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**Test methods for chromatic
dispersion of optical fibers**

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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 in accordance with the Industrial Standardization Law.

Consequently **JIS C 6827 : 1995** is replaced with this Standard.

This Standard has been made based on **IEC 60793-1-42 : 2001** *Optical fibres—Part 1-42 : Measurement methods and test procedures—Chromatic dispersion* for the purposes of making it easier to compare this Standard with International Standard; to prepare Japanese Industrial Standard conforming with International Standard; and to propose a draft of an International Standard which is based on Japanese Industrial Standard.

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.

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the original JIS is to be the final authority.

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Test methods for chromatic dispersion of optical fibers

Introduction This Japanese Industrial Standard has been prepared based on the first edition of **IEC 60793-1-42** *Optical fibres—Part 1-42 : Measurement methods and test procedures—Chromatic dispersion* published in 2001 with some modifications of the technical contents of the original International Standard.

Portions given sidelines or dotted underlines are the matters in which the contents the original International Standard have been modified. A list of modification with the explanations is given in annex 1 (informative).

1 Scope This Standard specifies the methods for chromatic dispersion of silica glass single-mode optical fibres and silica glass graded-index multimode optical fibres (hereafter generically referred to as “optical fibres”).

Remarks : The International Standard corresponding to this Standard is as follows.

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

IEC 60793-1-42 : 2001 *Optical fibres—Part 1-42 : Measurement methods and test procedures—Chromatic dispersion*
(MOD)

2 Normative references The following standards contain provisions which, through reference in this Standard, constitute provisions of this Standard. If the indication of the year of publication is given to these referred standards, only the edition of indicated year constitutes the provision of this Standard but the revision and amendment made thereafter do not apply. The normative references without the indication of the year of coming into effect apply limiting only to the most recent editions (including the amendments).

JIS C 6820 *General rules of optical fibers*

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

IEC 60793-1-40 : 1995 *Optical fibres—Part 1-40 : Measurement methods and test procedures—Attenuation*

IEC 60793-1-31 : 2001 *Optical fibres—Part 1-31 : Measurement methods and test procedures—Tensile strength*

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

4 Classification of test methods Test methods are classified into phase shift (method A), pulse (method B), differential phase shift (method C) and interferometry (method D). Methods A, B and C apply to the measurement of chromatic dispersion of the following fibres over a specified wavelength range:

- silica glass graded-index multimode optical fibres (SGI);
- silica glass single-mode optical fibres (SSMA, SSMB, SSMC, SSMD)

Method D applies to the measurement of chromatic dispersion values of silica glass single-mode optical fibres in the 1 000 nm to 1 700 nm wavelength range.

The methods A, B and C are suitable for fibre or cable lengths greater than 1 km. They may also be applied to shorter lengths, but accuracy and repeatability may be compromised. Method D is the preferred method for shorter piece fibres (1 m to 10 m).

In addition, the measurements of chromatic dispersion of quartz graded-index multimode optical fibres is carried out in the vicinity of the wavelength where the maximum band can be obtained.

5 Test condition Unless specified otherwise, the tests are carried out under the standard condition (temperature of 15 °C to 35 °C, relative humidity of 25 % to 75 % and air pressure of 86 kPa to 106 kPa) specified in 5.3 of JIS C 60068-1. If the measurement under standard condition is difficult, it is allowed, unless questions arise about the assessment, to carry out the test under other condition than that of standard.

6 Overview of methods

6.1 Method A—Phase shift This method describes a procedure for determining the chromatic dispersion of silica glass single-mode optical fibres, and silica glass graded-index multimode optical fibres, over a specified wavelength range using the relative phase shifts among sinusoidally modulated optical sources of different wavelengths. The sources are typically laser diodes (LD) or filtered light emitting diodes (LED). Relative phase shifts are converted to relative time delays, and the resultant spectral group delay data are then fitted to an equation defined for each fibre type.

6.2 Method B—Pulse This method is also called “spectral group delay in the time domain”. It describes a procedure for determining the chromatic dispersion of silica glass single-mode optical fibres and quartz graded-index multimode optical fibres with the use of an Nd: YAG/fibre Raman laser source or multiple laser diodes operating at a number of wavelengths, both greater than and less than, the typical zero-dispersion wavelength.

In this method, the time difference of optical pulse delay through a known length of fibre at several wavelengths is measured. A reference set of measurements shall also be taken through a short reference fibre and data is subtracted from data taken from the fibre under test to obtain relative spectral group delay. The resultant spectral group delay data is then fitted to an equation defined for each fibre type.

6.3 Method C—Differential phase shift This method describes a procedure for determining the chromatic dispersion of silica glass single-mode optical fibres and silica glass graded-index multimode optical fibres. The dispersion coefficient at a

particular wavelength is determined from the differential group delay between two closely spaced wavelengths.

