International Standard

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First edition

Optics and photonics — Test method for temperature coefficient of refractive index of optical glasses —

Part 2: Interferometric method

Optique et photonique — Méthode d'essai pour déterminer le coefficient de température de l'indice de réfraction des verres optiques —

Partie 2: méthode interférométrique

PROOF/ÉPREUVE

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This document was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 3, *Optical materials and components*.

A list of all parts in the ISO 6760 series can be found on the ISO website.

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Introduction

Optical glass is widely used in optical devices such as cameras, telescopes, and microscopes, and its refractive index is measured by the minimum deviation method (ISO 21395-1[4]) and the V-block refractometer method (ISO 21395-2[5]). Here, when designing an optical apparatus that requires high resolution, it is necessary to consider the temperature change of the refractive index of the optical glass in the usage environment. This document proposes a method for measuring the temperature coefficient of refractive index of optical glass with high accuracy.

Optics and photonics — Test method for temperature coefficient of refractive index of optical glasses —

Part 2: Interferometric method

1 Scope

This document specifies a test method for the temperature coefficient of refractive index of optical glass using interferometry. Temperature changes in optical glass lead to changes in the optical path length. The change in optical path length can be measured with an interferometer using the number of cycles of light/dark change of the interference stripe. This document defines a test method to measure the amount of change in the refractive index when the temperature of the specimen is changed continuously.

The intended temperature range for the specified measurement method is an arbitrary range.

The intended wavelength range for the specified measurement method is 365 nm to 1 014 nm.

The intended accuracy for the specified measurement method is within 1×10^{-6} K^{-1}.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
temperature coefficient of refractive index
ratio of refractive index change to temperature change at a selected wavelength

[SOURCE: ISO 9802:2022[3], 3.4.2.3, 3.4.2.4, modified — term and definition slightly reworded.]

3.2
temperature coefficient of absolute refractive index
$\Delta n_{abs}/\Delta T$
ratio of refractive index change in vacuum to temperature change at a selected wavelength

[SOURCE: ISO 9802:2022[3], 3.4.2.3, modified — term reworded.]

3.3
temperature coefficient of relative refractive index
$\Delta n_{rel}/\Delta T$
ratio of refractive index change at an air pressure of 1,013 25 × 10^5 Pa and a relative humidity of 0 % to temperature change at a selected wavelength

[SOURCE: ISO 9802:2022[3], 3.4.2.4, modified — term reworded and "0,101 33 × 10^6 Pa" and "0 % humidity" added.]

Note 1 to entry: This definition of $\Delta n_{rel}/\Delta T$ is for a specific pressure and humidity. $\Delta n_{rel}/\Delta T$ can be calculated for any other pressure and humidity by understanding the index of air in those conditions.

3.4
thermal chamber
chamber where the temperature of the specimen can be changed and/or maintained to a preset temperature

4 Principle

The temperature coefficient of refractive index is calculated in either Formula (1) or Formula (2) obtained by Annex C. The derivation of these formulae is described in Annex C. For a calculation method for obtaining the relative refractive index of glass at an arbitrary temperature and relative humidity, see Annex B.

$$\frac{\Delta n_{abs}}{\Delta T} = \frac{1}{2} \times \frac{f \times \lambda}{L \times \Delta T} - \alpha_l \times n_{abs} \quad (1)$$

$$\frac{\Delta n_{abs}}{\Delta T} = \frac{1}{2} \times \frac{f \times \lambda}{L \times \Delta T} - \alpha_l \times n_{rel} \quad (2)$$

where

$\frac{\Delta n_{abs}}{\Delta T}$ is the temperature coefficient of absolute refractive index of specimen (K^{-1});

$\frac{1}{2}$ is interferometer scale factor of double-path interferometers;

λ is the wavelength of the refractive index temperature coefficient measurement (m);

L is the measurement specimen length (m);

f is the number of cycles of light/dark change of interference fringes associated with changes in optical path length of the specimen corresponding to ΔT;

ΔT is the specimen temperature difference (K);

n_{abs} is the absolute refractive index of the specimen;

n_{rel} is the relative refractive index of the specimen;

α_l is the linear expansion coefficient of the specimen (K^{-1}).

