IEC 60793-1-44

Edition 2.0 2011-04

INTERNATIONAL STANDARD

NORME INTERNATIONALE

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

Fibres optiques –
Partie 1-44: Méthodes de mesure et procédures d'essai – Longueur d'onde de coupure

IEC 60793-1-44:2011

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FOREWORD

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

This second edition cancels and replaces the first edition published in 2001. This edition constitutes a technical revision.

The main change with respect to the previous edition is the withdrawal of Annex D.

Annexes A, B and C form an integral part of this standard.

This standard should be read in conjunction with IEC 60793-1-1.

This bilingual edition corresponds to the monolingual English version, published in 2011-04.

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

FDIS	Report on voting
86A/1369/FDIS	86A/1385/RVD

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

The French version of this standard has not been voted upon.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 60793-1-4x 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 publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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- withdrawn,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

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 standard gives the methods for measuring the cut-off wavelength of fibre and cable

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).

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

- bend-reference technique;
- multimode-reference technique using category A1 multimode fibre.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

3 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.

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 it is short and uncabled. Consequently, there are two overall types of cut-off wavelength:

- Cable cut-off wavelength, measured in an uncabled fibre deployment condition (method A), or in a cabled condition (method B);
- Fibre cut-off wavelength, measured on a short length of uncabled, primary-coated fibre.

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

4 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.

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.

This procedure 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 standard, will generally exhibit a value larger than λ_{cc}. For normal installed cable spans, it is common for the measured λ_c value to exceed the system 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).

5 Mapping functions

A mapping function is a formula by which the measured results of one type of cut-off wavelength are used to predict the results that one would obtain from another type.

An empirical mapping function is specific to a particular fibre type and design. Generate mapping functions by doing an experiment in which samples of fibre are chosen to represent the spectrum of cut-off wavelength values for the fibre type, then measure the values using the two methods to be mapped. Linear regression of the respective values will often produce a satisfactory mapping function. When establishing criteria for fibre selection, residual errors in the regression shall be taken into account.

The customer and the supplier shall agree to the confidence level of each mapping function established.

6 Reference test method

Method A of cable cut-off wavelength, using uncabled fibre, is the reference test method (RTM), which shall be the one used to settle 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 fibres, B5 fibres or some category C fibres.

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 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.

7.5 Cladding mode stripper

Provide a means to remove cladding-mode power from the specimen. Under some circumstances, the fibre coating will perform this function; otherwise, provide methods or devices that extract cladding-mode power at the input and output ends of the specimen.

7.6 Deployment mandrel

7.6.1 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 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.

7.6.2 Cable cut-off wavelength, 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 1.

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

7.6.3 Cable cut-off wavelength, Method B

Provide a means to make an 80 mm diameter loop at each end of the specimen. See Figure 2.

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

7.6.4 Fibre cut-off wavelength, Method C

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).

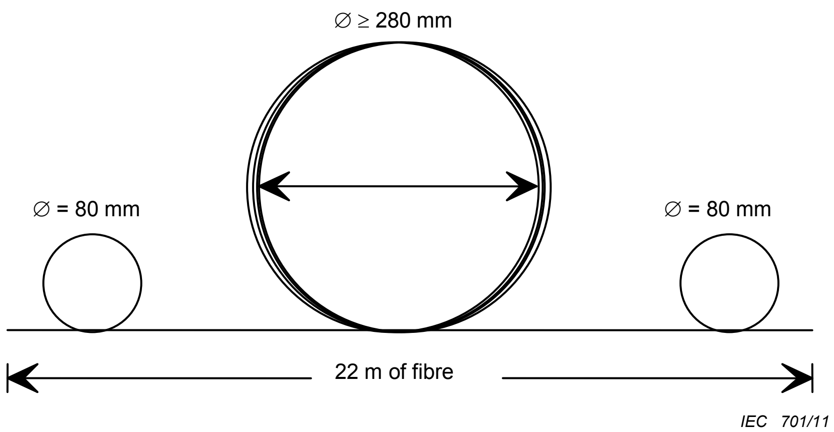


Figure 1 – Deployment configuration for cable cut-off wavelength, method A

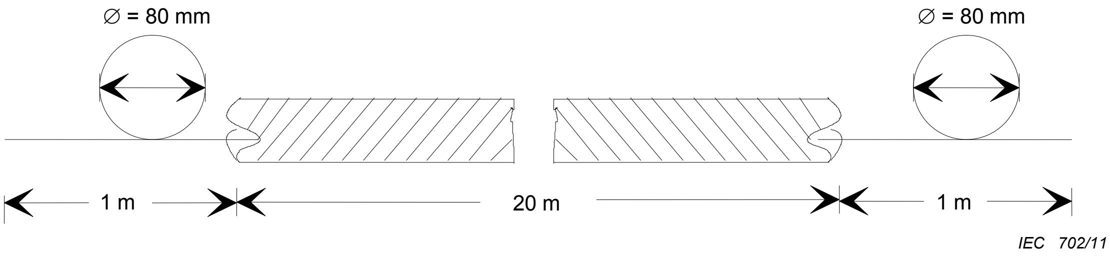


Figure 2 – Deployment configuration for cable cut-off wavelength, method B

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.