In this procedure, a modulated light source is coupled into the fibre under test, and the phase of the light exiting the fibre at a first wavelength is compared with the phase of the light exiting at a second wavelength. Average chromatic dispersion over the interval between the two wavelengths is determined from differential phase shift, wavelength interval, and fibre length.

The chromatic dispersion coefficient at a wavelength medial to the two test wavelengths is assumed to be equal to the average chromatic dispersion over the interval between the two wavelengths. The resultant chromatic dispersion data are then fitted to an equation defined for each fibre type.

6.4 Method D—Interferometry This method describes a procedure for determining the chromatic dispersion of silica glass single-mode optical fibres in the over 1 000 nm to 1 700 nm wavelength range. By using this test method, the chromatic dispersion of a short piece fibre can be measured.

In this test method, the wavelength-dependent time delay between the test sample and the reference path is measured by Mach-Zehnder interferometer. The reference path can be an air path or a single-mode fibre with known spectral group delay.

It should be noted that extrapolation of the chromatic dispersion values derived from the interferometric test in the fibres of a few metres length, to long fibre sections assumes longitudinal homogeneity of the fibre. This assumption may not be applicable in every case.

7 Reference test methods

7.1 Silica glass graded-index multimode optical fibres For silica glass graded-index multimode optical fibres, method B, spectral group delay in the time domain, is the reference test method.

7.2 Quartz single-mode optical fibres For silica glass single-mode optical fibres, method A, phase shift, is the reference test method. Method C, differential phase shift, may also be used to resolve disputes.

8 Apparatus The following apparatus is common to all measurement methods. Annexes A, B, C and D include layout drawings and other equipment requirements that individually apply for each of the methods A, B, C and D.

8.1 Launch optics The output from the signal sources shall be coupled to the fibre under test or the reference fibre such that the physical path length for each source is held constant during the measurement. (This requirement ensures that the relative phases of the sources do not change due to path length changes.) Suitable devices may include multichannel single-mode optical switches or demountable optical connectors.

When this method is used for silica glass graded-index multimode optical fibre, launch conditions shall comply with the impulse response specified in clause 13 of IEC 60793-1-4.

8.2 High-order mode filter (single-mode) When using this measurement method for single-mode optical fibre, use a method to remove high-order propagating modes in the wavelength range concerned. An example of such a high-order mode filter is a single loop of radius sufficiently small to shift cut-off wavelength below the minimum wavelength of interest.

8.3 Input positioning apparatus Provide means to couple the input of the specimen to the light source. Examples include the use of x-y-z micropositioner stages, or mechanical coupling methods such as connectors, vacuum splices, three-rod splices, etc. The position of the fibre shall remain stable over the duration of the test.

8.4 Output positioning apparatus Provide means of positioning the output end of the specimen such that the guided optical power is coupled to the system detector. Such coupling may include the use of lenses, or may be a mechanical connection to a detector pigtail.

8.5 Computation equipment A digital computer may be used for purposes of equipment control, data acquisition, and numerical evaluation of the data.

9 Sampling and specimens

9.1 Specimen length Methods A, B and C require the specimen to be a fibre or cable of known length sufficiently long to produce adequate phase measurement accuracy. A typical minimum length is 1 km. Method D, interferometry, requires a typical specimen length in the range of 1 m to 10 m.

9.2 Specimen end face Prepare a flat end face, orthogonal to the fibre axis, at the input and output ends of each specimen.

9.3 Reference fibre A fibre of the same type as the specimen shall be used to compensate for chromatic delays in the optical sources and other equipment components. The length of this fibre shall be less than or equal to 0.2 % of the specimen length. The temperature of the specimen should be stable during the measurement time, i.e. within 0.1 °C to 1 °C, depending upon the temporal behaviour of this change.

10 Procedure See annexes A, B, C and D for the procedures for methods A, B, C and D, respectively.

Reference fibre measurements are required for all methods. Reference fibre data can be stored for use in making measurements on the specimens. The reference fibre measurement procedure should be repeated when equipment changes on the source or receive optics or electronics occur.

11 Calculations The calculation of relative delay appropriate for each method is given in annexes A, B, C and D, respectively.

The remainder of this clause describes the numerical fit that can be applied for all methods to the spectral group delay data normalized by length, $\tau(\lambda)$.

