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**Optics and photonics — Test methods  
for telescopic systems —**

**Part 5:  
Test methods for transmittance**

*Optique et photonique — Méthodes d'essai pour systèmes  
télescopiques —*

*Partie 5: Méthodes d'essai du facteur de transmission*

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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).

This document was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 4, *Telescopic systems*.

This third edition cancels and replaces the second edition (ISO 14490-5:2017), which has been technically revised.

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

- updates in [Clause 5](#), in particular [5.7](#). "Veiling glare stop" was deleted, clarification of requirements on "Integration sphere", addition of [5.9](#);
- updates in [Clause 9](#), in particular [9.1](#) and [9.2](#). The function  $V(\lambda)$  for the 2° observer was replaced by the function  $V_{10}(\lambda)$  for the 10° observer to be consistent with [9.2](#), where the function  $V'(\lambda)$  for the 10° observer [now called  $V'_{10}(\lambda)$ ] was already used;
- clarification of requirements in [Clause 10](#);
- addition of [B.4](#);

A list of all parts in the ISO 14490 series can be found on the ISO website.

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).

# Optics and photonics — Test methods for telescopic systems —

## Part 5: Test methods for transmittance

### 1 Scope

This document specifies the test methods for the determination of the transmittance of telescopic systems and telescopic observational instruments.

### 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/CIE 11664-1:2019, *Colorimetry — Part 1: CIE standard colorimetric observers*

ISO 11664-2, *Colorimetry — Part 2: CIE standard illuminants*

ISO 14132-1, *Optics and photonics — Vocabulary for telescopic systems — Part 1: General terms and alphabetical indexes of terms in ISO 14132*

ISO 14490-1:2005, *Optics and optical instruments — Test methods for telescopic systems — Part 1: Test methods for basic characteristics*

CIE 18.2:1983, *Basis of Physical Photometry*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14132-1 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/>

### 4 Principle

To determine the spectral transmittance,  $\tau(\lambda)$ , the flux of radiation in a limited bundle of rays will be measured before entering  $\Phi_0(\lambda)$  and after passing  $\Phi_p(\lambda)$  through the optical system.

The spectral transmittance is given by [Formula \(1\)](#):

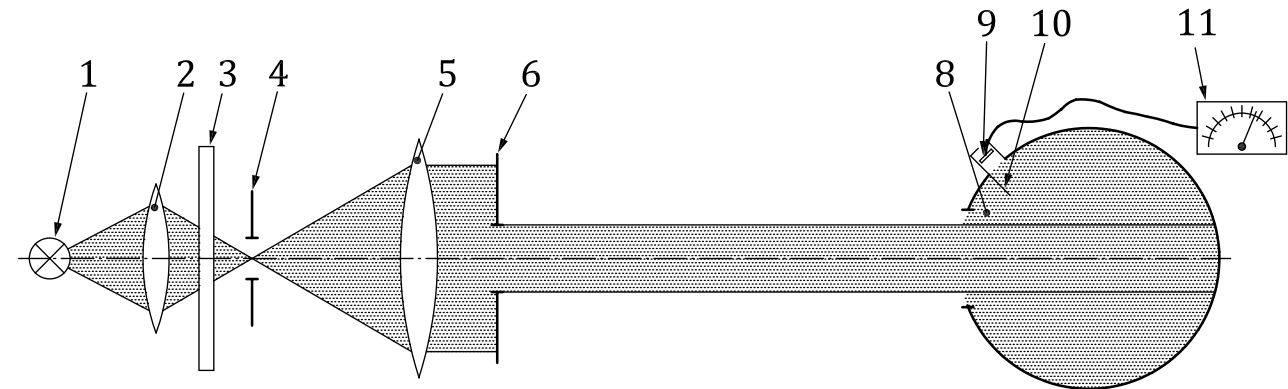
$$\tau(\lambda) = \frac{\Phi_p(\lambda)}{\Phi_0(\lambda)} \quad (1)$$

During the spectral measurement, the emergent light of the radiation source will be limited to a narrow wavelength band by means of a monochromator or a set of filters.

