>
<td></td>
</tr>
<tr>
<td>10.3.4 Step 3, determine the upper wavelength of the transition region</td>
<td></td>
</tr>
<tr>
<td>10.3.5 Step 4, determine the lower wavelength of the transition region</td>
<td></td>
</tr>
<tr>
<td>10.3.6 Step 5, characterize the transition region with the theoretical model</td>
<td></td>
</tr>
<tr>
<td>10.3.7 Step 6, compute the cut-off wavelength, ( \lambda_c )</td>
<td></td>
</tr>
<tr>
<td>11 Mapping functions</td>
<td>21</td>
</tr>
<tr>
<td>12 Results</td>
<td>21</td>
</tr>
<tr>
<td>13 Specification information</td>
<td>22</td>
</tr>
</tbody>
</table>
Annex A (normative) Requirements specific to method A – Cable cut-off wavelength, \( \lambda_{cc} \), using uncabled fibre

A.1 Specimen length
A.2 Procedure – Position specimen on deployment mandrel

Annex B (normative) Requirements specific to method B – Cable cut-off wavelength, \( \lambda_{cc} \), using cabled fibre

B.1 Specimen length
B.2 Procedure – Position specimen on deployment mandrel

Annex C (normative) Requirements specific to method C – Fibre cut-off wavelength, \( \lambda_c \)

C.1 Specimen length
C.2 Procedure – Position specimen on deployment mandrel

Annex D (informative) Cut-off curve artifacts

D.1 Description of curve artifacts
D.2 Curve-fitting technique for artifact filtering
  D.2.1 Overview
  D.2.2 General
  D.2.3 Step 1: define the upper wavelength region
  D.2.4 Step 2: characterize the spectral transmittance
  D.2.5 Step 3: calculate the deviation of the spectral transmittance from the linear fit
  D.2.6 Step 4: determine the end wavelength of the transition region
  D.2.7 Step 5: determine the start wavelength of the transition region
  D.2.8 Step 6: characterize the transition region with the theoretical model
  D.2.9 Step 7: compute the cut-off wavelength, \( \lambda_c \)

D.3 Fibre deployment method for artifact attenuation

Bibliography

List of comments

Figure 1 – Cut-off measurement system block diagram
Figure 2 – Deployment configuration for cable cut-off wavelength \( \lambda_{cc} \), method A
Figure 3 – Deployment configuration for cable cut-off wavelength \( \lambda_{cc} \), method B
Figure 3 – Default configuration to measure \( \lambda_c \)
Figure 4 – Deployment configurations for fibre cut-off measurement
Figure 4 – Standard deployment for fibre cut-off wavelength measurement
Figure 5 – Cut-off wavelength using the bend-reference technique
Figure 6 – Cut-off wavelength using the multimode-reference technique
Figure 7 – Cable cut-off vs fibre cut-off for a specific fibre (multimode reference)
Figure A.1 – Alternative cable cut-off deployment
Figure C.1 – Alternative fibre cut-off deployment – Sliding semi-circle
Figure C.2 – Alternative fibre cut-off deployment – Multi-bend
Figure C.3 – Alternative fibre cut-off deployment – Large curve
Figure D.1 – Cut-off curve with linear fit error (multimode reference)
Figure D.2 – Fibre cut-off curve fitting technique (multimode reference)
Figure D.3 – Curve fitting regions
Figure D.4 – Fibre cut-off curve with artifacts (multimode reference) .................................32
Figure D.5 – Fibre cut-off curve with artifacts (bend reference) ........................................32
Figure D.6 – Fibre deployment with large diameter bends for mode filtering .........................33
Figure D.7 – Fibre cut-off curve with mode attenuation (multimode reference) .................33
INTERNATIONAL ELECTROTECHNICAL COMMISSION

OPTICAL FIBRES –

Part 1-44: Measurement methods and test procedures – Cut-off wavelength

FOREWORD

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

2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.

3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.

4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.

5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.

6) All users should ensure that they have the latest edition of this publication.

7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.

8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

This commented version (CMV) of the official standard IEC 60793-1-44:2023 edition 3.0 allows the user to identify the changes made to the previous IEC 60793-1-44:2011 edition 2.0. Furthermore, comments from IEC SC 86A experts are provided to explain the reasons of the most relevant changes, or to clarify any part of the content.

A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text. Experts' comments are identified by a blue-background number. Mouse over a number to display a pop-up note with the comment.

This publication contains the CMV and the official standard. The full list of comments is available at the end of the CMV.
IEC 60793-1-44 has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics. It is an International Standard.

This third edition cancels and replaces the second edition published in 2011. This edition constitutes a technical revision.

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

a) used the diameter of the fibre loops to describe deployment;
b) added Annex D related to cut-off curve artifacts;
c) reorganized information and added more figures to clarify concepts.

