
**Optics and photonics — Optical
materials and components — Test
method for refractive index of infrared
optical materials**

*Optique et photonique — Matériaux et composants optiques —
Méthode d'essai de l'indice de réfraction des matériaux optiques
infrarouges*

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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).

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).

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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.

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

This second edition cancels and replaces the first edition (ISO 17328:2014), which has been technically revised.

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

- clarification of the description of the device;
- addition of contents to the test report.

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

This document applies to the measurement of relative refractive index to the air for infrared optical materials.

Two categories of major methods for measuring the refractive index of infrared materials exist. These are interferometric methods and minimum deviation methods. In this document, a test method using minimum deviation for infrared materials is described. The same method is applicable to materials used in the visible spectral range, either. It has the advantages of being applicable to more kinds of materials compared with interferometric methods and of ease of data processing because of the simple measurement principle.

Although the refractive index is temperature-dependent, this document describes a measurement method at a stable temperature (ambient air temperature).

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Optics and photonics — Optical materials and components — Test method for refractive index of infrared optical materials

1 Scope

This document provides a standard method for measuring the relative refractive index to the air of infrared materials used in the infrared spectral range from 0,78 μm to 25 μm .

This document excludes methods for measuring the refractive index of birefringent materials and methods for measuring the complex refractive index.

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 11382:2010, *Optics and photonics — Optical materials and components — Characterization of optical materials used in the infrared spectral range from 0,78 μm to 25 μm*

3 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 <https://www.electropedia.org/>

3.1 refractive index

n

ratio of the velocity of the electromagnetic waves at a specific wavelength in a vacuum to the velocity of the waves in the medium

[SOURCE: ISO 12123:2018, 3.1]

3.2 relative refractive index

ratio of the *refractive index* (3.1) of the material of the specimen to the *refractive index* (3.1) of the material in contact with the specimen at a specific wavelength

3.3 angle of minimum deviation

δ

angle between the ray incident upon the specimen prism and the ray exiting the specimen prism at its minimum value, which occurs when the ray inside the specimen prism makes equal angles with the entrance and the exit faces of the specimen prism

4 Method for measuring

4.1 General

In this document, the technique of the minimum deviation method for measuring refractive index is described.

The minimum deviation method shall be applied for measuring refractive index.

4.2 Principle

As shown in [Figure 1](#), when the monochromatic light beam is refracted by the specimen prism with minimum deviation, the relative refractive index of the specimen prism to the air at the wavelength of the monochromatic light beam is described by the following [Formula \(1\)](#):

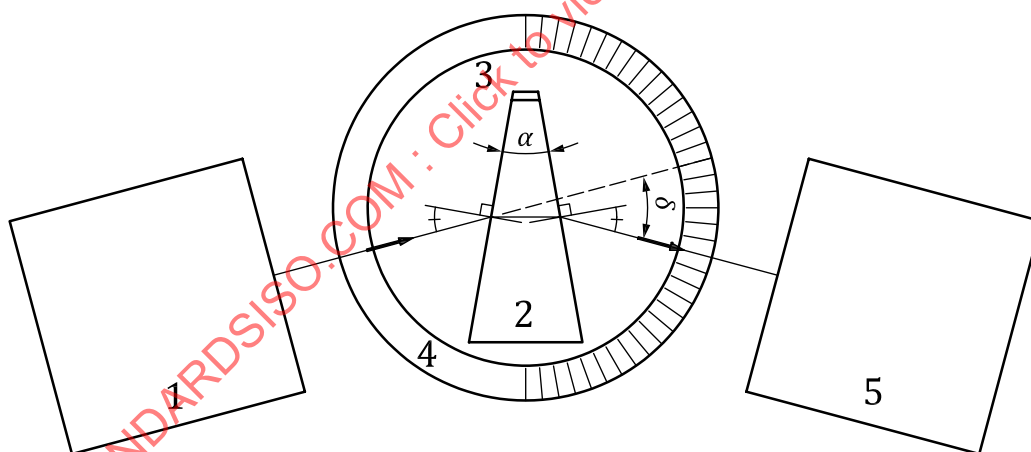
$$n_{\text{rel}} = \frac{\sin[(\alpha + \delta)/2]}{\sin(\alpha/2)} \quad (1)$$

where

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

α is the apex angle of the specimen prism;

δ is the angle of minimum deviation of the monochromatic light beam refracted by the specimen prism.

