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

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Contents

	Page
Introduction.....	1
1 Scope.....	1
2 Normative references	1
3 Terms and definitions	2
4 Classification of optical fibers	3
5 Test conditions	3
6 Optical fiber geometry measurement methods	3
6.1 Overview of method	3
6.2 Reference test method	4
6.3 Apparatus	5
6.4 Sampling and specimens	5
6.5 Procedure	5
6.6 Calculations	5
6.7 Results	5
6.8 Specification information	5
7 Coating geometry measurement method	6
7.1 Overview of method	6
7.2 Reference test method	6
7.3 Apparatus	6
7.4 Sampling and specimens	6
7.5 Procedure	7
7.6 Calculations	7
7.7 Results	7
7.8 Specification information	7
8 Length measurement	7
8.1 Overview of method	7
8.2 Reference test method	9
8.3 Apparatus	9
8.4 Sampling and specimens	9
8.5 Procedure	9
8.6 Calculations	9
8.7 Results	9
8.8 Specification information	10
Annex A (normative) Measurement method 1-A Refracted near-field method	11

Annex B (normative)	Measurement method 1-B Transverse interference method	14
Annex C (normative)	Measurement method 1-C Near-field light distribution method	18
Annex D (normative)	Measurement method 1-D Mechanical diameter method	24
Annex E (normative)	Measurement method 2-A Side-view light distribution method	27
Annex F (normative)	Measurement method 2-B Mechanical diameter method	31
Annex G (normative)	Measurement method 3-A Delay measuring method	32
Annex H (normative)	Measurement method 3-B Backscattering method	37
Annex I (normative)	Measurement method 3-C Fiber elongation method	44
Annex J (normative)	Measurement method 3-D Mechanical length method	48
Annex K (normative)	Measurement method 3-E Phase shift method	49
Annex JA (informative)	Comparison table between JIS and corresponding International Standards	56

Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of Economy, Trade and Industry, through deliberations at the Japanese Industrial Standards Committee as the result of proposal of revision of Japanese Industrial Standard submitted by Optoelectronic Industry and Technology Development Association (OITDA)/Japanese Standards Association (JSA) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law applicable to the case of revision by the provision of Article 14.

Consequently **JIS C 6822:1995** was revised and **JIS C 6862:1991** was withdrawn and both are replaced with this Standard.

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Attention is drawn to the possibility that some parts of this Standard may conflict with a patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have technical properties. The relevant Minister and the Japanese Industrial Standards Committee are not responsible for identifying the patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have the said technical properties.

Test methods for structural parameters of optical fibers— Dimensional characteristics

Introduction

This Japanese Industrial Standard has been prepared based on the first editions of **IEC 60793-1-20**, **IEC 60793-1-21** and **IEC 60793-1-22** published in 2001 with some modifications of the technical contents.

The portions with continuous sidelines or dotted underlines are the matters in which the contents of the corresponding International Standards have been modified. 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 dimensions 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 and all plastic multimode 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 60793-1-20:2001 *Optical fibres—Part 1-20: Measurement methods and test procedures—Fibre geometry*

IEC 60793-1-21:2001 *Optical fibres—Part 1-21: Measurement methods and test procedures—Coating geometry*

IEC 60793-1-22:2001 *Optical fibres—Part 1-22: Measurement methods and test procedures—Length measurement* (Overall evaluation: MOD)

The symbols which denote the degree of correspondence in the contents in the corresponding 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*

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

NOTE : Corresponding International Standard: IEC 60793-1-40 *Optical fibres—Part 1-40: Measurement methods and test procedures—Attenuation* (MOD)

JIS C 6827 *Test methods for chromatic dispersion of optical fibers*

NOTE : Corresponding International Standard: IEC 60793-1-42 *Optical fibres—Part 1-42: Measurement methods and test procedures—Chromatic dispersion* (MOD)

JIS C 6828 *End-face image analysis procedure for the calibration of optical fiber geometry test sets*

NOTE : Corresponding International Standard: IEC 61745 *End-face image analysis procedure for the calibration of optical fibre geometry test sets* (IDT)

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

3 Terms and definitions

For the purpose of this Standard, the terms and definitions given in clause 2 of JIS C 6820 and Annex A, and the following apply:

3.1 reference surface

surface defined in the detail specification, which may be either core or cladding

3.2 core concentricity error

distance between the center of the core and the center of the cladding for multimode optical fibers, and distance between the center of the near field profile and the center of the cladding for single-mode optical fibers

3.3 core diameter of multimode fiber

diameter of a circle approximating the circumference of the core area having a refractive index n_3 , which is a sum of refractive index of homogenous cladding n_2 and the difference between the maximum refractive index of the core n_1 and refractive index of homogenous cladding n_2 multiplied by the factor k

$$n_3 = n_2 + k(n_1 - n_2)$$

where, n_2 : refractive index of the homogenous cladding;

n_1 : maximum refractive index;

k : constant commonly called the “ k factor”.

