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PAS 61300-3-43

Pre-Standard

First edition
2006-02

Fibre optic interconnecting devices and passive components – Basic test and measurement procedures –

Part 3-43:
Examinations and measurements – Mode transfer function measurement for fibre optic sources

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

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IEC-PAS 61300-3-43 has been processed by subcommittee 86B: Fibre optic interconnecting devices and passive components, of IEC technical committee 86: Fibre optics.

The text of this PAS is based on the following document: This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document:

Draft PAS	Report on voting
86B/2199/NP	86B/2257/RVN

Following publication of this PAS, which is a pre-standard publication, the technical committee or subcommittee concerned will transform it into an International Standard.

This PAS shall remain valid for an initial maximum period of three years starting from 2006-02. The validity may be extended for a single three-year period, following which it shall be revised to become another type of normative document or shall be withdrawn.

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

Part 3-43: Examinations and measurements –
Mode transfer function measurement for fibre optic sources

1 Scope

This part of IEC 61300 describes the method for measuring the mode transfer function (MTF) to be used in characterizing the launch conditions for measurements of attenuation and or return loss of multimode passive components, according to IEC 61300-1 and IEC 61300-3-4. The MTF may be measured at the operational wavelengths.

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

IEC 61300-3-4, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-4: Examination and measurements – Attenuation*

3 General description

The modal distribution launched into multimode fibre can vary widely with different light sources. This variation in launched modal distribution can result in significant differences in measured attenuation in the same component. The MTF test method gives information about the launched modal distribution (LMD) condition in a measured component. The MTF test method is based on a measurement of the near-field intensity distribution in the fibre [1], [2][1].

4 Theory

For a fibre with a power-law index profile $n(r)$, given by

$$n(r) = n_1 \left[1 - 2\Delta \left(\frac{r}{a} \right)^{\alpha} \right]^{0,5} \qquad \left(\frac{r}{a} \right) \le 1 \qquad (1)$$

where
a is the fibre core radius;
α is the profile factor (α = 2 for a parabolic profile);
Δ is the relative index difference, given by

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[1] Figures in square brackets refer to the Bibliography.

$$\Delta = \frac{n_1^2 - n_2^2}{2n_1^2} \tag{2}$$

where
n_1 is the index at the fibre centre;
n_2 is the cladding index.

The near-field intensity profile in the fibre $I(r)$ may be determined from an integration of the mode transfer function MTF, δ, in the fibre, as follows (ignoring constants):

$$I(r) = \int_{\Delta \left(r/a\right)^{\alpha}}^{\Delta} MTF(\delta).\mathrm{d}\delta \tag{3}$$

where
δ is the normalized propagation constant;
r/a is the normalized radial position.

Differentiating both sides gives the MTF as follows (ignoring constants):

$$MTF(\delta) = \left[\frac{\mathrm{d}I(r)}{\mathrm{d}r}\cdot\frac{1}{r^{\alpha-1}}\right]_{\delta=\Delta\left(r/a\right)^{\alpha}} \tag{4}$$

The MTF is usually plotted in terms of the principal mode number, m, divided by the maximum principal mode number, M, where

$$\frac{m}{M} = \left[\frac{\delta}{\Delta}\right]^{(2+\alpha)/2\alpha} = \left[\frac{r}{a}\right]^{(2+\alpha)/2} \tag{5}$$

The term, m/M, is usually referred to as the relative mode number, or the normalized mode number.

The maximum principle mode number, M, is given by

$$M = \sqrt{\frac{\alpha}{\alpha+2}}\left(\frac{n_1 2\pi a}{\lambda}\right)\sqrt{\Delta} \tag{6}$$

A typical normalized MTF plot is shown in Figure 1, where it can be seen, in this example, that normalized mode numbers up to about 0,6 are equally filled and higher order modes are progressively less well-filled.

