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

Optique et instruments d'optique — 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.

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 11551 was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 9, *Electro-optical systems*.

This second edition cancels and replaces the first edition (ISO 11551:1997), which has been technically revised.

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 International Standard 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 may be changed, and the component may 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 International Standard, 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 and is independent of both the position of the irradiating beam on the sample surface and the power density of the impinging radiation.

For several bulk materials like CdTe, 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.

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

1 Scope

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

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 31-6:1992, *Quantities and units — Part 6: Light and related electromagnetic radiations*

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

ISO 14644-1:1999, *Cleanrooms and associated controlled environments — Part 1: Classification of air cleanliness*

3 Terms and definitions

For the purposes of this document, the terms and definitions in ISO 11145 and ISO 31-6 and the following apply.

3.1
absorptance
α
ratio of the radiant flux absorbed to the radiant flux of the incident radiation

NOTE The definition of absorptance used for this international Standard is limited to absorptance processes which convert the absorbed energy into heat. For certain types of optics and radiation, additional non-thermal processes may result in absorption losses which will not be detected by the test procedure described here (see Annex A).

4 Symbols and units of measure

Table 1 — Symbols and units of measure

Symbol	Term	Unit
c_i	Thermal capacity of test sample, holder, etc.	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
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
α	Absorptance	1
β	Angle of incidence	Rad
γ	Thermal loss coefficient	1/s
λ	Wavelength	nm

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 consists of dust-free filtered air with less than 50 % relative humidity. The residual dust is reduced in accordance with cleanroom class 7 as defined in ISO 14644-1:1999. In this connection, 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 may 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.

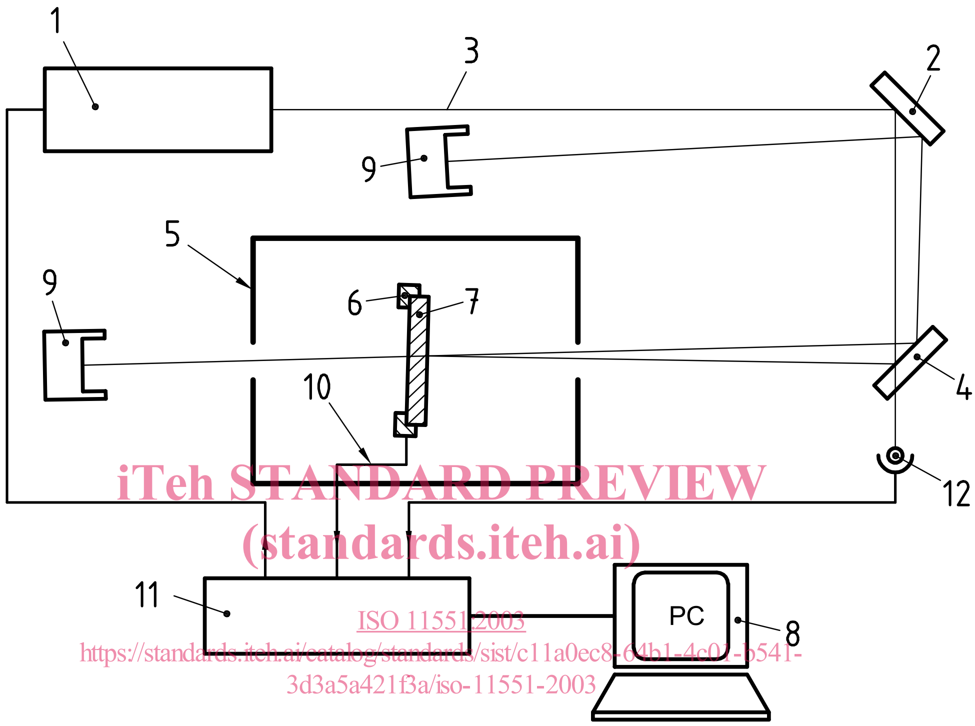
Wavelength, angle of incidence and state of polarization of the laser radiation used for the measurement shall correspond to the values specified by the manufacturer for the use of the test sample. If ranges are accepted for these three quantities, any combination of wavelength, angle of incidence and state of polarization may be chosen from those ranges.