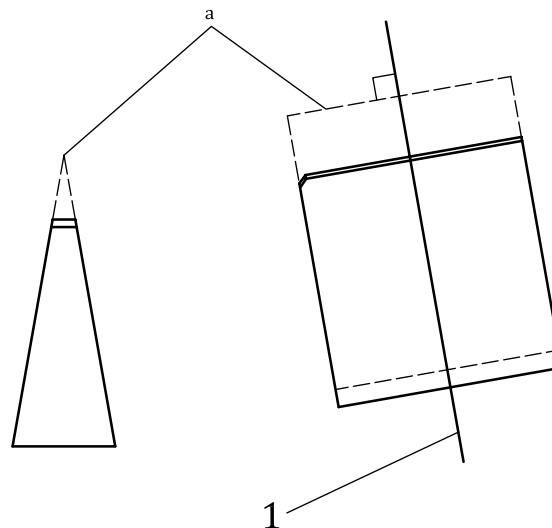


Key

- 1 monochromatic light source optics
- 2 specimen prism
- 3 rotating stage
- 4 goniometer
- 5 detector optics
- α apex angle of the specimen prism
- δ angle of minimum deviation

Figure 1 — Schematic of the minimum deviation method

The monochromatic light beam shall be parallel to the plane of section of the specimen prism, (see [Figure 2](#), item 2).

**Key**

- 1 plane of section
a Ridge line.

Figure 2 — Ridge line and the plane of section of the specimen prism

4.3 Apparatus and procedure for measurement

The apparatus for measurement shall be equipped with the following:

- a method to emit a collimated monochromatic light beam of a specified wavelength to the specimen prism;
- a method to vary the angle of the collimated monochromatic light beam to the entrance face of the specimen prism;
- a method to determine the direction of the monochromatic light beam refracted by the specimen prism;
- a method to indicate the angle of minimum deviation, δ ;
- a method to measure the temperature of the specimen prism.

Examples of apparatus for measurement of the angle of minimum deviation are shown in [Annex A](#). A procedure for measurement is also described in [Annex A](#). In addition, the absolute value of the angle of deviation error is described in [Annex B](#).

See [Figure 1](#).

4.4 Wavelength of light beam for measurement

The wavelengths of measurement shall adequately sample the spectral range of interest to enable curve fitting of the data to a dispersion formula, allowing calculation of the relative refractive index at any arbitrary wavelength within the spectral range.

5 Specimens

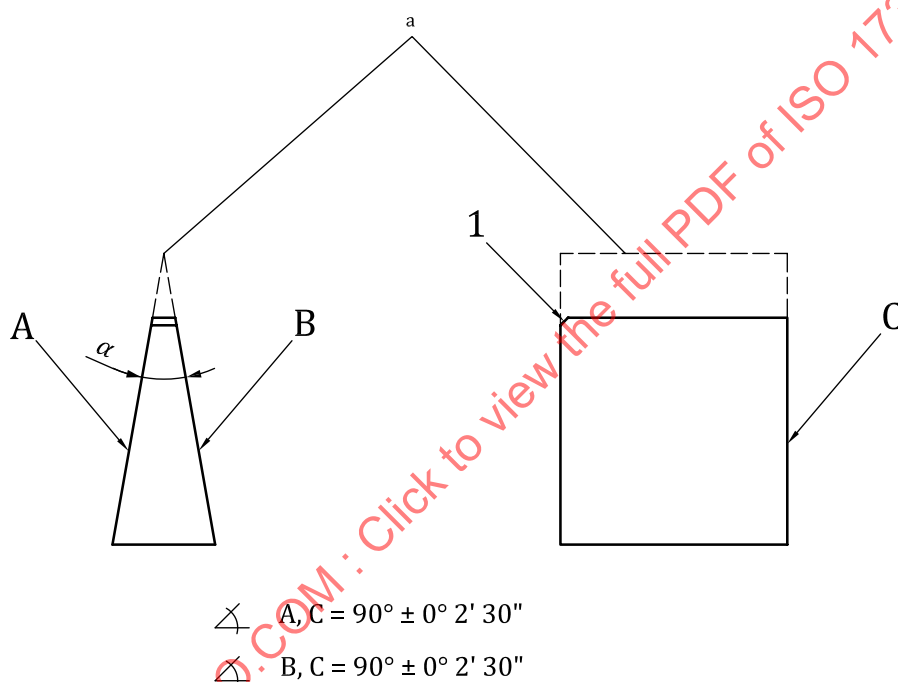
5.1 The shape and dimensions of the specimen prism

The specimen shall be a wedged prism made of the material to be measured. The entrance face and the exit face shall be polished.

