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Edition 2.0 2016-09

INTERNATIONAL STANDARD

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Optical amplifiers – Test methods – Part 4-1: Gain transient parameters – Two-wavelength method

Amplificateurs optiques – Méthodes d'essai – Partie 4-1: Paramètres de gain transitoire – Méthode à deux longueurs d'onde

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OPTICAL AMPLIFIERS – TEST METHODS –

Part 4-1: Gain transient parameters – Two-wavelength method

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International Standard IEC 61290-4-1 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 2011. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) extended the applicability from only EDFAs to all OFAs;
b) updated definitions for consistency with other documents in the IEC 61290-4 series.

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

CDV	Report on voting
86C/1347/CDV	86C/1397/RVC

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document 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* can be found on the IEC website.

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

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INTRODUCTION

This part of IEC 61290-4 is devoted to optical amplifiers (OAs). The technology of OAs is quite new and still emerging; hence amendments and new editions to this document can be expected.

Background information on the transient phenomenon in erbium-doped fibre amplifiers and the consequences on fibre optic systems is provided in Annex A and on slew rate effects in Annex B.

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OPTICAL AMPLIFIERS – TEST METHODS –

Part 4-1: Gain transient parameters – Two-wavelength method

1 Scope

This part of IEC 61290-4 applies to optical amplifiers (OAs) using active fibres (optical fibre amplifiers (OFAs)) containing rare-earth dopants including erbium-doped fibre amplifiers (EDFAs) and optically amplified elementary sub-systems. These amplifiers are commercially available and widely deployed in service provider networks.

The object of document is to provide the general background for OFA transients and related parameters, and to describe a standard test method for accurate and reliable measurement of the following transient parameters:

a) channel addition or removal transient gain overshoot and transient net gain overshoot;

b) channel addition or removal transient gain undershoot and transient net gain undershoot;

c) channel addition or removal gain offset;

d) channel addition or removal transient gain response time constant (settling time).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61291-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
surviving channel
optical signal that remains after a drop event

3.1.2
rise time
time it takes for the input optical signal to rise from 10 % to 90 % of the total difference between the initial and final signal levels during an add event

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Note 1 to entry: See Figure 1(a).

3.1.3
initial gain
gain of the surviving or pre-existing channel before a drop or add event

3.1.4
final gain
steady-state gain of the surviving or pre-existing channel after a long period of time (i.e. once the gain has stabilized) after a drop or add event

3.1.5
gain offset
change of the gain between initial and final state

Note 1 to entry: Gain offset is expressed in dB.

Note 2 to entry: Gain offset = final gain (in dB) – initial gain (in dB).

Note 3 to entry: Gain offset may be positive or negative for both channel addition and removal events.

3.1.6
gain stability
specified peak-to-peak gain fluctuations of the OFA under steady state conditions (i.e. not in response to a transient event)

3.1.7
transient gain response time constant
settling time
amount of time required to bring the gain of the surviving or pre-existing channel to the final gain

Note 1 to entry: This parameter is the measured time from the beginning of the drop or add event that created the transient gain response to the time at which the surviving or pre-existing channel gain first enters within the gain stability band centred on the final gain.

Note 2 to entry: Hereon, this will also be referred to as "settling time".

3.1.8
transient gain overshoot
difference between the maximum surviving or pre-existing channel gain reached during the OFA transient response to a drop or add event, and the lowest of either the initial gain and final gain

Note 1 to entry: Transient gain overshoot is expressed in dB.

Note 2 to entry: Hereon, this will also be referred to as "gain overshoot".

3.1.9
transient net gain overshoot
difference between the maximum surviving or pre-existing channel gain reached during the OFA transient response to a drop or add event, and the highest of either the initial gain and final gain

Note 1 to entry: The transient net gain overshoot is expressed in dB.

Note 2 to entry: The transient net gain overshoot is the transient gain overshoot minus the gain offset, and represents the actual transient response not related to the shift of the amplifier from the initial steady state condition to the final steady state condition.

Note 3 to entry: Hereon, this will also be referred to as "net gain overshoot".

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3.1.10
transient gain undershoot
difference between the minimum surviving or pre-existing channel gain reached during the OFA transient response to a drop or add event, and the highest of either the initial gain and final gain

Note 1 to entry: The transient gain undershoot is expressed in dB.

Note 2 to entry: Hereon, this will also be referred to as "gain undershoot".

