IEC 61300-3-53

Edition 1.0 2015-02

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Fibre optic interconnecting devices and passive components – Basic test and measurement procedures –
Part 3-53: Examinations and measurements – Encircled angular flux (EAF) measurement method based on two-dimensional far field data from step index multimode waveguide (including fibre)

Dispositifs d'interconnexion et composants passifs fibroniques – Procédures fondamentales d'essais et de mesures –
Partie 3-53: Examens et mesures – Méthode de mesure du flux angulaire inscrit (EAF) fondée sur les données bidimensionnelles de champ lointain d'un guide d'ondes multimodal à saut d'indice (fibre incluse)

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International Standard IEC 61300-3-53 has been prepared by subcommittee 86B: Fibre optic interconnecting devices and passive components, of IEC technical committee 86: Fibre optics.

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

FDIS	Report on voting
86B/3850/FDIS	86B/3875/RVD

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 61300 series, published under the general title, *Fibre optic interconnecting and passive components – Basic test and measurement procedures,* can be found on the IEC website.

The French version of this standard has not been voted upon.

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FIBRE OPTIC INTERCONNECTING DEVICES AND PASSIVE COMPONENTS – BASIC TEST AND MEASUREMENT PROCEDURES –

Part 3-53: Examinations and measurements – Encircled angular flux (EAF) measurement method based on two-dimensional far field data from step index multimode waveguide (including fibre)

1 Scope

This part of IEC 61300 is intended to characterize the encircled angular flux of measurement step index multimode waveguide light sources, in which most of the transverse modes are excited. The term waveguide is understood to include both channel waveguides and optical fibres but not slab waveguides in this standard.

Encircled angular flux (EAF) is the fraction of the total optical power radiating from a step index multimode waveguide's core within a certain solid angle. The EAF is measured as a function of the numerical aperture full angle. The basic approach is to collect, for every measurement, two dimensional far field data using a calibrated camera and to convert them mathematically into encircled angular flux.

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 60825-1, *Safety of laser products – Part 1: Equipment classification and requirements*

IEC 61300-1, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 1: General and guidance*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
encircled angular flux
EAF
fraction of the total optical power radiating from a step index multimode waveguide's core within a certain solid angle

3.2
$f\theta$ lens
lens converting the angle of incidence of the input beam, θ, into the output beam height, h

Note 1 to entry: The relationship between them is $h = f\theta$, where f is the focal length of the lens.

3.3
numerical aperture
NA
sine of the vertex half-angle of the largest cone of meridional rays that can enter or leave the core of an optical waveguide, multiplied by the refractive index of the medium in which the cone is located.

3.4
far field pattern
FFP
angular distribution of light radiating from a waveguide's core, which corresponds to the optical power distribution on a plane normal to the waveguide axis some distance from its end facet

Note 1 to entry: The distance depends on the largest waveguide cross-section, a, the wavelength, lambda and the angle, φ, to the optical axis. It is abbreviated to FFP. In the far field region the shape of the distribution does not change as the distance from the waveguide end facet increases; the distribution only scales in size with distance, L.

$$L >> \frac{2a^2(\cos\varphi)^2}{\lambda}$$

3.5
far field image
far field pattern formed on an imaging device

3.6
centroid
optical centre of the far field image

3.7
neutral density filter
ND
filter that attenuates light of all colours equally

4 Standard atmospheric conditions

The standard atmospheric conditions are specified in IEC 61300-1.

5 Apparatus

5.1 General

The optical source multimode waveguide shall be long enough to ensure that all cladding modes are stripped by passage through the waveguide. Often the fibre coating or tight buffer is sufficient to perform this function. Alternatively a cladding mode stripper shall be used in the source launch optical multimode fibre. An example of a typical cladding mode stripper which would be suitable for optical fibre is sufficient windings of the fibre around a mandrel of an appropriate diameter. The windings also have a more important essential effect to fully fill the transverse modes across the maximum mode field diameter. It should be checked that all of the transverse modes of the fibre are sufficiently well excited. This can be done by comparing the FFPs for different lengths of the launch fibre or different light sources. Once the FFP no longer changes in form as the launch fibre length is increased there is no need to increase the length further.

