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- (54) Title:** OPTICAL COMPONENT COMPRISING AN OPTICAL DEVICE AND MEANS FOR REDUCING RADIATION-INDUCED INFLUENCES ON SAID OPTICAL DEVICE

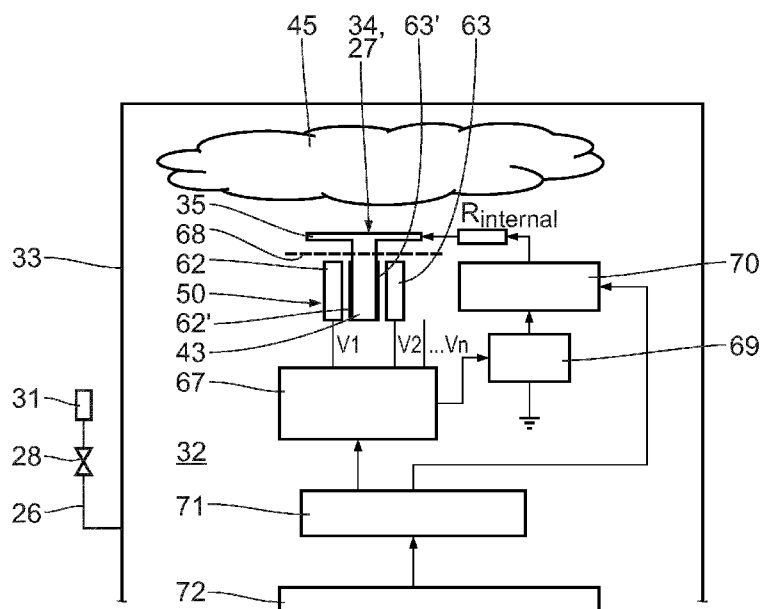


Fig. 5

- (57) Abstract:** An optical component comprises at least one means for reducing a radiation-induced influence on the displacement of an optical device (27).



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OPTICAL COMPONENT COMPRISING AN OPTICAL DEVICE AND MEANS FOR REDUCING
RADIATION-INDUCED INFLUENCES ON SAID OPTICAL DEVICE

The contents of German patent application no. 10 2013 209 442.6 and
German patent application no. 10 2013 218 748.3 is incorporated herein by
5 reference.

The invention relates to an optical component. The invention furthermore
relates to a method for positioning at least one optical device. Moreover,
the invention relates to an illumination optical unit and an illumination
10 system for a projection exposure apparatus and a projection exposure
apparatus comprising such an illumination optical unit. Finally, the
invention relates to a method for producing a micro- or nanostructured
component.

15 WO 2009/100 856 A1, for example, discloses a facet mirror for a
projection exposure apparatus, said facet mirror having a multiplicity of
individually displaceable individual mirrors. In order to ensure the optical
quality of a projection exposure apparatus, a very precise positioning of the
displaceable individual mirrors is necessary.

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The invention is based on the object of improving an optical component.

This object is achieved by means of the features of Claim 1. The heart of
the invention consists in providing the optical component with at least one
25 means for reducing a radiation-induced influence on the positioning of at
least one optical device. The optical component comprises, in particular, at
least one means for reducing the influences of the electrical charges
liberated by the illumination radiation.

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In particular, the stability of the at least one optical device is improved as a result. This leads to a more precise positioning of the at least one optical device.

- 5 According to the invention it has been recognized that high-energy photons can lead to a charge transfer to an optical device or away from an optical device, wherein said charge transfer, in the case of a device displaceable in an electromechanically actuable manner, can lead to a mechanical excitation thereof. In other words, the optical device can be mechanically
10 excited and/or disturbed by the impingement of illumination radiation.

The displaceable optical device can be in particular a mirror, in particular a micromirror, that is to say a mirror having a side length of less than 1 mm. The mirror or micromirror can be in particular part of a multimirror
15 arrangement (Multi Mirror Array, MMA). The MMA can comprise more than 1000, in particular more than 10 000, in particular more than 100 000, mirrors of this type. In particular, mirrors for reflecting VUV or EUV radiation can be involved.

- 20 The optical component can be in particular a facet mirror, in particular a field facet mirror, of an illumination optical unit for a projection exposure apparatus. In the case of an illumination optical unit for a VUV or EUV projection exposure apparatus, the optical component is preferably arranged in an evacuated chamber. During the operation of the projection
25 exposure apparatus, said chamber can be evacuated in particular to a pressure of less than 50 Pa, in particular less than 20 Pa, in particular less than 10 Pa, in particular less than 5 Pa. In this case, said pressure indicates in particular the partial pressure of hydrogen in the chamber.

