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**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*

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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](http://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](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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 [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

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](http://www.iso.org/members.html).

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## 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.

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# 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,  $\gamma$ , is identical to the azimuth,  $\Phi$  (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  $\gamma$  as term.]

3.2 Symbols

ISO 19962:2019

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Symbols used in this document are listed in [Table 1](#).

**Table 1 — Symbols**

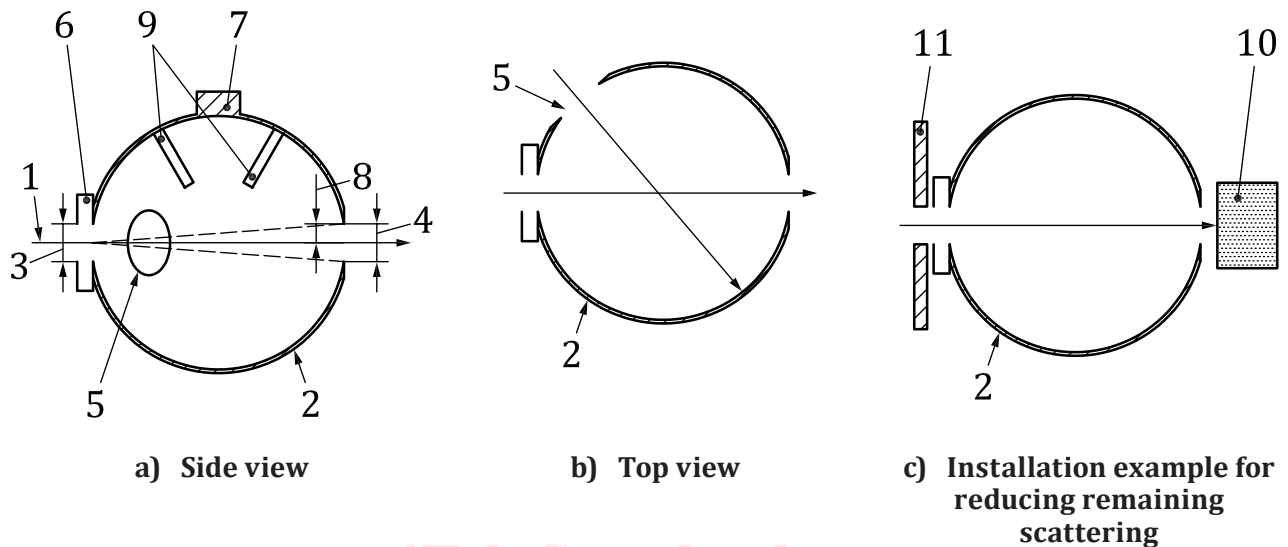
Symbol	Term
$\lambda$	Wavelength, expressed in nanometres
$\lambda_{\text{start}}$	Measurement starting wavelength
$\lambda_{\text{end}}$	Measurement ending wavelength
$S_f(\text{MCA}, \lambda_i)$	Forward scattering at $\lambda_i$ , MCA
$\overline{S_f(\text{MCA}, \lambda_{\text{start}} - \lambda_{\text{end}})}$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



#### Key

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

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.