INTERNATIONAL STANDARD

ISO 19962

First edition
2019-05

Optics and photonics — Spectroscopic measurement methods for integrated scattering by plane parallel optical elements

Optique et photonique — Méthodes de mesure spectroscopique pour la diffusion intégrée par des éléments optiques à plans parallèles

Reference number
ISO 19962:2019(E)

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Foreword

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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).

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ISO 19962 was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 1, *Fundamental Standards*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Light scattering by optical components reduces the efficiency of optical systems and degrades the quality of image formation. Imperfections of the coatings and optical surfaces of the components predominantly produce light scattering. These imperfections involve surface and interface roughness; contamination; scratches; and defects of substrates, thin films and interfaces. Imperfections divert a fraction of the incident radiation from the optical path. The spatial distribution of this scattered radiation is dependent on the power spectral density function of the surface and interface's roughness, on the wavelength of the incident radiation and on the individual optical properties of the component. The wavelength dependence of the scattered radiation is indispensable information for characterizing optical components.

This document proposes a simple spectroscopic method for probing minute scattered radiation using a conventional double-beam spectrophotometer (hereafter, double-beam spectrophotometer) that is widely used for evaluating optical components.

Optics and photonics — Spectroscopic measurement methods for integrated scattering by plane parallel optical elements

1 Scope

This document specifies procedures for determining the spectroscopic forward scattering characteristics of coated and uncoated optical surfaces over a specified wavelength range between 350 nm and 850 nm using a double-beam spectrophotometer with an integrating sphere. This document is also applicable to the forward scattering properties at a single wavelength.

This document is applicable to spectroscopic forward scattering measurements with collection angles larger than 2,7 degrees. ISO 13696 provides a measurement method for smaller collection angles.

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 291, *Plastics — Standard atmospheres for conditioning and testing*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions 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/

3.1.1
rear surface
surface that interacts last with the transmitted radiation

[SOURCE: ISO 13696:2002, 3.1.3]

3.1.2
forward scattered radiation
fraction of incident radiation scattered by an optical component into the forward half-space excluding that within a cone with a specified angle about the normal direction

Note 1 to entry: The forward half-space is defined by the half-space that contains the beam transmitted by the component that is limited by a plane containing the rear surface of the optical component.

3.1.3
forward scattering
ratio of the power of the forward scattered radiation to the power of the incident radiation

3.1.4
diffuse reflectance standard
diffuse reflector with known total reflectance

Note 1 to entry: Diffuse reflectance standards are usually fabricated from barium sulfate or polytetrafluoroethylene powders. The total reflectance of reflectors freshly prepared from these materials is typically greater than 0,98 within the range from 350 nm to 850 nm, and it can be considered as an 100 % reflectance standard.

[SOURCE: ISO 13696:2002, 3.1.7, modified — deleted NOTE and added Note 1 to entry.]

3.1.5
remaining scattering
ratio of the radiant power detected without a specimen to the radiant power of the incident radiation

3.1.6
minimum scattering collection angle
MCA
minimum angle from which an integrating sphere collects scattered radiation

3.1.7
angle of polarization
angle between the major axis of the instantaneous elliptical polarization state of the incident radiation and the plane of incidence

Note 1 to entry: For non-normal incidence, the plane of incidence is defined by the plane that contains the direction of propagation of the incident radiation and the normal at the point of incidence.

Note 2 to entry: The angle of polarization, γ, is identical to the azimuth, Φ, (according to ISO 12005), if the reference axis is located in the plane of incidence.

[SOURCE: ISO 13696:2002, 3.1.9, modified — changed the word of "ellipse" to "elliptical polarization state" and deleted γ as term.]

