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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)

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

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

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FOREWORD

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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.

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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.

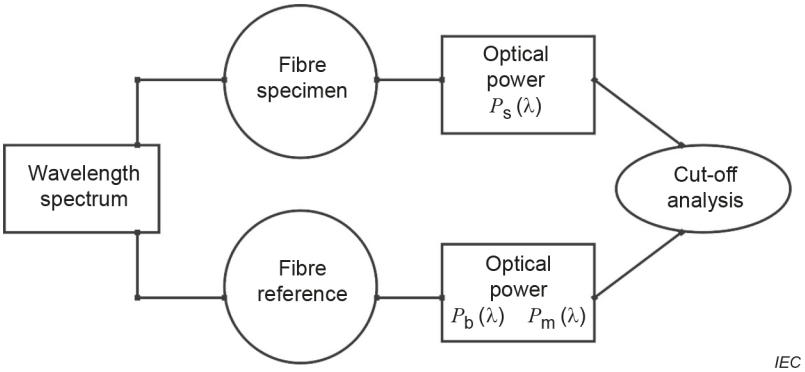


Figure 1 – Cut-off measurement system block diagram 2

The reference scan uses one of the following two techniques:

- ~~the specimen with an additional, smaller-radius fibre bend;~~
- ~~a (separate) category A1 multimode fibre.~~
- bend reference where a small diameter bend is added to the fibre specimen;
- multimode reference where the optical power through an A1(OM1-OM5) fibre is measured.

~~This procedure~~ Either reference technique can determine the cut-off wavelength of a fibre specimen in ~~either~~ a cabled or uncabled condition. ~~Each method has its own default configurations; the detail specification will give any different configuration required.~~

The fibre cut-off wavelength, λ_c, measured under the standard length and bend conditions described in this document, will generally exhibit a value larger than the cable cut-off wavelength, λ_{cc}. For normal installed cable spans, it is common for the measured λ_c value to exceed the ~~system~~ long fibre's transmission wavelength. ~~Thus Cable cut-off wavelength is the more useful description of system performance and capability.~~

~~For short cables, e.g. a pigtail with a length shorter (and possibly a bending radius larger) than described in this method, the cable may introduce modal noise near the cut-off wavelength when lossy splices are present (>0,5 dB).~~

Cable cut-off wavelength is more useful in describing an installed network system performance and capability, while fibre cut-off would apply to short cables or pigtails. The two cut-off wavelengths can be mapped to each other for a specific fibre type and cut-off measurement method. The customer and the supplier shall agree to the confidence level of each mapping function established (see Clause 11 for details).

6 Reference test method

Method A, cable cut-off wavelength using uncabled fibre, is the reference test method (RTM). This method shall be used to settle any disputes.

~~The apparatus for each method is described in Clause 7.~~

7 Apparatus

7.1 Light source

Provide a filtered white light source, with line width not greater than 10 nm, stable in position and intensity. The light source should be capable of operating over the wavelength range 1 000 nm to 1 600 nm for most category B fibres. An operating range of 800 nm to 1 700 nm

may be necessary for some ~~B4~~ B-655 fibres, ~~B5~~ B-656 fibres or ~~some~~ category C fibres. A scanning monochromator with a halogen bulb is one example of this kind of source.

7.2 Modulation

Modulate the light source to prevent ambient light affecting the results, and to aid signal recovery. A mechanical chopper with a reference output is a suitable arrangement.

7.3 Launch optics

Provide launch optics, such as a lens system or a multimode fibre, to overfill the test fibre over the full range of measurement wavelengths. This launch is relatively insensitive to the input end face position of the single-mode fibre and is ~~sufficient~~ able to excite the fundamental and any higher-order modes in the specimen. If using a butt splice, provide means of avoiding interference effects.

When using a multimode fibre, overfilling the reference fibre can produce an undesired ripple effect in the power-transmission spectrum. Restrict the launch sufficiently to eliminate the ripple effect. One example of restricted launch is in method A, attenuation by cut-back, of IEC 60793-1-40. Another example of restricted launch is a mandrel-wrap mode filter with sufficient (approximately 4 dB) insertion loss.

