INTERNATIONAL STANDARD

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Lasers and laser-related equipment — Determination of laser-induced damage threshold of optical surfaces —

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

Lasers et équipements associés aux lasers — Détermination du seuil d'endommagement provoqué par laser sur les surfaces optiques —

Partie 3: Vérification de la capacité à supporter la puissance (l'énergie) laser

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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 11254-3 was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 9, *Electro-optical systems*.

ISO 11254 consists of the following parts, under the general title *Lasers and laser-related equipment — Determination of laser-induced damage threshold of optical surfaces*:

— *Part 1: 1-on-1 test*

— *Part 2: S-on-1 test*

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

Introduction

Optical components can be damaged by laser irradiation of sufficiently high energy or power density. At any specified laser irradiation level the probability of laser damage is usually higher for the surface of a component than for its bulk. Thus the limiting value of an optical component is usually given by the damage threshold of its surface.

This document provides a test procedure for obtaining consistent measurement results, which may be used for acceptance tests or may be compared between different testing laboratories.

This testing procedure is applicable to all combinations of different laser wavelength and pulse length durations. Comparison of laser damage threshold data may be misleading unless the measurements have been taken at identical wavelengths and pulse lengths.

Lasers and laser-related equipment — Determination of laser-induced damage threshold of optical surfaces —

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

SAFETY PRECAUTIONS — Some laser and optical components are made of materials which are toxic if vaporized (e.g. ZnSe, GaAs, CdTe, ThF_4, chalcogenides, Be, Cr, Ni). Due care shall be taken not to damage these materials without taking suitable safety precautions.

1 Scope

This part of ISO 11254 describes a test procedure for assurance of power density (energy density) handling capability of optical surfaces, both coated and uncoated.

This part of ISO 11254 specifies this procedure by providing two test methods for assurance of the power density (energy density) handling capability of optical surfaces.

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

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

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 10110-7:1996, *Optics and optical instruments — Preparation of drawings for optical elements and systems — Part 7: Surface imperfection tolerances*

ISO 11145, *Optics and photonics — Lasers and laser-related equipment — Vocabulary and symbols*

3 Terms and definitions

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

3.1
surface damage
any permanent laser radiation-induced change of the surface characteristics of the specimen, which can be observed by an inspection technique described in this part of ISO 11254

3.2
1-on-1 test
test programme that uses one shot of laser radiation on each unexposed site on the specimen surface

3.3
S-on-1 test
test programme that uses S shots on each unexposed site on the specimen surface

3.4
target plane
plane tangential to the surface of the specimen at the point of intersection of the test laser beam propagation axis with the surface of the specimen

3.5
effective pulse duration
τ_{eff}
ratio of total pulse energy to peak pulse power

3.6
assurance level
ϕ
energy density/power density/linear power density of the laser radiation incident on the optical surface at which the component is tested

3.7
assurance area
A_ϕ
area over which the value of the energy density H(x,y,z) is equal to or greater than the assurance level, ϕ

3.8
confidence level
γ
complement of the probability of successful completion of the assurance test

3.9
effective beam diameter
twice the square root of the assurance spot area divided by pi (π)

See Table 1 for symbols and units.

$$d_{\phi,\,\text{eff}} = 2\sqrt{\frac{P}{\pi E_{\text{max}}}} \qquad (1)$$

3.10
flat-top beam
beam that has a broad area of nearly constant peak intensity (or fluence)

4 Symbols and units of measurement

Table 1 — Symbols and units of measurement

Symbol	Unit	Term
λ	nm	wavelength
α	rad	angle of incidence
p	1	degree of polarization
τ_{H}	ns, μs, ms, s	pulse duration
τ_{eff}	ns, μs, s	effective pulse duration
Q	J	pulse energy
P_{pk}	W	peak pulse power
P	W	power
H_{max}	J/cm^2	maximum energy density
E_{max}	W/cm^2	maximum power density
F_{max}	W/cm	maximum linear power density
d_{sep}	mm	separation of test sites
γ	1	confidence level
R	1	risk of false assurance
f_{test}	1	fraction of test area to be exposed
N_{d}	1	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
N_{TS}	1	number of sites in tested area to be interrogated
Ω_{x}	1	horizontal overlap
Ω_{y}	1	vertical overlap

5 Sampling

This part of ISO 11254 provides a procedure that will give a high level of confidence to the power density (energy density) handling capability of the component tested.

