

JAPANESE
INDUSTRIAL
STANDARD

Translated and Published by
Japanese Standards Association

JIS C 6825 : 2020

(OITDA/JSA)

**Test methods for structural
parameters of optical fibers—
Optical characteristics**

ICS 33.180.10

Reference number : JIS C 6825 : 2020 (E)

Date of Establishment: 1989-01-01

Date of Revision: 2020-08-20

Date of Public Notice in Official Gazette: 2020-08-20

Investigated by: Japanese Industrial Standards Committee
Standards Board for IEC area

JIS C 6825:2020, First English edition published in 2021-07

Translated and published by: Japanese Standards Association
Mita MT Building, 3-13-12, Mita, Minato-ku, Tokyo, 108-0073 JAPAN

In the event of any doubts arising as to the contents,
the original JIS is to be the final authority.

© JSA 2021

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 the publisher.

Printed in Japan

PROTECTED BY COPYRIGHT

Contents

	Page
Introduction	1
1 Scope	1
2 Normative references	1
3 Terms and definitions	2
4 Classification of optical fibers	2
5 Test site conditions	3
6 Test methods of numerical aperture (NA)	3
6.1 Overview of test method	3
6.2 Reference test method	4
6.3 FFP method	5
6.4 Reflection method	9
6.5 Specification information	10
7 Test methods of cut-off wavelength	11
7.1 Types of cut-off wavelength	11
7.2 Overview of test method	11
7.3 Mapping functions	12
7.4 Reference test method	12
7.5 Apparatus	12
7.6 Sampling and specimens	14
7.7 Positioning of specimen in apparatus	14
7.8 Procedure and calculation method	14
7.9 Results	14
7.10 Specification information	15
8 Test methods of mode field diameter (MFD)	15
8.1 General consideration	15
8.2 Reference test method	16
8.3 Apparatus	16
8.4 Sampling and specimens	18
8.5 Procedure	18
8.6 Calculations of MFD	18
8.7 Results	20
8.8 Specification information	21
Annex A (normative) Requirements related to numerical aperture test apparatus used in FFP method and reflection method	22
Annex B (informative) Mapping NA measurement to alternative lengths	29

Annex C (normative)	Product specific default values for NA measurement	30
Annex D (normative)	Requirements specific to cut-off wavelength test Method A — Cable cut-off wavelength (λ_{cc}) using uncabled fiber	31
Annex E (normative)	Requirements specific to cut-off wavelength test Method B — Cable cut-off wavelength (λ_{cc}) using cabled fiber	32
Annex F (normative)	Requirements specific to cut-off wavelength test Method C — Fiber cut-off wavelength (λ_c)	33
Annex G (normative)	Measurement of cut-off wavelength using bend reference technique and calculation procedure	35
Annex H (normative)	Measurement of cut-off wavelength using multimode reference technique and calculation procedure	37
Annex I (normative)	Curve-fitting technique for improved precision of cut-off wavelength test	39
Annex J (normative)	Requirements specific to Method A — Mode field diameter by direct far-field scan	42
Annex K (normative)	Requirements specific to Method B — Mode field diameter by variable aperture in the far field	44
Annex L (normative)	Requirements specific to Method C — Mode field diameter by near-field scan	47
Annex M (normative)	Requirements specific to Method D — Mode field diameter by optical time domain reflectometer (OTDR)	50
Annex N (informative)	Sample data sets and calculated values	55
Annex JA (informative)	Comparison table between JIS and corresponding International Standards	57

Foreword

This Japanese Industrial Standard has been revised by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee as the result of proposal for revision of Japanese Industrial Standard submitted by Optoelectronic Industry and Technology Development Association (OITDA)/Japanese Standards Association (JSA) with a draft being attached, based on the provision of Article 12, paragraph (1) of the Industrial Standardization Act applied mutatis mutandis pursuant to the provision of Article 16 of the said Act. This edition replaces the previous edition (**JIS C 6825:2009**), which has been technically revised.