The refractive index profile can be measured by profiling techniques such as the refracted near-field (RNF) or transverse interferometry measurements (TI), and by measurement of the near field of a fully illuminated core such as the transmitted near-field measurement (TNF). It is recommended that curve fitting be used with both the index profiling and the TNF techniques to improve the measurement precision of the core diameter.

NOTE 1 Typically, $k=0.025$ for either the fitted profiling methods or the unfitted TNF method, and is equivalent to a $k=0$ for the fitted TNF method.

NOTE 2 For fibers with refractive index profiles that have gradual transition region at their core/cladding boundary, a value of $k=0.05$ for the unfitted TNF method is equivalent to $k=0$ for the fitted TNF method.

NOTE 3 For single-mode optical fibers, the core boundary is not defined. Instead, the mode field diameter is defined and specified.

4 Classification of optical fibers

Optical fibers to which the test methods of structural parameters related to dimensions are applicable are classified as shown in table 1 in accordance with **JIS C 6820**.

Table 1 Classification of optical fibers

Type of optical fiber	JIS symbol	IEC symbol
Silica-based multimode fibers	SGI	A1
Silica-based multimode fibers	SQI, SSI	A2
Multi-component multimode fibers	CSI	None
Plastic cladding multimode fibers	RSI	A3
All plastic multimode fibers	PSI, PGI, PQI	A4
Single-mode 1 310 nm dispersion unshifted fibers	SMA	B1.1
Single-mode 1 550 nm cut-off shifted fibers	SMA · T	B1.2
Single-mode 1 310 nm dispersion unshifted, low OH fibers	SMA · U	B1.3
Single-mode 1 550 nm dispersion shifted fibers	SMB	B2
Single-mode dispersion flattened fibers	SMC	None
Single-mode non-zero dispersion shifted fibers	SMD	B4
Single-mode wideband non-zero dispersion-shifted fibers	SME	B5
Single-mode low OH, bending loss insensitive fibers	SMF · A	B6_a
Single-mode bending loss insensitive fibers	SMF · B	B6_b

5 Test conditions

The conditions of the test site shall be in accordance with the standard conditions (temperature of 15 °C to 35 °C, relative humidity of 25 % to 75 %, atmospheric pressure of 86 kPa to 106 kPa) as given in 5.3 of **JIS C 60068-1**. If testing under these conditions is not feasible, other conditions may be used, unless any doubt arises on judgment. In this case, the applied conditions shall be recorded in the report.

6 Optical fiber geometry measurement methods

6.1 Overview of method

The geometrical characteristics of uncoated optical fibers are fundamental values and are necessary for carrying out subsequent procedures such as handling, splicing, connectorization, cabling and measurements.

The fiber geometry characteristics are as follows and their measurement methods are shown in table 2.

- cladding diameter;
- cladding non-circularity;

- core diameter (multimode fiber only);
- core non-circularity (multimode fiber only);
- core-cladding concentricity error;
- theoretical NA (optional—multimode fiber only).

Table 2 Measurement methods

Method	Characteristics covered	Fiber category(ies) covered	Details
1-A Refracted near-field method ^{a), b)}	Cladding diameter Cladding non-circularity Core diameter Core non-circularity Core/cladding concentricity error Theoretical NA	All fibers shown in table 1	Annex A
1-B Transverse interference method	Core diameter Core non-circularity Theoretical NA	All multimode fibers shown in table 1	Annex B
1-C Near-field light distribution method ^{c)}	Cladding diameter Cladding non-circularity Core diameter Core non-circularity Core/cladding concentricity error	SGI, CSI, SQI, SSI, RSI, SMA, SMA · T, SMA · U, SMB, SMC, SMD, SME, SMF · A, SMF · B	Annex C
1-D Mechanical diameter method ^{d)}	Cladding diameter Cladding non-circularity	All fibers shown in table 1	Annex D
Notes ^{a)} The core diameter of single-mode fibers is not specified. ^{b)} Measurement of core diameter and the maximum theoretical NA of silica-based multimode fibers may also be made by this method. ^{c)} The single-near-field scan method can be used to determine a cross-sectional diameter of the core of silica-based multimode fibers. A core non-circularity value can be determined by scanning in multiple axes. ^{d)} In practice, for smooth and substantially circular fibers, mechanical diameter method gives a similar result to that obtained by the three aforementioned methods in which case cladding non-circularity of fiber can also be determined.			