5.2 Measurement method 1: $f\theta$ lens imaging

5.2.1 General

In theory, this measurement method, which is effectively a coherent optical method to Fourier Transform the near field to the far field using a lens, does not operate well using very wideband optical sources. Experimentally it has been shown to operate sufficiently well for sources up to 30 nm bandwidth which are most commonly used.

Figure 1 below shows the apparatus configuration. The measurement system consists of a micro-positioner, a far field broadband optical system, a camera and computer (beam analysis module). An appropriate type of camera (detector) should be chosen to suit the wavelength.

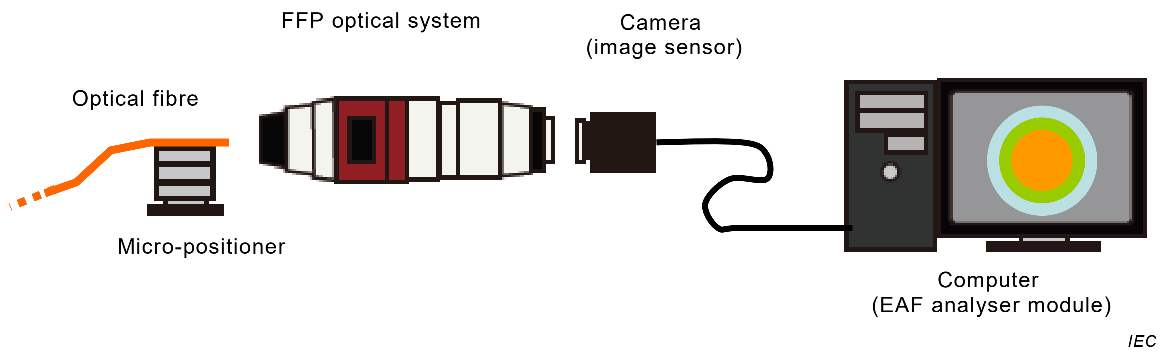

Figure 1 – Apparatus configuration: Measurement method 1: $f\theta$ lens imaging

5.2.2 Micro-positioner

The micro-positioner shall have a function of fixing an optical waveguide and moving in three directions (X, Y, Z). In addition yaw and pitch controls are recommended.

5.2.3 FFP optical system

As shown in Figure 2, basically, an $f\theta$ lens can directly convert input the light from the multimode waveguide to a far field image, however, scaling the far field image in order to fit the image sensor in the camera and adjustment of the light intensity in order to prevent saturation may be required. The FFP optical system shall be chosen to operate at the measurement wavelength across the required measurement bandwidth to match that of the detection system. See Annex A for more information.

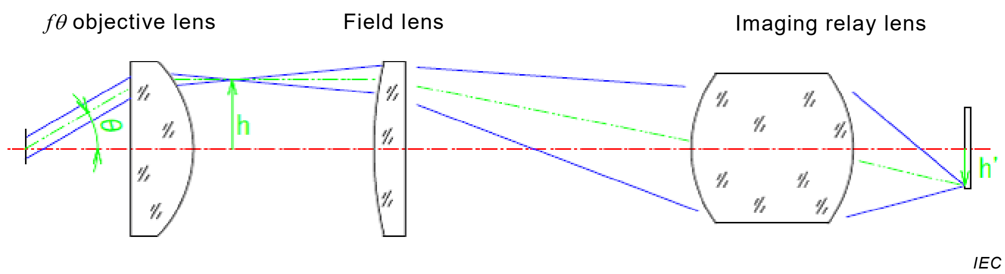

Figure 2 – Far field optical system diagram

5.2.4 Camera

Although the detector is typically a charge-coupled device (CCD) or a complementary metal oxide semiconductor (CMOS) camera, other types of array cameras may be considered. The type of image sensor shall be chosen by the measurement wavelength. Absolute radiometric measurement of flux (optical power flow) is not required.

5.2.5 Computer (EAF analyser module)

Since the acquired image contains many thousands of pixels, and the image conversion into encircled angular flux requires substantial computation, a computer is required. The computer will usually be connected to the image sensor through an image acquisition board (or with an embedded image acquisition circuit) and installed beam analysis software.

5.2.6 Calibration light source

Calibration light source is used when calibrating the apparatus in Clause 7. The calibration source is assumed to be broadband and incoherent so that speckle is not a problem, and to have a sufficiently symmetrical far field distribution so that the calculated centroid of the far field indicates the location of the optical centre axis of the waveguide with sufficient accuracy for the purposes of this standard.