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High-energy photons from the radiation source, in particular EUV photons, can lead to the generation of a plasma, in particular a hydrogen plasma. Other ionization mechanisms, for example the external photoelectric effect, in particular also VUV photons, are likewise possible. The radiation-
5 induced free charge carriers can accumulate on the mirror and lead to a mechanical disturbance thereof.

One aspect of the invention provides for the at least one means for reducing a radiation-induced influence on the positioning of the at least one optical
10 device to comprise a control device for the targeted application of an electrical bias potential to the at least one optical device. In other words, the electrical bias potential is applied to the optical device, such that the optical device is at said potential.

15 This makes it possible to reduce, in particular to minimize, in particular to eliminate, the radiation transfer, in particular the plasma-induced charge transfer, to the optical device. The bias potential can be chosen in particular in such a way that the current flowing away via the mirror is reduced, in particular minimized, in particular eliminated.

20 The bias potential can be fixedly predefined. It can also be controllable, in particular dynamically controllable, in particular controllable by closed-loop control.

25 Alternatively or additionally, a control device for the targeted application of a bias voltage to an actuator device can also be provided as means for reducing a radiation-induced influence on the positioning of the at least one optical device.

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According to the invention it has been recognized that, by applying a bias voltage to the actuator device, the effective elasticity constant of the optical device is modifiable.

5 In accordance with one aspect of the invention, the control device comprises a look-up table for determining the bias potential to be applied to the at least one optical device. The complexity of the control device is simplified as a result. Determining the bias potential with the aid of a look-up table makes possible, in particular, an uncomplicated, cost-effective
10 control. It is also possible to provide the control device with a plurality of look-up tables for different operating modes of the projection exposure apparatus. By way of example, in each case a dedicated look-up table can be provided for different radiation sources. The look-up tables can each have different values for the bias potential to be applied for different
15 operating modes of the radiation source. In this case, they can have, in particular, different pulse frequencies, pulse durations and intensities of the radiation source and also different states of the evacuable chamber, in particular the pressure thereof, in particular the partial pressures for different gases and also the gas composition in the chamber.

20 The look-up tables can be determined offline. They can be determined experimentally, in particular. They can also be determined with the aid of a model. In one particular advantageous embodiment, provision can also be made for designing the control device in such a way that the look-up tables
25 can be calibrated during the operation of the projection exposure apparatus.

One aspect of the invention provides for the control device to comprise at least one sensor, that is to say to be embodied as a closed-loop control device with at least one sensor.

In particular, a current flowing away through the mirror can be detected by means of the sensor. With the aid of the sensor, it is possible, in particular, to make the determination of the bias potential dynamically controllable by closed-loop control. The stability of the device is improved further as a result. It is possible, in particular, to monitor the effect of the bias potential with the aid of the sensor and to calibrate the exact value of the bias potential to be applied during the operation of the projection exposure apparatus.

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In accordance with one aspect of the invention, provision can be made for the at least one means for reducing a radiation-induced influence on the positioning of the at least one optical device to comprise at least one control device for applying a compensation potential to the at least one optical device and/or the at least one actuator device. The compensation potential can be applied in particular as part of the bias potential directly to the optical device. This enables, in particular, a particularly direct, unfiltered dynamic compensation of radiation-induced influences. As an alternative or in addition thereto, a compensation potential can also be applied to the actuator device. In this case, the electrical properties of the actuator device and also the actuation characteristic thereof should be taken into consideration when determining the compensation potential.

The compensation potential applied directly to the optical device can be, in particular, a time-dependent portion of the bias potential. In accordance with one aspect of the invention, the control device, for acting on the optical device and/or the actuator device, comprises a sensor device for detecting a radiation-induced charge offset in the optical device to be acted on. If the time constant of the electrical equivalent circuit of the optical

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device is significantly shorter than the characteristic time scale of the external electrical disturbances of the optical device, the current flowing away from the optical device is substantially resistive, that is to say in phase with the external disturbances. In this case, the charge offset can be

5 compensated for by the application of a corresponding compensation potential. Preferably, the sensor device for detecting the charge offset has a sampling frequency (sampling rate) that is greater than the pulse frequency of the radiation source. The sampling frequency of the sensor device is in particular at least double the magnitude, in particular at least five times the

10 magnitude, in particular at least ten times the magnitude, of the pulse frequency of the radiation source. The compensation potential can thus be generated with substantially negligible delay and be applied to the optical device.

