IEC 61290-3-3

Edition 1.0 2013-11

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Optical amplifiers – Test methods –
Part 3-3: Noise figure parameters – Signal power to total ASE power ratio

Amplificateurs optiques – Méthodes d'essais –
Partie 3-3: Paramètres du facteur de bruit – Rapport puissance du signal sur puissance totale d'ESA

IEC 61290-3-3:2013

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FOREWORD

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International Standard IEC 61290-3-3 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:

CDV	Report on voting
86C/1121/CDV	86C/1184/RVC

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 in 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 web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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- withdrawn,
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OPTICAL AMPLIFIERS –
TEST METHODS –

Part 3-3: Noise figure parameters –
Signal power to total ASE power ratio

1 Scope and object

This part of IEC 61290-3 applies to all commercially available single channel optical amplifiers (OAs), including OAs using optically pumped fibres (OFAs) based on either rare-earth doped fibres or on the Raman effect, semiconductor optical amplifier modules (SOA modules) and planar optical waveguide amplifiers (POWAs). More specifically, it applies to single channel OAs placed before optical receivers, where there are no optical bandpass filtering elements placed between the OA and the receiver.

The object of this part of IEC 61290-3 is to establish uniform requirements for accurate and reliable measurement of the ratio of the signal output power to the total ASE power generated by the OA in the optical bandwidth of the receiver. This quantity is a measure of the spontaneous-spontaneous beat noise at the receiver, and is correlated to the spontaneous-spontaneous noise factor of the OA, $F_{sp\text{-}sp}$, as defined in IEC 61290-3 and IEC 61291-1.

IEC 61290-3-1 describes a measurement method, using an optical spectrum analyzer, OSA, for the signal-spontaneous noise factor F_{sig-sp} but does not describe a method for measuring $F_{sp\text{-}sp}$. IEC 61290-3-2 describes a measurement method, using an electrical spectrum analyzer (ESA), for the total noise factor $F_{sp\text{-}sp} + F_{sig\text{-}sp}$. However, this method does not allow $F_{sp\text{-}sp}$ to be measured separately, and therefore does not provide a means of directly quantifying the effect of spontaneous-spontaneous beat noise at the receiver. This part of IEC 61290-3 complements IEC 61290-3-1 and IEC 61290-3-2 in that it provides such a means.

Two measurement methods are provided for the ratio of the signal output power to the total ASE power. The first method uses an OSA, while the second method uses a bandpass filter and an optical power meter.

2 Normative references

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

IEC 61290-3, *Optical amplifiers – Test methods – Part 3: Noise figure parameters*

IEC 61291-1:2012, *Optical fibre amplifiers – Part 1: Generic specification*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1
signal input power
P_{in}
power of the optical signal at the input to the OA

3.1.2
signal output power
P_{out}
power of the optical signal at the output of the OA

3.1.3
signal wavelength
λ_s
wavelength of the signal optical carrier

[SOURCE: IEC 61291-1:2012, definition 3.2.2.1.1]

3.1.4
signal gain
G
gain of the OA at the signal wavelength, defined as the ratio of the output signal power to the input signal power

3.1.5
amplified spontaneous emission band

ASE band
B_{ASE}
wavelength band that contains at least 99 % of the total ASE power generated by OA

3.1.6
ASE centre wavelength
λ_C
centre wavelength of the ASE band

3.1.7
ASE power
P_{ASE}
ASE power generated by the OA within the ASE band

3.1.8
signal to total ASE power ratio
Sig_ASE
ratio of the output signal power to the total ASE power within B_{ASE}

3.1.9
spontaneous–spontaneous noise factor
$F_{sp\text{-}sp}$
ratio of the electrical SNR due to spontaneous-spontaneous beat noise at the OA output to the electrical SNR due to shot noise at the OA input

Note 1 to entry: See also IEC 61290-3 for a detailed formula for of $F_{sp\text{-}sp}$.

3.2 Abbreviations

APD	avalanche photo diode
AFF	ASE flattening filter
ASE	amplified spontaneous emission

CD	chromatic dispersion
DFB	distributed feedback
EDFA	erbium-doped fibre amplifier
ESA	electrical spectrum analyzer
FWHM	full width half maximum
NF	noise figure
OA	optical amplifier
OFA	optical fibre amplifier
OSA	optical spectrum analyzer
PDG	polarization dependent gain
PMD	polarization mode dispersion
POWA	planar optical waveguide amplifier
RBW	resolution band width
SNR	signal to noise ratio
SOA	semiconductor optical amplifier
VOA	variable optical attenuator
WDM	wavelength division multiplexing

4 Background

In recent years, high-speed transmission links beyond 10 Gb/s have been commercially introduced. These links (as well as some high-end 10-Gb/s links, such as submarine links) require high sensitivity receivers, e.g. avalanche photo diode (APD) receivers, which operate in a limited input optical power dynamic range. In addition, specialized optical components such as chromatic dispersion (CD) compensators and polarization mode dispersion (PMD) compensators may be placed on the receiver module, thus introducing considerable optical insertion loss.

