
**Optics and photonics — Lasers and
laser-related equipment — Test
method for absorptance of optical
laser components**

*Optique et photonique — Lasers et équipements associés aux lasers
— Méthode d'essai du facteur d'absorption des composants optiques
pour lasers*

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee 9, *Laser and electro-optical systems*.

This third edition cancels and replaces the second edition ISO 11551:2003 which has been technically revised.

The main changes compared to the previous edition are as follows:

- a) Introduction: The assumptions were revised in the second paragraph. Minor wording and example adjustment in third paragraph.
- b) [Clause 4](#): Table for symbols and units was corrected.
- c) [Clause 5](#): More detailed specification of environmental conditions for UV- and IR applications are provided in the second paragraph. ISO 7 specification was deleted.

In the fourth paragraph, [Annex A](#) is explicitly mentioned for the dependence of absorption on other test parameters.

In the fifth paragraph, [Annex B](#) is explicitly mentioned to account for the critical issue of finite heat conductivity.

- d) In [7.2.3](#): In the first paragraph, the calibration procedure is specified in more detail, including the consideration of the heating scheme for thick samples.

Note 1 is complemented by the restriction for thin samples.

Note 2 is complemented with the consideration of heating scheme for finite heat conduction.

- e) In [7.3](#): In the first paragraph the specifications for the ambient temperature drift were clarified.

The requirements to the total temperature rise during heating were generalized.

In the third paragraph the terminology “pre-irradiation” was replaced by “drift record”. The description of the duration of the cooling period was complemented.

- f) In [8.1](#): In the first paragraph “heat capacity” was replaced by “specific heat capacity”.
- g) In [A.1](#): “irradiation dose” added as influencing parameter.
- h) In [A.3](#): Generalization of nonlinear absorption dependencies.
- i) In [B.3](#): More detailed comments on the convergence of the temperature curves in [Figure B.1](#). Correction of [Formulae \(B.2\)](#) and [\(B.3\)](#). An additional paragraph with explanations for thick test samples, including two references.

This corrected version of ISO 11551:2019 incorporates the following corrections:

- In [7.2.3](#), [Formulae \(B.1\)](#), [\(B.2\)](#) and [\(B.3\)](#), the symbol " α " has been changed into " a ";
- Two signs have been corrected in [Formula \(C.4\)](#) to read " $-B_{exp}$ " and " $-t_k$ " instead of " B_{exp} " and " t_k ".

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Introduction

To characterize an optical component, it is important to know its absorptance. When radiation impinges upon a component, a part of that radiation is absorbed, increasing the temperature of the component. In this document only the part of the absorbed power/energy, that is converted into heat, is measured. If enough energy is absorbed, the optical properties of the component can change, and the component can even be destroyed. Absorptance is the ratio of the radiant flux absorbed to the radiant flux of the incident radiation.

In the procedures described in this document, the absorptance is determined calorimetrically as the ratio of power or energy absorbed by the component to the total power or energy, respectively, impinging upon the component. The assumption is made that the absorptance of the test sample is constant within the temperature fluctuations experienced by the component during the measurement.

For most optical bulk materials, the absorptance depends on the position of the irradiating beam on the sample surface. Several infrared materials exhibit a strong dependence of absorptance on temperature, especially at high temperatures.

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Optics and photonics — Lasers and laser-related equipment — Test method for absorptance of optical laser components

1 Scope

This document specifies procedures and techniques for obtaining comparable values for the absorptance of optical laser components.

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.

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

ISO 14644-1:2015, *Cleanrooms and associated controlled environments — Part 1: Classification of air cleanliness by particle concentration*

ISO 80000-7, *Quantities and units — Part 7: Light and radiation*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 11145 and ISO 80000-7 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1 absorptance

a

ratio of the radiant flux absorbed to the radiant flux of the incident radiation

Note 1 to entry: The definition of absorptance used for this document is limited to absorptance processes which convert the absorbed energy into heat. For certain types of optics and radiation, additional non-thermal processes can result in absorption losses which will not be detected by the test procedure described here (see [Annex A](#)).

