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Part 1: Vocabulary

Optique et photonique — Réseaux de microlentilles —

Partie 1: Vocabulaire

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Contents

Page

Foreword

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This document was prepared by Technical Committee ISO/TC 172, *Optics and Photonics*, Subcommittee SC 9, *Laser and electro-optical systems*.

This third edition cancels and replaces the second edition (ISO 14880-1:2016), which has been technically revised.

A list of all parts in the ISO 14880 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.

Introduction

The expanded market in microlens arrays has generated a need to agree on basic terms and definitions for microlens arrays and systems and this document aims to satisfy that need.

This document aims to improve the compatibility and interchangeability of lens arrays from different suppliers and to enhance the development of technology using microlens arrays.

Microoptics and microlens arrays are found in many modern optical devices[1]. They are used as coupling optics for detector arrays, the digital camera being an example of a mass market application. They are used to enhance the optical performance of liquid crystal displays, to couple arrays of light sources and to direct illumination for example in 2D and 3D television, mobile phone and portable computer displays. Microlens arrays are used in wavefront sensors for optical metrology and astronomy, lightfield sensors for three–dimensional photography and microscopy and in optical parallel processor elements.

Multiple arrays of microlenses can be assembled to form optical systems such as optical condensers, controlled diffusers and superlenses[2][3]. Furthermore, arrays of microoptical elements such as micro-prisms and micro-mirrors are used[4][5].Examples of some of these applications are described in Annexes A to F.

Optics and photonics — Microlens arrays —

Part 1:
Vocabulary

1 Scope

This document defines terms for microlens arrays. It applies to arrays of very small lenses formed inside or on one or more surfaces of a common substrate. This document also applies to systems of microlens arrays.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

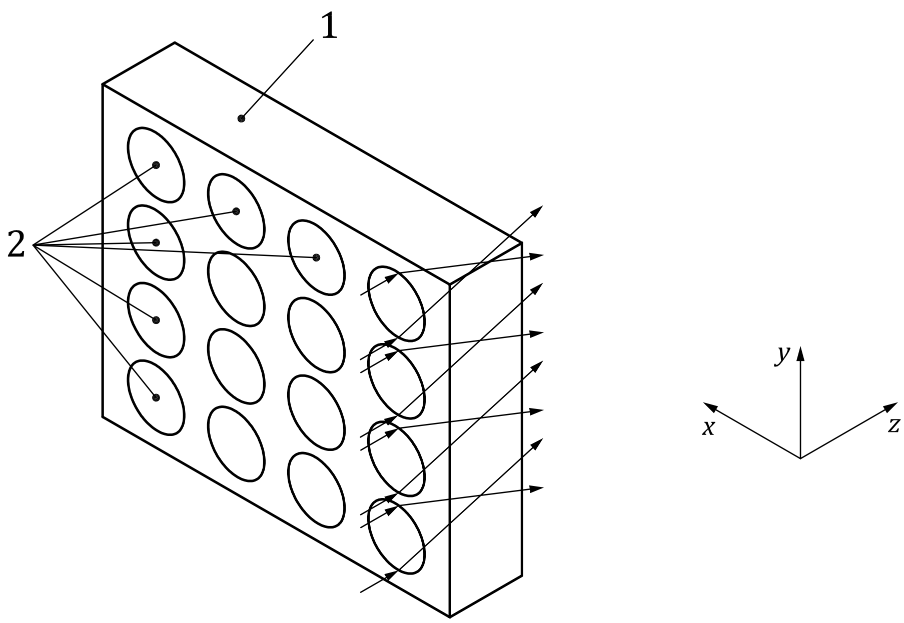
For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain 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/

NOTE 1 The coordinate system used for the description of the microlenses can be found in Figure 1. The description of the coordinate system and its application can be found in Clause 4.



Key

1 substrate

2 microlenses

Figure 1 — Microlens array with Cartesian coordinate system

NOTE 2 Five common types of microlenses are illustrated in Figure 5, and described in Clause 5.

