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Optics and optical instruments — Measurement of reflectance of plane surfaces and transmittance of plane parallel elements

Optique et instruments d'optique — Méthode de mesurage de la réflectance des surfaces planes et de la transmittance des éléments à plan parallèle

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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 3.

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 International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 15368 was prepared by Technical Committee ISO/TC 172, *Optics and optical instruments*, Subcommittee SC 1, *Fundamental standards*.

Annexes A and B of this International Standard are for information only.

Introduction

Measurements of reflectance and transmittance using spectrophotometers are the most fundamental methods for the characterization of optical components. Since the spectrophotometric methods are basic and normal, they are extensively used and further give measurement data for a wide range of wavelengths.

This International Standard describes the measurement of reflectance and transmittance using spectrophotometers which provides data with high reproducibility and repeatability.

Optics and optical instruments — Measurement of reflectance of plane surfaces and transmittance of plane parallel elements

1 Scope

This International Standard gives rules for the measurement of the spectral reflectance of plane surfaces and spectral transmittance of plane parallel elements using spectrophotometers over the spectral range 190 nm to 25 µm.

The transmittance τ and the reflectance ρ of optical components are generally divided into two parts as follows:

$$\tau = \tau_r + \tau_d \quad (1)$$

$$\rho = \rho_r + \rho_d \quad (2)$$

where

τ_r is the regular transmittance;

τ_d is the diffuse transmittance;

ρ_r is the regular reflectance;

ρ_d is the diffuse reflectance.

This International Standard applies only to measurements of the regular transmittance and the regular reflectance; it does not apply to those of the diffuse transmittance and the diffuse reflectance.

This International Standard is applicable to test specimens which are coated or uncoated optical components without optical power.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

IEC 60050-845:1987, *International Electrotechnical Vocabulary — Chapter 845: Lighting*

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

ISO 9211-1:1994, *Optics and optical instruments — Optical coatings — Part 1: Definitions*

ISO 9211-2:1994, *Optics and optical instruments — Optical coatings — Part 2: Optical properties*

ISO 10110-8:1997, *Optics and optical instruments — Preparation of drawings for optical elements and systems — Part 8: Surface texture*

3 Terms and definitions

For the purposes of this International Standard, the terms and definitions given in ISO 31-6, ISO 9211-1 and the following (which are given in IEC 60050-845) apply.

3.1
transmittance
⟨for incident radiation of given spectral composition, polarization and geometrical distribution⟩ ratio of the transmitted radiant or luminous flux to the incident flux in the given conditions

3.2
regular transmittance
ratio of the regularly transmitted part of the whole transmitted flux to the incident flux

3.3
internal transmittance
ratio of the radiation flux reaching the internal exit surface of the layer to the flux that enters into the layer after crossing the entry surface

3.4
reflectance
⟨for incident radiation of given spectral composition, polarization and geometrical distribution⟩ ratio of the reflected radiant or luminous flux to the incident flux in the given conditions

3.5
regular reflectance
specular reflectance
ratio of the regularly reflected part of the whole reflected flux to the incident flux

4 Symbols and units

For the purposes of this International Standard, the following symbols and units apply.