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

<table>
<thead>
<tr>
<th>Draft</th>
<th>Report on voting</th>
</tr>
</thead>
<tbody>
<tr>
<td>86A/2314/FDIS</td>
<td>86A/2327/RVD</td>
</tr>
</tbody>
</table>

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

This document is to be read in conjunction with IEC 60793-1-1.

A list of all parts of the IEC 60793-1 series, published under the general title Optical fibres – Measurement methods and test procedures, 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 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.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.
1 Scope

This part of IEC 60793 establishes uniform requirements for measuring the cut-off wavelength of single-mode optical fibre, thereby assisting in the inspection of fibres and cables for commercial purposes.

This document gives methods for measuring the cut-off wavelength of fibre and cable for uncabled or cabled single mode telecom fibre. These procedures apply to all category B and C fibre types.

There are two methods for measuring cable cut-off wavelength, $\lambda_{cc}$:

- Method A: using uncabled fibre;
- Method B: using cabled fibre.

There is only one method (Method C) for measuring fibre cut-off wavelength, $\lambda_c$.

The test method in this standard describes procedures for determining the cut-off wavelength of a sample fibre in either an uncabled condition ($\lambda_c$) or in a cable ($\lambda_{cc}$). Three default configurations are given here: any different configuration will be given in a detail specification. These procedures apply to all category B and C fibre types (see Normative references).

There are three methods of deployment for measuring the cut-off wavelength:

- method A: cable cut-off using uncabled fibre 22 m long sample, $\lambda_{cc}$;
- method B: cable cut-off using cabled fibre 22 m long sample, $\lambda_{cc}$;
- method C: fibre cut-off using uncabled fibre 2 m long sample, $\lambda_c$.

All methods require a reference measurement. There are two reference-scan techniques, either or both of which may can be used with all methods:

- bend-reference technique;

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60793-1-1, Optical fibres – Part 1-1: Measurement methods and test procedures – General and guidance

CONTENTS

FOREWORD ..................................................................................................................................... 4
1 Scope ........................................................................................................................................ 6
2 Normative references .................................................................................................................. 6
3 Terms and definitions .................................................................................................................. 6
4 Background ................................................................................................................................ 7
5 Overview of methods ................................................................................................................... 7
6 Reference test method ................................................................................................................ 8
7 Apparatus ................................................................................................................................... 8
  7.1 Light source ........................................................................................................................... 8
  7.2 Modulation ............................................................................................................................. 8
  7.3 Launch optics .......................................................................................................................... 8
  7.4 Support and positioning apparatus ......................................................................................... 8
  7.5 Deployment mandrel ............................................................................................................... 9
    7.5.1 General ............................................................................................................................ 9
    7.5.2 Cable cut-off wavelength deployment, method A ............................................................ 9
    7.5.3 Cable cut-off wavelength deployment, method B ............................................................ 9
    7.5.4 Fibre cut-off wavelength deployment, method C ............................................................. 9
  7.6 Detection optics ...................................................................................................................... 10
  7.7 Detector assembly and signal detection electronics ................................................................. 10
  7.8 Cladding mode stripper ......................................................................................................... 10
8 Sampling specimen .................................................................................................................... 10
  8.1 Specimen length ..................................................................................................................... 10
  8.2 Specimen end face .................................................................................................................. 10
9 Procedure .................................................................................................................................. 11
  9.1 Positioning of specimen in apparatus .................................................................................... 11
    9.1.1 General requirements for all methods ................................................................................. 11
    9.1.2 Deployment requirements for each method ....................................................................... 11
  9.2 Measurement of output power ............................................................................................... 11
    9.2.1 Overview ......................................................................................................................... 11
    9.2.2 Bend-reference technique ............................................................................................... 12
    9.2.3 Multimode-reference technique ....................................................................................... 12
10 Calculations ............................................................................................................................ 12
  10.1 Bend-reference technique ................................................................................................... 12
  10.2 Multimode-reference technique ......................................................................................... 13
11 Mapping functions .................................................................................................................... 14
12 Results ..................................................................................................................................... 14
13 Specification information .......................................................................................................... 15

Annex A (normative) Requirements specific to method A – Cable cut-off wavelength, \( \lambda_{cc} \), using uncabled fibre ........................................................................................................... 16
  A.1 Specimen length .................................................................................................................... 16
  A.2 Procedure – Position specimen on deployment mandrel ......................................................... 16

Annex B (normative) Requirements specific to method B – Cable cut-off wavelength, \( \lambda_{cc} \), using cabled fibre ........................................................................................................... 17
  B.1 Specimen length .................................................................................................................... 17
  B.2 Procedure – Position specimen on deployment mandrel ......................................................... 17
Annex C (normative)  Requirements specific to method C – Fibre cut-off wavelength, \( \lambda_c \) ........................................ 18
C.1  Specimen length .......................................................................................... 18
C.2  Procedure – Position specimen on deployment mandrel .................................. 18

