INTERNATIONAL STANDARD

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Lasers and laser-related equipment — Test methods for laser-induced damage threshold —

Part 3:
Assurance of laser power (energy) handling capabilities

Lasers et équipements associés aux lasers — Méthodes d'essai du seuil d'endommagement provoqué par laser —

Partie 3: Possibilités de traitement par puissance (énergie) laser

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 21254-3 was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 9, *Electro-optical systems*.

This first edition of ISO 21254-3:2011 cancels and replaces ISO 11254-3:2006, which has been technically revised.

ISO 21254 consists of the following parts, under the general title *Lasers and laser-related equipment — Test methods for laser-induced damage threshold*:

— *Part 1: Definitions and general principles*

— *Part 2: Threshold determination*

— *Part 3: Assurance of laser power (energy) handling capabilities*

— *Part 4: Inspection, detection and measurement* [Technical Report]

Introduction

This part of ISO 21254 describes two methods of verifying the power density (energy density) handling capability of optical components, both coated and uncoated.

The methods will give consistent measurement results and can therefore be used for acceptance testing or to produce results which can be compared between test laboratories.

The methods are applicable to all combinations of laser wavelengths and pulse lengths. Comparison of laser damage threshold data can, however, be misleading unless the measurements have been carried out at identical wavelengths and pulse lengths.

Lasers and laser-related equipment — Test methods for laser-induced damage threshold —

Part 3: Assurance of laser power (energy) handling capabilities

WARNING — The extrapolation of damage data can lead to an overestimation of the laser-induced damage threshold. In the case of toxic materials (e.g. ZnSe, GaAs, CdTe, ThF_4, chalcogenides, Be, Cr, Ni), this can lead to serious health hazards. See ISO 21254-1:2011, Annex A, for further comments.

1 Scope

This part of ISO 21254 specifies two methods of verifying the power density (energy density) handling capability of optical surfaces.

The first method provides a rigorous test that fulfils the requirements at a specified confidence level in the knowledge of potential defects.

The second method provides a simple, and hence inexpensive, test for an empirically derived test level.

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, *Optics and photonics — Lasers and laser-related equipment — Vocabulary and symbols*

ISO 21254-1:2011, *Lasers and laser-related equipment — Test methods for laser-induced damage threshold — Part 1: Definitions and general principles*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11145 and ISO 21254-1 and the following apply.

3.1
assurance level
ϕ
energy density/power density/linear power density of the laser radiation incident on the optical surface of the component being tested

3.2
assurance area
A_ϕ
area over which the value of $H(x,y,z)$ is equal to or greater than the assurance level ϕ

3.3
confidence level
γ
probability of successful completion of the assurance test

3.4
flat-top beam
beam which has a broad area of nearly constant peak intensity (or fluence)

3.5
fraction of test area to be exposed
f_{test}
proportion of the total area of the optical component which has to be interrogated to achieve a certain confidence level

3.6
area to be tested
A_{test}
area of the optical component which has to be interrogated to achieve a certain confidence level

3.7
horizontal overlap
Ω_x
proportion of overlapping beam area of two consecutive pulses in direction x

3.8
vertical overlap
Ω_y
proportion of overlapping beam area of two consecutive pulses in direction y

3.9
distance between test sites
d_{ts}
separation of test sites

4 Symbols and units of measurement

The symbols and units of measurement are compiled in Table 1. In addition, the terms and definitions given in ISO 21254-1 apply.

Table 1 — Symbols and units of measurement

Symbol	Unit	Term
γ		confidence level
f_{test}		fraction of test area to be exposed
N_d		number of damage-initiation sites
ϕ	J/cm^2, W/cm^2, W/cm	assurance level
A_ϕ	cm^2	assurance area
A_{test}	cm^2	area to be tested
Ω_x		horizontal overlap
Ω_y		vertical overlap
d_{ts}		distance between test sites

5 Test methods

5.1 Principle

This part of ISO 21254 provides methods that will give a high level of confidence in the power density (energy density) handling capability of the component tested.

The methods can be used in a wide variety of applications, including: non-destructive testing, witness sampling, lot sampling and sub-aperture inspection. The level of confidence that the component does not contain a defect with a lower damage threshold than the acceptable irradiation strength increases with the percentage fraction of the area tested. These confidence levels are discussed in Annexes B and C.