λ wavelength, expressed in nanometres

i angle of incidence, expressed in degrees

p, s state of polarization

τ transmittance

τ_r regular transmittance

τ_i internal transmittance

ρ reflectance

ρ_r regular reflectance

5 Test specimen

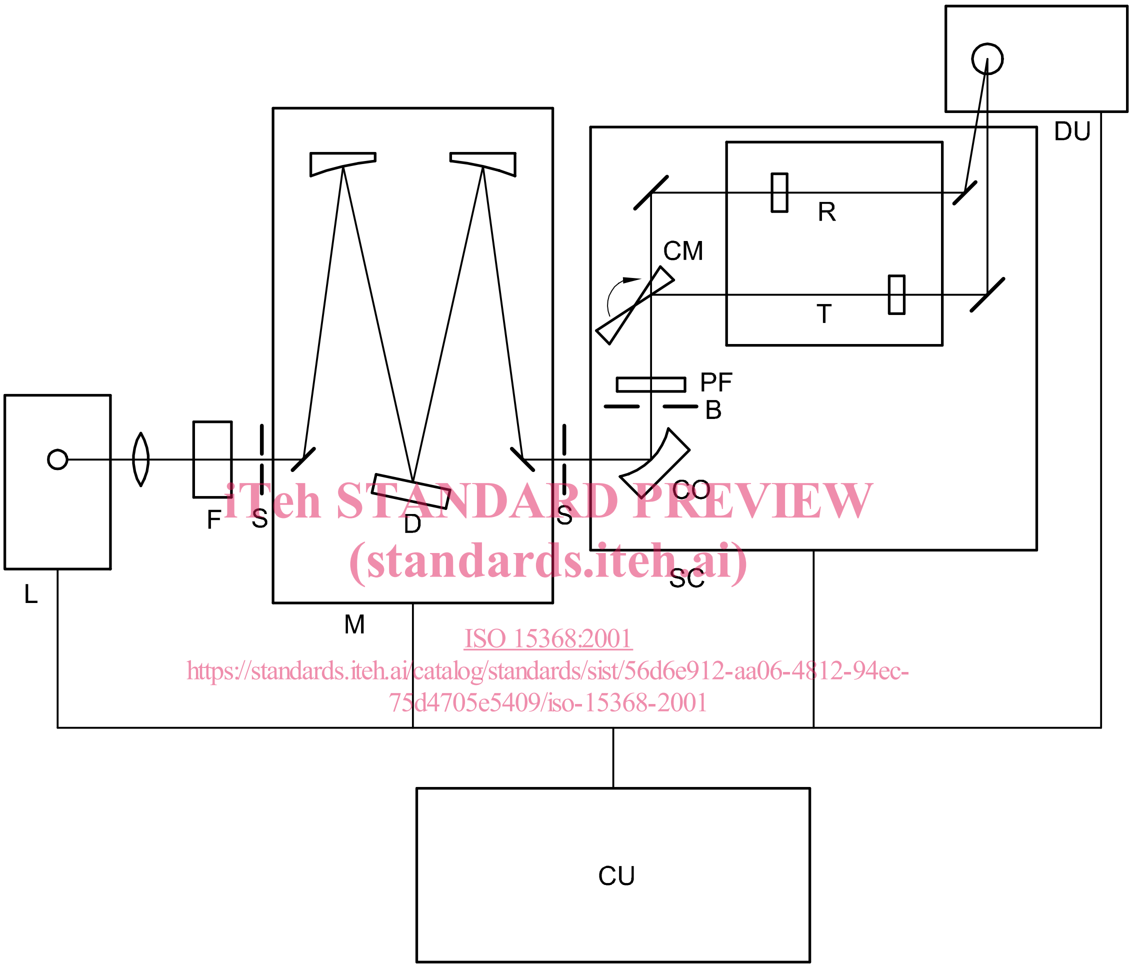
Storage, cleaning and preparation of a test specimen shall be carried out in accordance with the instructions of the manufacturer on the test specimen for normal use.

Wavelength, angle of incidence and state of polarization shall correspond to those specified by the manufacturer for the use of the test specimen.

6 Measuring apparatus

For the measurement specified in this International Standard, a spectrophotometer is required. Figure 1 shows an example of a double beam, dispersion type spectrophotometer. It consists of a light source, a monochromator, a specimen compartment, a detector unit and a control unit.

Details of the apparatus are described in annex A.



Key

L	Light source
F	Filter box
S	Slit
D	Dispersive element
M	Monochromator
SC	Specimen compartment
CO	Collecting optics
B	Baffle
PF	Polarization filter
CM	Chopper mirror
T	Test beam
R	Reference beam
DU	Detector unit
CU	Control unit

Figure 1 — Standard arrangement of a spectrophotometer

7 Test conditions

7.1 General

The light source, divergence of beam, beam diameter on the specimen, wavelength, spectral resolution, stepping interval, incident angle, detector and numerical correction shall be selected and documented.

7.2 Light source

The temporal variation of the intensity of the light source shall be measured and documented. The state of polarization (p or s) of the beam shall be selected and documented.

NOTE The state of polarization of the radiation reaching the detector may be affected by reflection on components in the reference/sample paths. It is suggested to rotate the sample in its incidence plane to check for polarization effects.

