

# INTERNATIONAL STANDARD

## Fibre optic active components and devices – Reliability standards – Part 3: Laser modules used for telecommunication



## THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2016 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Central Office  
3, rue de Varembe  
CH-1211 Geneva 20  
Switzerland

Tel.: +41 22 919 02 11  
Fax: +41 22 919 03 00  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://www.iec.ch)

### About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

### About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

#### IEC Catalogue - [webstore.iec.ch/catalogue](http://webstore.iec.ch/catalogue)

The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

#### IEC publications search - [www.iec.ch/searchpub](http://www.iec.ch/searchpub)

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications.

#### IEC Just Published - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

#### Electropedia - [www.electropedia.org](http://www.electropedia.org)

The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions in English and French, with equivalent terms in 15 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

#### IEC Glossary - [std.iec.ch/glossary](http://std.iec.ch/glossary)

65 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

#### IEC Customer Service Centre - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: [csc@iec.ch](mailto:csc@iec.ch).



IEC 62572-3

Edition 3.0 2016-02

# INTERNATIONAL STANDARD

---

**Fibre optic active components and devices – Reliability standards –  
Part 3: Laser modules used for telecommunication**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

ICS 31.260; 33.180

ISBN 978-2-8322-3186-9

**Warning! Make sure that you obtained this publication from an authorized distributor.**

## CONTENTS

|   |    |
|---|----|
| FOREWORD.....   | 3  |
| INTRODUCTION.....   | 5  |
| 1 Scope.....  | 6  |
| 2 Normative references.....   | 6  |
| 3 Terms, definitions, symbols and abbreviations.....  | 7  |
| 3.1 Terms and definitions.....  | 7  |
| 3.2 Symbols and abbreviations.....  | 8  |
| 4 Laser reliability and quality assurance procedure .....                                       | 8  |
| 4.1 Demonstration of product quality .....  | 8  |
| 4.2 Testing responsibilities.....   | 9  |
| 4.2.1 General .....   | 9  |
| 4.2.2 Recommendation applicable to laser customer/system supplier.....                          | 9  |
| 4.2.3 Recommendation applicable to system operator .....  | 9  |
| 4.3 Quality improvement programmes (QIPs).....  | 9  |
| 5 Tests.....  | 9  |
| 5.1 General.....  | 9  |
| 5.2 Structural similarity .....   | 10 |
| 5.3 Burn-in and screening (when applicable in the specification) .....                          | 10 |
| 6 Activities .....  | 14 |
| 6.1 Analysis of reliability results .....   | 14 |
| 6.2 Technical visits to LMMs .....  | 14 |
| 6.3 Design/process changes .....  | 15 |
| 6.4 Deliveries.....   | 15 |
| 6.5 Supplier documentation.....   | 15 |
| Annex A (informative) Guidance on testing in Table 1 and Table 2.....                           | 16 |
| A.1 Laser module life tests containing thermoelectric coolers (Table 1, test 1.1) .....         | 16 |
| A.2 Laser module life tests for uncooled modules (Table 1, test 1.2).....                       | 16 |
| A.3 Laser diode life tests on submounts (Table 1, test 1.3).....                                | 17 |
| A.4 Monitor photodiode life tests (Table 1, test 1.4).....                                      | 17 |
| A.5 Temperature cycling and thermal shock (Table 1, test 3 and Table 2, test 2) .....           | 18 |
| A.6 Sealing/hermeticity (Table 1, test 4 and Table 2, test 3) .....                             | 18 |
| A.7 Shock and vibration (Table 1, test 5 and Table 2, test 4).....                              | 18 |
| A.8 High-temperature storage (Table 1, test 6 and Table 2, test 5) .....                        | 18 |
| A.9 Electrostatic discharge sensitivity (ESD) (Table 1, test 7 and Table 2, test 6) .....       | 19 |
| A.10 Residual gas analysis (RGA) (Table 1, test 8 and, Table 2, test 7) .....                   | 19 |
| Bibliography .....  | 20 |
| Table 1 – Initial qualification ( <i>1 of 3</i> ).....  | 10 |
| Table 2 – Maintenance of qualification ( <i>1 of 2</i> ).....                                   | 13 |
| Table 3 – Performance for laser module reliability parameters .....                             | 14 |
| Table A.1 – Recommended life test conditions for laser modules containing Peltier coolers ..... | 16 |
| Table A.2 – Recommended life test conditions for uncooled laser modules .....                   | 17 |
| Table A.3 – Recommended laser diode life test conditions.....                                   | 17 |
| Table A.4 – Recommended photodiode life test conditions.....                                    | 18 |

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

**FIBRE OPTIC ACTIVE COMPONENTS AND DEVICES –  
RELIABILITY STANDARDS –****Part 3: Laser modules used for telecommunication**

## FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 62572-3 has been prepared by subcommittee 86C: Fibre optic systems and active devices of IEC technical committee 86: Fibre optics.