6.2 Reference test method

The reference test method depends on fiber category such as:

- multimode fibers: near-field light distribution method (method 1-C)

NOTE : The characteristics of the core of multimode fibers are defined in terms of refractive index profile, which is measured with the refractive near-field method (method 1-A). Use method 1-C to settle disputes with regard to cladding diameter, cladding non-circularity and core-cladding concentricity error of multimode fibers.

- single-mode fibers: near-field light distribution method (method 1-C).

6.3 Apparatus

Annexes A, B, C and D include layout drawings and other equipment requirements for each of the methods A, B, C and D, respectively.

6.4 Sampling and specimens

6.4.1 Specimen length

See Annexes A, B, C and D, respectively, for the specimen length required for measurement.

6.4.2 Specimen end face

For methods 1-A and 1-C only, prepare a clean, flat end face, perpendicular to the fiber axis, at the input and output ends of each specimen. The accuracy of measurements performed by methods 1-A and 1-C is affected by a non-perpendicular end face. End angles less than 1° are recommended.

The tighter requirements are necessary for end faces when using method 1-C (see C.2).

Because method 1-D is side-view only, it does not have tight end face requirements.

6.5 Procedure

Annexes A, B, C and D document the procedures. Use the procedures given in **JIS C 6828** for calibration.

6.6 Calculations

See Annexes A, B, C and D for calculations.

6.7 Results

The following information shall be provided with each measurement:

- date and title of measurement;
- identification and description of specimen;
- measurement results for each parameter specified (see Annexes A to D).

The following information shall be available upon request:

- measurement method used: 1-A, 1-B, 1-C, or 1-D;
- specimen length;
- arrangement of measurement set-up;
- details of measurement apparatus (see Annexes A to D);
- relative humidity and ambient temperature at the time of the measurement;
- most recent calibration information.

6.8 Specification information

The detail specification shall specify the following information:

- type of test fiber;
- failure or acceptance criteria;

- information to be reported;
- any deviations to the procedure that apply.

7 Coating geometry measurement method

7.1 Overview of method

This method is for measuring the coating geometry of optical fiber and jacketed optical fiber. Coating geometry measurements are fundamental values that need to be known for subsequent procedures such as cabling, connectorization, splicing, handling and for making other measurements.

The fiber coating geometry characteristics are as follows, and their measurement methods are shown in table 3:

- coating diameter;
- coating non-circularity;
- coating/cladding concentricity error.

Table 3 Measurement methods

Method	Characteristics covered	Fiber category(ies) covered	Details
2-A Side-view ^{a), b)}	Coating diameter Coating non-circularity Coating/cladding concentricity error	All fibers shown in table 1	Annex E
2-B Mechanical	Coating diameter Non-circularity	All fibers shown in table 1	Annex F
Notes ^{a)} For certain coating parameters evaluation, the cladding diameter should be measured using this procedure. However, due to the relatively poor accuracy of the method, this value of cladding diameter cannot be considered as an alternative to the values obtained by the “optical fiber geometry measurement methods” (see clause 6). ^{b)} Coating-cladding concentricity error is not defined for all plastic multimode fiber.			

Both methods in table 3 are conducted off-line during inspection. Neither of them is suitable for on-line, in-process measurements. Information common to both measurements appears in 7.2 to 7.7. See also Annexes E and F.

7.2 Reference test method

The reference test method is the side-view light distribution method (method 2-A).

7.3 Apparatus

Annexes E and F include layout drawings and other equipment requirements.

7.4 Sampling and specimens

7.4.1 Specimen length

The specimen shall be a short length of fiber, or as specified in the detail specification.

7.4.2 Specimen end face

Because the end faces of the specimen are not involved in the measurement itself, it is not necessary to have tight end-face requirements.

7.5 Procedure

See Annexes E and F for procedure.

7.6 Calculations

See Annexes E and F for calculations.