3.1.11
transient net gain undershoot
difference between the minimum surviving or pre-existing channel gain reached during the OFA transient response to a drop or add event and the lowest of either the initial gain and final gain

Note 1 to entry: The transient net gain undershoot is expressed in dB.

Note 2 to entry: The transient net gain undershoot is the transient gain undershoot minus the gain offset and represents the actual transient response not related to the shift of the amplifier from the initial steady state condition to the final steady state condition.

Note 3 to entry: Hereon this will also be referred to as "net gain undershoot".

3.2 Abbreviated terms

AGC automatic gain control
AOM acousto-optic modulator
BER bit error rate
DFB distributed feedback
DWDM dense wavelength division multiplexing
EDFA erbium-doped fibre amplifier
FWHM full-width half-maximum
NEM network equipment manufacturer
NSP network service provider
O/E optical-to-electronic
OA optical amplifier
OFA optical fibre amplifier
OSNR optical signal-to-noise ratio
SHB spectral-hole-burning
VOA variable optical attenuator
WDM wavelength division multiplexing

4 Measurement apparatus

When the input power to an OFA operating in saturation changes sharply, the gain of the amplifier will typically exhibit a transient response before settling back into the required gain. This response is dictated both by the optical characteristics of the active fibre within the OFA as well as the performance of the automatic gain control (AGC) mechanism.

Since a change in input power typically occurs when part of the dense wavelength division multiplexing (DWDM) channels within the specified transmission band are dropped or added, definitions are provided that describe a dynamic event leading to transient response. Rise and fall time definitions are shown in Figure 1.

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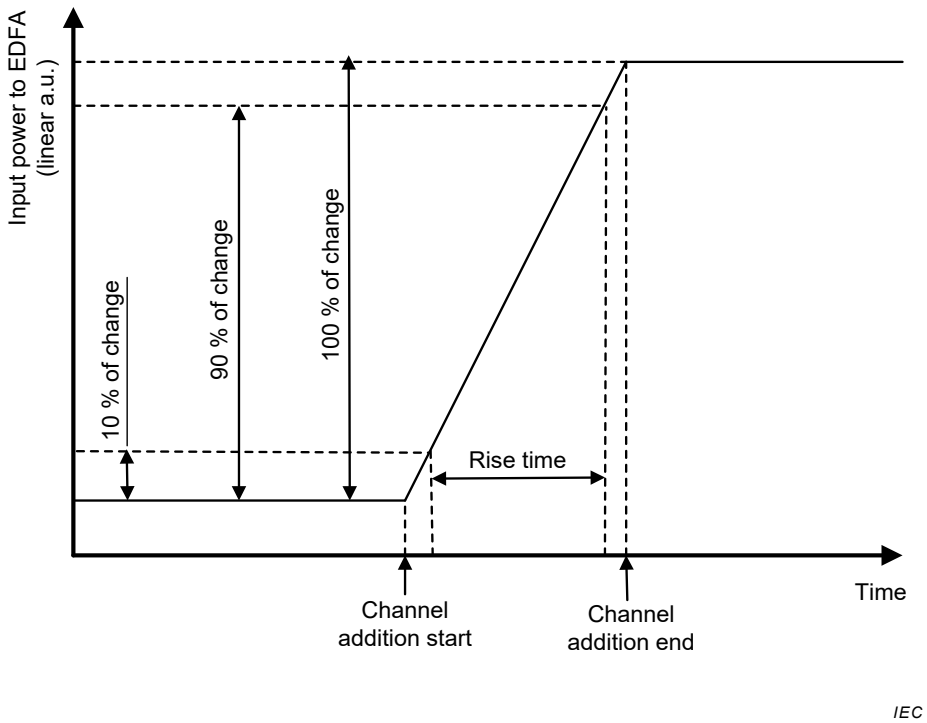
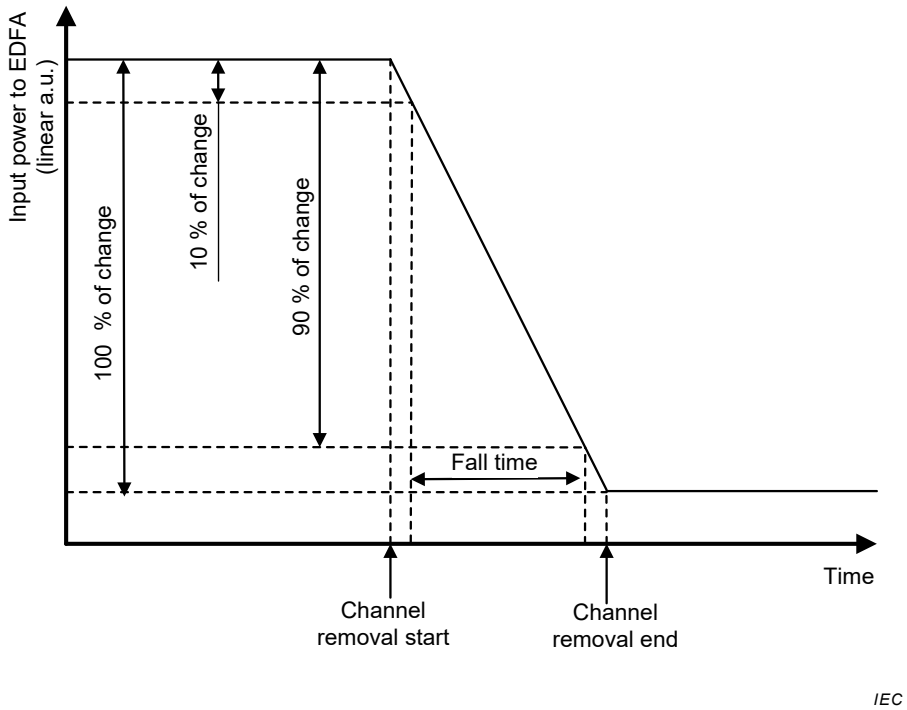


