TECHNICAL REPORT

ISO/TR 14880-5

First edition
2010-12-15

Optics and photonics — Microlens arrays —

Part 5:
Guidance on testing

Optique et photonique — Réseaux de microlentilles —

Partie 5: Lignes directrices pour essai

Reference number
ISO/TR 14880-5:2010(E)

Contents

Page

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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.

ISO/TR 14880-5 was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 9, *Electro-optical systems*.

ISO 14880 consists of the following parts, under the general title *Optics and photonics — Microlens arrays*:

— *Part 1: Vocabulary*

— *Part 2: Test methods for wavefront aberrations*

— *Part 3: Test methods for optical properties other than wavefront aberrations*

— *Part 4: Test methods for geometrical properties*

— *Part 5: Guidance on testing* [Technical Report]

Introduction

This part of ISO 14880 is intended as a guide to the selection and use of the appropriate method for testing optical and geometrical properties of a single microlens or microlens arrays. Examples of applications for microlens arrays include three-dimensional displays, coupling optics associated with arrayed light sources and photo-detectors, enhanced optics for liquid crystal displays, and optical parallel processor elements.

The testing of microlenses is in principle no different to testing any other lens. The same parameters need to be measured and the same techniques used. However, in many cases the measurement of very small lenses presents practical problems which make it difficult to use the standard equipment that is available for testing normal-size lenses.

The growing market in microlens arrays has generated a need for agreement on basic terminology and test methods. Standard terminology and clear definitions are needed not only to promote applications but also to encourage scientists and engineers to exchange ideas and new concepts based on common understanding.

The purpose of ISO 14880 is to improve the compatibility and interchange ability of lens arrays from different suppliers and to enhance development of the technology that uses microlens arrays. The various parts of ISO 14880 define terms and describe methods for testing wavefront aberrations, optical properties other than wavefront aberrations, and test methods for geometrical properties. This part of ISO 14880 contributes to the purpose by guiding the user to select the appropriate part of ISO 14880 for testing microlens properties, however the user is not limited to these techniques.

Optics and photonics — Microlens arrays —

Part 5:
Guidance on testing

1 Scope

This part of ISO 14880 gives guidelines for the testing of microlenses. It applies to microlenses in arrays where very small lenses are formed inside or on one or more surfaces of a common substrate.

This part of ISO 14880 addresses the measurement of optical and geometrical properties of single microlenses as well as microlens arrays.

When testing a microlens or microlens array, the test method is selected according to the parameters to be measured, the size and structure of the microlens and its application. This part of ISO 14880 guides the user to select the appropriate measurement method from the available ISO standards.

2 Normative references

The following referenced documents are indispensable for the application 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 14880-1, *Optics and photonics — Microlens arrays — Part 1: Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14880-1 apply.

4 Symbols and units

Symbols and units of measurement that are used in this part of ISO 14880 are given in Table 1.

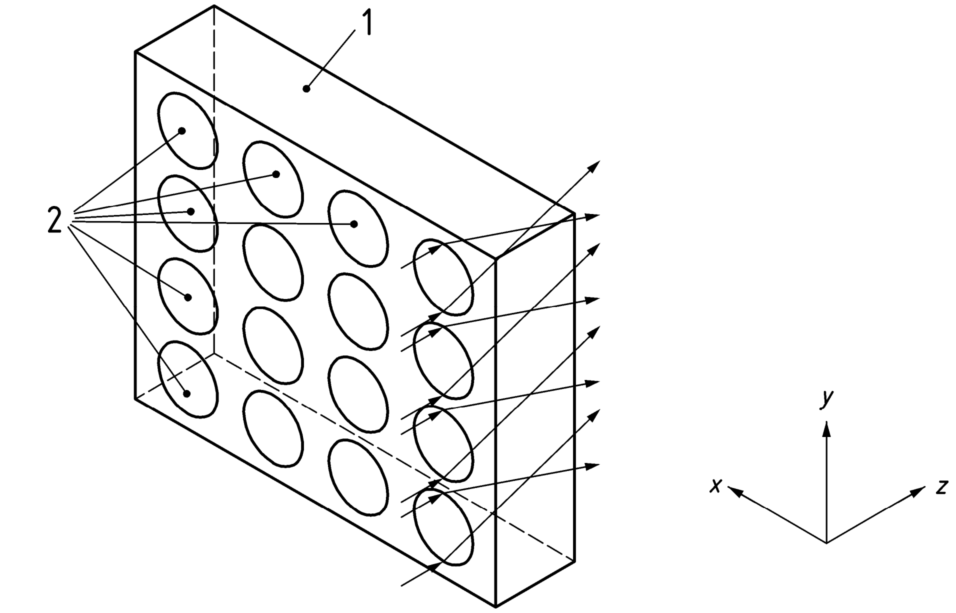
Table 1 — Symbols and units of measurement