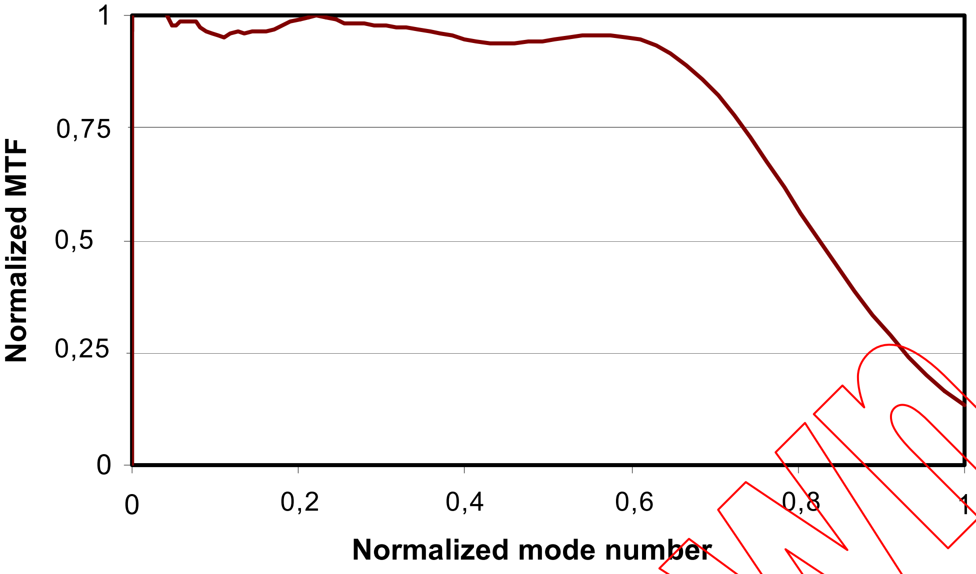

Figure 1 – Example of normalized MTF

4.1 Alternative method

If the profile factor, α, in equation (4) is not known, then an alternative expression for MTF can be used.

It is known [3] that, in a fully filled fibre (i.e., MTF = 1 for all mode numbers), the near-field intensity profile, I_o, is the same shape as the square of the refractive index profile, $n(r)^2$. Furthermore, the term $r^{\alpha-1}$ in equation (4) is equal (ignoring constants) to the differential of $n(r)^2$ and so equation (4) can be rewritten as:

$$MTF(\delta) = \left[\frac{\mathrm{d}I(r)}{\mathrm{d}r} \cdot \frac{1}{\mathrm{d}I_o(r)/\mathrm{d}r} \right]_{\delta=\Delta\left(r/a\right)^2} \tag{7}$$

where a value of α = 2 has been assumed in order to compute values for the normalized mode number.

Thus the MTF is equal to the ratio of the derivative of the intensity profile under test to the derivative of the intensity profile of the same fibre under fully filled conditions.

4.2 Mode power distribution

For graded index multimode fibre the number of discrete modes in a particular mode group is proportional to the principal mode number. Thus, higher-order-mode groups contain more modes and, therefore, will carry more light if all the modes are equally excited. This can be represented by the MPD, defined as:

$$MPD(m) = MTF(m) \cdot m \tag{8}$$

Because of this relationship of modes within mode groups, the MPD transform effectively displays the relative power in the mode groups.

An example of a normalized MPD is shown in Figure 2, where it can be seen, in this case, that the peak power level occurs around 0,65 of the normalized mode number.

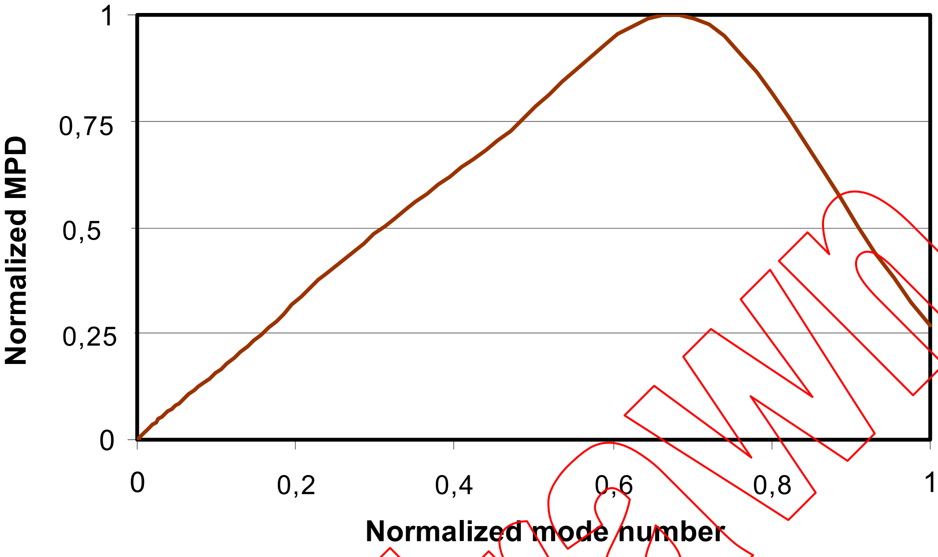

Figure 2 – Example of normalized MPD

4.3 Relative power distribution

The relative power distribution (RPD) is another way of expressing MTF data. It is defined as:

$$RPD(\mu) = \int_{\mu}^{1} MTF(m) \cdot \mathrm{d}m \tag{9}$$

where μ is a variable principle mode number, required for the integration, that takes on values from 1 to 0 (m is the principle mode number).

The RPD represents the area under the MTF curve as the mode number is progressively reduced from unity and is, therefore, a measure of the cumulative distribution of power starting at the highest mode number.

An example of a normalized RPD is shown in Figure 3.