15 In accordance with a further aspect of the invention, the at least one means for reducing the radiation-induced influence on the positioning of the at least one optical device comprises at least one shielding element.

The shielding element is preferably arranged in the beam path upstream of

20 the optical device. In other words, it is arranged in the beam path in the region between the radiation source and the optical device. It serves for electrostatic shielding, in particular. It also leads to electrodynamic shielding. The shielding element comprises in particular a grating and/or a mask, in particular a metal sheet.

25 The shielding element is preferably composed of an electrically conductive material. It can be composed of metal, in particular. In the region of the optical device, the shielding element is substantially radiation-transmissive. It is designed and/or arranged in particular in such a way that it leads to at

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most negligible shading of the optical device. It is designed in particular as a grating. In this case, the grating dimensions are adapted to the dimensions of the optical devices. The grating webs are adapted in particular to the distances between adjacent micromirrors. They have in particular a

5 thickness which is smaller than the distance between adjacent micromirrors. The thickness of the grating webs is in particular at most half the magnitude, in particular at most 0.2 times the magnitude, in particular at most 0.1 times the magnitude, of the distance between adjacent mirrors of the optical component.

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The distance between adjacent grating webs corresponds in particular to the dimensions of the mirrors, wherein the distance between adjacent mirrors should be taken into account, of course.

15 The grating can be a simple grating having exclusively parallel grating bars. A grating having crossed grating bars, in particular grating bars oriented perpendicularly to one another, can also be involved. The grating structure can be adapted in particular to the arrangement of the micromirrors. It is possible, in particular, for the grating structure to

20 correspond precisely to the arrangement of the interspaces between the individual micromirrors.

In the region which lies in a projection in the direction of the optical axis outside the totality of the optical devices of the optical component, the

25 shielding element can be embodied in a planar fashion, that is to say in a closed fashion. It can be embodied in particular as a mask, in particular as a shielding plate, in said region.

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In accordance with one aspect of the invention, the at least one shielding element comprises a control device for the targeted application of an electrical potential to said at least one shielding element. The shielding by means of the shielding element, in particular by means of the grating can
5 be improved further as a result.

The shielding element is arranged in particular at a distance from the optical device which is at least equal to a side length or a diameter of the optical device.

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The shielding element is preferably electrically insulated from the remainder of the optical component, in particular from the optical device and/or the actuator device.

15 A further object of the invention is to improve a method for positioning an optical device.

This object is achieved by means of the features of Claim 8. The method is, in particular, a method for reducing the radiation-induced influence on the
20 positioning of a displaceable optical device. The method according to the invention improves in particular the stability and the precision of the positioning of the displaceable optical device.

The essential advantages are evident from the above description of the
25 optical component. In order to reduce the radiation-induced influence on the positioning of the displaceable optical device, provision is made in particular for applying an electrical bias or compensation potential to the at least one optical device and/or the at least one actuator device and/or the at least one shielding element. This can be a constant potential or a time-

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dependent potential. The potential can be adapted in particular to the dynamic range of the radiation source, in particular to the pulse frequency thereof.

- 5 Further objects of the invention are to improve an illumination optical unit and an illumination system for a projection exposure apparatus and a projection exposure apparatus comprising an illumination optical unit of this type.
- 10 These objects are achieved by means of the features of Claims 9 to 11.

The advantages are evident from the above-described advantages of the optical component.

- 15 The advantages of the optical component according to the invention are manifested particularly well with the use of an illumination system comprising an EUV radiation source having a generated used radiation in the range of 5 nm to 30 nm or a VUV radiation source having a used radiation in the range of less than 200 nm.

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A further object of the invention is to improve a method for producing a micro- or nanostructured component.

This object is achieved by means of the features of Claim 12.

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The advantages are evident from those described above.