Annex D (informative)  Cut-off curve artifacts .................................................. 20
D.1  Description of curve artifacts ........................................................................ 20
D.2  Curve-fitting technique for artifact filtering .................................................. 20
D.2.1  Overview .................................................................................................... 20
D.2.2  General ....................................................................................................... 21
D.2.3  Step 1: define the upper wavelength region ............................................ 22
D.2.4  Step 2: characterize the spectral transmittance ....................................... 22
D.2.5  Step 3: calculate the deviation of the spectral transmittance from the linear fit ........................................................................................................... 22
D.2.6  Step 4: determine the end wavelength of the transition region ............... 23
D.2.7  Step 5: determine the start wavelength of the transition region .............. 23
D.2.8  Step 6: characterize the transition region with the theoretical model ....... 23
D.2.9  Step 7: compute the cut-off wavelength, \( \lambda_c \) ....................................... 24
D.3  Fibre deployment method for artifact attenuation ............................................ 25

Bibliography ............................................................................................................ 27

Figure 1 – Cut-off measurement system block diagram ........................................ 7
Figure 2 – Deployment configuration for cable cut-off wavelength \( \lambda_{cc} \), method A .................................. 9
Figure 3 – Deployment configuration for cable cut-off wavelength \( \lambda_{cc} \), method B ........ 9
Figure 4 – Standard deployment for fibre cut-off wavelength measurement .......... 10
Figure 5 – Cut-off wavelength using the bend-reference technique ....................... 11
Figure 6 – Cut-off wavelength using the multimode-reference technique .............. 12
Figure 7 – Cable cut-off vs fibre cut-off for a specific fibre (multimode reference) ...... 14
Figure A.1 – Alternative cable cut-off deployment .............................................. 16
Figure C.1 – Alternative fibre cut-off deployment – Sliding semi-circle ................. 18
Figure C.2 – Alternative fibre cut-off deployment – Multi-bend ............................. 19
Figure C.3 – Alternative fibre cut-off deployment – Large curve ......................... 19
Figure D.1 – Cut-off curve with linear fit error (multimode reference) ............... 20
Figure D.2 – Fibre cut-off curve fitting technique (multimode reference) ................ 21
Figure D.3 – Curve fitting regions ....................................................................... 21
Figure D.4 – Fibre cut-off curve with artifacts (multimode reference) ................. 25
Figure D.5 – Fibre cut-off curve with artifacts (bend reference) ............................ 25
Figure D.6 – Fibre deployment with large diameter bends for mode filtering ........ 26
Figure D.7 – Fibre cut-off curve with mode attenuation (multimode reference) ...... 26
FOREWORD

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

2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.

3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.

4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.

5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.

6) All users should ensure that they have the latest edition of this publication.

7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.

8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.

9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

IEC 60793-1-44 has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics. It is an International Standard.

This third edition cancels and replaces the second edition published in 2011. This edition constitutes a technical revision.

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

a) used the diameter of the fibre loops to describe deployment;
b) added Annex D related to cut-off curve artifacts;
c) reorganized information and added more figures to clarify concepts.
IEC 60793-1-44:2023 © IEC 2023 – 5 –

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

<table>
<thead>
<tr>
<th>Draft</th>
<th>Report on voting</th>
</tr>
</thead>
<tbody>
<tr>
<td>86A/2314/FDIS</td>
<td>86A/2327/RVD</td>
</tr>
</tbody>
</table>

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

This document is to be read in conjunction with IEC 60793-1-1.

A list of all parts of the IEC 60793-1 series, published under the general title *Optical fibres – Measurement methods and test procedures*, 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 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.

**IMPORTANT –** The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.
OPTICAL FIBRES –
Part 1-44: Measurement methods and test procedures – Cut-off wavelength

1 Scope

This part of IEC 60793 establishes uniform requirements for measuring the cut-off wavelength of single-mode optical fibre, thereby assisting in the inspection of fibres and cables for commercial purposes.

This document gives methods for measuring the cut-off wavelength for uncabled or cabled single mode telecom fibre. These procedures apply to all category B and C fibre types.

There are three methods of deployment for measuring the cut-off wavelength:

- method A: cable cut-off using uncabled fibre 22 m long sample, \( \lambda_{cc} \);
- method B: cable cut-off using cabled fibre 22 m long sample, \( \lambda_{cc} \);
- method C: fibre cut-off using uncabled fibre 2 m long sample, \( \lambda_{c} \).

All methods require a reference measurement. There are two reference-scan techniques, either or both of which can be used with all methods:

- bend-reference technique;

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60793-1-1, Optical fibres – Part 1-1: Measurement methods and test procedures – General and guidance