This third edition cancels and replaces the second edition published in 2014. This third edition constitutes a technical revision in which errors in Table 1 and Table 2 have been corrected.

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

| CDV          | Report on voting |
|--------------|------------------|
| 86C/1302/CDV | 86C/1345/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 62572 series, published under the general title *Fibre optic active components and devices – Reliability standards*, 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

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

A bilingual version of this publication may be issued at a later date.

## INTRODUCTION

The laser modules covered by this International Standard are purchased by system suppliers (SS) to be inserted in equipment, which in turn are supplied/sold to a system operator (SO) or a network operator (see definitions in Clause 3).

For the system operator to act as an informed buyer, he/she should have knowledge of the potential risks posed by the use of critical components.

Optoelectronic component technology is continuing to develop. Consequently, during product development phases, many failure mechanisms in laser modules have been identified. These failure mechanisms, if undetected, could result in very short laser lifetime in system use.

## **FIBRE OPTIC ACTIVE COMPONENTS AND DEVICES – RELIABILITY STANDARDS –**

### **Part 3: Laser modules used for telecommunication**

#### **1 Scope**

This part of IEC 62572 deals with reliability assessment of laser modules used for telecommunication.

The aim of this standard is

- to establish a standard method of assessing the reliability of laser modules in order to minimize risks and to promote product development and reliability;
- to establish means by which the distribution of failures with time can be determined. This should enable the determination of equipment failure rates for specified end of life criteria.

In addition, guidance is given in IEC TR 62572-2.

#### **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 60068-2-1, *Environmental testing – Part 2-1: Tests – Test A: Cold*

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

IEC 60749-6, *Semiconductor devices – Mechanical and climatic test methods – Part 6: Storage at high temperature*

IEC 60749-8, *Semiconductor devices – Mechanical and climatic test methods – Part 8: Sealing*

IEC 60749-10, *Semiconductor devices – Mechanical and climatic test methods – Part 10: Mechanical shock*

IEC 60749-11, *Semiconductor devices – Mechanical and climatic test methods – Part 11: Rapid change of temperature – Two-fluid-bath method*

IEC 60749-12, *Semiconductor devices – Mechanical and climatic test methods – Part 12: Vibration, variable frequency*

IEC 60749-25, *Semiconductor devices – Mechanical and climatic test methods – Part 25: Temperature cycling*

IEC 60749-26, *Semiconductor devices – Mechanical and climatic test methods – Part 26: Electrostatic discharge (ESD) sensitivity testing – Human body model (HBM)*



IEC TR 62572-2, *Fibre optic active components and devices – Reliability standards – Part 2: Laser module degradation*

MIL-STD-883, *Test method standard – Microcircuits*

### 3 Terms, definitions, symbols and abbreviations

#### 3.1 Terms and definitions

For the purposes of this document the following definitions apply.

##### 3.1.1

##### **laser module**

packaged assembly containing a laser diode with/without photodiode

Note 1 to entry: The module may also include a cooler and temperature sensor to enable laser temperature to be controlled and monitored. The optical output is normally via an optical fibre pigtail.

##### 3.1.2

##### **submount**

substrate upon which a laser diode or photodiode may be mounted for assembly into the laser module

Note 1 to entry: Components on submounts are also subject to qualification testing.

##### 3.1.3

##### **laser module manufacturer**

LMM

manufacturer of laser modules who provides devices meeting the requirements of the relevant detail specification (DS) and the customer's reliability requirements

##### 3.1.4

##### **network operator**

NO

organization which operates a telecommunications network

##### 3.1.5

##### **system supplier**

SS

manufacturer of telecommunications/data transmission equipment containing optoelectronic semiconductor lasers

Note 1 to entry: The system supplier can be a laser module customer.

##### 3.1.6

##### **system operator**

SO

network operator of telecommunications/data transmission equipment containing optoelectronic semiconductor lasers in the transmission path

Note 1 to entry: The system may also be part of other more extensive systems, for example telecommunications, rail, road vehicles, aerospace or weapons.

##### 3.1.7

##### **capability qualifying components**

CQC

components selected to represent critical stages of the process and limiting or boundary characteristics of mechanical and electro-optic design

Note 1 to entry: Such components should aid the identification of end product failure mechanisms to enable the determination of activation energies.