The sample is mounted in a suitable holder. The thermal sensors are either connected directly to the sample surface, or attached to the sample holder. Good thermal contact between sensor and sample or between holder and sample shall be achieved. Precaution shall be taken to avoid a possible drop in thermal conductance between temperature sensor and test sample.

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

Figure 1 — Typical arrangement for measurement of the absorptance

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 detector and the sensors used during absorptance tests while varying the ambient temperature slowly over a range of a few kelvins 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.

For calibration, a reference sample of known absorptance, which is similar to the samples under investigation with respect to substrate geometry, heat capacity and thermal conductivity, is tested for absorptance as described below. The irradiation time and evaluation method used for calibration shall be the same as for other typical absorptance tests for which the calibration shall be valid.

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 α in equations 2 (see 8.3) or 5 (see 8.4), and solving for f_c.

NOTE 1 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.

NOTE 2 An alternative to irradiating a calibration sample of known absorptance with the laser beam, the thermal energy may be deposited electrically in the test sample by attaching an electric resistor to the tested surface. The absorbed power is given by RI^2, where R is the electrical resistance and I is the electric current during “irradiation”. Care should be taken to ensure good thermal contact between resistor and sample. Furthermore, especially in the case of samples with low thermal conductivity, the area of the resistor should match the area irradiated by the laser beam under normal test conditions.

7.2.4 Measurement of the background signal

For maximum accuracy and suppression of possible signal distortions, the imaging and alignment of the laser beam shall be optimized. A measurement with an empty holder or with an absorptance-free component can be used to verify that the measuring arrangement is not influenced by reflected or stray radiation. The amplitude of the temperature fluctuations during the test interval shall be at least one order of magnitude below the temperature rise occurring during an absorptance test.

7.3 Determining the absorptance

The absorptance of optical components is determined calorimetrically by means of a measuring arrangement as shown in Figure 1. Before measurement commences, thermal equilibrium shall be established, so that non-linear temperature drift and temperature noise are at least one order of magnitude below the maximum temperature rise induced by irradiation. The maximum temperature rise during the test should not exceed a few kelvins.

If the absorptance is dependent either on the power or energy density of the impinging radiation, or the temperature of the test sample, this shall be noted in the test report. The test shall be performed under the conditions of the foreseen use of the components.

The test is performed in three successive intervals:

— the pre-irradiation interval $[t_0, t_1]$ (at least 30 s);

— the heating interval $[t_1, t_2]$ ($t_B = t_2 - t_1$ = 5 s to 300 s) during which the laser beam is switched on and impinges on the test sample surface;

— the cooling interval of at least 200 s.

For test samples with high thermal losses, the irradiation should end significantly before the temperature rise saturates due to a balance of absorbed power and thermal loss.

During the test, the sample temperature signal $T(t)$ and the laser power signal $P(t)$ are recorded. The resulting calorimetric data sets $[t_k, T(t_k)]$ and $[t_k, P(t_k)]$ with k, enumeration index, are stored for the evaluation of the absorptance.

8 Evaluation

8.1 General

The mass, m_i, of components heated during irradiation (test sample, holder, etc.) is determined by weighing. Thermal capacities are taken from tables.

For the calculation of absorptance, two alternative methods can be used: the exponential method or the pulse method. In general, the pulse method is applicable for irradiation times up to 120 s, while the exponential method can be applied for irradiation times from 60 s. Which method is preferable depends also on the individual properties of the tested specimen and the circumstances of the test. In many cases it can be helpful to apply both methods and gain additional information on the uncertainty in the result by comparing the two results.

8.2 Elimination of drift

Preceding the calculation of absorptance, the calorimetric data shall be analysed with respect to the possible occurrence of temperature drift phenomena. In the presence of temperature drift, a linear fit shall be performed to the temperature data sampled before irradiation. The approximated drift influence described by the resulting linear fit function is eliminated by subtracting the extrapolated fit values from the raw temperature data recorded during the test.

