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Test methods for bandwidth of
multimode 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.

Consequently **JIS C 6824**:1997 is 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 bandwidth of multimode optical fibers

Introduction

This Japanese Industrial Standard has been prepared based on the second edition of **IEC 60793-1-41** published in 2003 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 Standard have been modified. A list of modifications with the explanations is given in Annex JA.

1 Scope

This Standard specifies the test methods for bandwidth per unit length of silica-based multimode optical fibers, multi-component multimode optical fibers, plastic cladding multimode optical fibers and all plastic multimode optical fibers.

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

IEC 60793-1-41:2003 *Optical fibres—Part 1-41: Measurement methods and test procedures—Bandwidth* (MOD)

The symbols which denote the degree of correspondence in the contents in the corresponding International Standard 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. For standards with the year indication, only the editions of the indicated year shall be applied and any revisions (including amendments) made thereafter shall not be applied. For those without the indication of the year, the most recent edition (including amendments) shall be applied.

JIS C 6820 *General rules of optical fibers*

JIS C 6822 *Test methods for structural parameters of optical fibers—Dimensional characteristics*

NOTE : Corresponding International Standard: IEC 60793-1-20:2001 *Optical fibres—Part 1-20: Measurement methods and test procedures—Fibre geometry* (MOD)

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

NOTE : Corresponding International Standard: IEC 60068-1:1988 *Environmental testing—Part 1: General and guidance* (IDT)

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

IEC 60793-1-43:2001 *Optical fibres—Part 1-43: Measurement methods and test procedures—Numerical aperture*

3 Terms and definitions

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

3.1 overfilled launch

a launching method in which all modes of transmission of the test fiber are launched

3.2 restricted mode launch

a launching method in which only a part of all modes of transmission of the test fiber are launched

3.3 launch spot

the intensity distribution of optical beam on the plane of incidence at the end of an optical fiber

3.4 width at half maximum

the width between two points in a convex distribution curve of intensity where the intensity is one half of the maximum intensity

The total width is called Full Width at Half Maximum (FWHM) and the half is called Half Width at Half Maximum (HWHM).

3.5 -3 dB bandwidth

the value numerically equal to the lowest modulation frequency at which the magnitude of the baseband transfer function of an optical fiber decreases to -3 dB with respect to DC value

4 Classification of measurement methods

The baseband frequency response can be directly measured in the frequency domain by determining the optical fiber response to a sinusoidally modulated light source. Alternatively, it can be measured by observing the broadening of a narrow pulse of light. These two methods are:

- frequency sweeping method;
- pulse method.

Both methods shall be performed under either conditions of overfilled launch or restricted mode launch.

The reference method is the frequency sweeping method, and the substitution method is the pulse method. Where severe measurement is required, the reference test method shall be used. However, the substitution method may be used if there is no dispute.

NOTE : These measuring methods are generally used for production or research and development, and they are not suited to be applied at actual work sites.

5 Test conditions

The tests shall be performed under the standard conditions as given in 5.3 of JIS C 60068-1 unless otherwise specified. However, if testing under the standard conditions is not feasible, unless doubt in judgment can be caused, other conditions may be applied.

6 Apparatus

6.1 Radiation source

6.1.1 Frequency sweeping method

Use a radiation source such as a CW injection laser diode. The frequency sweeping method requires the capability to switch the energy of the light sources electrically, optically or mechanically.

6.1.2 Pulse method

Use a radiation source capable of emitting pulse trains of small specter width with short intervals (such as injection laser diode) for the purposes of the measurement. The pulse method requires the capability to modulate the energy of the light sources electrically, optically or mechanically.

6.1.3 For both methods

The common matters for the frequency sweeping method and the pulse method shall be as follows.

- a) Use a radiation source with a center wavelength that is known and within ± 10 nm of the nominal specified wavelength. For injection laser diodes, laser emission coupled into the fiber must exceed spontaneous emission by a minimum of 15 dB (optical).
- b) Use a source with sufficiently narrow linewidth to assure the measured bandwidth is at least 90 % of the intermodal bandwidth. This is accomplished by calculating the normalized intermodal dispersion limit (*NIDL*, refer to Annex A). For all plastic multimode fiber, the linewidth of the laser diode is narrow enough to neglect its contribution to bandwidth measurement.
- c) For silica-based multimode fibers, multi-component multimode fibers, and plastic cladding multimode fibers, calculate the normalized intermodal dispersion limit for each measurement wavelength from the optical source spectral width for that wavelength as follows. However, *NIDL* is not defined for wavelengths from 1 200 nm to 1 400 nm. The source spectral width for these wavelengths shall be less than or equal to 10 nm, FWHM.

$$NIDL = IDF / \Delta\lambda$$

where, *NIDL* : normalized intermodal dispersion limit (GHz · km)

$\Delta\lambda$: source full width half maximum (FWHM) spectral width (nm)

IDF : intramodal dispersion factor (GHz · km · nm) according to the wavelength of the source (see Annex A)

NOTE : The acceptability of an *NIDL* value depends upon the specific user's test requirements. For example, a $0.5 \text{ GHz} \cdot \text{km}$ *NIDL* would be satisfactory for checking that fibers had minimum bandwidths greater than some value less than $500 \text{ MHz} \cdot \text{km}$, but would not be satisfactory for checking that fibers had minimum bandwidths greater than $500 \text{ MHz} \cdot \text{km}$.