5.3 Measurement method 2: direct imaging

5.3.1 General

There are three alternative methods to detect the far field. One uses a detector, one uses a single-mode fibre and the other uses a camera.

5.3.2 Micro-positioner

Both the input step index multimode waveguide source and the photo detector (PD) shall be mounted on high precision motorized translation stages for accurate alignment with sub-micron step adjustment to maximize the light through the waveguide.

5.3.3 Optical power

The output from the multimode waveguide shall be set to a power level of 0 dBm.

5.3.4 Alignment

Firstly, the input waveguide and detector shall be properly aligned to obtain the maximum output power.

5.3.5 Detector

An integrating sphere PD preceded by a pinhole shall be placed sufficiently far from the optical source launch multimode waveguide facet so as to be in the Fraunhofer or far field. The Fraunhofer far field occurs when $L >> D^2/\lambda$ where L is the distance of the detection plane from the waveguide end facet, D is the diameter of the multimode waveguide core or strictly mode field diameter and λ is the wavelength. For example, a large area integrating sphere PD preceded by a pinhole, shown in Figure 3, shall be used to measure the integrated output optical power so avoiding inconsistencies due to laser speckle and spatial variation of efficiency across the photodiode detector. In this method the integrating sphere and its pinhole are moved in X and Y to sample the far field. This has the advantage that a very large area can be sampled. Moreover, it can also be moved in an arc on a goniometer so that its input facet always faces the centre of the core of the multimode waveguide output. This goniometric method can also be used to calibrate the far field in the $f\theta$ imaging method as the far field is measured directly as a function of angle. If the detector aperture is instead moved across an XY plane then the lateral position from the optical axis shall be converted to an angle of divergence from the optical axis. The angle is the arctangent of the ratio of the lateral X or Y position to the distance L. Therefore, considerable care needs to be taken to accurately measure L.

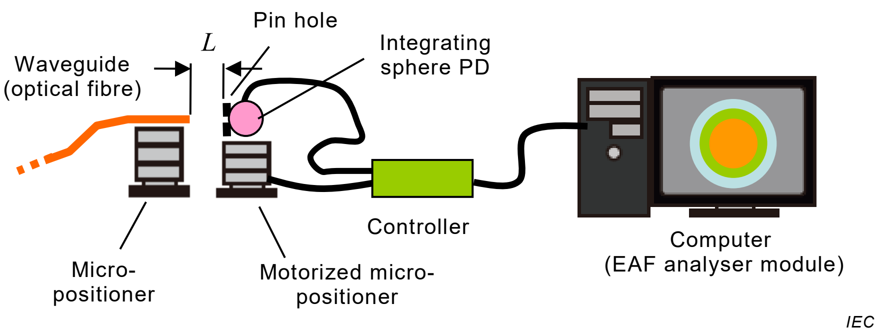

Figure 3 – Apparatus configuration: measurement method 2 – Direct imaging using an integrating sphere

5.3.6 Single-mode fibre

The single-mode optical fibre shall be placed sufficiently far from the optical source launch multimode waveguide facet so as to be in the Fraunhofer or far field. The Fraunhofer far field occurs when $L >> D^2/\lambda$ where L is the distance of the detection plane from the waveguide end facet, D is the diameter of the multimode waveguide core or strictly mode field diameter and λ is the wavelength. For example, a single-mode fibre attached to a detector, shown in Figure 4, shall be placed in the far field and moved in X and Y to sample the far field. This has the advantage that a very large area can be sampled. Moreover, it can also be moved in an arc on a goniometer so that its input facet always faces the centre of the core of the multimode waveguide output. This goniometric method can also be used to calibrate the far field in the fθ imaging method as the far field is measured directly as a function of angle. If the single-mode fibre core is instead moved across an XY plane then the lateral position from the optical axis shall be converted to an angle of divergence from the optical axis. The angle is the arctangent of the ratio of the lateral X or Y position to the distance L. Therefore, considerable care needs to be taken to accurately measure L.

