

# INTERNATIONAL STANDARD



Optical fibres –  
Part 1–43: Measurement methods and test procedures– Numerical aperture  
measurement

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INTERNATIONAL  
ELECTROTECHNICAL  
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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

## OPTICAL FIBRES –

**Part 1–43: Measurement methods and test procedures–  
Numerical aperture measurement**

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International Standard IEC 60793-1-43 has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

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

This edition includes the following significant technical changes with respect to the previous edition:

- expansion of the scope to include A1, A2, A3 and A4 multimode fibre categories;
- addition of measurement parameters of sample length and threshold values, product specific to the variables that are now found in the product specifications;
- a new Annex B entitled "Product specific default values for NA measurement";
- addition of a new Technique 4 for measuring NA of A4d fibres;

- a new Annex A entitled "Mapping NA measurement to alternative lengths" that gives a mapping function to correlate shorter sample length measurements to the length suggested in the reference test method  $N_{a_{ff}}$ .

This International Standard is to be used in conjunction with IEC 60793-1-1, IEC 60793-1-21 and IEC 60793-1-22.

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

CDV	Report on voting
86A/1566/CDV	86A/1622/RVC

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

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

A list of all parts in the IEC 60793 series, published under the general title *Optical fibres*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

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## OPTICAL FIBRES –

### Part 1–43: Measurement methods and test procedures– Numerical aperture measurement

#### 1 Scope

This part of IEC 60793 establishes uniform requirements for measuring the numerical aperture of optical fibre, thereby assisting in the inspection of fibres and cables for commercial purposes.

The numerical aperture (NA) of categories A1, A2, A3 and A4 multimode fibre is an important parameter that describes a fibre's light-gathering ability. It is used to predict launching efficiency, joint loss at splices, and micro/macrobending performance.

The numerical aperture is defined by measuring the far-field pattern ( $NA_{ff}$ ). In some cases the 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.

#### 2 Normative references

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

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

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

IEC 60793-1-22, *Optical fibres – Part 1-22: Measurement methods and test procedures – Length measurement*

IEC 60793-2-10, *Optical fibres – Part 2-10: Product specifications – Sectional specification for category A1 multimode fibres*

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

IEC 60793-2-30, *Optical fibres – Part 2-30: Product specifications – Sectional specification for category A3 multimode fibres*

IEC 60793-2-40, *Optical fibres – Part 2-40: Product specifications – Sectional specification for category A4 multimode fibres*

#### 3 Overview of method

This test procedure describes a method for measuring the angular radiant intensity (far-field) distribution from an optical fibre. The numerical aperture of multimode optical fibre can be



calculated from the results of this measurement using Equation (10) for NA in the far-field,  $NA_{ff}$ , as described in 8.3.

As background the maximum theoretical NA of a multimode fibre is defined as follows:

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

where

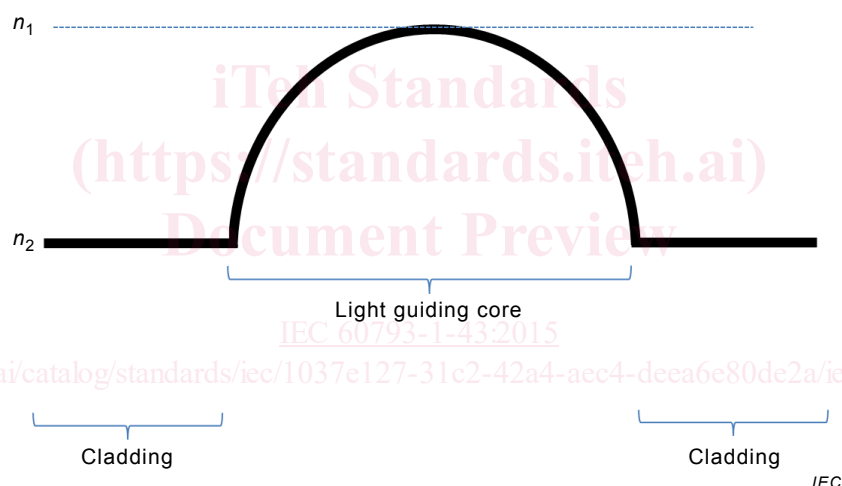
$NA_{th}$  is the maximum theoretical numerical aperture;

$\theta_m$  is the largest incident meridional ray angle that will be guided by the fibre.

In terms of the fibre index profile:

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

where  $n_1$  is the maximum refractive index of the core, and  $n_2$  is the average refractive index of the cladding far from the core region. Figure 1 below shows a refractive index profile of a graded index multimode fibre and indicates  $n_1$  and  $n_2$ .



**Figure 1 – Representative refractive index profile for a graded index multimode fibre**

$NA_{ff}$  can be determined from a far-field radiation pattern measurement on a short length of fibre or from a measurement of a fibre's refractive index profile. Using the far-field method, the intensity pattern,  $I(\theta)$ , of a fibre 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 fibre being measured and are given in the detailed product specification for the fibre being measured.

#### 4 Reference test method

The reference test method (RTM) for measuring numerical aperture is the far-field measurement defined in this standard.

NOTE The core and cladding indexes can be empirically determined by Method A (refractive near-field measurement) of IEC 60793-1-20 to approximate the theoretical NA ( $NA_{th}$ ).

## 5 Apparatus

### 5.1 Input system

#### 5.1.1 Light source

Use an incoherent light source capable of producing an area of substantially constant radiance (variations of less than 10 % in intensity) on the endface of the specimen. It shall be stable in intensity and position over a time interval sufficient to perform the measurement.

Class A fibres' core geometry shall be determined by employing an illuminator at the operating wavelength of the fibre that satisfies the following spatial and angular requirements.

The power per unit area in the focal plane of the fibre under test shall not vary more than  $\pm 10$  % across the core area.

The power per unit solid angle shall not vary more than  $\pm 10$  % across the core's acceptance cone.

#### 5.1.2 Input optics

Use a system of optical components to create a substantially constant radiance spot larger in diameter than the endface of the specimen and with a numerical aperture greater than that of the specimen. The light source shall be incoherent but with a spectral width  $< 100$  nm, full-width half-maximum.

The  $NA_{ff}$  is impacted by the measurement wavelength. For this reason, the centre wavelength is given as part of the detailed product specifications including IEC 60793-2-10, IEC 60793-2-20, IEC 60793-2-30 and IEC 60793-2-40. Default values for the centre wavelength are also listed in Annex B. Provide a means of verifying the alignment of the endface. Optical filters may be used to limit the spectral width of the source.

#### 5.1.3 Fibre input end support and alignment

Provide a means of supporting the input end of the specimen to allow stable and repeatable positioning without introducing significant fibre deformation. Provide suitable means to align the input endface with respect to the launch radiation.

#### 5.1.4 Cladding mode stripper

Provide means to remove cladding light from the specimen. Often the fibre coating is sufficient to perform this function. Otherwise, it will be necessary to use cladding mode strippers near both ends of the test specimen. Note that some detailed product specifications require longer specimen lengths to help remove cladding modes as well.

### 5.2 Output system and detection

#### 5.2.1 General

Four equivalent techniques may be used to detect the angular radiant intensity (far-field) distribution from the specimen. Techniques 1 and 2 are angular scans of the far-field pattern. Technique 3 is a scan of the spatial transform of the angular intensity pattern. (A small or large area scanning detector may be used.) Technique 4 uses an inverse far-field measurement.