### 3.2 Symbols and abbreviations

|                       |                                      |
|-----------------------|--------------------------------------|
| $T_A$                 | minimum storage temperature          |
| $T_B$                 | maximum storage temperature          |
| $T_C$                 | module case temperature              |
| $T_S$                 | submount temperature                 |
| $T_{S \text{ nom}}$   | recommended submount temperature     |
| $T_{op \text{ min}}$  | module minimum operating temperature |
| $T_{op \text{ max}}$  | module maximum operating temperature |
| $T_{stg \text{ min}}$ | module minimum storage temperature   |
| $T_{stg \text{ max}}$ | module maximum storage temperature   |
| Qc                    | test for gross leak detection        |
| Qk                    | test for fine leak detection         |
| $p$                   | periodicity (in months)              |
| $n$                   | sample size                          |
| CA                    | capability approval                  |
| CQC                   | capability qualifying components     |
| DS                    | detail specification                 |
| LMM                   | laser module manufacturer            |
| ML                    | median life                          |
| NO                    | network operator                     |
| QA                    | quality approval                     |
| QIP                   | quality improvement programmes       |
| RGA                   | residual gas analysis                |
| SO                    | system operator                      |
| SS                    | system supplier                      |

## 4 Laser reliability and quality assurance procedure

### 4.1 Demonstration of product quality

This standard (where required by the specification) gives the minimum mandatory requirements and is part of a total laser reliability and quality assurance procedure adopted by the laser module manufacturer.

It also provides guidance on the activities of system suppliers and system operators and provides feedback on field performance to laser module manufacturers and system suppliers.

The laser module manufacturer shall be capable of demonstrating, by means of qualification approval of devices, technology approval or capability approval of the manufacturing process, the following:

- a) a documented and audited manufacturing process including the qualification of purchased components in accordance with an internationally recognized quality management system;
- b) a performance qualification programme, including for example, accelerated life testing, burn-in and screening of components and modules;
- c) a qualification maintenance programme to ensure continuity of reliability performance;

d) a procedure to provide feedback on reliability issues to development and production.

## **4.2 Testing responsibilities**

### **4.2.1 General**

The testing detailed in Table 1 and Table 2 is to be performed by the laser module manufacturer and component suppliers (where applicable). Additional testing may be specified in the specification.

### **4.2.2 Recommendation applicable to laser customer/system supplier**

The system supplier is recommended to have a programme to analyse and verify the results including failure analysis. This programme includes an independent life test of fully packaged laser modules (see Table 2, test 1 and/or test 2 and 3 and/or test 5 (sample size >10 per test)).

### **4.2.3 Recommendation applicable to system operator**

The system operator is recommended to have a programme to monitor and report field failure rates in sufficient detail to enable the system supplier and laser module manufacturer to initiate any necessary corrective actions at an early stage in the lifetime of a product.

Suppliers may have different approaches (i.e. to reliability concepts) during the development of product maturity, and resource limitations may dictate testing strategies.

Alternative tests and activities to those specified are permitted, provided the LMM/SS/SO can show intent to remove end-product failures and the associated failure mechanisms. However, this will require significant data to substantiate compliance.

## **4.3 Quality improvement programmes (QIPs)**

Quality improvement programmes (QIPs) shall be initiated with component suppliers and customers (SOs, SSs and LMMs) to address non-compliances (including quality and reliability problems identified during subsequent service life of the laser). The correction of non-compliances and subsequent QIPs are a required strategy to minimize reliability risks. The operation of QIPs should be stated in the quality approval (QA) generic and capability approval documents.

## **5 Tests**

### **5.1 General**

The tests described in Table 1 and Table 2 are designed to accelerate the main failure mechanisms known to be reliability hazards in laser modules and shall follow the guidance from IEC TR 62572-2. Where appropriate, the CQC shall demonstrate an ability to reduce end product failure mechanisms. Final product validation is required to demonstrate that CQCs are operating at the boundaries of the process or technology. These tests will reduce the risk of unreliable components entering system use and will enable estimates to be made of the distribution of laser lifetimes and hence the laser failure rates.

The sample size and level of testing may vary depending on the business volume between the laser customer/system supplier (SS) and laser module manufacturer (LMM). This information will be given in the capability approval (CA) document and the specification where appropriate.

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

*Table 1 – Initial qualification*

These tests will normally be performed by the laser manufacturer as part of an initial qualification programme.

*Table 2 – Maintenance of qualification*

These tests cover periodic monitoring performed on production devices to ensure that the quality and reliability performance established during initial qualification is maintained or improved.

## 5.2 Structural similarity

Where a range of laser modules is produced by a laser manufacturer, there may be some significant structural similarity between different type codes. A combination of results from different test programmes, where appropriate, is therefore permitted.

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 shall be presented which demonstrates that all results are directly relevant.

## 5.3 Burn-in and screening (when applicable in the specification)

NOTE See IEC TR 62572-2.