This **JIS** document is protected by the Copyright Act.

Attention is drawn to the possibility that some parts of this Standard may conflict with patent rights, published patent application or utility model rights. The relevant Minister and the Japanese Industrial Standards Committee are not responsible for identifying any of such patent rights, published patent application or utility model rights.

Blank

Test methods for structural parameters of optical fibers—Optical characteristics

Introduction

This Japanese Industrial Standard has been prepared based on **IEC 60793-1-1:2017**, Edition 4, **IEC 60793-1-43:2015**, Edition 2, **IEC 60793-1-44:2011**, Edition 2 and **IEC 60793-1-45:2017**, Edition 2 by incorporating the part corresponding to this Standard without any modifications of the technical contents, but also adding some **JIS** specification contents (classification of optical fiber, standard atmospheric condition and test method for all plastic multimode optical fiber) that are not given in the said corresponding International Standards.

The dotted underlines indicate changes from the corresponding International Standard. A list of modifications with the explanations is given in Annex JA.

1 Scope

This Standard specifies the test methods for structural parameters related to the optical characteristics of optical fibers or jacketed optical fibers of single-mode optical fibers, silica-based multimode optical fibers, multi-component multimode optical fibers, plastic cladding multimode optical fibers, all plastic multimode optical fibers and intraconnection optical fibers (hereafter generically referred to as optical fibers).

NOTE The International Standards corresponding to this Standard and the symbol of degree of correspondence are as follows.

IEC 60793-1-1:2017 *Optical fibres—Part 1-1: Measurement methods and test procedures—General and guidance*

IEC 60793-1-43:2015 *Optical fibres—Part 1-43: Measurement methods and test procedures—Numerical aperture measurement*

IEC 60793-1-44:2011 *Optical fibres—Part 1-44: Measurement methods and test procedures—Cut-off wavelength*

IEC 60793-1-45:2017 *Optical fibres—Part 1-45: Measurement methods and test procedures—Mode field diameter* (overall evaluation: MOD)

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standards and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21-1**.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS C 6820 *General rules of optical fibers*

NOTE Corresponding International Standards: IEC 60793-1-1 *Optical fibres—Part 1-1: Measurement methods and test procedures—General and guidance* and IEC 60793-2 *Optical fibres—Part 2: Product specifications—General*

JIS C 6823 *Measuring methods for attenuation of optical fibers*

NOTE Corresponding International Standards: 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*, 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* and IEC/TR 62221 *Optical fibres—Measurement methods—Microbending sensitivity*

JIS C 6832 *Silica glass multimode optical fibers*

NOTE Corresponding International Standard: IEC 60793-2-10 *Optical fibres—Part 2-10: Product specifications—Sectional specification for category A1 multimode fibres*

JIS C 6834 *Plastic cladding multimode optical fibers*

NOTE 1 Corresponding International Standard: IEC 60793-2-30 *Optical fibres—Part 2-30: Product specifications—Sectional specification for category A3 multimode fibres*

NOTE 2 The current edition of **JIS C 6834** is based on **IEC 60793-2:1992**. If any doubt arises, check **IEC 60793-2-30** which the corresponding International Standard refers to.

JIS C 6837 *All plastic multimode optical fibers*

NOTE Corresponding International Standard: IEC 60793-2-40 *Optical fibres—Part 2-40: Product specifications—Sectional specification for category A4 multimode fibres*

JIS C 60068-1 *Environmental testing—Part 1: General and guidance*

NOTE Corresponding International Standard: IEC 60068-1:2013 *Environmental testing—Part 1: General and guidance*

IEC 60793-2-20 *Optical fibres—Part 2-20: Product specifications—Sectional specification for category A2 multimode fibres*

3 Terms and definitions

For the purpose of this Standard, the terms and definitions given in **JIS C 6820** apply.

4 Classification of optical fibers

Optical fibers covered by this Standard are classified into 20 types given in Table 1 according to classification specified in **JIS C 6820**.