4 Symbols and units of measure

Symbol	Term	Unit
C_{eff}	Thermal capacity of test sample, holder, etc.	J/K
c_p	Specific heat capacity of test sample	J/(kg·K)
$d_{\sigma_x}, d_{\sigma_y}$	Beam width on test sample	mm
m_i	Mass of test sample, holder, etc.	kg
P	cw power	W

Symbol	Term	Unit
P_{av}	Average laser power for continuous pulse mode operation	W
P_{pk}	Typical peak power for repetitive pulse mode operation	W
t_B	Duration of irradiation	s
Δt	Time interval	s
T_{amb}	Ambient temperature	K
ΔT	Temperature difference	K
a	Absorptance	1
β	Angle of incidence	Rad
γ	Thermal loss coefficient	1/s
λ	Wavelength	nm
κ	Heat conductivity	W/(mK)
η	Mass density	kg/m ³
Q	Heat source	W/m ³

5 Preparation of test sample and measuring arrangement

Storage, cleaning and the preparation of the test samples are carried out in accordance with the manufacturer's instructions for normal use.

The environment of the testing place shall be adapted to the application and test wavelength. It should consist of dust-free filtered air with less than 50 % relative humidity. The residual dust shall be reduced in accordance with cleanroom class 7 as defined in ISO 14644-1:2015. However, some specific spectral ranges might require nitrogen purged environments (deep UV) or zero humidity (several IR wavelengths). Nitrogen quality for the deep UV range should be at 99,999 % or higher. If these conditions cannot be supplied, absorption within the surrounding atmosphere will be included in the test result. An environment free from draughts is very important in order to keep thermal disturbances and heat loss by convection as small as possible. Measurements in ambient atmosphere and vacuum can have different influences on the measured absorptance.

A laser shall be used as the radiation source. To keep errors as low as possible, the laser power chosen for measurements is as high as possible but without causing any deterioration to the component.

Wavelength, angle of incidence and state of polarization of the laser radiation used for the measurement shall correspond to the values specified by the manufacturer for the use of the test sample. If also ranges are accepted for these three quantities, any combination of wavelength, angle of incidence and state of polarization may be chosen from those ranges. The absorption of an optical component can depend on further parameters, e.g. power density or irradiation dose. In such cases, the measurement sequence should be chosen individually. For more details, refer to [Annex A](#).

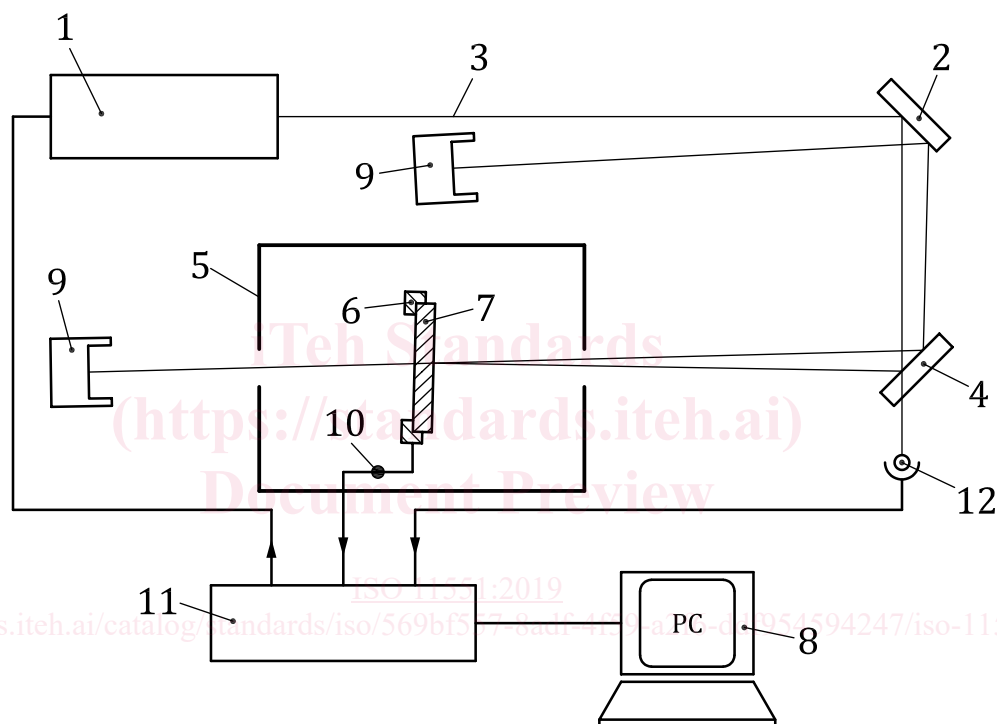
The test sample is mounted in a suitable holder. It is preferable to mount the sample in a manner that minimizes any thermal contact between the sample and the holder. In this arrangement, the thermal sensor is attached directly to the sample surface. Reproducible thermal contact between the thermal sensor and the sample surface is important. Also, care should be taken to maintain constant thermal impedance between the sample and the holder. Accurate calibration is critically dependent on the location of the thermal sensor, on the material the sample is made of, and on the sample geometry. Refer to [Annex B](#) for a detailed discussion of these considerations.

