JSO-/TC-172/SC-3/WG Secretariat:-JISC

Date: 2024-02-16xx

# Optics and photonics-\_— Test method for temperature coefficient of refractive index of-\_optical glasses-—\_\_\_\_

## iTeh Standards

Part\_2: Interferometric method

Optique et photonique-<u> — Méthode d'essai pour déterminer le coefficient de température de l'indice de</u> réfraction des verres optiques<del> — Partie 2: méthode interférométrique —</del>

Partie 2: méthode interférométrique

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#### Foreword

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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-<u>1</u><sup>[3]</sup>) and the V-block refractometer method (ISO\_21395-<u>2</u><sup>[4]</sup>). 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.

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International Standard	<del>ISO 6760-2:2024(en)</del>		
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Optics and photonics— <u>—</u> Test method for of-refractive index of optical glasses— <u>—</u> Part—	temperature coefficien _22	Formatted: Right: 1.5 cm, Header distance from edge from edge: 0.5 cm Formatted: Main Title 2, A and Asian text, Adjust spac	
Interferometric method		numbers	
1 Scope			
This document specifies a test method for the temperature coefficient of interferometry. Temperature changes in optical glass lead to changes i optical path length can be measured with an interferometer using the of the interference stripe. This document defines a test method to a refractive index when the temperature of the specimen is changed con	n the optical path length. The change in number of cycles of light/dark chang measure the amount of change in th		
The intended temperature range for the specified measurement metho	od is an arbitrary range.		
The intended wavelength range for the specified measurement method	l is 365 nm to 1 014 nm.		
The intended accuracy for the specified measurement method is withi	$1 + \times 10^{-6} \text{ K}^{-1}$ .		
2 Normative references (https://sts	andards.iteh.		
The following documents are referred to in the text in such a way that requirements of this document. For dated references, only the edition the latest edition of the referenced document (including any amendment)	some or all of their content constitute cited applies. For undated references	5	
There are no normative references in this document.	)/PRF 6760-2		
3 Terms and definitions ch.ai/catalog/standards/iso/	36da9bd1-85c0-493e-bd7f	Formatted: Adjust space b Adjust space between Asia	petween Latin and Asian text,
For the purposes of this document, the following terms and definitions	apply	Adjust space between Asia	
ISO and IEC maintain terminology databases for use in standardization	at the following addresses:		
<ul> <li>— ISO-Online browsing platform: available at <a href="https://www.iso.org">https://www.iso.org</a></li> </ul>	<del>rg/obp</del> https://www.iso.org/obp	Commented [eXtyles3]: T https://www.iso.org/obp has	
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<b>3.1</b> <b>temperature coefficient of refractive index</b> ratio of refractive index change to temperature change at a selected wa	avelength	Adjust space between Asia stops: Not at 0.7 cm + 1.4	
Note 1 to entry: Similar to ISO 9802 <sup>[2]</sup> .		Formatted: Adjust space b Adjust space between Asia	petween Latin and Asian text, In text and numbers
[SOURCE: ISO 9802:2022 <sup>[3]</sup> , 3.4.2.3, 3.4.2.4, modified — term and defir	ition slightly reworded.]		
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3.2 temperature coefficient of absolute refractive index		prmatted: Adjust space between Latin and Asian text, Jjust space between Asian text and numbers
An <sub>abs</sub> /AT ratio of refractive index change in vacuum to temperature change at a selected wavelength	Fo	ormatted: Regular, Font: Bold
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[SOURCE: <u>ISO 9802</u> <sup>[2]</sup> +: <u>2022;<sup>[3]</sup>, 3.4.2.3</u> , modified <u>— term reworded</u> .]	11	ormatted: Regular Sub, Font: Bold, Not Superscript/ lbscript
3.3 temperature coefficient of relative refractive index	Fo	ormatted: Regular, Font: Bold
$\Delta n_{re} \sqrt{\Delta T}$	Fo	ormatted: Regular Italic, Font: Bold, Not Italic
