INTERNATIONAL STANDARD

IEC 61280-1-4

First edition
2003-01

Fibre optic communication subsystem test procedures –

Part 1-4: General communication subsystems – Collection and reduction of two-dimensional nearfield data for multimode fibre laser transmitters

Procédures d'essai des sous-systèmes de télécommunication à fibres optiques –

Partie 1-4: Procédures d'essai des sous-systèmes généraux de télécommunication – Recueil et réduction de données à deux dimensions de champs proches pour les émetteurs de laser à fibres multimodales

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

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International Standard IEC 61280-1-4 has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics

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

FDIS	Report on voting
86C/465/FDIS	86C/494/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.

The committee has decided that the contents of this publication will remain unchanged until 2008. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

FIBRE OPTIC COMMUNICATION SUBSYSTEM TEST PROCEDURES –

Part 1-4: General communication subsystems – Collection and reduction of two-dimensional nearfield data for multimode fibre laser transmitters

1 General

1.1 Scope and object

This part of IEC 61280 sets forth a standard procedure for the collection of two-dimensional fibre optic nearfield grayscale data and subsequent reduction to one-dimensional data expressed as a set of three sampled parametric functions of radius from the fibre's optical center. The object of this standard is to reduce measurement errors and inter-laboratory variation, supporting accurate mathematical prediction of minimum guaranteed link length in gigabit and ten gigabit fibre optic data communications systems.

These radial functions are intended to characterize fibre optic laser sources for use in mathematical models predicting the minimum guaranteed length of a communications link.

Although available as a byproduct, estimation of the nearfield diameter is not an objective.

1.2 Assumptions

The 50-micron or 62,5-micron core near-parabolic graded-index multimode fibre used as the “test jumper assembly” is treated as if it possessed perfect circular symmetry about its optical center, as asymmetries in the launched optical flux distributions will dominate any lopsidedness of the test jumper assembly. It is further assumed that all cladding modes will be stripped by passage through the specified ten meters or more of fibre. The modes of a mode group need not carry equal flux. (In fact, with such short fibres, one thousand meters or less, unequal distribution of flux in the modes of a group is the norm, not the exception.)

The fibre micropositioner that moves the fibre in the receiving camera's field of view, being used to calibrate the camera for geometric distortions, is used as a reference standard. The microscope objective, used to project the magnified nearfield onto the CCD chip, is treated as an optically perfect thick lens.

The flux detectors are required to be both linear and memoryless; this excludes for instance lead sulphide vidicon detectors. Detectors shall meet the detector requirements of IEC 60793-1-43. Absolute radiometric measurement of flux (optical power flow) is not required. A computer is required to perform the needed computations, which are too extensive to be performed manually. Although the present measurement method assumes a CCD camera, mechanically-scanned “slitscan” and pinhole cameras may also be used.

Safety: all procedures in which an LED or laser source is used as the optical source shall be carried out using safety precautions in accordance with IEC 60825-2.

2 Normative references

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

IEC 60793-1-20: *Optical fibres – Part 1-20: Measurement methods and test procedures – Fibre geometry*

IEC 60793-1-41: *Optical fibres – Part 1-41: Measurement methods and test procedures – Bandwidth*

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

IEC 60825-2: *Safety of laser products – Part 2: Safety of optical fibre communication systems*

3 Apparatus

As the objective of this international standard is to optically characterize laser sources, many different laser sources will be used, while the rest of the apparatus is held constant. The apparatus is calibrated using a broadband incoherent calibration source (such as a light-emitting diode (LED) or a xenon arc lamp) in place of the lasers.

3.1 Sources

There are two kinds of sources used in the present measurement method: the incoherent broadband overfilled source used for calibration, and the various laser sources being tested, as described in the following paragraphs.

There is always an optical connector between the source and the test jumper assembly.

3.1.1 Calibration source

The purposes of the calibration source are to find the optical center of the test jumper assembly, and also to determine the geometric corrections needed to convert 2D nearfield measurements taken in camera ("TV") coordinates into the equivalent true geometric measurements, compensating for non-square pixels, imprecisely known magnification factors, and the like. For these purposes, an incoherent broadband source that overfills the modes of the test jumper assembly is used in place of the laser sources under test.

Any spectrally broad non-coherent light source, such as a tungsten-halogen lamp, a xenon arc lamp or a light-emitting diode (LED) may be used to overfill the test jumper assembly's fibre. The chosen calibration source shall be stable in intensity over a time period sufficient to perform the measurements.