The screening test should be designed by the laser module manufacturer specifically for his particular technology. Any approach based on similarity to that which is performed by other manufacturers is good for comparison purposes, but can be ineffective in achieving the actual screening goal. This is particularly true for fibre optic components whose technology is not yet mature and varies significantly from supplier to supplier.

Where a manufacturer can demonstrate component and process stability, screening procedures may be revised.

**Table 1 – Initial qualification (1 of 3)**

| Test no. | Test                                    | References | Conditions  | n                            |
|----------|---|------------|---|------------------------------|
| 1        | Initial endurance test                  |            |   |                              |
| 1.1      | a) Module with thermoelectric cooler    |            | $\Phi_e$ specified, constant power<br>Temperature: $T_c = T_{op\ max}$<br>$T_s = T_{s\ nom}$<br>Duration: 5 000 h <sup>a</sup>  | 25                           |
| 1.2      | b) Module without thermoelectric cooler |            | $\Phi_e$ specified, constant power<br>Temperature: $T_c = T_{op\ max}$<br>Duration: 5 000 h <sup>a</sup>  | 25                           |
| 1.3      | Laser diode (submount)                  |            | Temperature: at least two test temperatures:<br>$\Phi_e$ specified, constant power<br>$T_{s1} = T_{s\ max}$<br>$T_{s2} \leq (T_{s1} - 20) ^\circ C$ or<br>$T_{s2} \leq (T_{s1} - 10) ^\circ C$ if applicable<br>Duration: > 5 000 h | See footnote<br>See footnote |

**Table 1 (2 of 3)**

| Test no. | Test  | References                     | Conditions  | n  |
|----------|---|--------------------------------|---|--|
| 1.4      | Photodiode (in representative package)                |                                | Temperature: at least two test temperatures:<br>$V_r$ or $I_r$ specified<br>$T_{s1} = 125\text{ °C min}^b$<br>$T_{s2} \leq (T_{s1} - 30\text{ °C})$<br>Duration: > 1 000 h              | See footnote <sup>d</sup><br>See footnote <sup>d</sup> |
| 1.5      | High temperature storage of the thermoelectric cooler |                                | $T = T_{\text{stg max}}$ of the cooler<br>Duration: 1 000 h   | 25   |
| 1.6      | Power cycle tests cooled devices                      |                                | Number of cycles: 20 K<br>$T_c = T_{\text{op max}}$<br>$T_s = T_c$ to $(T_c - \Delta T_{\text{max}})$   | 25   |
| 1.7      | High-temperature storage of the thermal sensor        |                                | $T = T_{\text{stg max}}$ of the sensor  | 25   |
| 2        | Fibre test  |                                |   |  |
| 2.1      | Fibre proof test                                      |                                | Proof test <sup>d</sup><br>Duration <sup>d</sup><br>Min. bend radius <sup>d</sup>   | 10   |
| 2.2      | Fibre retention                                       |                                |   |  |
| 2.2.1    | Fibre pull  |                                | Fibre pull <sup>d</sup>   | 10   |
| 2.2.2    | Side pull   |                                | Side pull <sup>d</sup>  |  |
| 3        | Change of temperature                                 |                                | See footnotes <sup>c</sup> and <sup>d</sup>   |  |
| 3.1      | Rapid change of temperature                           | IEC 60749-11                   | Temperature:<br>$T_A = T_{\text{stg min}}$<br>$T_B = T_{\text{stg max}}$<br>Number of cycles = 50   | 10   |
| 3.2      | Temperature cycling                                   | IEC 60749-25<br>IEC 60068-2-14 | Temperature:<br>$T_A = T_{\text{stg min}}$<br>$T_B = T_{\text{stg max}}$<br>> 1 °C/min<br>Number of cycles = 500  | 10   |
| 4        | Sealing   | IEC 60749-8                    | See footnote <sup>d</sup><br>Test Qk followed by Test Qc<br>See footnotes <sup>c</sup> and <sup>d</sup> and Clause A.6  | 10   |
| 5        | Shock and vibration                                   |                                | See Clause A.7  |  |
| 5.1      | Shock   | IEC 60749-10                   | 5 000 m/s <sup>2</sup> , 0,5 ms with/without thermoelectric cooler,<br>15 000 m/s <sup>2</sup> , 0,5 ms without thermoelectric cooler (where appropriate)<br>6-directions, 5 times each | 10   |
| 5.2      | Vibration   | IEC 60749-12                   | 20 Hz to 2 000 Hz, 200 m/s <sup>2</sup> ,<br>3-directions, 30 min each  | 10   |