3.2 Symbols

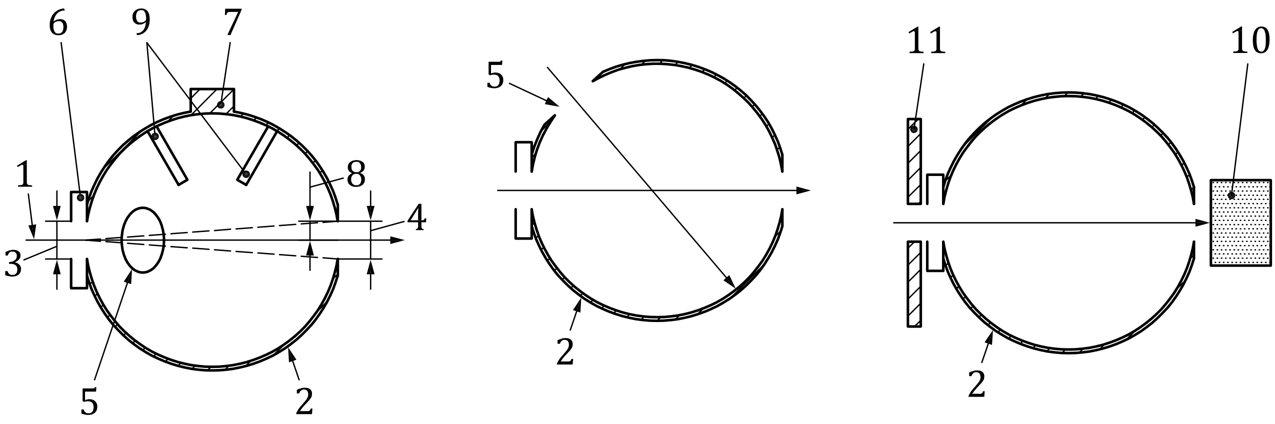
Symbols used in this document are listed in Table 1.

Table 1 — Symbols

Symbol	Term
λ	Wavelength, expressed in nanometres
λ_{start}	Measurement starting wavelength
λ_{end}	Measurement ending wavelength
$S_f(MCA, \lambda_i)$	Forward scattering at λ_i, MCA
$\overline{S_f(MCA, \lambda_{start} - \lambda_{end})}$	Mean forward scattering at MCA
$\tau_{st}(\lambda_i)$	Signal value of specimen transmittance as a measurement value of the spectrophotometer
$\tau_{rs}(\lambda_i)$	Signal value of remaining scattering as a measurement value of the spectrophotometer
$\tau_{ss}(\lambda_i)$	Signal value of scattering with specimen (including remaining scattering) as a measurement value of the spectrophotometer

4 Principle

The fundamental principle (see Figure 1) of the measurement apparatus is based on the collection and integration of the forward scattered radiation. For this purpose, an integrating sphere with a diffusely reflecting coating on the inner surface is used. Beam ports transmit the incident radiation beam into and out of the integrating sphere. The specimen is placed in front of the entrance port. The forward scattered radiation is integrated by the sphere and measured by a detector attached to an additional port. The number, the location, and the shapes of baffles shall be optimized so that any difference in measurement values shall not arise when the same amount of scattered radiation is generated at the entrance and exit ports.



a) Side view **b) Top view** **c) Installation example for reducing remaining scattering**

Key

1 incident radiation
2 integrating sphere
3 entrance port
4 exit port
5 reference port
6 specimen holder
7 detector
8 minimum scattering collection angle, expressed in degrees
9 radiation baffles
10 light trap
11 shading mask

Figure 1 — Illustration of apparatus to measure forward scattering

5 Measurements using a double-beam spectrophotometer

5.1 General

A double-beam spectrophotometer with an integrating sphere, a very common instrument in almost all organizations related to optical technologies, is used to measure spectroscopic forward scattering characteristics. In this document, a simple and handy way to implement forward scattering measurements is realized. The measurement method described has an easy implementation and is cost-effective.

Since the measured forward scattering strongly depends on the minimum scattering collection angle, the minimum scattering collection angle shall be recorded and considered when comparing the results obtained with different instruments.

The minimum scattering collection angle is determined by the setup of the double-beam spectrophotometer and the geometry of the integrating sphere, in particular the opening angle of the exit port. In this document, the collection angle is larger than 2,7 degrees.

Consult ISO 13696 for angle scattering measurements smaller than 2,7 degrees and realizing lower remaining scattering. ISO 13696 proposes a laser light source based scattering measurement setup with a minimum scattering collection angle less than 2 degrees and with remaining scattering less than 0,000 15 %.

The minimum scattering collection angle in this document changes from 2,7 degrees to 8,6 degrees depending on the diameter of the integrating sphere, which ranges from 270 mm to 60 mm (see Annex C for additional information). Although the desired remaining scattering value should be one order of magnitude less than the value of forward scattering, it can be challenging with the spectrophotometer setup presented here. In this document the remaining scattering value should preferably be less than 0,02 %. If it is more than 0,02 %, reduction efforts shall be employed such as installing a light trap, shading masks, and shading walls [see Figure 1 c)] as necessary. If a remaining scattering value less than 0,02 % cannot be obtained, it is mandatory that the value shall be recorded and documented. As described in 7.7, the formula for subtracting the remaining scattering contribution shall be used for obtaining the measured forward scattering value.