7.7 Results

The following information shall be provided with each measurement:

- date and title of measurement;
- identification and description of specimen;
- measurement results as required by the detail specification.

The following information shall be available upon request:

- length of specimen;
- measurement method used: 2-A or 2-B;
- description of measurement apparatus arrangement;
- details of computation technique;
- date and details of the latest calibration.

7.8 Specification information

The detail specification shall specify the following information:

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

8 Length measurement

8.1 Overview of method

This method is for measuring the length and elongation of optical fiber (typically within cable). The length of an optical fiber is one of the most fundamental values and shall be known for the evaluation of transmission characteristics such as losses and bandwidths.

Characteristics specified related to the length of optical fibers and their measurement methods are shown in table 4.

Table 4 Measurement methods

Method	Characteristics covered	Fiber category(ies) covered	Details
3-A Delay measuring	Length	SGI and all single-mode fibers shown in table 1	Annex G
3-B Backscattering	Length	SGI and all single-mode fibers shown in table 1	Annex H
3-C Fiber elongation ^{a), b)}	Fiber elongation	SGI, SMA, SMA · T, SMA · U	Annex I
3-D Mechanical	Length	All fibers shown in table 1	Annex J
3-E Phase shift	Length	SGI and all single-mode fibers shown in table 1	Annex K
Notes ^{a)} The measurement of fiber elongation is part of several measurement methods for fibers and fiber optic cables, such as those in JIS C 6850. ^{b)} This measurement is applicable unreservedly to single-mode fibers. For silica-based multimode fibers, take particular care when interpreting the results because the results of this measurement may be influenced by interfering modal effects, for example, due to the occurrence of non-longitudinal stresses on the fiber. Application of the measurement to other multimode fibers is under consideration.			

8.1.1 Method 3-A Delay measuring method (see Annex G)

The delay measuring method applies to measurements of the fiber length by the measurement of the propagation time of an optical pulse or a pulse train on the basis of a known value of the group index of the fiber. Alternatively, this method is suitable for measuring the group index of a fiber of known length. Therefore, in practice this fiber length measurement method is calibrated against a known length of fiber of the same type.

8.1.2 Method 3-B Backscattering method (see Annex H)

The backscattering method, which is a single-sided measurement, uses an optical time domain reflectometer (OTDR), and measures the optical power backscattered from different points in the fiber to the beginning of the fiber.

8.1.3 Method 3-C Fiber elongation method (see Annex I)

This measurement method describes a procedure for determining the fiber elongation. It does not measure absolute strain, but instead measures the changes in strain from one loading condition to another.

8.1.4 Method 3-D Mechanical length method (see Annex J)

This measurement method describes a procedure for determining the fiber length by winding a fiber around a fixed diameter calibrated wheel that rotates. The length is determined by the number of revolutions of the wheel.

8.1.5 Method 3-E Phase shift method (see Annex K)

The phase shift method describes a procedure for determining the fiber length. The length is determined from the phase shift that occurs when a predetermined modulation frequency $f_{\max}$ is applied.

8.2 Reference test method

The reference test method varies depending on whether the fiber is cabled or not, such as

- uncabled fiber mechanical length method: (method 3-D);
- length of fiber within cable: backscattering method (method 3-B);
- elongation of fiber within cable: fiber elongation method (method 3-C);
- elongation of uncabled fiber: fiber elongation method (method 3-C).

8.3 Apparatus

Annexes G to K include layout drawings and other equipment requirements.

8.4 Sampling and specimens

See the appropriate Annexes G to K for specific requirements. General requirements follow. Prepare a flat end face, perpendicular to the fiber axes, at the input and output ends of each specimen for measurements based on optical delay measurements.

8.5 Procedure

See the appropriate Annexes G to K for procedure.

8.6 Calculations

See the appropriate Annexes G to K for calculations.

8.7 Results

The following information shall be provided with each measurement:

- date and title of measurement;
- identification and description of specimen (including whether fiber or cable);
- specimen length, or elongation;
- measurement method used: 3-A, 3-B, 3-C, 3-D or 3-E;
- other results, as required by the appropriate Annexes G to K.

The following information shall be available upon request:

- description of measurement apparatus arrangement;
- type and wavelength of measurement source;
- launch conditions;
- details of computation technique;
- date of latest calibration of equipment.

See Annexes G to K for any additional information that shall be available upon request.