Table 1 Classification of optical fibers

Type of optical fiber	JIS symbol	IEC symbol (reference)
Silica-based graded index type multimode optical fiber	<u>SGI</u>	A1
Silica-based step index type multimode optical fiber	<u>SSI</u>	A2
Silica-based quasi step index type multimode optical fiber	<u>SQI</u>	A2
Multi-component step index type multimode optical fiber	<u>CSI</u>	—
Plastic cladding step index type multimode optical fiber	<u>RSI</u>	A3
All plastic step index type multimode optical fiber	<u>PSI</u>	A4
All plastic graded index type multimode optical fiber	<u>PGI</u>	A4
Silica-based 1 310 nm dispersion-unshifted type single-mode optical fiber	<u>SMA</u>	B1.1
Silica-based 1 550 nm cut-off shifted type single-mode optical fiber	<u>SMA • T</u>	B1.2
Silica-based 1 310 nm dispersion-unshifted, low OH type single-mode optical fiber	<u>SMA • U</u>	B1.3
Silica-based 1 550 nm dispersion-shifted type single-mode optical fiber	<u>SMB</u>	B2
Silica-based dispersion-flattened type single-mode optical fiber	<u>SMC</u>	—
Silica-based non-zero dispersion-shifted type single-mode optical fiber	<u>SMD</u>	B4
Silica-based wideband non-zero dispersion-shifted type single-mode optical fiber	<u>SME</u>	B5
Silica-based low OH, bending loss insensitive type single-mode optical fiber	<u>SMF • A</u>	B6_a
Silica-based bending loss insensitive type single-mode optical fiber	<u>SMF • B</u>	B6_b
Intraconnection optical fiber suitable for use with SMA at wavelengths from 1 260 nm to 1 625 nm.	<u>ICA</u>	C1
Intraconnection optical fiber suitable for use at wavelengths from 1 260 nm to 1 360 nm.	<u>ICB</u>	C2
Intraconnection optical fiber suitable for use at wavelengths from 1 530 nm to 1 625 nm.	<u>ICC</u>	C3
Intraconnection optical fiber suitable for use at wavelength 980 nm	<u>ICD</u>	C4

5 Test site conditions

The conditions of the test site shall be in accordance with the standard atmospheric conditions (temperature 15 °C to 35 °C, relative humidity 25 % to 75 %, atmospheric pressure 86 kPa to 106 kPa) as given in 4.3 of **JIS C 60068-1**. If testing under the standard atmospheric conditions is not feasible, it may be carried out under other conditions as long as no doubt arises in judgement. In this case, the applied conditions shall be recorded in the report.

6 Test methods of numerical aperture (NA)

6.1 Overview of test method

The numerical aperture (NA) of multimode optical fiber of SGI, SSI, SQI, RSI and PSI is an important parameter that describes a fiber's light gathering ability. It is used to predict launching efficiency, joint loss at splices, microbending performance and bending loss performance. The numerical aperture is defined by measuring the far-field

pattern [FFP (Far-Field Pattern) method]. In some cases the maximum theoretical numerical aperture (NA_{th}) is used in the literature, which can be determined from measuring the difference in refractive indexes between the core and cladding. Ideally these two methods should produce the same value.

As background the maximum theoretical numerical aperture NA_{th} of a multimode fiber is defined by Equation (1):

$$NA_{th} = \sin \theta_m \dots\dots\dots (1)$$

where, NA_{th} : maximum theoretical numerical aperture;
 θ_m : largest incident meridional ray angle that will be guided by the fiber (rad).

In terms of the fiber index profile:

$$NA_{th} = \sqrt{n_1^2 - n_2^2} \dots\dots\dots (2)$$

where, n_1 : maximum refractive index of the core;
 n_2 : average refractive index of the cladding far from the core region.

Figure 1 below shows a refractive index profile of a graded index multimode fiber and indicates n_1 and n_2 .