5 Test arrangement

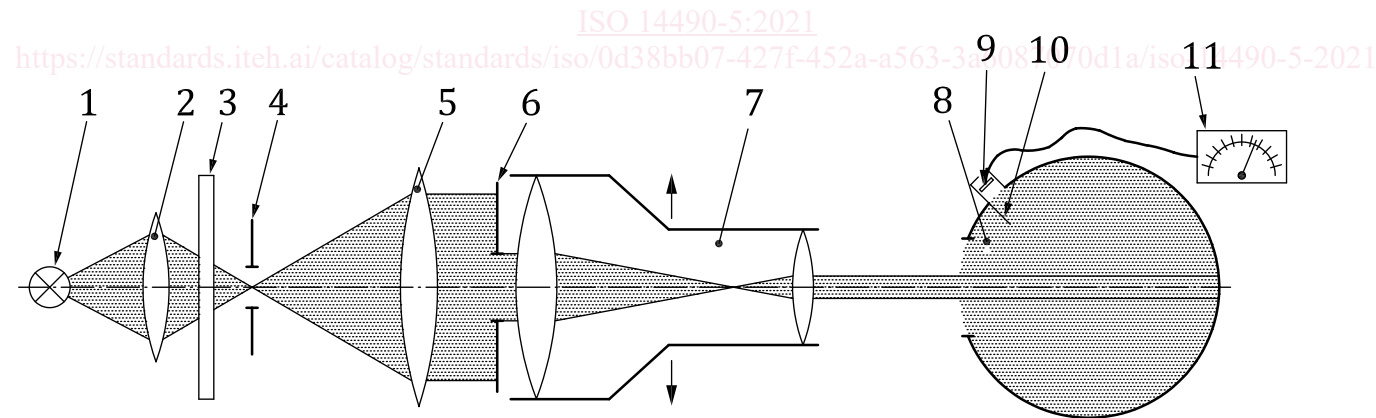
5.1 General

The test arrangement as given in [Figure 1](#) and [Figure 2](#) consists of a radiation source (optionally with a condenser, a monochromator or a set of filters, a selectable diaphragm as field stop, a collimator lens, an aperture stop, a test specimen mounting, an integrating sphere, a radiation detector and a signal processing unit comprising a radiation detector and a measurement and evaluation unit).



- Key**
- |   |                                    |    |                                 |
|---|------------------------------------|----|---------------------------------|
| 1 | radiation source                   | 6  | aperture stop                   |
| 2 | condenser                          | 8  | integrating sphere              |
| 3 | monochromator/set of filters       | 9  | radiation detector              |
| 4 | selectable diaphragm as field stop | 10 | baffle                          |
| 5 | collimator lens                    | 11 | measurement and evaluation unit |

Figure 1 — Test arrangement without test specimen (schematic)



- Key**
- |   |                                    |    |                                 |
|---|------------------------------------|----|---------------------------------|
| 1 | radiation source                   | 7  | test specimen                   |
| 2 | condenser                          | 8  | integrating sphere              |
| 3 | monochromator/set of filters       | 9  | radiation detector              |
| 4 | selectable diaphragm as field stop | 10 | baffle                          |
| 5 | collimator lens                    | 11 | measurement and evaluation unit |
| 6 | aperture stop                      |    |                                 |

Figure 2 — Test arrangement with test specimen (schematic)

## 5.2 Radiation source and condenser

The radiation source shall emit a continuous flux of radiation in the specified wavelength range. The variation of flux during the measurement of a pair of values shall be less than 1 %. The condenser adapts the radiation source to the optical measurement path. It should be, for example, an achromatic doublet or an off-axis paraboloidal mirror to avoid introducing too much lateral chromatism into the optical ray path.

## 5.3 Monochromator or set of filters

The monochromator or the set of filters can be omitted if the signal processing unit comprises a spectral detector.

Grating or prism monochromators can be used to select the wavelength. The smallest adjustable wavelength interval shall be less than 2 % of the dominant wavelength (usually 0,55  $\mu\text{m}$ ) of the respective measurement.

The necessary spectral bandwidth depends on the sample. It should be ensured that a steep change in the transmission curve is detected correctly. Thus, the bandwidth should be selected such that the transmittance across the band changes by less than 4 %. This condition cannot always be satisfied because of technical measurement and energetical reasons or because the time/cost effort is not adequate. In these cases, a maximum bandwidth of 4 % of the wavelength is allowable. A bandwidth of less than 2 % of the wavelength is necessary if the colour contribution indices are to be calculated.

Instead of a monochromator, a set of narrow-band filters (full width half maximum <20 nm) may be used. They are especially useful with flat-shaped transmission curves. The number of measuring points shall allow for a definite curve fitting. A measurement with spectral filters instead of a monochromator is also appropriate if only single measurements are required.