Optionally, an IEC 60793-1-41 mode scrambler may be used with the chosen calibration source to ensure more uniform overfilling of the fibre.

3.1.2 Laser under test

The only requirements on the lasers under test are that they have an operating wavelength compatible with the test jumper assembly and the detector, and have optical connectors or splices compatible with those of the test jumper assembly. The construction details of the laser sources are otherwise unspecified.

The laser drive current shall be sufficient to ensure that the laser always acts as a laser, rather than an LED.

3.2 Test jumper assembly

The purpose of the test jumper assembly is to strip cladding modes, and to allow speckle to be averaged out by mechanical flexing of a portion of the test jumper assembly.

The test jumper assembly shall be at least ten meters in length, made of germanium-doped near-parabolic graded-index fused-silica multimode “glass” category A1 fibre with a core diameter of either 50 µ or 62,5 µ and an overall glass diameter of 125 µs. The test jumper assembly shall consist of a single, uncut length of fibre with connectors at each end. The test jumper assembly connectors shall have single-mode mechanical tolerances, even though the fibre is multimode.

3.3 Fibre shaker

The purpose of the fibre shaker is to ensure that optical speckle is averaged out, with only a few percent of residual ripple or noise due to speckle being allowed to remain in the measured nearfields. Manual shaking of the fibre is generally not sufficient.

Part of the test jumper assembly shall be mechanically shaken continuously in each of three nominally orthogonal directions (using three independent shaker mechanisms) during the measurement, making at least one hundred shake cycles in each of the three directions during the measurement period. The shake frequencies in the three directions shall be chosen such that the three shake cycles synchronize no more often than once every five hundred cycles of the middle shake frequency.

A fibre shaker mechanism may be of any design as long as it induces large amplitude movements and flexing in the optical fibre. Fibre transverse displacements of more than 25 mm are suggested. The fibre shakers shall include a fibre-holding fixture for securely holding the fibre.

One exemplary mechanism design has three turns of fibre coiled into a 3-ply figure-eight arrangement, with the loops each being approximately 120 mm in diameter. A motor-driven eccentric drives a slider back and forth at about one stroke per second, alternately flattening and stretching one loop of the figure eight with 25 mm amplitude. Three such mechanisms in series will consume about $3 \times 3 \times (2 \times \pi \times 0{,}120) = 6{,}8$ meters of the test jumper assembly’s fibre.

The fibre ends leading into and out of the fibre shakers shall be mechanically fixed or stabilized to prevent movement of fibres at connection points. In addition, the fibre shakers shall be mechanically isolated from the rest of the test setup so that vibrations are not transmitted to connection points throughout the apparatus, or to the micropositioner, camera, or microscope objective.

NOTE 1 Vibration reduction is easier if the fibre shaker is both statically and dynamically balanced, and if all moving components are light in weight.

NOTE 2 There is no required relation between the measurement period (containing the one hundred strokes) and the duration of a CCD camera exposure. Typically, in each measurement period, many exposures are taken and later summed, to avoid saturation of the CCD, and to ensure that speckle is in fact averaged out. Too short a total exposure time will prevent the desired averaging out of speckle.

3.4 Micropositioner

The purpose of the micropositioner is to bring the projected image of the fibre face into focus on the CCD chip within the camera, and also to support geometric calibration of the apparatus by making calibrated moves in X and Y, these axes being perpendicular to the optic axis Z.

The X-axis and Y-axis accuracy and resolution shall be one micron or less (finer), and it shall be possible to sweep the centroid of the calibration-source nearfield image from one edge of the CCD chip to the other, in both X and Y directions, by adjustment of the X and Y axes alone, with the nearfield image remaining substantially in focus on the CCD chip. The X-axis and Y-axis repeatability error shall be no larger than one third of a micron. It shall be possible to mechanically lock both the X and Y axes, to prevent drift in the apparent location of the test jumper assembly's optical center as tests are performed.

The Z-axis accuracy, repeatability, and resolution are unspecified, but shall be sufficient to bring the system into focus, and it shall be possible to mechanically lock the Z axis once focus is achieved, to prevent drift in the system magnification as tests are performed.

3.5 Microscope objective

Suitable optics shall be provided which project the magnified image of the output end of the test jumper assembly onto the receiving CCD chip such that the CCD can measure the entire nearfield flux distribution. These optics shall not restrict the numerical aperture of the formed image. (Based on IEC 60793-1-43.)