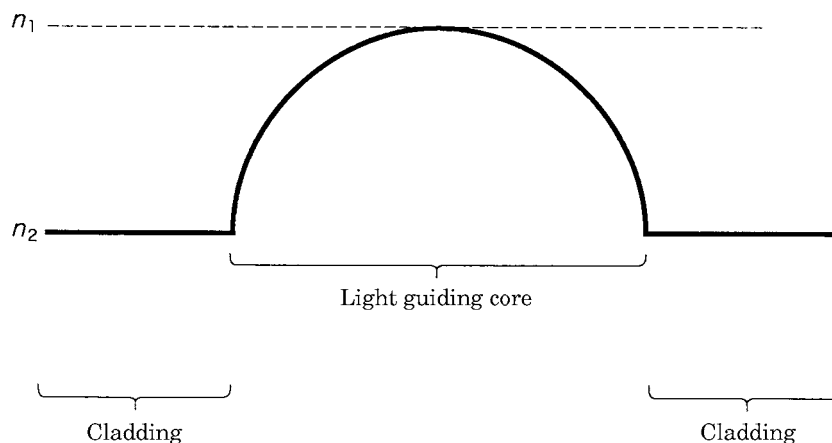


Figure 1 Representative refractive index profile for a graded index multimode fiber

Far-field numerical aperture NA_{ff} can be determined from a far-field pattern (FFP) measurement on a short length of fiber or from a measurement of a fiber's refractive index profile.

6.2 Reference test method

The reference test method (RTM) for measuring numerical aperture is the FFP measurement defined in this Standard. For the measurement of theoretical numerical aperture of all plastic multimode optical fiber, the reflection method may be used.

6.3 FFP method

6.3.1 Overview of test method

Using the far-field pattern method, the intensity pattern, $I(\theta)$, of a fiber is acquired, and the NA_{ff} (numerical aperture in the far-field) is defined as the sine of the half-angle where the intensity has decreased to a threshold percentage (k_{NA} %) of its maximum value. The threshold used depends on the type of multimode fiber being measured and are given in the detailed product specification for the fiber being measured.

6.3.2 Apparatus

The input and output systems and detection system mechanics shall be as shown in Clause A.1.

6.3.3 Sampling and specimens

6.3.3.1 Specimen length

The NA_{ff} can be impacted by the specimen length. For this reason, the specimen length is given as part of the detailed product specifications including **JIS C 6832**, **JIS C 6834**, **JIS C 6837** and **IEC 60793-2-20**. Default values are also listed in Annex C. Longer specimen lengths than what are practical to measure on a regular basis may be required for some products. In these cases a mapping function may be used as described in informative Annex B.

6.3.3.2 Specimen endface

Prepare a flat endface, orthogonal to the fiber axis, at the input and output ends of each specimen. The accuracy of these measurements is affected by a non-perpendicular endface. End angles less than 2° are recommended.

6.3.4 Procedure

The following procedure shall be followed.

- Place the specimen ends in the support devices. The input end shall be approximately at the centre of the input place of the focused image of the constant radiance spot.
- Set the optical source to the desired wavelength and spectral width.
- Scan the far-field radiation pattern along a diameter and record intensity versus angular position.

6.3.5 Calculations

6.3.5.1 Far-field versus maximum theoretical value

The relationship between the far-field numerical aperture NA_{ff} and the maximum theoretical numerical aperture NA_{th} as described in Equation (3) is dependent upon the measurement wavelength of the far-field and profile measurements. Most far-field measurements are made at 850 nm, whereas profile measurements are commonly made at 540 nm or 633 nm. For these wavelengths, the relationship between NA_{ff} and NA_{th} is given by Equation (3):

$$NA_{ff} = \beta NA_{th} \dots\dots\dots (3)$$

where, NA_{ff} : numerical aperture in the far-field;
 $\beta=0.95$ when the profile measurement is made at 540 nm,
and $\beta=0.96$ when the measurement is made at 633 nm;
 NA_{th} : maximum theoretical numerical aperture.

Report NA_{ff} at 850 nm as the fiber numerical aperture. This value may be obtained directly from a far-field measurement at 850 nm or, using Equation (6), indirectly from a profile measurement.

