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INTERNATIONAL STANDARD

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Optical amplifiers – Test methods – Part 10-2: Multichannel parameters – Pulse method using a gated optical spectrum analyzer

Amplificateurs optiques – Méthodes d'essai – Partie 10-2: Paramètres à canaux multiples – Méthode d'impulsion utilisant un analyseur de spectre optique stroboscopique

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International Standard IEC 61290-10-2 has been prepared by subcommittee 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics.

This second edition cancels and replaces the first edition published in 2003. It is a technical revision with updated references and cautions on proper use of the procedure.

This standard is to be read in conjunction with IEC 61291-1.

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

FDIS	Report on voting
86C/772/FDIS	86C/787/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 of the IEC 61290 series, published under the general title *Optical amplifiers – Test methods:*[1] can be found on the IEC website.

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

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- withdrawn,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

[1] The first editions of some of these parts were published under the general title *Optical fibre amplifiers – Basic specification* or *Optical amplifier test methods*.

INTRODUCTION

As far as can be determined, this part of IEC 61290 is the first International Standard on this subject. The technology of optical amplifiers is still evolving, hence amendments and new editions to this document should be expected.

Each abbreviation introduced in this standard is explained in the text at least the first time it appears. However, for an easier understanding of the whole text, a list of all abbreviations used is given in Clause 3.

OPTICAL AMPLIFIERS – TEST METHODS –

Part 10-2: Multichannel parameters – Pulse method using a gated optical spectrum analyzer

1 Scope and object

This part of IEC 61290 applies to optical fibre amplifiers (OFA) using active fibres, containing rare-earth dopants, currently commercially available.

The object of this International Standard is to establish uniform requirements for accurate and reliable measurements of the signal-spontaneous noise figure as defined in IEC 61291-1.

The test method independently detects amplified signal power and amplified spontaneous emission (ASE) power by launching optical pulses into the OFA under test. The ASE level is measured by synchronously measuring the power on an optical spectrum analyzer (OSA) during the optical pulse off period. The average optical signal level is measured by random sampling in the OSA.

Such measurement is possible because the gain response of the rare-earth doped OFA is relatively slow, particularly in Er-doped OFA. However, since the OFA gain dynamics vary with amplifier types, operating conditions, and control schemes, the gain dynamics should be carefully considered when applying the present test method to various OFA. The manufacturer of the OFA should present data validating the required modulation frequency to limit the error to <1 dB. The measurements for obtaining this information are described in Annex A.

Two alternatives for determining the signal-spontaneous noise figure are specified; namely, the optical switching technique and the gated-OSA technique. The procedure described in this standard is the gated-OSA technique. The optical switching technique is described in IEC 61290-10-1.

The test method described is, in general, for multichannel applications. Single-channel applications are a special case of multichannel applications.

NOTE All numerical values followed by (‡) are suggested values for which the measurement is assured. Other values may be acceptable but should be verified.

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 61291-1, *Optical amplifiers – Part 1: Generic specification*

3 Symbols and abbreviated terms

AGC automatic gain control
ALC automatic level control
ASE amplified spontaneous emission
CW continuous wave
DBR distributed Bragg reflector (laser diode)
DFB distributed feed-back (laser diode)
ECL external cavity laser (diode)
FWHM full-width half maximum
LED light emitting diode
OFA optical fibre amplifier
OSA optical spectrum analyzer
WDM wavelength-division multiplexing (or multiplexer)
$P_{\mathrm{i}}^{\mathrm{PM}}$ source input power on the power meter
$P_{\mathrm{i}}^{\mathrm{OSA}}$ input signal power
$\lambda_{\mathrm{signal}}$ signal wavelength
B_{RBW} resolution bandwidth
$P_{\mathrm{total}}^{\mathrm{meas}}$ output signal power plus ASE
$N_{\mathrm{ASE}}^{\mathrm{meas}}$ measured ASE power
C_{cal} calibration coefficient
$P_{\mathrm{o}}^{\mathrm{linear}}$ linear output signal power
P_{o} output signal power
G gain
$NF_{\mathrm{sig\text{-}sp}}$ signal-spontaneous noise figure
h Planck's constant
υ signal frequency

4 Apparatus

The basic measurement set-up is shown in Figure 1. A source module provides pulsed light to the OFA under test and a synchronization signal to trigger the OSA gating function. The optical attenuator adjusts the power level to the input of the OSA to a value within the OSA measurement range.

