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Optics and optical instruments — Lasers and laser-related equipment — Lifetime of lasers

Optique et instruments d'optique — Lasers et équipements associés aux lasers — Durée de vie des lasers

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 17526 was prepared by Technical Committee ISO/TC 172, *Optics and optical instruments*, Subcommittee SC 9, *Electro-optical systems*.

Introduction

There are many different types of lasers with very different attributes and very different areas of application; not all types of lasers can be treated by the same means and measures to characterize and specify their longterm behaviour and lifetime.

This International Standard covers many types of laser, but not all methods and procedures can be applied to all types.

There are lasers, primarily laser diodes in the lower power range, which are produced in large quantities and which allow the performance of lifetime tests on large quantities to gain results on a statistically significant level. In this case and if more than approximately 50 lasers are used for testing, lifetime predictions using informative annex B of IEC 61751:1998, may be applied alternatively to this International Standard.

High-power lasers are manufactured in low quantities and lifetime tests cannot be carried out on statistically significant sample sizes.

There are types of laser of which the main components cannot be repaired, e.g. sealed-tube gas lasers or semiconductor lasers. There are others that can easily be repaired, e.g. CO_2 lasers. The former class may be characterized by “lifetime”, the latter more appropriately characterized by “meantime to failure”.

Optics and optical instruments — Lasers and laser-related equipment — Lifetime of lasers

1 Scope

This International Standard covers terms and definitions as well as test methods and evaluation procedures to characterize, estimate and predict the longterm behaviour of various types of lasers.

This International Standard defines terms for the lifetime of lasers and specifies test procedures and fundamental aspects for the determination of lifetime. It applies for all types of lasers for which lifetime is a critical issue, including diode lasers except those used in telecommunications.

2 Normative references

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

ISO 11145:2001, *Optics and optical instruments — Lasers and laser-related equipment — Vocabulary and symbols*

ISO 11554:2003, *Optics and optical instruments — Lasers and laser-related equipment — Test methods for laser beam power, energy and temporal characteristics*

IEC 60050-191:1990, *International Electrotechnical Vocabulary. Chapter 191: Dependability and quality of service*

IEC 61703:2001, *Mathematical expressions for reliability, availability, maintainability and maintenance support terms*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11145 and the following apply.

NOTE For simplicity, in all following parts of this International Standard the term “power” refers to cw or repetitive-cw mode, whereas “energy“ refers to pulse and quasi-cw mode.

3.1 Modes of operation

NOTE 1 The following modes of operation define the temporal and pulsed characteristics of the laser.

NOTE 2 There might be modes of operation that are not covered by the subsequent classification. These modes should be described in detail in the test report.

3.1.1
cw-mode
mode where the laser emits radiation continuously over periods of time longer than or equal to 0,25 s

3.1.2
repetitive cw-mode
mode in which the laser is operated in cw-mode but repetitively switched on and off more than once per minute

3.1.3
pulsed mode
mode in which the laser delivers its energy in the form of a single pulse or a train of pulses

NOTE 1 The duration of a pulse is shorter than 0,25 s.

NOTE 2 The subsequently defined modes of operation (3.1.4 to 3.1.7) are special cases of pulsed mode.

3.1.4
pulse train mode
mode in which the laser emits at least 100 subsequent radiation pulses (pulse duration $< 0{,}25$ s) at a continuous pulse repetition rate

3.1.5
single pulse mode
mode in which the laser emits single pulses at low repetition rate, i.e. the laser medium has reached its equilibrium state between subsequent pulses

NOTE The laser is considered to be in its state of equilibrium, if each pulse is identical to the first pulse after switch-on of the laser in all characteristics that are relevant for the intended application.

3.1.6
burst pulse mode
mode in which a pulsed laser beam emitting at a fixed pulse repetition rate f_P is repetitively switched on and off, where each burst contains at least two pulses and the time interval between two bursts is at least $2 \times$ the inverse of the pulse repetition rate

3.1.7
quasi-cw-mode
mode in which the duration of the laser radiation is so long that the laser active material has reached its optical but not its thermal equilibrium

NOTE For some laser types (especially diode lasers and diode laser based devices) this operation mode is relevant.