7.4 Support and positioning apparatus

Provide a means to stably support the input and output ends of the specimen for the duration of the test; vacuum chucks, magnetic chucks, or connectors may be used for this purpose. Support the fibre ends such that they can be repeatedly positioned in the launch and detection optics. When measuring λ_{cc} in method B, provide a means to suitably support the cable ends. The mechanism used to hold the fibre ends allows for fibre positioning with respect to the launch and detection optics. Holding and moving of the fibre should not cause micro-bends that affect the measurement accuracy. 3

7.5 Deployment mandrel

7.5.1 General

~~Use a means to stably support the input and output ends of the specimen for the duration of the measurement. Support the fibre ends so that they can be repeatedly and stably positioned with respect to the launch and detection optics without introducing microbends into the specimen.~~

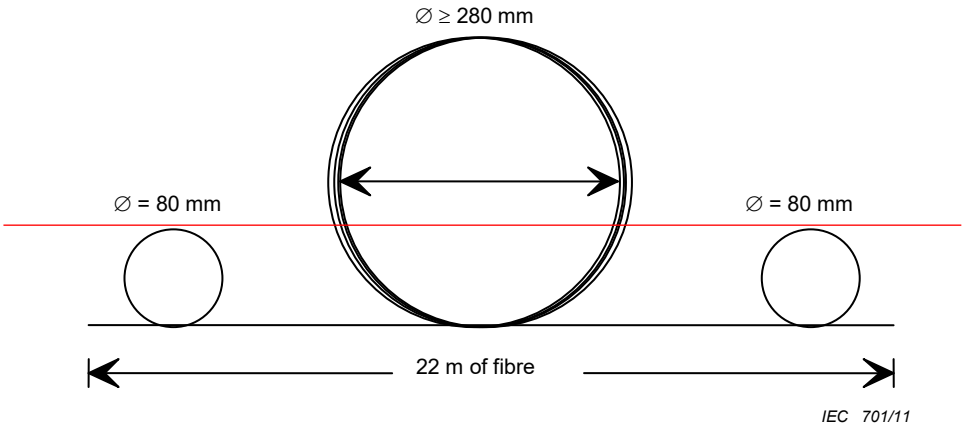
The fibre specimen's two ends, input and output, are mechanically held in place during the measurement. The deployment and length of the specimen, together with the support apparatus, are key elements of the measurement method, and they distinguish the types of cut-off wavelength.

Additional, alternative deployments may be used if the results obtained have been demonstrated to be empirically equivalent to the results obtained using the standard deployment, to within 10 nm, or they are greater than those achieved with the standard configurations.

7.5.2 Cable cut-off wavelength deployment, method A

Provide a means to make an 80 mm diameter loop at each end of the specimen and a loop of diameter ≥ 280 mm in the central portion. See Figure 2.

~~NOTE Two loops at one end can be substituted for one loop at each end.~~



Dimensions in millimetres

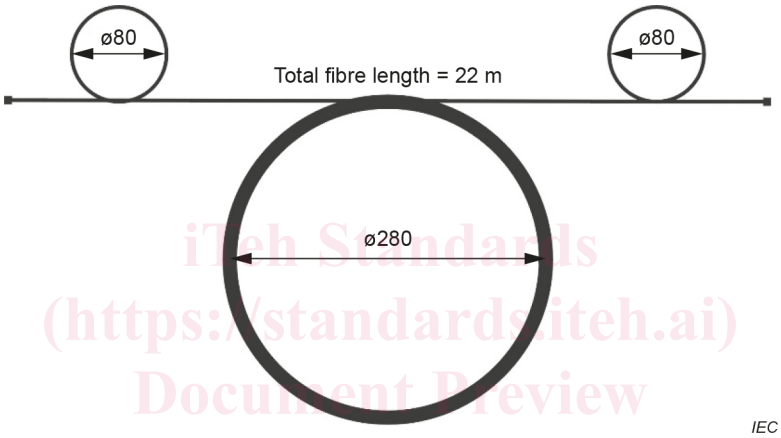
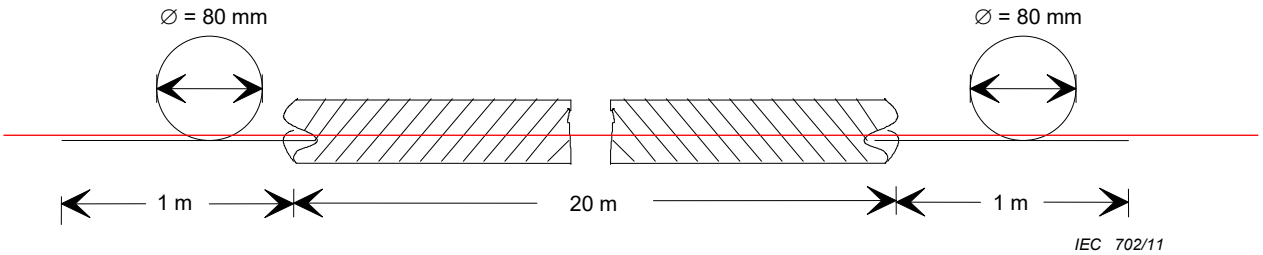


Figure 2 – Deployment configuration for cable cut-off wavelength λ_{cc}, method A

7.5.3 Cable cut-off wavelength deployment, method B

Provide a means to make an 80 mm diameter loop at each end of the specimen. See Figure 3. The cabled fibre between the two 80 mm loops has a bending diameter greater than 280 mm.