It may be used in a wide variety of applications, including: non-destructive inspection, 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.

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

This will define such parameters as the acceptable irradiation spot area, A_{ϕ}, the spot site separation, d_{sep}, and the total number of sites, N_{TS}, to be irradiated.

6 Test method

6.1 Principle

This test irradiates sampled test sites on the specimen surface at an agreed or specified irradiation strength, irradiating in sequence, a fraction of the specimen area and verifying that no damage is observable. Enough samples (test sites) of the optical surface under test shall be irradiated so that a given confidence level can be established. See Figure 1.

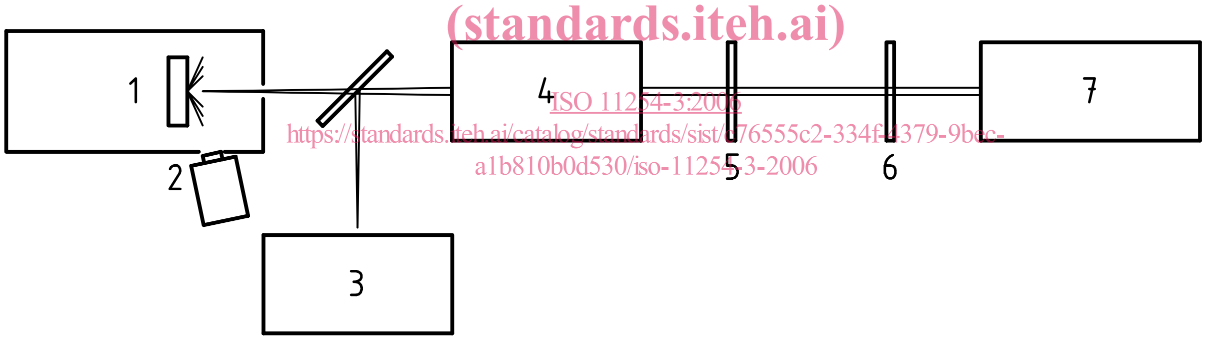
Since the observation of any damage during a test constitutes failure, this test can be non-destructive for acceptable parts.

Microscopic examination of the testing site before and after irradiation is used to detect damage.

This procedure is applicable to testing with all laser systems. The polarization state is set with an appropriate waveplate.

The fluence handling ability of an optical surface under irradiation by short pulsed lasers is usually expressed in units of energy density (joules per square centimetre).

The power handling ability of an optical surface under irradiation by quasi-continuous wave (cw) or cw-lasers is usually expressed in units of linear power density (watts per centimetre). Power density refers to the average power per unit area during the irradiation time. The proper units and physical parameter for scaling results for quasi-cw and cw-lasers is the linear power density expressed in watts per centimetre.



Key

1 sample in compartment
2 online damage detector
3 beam diagnostic
4 focusing system
5 waveplate
6 variable attenuator
7 laser system

Figure 1 — Basic approach to laser damage testing

6.2 Apparatus

6.2.1 Laser system

A laser system delivering laser radiation with a reproducible near flat-top spatial profile is required. The temporal profile of the pulses is monitored during the measurement. For the different laser groups, the maximum permissible variations of the pulse parameters are compiled in Table 2. Stability criteria for the beam parameters, and therefore the incident energy density of the laser, shall be determined and documented in an error budget and included with the test report as shown in Annex A.

References for the production of a flat-top beam and laser damage scaling are contained in the Bibliography.

Table 2 — Maximum variation of laser system parameters and corresponding percentage variation of the assurance pulse power density

Laser type	Pulse energy Q	Average power P_{av}	Pulse duration τ_H	Assurance area A_ϕ	Power density E_{max}
pulsed	± 5	–	± 10	± 10	± 15
cw	—	± 5	—	± 6	± 20
NOTE Variations are tabulated in percent.					