**Table 1** (3 of 3)

| Test no.   | Test   | References               | Conditions   | <i>n</i>    |
|--|--|--------------------------|--|-------------|
| 6  | High temperature storage<br>(not applicable if module life test performed at equivalent case temperature and submount temperature) | IEC 60749-6              | Temperature: $T = T_{\text{stg max}}$<br>Duration: $> 2\,000\text{ h}$<br>(See IEC TR 62572-2)         | 10          |
| 7  | ESDS, modules<br>a) Lasers<br>b) Photodiodes   | IEC 60749-26             | Human body model, see Clause A.9<br>5 discharges/test voltage, charge-discharge cycle $> 0,1\text{ s}$ | 5 per wafer |
| 8  | Residual gas analysis  | MIL-STD-883, Method 1018 | See footnote <sup>d</sup><br>See Clause A.10   | 6           |
| 9  | Low-temperature storage  | IEC 60068-2-1            | $T = T_{\text{stg min}}$<br>Duration: $> 1\,000\text{ h}$  | 10          |
| <sup>a</sup> Provided data about the distribution of wear-out lifetime is accumulated with sufficient accuracy. Provisional approval for product shipment shall be granted at 2 000 h. It is also recommended to continue the test until accurate extrapolation of lifetime is possible with an upper limit of 10 000 h. Durations up to 5 000 h may be needed for accurate lifetime prediction.<br><sup>b</sup> Or as limited by technology.<br><sup>c</sup> Results from tests 1.1 and 1.2 shall be supplemented by a laser customer/SS independent test of fully packaged modules in accordance with Table 2, test 2 and/or test 3 (sample size $\geq 10$ per test). See also 4.2.<br><sup>d</sup> Number of samples and conditions shall be determined by a laser customer/SS and LMM. |  |                          |  |             |

**Table 2 – Maintenance of qualification (1 of 2)**

| Test no.  | Test  | References                     | Conditions  | <i>n</i>  | <i>p</i> |
|---|---|--------------------------------|---|---|----------|
| 1   | Ongoing reliability test<br>a) Module (cooled)<br>b) Module (uncooled)<br>c) Laser diode (submount)<br>d) Photodiode            |                                | Periodic testing:<br>Test 1.1<br>Test 1.2<br>Test 1.3<br>Test 1.4   | See NOTES<br>10<br>10<br>25 <sup>a</sup><br>25 <sup>a</sup> | 6        |
| 2   | Temperature cycling   | IEC 60749-25<br>IEC 60068-2-14 | Temperature:<br>$T_A = T_{\text{stg min}}$<br>$T_B = T_{\text{stg max}}$<br>> 1 °C /min<br><br>Periodic testing: number of cycles = 100 (see NOTE 1 )   | 10  | 6        |
| 3   | Sealing   | IEC 60749-8                    | See NOTE 2<br><br>Test Qk followed by Test Qc<br><br>See NOTES and Clause A.6   | 10  | 6        |
| 4   | Shock and vibration   |                                | See NOTES and Clause A.7  |   |          |
| 4.1   | Shock   | IEC 60749-10                   | 5 000 m/s <sup>2</sup> , 0,5 ms with/without thermoelectric cooler,<br><br>15 000 m/s <sup>2</sup> , 0,5 ms without thermoelectric cooler (where appropriate),<br><br>6-direction, 5 times each | 10  | 12       |
| 4.2   | Vibration   | IEC 60749-12                   | 20 Hz to 2 000 Hz, 200 m/s <sup>2</sup><br><br>3-direction, 30 min each   | 10  | 12       |
| 5   | High temperature storage (not applicable if module life test performed at equivalent case temperature and submount temperature) | IEC 60749-6                    | Temperature:<br>$T = T_{\text{stg max}}$<br><br>Duration: > 2 000 h<br><br>Periodic testing: see NOTES (See IEC TR 62572-2)   | 10  | 12       |
| 6   | ESDS, modules<br>a) Lasers<br>b) Photodiodes  | IEC 60749-26                   | Periodic testing: see Clause A.9<br><br>Human body model<br><br>5 discharges/test voltage,<br><br>Charge-discharge cycle > 0,1 s  | 5 per wafer   | 12       |
| 7   | Residual gas analysis   | MIL-STD-883, Method 1018       | See NOTE 2<br><br>Periodic testing: see NOTES and Clause A.10   | See NOTE 2  | 6        |
| NOTE 1 Results of test 2 are supplemented by a laser customer/system supplier (SS) independent test of fully packaged modules in accordance with Table 2, test 2 and/or test 3 and/or test 5 (sample size ≥ 10 per test). See also 4.2. |   |                                |   |   |          |
| NOTE 2 Number of samples and conditions are determined by a laser customer/SS and LMM.  |   |                                |   |   |          |
| <sup>a</sup> Out of different wafers.   |   |                                |   |   |          |

## 6 Activities

### 6.1 Analysis of reliability results

The laser module customer/system supplier (SS) shall have a programme to analyse and verify a laser manufacturer's reliability claims. In particular

- life test data for the complete laser module,
- life test data for initial components, for example laser diode and photodiode,
- environmental test result, i.e. inspection requirements group B, C of the detail specification;
- where appropriate, the data and test results of appropriate CQCs (see Clause 5).