5.2 Double-beam spectrophotometer

5.2.1 General

The double-beam spectrophotometer used for the spectroscopic forward scattering measurements has four functional sections: the radiation source, the optical system, the integrating sphere, and the detector. These functional sections are described in detail below.

The spectrophotometer shall be able to measure the wavelength range from 350 nm to 850 nm. The wavelength resolution (slit width) shall be 5 nm and stray light shall be 0,000 10 % or less. A user can also specify a wavelength resolution less than 5 nm as long as the dynamic range described in Annex B is preserved.

Using a tungsten-halogen lamp as a light source and a photomultiplier as a detector, the performance certification requirement described in Annex B is satisfied over the wavelength range from 350 nm to 850 nm. This document can also be applied to a wider wavelength range if it is confirmed to meet the performance certification requirement.

5.2.2 Radiation source

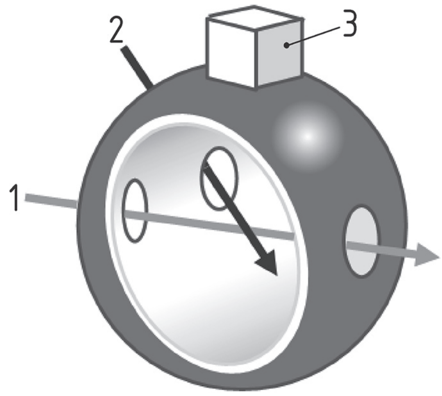
A radiation source with a minimal spectral range of 350 nm to 850 nm shall be used, such as a tungsten halogen lamp.

5.2.3 Optical system

The optical system of the spectrophotometer delivers light emitted by the radiation source to the integrating sphere. The optical system shall have a double-beam configuration with a reference beam and a sample beam. By performing a reference beam intensity measurement and giving its feedback to the sample beam intensity measurement at the same time, the source radiation intensity drift can instantaneously be cancelled.

The optical system shall have a monochromator including a diffraction grating as a dispersive element to obtain monochromatic light with a certain wavelength resolution for irradiating a specimen. For blocking the higher order light diffracted from the grating, an auxiliary prism or an absorption filter may be used. For measurements requiring high spectral resolution and/or low stray light, a double monochromator configuration is recommended.

Although the incident beam to the specimen in the spectrophotometer is polarized in general, polarization does not affect the forward scattering for optically isotropic specimens because the specimen should be irradiated at 0 degree incidence. If the specimen is not optically isotropic, the effect of polarization may be taken into account.



Key

1 incident light

2 reference light

3 detector

Figure 2 — Integrating sphere in the double-beam spectrophotometer

5.2.4 Integrating sphere

An integrating sphere is used for collection and integration of the forward scattered radiation by the specimen. The incident radiation shall be introduced into the integrating sphere at an incident angle of 0 degrees. The integrating sphere shall be equipped with an entrance port and an exit port for the incident radiation beam and another entrance port for the reference beam (see Figure 2). The inner surface shall be coated with a highly diffusive reflecting material with a Lambertian characteristic.

The value of the exit port area divided by the inner surface area of the integrating sphere shall be 0,03 or less and the minimum scattering collection angle [see Figure 1 a)] shall be 2,7 degrees to 8,6 degrees. Radiation baffles may be installed in the integrating sphere to shield the sensitive area of the detector against the direct radiation scattered by the specimen.

"The inner surface area of the integrating sphere" equals the entire surface area of a sphere whose diameter is identical to that of the integrating sphere. The typical inner diameter of the integrating sphere for a conventional spectrophotometer is 60 mm or larger.

5.2.5 Detection system

The detection system shall have sufficient sensitivity, linearity, and dynamic range for the radiation source. Normally, a photomultiplier is attached to the detection port of the integrating sphere with its sensitive area forming a part of the inner surface.

5.3 Test environment

The temperature range and relative humidity of the test environment are defined below.

Temperature: 20 °C to 35 °C

Relative Humidity: 60 % or less