In multi-channel wavelength division multiplexed (WDM) links a multi-channel OA is often placed at the end of the link before the WDM signal is demultiplexed into individual channels. The total output power of the multi-channel OA is typically such that the optical power per channel is in the range of 0 dBm to 5 dBm. This power is then attenuated by the demultiplexer, and further attenuated by the specialized optical components mentioned above. Thus, the optical power reaching the receiver may be below the required input optical power dynamic range. In this case, a single channel OA may be placed on the receiver module to boost the optical power reaching the receiver.

In such a situation, there is typically no optical bandpass filter between the single channel OA and the receiver, so that all the amplified spontaneous emission (ASE) noise generated by the amplifier reaches the receiver. This can result in a significant level of spontaneous-spontaneous beat noise at the receiver. One way to characterize this noise is through the spontaneous-spontaneous noise factor, $F_{\text{sp-sp}}$, as defined in IEC 61290-3 and IEC 61291-1. Another way to characterize the spontaneous-spontaneous beat noise is through the signal to total ASE power ratio, Sig_ASE, at the OA output, given by the following:

$$Sig\_ASE = \frac{P_{\text{out}}}{P_{\text{ASE}}} \tag{1}$$

where P_{out} is the signal output power of the OA, and P_{ASE} is the ASE power generated by the OA within the ASE band, given by

$$P_{ASE} = \int_{B_{ASE}} \rho_{ASE}(\lambda) d\lambda \qquad (2)$$

where B_{ASE} is the ASE band of the OA defined as a wavelength band that contains at least 99 % of the total ASE power generated by OA.

Care should be taken to define B_{ASE} such that it excludes other sources of noise not related to ASE. In particular, B_{ASE} should exclude possible pump leakage power exiting the OA output port. For example, for a C-band EDFA pumped by a 1 480 nm pump, B_{ASE} should not include wavelengths below 1 500 nm. This guarantees that B_{ASE} includes at least 99 % of the ASE generated within the EDFA on the one hand, while excluding possible 1 480 nm pump leakage power on the other.

NOTE 1 In many OAs, and especially in OFAs, the ASE is polarization independent. In some OAs, such as some types of SOA modules, the ASE may be polarization dependent. P_{ASE} refers to the total power in both polarization directions.

While there is no direct relation between Sig_ASE and $F_{sp\text{-}sp}$, it is clear that there is a correlation between them, and that both quantities can be used to quantify the effect of spontaneous-spontaneous beat noise at the receiver. The higher is Sig_ASE, the lower is the spontaneous-spontaneous beat noise (and the lower $F_{sp\text{-}sp}$), and vice-versa.

In this standard, a measurement method for Sig_ASE is presented. Annex A provides a brief technical discussion of the various OA parameters that can affect and determine the Sig_ASE value.

NOTE 2 All quantities in this standard are in linear units, unless specifically defined otherwise.

5 Apparatus

5.1 Measurement using an OSA

This subclause describes the apparatus used for measuring Sig_ASE using an OSA. Figure 1 shows the test set-up used for OSA calibration, as well as for measuring the signal input power and the source spontaneous emission power. Figure 2 shows the test set-up used to measure the signal output power and the ASE power.

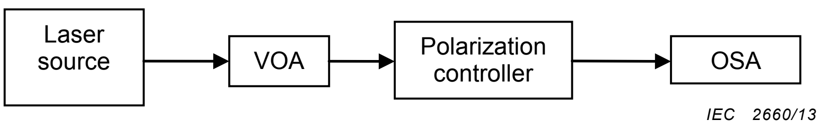

Figure 1 – Test set-up for OSA calibration and for measuring signal input power and source spontaneous emission power

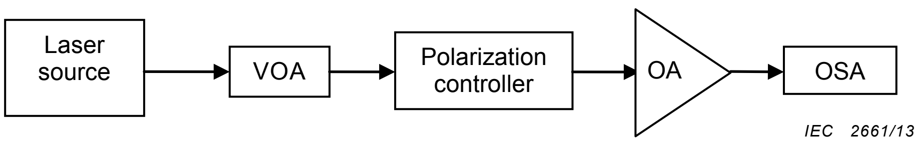

Figure 2 – Test set-up for measuring signal output power and ASE power using an OSA

The test equipment listed below, with the required characteristics, is needed.

a) A laser source with the following characteristics:
   1) Either a tuneable laser or a set of discrete lasers able to support the range of signal wavelengths for which the OA under test is to be tested.
   2) An achievable output power such that the input signal power to the OA under test is above the maximum specified input signal power.
   3) A single line output with a side mode suppression ratio of at least 40 dB.
   4) A FWHM linewidth <0,01 nm.
   5) Output power stability <0,05 dB.
b) VOA – A variable optical attenuator (VOA) with a dynamic range sufficient to support the required range of input signal power levels at which the OA under test is to be tested. The reflectance from each port of the device should be <–50 dB.