The analysis of results should lead to reporting of the laser module reliability parameters for each of the laser module types. Minimum reliability parameters are presented in Table 3.

Where data reveals more than one wear-out mechanism, median life and dispersion in each case shall be stated.

The failure criteria used to derive these reliability parameters shall be agreed between the laser customer/system supplier (SS) and laser module manufacturer (LMM). The criteria will be stated in the detail specification (see IEC TR 62572-2).

**Table 3 – Performance for laser module reliability parameters**

| Parameter  | Measured value |
|--|----------------|
| Median life (ML) at 25 °C or 55 °C <sup>a</sup>  | Years          |
| Dispersion(s)  |                |
| Wear-out failure rate  |                |
| at 5 years ( $\lambda$ ) <sub>5</sub>  | FITs           |
| at 10 years ( $\lambda$ ) <sub>10</sub>  | FITs           |
| at 20 years ( $\lambda$ ) <sub>20</sub>  | FITs           |
| Wear-out activation energy   | eV             |
| Random failure rate  |                |
| ( $\lambda_a$ ) at 25 °C <sup>b</sup>  | FITs           |
| Confidence limits used   | %              |
| Random failure activation energy   | eV             |
| Guidance on these activities is given in IEC TR 62572-2.   |                |
| NOTE This table assumes a log-normal distribution of times to failure. The dispersion parameter is the standard deviation of the logarithm to the base 'e' of the times to failure (see IEC TR 62572-2). |                |
| <sup>a</sup> Special attention should be paid to all extrapolation models used, and the justification for activation energies employed in reliability predictions is to be stated.                       |                |
| <sup>b</sup> The reference temperature used for all parameters in this table is 25 °C. An alternative reference temperature (50 °C) may be used provided activation energies are given.                  |                |

### 6.2 Technical visits to LMMs

Laser module designs continue to evolve, and an LMM may introduce significant changes which impinge on reliability. Under the negotiation between customer and manufacturer, technical visits should be performed until there is sufficient evidence of a maturing technology and production stability. These technical meetings/visits shall contain an item on the agenda that concerns quality and reliability. Where an LMM holds a capability approval, the frequency of these technical visits may be reduced provided the manufacturer can demonstrate



- a) that the CQCs fully represent any relevant design, process updates and reliability issues,
- b) satisfactory self-audit of the quality system.

### **6.3 Design/process changes**

The customer/system supplier (SS) shall be informed by the laser module manufacturer (LMM) of any design or process change which may affect the form, fit or function of the end product.

### **6.4 Deliveries**

Laser module designs will continue to evolve and therefore each delivered lot shall be manufactured according to a stated technology and production process.

This should be verified by the supplier and customer before delivery.

### **6.5 Supplier documentation**

The laser customer/system supplier (SS) and component manufacturer or LMM shall incorporate, wherever possible, the tests and activities described in this standard into their in-house component qualification, or where appropriate, capability approval procedures and purchasing specifications. This documentation will be used in reliability/technical presentations, tender submissions and marketing briefs to customers.

## Annex A (informative)

### Guidance on testing in Table 1 and Table 2

#### A.1 Laser module life tests containing thermoelectric coolers (Table 1, test 1.1)

With laser modules containing thermoelectric coolers (for example Peltier), it is difficult to provide a significant degree of overstress to all key components simultaneously. During “normal operation”, the laser submount temperature is usually controlled at  $T_s = 25\text{ °C}$ . However, for a life test with a case temperature of  $T_c = T_{op\ max}$ , a useful stress can be obtained for the laser diode, fibre fixing, photodiode and thermal sensor if the cooler is operated at a relatively high current to maintain a submount temperature of  $T_s = T_{s\ nom}$ . The conditions in Table A.1 are recommended.

Some additional testing of the cooler is recommended, for example  $T_c = T_{op\ max}$  and  $T_s = T_s - 10\text{ °C}$ .