3.2 Operating conditions

NOTE 1 In the following definitions different modes of long-term operation are defined under which a lifetime test is performed.

NOTE 2 For simplicity, in the subsequent clauses, only the term “laser” is used, although the respective definitions and methods might also refer to laser devices, laser units, laser modules, etc. in accordance with 3.4.

3.2.1
automatic pump power control mode
APPC-mode
mode in which the laser is operated at a constant, automatically controlled pump power (energy) with all other operating conditions (e.g. temperature) being kept constant

NOTE For optically pumped lasers, e.g. solid-state lasers, the operating current for the arc lamps or pump diodes is adjusted to compensate for degradation of the pump source.

3.2.2
automatic current control mode
ACC-mode
mode in which the laser is operated at constant, automatically controlled operation current with all other operating conditions (e.g. temperature) being kept constant

NOTE ACC-mode is only applicable for lasers with current-controlled output power, e.g. arc lamp pumped solid-state-lasers, some types of gas lasers or diode lasers. For certain types of lasers, an automatic voltage control mode (AVC-mode) may also be applied.

3.2.3
automatic power control mode
APC-mode
mode in which the laser is operated at constant automatic controlled optical output power (energy) by adjusting the pump power (energy) (e.g. operation current or optical pump power) with all other operating conditions (e.g. temperature) being kept constant

3.2.4
user selected mode
mode in which the laser is operated at constant user-accessible settings

NOTE Examples of the parameters to be held on a constant level are: the current of the exciting discharge of a gas laser, the current of the flashlamp of a solid state laser, the current of a diode laser, pump power or pump energy.

3.3 Lifetime related terms

3.3.1
time to failure
TTF
total time duration of operating time of an item, from the instant it is first put in an up state, until failure or from the instant of restoration until next failure

[IEC 60050-191-10-02:1990]

NOTE If time to failure refers to a significant component or subsystem of the laser, this should be stated with the TTF-statement.

3.3.2
mean time to failure
MTTF
expectation of the time to failure

[IEC 60050-191-12-07:1990]

3.3.3
availability
ability of an item to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval, assuming that the required external resources are provided

NOTE 1 This ability depends on the combined aspects of the reliability performance, the maintainability performance and the maintenance support performance.

NOTE 2 Required external resources, other than maintenance resources do not affect the availability performance of the item.

NOTE 3 In French, the term "disponibilité" is also used in the sense of "instantaneous availability".

[IEC 60050-191-02-05:1990]

NOTE 4 See also IEC 61703:2001, subclause 6.3.10.

3.3.4
degradation
decrease of the performance of a laser during time of operation when tested at constant operating and environmental conditions

3.3.5
power degradation
gradual decrease of the optical output power of a laser during time of operation when tested at constant operating and environmental conditions

NOTE Occasional discontinuities (< 10 % power drop) as e.g. caused by failures of small parts of a laser can be included.

3.3.6
(power) degradation rate
ratio of decrease of the laser output power (energy) to operation duration under constant test conditions

NOTE If the laser is tested in automatic pump power control mode (APPC-mode) or in automatic current control mode (ACC-mode) the degradation rate is measured as the ratio of the power decrease between time t_1 and t_2 (P_1 and P_2, respectively) $P_2 - P_1$ and the time interval $\Delta t = t_2 - t_1$:

$$\frac{\Delta P}{\Delta t} = \frac{P_2 - P_1}{t_2 - t_1}$$

For pulsed lasers the power P is replaced by the energy E

$$\frac{\Delta E}{\Delta t} = \frac{E_2 - E_1}{t_2 - t_1}$$

If the laser is tested in automatic power control mode (APC-mode) the degradation rate is measured as the ratio of the pump power P_{pump} increase between time t_1 and t_2 ($P_{\text{pump,1}}$ and $P_{\text{pump,2}}$, respectively) $P_{\text{pump,2}} - P_{\text{pump,1}}$ and the time interval $\Delta t = t_2 - t_1$

$$\frac{\Delta P_{\text{pump}}}{\Delta t} = -\frac{P_{\text{pump,2}} - P_{\text{pump,1}}}{t_2 - t_1}$$

For pulsed lasers that are pumped in pulsed mode the pump power P_{pump} is replaced by the pump energy E_{pump}.