NOTE 3 For common microlens array applications, see Annexes A to F.

3.1 Symbols and units of measure

Table 1 lists symbols and units which are used in this document.

Table 1 — Symbols and units of measure

Symbol	Unit	Term
A_d	mm^2	diffraction-limited optical aperture
A_g	mm^2	geometric aperture
a_1, a_2	mm	lens radius
$2a_1$, $2a_2$	mm	lens width
D_n	mm^{-2}	lens density
h	mm	surface modulation depth
L_1, L_2	mm	edge lengths of substrate
NA	none	numerical aperture
NA_d	none	diffraction-limited numerical aperture
NA_g	none	geometric numerical aperture
$n(x, y, z)$	none	refractive index
n_0	none	refractive index at the centre of the lens
P_x, P_y	mm	pitch
$f_{E,b}$	mm	effective back focal length
$f_{E,f}$	mm	effective front focal length
R_c	mm	radius of curvature
S_x, S_y, S_z	mm	coordinates of focal spot position
ΔS_x, ΔS_y, ΔS_z	mm	focal spot position shift
T	mm	thickness of substrate
T_c	mm	physical thickness
w_x, w_y	µm	focal spot size
x, y, z	mm	coordinates of lens aperture centre position
Θ	degree	acceptance angle
Φ_{rms}	parts of wavelength	wavefront aberration
λ	nm	wavelength
ν_{eff}	none	effective Abbe-number

3.2 Basic definitions of microlens and microlens array

3.2.1
microlens
lens in an array with an aperture of less than a few millimetres including lenses which work by refraction at the surface, refraction in the bulk of the substrate, diffraction or a combination of these

Note 1 to entry: The microlens can have a variety of aperture shapes: circular, hexagonal or rectangular for example. The surface of the lens can be flat, convex or concave.

3.2.2
microlens array
regular arrangement of microlenses on/in a single substrate

Note 1 to entry: Irregular or structured arrays are sometimes used, for example, in beam shaping, diffusion, and homogenization.

3.3 General terms and definitions

3.3.1
effective front focal length
$f_{E,f}$
distance from the vertex of the microlens to the position of the focus given by finding the maximum of the power density distribution when collimated radiation is incident from the back of the substrate

Note 1 to entry: The effective front focal length can differ from the paraxial front focal length in the case of aberrated lenses.

Note 2 to entry: The effective front focal length is different from the classical effective focal length since it is measured from the lens vertex.

3.3.2
effective back focal length
$f_{E,b}$
distance from the back surface of the substrate or the vertex of the microlens to the position of the focal point, when collimated radiation is incident from the lens side of the substrate

Note 1 to entry: The effective back focal length can differ from the paraxial back focal length in the case of aberrated lenses.

Note 2 to entry: In case the microlens or microlenses are formed on both sides of the substrate, “effective back focal length” is defined from the vertex of the microlens to the position of the focal point.

3.3.3
radius of curvature
R_c
distance from the vertex of the microlens to the centre of curvature of the lens surface

Note 1 to entry: The radius of curvature is expressed in millimetres.

3.3.4
wavefront aberration
Φ_{rms}
root mean square of deviation of the wavefront from an ideal spherical or other wavefront

Note 1 to entry: The wavefront aberration is expressed in parts of the wavelength, λ.

3.3.5.1
chromatic aberration
change of the focal length with wavelength

Note 1 to entry: Chromatic aberration is characterized by the effective Abbe-number, which is given by:

$$v_{eff} = \frac{\dfrac{1}{f(\lambda_2)}}{\dfrac{1}{f(\lambda_1)} - \dfrac{1}{f(\lambda_3)}}$$

where the values of λ_1, λ_2 and λ_3 are specified in order to correspond to current practice in optical lens design. The effective Abbe-number is dimensionless.