**Table A.1 – Recommended life test conditions for laser modules containing Peltier coolers**

|                                   |   |
|-----------------------------------|---|
| <b>Case temperature</b>           | $T_{op\ max}$   |
| <b>Laser submount temperature</b> | $T_s = T_{s\ nom}$  |
| <b>Optical power</b>              | Fibre output set to $P_{max}$ at start of life test (using monitor circuit) |
| <b>Laser current</b>              | To maintain constant monitor output   |
| <b>Monitor current</b>            | Normal bias   |
| <b>Thermal sensor current</b>     | Normal bias   |
| <b>Cooler current</b>             | To maintain constant thermistor resistance (or sensor conditions)           |
| <b>Duration</b>                   | > 5 000 h   |

#### A.2 Laser module life tests for uncooled modules (Table 1, test 1.2)

For modules without thermoelectric coolers (for example Peltier), life tests can be readily performed over a range of temperatures up to the recommended maximum operating temperature for the module. During initial qualification, service life tests at two or more temperatures, for example  $T_c = T_{op\ max}$  and  $T_c$  in the range of  $40\text{ °C}$  to  $50\text{ °C}$ , are recommended. Here, the accuracy of lifetime estimation becomes high in proportion to the number of test levels.

An additional life test at low temperature (duration > 2 000 h at  $T_{op\ min}$ ) may be required for modules containing epoxies or organic materials.

If only a single life test is to be performed, for example during maintenance of qualification testing, the conditions in Table A.2 are recommended.

**Table A.2 – Recommended life test conditions for uncooled laser modules**

|                             |   |
|-----------------------------|---|
| <b>Case temperature</b>     | $T_{op\ max}$   |
| <b>Optical power</b>        | Fibre output set to $P_{max}$ at start of life test (using monitor circuit) |
| <b>Laser current</b>        | To maintain constant monitor photocurrent                                   |
| <b>Monitor photocurrent</b> | Normal bias   |
| <b>Duration</b>             | > 5 000 h   |

**A.3 Laser diode life tests on submounts (Table 1, test 1.3)**

The laser life test shall be performed with the laser operating at constant light output, as it would be in normal operation, unless otherwise agreed with the user. Temperatures in the range  $T_s = 50\ ^\circ\text{C}$  to  $80\ ^\circ\text{C}$  are often used. The acceleration in the rate of degradation, relative to normal operation, is therefore relatively small. The maximum temperature at which life tests can be performed under lasing operating conditions is usually in the range  $T_s = 70\ ^\circ\text{C}$  to  $100\ ^\circ\text{C}$ . However, constant current/life tests at temperatures up to  $T_s = 150\ ^\circ\text{C}$  can be useful in studying the reliability of contact metallizations. Actual failures do not often occur in well screened laser diodes tested at temperatures  $T_s < 90\ ^\circ\text{C}$ . In order to estimate the laser life, some extrapolation is required to predict when the threshold or operating current will exceed the pre-determined failure criterion. To obtain a reasonable increase in operating current, a life test duration greater than 5 000 h is required.

If a single life test is to be performed, for example during maintenance of qualification testing, the conditions in Table A.3 are recommended.

**Table A.3 – Recommended laser diode life test conditions**

|                      |                                     |
|----------------------|-------------------------------------|
| <b>Temperature</b>   | $T_s = 70\ ^\circ\text{C}$          |
| <b>Optical power</b> | Maximum specified                   |
| <b>Bias</b>          | To maintain constant monitor output |
| <b>Duration</b>      | > 5 000 h                           |

**A.4 Monitor photodiode life tests (Table 1, test 1.4)**

Photodiode life tests are best performed with the devices under reverse bias if the susceptibility to increased dark current is to be assessed. To obtain failures in a reasonable timescale, temperatures in the range  $T_s = 125\ ^\circ\text{C}$  to  $200\ ^\circ\text{C}$  are usually required. Devices with organic passivations should be tested at temperatures below the curing temperature of the passivation.

Increased bias voltage can also be used to accelerate failure, but the dependence of lifetime on voltage would then need to be determined before a prediction of operating lifetime could be made.

It is necessary for measurements of photodiode dark currents to include measurement at the normal operating temperature. Measurements made at only the life test temperature may not detect increased surface leakage, because bulk dark currents dominate at high temperatures.

Failed photodiodes with increased dark currents (as a result of the accumulation of mobile charge) will often recover quickly if stored at high temperatures without bias. It is essential, that at the end of the test duration, the reverse bias conditions are maintained until the temperature is below  $30\ ^\circ\text{C}$ . The post test measurements shall be completed within 3 h. The increase in dark current of photodiodes with exposed junctions (for example unpassivated

mesa devices) is very sensitive to the package atmosphere, and small traces of oxygen or water vapour can result in decreased lifetimes. Life tests should therefore be performed with the photodiodes sealed in representative hermetic packages, and not on open submounts. Tests in flowing (nominally dry) nitrogen can produce variable results. The conditions in Table A.4 are recommended.