## 5.4 Collimator

The collimator may contain a refracting lens or a mirror. The collimator shall be adjusted to the aligned components in such a way that full and uniform illumination of the following aperture stop is assured. The focal length of the collimator shall be long enough that in relation to the field stop of the collimator the spot diameter is small enough to pass the image plane of the test specimen and is not obscured by target marks and internal structures. One-third of the image plane diameter should not be exceeded.

The ray bundle shall be collimated as well as possible within the measurement distance by adjusting the collimator position. The axial chromatic aberration of a refracting lens shall be less than or equal to 1 % of its focal length in the spectral range used. An off-axis parabolic mirror or an equivalent system is also suitable as a collimator.

## 5.5 Aperture stop

The aperture stop should be circular and located close to the objective lens of the test specimen if possible. The diameter should be  $\leq 50$  % of the entrance pupil of the test specimen, as well as smaller than the opening of the integrating sphere. Auxiliary systems can be used for beam forming to realize these requirements. These systems shall stay in the ray path during the measurement with and without test specimen.

Generally, the smallest possible aperture stop should be used which is compatible with the signal-to-noise requirements of the detector.

Special care should be taken when measuring telescopic systems with variable magnification where at some magnification settings the entrance pupil can be considerably smaller than the free objective lens diameter.

## 5.6 Specimen mounting

The mounting of the test specimen shall be designed in a way that the test specimen can be positioned and aligned and held stable.

The test specimen should be oriented such that no obstructions occur in the measurement beam (e.g. by reticle structures).

## 5.7 Integrating sphere

The distance between the aperture stop and the integration sphere shall be arranged according to the requirements of the test specimen. The distance shall not be changed during the measurement with and without test specimen such that the light is always completely collected by the integrating sphere. To avoid the impact of multiple reflections, a large distance, e.g. 100 mm, between the eyepiece and the integrating sphere is recommended. The position of the integrating sphere should be chosen so that the diameter of the ray bundle entering the integrating sphere is almost the same as without the specimen.

The integrating sphere has two openings, one for the input of the bundle of rays to be measured and one for the detector. The openings shall not be located opposite each other. Direct radiation incident on the detector is prevented by baffles. The surfaces of the two openings together shall not occupy more than 5 % of the internal surface of the sphere. The diameter of the integrating sphere opening shall exceed the maximum diameter of the aperture stop (item 6 in [Figure 1](#) and [Figure 2](#)) by at least 5 % to 7 %.

The reflectance of the internal coating of the integrating sphere shall be as high as possible and diffuse across the whole spectral range. The reflectance across the whole spectral range from 380 nm to 780 nm shall be at least 85 %.

## 5.8 Radiation detector

The linearity of the signal processing unit (radiation detector together with measurement and evaluation unit) shall be better than 0,5 %.

## 5.9 Selectable diaphragm as field stop

The diameter should be selected such that the angular extension on the eyepiece side of the test specimen does not exceed 5 degrees to avoid pupil and reticle vignetting.

# 6 Procedure

## 6.1 Preparation of the test arrangement

Insert the test specimen in its mounting with the objective lens facing the radiation source (see [Figure 1](#)). The entrance and the exit surface of the front lenses of the test specimen shall be clean and without dust.

Take care to avoid multiple reflections between the aperture stop, the test specimen and other parts, which may upset the measurement result, by the use of additional protective screens.

For systems with a reticle at an intermediate image plane, take care that parts of the test specimen's reticle do not obscure any light passing through it. Ensure that the ambient light does not influence the measurement result.

## 6.2 Determination of the measurement values

Carry out the measurements in the spectral range from 380 nm to 780 nm, if colour contribution indices are not to be calculated.

First, determine a measuring value,  $S_0(\lambda)$ , which is proportional to the flux of radiation,  $\Phi_0(\lambda)$ , through the aperture stop using the test arrangement without the test specimen. Then, insert the test specimen into the ray path and determine the measuring value,  $S_p(\lambda)$ , which is proportional to the flux of radiation,  $\Phi_p(\lambda)$ . The ratio of both values with and without the test specimen is the spectral transmittance given by [Formula \(2\)](#):

$$\tau(\lambda) = \frac{\Phi_p(\lambda)}{\Phi_0(\lambda)} = \frac{S_p(\lambda)}{S_0(\lambda)} \quad (2)$$

Carry out this procedure at the required wavelengths to determine the spectral slope. The wavelengths shall be chosen in a way that the shape of the transmission curve can be clearly recognized to correctly reproduce critical ranges of the curve.