	Symbol	Unit	Term
1	A_d	mm^2	diffraction-limited optical aperture
2	A_g	mm^2	geometric aperture
3	a_1, a_2	mm	lens radius
4	$2a_1$, $2a_2$	mm	lens width
5	D_n	mm^{-2}	lens density
6	h	mm	surface modulation depth
7	L_1, L_2	mm	edge length of substrate
8	NA	none	numerical aperture
9	NA_d	none	diffraction limited numerical aperture
10	NA_g	none	geometrical numerical aperture
11	n (x, y, z)	none	refractive index
12	n_0	none	refractive index (lens centre)
13	P_x, P_y	mm	pitch
14	$f_{E,b}$	mm	effective back focal length
15	$f_{E,f}$	mm	effective front focal length
16	R_c	mm	radius of curvature
17	S_x, S_y, S_z	mm	coordinates of focal spot position
18	ΔS_x, ΔS_y, ΔS_z	mm	focal spot position shift
19	T	mm	thickness of substrate
20	T_c	mm	physical thickness
21	W_x, W_y	mm	focal spot size
22	x, y, z	mm	coordinate of lens aperture centre position
23	θ	degree	acceptance angle
24	Φ_{rms}	parts of the wavelength, λ	wavefront aberration
25	λ	µm	wavelength
26	ν_{eff}	none	effective Abbe-number

5 Coordinate system

A Cartesian coordinate system as shown in Figure 1 can be used to describe the radiation propagation in a microlens array. Most parameters to be measured relate to individual microlenses.

The fundamental structure of a microlens array is illustrated in Figure 2.



Key

1 Substrate

2 Microlens

Figure 1 — Microlens array with a Cartesian coordinate system

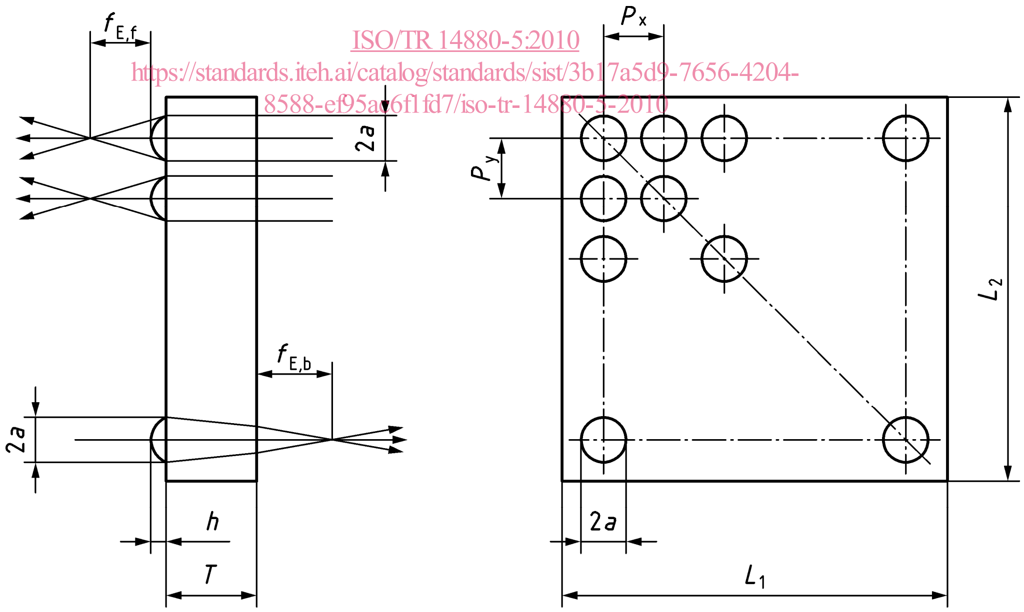


Figure 2 — Fundamental structure of microlens array

6 Test conditions

Care should be taken to ensure the test samples and equipment are handled under the conditions described in the appropriate standard, e.g. ISO 14880-2.