5 Measuring apparatus

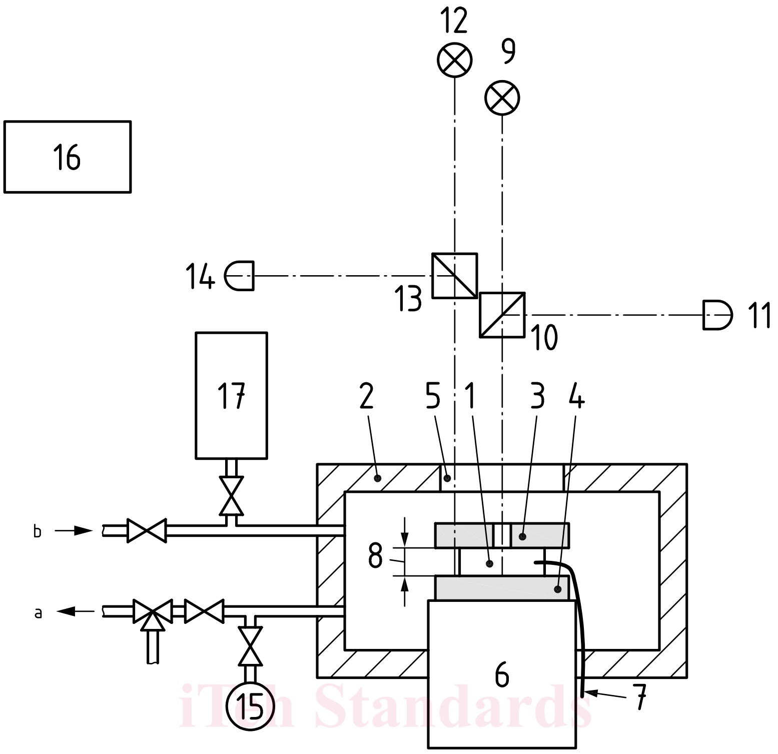
5.1 General

The measuring equipment shall be in accordance with the requirements in 5.2 to 5.9.

a) For measuring equipment, use the Fizeau-interference measurement principle in which the measured sample itself constitutes the interference space.

b) The resolution to read the number of cycles of light and dark changes in the interference space. The resolution shall be 1/10 cycle or less.

Figure 1 shows an example of a schematic diagram of the measuring equipment.



Key

1 specimen
2 thermal chamber shell
3 transmission flat
4 reference flat
5 window
6 heating/cooling unit
7 temperature sensor
8 mechanical length of the specimen
9 light source for optical path length change of the specimen measurement
10 beam splitter for optical path length change measurement
11 detector for optical path length change of the specimen measurement
12 light source for expansion measurement
13 beam splitter for expansion measurement
14 detector for expansion measurement
15 vacuum gauge
16 barometer
17 cushioning chamber (e.g. flexible plastic bag)
a Connection to vacuum pump.
b Dry air inlet.

Figure 1 — Example of a schematic drawing of a Fizeau-interferometric type of measurement equipment

5.2 Light sources

For change in optical path length of specimen light source and linear expansion coefficient light source, use a light source with sufficient intensity, monochromaticity and coherence to obtain interference fringes with the required precision. The wavelength for the measurement of the change in optical path length of specimen and linear expansion coefficient do not need to be the same.

NOTE 1 A sufficient light source, such as a laser, has to provide adequate illumination to enable accuracy, precision, and repeatability for the test.

NOTE 2 Examples of light sources are listed in ISO 7944:—[2], Table 1, Table 2 and Table 3.

5.3 Thermal chamber

The thermal chamber has a window for observing changes in the optical path length. Thermal chamber shall

a) have the ability to change the temperature of the specimen between the temperatures to be measured,

b) have the ability to maintain the temperature of the specimen within ±0,5 K,

c) have a thermometer to measure the temperature of the specimen with an accuracy of ±0,2 K or better,

d) have the ability to be filled with dry air at a relative humidity of 0 % or provide a vacuum with a residual pressure of less than 10 Pa to prevent condensation. When the inside of the thermal chamber is filled with dry air, the structure shall be such that the air pressure in the thermal chamber is the same as the atmospheric pressure around the container, and

e) have a window of the thermal chamber, which shall be made of quartz glass with a wedge angle of approximately 6 arc min (0,1°) on the opposite plane and polished on both sides.

NOTE Quartz glass is used because it has a wide wavelength range with a high transmittance, has a high durability against temperature changes, and is resistant to breakage.