NOTE The actual magnification of the microscope objective as used in the present apparatus generally will not be the same as the nominal magnification factor engraved into the side of the objective, because the present apparatus differs from the standard microscope for which that nominal magnification factor was computed.

3.6 Detector

The flux detectors shall be both linear and memoryless; this excludes for instance lead sulphide vidicon detectors. Detectors shall satisfy the detector requirements of IEC 60793-1-43. Absolute radiometric measurement of flux (optical power flow) is not required.

Automatic gain control (AGC), if present, shall be disabled.

In CCDs with anti-blooming provisions, "saturation" is considered to occur at the "white-clip" level, not ultimate saturation, to preserve linearity of response.

If more than one in one thousand of the CCD's pixels are bad, or if the camera's offsets and pixel crosstalk are too large to allow accurate measurements, replace the camera. See 5.2.2 for details.

NOTE 1 Detector saturation may often be avoided by taking a number of very short exposures and summing them pixel for pixel.

NOTE 2 Neutral-density (ND) filters, optionally used to prevent detector saturation, are most conveniently placed between the microscope objective and the detector, and should be slightly tilted (by a few degrees of angle) to prevent reflections from the filter from reaching the source.

4 Sampling and specimens

Laser sources to be tested shall be chosen and prepared as defined by the user of this standard, who shall document the sampling and preparation procedures used, as described in Clause 7 of this standard. See Clause 3 for technical requirements on sources.

5 Procedure

5.1 Overview of the measurement procedure

This procedure consists of the following steps:

a) calibrate the camera,
b) measure the calibration source's 2D nearfield flux distribution,
c) measure one or more laser launch 2D nearfield flux distributions,
d) perform the calculations, and
e) report the results.

Note that calibration of the apparatus is critical to the accuracy of this measurement procedure. (See A.5 for description of the kinds of noise and errors which calibration can correct.) There is one calibration procedure and one nearfield measurement procedure, each being used multiple times. The following paragraphs first describe these two basic procedures, and then describe how these two procedures are used to implement the overall procedure.

The receiver end of the test jumper assembly shall be firmly attached to the camera and micropositioner assembly and left undisturbed during this entire process. All three micro-positioner axes shall be locked once calibration is complete, so that the fibre optical center and geometric scale factors (magnifications) found with the calibration source will continue to apply to measurements of the laser-source nearfields, without undue drift.

Calibrate the camera setup again, after taking all the laser data, to detect any drift in the camera or setup. Drift in geometric calibration can cause severe errors in the computed radial data functions.

The equipment must remain stable over the course of all measurements. Unless it can be shown not to be required, the laboratory ambient temperature shall be stable to within 2 °C, the equipment shall be allowed to warm up for at least fifteen minutes before calibrations or measurements are made, and any automatic gain control (AGC) features shall be disabled.

NOTE The tight temperature tolerance is required to counter the temperature sensitivity of the optical flux detectors in the camera, particularly the dark current. See A.5 for details.

5.2 Camera calibration

Any data taken shall be conditioned before use is made of that data. Conditioning involves pixel-by-pixel removal of offsets (due to dark current and fixed-pattern noise and the like), normalization for differences in pixel sensitivity (responsivity), possible identification of bad pixels and correction for the camera's geometric distortions. These issues are discussed individually in the following paragraphs.

5.2.1 Camera geometric calibration

The purpose of geometric calibration is to obtain the measurement data needed to compute the transform matrix. The transform matrix will be used to compensate measured 2D nearfield data for the actual size and shapes of the pixels in the CCD camera, and to calculate the actual magnification of the microscope objective lens as used in the present apparatus.

To calibrate cameras for these geometric effects, a fibre micropositioner, which is mechanical and built for precision, will be used as the reference standard.

Perform the following steps.

a) Overfill the fibre with light from the calibration source.

b) Move the test jumper assembly's receiver end to three well-separated non-collinear positions (calibration points) in the camera's field of view.

c) Record both the fibre position in true space (micropositioner X and Y coordinates) and the location of the corresponding centroid of flux in TV space (camera coordinates).

d) Solve for the 3x3 transform matrix mapping from the one 2D space to the other, as detailed in 6.1 and 6.2.

e) The "three well-separated non-collinear positions" can be in a rough equilateral or right triangle; any reasonable triangle will work, but the closer to equilateral, the better. The triangle should be as large as possible without having any part of the nearfield clipped off by the encroaching edges of the TV frame. The broadband incoherent source's intensity should be set such that the peak intensity is at about 75 % of camera saturation.