For certain types of lasers, e.g. gas lasers or diode lasers, the pump power is essentially proportional to the operating current I. Therefore the pump power P_{pump} can be replaced by the operating current I in the formula in those cases:

$$\frac{\Delta I}{\Delta t} = -\frac{I_2 - I_1}{t_2 - t_1}$$

3.3.7
end of life
EOL
duration after which the laser does not fulfil its output power specifications for the first time

3.3.7.1
end of life for ACC- or APPC mode
$\tau^{\text{ACC}}_{\text{EOL},\alpha}$ **or** $\tau^{\text{APPC}}_{\text{EOL},\alpha}$
⟨ACC- or APPC-mode⟩ duration $\tau^{\text{ACC}}_{\text{EOL},\alpha}$ or $\tau^{\text{APPC}}_{\text{EOL},\alpha}$ after which the power has dropped to α % of the initial power P_0 [= $P(t = 0)$]:

$P(\tau^{\text{ACC}}_{\text{EOL},\alpha}) = (\alpha/100\ \%)\ P_0$ or $P(\tau^{\text{APPC}}_{\text{EOL},\alpha}) = (\alpha/100\ \%)\ P_0$, respectively

NOTE For high power diode lasers α = 80 % is frequently used. For low power diode lasers α = 50 % is common. The manufacturer/furnisher should specify the value α in the technical documentation.

3.3.7.2
end of life for APC mode
$\tau^{\mathrm{APC}}{}_{\mathrm{EOL},\alpha}$
⟨APC-mode⟩ duration $\tau^{\mathrm{APC}}{}_{\mathrm{EOL},\alpha}$ after which the pump power P_{pump} has to be increased by (100 – α)/α of the initial pump power $P_{\mathrm{pump},0}$ above the (initial) threshold pump power $P_{\mathrm{th},0}$:

$$P_{\mathrm{pump}}\left(\tau^{\mathrm{APC}}{}_{\mathrm{EOL},\alpha}\right) = P_{\mathrm{pump},0} + \frac{100\,\% - \alpha}{\alpha}\left[P_{\mathrm{pump},0} - P_{\mathrm{th},0}\right]$$

NOTE 1 For current-controlled lasers (ref. 3.2.2) the pump power is replaced by the operating current I and consequently

$$I\left(\tau^{\mathrm{APC}}{}_{\mathrm{EOL},\alpha}\right) = I_0 + \frac{100\,\% - \alpha}{\alpha}\left[I_0 - I_{\mathrm{th},0}\right]$$

NOTE 2 This EOL-definition ensures comparability with ACC-mode lifetimes for diode lasers (see [1, 2]) provided that threshold current and slope efficiency show identical long-term behaviour in APC- and ACC mode.

NOTE 3 For high power diode lasers α = 80 % is frequently used. For low power diode lasers α = 50 % is common. The manufacturer/furnisher should specify the value α in the technical documentation.

3.4 Types and classification

For this International Standard the general definitions of ISO 11145:2001, Figure 1, concerning “laser” apply. Additionally to the classification given in ISO 11145 the following classification is used:

NOTE A laser unit may consist of different lasers or laser devices. (Examples are lasers that are pumped by other lasers, oscillator-amplifier configurations and multi laser modules.)

3.4.1
multi-laser module
two or more lasers or laser devices which are combined into one unit by the manufacturer and cannot be separated by the user

3.4.2
laser source
laser radiation source including all devices that are essential for its operation, excluding electrical power supplies and controller and external cooling equipment (e.g. water chiller)

NOTE Unlike a "Laser device" as shown in Figure 1 of ISO 11145:2001 a laser source includes the "Laser" and essential "Beam-guiding devices", but no "Supply".

3.5 Others

3.5.1
burn-in
procedure applied by the manufacturer to a laser or a significant component of a laser, where the laser or the component is operated and tested at manufacturer-defined operating conditions

NOTE Frequently, a burn-in procedure is part of the manufacturer”s quality assurance programme.

3.5.2
screening
selection procedure applied by the laser manufacturer according to specific attributes or parameters

NOTE A burn-in procedure is one possible type of screening procedure.