IEC 61291-5-2

Edition 2.0 2017-01

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Optical amplifiers –
Part 5-2: Qualification specifications – Reliability qualification for optical fibre amplifiers

Amplificateurs optiques –
Partie 5-2: Spécifications de qualification – Qualification de fiabilité pour amplificateurs à fibres optiques

IEC 61291-5-2:2017-01(en-fr)

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OPTICAL AMPLIFIERS –

Part 5-2: Qualification specifications – Reliability qualification for optical fibre amplifiers

FOREWORD

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International Standard IEC 61291-5-2 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 2002. It constitutes a technical revision.

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

a) removal of the contents on the relating quality management system from scope, terms and definitions, and the reliability requirements;
b) moving fit-rate calculation to Annex B (informative);
c) change of requirements for shock test;
d) amendment of abbreviations related to changes a) and b).

The text of this International Standard is based on the following documents:

CDV	Report on voting
86C/1376/CDV	86C/1426/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 in the IEC 61291 series, published under the general title *Optical amplifiers,* can be found on the IEC website.

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

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- withdrawn,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

OPTICAL AMPLIFIERS –

Part 5-2: Qualification specifications – Reliability qualification for optical fibre amplifiers

1 Scope

This part of IEC 61291 applies to optical amplifiers (OAs) and optically amplified, elementary sub-systems for terrestrial applications, using active fibres (optical fibre amplifiers (OFAs)) containing rare-earth dopants, which are commercially available.

The black box approach is used in this document. The black box approach is adopted in order to give product specifications which are independent of OA implementation details. For reliability qualification purposes, some information about the internal components is needed; these internal parts are themselves treated as black boxes. This document gives requirements for the evaluation of OA reliability by combining the reliability of such internal black boxes.

The object of this document is to specify the minimum list of reliability qualification tests, requirements on failure criteria during testing and on reliability predictions, and give the relevant normative references to establish a standard method for the assessment of the reliability of OFA devices and sub-systems in order to minimize risks and to promote product development and reliability qualification.

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 60050-731, *International Electrotechnical Vocabulary – Chapter 731: Optical fibre communication*

IEC 60068-2-2:2007, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

IEC 60068-2-14, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60068-2-21, *Environmental testing – Part 2-21: Tests – Test U: Robustness of terminations and integral mounting devices*

IEC 60068-2-27, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

IEC 60068-2-31, *Tests – Test Ec: Rough handling shocks, primarily for equipment-type specimens*

IEC 60068-2-78, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

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

IEC 61300-2-4, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2-4: Tests – Fibre/cable retention*

IEC 62005-9-1, *Fibre optic interconnecting devices and passive components – Reliability – Part 9-1: Qualification of passive optical components*

IEC 62005-9-2, *Reliability of fibre optic interconnecting devices and passive optical components – Part 9-2: Reliability qualification for single fibre optic connector sets – Single mode*

TIA 455-11, *FOTP-11 Vibration Test Procedure for Fiber Optic Components and Cables*

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, IEC 60050-731 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
failure
non-compliance to product specification or change in parameters as agreed by the customer and supplier

3.1.2
OFA manufacturer
OFAM
manufacturer who provides optical fibre amplifier (OFA) devices or subsystems meeting the requirements of the applicable product specification (PS)

Note 1 to entry PS includes the reliability requirement.

3.2 Abbreviated terms

EDFF	erbium doped fluoride fibre
EDSFA	erbium doped silica fibre amplifier
EDTF	erbium doped tellurite fibre
FIT	failure in time
FFS	for further study
OA	optical amplifier
OFA	optical fibre amplifier
OFAM	optical amplifier manufacturer
OFAM	optical fibre amplifier manufacturer
PDFF	praseodymium doped fluoride fibre
PS	product specification
RH	relative humidity
DFF	thulium doped fluoride fibre
UCL	upper confidence level

4 Reliability requirements

4.1 Tests

4.1.1 General

An optical fibre amplifier (OFA) device or sub-system is an assembly of various parts and components of different nature. A main point in the reliability testing of the OFA device or sub-system is to ensure the reliability of each part and basic manufacturing process used and to provide a route that may result in an understanding of design margins. For the purpose of this document, each internal part shall be seen as a black box.