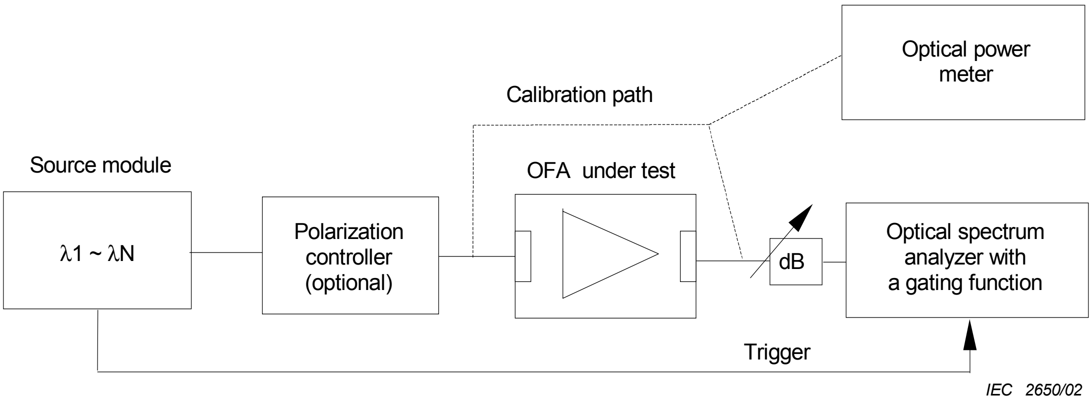

Figure 1 – Test apparatus for signal-spontaneous noise figure parameter measurement – Typical arrangement

The characteristics of the test apparatus are:

a) *Source module:* Two arrangements of the source module are possible, as shown in Figure 2. The first source module (Figure 2a) consists of continuous wave (CW) optical sources with an external optical switch and attenuator(s). The second source module (Figure 2b) consists of directly modulated optical sources and attenuator(s). While only one attenuator is shown, for the multi-wavelength source it will usually be necessary to independently set channel power so that an attenuator is necessary for each channel.

Unless otherwise specified, the full-width half maximum (FWHM) of the output spectrum of both source modules shall be narrower than 0,1 nm (‡)[2] for each wavelength channel so as not to cause any interference to adjacent channels. In the case of a single-channel source, it shall be narrower than 1 nm (‡). Distributed feed-back lasers (DFB), distributed Bragg reflector lasers (DBR) and external cavity laser diodes (ECL), for example, are applicable. The suppression ratio of the side modes of the DFB laser, the DBR laser or the ECL shall be higher than 30 dB (‡). The output power fluctuation shall be less than 0,05 dB(‡), which is more easily attainable with an optical isolator placed at the output port of each source. (Power fluctuation in the measurements can also be caused by interference effects if the setup or amplifier has multiple paths, such as cavities between two reflections. These fluctuations should be controlled by using connectors or splices with reflections weaker than -40 dB (‡) and if needed by increasing the source linewidth to achieve coherence lengths much shorter than any unavoidable cavities in the setup.)

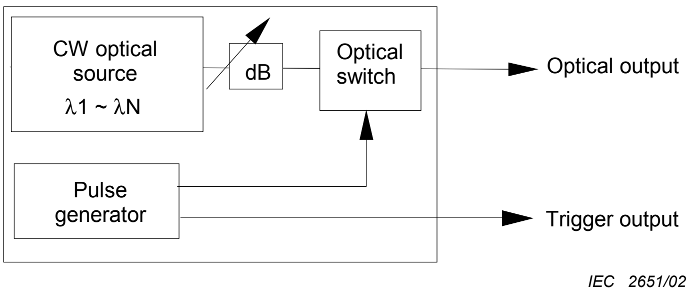

Figure 2a – Optically switched source module

2) See Note in Clause 1.

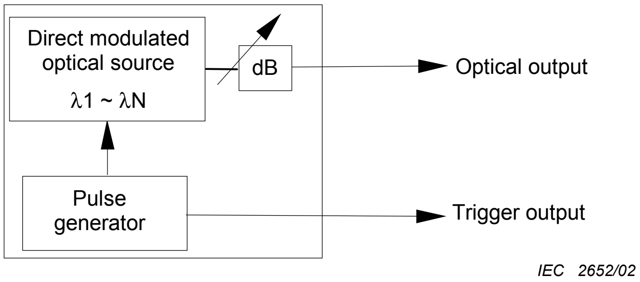

Figure 2b – Directly modulated source module

Figure 2 – Two arrangements of the optical pulse source module

For either arrangement of the source module, the extinction ratio shall be greater than 65 dB (‡). For the directly modulated wavelength-division multiplexing (WDM) source, care should be taken to ensure timing synchronization of the individual lasers. The optical switch in the arrangement of Figure 2a is typically an acousto-optic device in order to obtain the necessary extinction ratio.