For the far-field and profile measurements of all plastic multimode fibers shown in Table 2, the wavelength used shall be normally 633 nm or 650 nm.

Table 2 Fibers to be measured at wavelength of 633 nm or 650 nm

PSI-485/500	PSI-735/750	PSI-980/1000-A1 and A2	PSI-980/1000-B	PGI-500/750
-------------	-------------	------------------------	----------------	-------------

6.3.5.2 Threshold intensity angle, θ_k

Normalize the scanned pattern to the peak intensity. For measurement Techniques 1, 2 and 3, note the points on the pattern at which the intensity is k_{NA} % of the maximum. The value of k_{NA} is product specific. For this reason, they are given as part of the detailed product specifications including **JIS C 6832**, **JIS C 6834**, **JIS C 6837** and **IEC 60793-2-20**. Default values listed in Annex C shall be used for measurement. Record half the angle between these points as θ_k .

6.3.5.3 Far-field numerical aperture NA_{ff}

When the NA measurement is conducted using Techniques 1 and 2, calculate the far-field numerical aperture using Equation (4):

$$NA_{ff} = \sin \theta_k \dots\dots\dots (4)$$

where, NA_{ff} : numerical aperture in the far-field;
 θ_k : threshold intensity angle (°).

Figure 2 gives an example of a far-field scan of a SGI-50/125-A2 multimode fiber with an $NA_{ff}=0.20$. The data is normalized so the maximum value of one is in the centre of the scan and the $k_{NA}=5$ % level is shown as a dashed line.

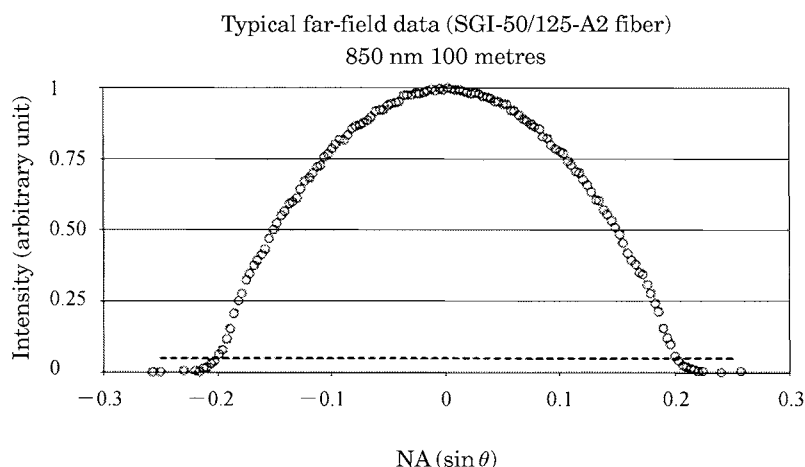


Figure 2 Example of a far-field NA measurement

6.3.5.4 Calculating far-field intensity pattern when using Technique 3

When using Technique 3, the distance, y , shall be transformed into the angle θ . This is done using the following approach.

Find the central y position y_0 in the scan by typical centring techniques (the average of the distance at which the intensity becomes 50 % is defined as y_0). Subtract y_0 from the recorded y positions, yielding a corrected set of positions, y' . Now calculate the set of θ 's using Equation (5):

$$\theta = \arcsin(y'/f) \dots\dots\dots (5)$$

Finally, compute the far-field intensity pattern using Equation (4).

6.3.5.5 Calculating NA when using Technique 4

When using Technique 4, a local minimum in the far-field intensity pattern is used to determine the numerical aperture. Figure 3 shows a representative data from this measurement.