**Table A.4 – Recommended photodiode life test conditions**

|                    |   |
|--------------------|---|
| <b>Temperature</b> | In the range $T_s = 125\text{ °C}$ to $200\text{ °C}$   |
| <b>Bias</b>        | Specified maximum reverse bias voltage.<br>Bias to be maintained during cool down prior to measurements |
| <b>Duration</b>    | 1 000 h   |
| <b>Atmosphere</b>  | Photodiode in representative hermetic package   |

### **A.5 Temperature cycling and thermal shock (Table 1, test 3 and Table 2, test 2)**

It is difficult to quantify the acceleration (with respect to normal operation) obtained from a temperature cycling test. Nevertheless, it has been clearly demonstrated that temperature cycling from  $T_c = -40\text{ °C}$  to  $+70\text{ °C}$  can reveal potentially serious hazards in laser modules associated with fibre instability, thermal mismatch between piece parts (for example coolers and submounts), and with fibre breaks.

For initial qualification, number of cycles = 500 from  $T_{stg\ min}$  to  $T_{stg\ max}$  are required. For periodic testing (3 and/or 6 monthly), the number of cycles = 100. The temperature cycling procedure should follow either:

- IEC 60068-2-14, Test Na: two-chamber method;
- IEC 60068-2-14, Test Nb: single-chamber method, rate of change equal to  $1\text{ °C/min}$ ,  $3\text{ °C/min}$ , or  $5\text{ °C/min}$ .

Well designed and constructed modules should be able to withstand such a test with negligible changes in module performance.

### **A.6 Sealing/hermeticity (Table 1, test 4 and Table 2, test 3)**

The post-test assessment for test 4, Table 1 and test 3, Table 2 shall be fine-leak testing, Test Qk, followed by the gross-leak Test Qc. Suitable precautions shall be taken to eliminate absorption of helium by the fibre coating to avoid measurement errors.

### **A.7 Shock and vibration (Table 1 , test 5 and Table 2, test 4)**

These tests are designed to simulate conditions involving vibration and shock that a component may be subjected to in service or during transportation. For a module with thermoelectric cooler, the cooler is the limiting device, so the shock test should be limited to  $5\,000\text{ m/s}^2$ .

### **A.8 High-temperature storage (Table 1, test 6 and Table 2, test 5)**

Temperature storage testing has the advantage of being relatively inexpensive because no bias circuitry is required. Provided the test is performed at or below the maximum storage temperature for the module  $T_c \leq T_{stg\ max}$ , it can be regarded as non-destructive. Storage at high temperatures (for example  $T_c = 70\text{ °C}$ , duration = 1 000 h) will, although the stress is relatively small, provide useful protection against major problems with fibre alignment

instability and will identify some potential metallization and solder failure mechanisms, for example thermoelectric cooler or thermistor failures.

### **A.9 Electrostatic discharge sensitivity (ESD) (Table 1, test 7 and Table 2, test 6)**

Optoelectronic components are sensitive to damage by electrostatic discharge (ESD) at all stages during manufacture, testing, assembly into equipment and operation. Exposure to ESD can result in sudden failure, parametric shifts, or even latent damage leading to a reduced lifetime during subsequent operation. The sensitivity of the laser and monitor photodiode to ESD damage should be determined so that the appropriate level of precautions can be taken to avoid damage.

The minimum recommended testing for modules is to subject five laser diodes and five monitor photodiodes on a wafer basis, to the “human body model” test described in IEC 60749-26. However, rather than applying a single go-no-go test condition, transients of increasing voltage should be applied to determine the threshold at which failures occur.

Failure should be defined as a parametric change in

- photodiode dark current or in laser threshold current;
- slope efficiency;
- forward voltage;
- reverse leakage current or light output spectrum.

The criteria are given in IEC TR 62572-2.

### **A.10 Residual gas analysis (RGA) (Table 1, test 8 and, Table 2, test 7)**

Certain laser module reliability hazards associated with high package water content are unlikely to be detected with the testing described in Table 1 and Table 2. Hermeticity testing and residual gas analysis of transmitter modules is necessary to demonstrate that the module package contains a dry, inert atmosphere throughout its operating life. High-temperature life testing alone is not likely to detect reliability hazards associated with high package water content. See also Clause A.2, Table 1, Test 8 and Table 2, test 7.

**Caution:** the pre-bake temperature for RGA in MIL-STD-883, method 1018 is 100 °C. This may be greater than the storage temperature  $T_{\text{stg max}}$  of most optoelectronic components. A lower pre-bake temperature of  $T_c = T_{\text{stg max}}$  for a longer period is therefore recommended until the background level of RGA remains constant. This level can then be eliminated from the results.

## Bibliography

IEC 60747-1, *Semiconductor devices – Part 1: General*

---



INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

3, rue de Varembé  
PO Box 131  
CH-1211 Geneva 20  
Switzerland

Tel: + 41 22 919 02 11  
Fax: + 41 22 919 03 00  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://www.iec.ch)