The pulse generator in combination with the modulator driver shall provide optical pulses with the repetition frequency variable from 25 kHz to 300 kHz and a 50 % duty cycle. The 10 % to 90 % rise and fall times shall be less than 10 % of the pulse width (‡). The trigger output shall be coincident with the optical pulse turn-on edge with a precision of ±1 µs (‡).

If an optical attenuator is not built into the source module, it shall have an attenuation range greater than 40 dB (‡) and stability better than ±0,1 dB. The reflectance from this device shall be smaller than –40 dB (‡) at each port.

b) *Variable optical attenuator:* The variable optical attenuator in front of the OSA shall have an attenuation range and stability better than 20 dB (‡) and ±0,1 dB respectively.

c) *Optical spectrum analyzer:* This device shall have polarization sensitivity less than ±0,05 dB(‡), stability better than ±0,1 dB (‡), wavelength accuracy better than ±0,5 nm (‡), and wavelength reproducibility better than ±0,01 nm (‡). Resolution bandwidth should be calibrated with an accuracy better than ±3 % The device shall have a measurement range at least from –75 dBm to +10 dBm (‡) with a resolution bandwidth better than 0,1 nm (‡). The reflectance from this device shall be smaller than –35 dB (‡) at its input port. The OSA shall have a data sampling (gating) capability based on external triggering with adjustable delay. The trigger delay resolution shall be ≤1 µs (‡). The OSA shall also have the ability to do *continuous* (ungated) sampling in order to measure the average power over the pulse period.

d) *Optical power meter:* This device shall have a measurement accuracy better than ±0,2 dB (‡), irrespective of the state of the input light polarization, within the operational wavelength band of the OFA and within a power range from –40 dBm to +20 dBm (‡).

e) *Optical connectors:* The connection loss repeatability shall be better than ±0,1 dB (‡). The reflectance from this device shall be smaller than –40 dB (‡).

f) *Optical fibre jumpers:* The mode field diameter of the optical fibre jumpers shall differ from that of the fibres used at input and output ports of the OFA by no more than ±0,5 µm. The reflectance from optical fibre jumpers shall be less than –40 dB (‡) and their length shall be less than 10 m.

g) *Polarization controller:* This device shall be able to provide as input signal light all possible states of polarization (linear, elliptical and circular). For example, the polarization controller may consist of an all-fibre-type polarization controller or a quarter-wave plate rotatable by a minimum of 90° and a half-wave plate rotatable by a minimum of 180°. The loss variation of the polarization controller shall be less than 0,1 dB (‡). The reflectance from this device shall be smaller than –40 dB (‡) at each port. The polarization controller needs to operate in a randomizing mode in which the polarization is scrambled at a rate faster than the averaging time of the OSA.

5 Test sample

The OFA shall operate under nominal operating conditions. If the OFA is likely to cause laser oscillations due to unwanted reflections, optical isolators should be used to bracket the OFA under test. This will minimize the signal instability and the measurement inaccuracy.

Care shall be taken in maintaining the state of polarization of the input light during the measurement. Changes in the polarization state of the input light may result in input optical power changes because of the slight polarization dependency expected from each of the optical components resulting in measurement errors. This problem is largely eliminated if the optional polarization controller is used.

6 Procedure

6.1 General

The test procedure consists of two parts:

a) calibration;

b) OFA measurement.

6.2 Calibration

To calibrate the system:

a) Select the modulation frequency and output power (or attenuator setting) of the source module.

b) Set the output attenuator to a value such that the maximum expected power from the OFA does not exceed the specified input level on the OSA.

   If a polarization controller is used, set it to its randomizing mode in which it scrambles the state of polarization.

c) Connect the source to the optical power meter as indicated in Figure 1 and set and measure the source input power on the power meter, P_i^{PM} (dBm). If the source is a multi-wavelength source, turn on only one source at a time and set and measure P_i^{PM} at each wavelength.

d) Set the OSA to continuous sampling (no triggering). In this mode, the average power over the pulse period is measured.

e) Connect the source to the OSA through the attenuator as shown in Figure 1 and measure the input signal power, P_i^{OSA}. For the multi-wavelength source, repeat at each wavelength.

NOTE The optical power meter detects total signal power including the source spontaneous emission. For signal to spontaneous emission ratios of <40 dB/nm, it is necessary to consider the effect on OSA calibration and correct accordingly.

6.3 Output signal and noise measurement

To measure the output signal and noise:

a) Connect the OFA between the source and output attenuator as shown in Figure 1.

b) Set the OSA to continuous sampling in order to measure the average power over the pulse period. At the signal wavelength, λ_{signal}, take an OSA reading in resolution bandwidth, B_{RBW}. A typical value of B_{RBW} is 0,2 nm. The measured quantity, expressed in decibels referred to 1 mW (dBm), is