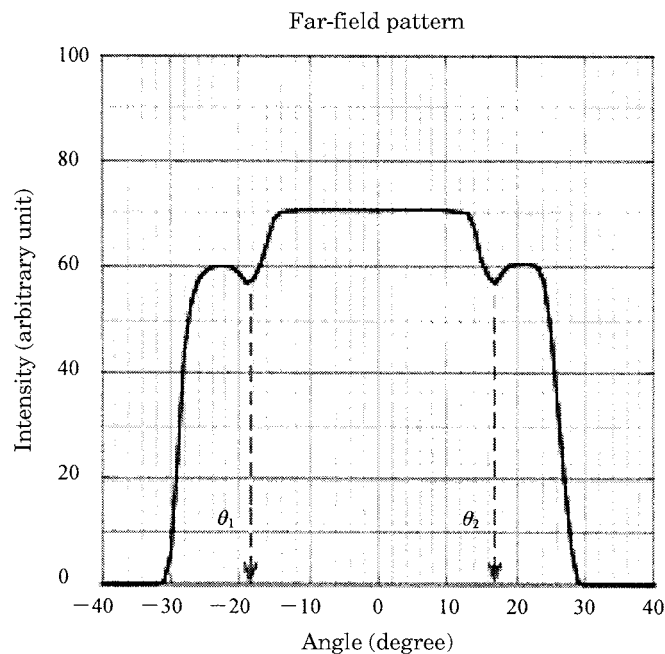


Figure 3 Sample output of a PSI-980/1000-B fiber measured using Technique 4

The two angles, θ_1 and θ_2 are determined by finding the local minimums as shown in Figure 3. The NA_{ff} is then determined using Equation (6) below:

$$NA_{ff} = \sin\left(\frac{|\theta_1| + |\theta_2|}{2}\right) \dots\dots\dots (6)$$

6.3.6 Results

6.3.6.1 Information available with each measurement

Report the following information with each measurement:

- date and title of measurement;
- identification of specimen;
- optical source wavelength;
- measurement results obtained from 6.3.5.

6.3.6.2 Information available upon request

The following information shall be available upon request:

- centre wavelength and spectral width of interference filters, if used;
- detection system technique used (method specified in Annex A);
- detection system calibration and angular resolution;
- size and numerical aperture of launch spot;
- technique used to strip cladding modes;
- specimen length(s).

6.4 Reflection method

6.4.1 Scope

This method measures the *NA* of an optical fiber from the reflected light intensity distribution of the end face of the all plastic multimode fiber.

6.4.2 Apparatus

The configuration of an apparatus used shall be as shown in Clause A.2.

6.4.3 Sampling and specimens

6.4.3.1 Specimen length

The specimen length is not specified.

6.4.3.2 Specimen endface

Prepare a flat endface, orthogonal to the fiber axis, at the input and output ends of each specimen. The accuracy of these measurements is affected by a non-perpendicular endface. End angles less than 2° are recommended.

6.4.4 Procedure

6.4.4.1 Preparation

Measure in advance the reflected light intensity V_0 of a flat and smooth surface with a known refractive index n_0 . Set the specimen of which the end face has been polished smooth by embedding in resins on an XY stage.

6.4.4.2 Measurement

Move the XY stage, and measure the reflected light intensity $V(x, y)$ at coordinates (x, y) .

6.4.5 Calculations

6.4.5.1 Refractive index $n(x, y)$

Calculate the refractive index by Equation (7):

$$n(x, y) = \frac{2}{1 - \left[\frac{V(x, y)}{V_0} R \right]^{\frac{1}{2}}} - 1 \quad \text{..... (7)}$$

where,

$$R = \left(\frac{n_0 - 1}{n_0 + 1} \right)^2 \quad \text{..... (8)}$$

6.4.5.2 Core/cladding boundary

From the refractive index profile shown in Figure 4, when the maximum relative index difference is taken as Δ , the boundary located at a distance of 0.05Δ from the cladding shall be taken as a core/cladding boundary.

