DEVICE AND METHOD FOR EXPOSING A LIGHT-SENSITIVE LAYER TO LIGHT

The present invention relates to a method for exposing a light-sensitive layer to light and to a corresponding device.

Digital micro-mirror devices (DMDs) have been known in the art for a long time. These are optical elements which consist of a plurality of small mirrors which can be individually moved/aligned. Each mirror can be selectively electrically activated and oriented. This means that an optical system with a DMD can be used to selectively deflect a broad light beam in a spatially resolved manner. In most cases only two fully deflected positions per mirror are under consideration. Either a mirror allows the incident part of the light beam to pass through the optical system or it reflects the incident part of the light beam in such a way that the light is not passed further through the system. Each mirror of such a DMD can then be interpreted as a digital light switch.

In the art DMDs of this kind are used above all in projectors. They are also increasingly used in industrial environments, for example in 3D printing, 3D surveys and maskless lithography.

In the art all the known maskless exposure devices have a single light source, which irradiates the DMD and thus the surface to be exposed.

Embodiments of the present invention eliminate the disadvantages of the state of the art and in particular achieve an improved exposure result.

According to a first aspect of the present invention, there is provided a method for exposing a light-sensitive layer to light using an optical system having an optical path, wherein at least one light beam is generated by at least one light source, respectively, and pixels of an exposure pattern grid are illuminated by at least one micro-mirror device with a plurality of micro-mirror, characterised in that horizontal and/or vertical exposure pattern grid lines of the exposure pattern grid are sheared, wherein the shearing of a DMD-picture leaving the micro-mirror device is effected along the optical path, wherein the intensity profile of the pixel (23) is chosen such that more than 50% of the energy of the pixel (23) are to be found in the directly corresponding image surface and the remaining less than 50% are distributed across the adjacent fields.

According to a second aspect of the present invention, there is provided a device for exposing a light-sensitive layer to light using an optical system having at least one light source for generating at least one light beam, at least one micro-mirror device with a plurality of micro-mirrors, wherein each micro-mirror serves to illuminate one pixel of an exposure pattern grid, characterised in that horizontal and/or vertical exposure pattern grid lines of the exposure pattern grid are sheared, wherein the shearing of a DMD-picture leaving the micro-mirror device is effected along the optical path, wherein the intensity profile of the pixel (23) is chosen such that more than 50% of the energy of the pixel (23) are to be found in the directly corresponding image surface and the remaining less than 50% are distributed across the adjacent fields.

The scope of the invention also covers all combinations of at least two features indicated in the description, the claims and/or the drawings. In case of value ranges, all values within the said limits are deemed disclosed as limit values and can be claimed in random combination.

The invention shows, in particular, how an improved, faster higher-resolution exposure operation can be carried out.

The core idea of the invention consists in performing a distortion of the DMD image with the aid of optical elements in such a way that an increased resolution can be achieved from the pattern of the intensity profiles.

The intensity profile is preferably chosen such that 50% of the energy of a pixel are to be found in the directly corresponding image surface and a further 50% are distributed across the adjacent fields. In a more preferred embodiment according to the invention the intensity profile of a pixel is chosen such that more than 50% of the energy of a pixel are to be found in the directly corresponding image surface and the remaining less than 50% are distributed across the adjacent fields. In another less preferred embodiment according to the invention the intensity profile of a pixel is chosen such that less than 50% of the energy of a pixel are to be found in the directly corresponding image surface and the remaining more than 50% are distributed across the adjacent fields.

In particular, the invention describes a maskless exposure device / a maskless exposure method. The exposure device is described by way of a number of embodiments which can be combined with each other.

2, the x-coordinate and the y-coordinate extend in parallel to the mirror surface edges 2kx and 2ky of the mirror surface 2 and define a mirror plane.

