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Optics and photonics — Microlens arrays —

Part 1: Vocabulary and general properties

Optique et photonique — Réseaux de microlentilles —

Partie 1: Vocabulaire et propriétés générales

Reference number
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Foreword

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The committee responsible for this document is ISO/TC 172, *Optics and photonics*, Subcommittee SC 9, *Electro-optical systems*.

This second edition cancels and replaces the first edition (ISO 14880-1:2001), which has been technically revised. It also incorporates the Technical Corrigenda ISO 14880-1:2001/Cor 1:2003 and ISO 14880-1:2001/Cor 2:2005.

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

— *Part 1: Vocabulary and general properties*

— *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*

Introduction

The aim of this part of ISO 14880 is to clarify the terms used in the field of 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]

The expanded market in microlens arrays has generated a need to agree on basic terms and definitions for microlens arrays and systems and this part of ISO 14880 aims to satisfy that need.

Optics and photonics — Microlens arrays —

Part 1: Vocabulary and general properties

1 Scope

This part of ISO 14880 defines terms for microlens arrays. It applies to microlens arrays which consist of arrays of very small lenses formed inside or on one or more surfaces of a common substrate and systems. The aim of this part of ISO 14880 is to improve the compatibility and interchangeability of lens arrays from different suppliers and to enhance the development of technology using microlens arrays.

2 Terms and definitions

2.1 Basic definition of microlens and microlens array

2.1.1
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.

2.1.2
microlens array
regular arrangement of microlenses on a single substrate

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

2.2 General terms and definitions

2.2.1
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.

2.2.2
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.

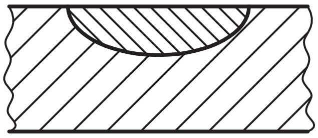
Note 2 to entry: In case the microlens or microlenses are formed on both sides of the substrate, “effective back focal length” is defined from the vertex of the microlens to the position of the focal point.

2.2.3
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.

2.2.4
wavefront aberration
Φ_{rms}
root mean square of deviation of the wavefront from an ideal spherical or other wavefront

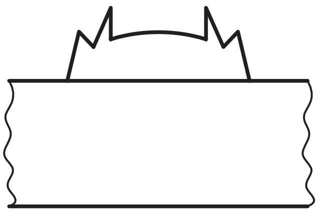
Note 1 to entry: The wavefront aberration is expressed in parts of the wavelength, λ.



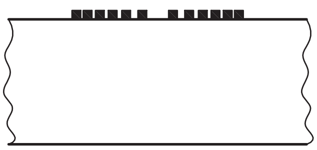
a) Microlens with a graded refractive index

b) Surface relief refractive microlens

c) Fresnel microlens



d) Hybrid microlens



e) Diffractive binary-optic microlens

Figure 1 — Five different types of microlens

2.2.5.1
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:

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

where the values of λ_1, λ_2 and λ_3 are specified in order to correspond to current practice in optical lens design; there are no units.

Note 2 to entry: At optical wavelengths, the C, D, F lines are generally used as $\lambda_1 < \lambda_2 < \lambda_3$. However, other wavelengths such as the infrared spectrum can be used where appropriate.

2.2.5.2
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 into focus in the same plane radiation of two wavelengths, for example, red and blue light or infrared wavelengths where appropriate.

2.2.6.1
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.

2.2.6.2
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 focus 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.

2.2.6.3
lens width
$2a_1$, $2a_2$
widths of the microlens on the substrate consisting of the geometric aperture of the microlens given by a variety of shapes such as circular, semi-rectangular, elliptical and so on

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.

2.2.6.4
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.

2.2.6.5
geometrical numerical aperture
NA_g
sine of half the angle subtended by the aperture of the lens at the focal point

2.2.6.6
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

2.2.7
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.

2.2.8
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.

2.2.9
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.

2.2.10
lenticular lens array
generally used to describe an array of cylindrical microlenses

2.2.11
beam homogenizer
one or more microlens arrays designed to shape the intensity distribution of an incident wavefront

2.2.12
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

2.2.13
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.

2.2.14
Gabor superlens
optical system formed from a pair of afocal microlens arrays which can have different periods and focal lengths

Note 1 to entry: It is able to produce "integral" images which are very different from those produced by conventional lenses.

2.3 Terms relating to properties of the microlens array

2.3.1 Geometrical properties

2.3.1.1
structure of the microlens array
geometrical arrangement of the individual microlenses and feature of the substrate

Note 1 to entry: There are generally two types of arrangements: regular and irregular. Regular can be rectangular, hexagonal or polar regardless of the overlapping of microlenses on the substrate. The specification has to completely describe the arrangement for the microlens array. The lens array positions X_j, Y_j and aperture vertex coordinates are used to define this structure. For regular structures, only the spacing and geometry are to be defined.

2.3.1.2
lens aperture centre position
X, *Y*, *Z*
coordinates of the location of the centre of a given lens in the array

Note 1 to entry: The index *j* may be added as needed to identify a particular lens number.

Note 2 to entry: The coordinates of the lens aperture centre position are expressed in millimetres.

2.3.1.3
focal spot position
S_x, S_y, S_z
coordinates of the focal spot geometrical positions

Note 1 to entry: The index *j* may be added to specify a particular microlens.

Note 2 to entry: The focal spot position need not be specified if the array is telecentric and regular.

Note 3 to entry: The coordinates of the focal spot position are expressed in millimetres.

2.3.1.4
focal spot position shift
ΔS_x, ΔS_y, ΔS_z
offset distance from the *X*, *Y*, *Z* coordinates of the lens position to the focal spot position

Note 1 to entry: $\Delta S_x = X-S_x$, $\Delta S_y = Y-S_y$, $\Delta S_z = Z-S_z$.

Note 2 to entry: The focal spot position shift is expressed in millimetres.

2.3.1.5
pitch
P_x, P_y
distance between the centres of adjacent lenses which can vary across and will vary with direction

Note 1 to entry: P_x, P_y are defined as pitch of *x*, *y* direction as shown in Figure 2.

Note 2 to entry: The pitch is expressed in millimetres.

2.3.1.6
lens density
D_n
number of lenses per unit area of the array

Note 1 to entry: The lens density is expressed in millimetres to the power minus two.