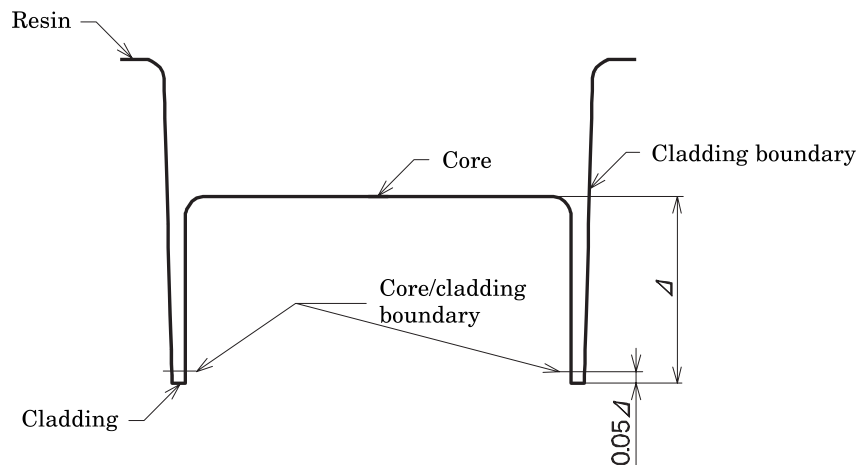


Figure 4 Refractive index profile

6.4.5.3 NA

Measure the reflected light intensity at multiple points for each core area and cladding area, and calculate the refractive index. Take each average as n_1 and n_2 .

Calculate the *NA* by Equation (2).

6.4.6 Results

6.4.6.1 Information available with each measurement

The following information shall be reported for each measurement:

- date and title of measurement;
- identification of specimen;
- optical source wavelength;
- measurement results obtained from **6.4.5**.

6.4.6.2 Information available upon request

The following information shall be available upon request:

- beam spot diameter at the end face of the optical fiber;
- number of measurement points of core/cladding refractive index;
- measured values of core/cladding refractive index;
- detection system calibration and angular resolution.

6.5 Specification information

The detail specification shall specify the following information:

- type of fiber measured;
- failure or acceptance criteria;
- information to be reported;
- any deviations to the procedure that apply;
- specimen length (except for the reflection method);

- optical source wavelength;
- threshold (k) (except for the reflection method).

7 Test methods of cut-off wavelength

7.1 Types of cut-off wavelength

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

In optical fibers, 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 fiber performance in a telecommunications network, theoretical cut-off wavelength is less useful than the lower value actually measured when the fiber 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 (LP_{01}) power has decreased to less than or equal to 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 fiber, the resulting value of cut-off wavelength depends on whether the measured fiber 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 (λ_{cc}), measured in an uncabled fiber deployment condition, or in a cabled condition;
- fiber cut-off wavelength (λ_c), measured on a short length of uncabled, primary-coated fiber.

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

The fiber cut-off wavelength, (λ_c), measured under the standard length and bend conditions described in this Standard, will generally exhibit a value larger than cable cut-off wavelength (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).

7.2 Overview of test method

This sub-clause specifies methods of measuring each of three types of cut-off wavelengths. The described test methods are applicable to all single-mode optical fiber.

Two methods exist for measuring cable cut-off wavelength (λ_{cc}).

- Method A: method using uncabled fiber
- Method B: method using cabled fiber

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

All of the methods shall use the transmitted-power technique, which measures the variation with wavelength of the transmitted power of a fiber under test compared to a reference transmitted-power wavelength scan. The reference scan uses one or both of the following two techniques for the measurement of all types of cut-off wavelengths. The reference scan normalizes wavelength-dependent fluctuations in the measurement equipment so that the attenuation of the LP₁₁ mode in the specimen can be properly characterized and the cut-off wavelength precisely determined:

- bend reference technique (using the specimen with an additional, smaller-radius fiber bend);
- multimode reference technique (using a separate SGI multimode fiber).

This procedure can determine the cut-off wavelength of a fiber specimen in either a cabled or uncabled condition. Each method has its own default configurations.

7.3 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 fiber type and design. Generate mapping functions by doing an experiment in which samples of fiber are chosen to represent the spectrum of cut-off wavelength values for the fiber 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 fiber 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.

7.4 Reference test method

Method A of cable cut-off wavelength, using uncabled fiber, shall be the reference test method (RTM).