7 Test guide

7.1 General

It is usually necessary to ensure optical surfaces are clean before measurement.

7.2 Guide to test with measurement equipment

Table 2 shows several measurement methods and types of equipment which can be used to measure parameters.

For example, a lens radius (a_1, a_2) can be measured with a stylus instrument, a confocal measurement system or a microscope with linear scale.

Table 2 — Test equipment and reference standard for parameters to be measured

	Symbol	Unit	Term (parameter to be measured)	Equipment	Reference standards
1	A_d	mm^2	diffraction-limited optical aperture	microscope with linear scale	—
				interferometer with aperture stop and linear scale	—
2	A_g	mm^2	geometrical aperture	micrometer	—
				microscope with linear scale	—
3	a_1, a_2	mm	lens radius	stylus instrument	ISO 14880-4
				confocal measurement systems	ISO 14880-4
				microscope with linear scale	—
4	$2a_1$, $2a_2$	mm	lens width	stylus instrument	ISO 14880-4
				confocal measurement systems	ISO 14880-4
				microscope with linear scale	—
5	D_n	mm^{-2}	lens density	stylus instrument	ISO 14880-4
				confocal measurement systems	ISO 14880-4
				microscope with linear scale	—
6	h	mm	surface modulation depth	stylus instrument	ISO 14880-4
				confocal measurement systems	ISO 14880-4
7	L_1, L_2	mm	edge lengths of substrate	microscope with linear scales	—
8	NA	none	numerical aperture	calculated from aperture and focal length values	—
				measured directly from the divergence introduced by the microlens when illuminated by a collimated beam	—
9	NA_d	none	diffraction-limited numerical aperture	calculated from diffraction-limited aperture and focal length values	—
10	NA_g	none	geometrical numerical aperture	calculated from geometrical aperture and focal length values	—

Table 2 (*continued*)

	Symbol	Unit	Term (parameter to be measured)	Equipment	Reference standards
11	$n\ (x, y, z)$	none	refractive index	refractometer, for example Abbe or Pulfrich type or interferometer such as Mach-Zehnder or shearing type	—
12	n_0	none	refractive index (lens centre)	refractometer, for example Abbe or Pulfrich type or interferometer such as Mach-Zehnder or shearing type	—
13	P_x, P_y	mm	pitch	stylus instrument	ISO 14880-4
				microscope with linear scale	—
14	$f_{E,b}$	mm	effective back focal length	collimated source and microscope	ISO 14880-3
				wavefront measuring systems with linear scale	ISO 14880-3
				confocal measurement systems	ISO 14880-3
15	$f_{E,f}$	mm	effective front focal length	collimated source and microscope	ISO 14880-3
				wavefront measuring systems with linear scale	ISO 14880-3
				confocal measurement systems	ISO 14880-3
16	R_c	mm	radius of curvature	collimated source and microscope	ISO 14880-4
				interferometer with linear scale	ISO 14880-4
17	S_x, S_y, S_z	mm	coordinates of focal spot position	microscope with linear scale	—
18	ΔS_x, ΔS_y, ΔS_z	mm	focal spot position shift	microscope with linear scale	—
19	T	mm	thickness of substrate	micrometer	—
20	T_c	mm	physical thickness	micrometer	ISO 14880-4
21	W_x, W_y	mm	focal spot size	image sensor camera	—
22	x, y, z	mm	coordinates of lens aperture centre position	microscope with linear scale	—
23	θ	degree	acceptance angle	gonio photometer	—
24	Φ_{rms}	parts of the wavelength, λ	wavefront aberration	interferometer	ISO 14880-2 ISO 10110-14
				Shack-Hartmann sensor	ISO 14880-2
25	λ	µm	wavelength	spectrometer	—
26	ν_{eff}	none	effective Abbe-number	effective Abbe-number is given by: $\nu_{eff} = \dfrac{\dfrac{1}{f(\lambda_2)}}{\dfrac{1}{f(\lambda_1)} - \dfrac{1}{f(\lambda_3)}}$	ISO 14880-3
27	CE	none	coupling efficiency	calculated from Strehl ratio	ISO 14880-3