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Further details and advantages of the invention will become apparent from the description of exemplary embodiments with reference to the drawings, in which:

- 5 Figure 1 schematically shows a microlithographic projection exposure apparatus with – illustrated in meridional section – an illumination optical unit and a projection optical unit;
- 10 Figure 2 schematically shows two mutually adjacent individual mirrors of an embodiment of one of the facet mirrors of the illumination optical unit according to Figure 1 in a sectional side view, wherein the individual mirror illustrated on the left in Figure 2 is illustrated in an
15 untilted neutral position and the individual mirror illustrated on the right in Figure 2 is illustrated in a position tilted by the actuator;
- Figure 3 shows a section according to line III – III in Figure 2,
20 wherein the line II-II indicates the direction of the section in Figure 2,
- Figure 4 shows a schematic illustration of the individual mirrors in accordance with Figure 2, in which illustration the
25 contact structures are highlighted,
- Figure 5 shows a schematic illustration of the individual mirrors in accordance with Figure 2, which illustration

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schematically illustrates the control device for applying an electrical bias potential to the individual mirrors,

5 Figure 6 shows a schematic illustration of the method for optimizing the bias potentials to be applied,

10 Figure 7 shows a schematic illustration of the method for the offline determination of the dynamic bias potentials to be applied,

15 Figure 8 shows a schematic illustration of the method for applying the bias potentials,

20 Figure 9 shows a schematic illustration of the method for a real-time adaptation of the bias potentials,

25 Figure 10 shows an illustration of the facet mirror with a shielding element, and

30 Figure 11 shows a plan view of the facet mirror in accordance with Figure 10.

35 Figure 1 schematically shows a microlithographic projection exposure apparatus 1 in a meridional section. An illumination system 2 of the projection exposure apparatus 1 has, besides a radiation source 3, an illumination optical unit 4 for exposing an object field 5 in an object plane 6. The object field 5 can be fashioned rectangularly or arcuately with an x/y aspect ratio of 13/1, for example. In this case, a reflective reticle (not illustrated in Figure 1) arranged in the object field 5 is exposed, said reticle bearing a struc-

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ture to be projected by the projection exposure apparatus 1 for the production of micro- or nanostructured semiconductor components. A projection optical unit 7 serves for imaging the object field 5 into an image field 8 in an image plane 9. The structure on the reticle is imaged onto a light-sensitive layer of a wafer arranged in the region of the image field 8 in the image plane 9, said wafer not being illustrated in the drawing.

The reticle, which is held by a reticle holder (not illustrated), and the wafer, which is held by a wafer holder (not illustrated), are scanned synchronously in the y-direction during the operation of the projection exposure apparatus 1. Depending on the imaging scale of the projection optical unit 7, it is also possible for the reticle to be scanned in the opposite direction relative to the wafer.

The radiation source 3 is an EUV radiation source having an emitted used radiation in the range of between 5 nm and 30 nm. This can involve a plasma source, for example a GDPP source (gas discharge produced plasma) or an LPP source (laser produced plasma). Other EUV radiation sources, for example those based on a synchrotron or on a free electron laser (FEL), are also possible.

A VUV radiation source, in particular for generating radiation having a wavelength of less than 200 nm, can also be involved.

EUV radiation 10 emerging from the radiation source 3 is concentrated by a collector 11. A corresponding collector is known for example from EP 1 225 481 A. Downstream of the collector 11, the EUV radiation 10 propagates through an intermediate focal plane 12 before it impinges on a field facet mirror 13. The field facet mirror 13 is arranged in a plane of the

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illumination optical unit 4 which is optically conjugate with respect to the object plane 6.

The EUV radiation 10 is hereinafter also designated as used radiation,
5 illumination light or as imaging light. The used radiation can also be VUV radiation, in particular having a wavelength of less than 200 nm.

Downstream of the field facet mirror 13, the EUV radiation 10 is reflected by a pupil facet mirror 14. The pupil facet mirror 14 lies either in the
10 entrance pupil plane of the illumination optical unit 7 or in a plane that is optically conjugate with respect thereto. The field facet mirror 13 and the pupil facet mirror 14 are constructed from a multiplicity of individual mirrors, which will be described in even greater detail below. In this case, the subdivision of the field facet mirror 13 into individual mirrors can be
15 such that each of the field facets, which by themselves illuminate the entire object field 5, is represented by exactly one of the individual mirrors. Alternatively, it is possible for at least some or all of the field facets to be constructed by a plurality of such individual mirrors. The same correspondingly applies to the configuration of the pupil facets of the pupil
20 facet mirror 14 respectively assigned to the field facets, which pupil facets can in each case be formed by a single individual mirror or by a plurality of such individual mirrors.