7.5 Apparatus

7.5.1 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 silica-based single-mode optical fibers. An operating range of 800 nm to 1 700 nm may be necessary for some SMD fibers, SME fibers or some intraconnection optical fibers.

7.5.2 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.

7.5.3 Launch optics

Provide launch optics, such as a lens system or a multimode fiber, to overfill the test fiber over the full range of measurement wavelengths. This launch is relatively insensitive to the input end face position of the specimen, 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 fiber, overfilling the reference fiber 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 **JIS C 6823**. Another example of restricted launch is a mandrel-wrap mode filter with sufficient (approximately 4 dB) insertion loss.

7.5.4 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 fiber ends such that they can be repeatedly positioned in the launch and detection optics. When measuring the cable cut-off wavelength, λ_{cc} , in Method B, provide a means to suitably support the cable ends.

7.5.5 Cladding mode stripper

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

7.5.6 Deployment mandrel

Use a means to stably support the input and output ends of the specimen for the duration of the measurement. Support the fiber 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. The deployment of the mandrel used for measurements shall be as given in Annexes D, E and F. 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.

7.5.7 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 fiber pigtailed to a detector, or direct coupling may be used.

7.5.8 Detector assembly and signal detection electronics

Use a detector that is sensitive to the output radiation over the range of wavelengths to be measured. 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.

7.6 Sampling and specimens

7.6.1 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 D or E for the cable cut-off wavelength measurement or Annex F for fiber cut-off wavelength.

7.6.2 Specimen end face

Prepare a flat endface, orthogonal to the fiber axis, at the input and output ends of each specimen.

7.7 Positioning of specimen in apparatus

7.7.1 General requirements for all methods

Align the input and output ends of the specimen to the launch and detection optics. Do not change the launch and detection conditions during the course of the measurement.

Unless otherwise specified, when installing the specimen in the apparatus, and when using a cladding-mode stripper, take care to avoid imposing any additional fiber bends smaller than those specified in the configuration for the particular measurement being made.

7.7.2 Deployment requirements for each method

Deploy the specimen in accordance with requirements in 7.5, Annexes D, E and F:

- cable cut-off wavelength, Method A (see Annex D);
- cable cut-off wavelength, Method B (see Annex E);
- fiber cut-off wavelength, Method C (see Annex F).

7.8 Procedure and calculation method

Determine cut-off wavelength according to procedures specified in Annexes G and H:

- bend-reference technique (see Annex G);
- multimode-reference technique (see Annex H).

7.9 Results

7.9.1 Information available with each measurement

Report the following information with each measurement:

- date and title of measurement;
- identification of specimen;
- measurement results.

7.9.2 Information available upon request

The following information shall be available upon request:

- if measuring cable cut-off wavelength, the method used: A or B;
- length of specimen;
- reference technique used (bend or multimode);
- type of multimode fiber used (if using multimode-reference technique);
- description of all key equipment used (light source, launch optics, cladding-mode stripper, specimen-support mechanisms, and detection optics);
- description of monochromator (spectral scanning range, spectral width, and incremental steps);
- description of detection and recording techniques;
- description of deployment configuration used;
- typical plot of the spectral curve, $A_b(\lambda)$ or $A_m(\lambda)$;
- date of latest calibration of measurement equipment.

7.10 Specification information

The detail specification shall specify the following information:

- type of fiber or cable to be measured;
- failure or acceptance criteria;
- information to be reported;
- any deviations to the procedure that apply.

8 Test methods of mode field diameter (MFD)

8.1 General consideration

The mode field diameter (MFD) measurement represents a measure of the transverse extent of the electromagnetic field intensity of the guided mode in a fiber cross section, and it is defined from the far-field intensity distribution as a ratio of integrals known as the Petermann II definition [see Equation (9)].

The definitions of MFD are strictly related to the measurement configurations. The mathematical equivalence of these definitions (see Figure 5) results from transform relationships between measurement results obtained by different implementations.