8.8 Specification information

The detail specification shall specify the following information;

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

Annex A (normative)

Measurement method 1-A

Refracted near-field method

Introduction

The refracted near-field measurement directly measures the refractive index variation across the fiber (core and cladding). The method can be calibrated to give absolute values of refractive indexes. It can be used to obtain profiles of both single-mode and multimode fibers.

A.1 Apparatus

See figures A.1 and A.2 for schematic diagrams of the test apparatus.

A.1.1 Source

Provide a stable laser giving a few milliwatts of power in the TEM₀₀.

A HeNe laser, which has a wavelength of 633 nm, may be used, but apply a correction factor to the results for extrapolation of different wavelengths.

Introduce a quarter-wave plate to change the beam from linear to circular polarization because the reflectivity of light at an air-glass interface is strongly angle and polarization-dependent.

If necessary, place a spatial filter, such as a pin-hole, at the focus of lens 1 (see figure A.2).

A.1.2 Launch optics

Arrange the launch optics of overfill the numerical aperture (NA) of the fiber. This brings a beam of light to a focus on the flat end of the fiber. The optical axis of the beam of light should be within 1° of the axis of the fiber. Determine the resolution of the equipment by the size of the focused spot, which should be as small as possible in order to maximize the resolution, e.g. less than 1.5 μm. The equipment enables the focused spot to be scanned across the fiber diameter.

A.1.3 Liquid cell

The liquid in the liquid cell shall have a refractive index slightly higher than that of the fiber cladding.

A.1.4 Sensing

Provide a suitable way to collect the refracted light and bring it to the detector, making sure that all the refracted light is captured. By calculation, determine the required size of the disc and its position along the central axis.

A.2 Sampling and specimens

Use a length of fiber less than 2 m.

Remove all fiber coatings from the section of fiber to be immersed in the liquid cell.

A.3 Procedure

Figure A.2 is a schematic diagram of the test apparatus.

A.3.1 Fiber index profile plot

Immerse the launch end of the test fiber in a liquid cell whose refractive index is slightly higher than that of the fiber cladding. The location of the fiber can be determined by a method such as back illumination with a tungsten light. Lenses 2 and 3 produce a focused image of the fiber.

Adjust the position of lens 3 to center and focus the fiber image, and simultaneously center and focus the laser beam on the fiber.

Center the disc on the output cone. For multimode fiber, position the disc on the optical axis to just black the leaky modes. For single-mode fiber, position the disc to give optimum resolution.

Collect the refracted modes passing the disc and focus them onto a photodiode. Traverse the focused laser spot across the fiber end, and directly obtain a plot of the fiber refractive index variation.

A.3.2 Equipment calibration

During the measurement, the angle of the cone of light varies according to the refractive index seen at the entry point to the fiber (hence the change of power passing the discs). With the fiber removed and the liquid index and cell thickness known, this change in angle can be simulated by translating the disc along the optic axis. By moving the disc to a number of predetermined positions, the profile can be scaled in terms of relative index. Absolute indices, i.e. n_1 and n_2 , can only be found if the cladding index or the liquid index, at the measurement wavelength and temperature, is known accurately.

A.4 Calculations

From the raster scan of the cross-section of the profile, calculate any or all of the following quantities:

- core diameter;
- cladding diameter;
- core/cladding concentricity error;
- core non-circularity;
- cladding non-circularity;
- maximum theoretical NA;
- index difference;
- relative index difference;
- indications of accuracy and reproducibility.

A.5 Results

In addition to the results listed in 6.7, and depending on the specification requirements, the following information shall be provided on request:

- Profiles through core and cladding centers calibrated for a given wavelength.
- Profiles along the core major and minor axes calibrated for a given wavelength.
- Profiles along the cladding major and minor axes calibrated for a given wavelength.