ratio of refractive index change at an air pressure of $1,013 25 \times 10^5$ Pa and a relative humidity of 0 % to temperature change at a selected wavelength	cit	<b>commented [eXtyles4]:</b> No section matches the in-text ation "3.4.2.3". Please supply the missing section or delete e citation.
[SOURCE: JSO_9802 <sup>[2]</sup> ;2022; <sup>[3]</sup> , 3.4.2.4, modified:— <u>term reworded and "</u> 0,101 33 × 10 <sup>6</sup> Pa" and "0 %	Fo	ormatted: Default Paragraph Font
humidity"_added-]_]	Fo	ormatted: Default Paragraph Font
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 $\Delta T$	Fo	ormatted: Regular, Font: Bold
other pressure and humidity by understanding the index of air in those conditions.	Fo	ormatted: Regular Italic, Font: Bold, Not Italic
3.4 thermal chamber	1 11	prmatted: Regular Sub, Font: Bold, Not Superscript/
chamber where the temperature of the specimen can be changed and/or maintained to a preset temperature	Fo	ormatted: Regular, Font: Bold
4 Principle 11eh Standards	Fo	ormatted: Regular Italic, Font: Bold, Not Italic
The temperature coefficient of refractive index is calculated in either Formula (1) Formula (1) or Formula (2) Formula (2) obtained by Annex C. Annex C. The derivation of these formulae is described in	cit	<b>commented [eXtyles5]:</b> No section matches the in-text ation "3.4.2.4". Please supply the missing section or delete e citation.
Annex G.Annex C. For a calculation method for obtaining the relative refractive index of glass at an arbitrary	Fo	ormatted: Default Paragraph Font
temperature and relative humidity, see Annex B. Annex B.	Fo	ormatted: Default Paragraph Font
$\frac{\Delta n_{\text{abs}}}{\Delta T} - \frac{1}{2} \times \frac{f \times \lambda}{L \times \Delta T} - \alpha_{\text{I}} \times n_{\text{abs}} - (1)$ ISO/PRF 6760-2	Ac sto	<b>prmatted:</b> Adjust space between Latin and Asian text, djust space between Asian text and numbers, Tab ops: Not at 0.7 cm + 1.4 cm + 2.1 cm + 2.8 cm + 5 cm + 4.2 cm + 4.9 cm + 5.6 cm + 6.3 cm + 7 cm
$\frac{\Delta n_{abs}}{\Delta T} = \frac{1}{2} \frac{f \times \lambda}{L \times \Delta T} = \frac{1}{\alpha_1} \times \frac{n_{rel}}{(2)}$ /catalog/standards/iso/36da9bd1-85c0-493e-bd7f-c8		ormatted: Adjust space between Latin and Asian text, djust space between Asian text and numbers
$\frac{\Delta n_{\rm abs}}{\Delta T} = \frac{1}{2} \times \frac{f \times \lambda}{L \times \Delta T} - \alpha_{\rm l} \times n_{\rm abs} \tag{1}$		
$\frac{\Delta n_{\rm abs}}{\Delta T} = \frac{1}{2} \times \frac{f \times \lambda}{L \times \Delta T} - \alpha_{\rm l} \times n_{\rm rel} \tag{2}$	be	ormatted: where_keep-with-next, Adjust space etween Latin and Asian text, Adjust space between sian text and numbers
where *	Fo	ormatted Table
$\frac{\Delta n_{\text{abs}}}{\Delta T}$ is the temperature coefficient of absolute refractive index of specimen (K <sup>-1</sup> );	an nu	ormatted: Table body (+), Adjust space between Latin Id Asian text, Adjust space between Asian text and Imbers
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$\frac{1}{2^2}$ is interferometer scale factor of double-path interferometers;	an	ormatted: Table body (+), Adjust space between Latin ad Asian text, Adjust space between Asian text and umbers
$\lambda_{\perp}$ is the wavelength of the refractive index temperature coefficient measurement (m);		prmatted: Font: Not Italic
L is the measurement specimen length (m);	Fo	ormatted
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	<i>f</i>	is the number of cycles of light/dark change of interference fringes associated with changes in optical path length of the specimen corresponding to $\Delta T_i$			Formatted	
	$\Delta T$	is the specimen temperature difference (K);		$\backslash$	Formatted	
		is the absolute refractive index of the specimen;			Formatted	
	n <sub>abs</sub>	is the relative refractive index of the specimen;		$\mathbf{x}$	Formatted	
	n <sub>rel</sub>	-			Formatted	
	$\alpha_{l}$	is the linear expansion coefficient of the specimen (K <sup>-1</sup> ).			Formatted	
5	Measu	ring apparatus	4		Formatted	
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.'he	measuri	ng equipment shall be in accordance with the requirements in <mark>5.2 to 5.9</mark> .5.2 to 5.9.	•	-(	Formatted	
		neasuring equipment, use the Fizeau-interference measurement principle in which the measure	d•	-(	Formatted	
:	sample	itself constitutes the interference space.		Á	Formatted	
		resolution to read the number of cycles of light and dark changes in the interference space. Th	e,	/[	Formatted	