An example of the shape of the specimen prism is shown in Figure 3. The optimum apex angle (such that error in measurement of the apex angle is least severe) for a material of the relative refractive index, n_{rel} , is given by Formula (2):

$$\alpha = 2\arctan(1/n_{\text{rel}}) \quad (2)$$

For low index materials, this relation may result in undesirably large apex angles; this relation shall be used as guidance.



Key

- 1 chamfer
- α apex angle of the specimen prism
- A entrance face of the specimen prism
- B exit face of the specimen prism
- C side face of the specimen prism
- a Ridge line.

Figure 3 — Shape of the specimen prism

5.2 Surface accuracy

The surface accuracy of the entrance face and the exit face of the specimen prism shall be measured with an interferometer. Any measured power term shall not be subtracted from measurement data. A surface flatness error should be 150 nm P-V or less over the entire clear aperture of the specimen prism faces.

6 Test report

The test report shall specify the following:

- a) specimen name in accordance with ISO 11382:2010, 5.6;
- b) date, place, measurer name;
- c) temperature, humidity, air pressure of the ambient air;
- d) apex angle of the specimen prism;
- e) temperature of the specimen prism;
- f) surface accuracy of the entrance face and the exit face;
- g) wavelengths and bandwidth (full width at half maximum) of wavelengths for measurement;
- h) angles of minimum deviation;
- i) relative refractive indices to the air.

The value of a) shall be specified. For example, "Germanium – Manufacturer A – Monocrystalline n type – Zone fusion – ISO 11382" or "ZnS – Manufacturer B – Polycrystalline – Hot pressed – ISO 11382".

The values of c), d), e), g), h) and i) shall be specified with values of uncertainty. In the case of the ambient medium is not air, add the name of ambient medium to the report.

Analysis errors are described in [Annex B](#).

Annex A
(informative)

Apparatus for measurement

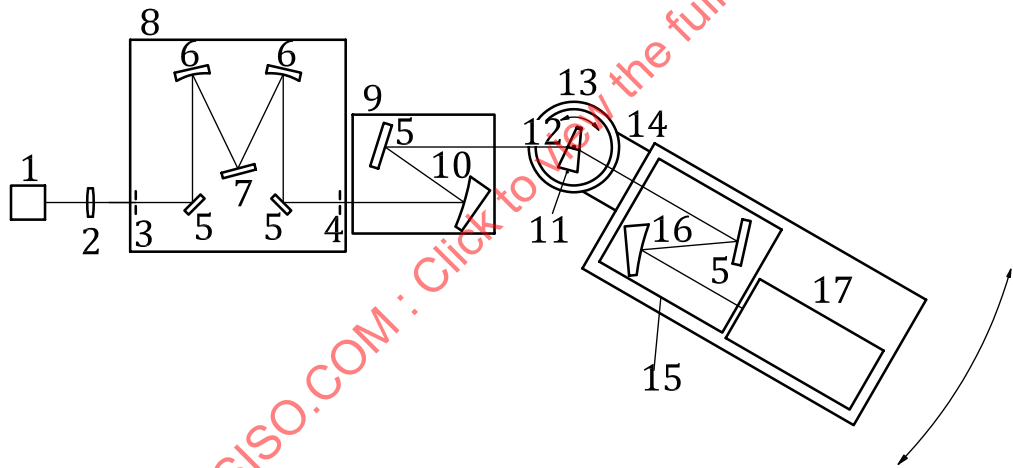
A.1 General

Examples of apparatus for measurement of the relative refractive index and the measurement procedure are described.

In the measurement room, air temperature, pressure and humidity and the temperature of the specimen prism are kept at specified values during the measurement time.

A.2 Apparatus for measurement

The apparatus is composed of those parts as [Figure A.1](#). It is shown in a configuration that uses a monochromator. However, the monochromator may be replaced with another wavelength selecting unit.