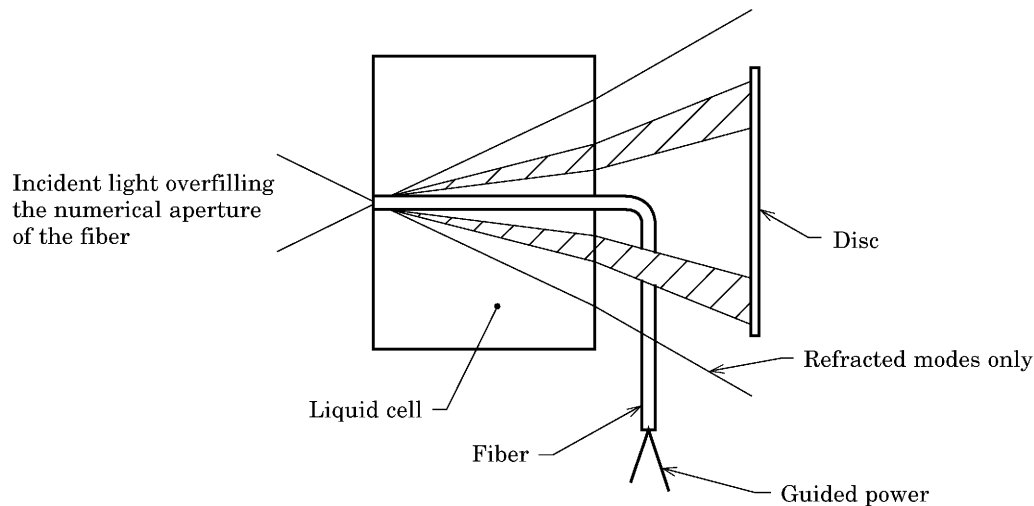


Figure A.1 Refracted near-field method—Schematic diagram

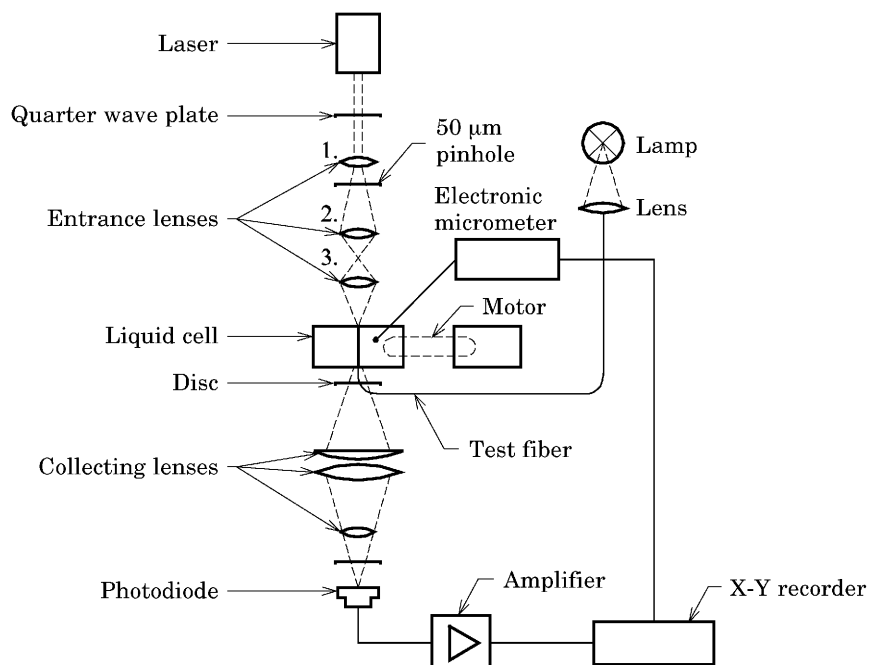


Figure A.2 Typical arrangement of the refracted near-field test set

Annex B (normative)

Measurement method 1-B

Transverse interference method

Introduction

This test method establishes procedures to be followed for determining the refractive index profile, $n(r)$, of an optical fiber specimen by transverse interferometry. The glass geometry characteristic parameters are then obtained by calculations involving the measured refractive index profile.

The method is based on the use of an interference microscope focused on the side view of a fiber specimen that is illuminated perpendicular to its axis so as to generate a fringe pattern. The refractive index profile is obtained from video detection and digitization of the interference fringes under computer control.

This method is particularly suited for the measurement of a core diameter and a maximum theoretical numerical aperture of a multimode fiber, but is less well suited for parameters related to the cladding.

B.1 Apparatus

Figure B.1 shows the equipment necessary to make this measurement.