Note 2 to entry: At optical wavelengths the C line (656,3 nm) as λ3, d line (587,56 nm) as λ2, F line (486,1 nm) as λ1 are generally used. However, other wavelengths such as the infrared spectrum can be used where appropriate, provided that $\lambda_1 < \lambda_2 < \lambda_3$.

3.3.5.2
achromatic microlens array
microlens array designed to limit the effects of chromatic aberration

Note 1 to entry: Achromatic microlens arrays are generally corrected to bring radiation of two wavelengths into focus in the same plane, for example, red and blue light or infrared wavelengths where appropriate.

3.3.6.1
aperture shape
shape which is specified as square, circular, hexagonal, circular sector or other geometric shape

Note 1 to entry: For non-regular shapes, the vertices of the microlens aperture are to be defined by coordinates, Xa_{jk}, Ya_{jk}, where j is the microlens number index and k is the vertex number index.

3.3.6.2
geometric aperture
A_g
area in which the optical radiation passing through it is deviated towards the focused image and contributes to it

Note 1 to entry: For graded index microlenses where no obvious boundary exists, the edge is the locus of points at which the change of index is 10 % of the maximum value.

Note 2 to entry: The geometric aperture is expressed in square millimetres.

3.3.6.3
lens width
$2a_1$, $2a_2$
width of the microlens on the substrate defined by the geometric aperture of the microlens

Note 1 to entry: The widths are determined by measuring the longest distance ($2a_1$) and the shortest distance ($2a_2$) between the lens edges as shown in Figure 2. If the lens is circular symmetric, then the term diameter can be used.

Note 2 to entry: Lens widths are expressed in millimetres.

Note 3 to entry: The geometric aperture of the microlens can be given by a variety of shapes such as circular, rectangular, elliptical and so on.

3.3.6.4
diffraction-limited optical aperture
A_d
area within which the peak-to-valley wavefront aberrations are less than one quarter of the wavelength of the radiation with which it is tested

Note 1 to entry: The diffraction-limited optical aperture is expressed in square millimetres.

3.3.6.5
geometrical numerical aperture
NA_g
sine of half the angle subtended by the aperture of the lens at the focal point

3.3.6.6
diffraction-limited numerical aperture
NA_d
sine of half the angle subtended by the diffraction limited optical aperture of the lens at the focal point

3.3.7
focal ratio
ratio of the focal length to the lens width of the geometrical aperture

Note 1 to entry: The focal ratio is equivalent to the practical *f*-number.

3.3.8
imaging quality
quality of the microlens which is determined by Modulation Transfer Function (MTF) according to ISO 15529 or the Strehl ratio

Note 1 to entry: The imaging quality should be measured in the conjugates in which the microlenses are to be used and preferably for a range of angles of incidence.

3.3.9
focal spot size
w_x, w_y
half width in the *x* direction and *y* direction, respectively, at which power density is decreased to the $1/e^2$ irradiance levels at the practical focus point when the microlens is irradiated with a uniform plane wavefront

Note 1 to entry: Focal spot sizes are expressed in micrometres.

3.3.10
lenticular microlens array
array of cylindrical microlenses

Note 1 to entry: Historically the term lenticular means lens-shaped, but in practice it is used to describe cylindrical lenses.

3.3.11
beam homogenizer
one or more microlens arrays designed to shape the intensity distribution of an incident wavefront

3.3.12
structured microlens array
microlens array with regular or random geometry designed to shape an incident wavefront, often used for applications with a broad range of wavelengths

3.3.13
condenser array
dual array of cylindrical or spherical microlenses designed to illuminate a large field at a relatively short working distance

Note 1 to entry: For convenience, the dual arrays can be formed either side of a single substrate.

3.3.14
Gabor superlens
optical system formed from a pair of afocal microlens arrays which can have different periods and focal lengths

Note 1 to entry: The Gabor superlens is able to produce “integral” images which are very different from those produced by conventional lenses.