This document is based on the assumption that the reliability of an optical amplifier (OA) can be evaluated with sufficient confidence from the failure in time (FIT) rates of its internal black boxes when the assembly process of the constituents has been qualified.

The procedures to qualify the assembly process are described in 4.1.3.

The reliability assurance is confirmed by the test procedure described in 4.1.4 carried out on the OFA device or sub-system as a whole.

The basic parts usually constituting an OFA are listed below:

- passive optical components;
- opto-electronic components;
- doped fibres or doped fibre modules;
- optical connectors;
- electronics;
- others (to be specified);
- mechanical packaging.

The OFA manufacturer (OFAM) should declare the number and type of the internal black boxes constituting the OFA and give the failure rates (in FIT) for each of them.

The OFA failure rate should be calculated by suitably combining the FIT rates of its internal parts, as described in Annex B.

4.1.2 Reliability qualification of components

Table 1 and Table 2 give the minimum list of tests to be performed on the various parts, where used, constituting the OFA in order to guarantee the claimed reliability level. Normative references for tests and test conditions are given in Annex A.

Table 1 – Minimum test list for passive optical components, pump laser modules, monitor diode modules and optical connectors

Component	Reference
Pump laser diode	IEC 62572-3 (informative)
Photo diode	To be defined
Passive optical components	IEC 62005-9-1
Optical connectors	IEC 62005-9-2
Variable optical attenuators	To be defined

Table 2 – Minimum test list for doped fibre

Test
Proof test
Hydrogen aging
Fibre coating strip force (for non-hermetic fibre only)

A set of test conditions suitable to the test lists in Table 1 and Table 2 to assess the reliability of OFA components (seen as black boxes) is given for reference in Annex A. These test conditions specify the common practice in the OFA manufacturing industry.

4.1.3 Reliability qualification of the OFA assembly process

Fibre arrangement and assembly of the optical and electrical components are very important aspects for assessing the reliability of an OFA. In particular, the fibre winding and splice process is one of the most critical steps in the OFA assembly process.

The splice process shall be qualified according to the relevant fibre and coating material.

Table 3 indicates the tests required on splices.

Table 3 – Tests required for splices

Tests	Conditions	Reference
High temperature storage	+85 °C 2 000 h	IEC 60068-2-2, Tests B
Change of temperature (Thermal cycling)[a]	-40 °C /+85 °C 2 °C/min *Q* = 100 cycles *I* = 500 cycles	IEC 60068-2-14
Damp heat	40 °C 93 % RH 500 h	IEC 60068-2-78
Shock	1 000 m/s^2 6 ms 6 times/axis	IEC 60068-2-27
Vibrations	5 Hz to 50 Hz, 15 m/s^2 50 Hz to 500 Hz, 30 m/s^2 3 axis Duration 15 sweeps	TIA 455-11
Robustness test (Pull test)	5 N 10 s	IEC 60068-2-21
[a] *Q*: data for qualification, *I*: data for information.		

The number of samples is to be agreed between customer and supplier according to the level of confidence and the level of reliability required.

4.1.4 Reliability qualification of the OFA device or sub-system

A reliability qualification procedure related to the complete OFA device or sub-system is described in Table 4. It gives the minimum list of tests to be performed on OFA devices and sub-systems in order to assure reliability. Normative references, where tests and test conditions are specified, are given in Annex A.

The purpose of the testing is to assess the prediction of the failure rate of the complete OFA performed according to the procedure of 4.1.2.

On the basis of the reliability assurance required for the reliability tests for the OFA internal black boxes, the sampling level is generally low (for example a few samples for each amplifier type).

In some specific cases (for example, non-silica glass OFAs), the use of adhesives in the OFA can be considered as a critical process and shall be qualified separately. Depending on the possible function of the adhesive (mechanical anchoring, splice protection, index matching, etc.), the different failure modes shall be addressed and supported by reliability data.