Key

1	light source	10	collimating mirror
2	relay optics	11	specimen prism
3	entrance slit or entrance pinhole	12	rotating stage
4	exit slit or exit pinhole	13	goniometer
5	plane mirror	14	rotating arm
6	concave mirror	15	focusing unit
7	grating	16	focusing mirror
8	monochromator	17	detector unit
9	collimating unit		

NOTE Arrows indicate rotation of rotating stage and rotating arm.

Figure A.1 — Outline of configuration

A.2.1 Light source

The light source emits the light which includes the spectrum of measurement wavelengths.

A.2.2 Wavelength selecting unit

The wavelength selecting unit selects a desired light and guides it to the exit slit or the exit pinhole that is located at the focus of the collimating unit.

The grating monochromator is a part for selecting the monochromatic light beam of desired wavelength from the light source.

The light beam from the light source enters the grating monochromator through the entrance slit or the entrance pinhole, and the monochromatic light beam of selected wavelength is passed through the exit slit or the exit pinhole.

The optical systems of the grating monochromator are composed of the reflecting optical components to make the grating monochromator operational in the wide spectral range. The calibration light beams are the monochromatic emission lines which wavelengths are known accurately. The calibration light beams are applied to the calibration of the wavelength-counter of the grating monochromator.

The light beam from the light source and the calibration light beam are transmitted at the same position on the entrance slit and the exit slit of the grating monochromator.

Band-pass filter can also be used as wavelength selecting units.

NOTE 1 Some bandpass filters shift their centre wavelengths with temperature.

NOTE 2 The wavelength of the light beam exited from the grating monochromator changes along with the longitudinal direction of the slit.

A.2.3 Collimating unit

The collimating unit is a unit for collimating the monochromatic light beam from the exit slit or the exit pinhole of the wavelength selecting unit. It consists of reflecting optics to avoid errors caused by chromatic aberration of the optics.

A.2.4 Goniometer

The goniometer consists of a rotating stage and a rotating arm. It has a function for reading a rotation angle of the rotating arm. The rotating stage holds the specimen prism at the position where the entrance face of the specimen prism is illuminated by the monochromatic light beam from the collimating unit and rotates the specimen prism. The rotating arm rotates a focusing unit and a detector unit.

The rotating axis of the rotating stage and the rotating axis of the rotating arm are parallel to the ridge line defined by the entrance face and the exit face of the specimen prism. The holder of the specimen prism has an adjusting mechanism for tilting.

The plane of section of the specimen prism is maintained parallel to the monochromatic light beam. The plane of section is defined as a plane normal to the ridge line of the specimen prism.

NOTE 1 The measured angle of minimum deviation alters due to the angle between the monochromatic light beam and the plane of section, (see [Figure 2](#), item 2).

NOTE 2 The relationship between change in the specimen prism rotation angle and change in rotating arm angle to maintain the condition of minimum deviation once established is a fixed ratio of 1:2 respectively.

A.2.5 Focusing unit

The focusing unit focuses the monochromatic light beam refracted by the specimen prism and forms the image of the exit slit or the exit pinhole of the wavelength selecting unit. The focusing unit is placed on the rotating arm of the goniometer.

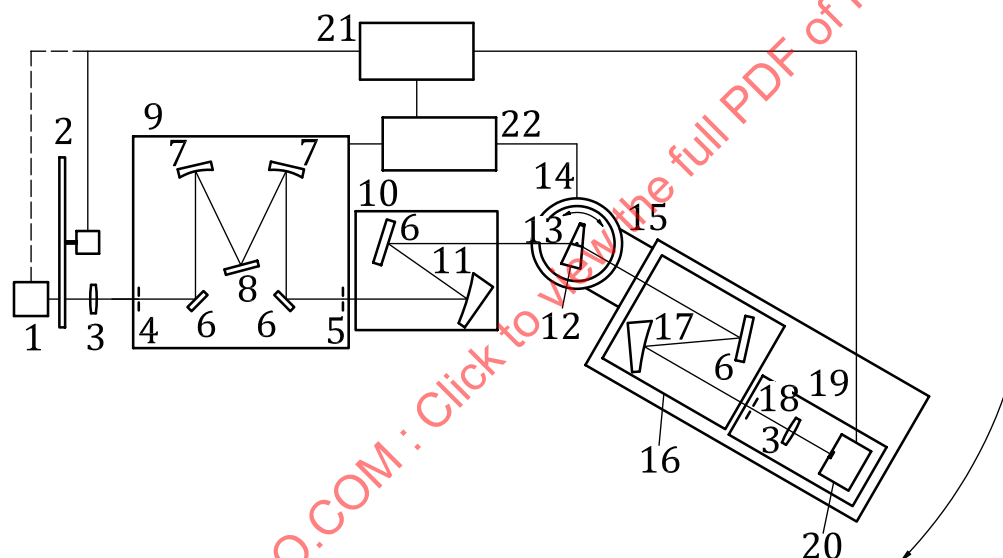
A.2.6 Detector unit

A.2.6.1 General

The detector unit is unified with the focusing unit on the rotating arm.

