IEC 60793-1-44

Edition 3.0 2023-07
COMMENTED VERSION

INTERNATIONAL STANDARD

colour inside

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



IEC 60793-1-44:2023-07 CMV(en)



THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2023 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC 60793-1-44

Edition 3.0 2023-07
COMMENTED VERSION

INTERNATIONAL STANDARD

colour inside

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.

® Registered trademark of the International Electrotechnical Commission

CONTENTS

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

Annex A (normative) Requirements specific to method A – Cable cut-off wavelength, λ_{cc}, using uncabled fibre 23
A.1 Specimen length 23
A.2 Procedure – Position specimen on deployment mandrel 23
Annex B (normative) Requirements specific to method B – Cable cut-off wavelength, λ_{cc}, using cabled fibre 24
B.1 Specimen length 24
B.2 Procedure – Position specimen on deployment mandrel 24
Annex C (normative) Requirements specific to method C – Fibre cut-off wavelength, λ_c 25
C.1 Specimen length 25
C.2 Procedure – Position specimen on deployment mandrel 25
Annex D (informative) Cut-off curve artifacts 27
D.1 Description of curve artifacts 27
D.2 Curve-fitting technique for artifact filtering 27
D.2.1 Overview 27
D.2.2 General 28
D.2.3 Step 1: define the upper wavelength region 29
D.2.4 Step 2: characterize the spectral transmittance 29
D.2.5 Step 3: calculate the deviation of the spectral transmittance from the linear fit 29
D.2.6 Step 4: determine the end wavelength of the transition region 30
D.2.7 Step 5: determine the start wavelength of the transition region 30
D.2.8 Step 6: characterize the transition region with the theoretical model 30
D.2.9 Step 7: compute the cut-off wavelength, λ_c 31
D.3 Fibre deployment method for artifact attenuation 32
Bibliography 34
List of comments 35

Figure 1 – Cut-off measurement system block diagram 9
Figure 2 – Deployment configuration for cable cut-off wavelength λ_{cc}, method A 11
Figure 3 – Deployment configuration for cable cut-off wavelength λ_{cc}, method B 12
~~Figure 3 – Default configuration to measure λ_c .....~~
~~Figure 4 – Deployment configurations for fibre cut-off measurement .....~~
Figure 4 – Standard deployment for fibre cut-off wavelength measurement 13
Figure 5 – Cut-off wavelength using the bend-reference technique 15
Figure 6 – Cut-off wavelength using the multimode-reference technique 15
Figure 7 – Cable cut-off vs fibre cut-off for a specific fibre (multimode reference) 21
Figure A.1 – Alternative cable cut-off deployment 23
Figure C.1 – Alternative fibre cut-off deployment – Sliding semi-circle 25
Figure C.2 – Alternative fibre cut-off deployment – Multi-bend 26
Figure C.3 – Alternative fibre cut-off deployment – Large curve 26
Figure D.1 – Cut-off curve with linear fit error (multimode reference) 27
Figure D.2 – Fibre cut-off curve fitting technique (multimode reference) 28
Figure D.3 – Curve fitting regions 28

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:

Draft	Report on voting
86A/2314/FDIS	86A/2327/RVD

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 ~~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, λ_{cc}:~~

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

~~There is only one method (Method C) for measuring fibre cut-off wavelength, λ_c.~~

~~The test method in this standard describes procedures for determining the cut-off wavelength of a sample fibre in either an uncabled condition (λ_c) or in a cable (λ_{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, λ_{cc};
- method B: cable cut-off using cabled fibre 22 m long sample, λ_{cc};
- method C: fibre cut-off using uncabled fibre 2 m long sample, λ_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;
- multimode-reference technique using category A1(OM1-OM5) multimode fibre.

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

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

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

4 Background

Theoretical cut-off wavelength is the shortest wavelength at which only the fundamental mode can propagate in a single-mode fibre, as computed from the refractive index profile of the fibre.

In optical fibres, the change from multimode to single mode behaviour does not occur at an isolated wavelength, but rather smoothly over a range of wavelengths. For purposes of determining fibre performance in a telecommunications network, theoretical cut-off wavelength is less useful than the lower value actually measured when the fibre is deployed.

Measured cut-off wavelength is defined as the wavelength greater than which the ratio between the total power, including launched higher-order modes, and the fundamental mode power has decreased to less than 0,1 dB. According to this definition, the second-order (LP_{11}) mode undergoes 19,3 dB more attenuation than the fundamental (LP_{01}) mode at the cut-off wavelength. 1

Because measured cut-off wavelength depends on the length and bends of the fibre, the resulting value of cut-off wavelength depends on whether the measured fibre is configured in a deployed, cabled condition or if it is short and uncabled. Consequently, there are two overall types of cut-off wavelength:

- cable cut-off wavelength (λ_{cc}) measured in an uncabled fibre deployment condition (method A), or in a cabled condition (method B);
- fibre cut-off wavelength (λ_c) measured on a short length of uncabled, primary-coated fibre (method C).

Cable cut-off wavelength is the preferred attribute to be specified and measured.

5 Overview of methods

~~All of the methods shall use the transmitted-power technique, which measures the variation with wavelength of the transmitted power of a fibre under test compared to a reference transmitted-power wavelength scan. The reference scan normalizes wavelength-dependent fluctuations in the measurement equipment so that the attenuation of the LP_{11} mode in the specimen can be properly characterized and the cut-off wavelength precisely determined.~~

All of the methods shall use the transmitted-power technique. A general system block diagram is depicted in Figure 1. A fibre specimen is scanned by a wavelength spectrum. The output optical power is measured and stored. This stored data is then analysed against a reference power spectrum. The reference scan normalizes any wavelength-dependent fluctuations in the measurement equipment that is not associated with the loss of the LP_{11} mode. The resulting attenuation will thus properly characterize the cut-off wavelength.