Discussions shall be held between the test house and the user/component manufacturer to define the confidence level required and the number of shots per site (1-on-1 or S-on-1 testing) and the pulse-repetition frequency at which the tests are to be carried out.

This will define parameters such as the assurance area, A_ϕ, the distance between test sites, d_{ts}, and the total number of sites, N_{ts}, to be irradiated.

The apparatus for, general principles of and sampling for laser-induced damage testing are described in ISO 21254-1. A laser system with a suitable beam preparation system delivering laser radiation with a reproducible flat-top spatial profile is required for the assurance of laser power (energy) handling capabilities.

In this test, sampled test sites on the specimen surface are irradiated at an agreed or specified irradiation strength, irradiating in sequence a fraction of the specimen area and verifying that no damage is observed. Enough test sites on the optical surface under test shall be irradiated so that a given confidence level can be established.

Since the observation of any damage during a test constitutes a failure, this test can be non-destructive for parts for which this is considered acceptable.

The microscopic examination of the test site before and after irradiation is used to detect any damage.

The fluence-handling capability of an optical surface under irradiation by short pulsed lasers is usually expressed in units of energy density, i.e. joules per square centimetre.

The power-handling capability of an optical surface under irradiation by cw (continuous-wave) lasers or quasi-cw lasers is usually expressed in units of linear power density, i.e. watts per centimetre. The proper physical parameter and units for scaling results obtained with quasi-cw and cw-lasers is the linear power density, expressed in watts per centimetre.

5.2 Test methods

5.2.1 General

In tests that sample the ability of a specimen to withstand laser irradiation, it is possible to define two types of test.

The first, a type 1 test, allows the determination of a confidence level that permits no more than a certain number of defects to exist within the area tested. The type 1 test is described in 5.2.2.

The second, a type 2 test, is designed usually empirically, to be used on a specific specimen for a specific use. Such tests are employed to provide cost-effective screening at a high rate in an industrial environment. It should be noted that such empirically derived tests were the first widely used laser damage tests in production systems. The criteria that need to be specified to define a type 2 test are given in 5.2.3.

5.2.2 Type 1 test

Depending on the application, select the assurance level, ϕ, the confidence level, γ, and the number of defects, N_d, per specimen (usually the responsibility of the user).

Use Figure 1 to determine the fraction, f_{test}, of the area to be tested, A_{test}, that is to be exposed.

Determine (by measurement) A_ϕ from the power-density or energy-density profile of the irradiating beam in the target plane.

Determine the number of interrogations, N_{ts}, that will need be made to expose the fraction f_{test} of the surface under test:

$$N_{ts} = \frac{A_{test} \cdot f_{test}}{A_\phi} \quad (1)$$

Determine the distance between test sites, d_{ts}, for hexagonal close-packed arrays and for square arrays:

$$d_{ts} = \sqrt{\frac{2A_{test}}{N_{ts}\sqrt{3}}} \quad \text{for hexagonal close packed arrays} \quad (2)$$

$$d_{ts} = \sqrt{\frac{A_{test}}{N_{ts}}} \quad \text{for square arrays} \quad (3)$$