	resoluti	on shall be 1/10 cycle or less.			Formatted	
igu	<del>re 1</del> Figu	<u>re 1</u> shows an example of a schematic diagram of the measuring equipment.			Formatted	
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5 window 15	vacuum gauge	Formatted: Font: 9 pt, Font color: Auto
6 heating/cooling unit 16	barometer.	Formatted: Font: 9 pt, Font color: Auto
7     temperature sensor     17       8     mechanical length of the specimen.     -a		Formatted: Font: 9 pt, Font color: Auto
	- <u>Connection to vacuum pump.</u>	Formatted: Font: 9 pt, Font color: Auto
9 light source for optical path length change of the specimen-	-bry an inter.	
10 beam splitter for optical path length change measurement	-	Formatted: Adjust space between Latin and Asian text, Adjust space between Asian text and numbers, Tab
* Connection to vacuum pump	-	stops: Not at 0.7 cm + 1.4 cm + 2.1 cm + 2.8 cm +
• Dry air inlet	-	3.5 cm + 4.2 cm + 4.9 cm + 5.6 cm + 6.3 cm + 7 cm
Figure 1- — Example of a schematic drawing of	a Fizeau-interferometric type of measurement 🚽	Formatted: Font: 9 pt, Font color: Auto
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5.2 Light sources		Formatted: Font: 9 pt, Font color: Auto
For change in optical path length of specimen light sou	rce and linear expansion coefficient light source, use a	Formatted
light source with sufficient intensity, monochromaticity	and coherence to obtain interference fringes with the	Formatted: Font: 9 pt, Font color: Auto
required precision. The wavelength for the measureme linear expansion coefficient do not need to be the same		Formatted: Font: 9 pt, Font color: Auto
initear expansion coefficient do not need to be the same		Formatted: Font: 9 pt, Font color: Auto
	rovide adequate illumination to enable accuracy, precision,	Formatted
and repeatability for the test.	ileh Standards	Formatted: Font: 9 pt, Font color: Auto
NOTE 2 Examples of light sources are listed in <u>ISO 7944</u> :	<u>-[2],</u> Table 1, Table 2, and Table 3 in ISO 7944	Formatted
5.3 Thermal chamber	s://standards.iteh.	Formatted: Font: 9 pt, Font color: Auto
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The thermal chamber has a window for observing char	ges in the optical path length. Thermal chamber shall $\blacktriangleleft$	Formatted: Font: 9 pt, Font color: Auto
a) a) have the ability to change the temperature of th	e specimen between the temperatures to be measured,	Formatted
b)_b)_have the ability to maintain the temperature of	the specimen within $\pm 0.5 K$	Formatted: Font: 9 pt, Font color: Auto
b) have the ability to maintain the temperature of	the specimen within ±0,5 K, 60-2	Formatted: Font: 9 pt, Font color: Auto
<u>c)</u> have a thermometer to measure the temperature	e of the specimen with an accuracy of ±0,2 K or better,	Formatted: Font: 9 pt, Font color: Auto
d) d) have the ability to be filled with dry air at a	relative humidity of $0\%$ or provide a vacuum with a	Formatted
	densation. When the inside of the thermal chamber is	Formatted
	he air pressure in the thermal chamber is the same as	Formatted
the atmospheric pressure around the container <u>, ar</u>	<u>d</u>	Formatted
e)_e)_have a window of the thermal chamber, which	shall be made of quartz glass with a wedge angle of	Formatted
approximately 6 arc min (0,1°) on the opposite pla	ne and polished on both sides.	<b>Commented [eXtyles6]:</b> ISO 7944: current stage is 40.60
NOTE Quartz glass is used because it has a wide wavele	ength range with a high transmittance, has a high durability	Formatted
against temperature changes, and is resistant to breakage.		Formatted
5.4 Flat plates	*	Formatted
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	other is a reference flat plate, are used to measure the vith the change of the optical path length by using	Formatted

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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

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Figure 2.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. Annex F.

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

- a) 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) 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) c) 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) 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) 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.

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