A.2.6.2 Photodetector

As shown in [Figure A.2](#), the slit or the pinhole is placed on the focal plane of the focusing unit, and then the monochromatic light beam through the slit or the pinhole is detected by the detector unit. If necessary, relay optics may be put between the slit or the pinhole and the photodetector to focus the monochromatic light beam on the photodetector. Many other valid or even preferred configurations are also available.



Key

1	light source	12	specimen prism
2	chopper	13	rotating stage
3	relay optics	14	goniometer
4	entrance slit	15	rotating arm
5	exit slit	16	focusing unit
6	plane mirror	17	focusing mirror
7	concave mirror	18	slit
8	grating	19	detector unit
9	monochromator	20	photodetector
10	collimating unit	21	lock-in amplifier
11	collimating mirror	22	control unit

NOTE 1 Arrows indicate rotation of rotating stage and rotating arm.

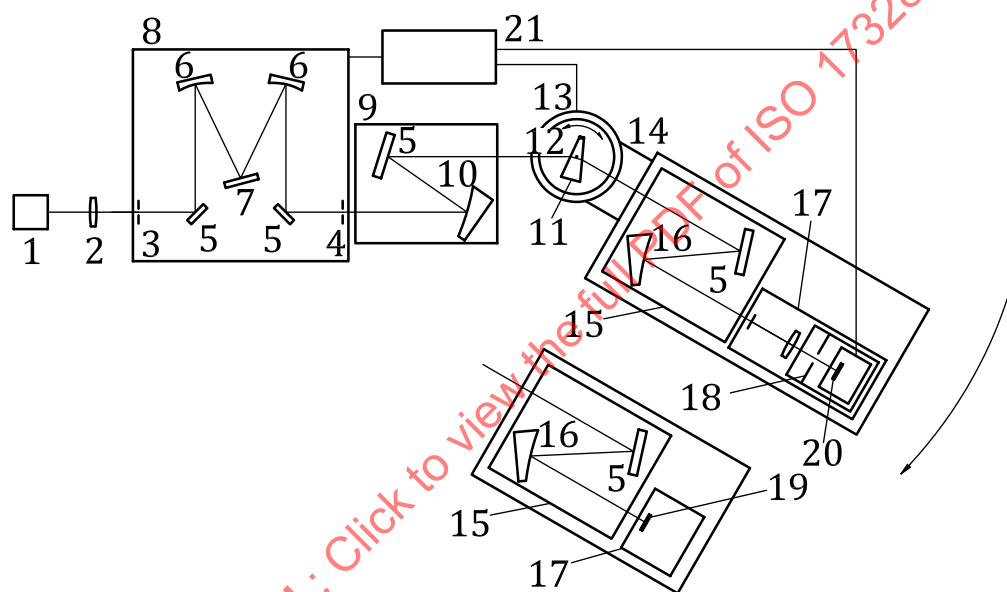
NOTE 2 A chopper and a lock-in amplifier are used for obtaining a high signal to noise ratio. The blinking light source is also used.

Figure A.2 — Configuration employing point sensor

A.2.6.3 Image sensor

As shown in [Figure A.3](#), the image of the exit slit or the exit pinhole of the wavelength selecting unit is formed on the image sensor surface. Many other valid or even preferred configurations are also available. The area array image sensor is generally used. The line sensor is also used.

NOTE If the image sensor is a cooled type, a cold aperture, or a cold stop, is set up in the sensor dewar. In that case, a relay optics can be necessary between the focusing unit and the detector unit to project the image of the exit slit or the exit pinhole of the wavelength selecting unit on the image sensor surface.