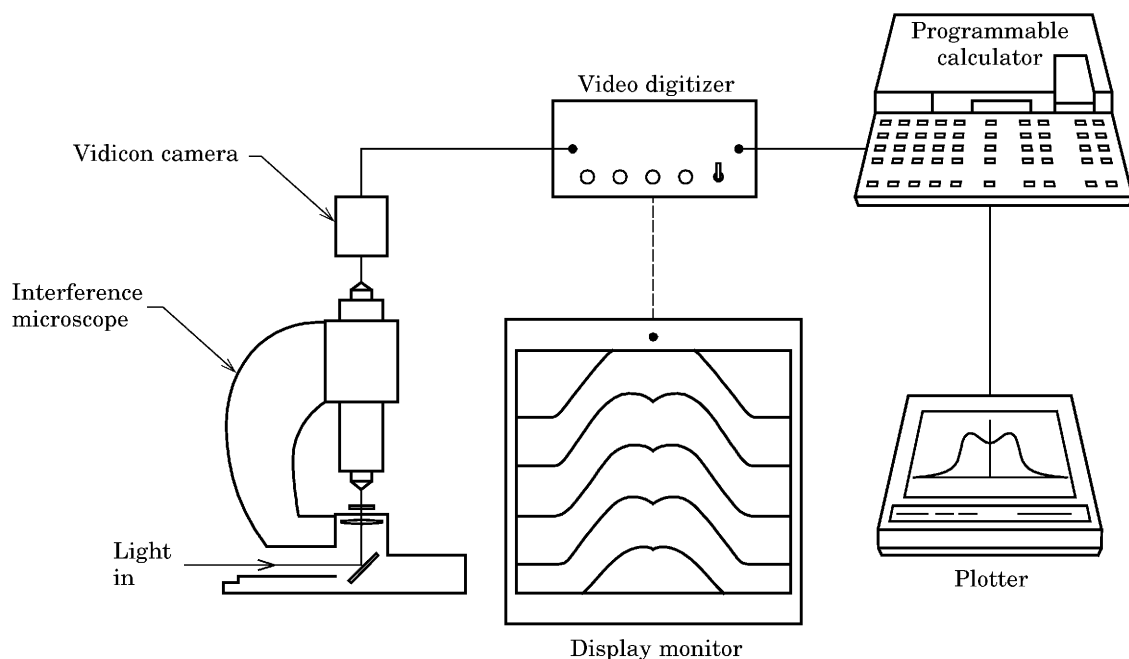


Figure B.1 Test apparatus

B.1.1 Transmitted light-interference microscope

This special-purpose microscope is a combination of two microscopes and an interferometer allowing the magnified image of the test objects to appear together with the interference fringes. A parallel condenser and objective lens system create a sample

test path and a reference path for the quasi-coherent illuminating light obtained using a narrow-band filter and a white light source.

B.1.2 Television camera and monitor

The camera produces an electronic picture that permits the quantification of fringe shading so that analytical methods can be utilized to locate precisely the center coordinates of a fringe. It also permits measurements to be made at wavelengths outside the visible spectrum. The monitor allows the operator to view the test specimen easily and aids in the set-up procedures necessary to provide proper adjustment of the specimen and the fringes.

B.1.3 Video digitizer

This unit operates with the camera and computer controller so that the output field of the microscope as seen by the camera can be digitized. The computer addresses a location on the camera vidicon, and the digitizer returns to the calculator, for example, an 8-bit binary number indicating shade of grey at the addressed location. The location of the point being encoded is indicated by a dot cursor on the monitor as an operator aid.

B.1.4 Computer and plotter

The computer accumulates intensity versus position data so that the displacement of a fringe from its cladding level can be determined as a function of core radial position. The computer calculates Δn and then plots the index profile along with the radial coordinates. The computer then determines a best-fit power-law curve to the index profile, and the curve is drawn by the plotter.

B.2 Sampling and specimens

Use a 20 mm length of clean, uncoated fiber for the specimen.

B.3 Procedure

B.3.1 Preparation

Place the specimen on its side under the test objective of the microscope on an optically flat specimen plate (supplied with the microscope). Then place equal amounts of oil having a refractive index equal to that of the cladding on the specimen plate and on the reference plate. Using $\times 100$ immersion objectives, raise the stage of the microscope until the objectives are in contact with the oil. Then locate the fiber in the field of view of the objective and focus it with the reference beam blocked.

Then unlock the reference beam and adjust the microscope controls to produce a high-contrast fringe pattern, as illustrated on the display monitor in figure B.1, where the curves in the fringes are caused by the core.

B.3.2 Axis orientation

Orient the fiber axis perpendicular to the fringe lines and adjust the separation between fringe lines using microscope controls so that approximately four fringes are visible on the monitor. For convenience of analysis, make the fringe lines parallel to the horizontal scan lines of the camera, again using microscope controls.