   NOTE 1 If the output power of the laser source can be varied over the required dynamic range, then the VOA may not be needed.
c) Polarization controller – a device capable of transforming any input polarization state to any output polarization state. The reflectance from each port of the device should be <–50dB.

   NOTE 2 If the polarization dependent gain (PDG) of the an OFA or POWA is <0,3 dB, the polarization controller may not be needed.
d) OSA – the OSA shall have the following characteristics:
   1) Polarization sensitivity less than 0,1dB.
   2) Power stability better than 0,1dB.
   3) Wavelength accuracy better than 0,05 nm.
   4) The resolution bandwidth (RBW) of the OSA should be set to a value in the range of 0,2 nm to 1 nm, preferably 0,5 nm.
   5) Reflectance from the input port of the OSA should be <–50 dB.

5.2 Measurement using a bandpass filter and an optical power meter

This subclause describes the apparatus used for measuring Sig_ASE using a filter and an optical power meter. Figure 3 shows the test set-up used for the filter insertion loss calibration, as well as for measuring the signal input power. Figure 4 shows the test set-up used to measure the signal output power and the ASE power. This measurement method does not allow for the measurement of the laser source spontaneous emission, thus requiring a laser source with low enough spontaneous emission so as not to affect the Sig_ASE measurement (see laser source requirements below).

In cases where the OA may emit power outside of B_{ASE} (for example, pump leakage in the case of an amplifier employing 1 480 nm pumps), then a filter should be placed before the optical power meter to filter out such unwanted components. Such a filter should have an insertion loss ripple of <0,5 dB over B_{ASE}, and should have an extinction ratio of at least 30 dB (relative to the insertion loss within B_{ASE}) for the unwanted wavelength components. This filter should be placed before the optical power meter in Figure 3 and Figure 4.

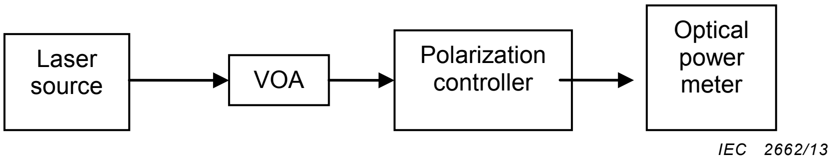

Figure 3a – Test set-up without bandpass filter

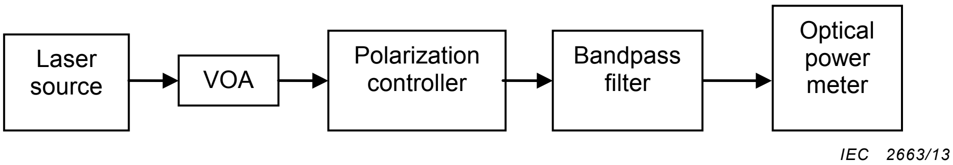

Figure 3b – Test set-up with bandpass filter

Figure 3 – Test set-ups for filter calibration and measuring the signal input power

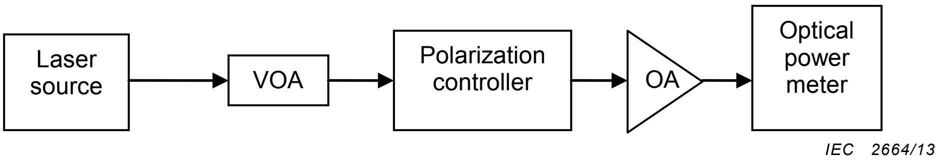

Figure 4a – Test set-up without bandpass filter

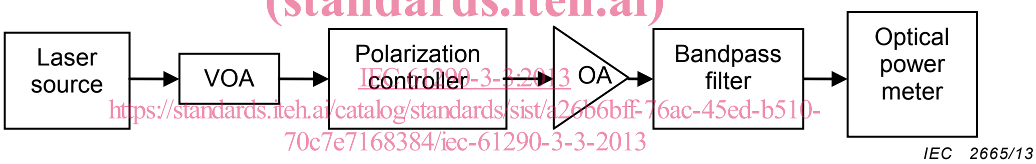

Figure 4b – Test set-up with bandpass filter

Figure 4 – Test set-ups for measuring output signal power and ASE power using a filter and an optical power meter

The test equipment listed below, with the required characteristics, is needed.

a) A laser source with the following characteristics:

1) Either a tuneable laser or a set of discrete lasers able to support the range of signal wavelengths for which the OA under test is to be tested.

2) An achievable output power such that the input signal power to the OA under test is above the maximum specified input signal power.

3) A single line output with a side mode suppression ratio of at least 40 dB.

4) A total spontaneous emission power within B_{ASE} which is at least $X +$ 20 dB less than the laser output power, where X is the lowest specified Sig_ASE ratio of the OA.

5) A FWHM linewidth <0,01 nm.

6) Output power stability <0,05 dB.

b) VOA – A variable optical attenuator (VOA) with a dynamic range sufficient to support the required range of input signal power levels at which the OA under test is to be tested. The reflectance from each port of the device should be <–50 dB.

NOTE 2 If the output power of the laser source can be varied over the required dynamic range, then the VOA may not be needed.