

Application guide for non-linear coefficient measuring methods

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National foreword

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**Guide d'application pour les méthodes de mesure
du coefficient de non-linéarité**

**Application guide for non-linear coefficient
measuring methods**



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NON-LINEAR COEFFICIENT MEASURING METHODS – APPLICATION GUIDE

1 Scope and object

This technical report is intended to provide guidance for uniform measurements of the non-linear coefficient of single-mode fibres (IEC 60793-2-50) in the 1 550 nm region.

The non-linear coefficient (nLc) is the ratio of the Kerr non-linear refractive index, n_2 , to effective area, A_{eff} (see IEC/TR 62284) as:

$$\text{nLc} = \frac{n_2}{A_{\text{eff}}} \quad (1)$$

The non-linear coefficient is related to the following non-linear optical distortion effects as a combined parameter:

- Self-phase modulation (SPM)
- Cross-phase modulation (XPM)
- Four-wave mixing (FWM)

Other fibre attributes, such as chromatic dispersion and polarisation mode dispersion, also influence the transmission.

Two methods are given, with details specific to each in normative annexes. They are:

- Method A Continuous-wave dual-frequency
- Method B Pulsed single-frequency

Both methods require injecting very high powers (5 dBm or more) into the fibre, measurement of this power (absolute), and measurement of the output spectrum which is modified by non-linear effects. Both methods use calculations that combine these measured results with those derived from other measurements such as attenuation (IEC 60793-1-40) and chromatic dispersion (IEC 60793-1-42). Both methods have limitations on the length of fibre that can be measured – in a relationship with the chromatic dispersion at the wavelength being measured.

Method A [1] ¹⁾ Requires injecting the light of two wavelengths into the fibre. The light of both wavelengths is constant at various power levels. At higher power, the lights beat due to the non-linear effect and produce an output spectrum that is spread. The relationship of the power level to a particular metric of spectrum spreading is used to calculate the non-linear coefficient.

Method B [2], [3] requires injecting pulsed light at a single wavelength. The pulses should be of duration substantially less than 1 ns and the input peak power of these pulses should be measured and related to the non-linear spreading of the output spectrum.

Measurements of the non-linear coefficient are used to characterise specific single-mode fibre designs for the purpose of system design relative to power levels and distortion or noise effects derived from the non-linear optical behaviour.

Figures in square brackets refer to the bibliography.

2 Reference documents

IEC 60793-1-1, ____ *Optical fibres – Part 1-1: Measurement methods and test procedures – General and guidance* ²⁾

IEC 60793-1-40, *Optical fibres – Part 1-40: Measurement methods and test procedures – Attenuation*

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

IEC 60793-2-50, *Optical fibres – Part 2-50: Product specifications: Sectional specification for class B single-mode fibres*

IEC 61315, *Calibration of fibre optic power meters*

3 Apparatus

The following apparatus is common to both measurement methods. Annexes A and B include layout drawings and other equipment requirements for each of the methods, respectively.

3.1 Light source

See annexes A and B for detailed characteristics of the light sources.

3.2 Input optics

The input optics include one or more lasers, amplifiers, variable attenuators, couplers and power meters. Bandpass filters and oscilloscopes may be needed for Method B. See annexes A and B for specific details.

3.3 Input positioner

Provide means of positioning the input end of the specimen to the light source. Typically, this connection is with a fusion splice to a short (1 m) pigtail of type B1.1 fibre.

3.4 Cladding mode stripper

Use a device that extracts cladding modes. Under some circumstances, the fibre coating will perform this function.

3.5 Output positioner

Provide a suitable means for aligning the fibre to the output optics. Typically, this connection is with a fusion splice to a pigtail of type B1.1 fibre.

3.6 Output optics

The output optics include a power meter and optical spectrum analyser. An oscilloscope may be required for Method B. See annexes A and B for details.

2) 2nd edition, to be published.

3.7 Computer

Use a computer to perform operations such as controlling the apparatus, taking intensity measurements and processing the data to obtain the final results.

4 Samples and specimens

A specimen is a known length of single-mode optical fibre (IEC 60793-2-50). The sample and pigtailed should be fixed in position at a nominally constant temperature throughout the measurement. Standard ambient conditions (IEC 60793-1-1) should be employed, unless otherwise specified.

End faces for the input and output ends of the test sample should be prepared as appropriate to obtain low loss fusion splices.

The measurement method is limited with regard to the measurable length because of chromatic dispersion. For this reason, the specimen is normally cut from a longer piece of fibre that has been characterised for attenuation coefficient, α_{dB} , and chromatic dispersion, D , at the wavelength of interest (1 550 nm). The length of the fibre after being cutback is referred to as L .

See annexes A and B for details specific to the length and chromatic dispersion requirements.

The fibre may be deployed on a common shipping spool.

5 Procedure

- a) Deploy the fibre or cable and prepare the ends.
- b) Attach the ends to the input and output optics.
- c) Engage the computer to complete the scans and measurements found in annexes A and B for the measurement methods.
- d) Complete the documentation.

6 Calculations of interpretation of results

Unless otherwise specified, the units are in meters, seconds, watts, and radians.

The fundamental relationships for the two methods are nearly the same, so they are presented here for comparison.

$$\text{Method A} \quad \varphi = \frac{2\pi}{\lambda} \frac{n_2}{A_{\text{eff}}} L_{\text{eff}} 2P \quad (2a)$$

$$\text{Method B} \quad \varphi = \frac{2\pi}{\lambda} \frac{n_2}{A_{\text{eff}}} L_{\text{eff}} P_{\text{peak}} \quad (2b)$$

where

- φ is the non-linear phase shift (rad);
- λ is the wavelength (m) (centre of two wavelengths for method A);
- n_2 is the Kerr non-linear refractive index;
- A_{eff} is the effective area;
- L_{eff} is the effective length (m);