6.2.2 Variable attenuator and beam delivery system

The laser output shall be attenuated to the required level with an external variable attenuator free of drifts in transmissivity and imaging properties.

The beam delivery system and the attenuator shall not affect the properties of the laser beam in a manner inconsistent with the tolerances given in 6.2.1. The polarization state of the laser beam shall not be altered by the beam delivery system.

6.2.3 Focusing system

The focusing system shall deliver a flat top energy distribution along a section of the beam. The beam shall have a central peak region where the local fluence or power density for pulsed lasers or linear power density for cw lasers varies less than the values given in Table 3.

Table 3 — Maximum variations in central peak regions

Laser type	Maximum variation (peak to valley) over the central peak region expressed as a percentage of the maximum value
pulsed	± 11 %
cw	± 14 %

Coherence effects in specimens with parallel surfaces may affect the measurement. These effects shall be eliminated by appropriate techniques such as wedging or tilting of the specimen. The application of a highly converging beam is a method for removing coherence effects in the specimen.

6.2.4 Specimen holder

The test station shall be equipped with a manipulator for a precise placement of the test sites on the specimen with precision sufficient for the specimen size.

6.2.5 Damage detection

A microscope technique shall be used to inspect the surface before and after the test. The inspection shall be made with an incident light microscope having Nomarski-type differential interference contrast. A magnification in the range from 100 × to 150 × shall be used. For routine inspection and objective measurement of laser damage, an image analyser may be attached to the microscope.

An appropriate online damage detection system may be installed to evaluate the state of the surface under test. For online detection, any appropriate technique may be used. Techniques suited to this purpose are online microscopic techniques in conjunction with image analysers, photoacoustic and photothermal detection, and scatter measurements using a separate laser or radiation from the damaging laser. A typical set-up for an online scatter measurement system is described in ISO 11254-2.

6.2.6 Beam diagnostics

6.2.6.1 Total pulse energy and power

The diagnostic package shall be equipped with a calibrated detector to measure the pulse energy or beam power delivered to the target plane. This instrument shall be traceable to a national standard with an absolute uncertainty of ± 5 % or better.

6.2.6.2 Temporal profile

The diagnostic package shall include suitable instrumentation for analysing the temporal profile of the laser to determine the pulse duration.

6.2.6.3 Spatial profile

The spatial profile shall be analysed in the target plane or an equivalent plane. The diagnostic package shall be equipped with instrumentation to measure the two dimensional spatial profile with a spatial resolution to the requirements stated in Table 2.

6.3 Preparation of test specimens

Wavelength, angle of incidence and degree of polarization of the laser radiation used in the test shall be in accordance with the specifications by the manufacturer for normal use. If ranges are given for the values of these parameters, an arbitrary combination of wavelength, angle of incidence and polarization within these ranges may be used.

Storage, cleaning and preparation of the specimens shall be according to the specifications provided by the manufacturer for normal use.

In the absence of manufacturer specified instructions, the following procedure shall be used.

The specimen shall be stored at less than 50 % RH for 24 h prior to testing. The specimen shall be handled by the non-optical surfaces only. Before testing, a microscopic evaluation of surface quality and cleanliness in accordance with ISO 10110-7 shall be made using a Nomarski/darkfield microscope at 150 × magnification or higher.

If contaminants are seen on the specimen, the surface shall be cleaned. The cleaning procedure shall be documented. If the contaminants are not removable they shall be documented by photographic and/or electronic means before testing. The test site shall be inspected for dust particles during irradiation. The test environment shall be clean filtered air of less than 50 % RH and shall be documented.

The testing-sites shall be arranged in a well defined and reproducible arrangement. The test grid shall be referred to fixed reference points on the specimen.

6.4 Test procedures

6.4.1 General

In tests that sample the ability of an optic 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 a tested area. The Type 1 test is discussed in 6.4.2.

The second, a Type 2 test, is designed, usually empirically, to be used on a specific optic for a specific use. Such tests are used to provide a cost effective screen in a high rate industrial environment. It should be noted that such empirically derived tests were the first widely used laser damage tests applied to production systems. The criteria that shall be specified to define a Type 2 test are given in 6.4.3.