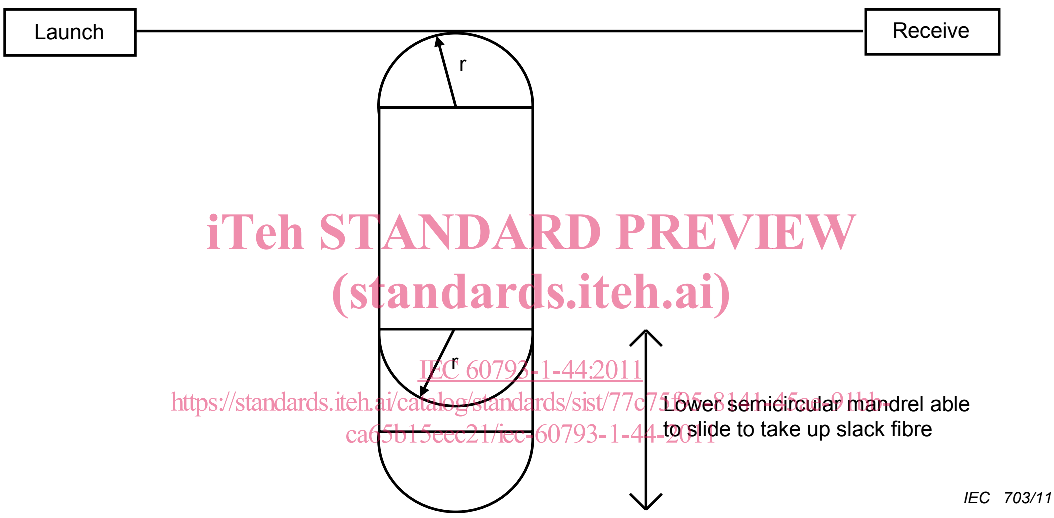
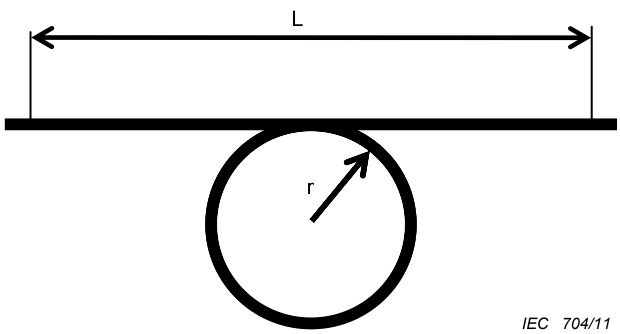


Figure 3 – Default configuration to measure λ_c

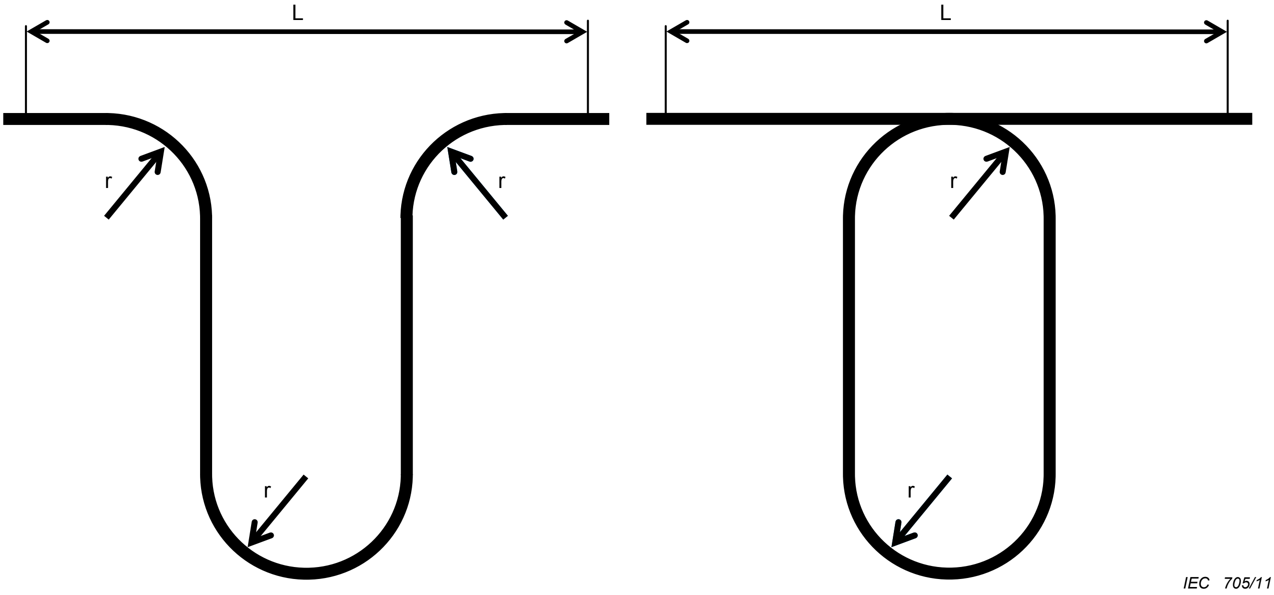


Key

r = 140 mm

L = 2 m (entire fibre length)

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



Key

r = 140 mm

L = 2 m (entire fibre length)

Figure 4b) – Alternative deployment configuration for fibre cut-off wavelength measurement – split mandrel

Figure 4 – Deployment configurations for fibre cut-off measurement

7.7 Detection optics

Couple all power emitted from the specimen onto the active region of the detector. As examples, an optical lens system, a butt splice with a multimode fibre pigtailed to a detector, or direct coupling may be used.

7.8 Detector assembly and signal detection electronics

Use a detector that is sensitive to the output radiation over the range of wavelengths to be measured and that is linear over the range of intensities encountered. A typical system might include a germanium or InGaAs photodiode, operating in the photo-voltaic mode, and a current-sensitive preamplifier, with synchronous detection by a lock-in amplifier. Generally, a computer is required to analyse the data.

8 Sampling and specimens

8.1 Specimen length

Choose the specimen length according to which parameter is being measured and, if the parameter is cable cut-off wavelength, the method to be used. See the appropriate annex: Annex A or B for the cable cut-off wavelength measurement or Annex C for fibre cut-off wavelength.