The following is a list of symbols used and their explanations:

- λ is the wavelength (nm);
 $\tau(\lambda)$ is the normalized spectral group delay data fit (ps/km);
 $D(\lambda)$ is the chromatic dispersion coefficient, which = $d\tau/d\lambda$;
 λ_0 is the zero dispersion wavelength (nm);
 $\tau(\lambda_0)$ is the relative delay minimum at the zero dispersion wavelength, λ_0 ;
 S_0 is the dispersion slope at the zero dispersion wavelength (ps/nm² × km);
 $S(\lambda)$ is the dispersion slope (ps/nm² × km).

NOTE : $\tau(\lambda)$ and $D(\lambda)$ may either be direct measurements or the result of fitting the direct measurements to a specified function.

Where, for example, a data fitting function is specified, the parameters of the expression on the right side of the equation are determined so as to minimize the sum of squared errors with regard to the direct measurements. Once determined, this expression is used to determine the values of other various parameters.

The fit parameters are given as the variables a , b , c , d , or e .

11.1 Silica glass grated-index multimode and silica glass reference single-mode optical fibres The following applies to silica glass grated-index multimode optical fibres (SGI), and to silica glass reference single-mode optical fibres (SSMA) around 1 310 nm.

The delay data fit is as follows:

$$\tau(\lambda) = a + b\lambda^2 + c\lambda^{-2} \dots\dots\dots (1)$$

An equivalent form is given as:

$$\tau(\lambda) = \tau(\lambda_0) + \frac{S_0}{8} \left(\lambda - \frac{\lambda_0^2}{\lambda} \right)^2 \dots\dots\dots (2)$$

The chromatic dispersion is $D(\lambda) = d\tau/d\lambda$. For equations (1) and (2), these are, respectively:

$$D(\lambda) = 2(b\lambda - c\lambda^{-3}) \dots\dots\dots (3)$$

$$D(\lambda) = \frac{S_0}{4} \lambda \left(1 - \frac{\lambda_0^4}{\lambda^4} \right) \dots\dots\dots (4)$$

The zero dispersion wavelength is defined as

$$\lambda_0 = \left(\frac{c}{b} \right)^{\frac{1}{4}} \dots\dots\dots (5)$$

when the delay data are expressed according to equation (1).

At the zero dispersion wavelength the dispersion slope is defined as

$$S_0 = S(\lambda_0) = 8b \dots\dots\dots (6)$$

when using the dispersion representation of equation (3).

11.2 Dispersion shift single-mode optical fibres The following applies to dispersion shift single-mode optical fibres (SSMB).

Fit the measured group delay per unit fibre length versus wavelength by the quadratic expression:

$$\tau(\lambda) = \tau_0 + \left(\frac{S_0}{2} \right) (\lambda - \lambda_0)^2 \dots\dots\dots (7)$$

The chromatic dispersion coefficient can be determined from the differentiated quadratic expression:

$$D(\lambda) = (\lambda - \lambda_0)S_0 \dots\dots\dots (8)$$

The value of the dispersion slope is:

$$S(\lambda_0) = dD(\lambda_0)/d\lambda \text{ at } \lambda_0 \dots\dots\dots (9)$$

NOTES 1 These equations for $\tau(\lambda)$ and $D(\lambda)$ are sufficiently accurate over the 1 500 nm to 1 600 nm range. They are not meant to be used in the 1 300 nm region.

2 Alternatively, the chromatic dispersion coefficient can be measured directly, for example by the differential phase-shift method. In this case, fit a straight line directly to the dispersion coefficient for determining λ_0 and S_0 .

11.3 Dispersion flat single-mode optical fibres The following applies to silica glass dispersion flat single-mode optical fibres (SSMC).

The five-term delay data fit is as follows:

$$\tau(\lambda) = a + b\lambda^2 + c\lambda^{-2} + d\lambda^4 + e\lambda^{-4} \dots\dots\dots (10)$$

NOTE : Investigations have shown that in practice the fit coefficient will be small over the wavelength range 1 200 nm to 1 600 nm. Therefore, a simplified four-term fit can also be used:

$$\tau(\lambda) = a + b\lambda^2 + c\lambda^{-2} + d\lambda^4 \dots\dots\dots (11)$$

Obtain the chromatic dispersion by:

$$D(\lambda) = \frac{d\tau}{d\lambda} = 2b\lambda - 2c\lambda^{-3} + 4d\lambda^3 - 4e\lambda^{-5} \dots\dots\dots (12)$$

For the simplified four-term fit

$$D(\lambda) = 2b\lambda - 2c\lambda^{-3} + 4d\lambda^3 \dots\dots\dots (13)$$

NOTE : These equations are sufficiently accurate over the 1 200 nm to 1 600 nm range.

11.4 Non-zero dispersion shift single-mode optical fibres For this fibre type (SSMD) the minimum and maximum dispersion coefficients over a specified wavelength range are required. Fitting approaches for use with methods A and B are under consideration. Method C can be used to obtain these values directly.