The beam diameter on the specimen shall be larger than 1 mm. On the surface of the specimen the beam profile shall be smooth so that the local peak power density does not exceed the average power density by a factor of greater than two. The beam diameter and the beam divergence (see also 9.9) shall be documented.

7.3 Monochromator

The type of dispersive element and its characteristics shall be documented.

Optics for blocking out higher order diffraction light shall be documented.

The spectral range and spectral resolution shall be selected in order to satisfy the specification of the measurement, and be documented.

The type of spectrophotometer (single or double beam, dispersion or Fourier-transform) shall be documented.

7.4 Detection system

An appropriate detector for the measuring spectral region shall be selected and documented. In the case of a dispersion type spectrophotometer, a lock-in detection technique is frequently used and a light chopper or a chopper mirror is installed in the beam to modulate the output signal. The detection system shall have a dynamic range greater than 10^4 and a deviation from linearity less than 10^{-2}. Photometric linearity shall be calibrated by a double aperture method that uses double apertures and neutral density filters [1].

When an integrating sphere or a diffuser is used, this shall be documented.

7.5 Numerical correction

Numerical correction can include spectral correction, averaging, smoothing, calibration of photometric linearity and others.

Spectral correction can be made referring to an appropriate wavelength standard (see 9.2). Random noise can be reduced by averaging or smoothing. Averaging can be made by repeating measurement or increasing sampling time. Smoothing can be made by averaging data in the finite spectral bandwidth after measurement, although it reduces spectral resolution. Sampling time and smoothing factors shall be documented.

For details on the calibration of photometric linearity, see 7.4.

Calibration of the spectrophotometer can be done by measuring the transmittance of a reference sample (standard) using the method given in 8.2.1. A reference sample for the transmittance from ultraviolet to near infrared region shall be an accurately parallel plate of fused silica with P2 grade surface specified in ISO 10110-8. Accuracy and repeatability of the transmittance of this reference sample is from $\pm$ 0,02 % to $\pm$ 0,5 % including photometric noise. Other standard reference materials which are checked at an accredited laboratory may be used.

8 Test procedure

8.1 Measurement of reflectance

8.1.1 General

Either of the two types of measurements of reflectance, a direct method or a relative method, shall be chosen.

The incident angle shall be selected according to the manufacturer's instruction. Reflectance of normal incidence cannot usually be measured and the incident angle from 5° to 15° instead of 0°, which shall be documented, is used. In the case of an incident angle other than 0°, the reflectance depends on the state of polarization of the incident light, so that in the case of an angle larger than 10°, the state (p or s) shall also be selected and documented.

8.1.2 Direct measurement of regular reflectance

Figure 2 shows two methods of the direct measurement of reflectance. In Figure 2 a), the reflected flux Φ_1 without a specimen is measured, and then the reflected flux Φ_2 with the specimen is measured after changing the optical arrangement as in Figure 2 b) and c). The regular reflectance of the specimen is given as

$$\rho_r = \frac{\Phi_2}{\Phi_1} \tag{3}$$

[in the case of an arrangement as shown in Figure 2 b)]

$$\rho_r = \sqrt{\frac{\Phi_2}{\Phi_1}} \tag{4}$$

[in the case of an arrangement as shown in Figure 2 c)]

irrespective of the magnitudes of the reflectance of the reference mirror and other optics.

8.1.3 Relative measurement of regular reflectance

The relative measurement is easier than the direct measurement. An example of a reference sample for the reflectance is an aluminum mirror or a fused silica plate with a wedge angle, polished smoothly and kept clean. The successive measurements of the reflected flux of the reference sample Φ_{ref} and that of a specimen Φ_s are made using the arrangement of Figure 2 a). Then the regular reflectance of the specimen is given as

$$\rho_r = \frac{\Phi_s}{\Phi_{ref}} \times \rho_{ref} \tag{5}$$

where ρ_{ref} is the regular reflectance of the reference sample.

The value ρ_{ref} is calibrated separately by the direct method given in 8.1.2. For a low reflectance specimen such as an anti-reflection coated or uncoated glass plate, the relative measurement is recommended. In such a case, fused silica plate is used as the reference sample for the region from ultraviolet to near infrared. The reflectance of the fused silica plate shall be numerically calculated from its refractive index. The refractive index of the fused silica is given in annex B.