(a) Definitions of rise and fall times in the case of a channel addition event



(b) Definitions of rise and fall times in the case of a channel removal event

Figure 1 – Definitions of rise and fall times

The parameters generally used to characterize the transient gain behaviour of a gain controlled OFA for the case of channel removal are defined in Figure 2(a). The figure specifically represents the time dependence of the gain of one of the surviving channels when channels are removed. Likewise, the transient gain behaviour for the case when channels are added is shown in Figure 2(b). The main transient parameters are: transient gain response time constant (settling time), gain offset, transient net gain overshoot, and transient gain net undershoot. The transient gain overshoot and undershoot are particularly critical to carriers

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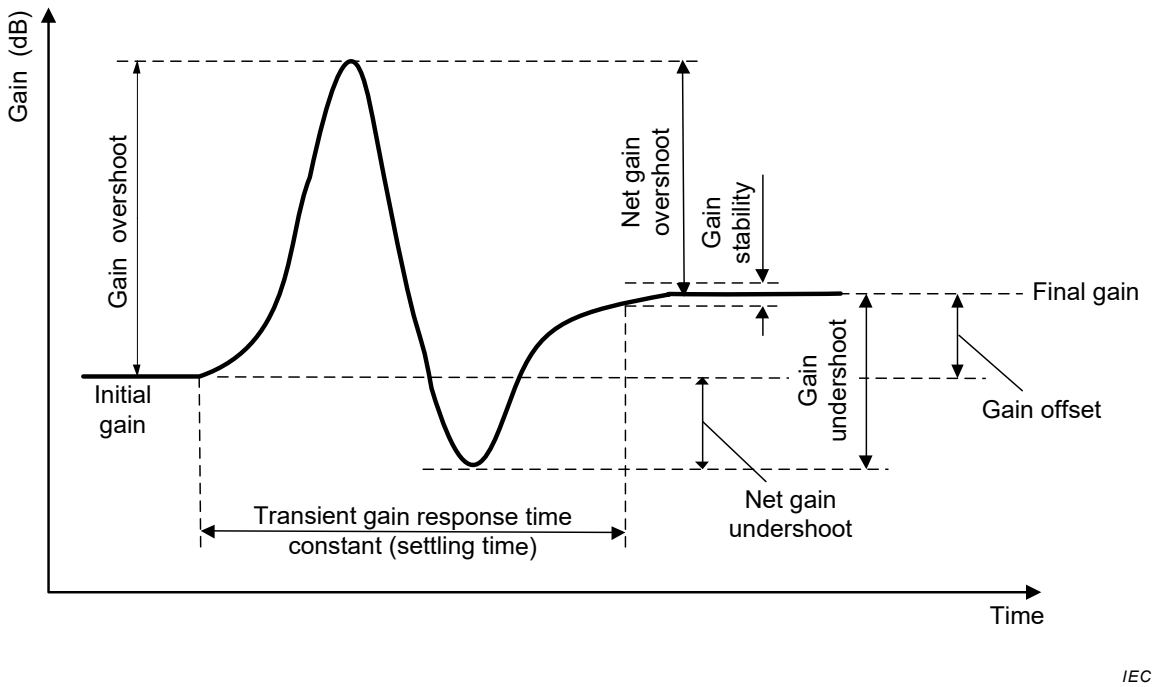
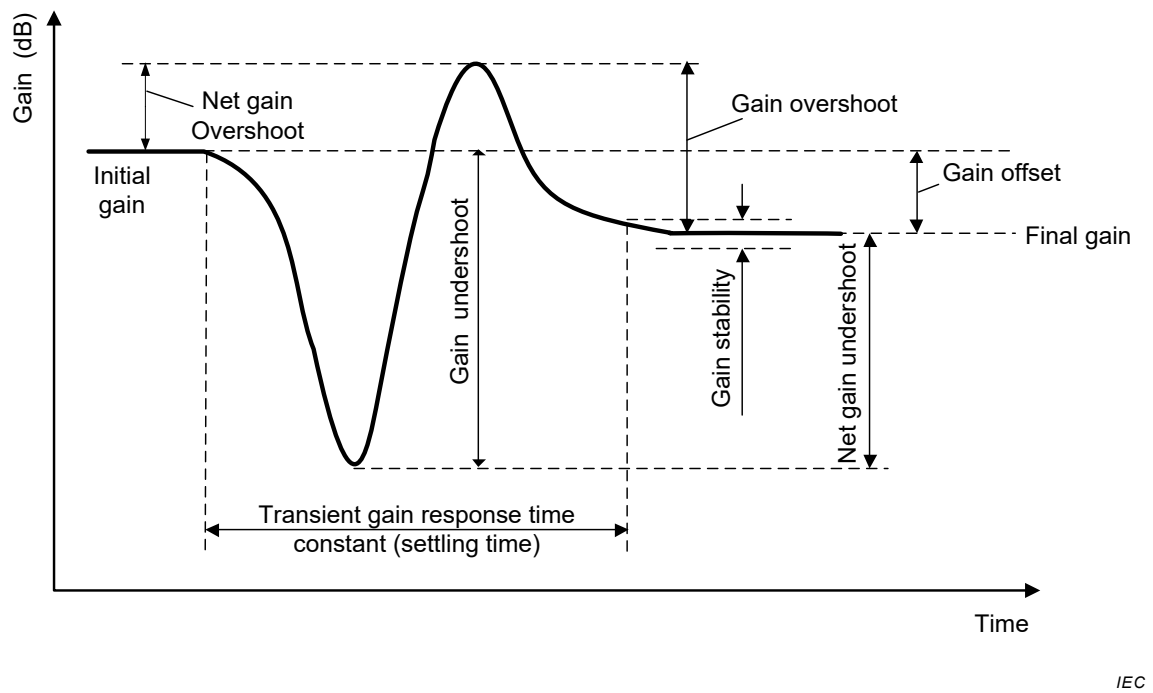
and network equipment manufacturers (NEMs) given that the speed and amplitude of gain fluctuations compound through the network as the optical signal passes through an increasing number of cascaded amplifiers. Properly designed optical amplifiers have very small values for these transient parameters.



(a) OFA transient gain response for a channel removal event



(b) OFA transient gain response for a channel addition event

Figure 2 – OFA transient gain response

Figure 3 shows a typical setup to characterize the transient response properties of OFAs.

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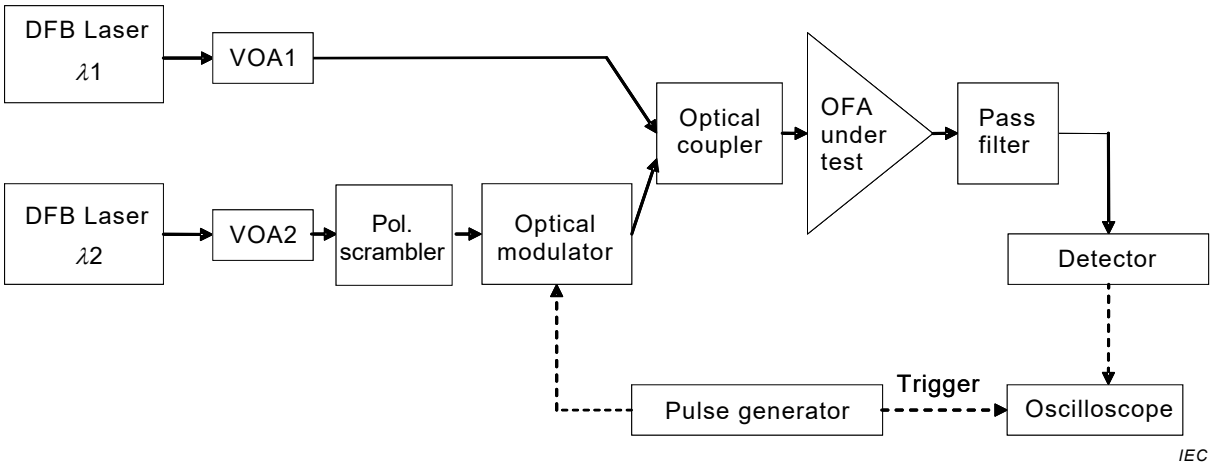