It can be difficult to attach the thermal sensor to a small test sample or a sample having an irregular shape. Such a sample is mounted to the holder in a manner that maximizes thermal contact between the sample and the holder, while the thermal sensor is attached to or integrated into the holder. Reproducible thermal contact between the thermal sensor and the holder is important. Also, care should be taken to maintain constant thermal conductance between the sample and the holder.

In order to increase the precision of the measurements, the sample should be mounted inside a chamber designed for thermal shielding, with apertures for the laser beam. Special attention shall be given to ensure that the temperature measurement itself does not cause a change of the sample temperature.

Suitable diaphragms should be placed in the beam path in front of and behind the test sample to ensure that only the test sample is irradiated by the measuring beam and that reflected or stray radiation will not strike the holder or the chamber walls. The number of transmissive optics employed for beam guiding should be minimized in order to reduce possible distortions by multi-reflections or scattered radiation. The transmitted and reflected partial beams shall be directed on to beam dumps with minimized back scatter.

[Figure 1](#) shows a schematic measuring arrangement. The curved folding mirror M1 is recommended for imaging the laser output window on to the sample in order to avoid diffracted radiation influencing the measurement.



Key

1	laser	7	test sample
2	mirror M1	8	personal computer
3	optical axis	9	beam stop
4	mirror M2	10	thermal sensor
5	test chamber	11	control unit
6	sample holder	12	power detector

Figure 1 — Typical arrangement for measurement of the absorbance

6 Characteristic features of the laser radiation

The following physical quantities are needed for characterizing the laser radiation used for the test:

- wavelength, λ ;
- angle of incidence, β ;
- state and degree of polarization;

- beam widths on the test sample, $d_{\sigma x}$, $d_{\sigma y}$;
- average power, P_{av} , for cw or continuously pulsed lasers;
- typical peak power, P_{pk} , and pulse energy Q in the case of continuously pulsed lasers;
- duration of irradiation, t_B .

7 Test procedure

7.1 General

The following auxiliary tests shall be performed on a regular basis and whenever the measuring arrangement has been altered.

7.2 Calibration

7.2.1 Calibration of the power signal

Calibrate the power signal by placing a calibrated laser power detector at the location of the test components and, in order to obtain correct calibration, compare the measured laser power to the signal of the power monitor used during absorptance tests.

7.2.2 Calibration of the temperature signal

Calibrate the temperature signal by fixing a test sample, to which a calibrated thermal sensor is attached, to the sample holder. Compare the temperature signals of this calibrated sensor and the sensors used during absorptance tests while varying the ambient temperature slowly over the linearity range of the temperature detectors at the typical test temperature.

7.2.3 Calibration of the thermal response

For certain types of sample materials and geometries, the temperature rise induced by the absorbed heat may differ from the theoretical response expected for ideal materials having infinite thermal conductivity. In these cases, a correction factor f_c shall be determined, which compensates for the influence of such phenomena on the absorptance test result. f_c is unity if the influence of limited thermal conductivity can be neglected. In order to derive a correct value for f_c , the heating scheme of the calibration routine needs to be consistent with the heating characteristic of the samples to be tested. Surface absorbers shall be related to a correction factor derived from a calibration based on surface heating. And a bulk absorber shall be corrected with a bulk heated calibration sample.

For calibration, a reference sample of known absorptance, which is identical to the samples under investigation with respect to substrate geometry and thermal diffusivity, is tested for absorptance as described below. The irradiation time and evaluation method used for calibration shall be the same as for the sample under test.

Depending on the evaluation method used for the absorptance test, the correction coefficient can be calculated by substituting the value of the known calibration sample absorptance for a in [Formula \(2\)](#) (see [8.3](#)) or [Formula \(5\)](#) (see [8.4](#)), and solving for f_c .

A known absorptance can be achieved by applying a thin, high-absorbing coating to the sample surface area that is exposed to irradiation. High absorptance values can be determined with sufficient accuracy, e.g. by measuring the fraction of transmitted, reflected and scattered radiation. For absorptance testing of samples with high absorptance values, the laser power should be suitably attenuated in order to avoid damage to the samples and to ensure that the resulting temperature rise is in the same order of magnitude as the temperature which is achieved for typical measurements. This procedure applies only for samples of high surface absorption, where bulk absorption can be neglected.