### 6.3 Further test methods

Integral testing methods that can be much less expensive are sufficient for many purposes such as comparison measuring or verification of the required transmission values for a standard illuminant. The transmittance can be measured directly by integral testing methods, utilizing the test assembly (see [Figure 1](#)), and additional suitable compensating filters. For example, a measurement could use a conversion filter that modifies the spectral sensitivity of the integrating sphere and the detector to be the same as that of the eye. A calibrated specimen shall be used to verify the accuracy of this simplified test method. If necessary, the measured values of an integral measurement are to be confirmed by a spectral measurement and calculated according to this document. If a test arrangement without an integrating sphere is used, the radiation detector shall be checked to ensure that the readout does not depend on the illuminated area of the radiation detector using an appropriate procedure, for example, described in [Annex A](#).

## 7 Precision of the measurement

The error in repeatability of the transmittance values shall not exceed 2 %. The test arrangement shall be designed and the parts chosen such that this requirement is fulfilled.

## 8 Presentation of the results

The measuring results shall be presented in tabular and graphical form, as follows:

- a) for presentation in tabular form, the results shall be indicated with three decimal digits;
- b) for graphical presentation, the values shall be plotted linearly over the wavelength.

## 9 Analysis

### 9.1 Effective transmittance for photopic vision

The effective transmittance for photopic vision,  $\tau_D$ , valid for the total visible wavelength range is determined by the radiation function,  $S_{D65}(\lambda)$ , the spectral transmittance of the telescopic system and the spectral luminous efficiency function,  $V_{10}(\lambda)$ , for photopic vision. As a radiation function, the

standard illuminant D65 as specified in ISO 11664-2, shall be used. The effective transmittance for photopic vision is given by [Formula \(3\)](#):

$$\tau_D = \frac{\int_{380\text{nm}}^{780\text{nm}} S_{D65}(\lambda) \times \tau(\lambda) \times V_{10}(\lambda) \times d\lambda}{\int_{380\text{nm}}^{780\text{nm}} S_{D65}(\lambda) \times V_{10}(\lambda) \times d\lambda} \quad (3)$$

where

- $\tau(\lambda)$  is the spectral transmittance of the telescopic system;
- $S_{D65}(\lambda)$  is the radiation function (relative spectral power distribution) of the standard illuminant D65 as specified in ISO 11664-2;
- $V_{10}(\lambda)$  is the spectral luminous efficiency function for photopic vision (10° standard observer) as specified in ISO/CIE 11664-1:2019, Table 2,  $\bar{y}_{10}(\lambda)$ .

Wavelength intervals of 5 nm will be adequate for most measurement purposes.

NOTE  $V(\lambda)$  and  $V'(\lambda)$  values are based on anthropological measurements which can be not representative for all ethnic groups.

## 9.2 Effective transmittance for scotopic vision

[Formula \(4\)](#) for the calculation of the effective transmittance for scotopic vision,  $\tau_N$ , results if the spectral luminous efficiency function,  $V'_{10}(\lambda)$ , for scotopic vision is inserted:

$$\tau_N = \frac{\int_{380\text{nm}}^{780\text{nm}} S_{D65}(\lambda) \times \tau(\lambda) \times V'_{10}(\lambda) \times d\lambda}{\int_{380\text{nm}}^{780\text{nm}} S_{D65}(\lambda) \times V'_{10}(\lambda) \times d\lambda} \quad (4)$$

where

- $\tau(\lambda)$  is the spectral transmittance of the telescope;
- $S_{D65}(\lambda)$  is the radiation function (relative spectral power distribution) of the standard illuminant D65 as specified in ISO 11664-2;
- $V'_{10}(\lambda)$  is the spectral luminous efficiency function for scotopic vision (10° standard observer) as specified in CIE 18.2:1983, Table 3.

Wavelength intervals of 5 nm will be adequate for most measurement purposes.

## 10 Test report

A test report shall be presented and shall include the general information specified in ISO 14490-1:2005, Clause 13, and the result of the test as specified in [Clause 8](#) a) and b) and in [9.1](#) and [9.2](#).

The test report shall also include essential features of the test arrangement:

- type and main features of the light source;
- diameter of the field stop inside the collimator;
- focal length of the collimator;
- diameter of the aperture stop;
- distance between collimator and test specimen;