~~NOTE Two loops at one end can be substituted for one loop at each end.~~



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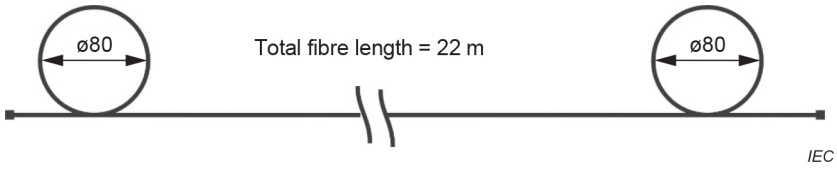
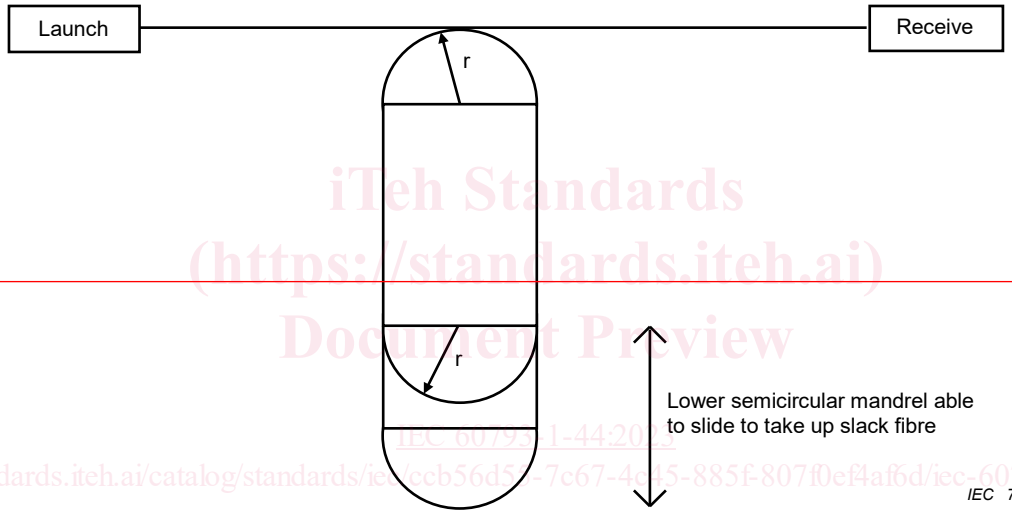


Figure 3 – Deployment configuration for cable cut-off wavelength λ_{cc}, method B

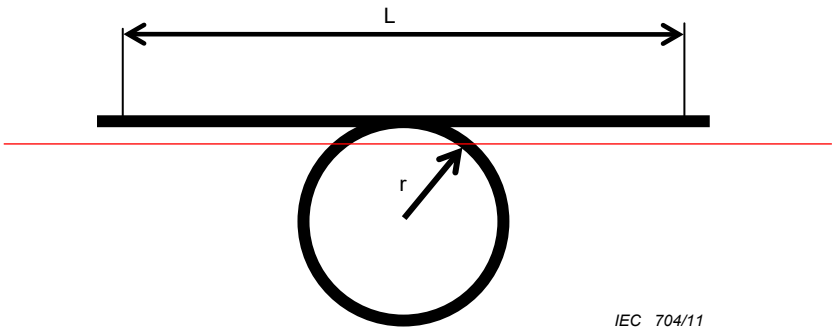
7.5.4 Fibre cut-off wavelength deployment, method C 4

~~Provide a circular mandrel as the initial fibre cut-off wavelength deployment. (See Figure 4a). A split, semicircular mandrel with a radius of 140 mm that is capable of sliding, hence able to take up slack fibre, is an alternative deployment . (See Figures 3 and 4b).~~

~~NOTE The introduction of a minimum bend of the cable sufficient to permit connection of the two ends of the whole specimen to the measurement setup is allowed.~~



~~**Figure 3 – Default configuration to measure λ_c**~~



~~**Key**~~

~~r = 140 mm~~

~~L = 2 m (entire fibre length)~~

~~**Figure 4a) – Initial deployment configuration for fibre cut-off wavelength measurement – circular mandrel**~~