Key

1	light source	12	rotating stage
2	relay optics	13	goniometer
3	entrance slit	14	rotating arm
4	exit slit	15	focusing unit
5	plane mirror	16	focusing mirror
6	concave mirror	17	detector unit
7	grating	18	cold aperture
8	monochromator	19	image sensor
9	collimating unit	20	cooled image sensor
10	collimating mirror	21	control unit
11	specimen prism		

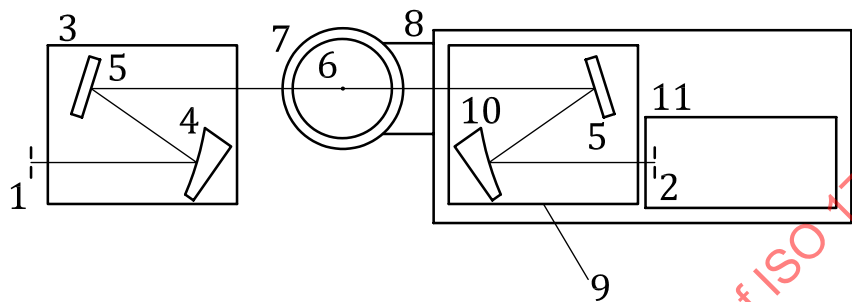
NOTE Arrows indicate rotation of rotating stage and rotating arm.

Figure A.3 — Configuration employing image sensor

A.3 Procedure for measurement

A.3.1 Initial position

As shown in [Figure A.4](#), the exit slit or the exit pinhole image of the wavelength selecting unit is set on the slit of the photodetector or the standard pixel of the image sensor by adjusting the angle of the rotating arm without the specimen prism. This angle is defined as the initial position of the optical system. Measurements should be implemented to ensure either that the initial position is stable over the course of measurements over wavelength and temperature, or that any variations in initial position are detected and compensated.



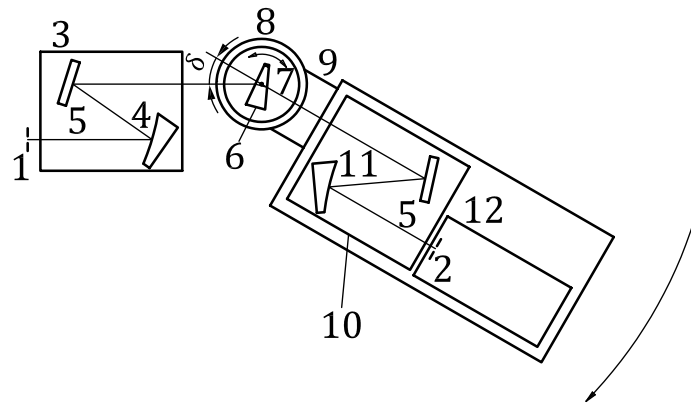
Key	
1	exit slit (of monochromator)
2	slit
3	collimating unit
4	collimating mirror
5	plane mirror
6	rotating stage
7	goniometer
8	rotating arm
9	focusing unit
10	focusing mirror
11	detector unit

Figure A.4 — Initial position of optical system

A.3.2 Angle of minimum deviation

After setting the initial position of the rotating arm, the specimen prism is set on the rotating stage. It is then rotated to establish the condition of minimum deviation. The angle of minimum deviation, δ , which depends on wavelength, specimen prism temperature, and air temperature, is the difference between the angle of the rotating arm read out with the rotating arm positioned to detect the monochromatic light beam refracted by the specimen prism and the rotating arm angle at the initial position and soak time prior to measurement to insure it has reached thermal equilibrium. See [Figure A.5](#).

In the case of photodetector, the angles of deviation measured at each step of the rotating stage are fitted a parabolic curve to determine the angle of minimum deviation.

**Key**

1	exit slit (of monochromator)	8	goniometer
2	slit	9	rotating arm
3	collimating unit	10	focusing unit
4	collimating mirror	11	focusing mirror
5	plane mirror	12	detector unit
6	specimen prism	δ	angle of minimum deviation
7	rotating stage		

NOTE Arrows indicate rotation of rotating stage and rotating arm.

Figure A.5 — Position of optical system at measurement of angle of minimum deviation

[Figure A.6](#) illustrates an alternate method of establishing the angle of minimum deviation. In this method, the minimum deviation condition is established for two positions of the specimen prism - with the collimated beam entering the specimen prism first through one of its polished faces and then through the other. The angle of minimum deviation, δ , is half of the total angular excursion of the rotating arm between the two minimum deviation positions.