Table 4 – Minimum list for tests required on OFA devices and sub-systems

Test		Condition	Duration	Operating	Samples
Temperature storage		$T_{stg,min}/T_{stg,max}$	72 h	-	3
Temperature cycling[a]		$T_{stg,min}/T_{stg,max}$ Ramp > 1 °C/min	Q = 100 cycles I = 500 cycles	Y	3
Damp heat		85 °C to 85 % RH [b]	Q = 500 h I = 1 000 h	-	3
Mechanical test	Shock (≤ 0,225 Kg) [c]	3 000 m/s² 3 ms pulse	5 shocks per direction, 6 directions	-	3
		See table below [d]	See table below [c]	-	
	Shock (> 0,225 Kg) [c]	500 m/s², 11 ms pulse	5 shocks per direction, 6 directions	-	3
		See table below [d]	See table below [c]	-	
	Shock: circuit pack, blades and racks [c]	See table below [d]	See table below [c]	-	3
	Vibration (≤ 1 Kg)	200 m/s², 20 Hz to 2 000 Hz to 20 Hz 3-axis, 4 cycles per axis, 2 h/axis	4 mins/cycle	-	3
	Vibration (> 1 Kg)	5 Hz to 50 Hz, 15 m/s² 50 Hz to 500 Hz, 30 m/s² 3-axis	0,1 oct/min 0,25 oct/min	-	3
	Vibration: circuit pack, blades and racks	5 Hz to 100 Hz to 5 Hz, 10 m/s² 3-axis	0,25 oct/min	-	3
	Pull [e]	5 N, 10 N and 100 N [d]		-	≥ 12
Endurance [a]		$T_{op,\ max}/P_{nom}$	Q = 1 000 h I = 2 000 h	Y	3

<table>
<tr><th>Test</th><th>Condition</th><th>Duration</th><th>Operating</th><th>Samples</th></tr>
<tr><td colspan="5">
No failures are allowed

Tests may be performed sequentially or in parallel.

If the storage temperature is lower than the specified humidity temperature, another test at $T_{stg,max}$ and RH ≥ 85 % is done.

If the maximum storage temperature is similar to the maximum operating temperature, the storage test at $T_{stg,max}$ is not required and is replaced by the endurance test. The endurance test is performed at fixed pump current, output power or pump monitor current (nominal values given in the product specification (PS)). To check any drift of the amplifier, relevant parameters [such as output power, pump parameters (if accessible) etc.] may be measured during the test.

A reference to the temperature cycle test method is provided in Annex B.

$T_{stg,min}$ is the OFA minimum storage temperature;
$T_{stg,max}$ is the OFA maximum storage temperature;
$T_{op,max}$ is the OFA maximum operating temperature;
P_{nom} is the OFA nominal output power.
</td></tr>
</table>

[a] Q: qualification, I: information.

[b] Damp heat: the damp heat test at 85 °C/85 % RH has been advocated by some manufacturers, as justified by observations of conditions within peculiar environments. These test conditions may be used for OFAs to be deployed in very hard environments. Otherwise, the damp heat test at 40 °C/93 % RH may be used.

[c] Either controlled shock test or drop test can be applied.

[d] Mechanical test: shock (free drop, IEC 60068-2-27 and IEC 60068-2-31)

Mass kg	Drop height mm
0 ≤ mass < 10	100
10 ≤ mass < 25	75

[e] Pigtail testing – pull test (the first figure in each row below is the outer diameter of the buffered or cabled fibre to which the specified test conditions do apply)

Cable retention (pull)	reinforced fibre: 20 N to 100 N, 3 times, 5 s pulls secondary coated fibre: 10 N, 3 times, 5 s pulls primary coated fibre: 5 N, 3 times, 5 s pulls	IEC 61300-2-4

It is essential that the evaluated OFA devices or sub-systems are entirely representative of standard production and have passed all the production procedures and/or specified (where applicable in the DS) burn-in and screening procedures.

Aspects of the test conditions not provided in this document are given in the relevant PS.

4.1.5 Structural similarity

Where a range of optical amplifier modules is produced by an OFAM, there can be some significant structural similarity between different type codes. A combination of results from different test programmes, where appropriate, is therefore permitted. Although an understanding of similarity is necessary, it is also important to provide an assessment of differences. All assessments should be compared on a test-by-test basis.

Consideration should be given to the fact that minor differences in technology or processing can have a major impact on reliability, whilst not being apparent during quality assessment.

Evidence should be presented which demonstrates that all results are directly relevant.