If the *NIDL* is too low, a source with smaller spectral width is required.

- d) The radiation source shall be stable throughout the duration of a single pulse and over the time during which the measurement is made.

6.2 Launch system

6.2.1 Overfilled launch (OFL)

6.2.1.1 OFL condition for silica-based multimode fiber

Use a mode scrambler between the light source and the test fiber to produce a controlled launch irrespective of the radiation properties of the light source. The output of the mode scrambler shall be coupled to the input end of the test fiber in accordance with Annex E. The fiber position shall be stable long enough to perform the measurement. A viewing system may be used to aid fiber alignment where optical imaging is used.

Provide means to remove cladding light from the test sample. Often the fiber coating is sufficient to perform this function. Otherwise, it will be necessary to use cladding mode strippers near both ends of the test fiber. The fibers may be retained on the cladding mode strippers with small weights, but care must be taken to avoid microbending at these sites.

NOTE : Bandwidth measurements obtained by the overfilled launch (OFL) support the use of silica-based multimode fibers, especially in LED applications at 850 nm and 1 300 nm. Some laser applications may also be supported with this launch, but could result in reduced link lengths (at 850 nm) or restrictions on the laser sources (at 1 300 nm).

6.2.1.2 OFL condition for multi-component multimode fibers, plastic cladding multimode fibers and all plastic multimode fibers

OFL is obtained with a geometrical optic launch by combining lens and aperture in which the maximum theoretical numerical aperture of the fiber is exceeded by the launching cone and in which the diameter of the launched spot is in the order of the core diameter of the fiber.

6.2.2 Restricted mode launch (RML)

6.2.2.1 RML condition for silica-based multimode fiber

The RML for bandwidth is created by filtering the overfilled launch (as defined by Annex E) with a RML fiber. The OFL needs to be only large enough to overfill the RML fiber both angularly and spatially. The RML fiber has a core diameter of $23.5 \mu\text{m} \pm 0.1 \mu\text{m}$, and a numerical aperture of 0.208 ± 0.01 . The fiber must have a GI type profile with an alpha of approximately 2 and an OFL bandwidth greater than $700 \text{ MHz} \cdot \text{km}$

at 850 and 1 300 nm. For convenience, the clad diameter should be 125 μm . The RML fiber should be at least 1.5 m in length to eliminate leaky modes; and it should be less than 5 m in length to avoid transient loss effects. The launch exiting the RML fiber is then coupled into the test fiber.

In order to remove cladding light from the test fiber, perform fiber coating on the fiber and/or use cladding mode strippers near both ends of the test fiber. The fibers may be retained on the cladding mode strippers with small weights, but care shall be taken to avoid microbending at these sites.

In order to achieve the highest accuracy, tight tolerances are required on the geometry and profile of the RML fiber. In order to achieve the highest measurement reproducibility, tight alignment tolerances are required in the connection between the launch RML fiber and the test fiber to ensure the RML fiber is centered to the test fiber.

NOTE : Modal bandwidth measurements on type A1b fibers (62.5/125 μm) in **IEC 60793-2-10** obtained by this restricted mode launch at 850 nm have been shown to correlate with the effective modal bandwidth produced by 850-nm laser transmitters only when such transmitters meet certain launch conditions. More specifically, for type A1b fibers, “850-nm restricted mode launch (RML) bandwidth $\geq 385 \text{ MHz} \cdot \text{km}$ ” provides a minimum of 385 MHz $\cdot$ km effective modal bandwidth for sources meeting the following three launch conditions:

- a) Nominal operating wavelength: 850 nm;
- b) Encircled flux at 4.5 μm radius: 25 % max;
- c) Encircled flux at 15 μm radius: 75 % min.

The encircled flux is measured according to **IEC 61280-1-4**.

6.2.2.2 RML condition for plastic cladding multimode fibers

RML condition for plastic cladding multimode fiber is created with geometrical optical launch which corresponds to a numerical aperture launch, made by a combination of lens and aperture, etc. of 0.3.

Spot size shall be larger or equal to the size of core of test fiber.

6.2.2.3 RML condition for all plastic multimode fiber

The restricted mode launch (RML) for all plastic multimode fiber is created by filtering the overfilled launch with a mandrel wrapped mode filter, shown in figure 1. The mode filter shall be made with the fiber of the same category as the test fiber. In order to avoid redundant loss, the length of fiber should be 1 m. The diameter of the mandrel shall be 20 times as large as that of the fiber cladding and the number of coils shall be 5.