5.4 Flat plates

Two flat plates, one is a transmission flat plate and the other is a reference flat plate, are used to measure the linear expansion coefficient of the specimen along with the change of the optical path length by using interference action. In the thermal chamber, the specimen is sandwiched between two plate's interference surfaces. Each interference surface shall be parallel with each interference surface of the specimen. Examples include point contact, line contact, surface contact, etc. An example of point contact is shown in Figure 2. The contact points of the specimen and the flat plate are on the same plane. The flat plate geometry is described in Annex F.

The required accuracies of the two flat plates are as follows:

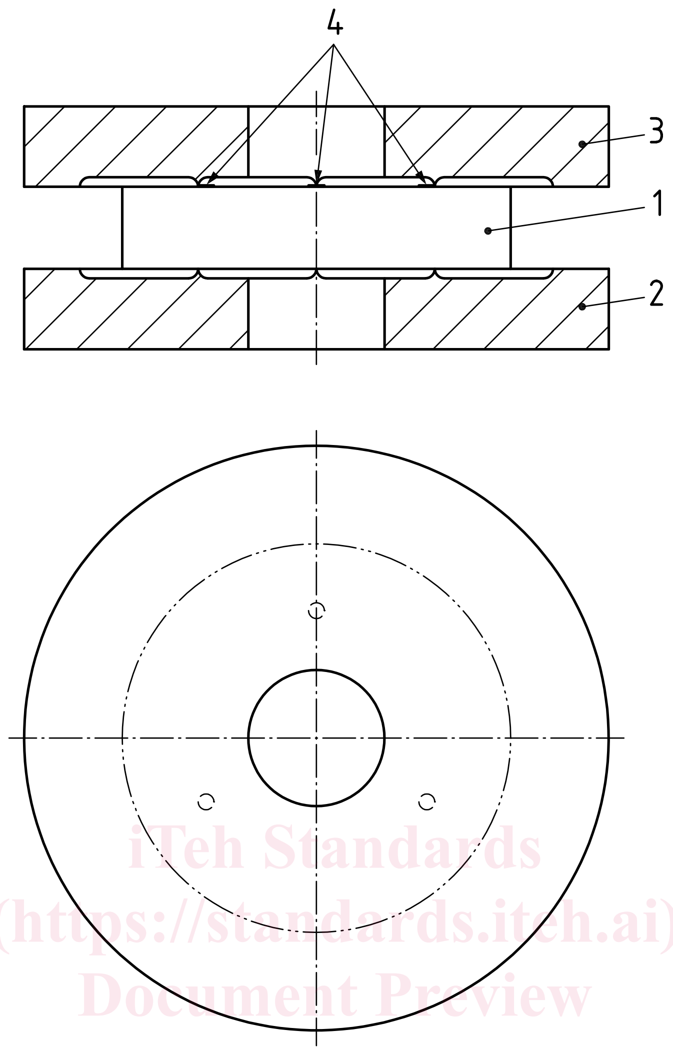
a) The transmission flat plate and reference flat plate shall be made of quartz glass or extremely low-expansion glass ceramics, where both sides of which have been polished with a wedge angle of approximately 6 arc min (0,1°).

b) The flatness of the surface used for the interference action shall be $\lambda/2$ or less (1/2 of the measurement wavelength of the linear expansion coefficient).

c) There shall be a hole in the centre of the transmission flat plate to secure the optical path for measurement of change in the optical path length of the specimen.

d) The back surface not involved in interference of the reference flat plate may be ground glass surface without polishing. In this case, the wedge angle of the reference flat plate is not required.

e) A suitable method should be used to ensure that reflections from the rear surface of the reference flat plate do not cause confusion with desired interference pattern. For example, there are sanding and donut-shaped processing by making a hole in the relevant position.



Key

1 specimen

2 transmission flat plate

3 reference flat plate

4 contact point

Figure 2 — Example of point contact between the specimen and 2 flat plates

5.5 Interferometer for optical path length change measurement

The interferometer used shall be able to measure the optical path length change of the specimen while changing the temperature of the specimen.

5.6 Interferometer for expansion measurement

The interferometer used shall be able to measure the length change of the specimen while changing the temperature of the specimen.

5.7 Detectors

The detector used shall be able to detect bright to dark changes due to interference of reflected light from the specimen, and bright to dark changes due to interference of reflected light from 2 flat plates.