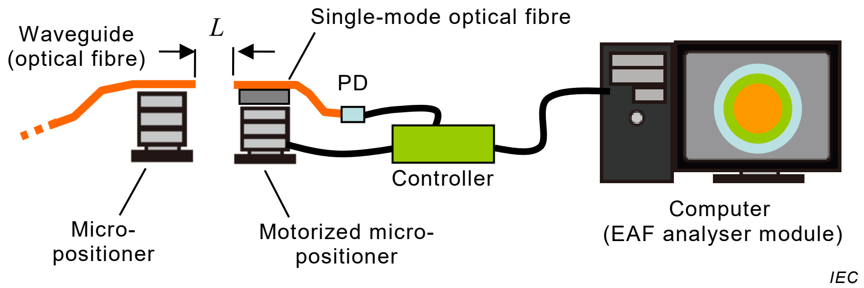

Figure 4 – Apparatus configuration: measurement method 2 – Direct imaging using a single-mode fibre

5.3.7 Imaging device

An imaging device plane without any lens system shall be placed sufficiently far from the optical source launch multimode waveguide facet so as to be in the Fraunhofer or far field. The Fraunhofer far field occurs when $L >> D^2/\lambda$ where L is the distance of the detection plane from the waveguide end facet, D is the diameter of the multimode waveguide core or strictly mode field diameter and λ is the wavelength. For example, an imaging device, shown in Figure 5, shall be placed L away from the exit facet of the multimode waveguide. The distance L between the imaging device and the waveguide end facet is much larger than the core size of the waveguide, so the field captured is the far field distribution. The imaging device may for example, be a CCD camera with its lens removed so that the light distribution falls directly on the CCD chip. The lateral position from the optical axis in the far field shall be converted to an angle of divergence from the optical axis. The angle is the arctangent of the ratio of the lateral X or Y position to the distance L. Therefore, considerable care needs to be taken to accurately measure L.

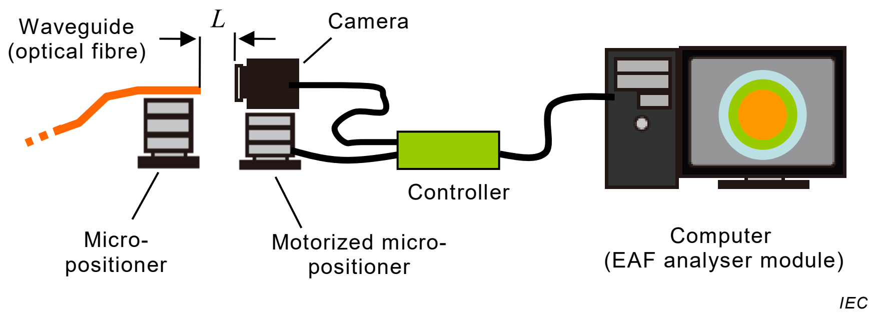

Figure 5 – Apparatus configuration: measurement method 2 – Direct imaging using an imaging device

6 Sampling and specimens

Light sources to be tested shall be chosen and prepared by the user of this standard, who shall document the sampling and preparation procedures used. The only requirements on the light sources under test are that they have an operating wavelength compatible with the detector and fθ lens, and have optical connectors or splices compatible with the input port of the apparatus. The construction details of the light sources are otherwise unspecified.

7 Geometric calibration

Calibration of the apparatus is critical to the accuracy of this measurement procedure. Calibration shall be performed periodically. If the calibration is known to drift significantly during a measurement interval, the drift of the source(s) shall be identified and eliminated. If the apparatus is disassembled or its components in or affecting the optical path are otherwise manipulated, calibration shall be performed before measurements are made.

The purpose of geometric calibration is to obtain the measurement data needed to compute the conversion factor. The factor will be used to convert camera coordinates to light launching angle relative to the optical axis of optical waveguide.

Calibration is performed to measure the conversion factor that relates the light launching angle to the pixel of the detector corresponding to this angle. The factor has a unit of degree per pixel, and will be used to convert camera coordinates to far field angle coordinates. The collimated light source for geometric calibration, shown in Figure 6, shall have a spectral power distribution similar to that of the measurement light source and the central wavelength within 30 nm around the nominal wavelength of the measurement light source.

An example of the calibration procedure is stated below:

Step 1 Set a collimated light source whose incident angle relative to the optic axis of the far field optical system can be precisely controlled. An example of the calibration apparatus is shown in Figure 6.

Step 2 Measure the conversion factors from the whole range of angles to be measured with an interval small enough (e.g. 1°) to enable accurate interpolation.