Figure 4b shows the same DMD 1, wherein one of the mirrors 3 is arranged in a position tilted or rotated about the x-axis. The part of the beam 6 hitting the tilted mirror 3 is therefore reflected in a direction which is not identical to the reflection direction of the parts of the beam 6 reflected by the non-tilted mirrors 3.

Figure 5a shows a first less preferred inventive exposure pattern 24, which in both mutually orthogonal directions K2x, K2y, is at equidistant distances from the exposure pattern grid lines. The exposure pattern 24 is thus isotropic and homogeneous in both directions K2x and K2y.

Figure 5b shows a second more preferred exposure pattern 24' according to the invention, which has, for each direction, its own equidistant direction-related distance between the exposure pattern grid lines. The exposure pattern 24' is thus isotropic, but homogeneous in each of directions K2x and K2y.

It is also feasible for exposure to take place at exposure pattern grid line intersections 25 and/or exposure pattern partial surfaces 26 and not within individual grid surfaces.

The different exposure patterns 24, 24', 24'', 24''' may be generated/modified in particular, by optical elements (not shown) arranged upstream and/or downstream of the DMD 1 (not shown). The DMD 1 (not shown) would preferably be isotropic and homogenous, wherein the optical elements (not shown), in particular only the downstream elements, are configured so as cause an anisotropic and/or homogenous image of the DMD.

Figure 6 shows a schematic not-to-scale top view of an exposure pattern 24'' distorted in particular, by optical elements of the optical system 8.

List of reference symbols

1	DMD
2	mirror surface
2kx, 2ky	mirror surfaces edges
3,3’	mirror
4	writing area
5	buffer area
6	light beam (beam)
6’	modified/structured beam
6.1’	first modified beam
6.2’	second modified beam
7,7’	light source
8	optical system
9	layer
10	substrate
11	substrate holder
12, 12’, 12’’	structures
13	fixing means
14	mirror
14’	beam splitter
14’’	semi-transparent mirror
23, 23’	pixel
24, 24’, 24’’, 24’’’	exposure pattern grid
25	exposure pattern grid line intersection
26	exposure pattern partial surface
28	pattern
1,1’	length

Claims

1. A method for exposing a light-sensitive layer (9) to light using an optical system (8) having an optical path,

wherein at least one light beam (6, 6') is generated by at least one light source (7), respectively, and pixels (23) of an exposure pattern grid (24, 24', 24'', 24''') are illuminated by at least one micro-mirror device (1) with a plurality of micro-mirrors (3),

characterised in that horizontal and/or vertical exposure pattern grid lines of the exposure pattern grid (24, 24', 24'', 24''') are sheared, wherein the shearing of a DMD-picture leaving the micro-mirror device (1) is effected along the optical path,

wherein the intensity profile of the pixel (23) is chosen such that more than 50% of the energy of the pixel (23) are to be found in the directly corresponding image surface and the remaining less than 50% are distributed across the adjacent fields.

2. The method according to claim 1, wherein the horizontal and/or vertical exposure pattern grid lines are arranged so as to extend or be aligned in parallel to other horizontal and/or vertical exposure pattern grid lines, respectively.

3. The method according to one of the preceding claims, wherein the horizontal and/or vertical exposure pattern grid lines are arranged obliquely.

4. A device for exposing a light-sensitive layer (9) to light using an optical system (8) having

- at least one light source (7) for generating at least one light beam (6, 6'),
- at least one micro-mirror device (1) with a plurality of micro-mirrors (3), wherein each micro-mirror (3) serves to illuminate one pixel (23) of an exposure pattern grid (24, 24', 24'', 24'''),

characterised in that horizontal and/or vertical exposure pattern grid lines of the exposure pattern grid (24, 24', 24'', 24''') are sheared, wherein the shearing of a DMD-picture leaving the micro-mirror device (1) is effected along the optical path,

wherein the intensity profile of a pixel is chosen such that more than 50% of the energy of the pixel are to be found in the directly corresponding image surface and the remaining less than 50% are distributed across the adjacent fields.