Figure 3 – Generic transient control measurement setup

5 Test specimen

The OFA shall operate at 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 signal instability and measurement inaccuracy.

6 Procedure

In the setup shown in Figure 3, the input signal power into the amplifier being tested is the combination of two distributed feedback (DFB) lasers with wavelengths approximately 1 nm apart. One of the wavelengths represents add or drop channels while the other represents pre-existing or surviving channels. Each wavelength channel is subsequently adjusted with a variable optical attenuator (VOA) to the desired optical input power levels. One optical modulator driven by a function generator acts as an on/off switch, to simulate add and drop events. The two optical channels are subsequently combined onto the same fibre before the signal is directed to the amplifier being tested. A tuneable filter, an optical-to-electronic (O/E) converter and an oscilloscope are placed in tandem at the output of the amplifier. The pre-existing or surviving channel is selected with the tuneable filter and its transient response is monitored with the O/E converter and oscilloscope. A waveform similar to the one shown in Figure 2 is displayed on the oscilloscope's screen.

To simulate a drop event at the input of the amplifier being tested, the two lasers are set so that their total input power is equal to the amplifier's typical input power (e.g. 1 dBm). Therefore, the two lasers at –2 dBm each represent 20 optical channels having –15 dBm power per channel. When the function generator turns the modulator into the "off" position, the second laser is completely suppressed, changing the system's channel loading. For instance, when one laser is switched off, it simulates a 3 dB "drop" or a change in the system's channel loading from 40 channels to 20 channels. Similarly, when the modulator is changed into an "on" state, the addition of a second laser simulates a 3 dB add in optical power, or a change in the system's channel loading from 20 channels to 40 channels. For other transient control measurements, the VOAs can be adjusted accordingly so that the input power levels will differ by an appropriate value.

Several transient control measurements can be performed, according to the operating conditions and specifications that are provided. Measurements may also be taken for various add and drop scenarios as shown in Table 1. These measurements are typically performed over a broad range of input power levels.

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Table 1 – Examples of add and drop scenarios for transient control measurement

Scenario	Total channels	Pre-existing or surviving channels	Channels added or dropped
20 dB add or drop	100	1	99
16 dB add or drop	40	1	39
13 dB add or drop	40	2	38
10 dB add or drop	40	4	36
6 dB add or drop	40	10	30
3 dB add or drop	40	20	20

7 Calculations

The results of the transient measurement are the following parameters:

- Channel addition or removal transient gain overshoot and transient net gain overshoot
- Channel addition or removal transient gain undershoot and transient net gain undershoot
- Channel addition or removal gain offset
- Channel addition or removal transient gain response time constant (settling time)

These parameters can be extracted from the oscilloscope display, as described in Figure 2.

8 Test results

Table 2 shows typical measurement conditions and transient control measurement results of C-band OFAs. The measurement conditions include gain, surviving channel wavelength, input power, transient type (e.g., 3 dB drop, 1 dB add), and different transient parameters. In order to characterize the OFA transient, the user should choose the measurement conditions to adequately characterize the dynamic range of the OFA. The values of amplifier gain, pre-existing or surviving channel wavelength and added or dropped channel wavelength shall be provided by the specifier.

Typical values of transient parameters are listed in the last row of Table 2.

Table 2 – Typical results of transient control measurement

Amplifier gain[a] (___dB)			**Pre-existing or surviving channel wavelength**[a] (___nm) **Added or dropped channel wavelength**[a] (___nm)		
Transient event description	**Input power** dBm	**Transient net gain overshoot** dB	**Transient net gain undershoot** dB	**Transient gain response time constant** µs	**Gain offset** dB
3 dB add or drop	–4	0,5	0,2	10	–0,2
x dB add or drop					
y dB					
Typical values		< 1	< 0,5	< 100	< 0,5
[a] Values of gain and wavelength to be provided by the specifier.					

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