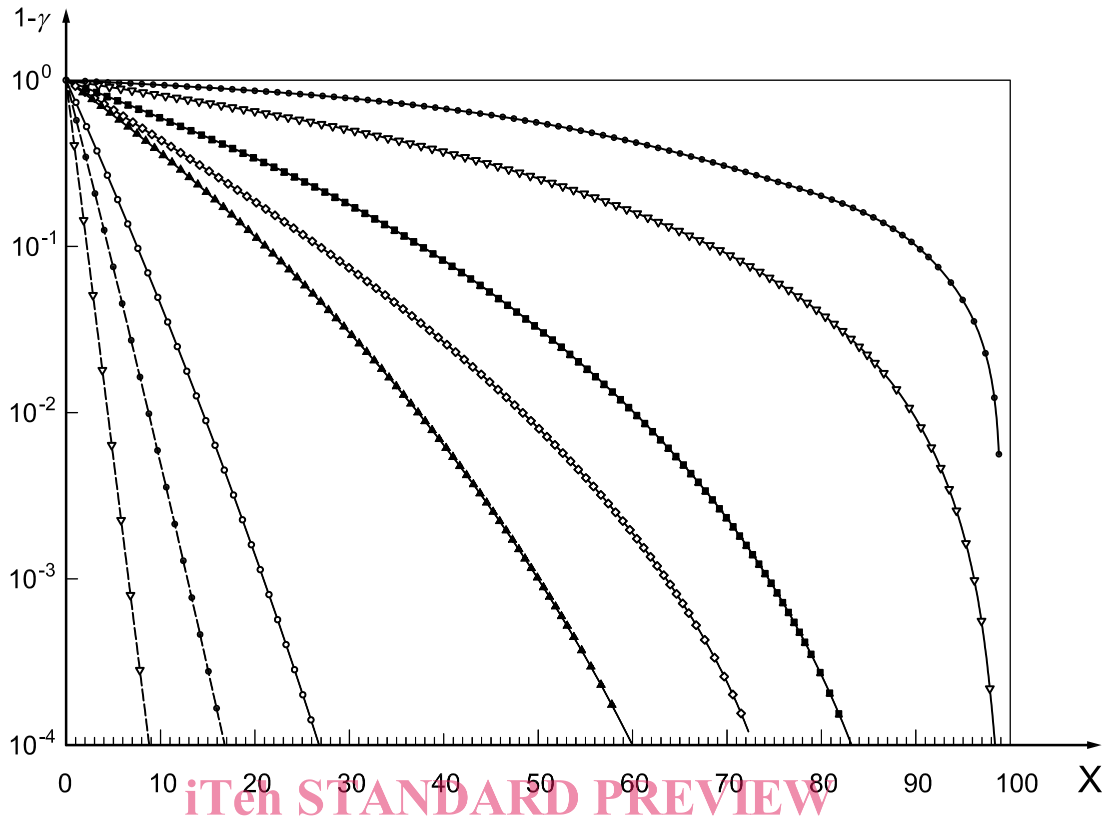
Calculate the overlap, Ω_x:

$$\Omega_x = \frac{\iint H(x,y) \cdot H(x - d_{ts}, y)\,dxdy}{\iint H(x,y)^2\,dxdy} \quad (4)$$

It might not be possible in all cases to perform an unconditioned assurance test, i.e. Ω_x or Ω_y << 1. Also note that, if $H(x,y)$ is significantly unsymmetric, it is necessary to calculate Ω_y and to consider using a different site spacing in the x- and y-directions:

$$\Omega_y = \frac{\iint H(x,y) \cdot H(x, y - d_{ts})\,dxdy}{\iint H(x,y)^2\,dxdy} \quad (5)$$

Irradiate the optical surface under test step by step for N_{ts} test sites. Each test site shall be separated by a distance corresponding to that in a hexagonal closed-packed array with a lattice constant of d_{ts}. For an S-on-1 test, each test site shall be irradiated with the required number of pulses for the particular application. If there is damage at any site, the part is considered to have failed the test and shall be disposed of accordingly. If the part under test resists irradiation (no damage at any site), then it is considered to have passed the test for the particular test parameters used.



Key

X percentage of the area tested

- 1 defect
- 2 defects
- 5 defects
- 7 defects
- 10 defects
- 30 defects
- 50 defects
- 100 defects

Figure 1 — Operating-characteristic curve

NOTE The derivation of the curve in Figure 1, called the operating-characteristic (OC) curve, is based on a defect-dominated damage mechanism. Details of the derivation of the OC curve are given in Annex C.

5.2.3 Type 2 test

In order to specify a type 2 test, the following parameters shall be specified and controlled:

— assurance level, ϕ;

— area over which at least this assurance level applies, A_ϕ;

— number of spots tested, N_{ts};

— number of shots to which each spot is exposed, S;

— pulse-repetition frequency in an S-on-1 test, f_p;

— distance between test sites, d_{ts}.

If the user does not specify these parameters, then the testing laboratory shall use the maximum spot area at which a sufficient level of irradiation for assurance can be produced. The test laboratory shall also propose an