The EUV radiation 10 impinges on the two facet mirrors 13, 14 at an angle
25 of incidence which is less than or equal to 25° . Therefore, the EUV radiation 10 is applied to the two facet mirrors in the range of normal incidence operation. Application with grazing incidence is also possible. The pupil facet mirror 14 is arranged in a plane of the illumination optical unit 4 which constitutes a pupil plane of the projection optical unit 7 or is

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optically conjugate with respect to a pupil plane of the projection optical unit 7. With the aid of the pupil facet mirror 14 and an imaging optical assembly in the form of a transfer optical unit 15 having mirrors 16, 17 and 18 designated in the order of the beam path for the EUV radiation 10, the field facets of the field facet mirror 13 are imaged into the object field 5 in a manner superimposed on one another. The last mirror 18 of the transfer optical unit 15 is a mirror for grazing incidence ("grazing incidence mirror"). The transfer optical unit 15 together with the pupil facet mirror 14 is also designated as subsequent optical unit for transferring the EUV radiation 10 from the field facet mirror 13 toward the object field 5. The illumination light 10 is guided from the radiation source 3 toward the object field 5 by means of a plurality of illumination channels. Each of said illumination channels is assigned a field facet of the field facet mirror 13 and a pupil facet of the pupil facet mirror 14 disposed downstream thereof. The individual mirrors of the field facet mirror 13 and of the pupil facet mirror 14 can be tiltable by an actuator system, with the result that a change in the assignment of the pupil facets to the field facets and accordingly a changed configuration of the illumination channels can be achieved. This results in different illumination settings which differ in the distribution of the illumination angles of the illumination light 10 over the object field 5.

In order to facilitate the explanation of positional relationships, inter alia a global Cartesian xyz coordinate system is used hereinafter. The x-axis runs perpendicularly to the plane of the drawing toward the observer in Figure 1. The y-axis runs toward the right in Figure 1. The z-axis runs upward in Figure 1.

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Different illumination settings can be achieved by means of a corresponding tilting of the individual mirrors of the field facet mirror 13 and a corresponding change in the assignment of said individual mirrors of the field facet mirror 13 to the individual mirrors of the pupil facet mirror 14. Depending on the tilting of the individual mirrors of the field facet mirror 13, the individual mirrors of the pupil facet mirror 14 that are newly assigned to said individual mirrors are tracked if necessary by tilting such that an imaging of the field facets of the field facet mirror 13 into the object field 5 is once again ensured.

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The field facet mirror 13 in the form of a multi- or micro-mirror array (MMA) forms an optical assembly for guiding the used radiation 10, that is to say the EUV radiation beam. The field facet mirror 13 is embodied as a microelectromechanical system (MEMS). It has a multiplicity of individual mirrors 27 arranged in matrix-like fashion in rows and columns in an array. The individual mirrors 27 are designed to be tiltable by an actuator system, as will also be explained below. Overall, the field facet mirror 13 has approximately 100 000 of the individual mirrors 27. Depending on the size of the individual mirrors 27, the field facet mirror 13 can also have for example 1000, 5000, 7000 or else hundreds of thousands of individual mirrors 27, in particular at least 100 000 individual mirrors 27, in particular at least 300 000 individual mirrors 27, in particular at least 500 000 individual mirrors 27.

25 A spectral filter can be arranged upstream of the field facet mirror 13, that is to say between the radiation source 3 and the field facet mirror 13, said spectral filter separating the used radiation 10 from other wavelength components – not usable for the projection exposure – of the emission of the radiation source 3. The spectral filter is not illustrated.

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Used radiation 10 having a power of 840 W and a power density of 6.5 kW/m² is applied to the field facet mirror 13. Generally, other powers and power densities are also possible. The power density is at least
5 500 W/m², in particular at least 1 kW/m², in particular at least 5 kW/m², in particular at least 10 kW/m², in particular at least 60 kW/m².

The entire individual-mirror array of the facet mirror 13 has a diameter of 500 mm and is designed in a manner closely packed with the individual
10 mirrors 27. The individual mirrors 27 represent, insofar as a field facet is realized by in each case exactly one mirror element, apart from a scaling factor, the form of the object field 5. The facet mirror 13 can be formed from 500 individual mirrors 27 respectively representing a field facet and having a dimension of approximately 5 mm in the y-direction and 100 mm
15 in the x-direction. As an alternative to the realization of each field facet by exactly one individual mirror 27, each of the field facets can be approximated by groups of smaller individual mirrors 27. A field facet having dimensions of 5 mm in the y-direction and of 100 mm in the x-direction can be constructed e.g. by means of a 1 × 20 array of individual mirrors 27 hav-
20 ing the dimensions of 5 mm × 5 mm through to a 10 × 200 array of individual mirrors 27 having the dimensions of 0.5 mm × 0.5 mm. The area coverage of the complete field facet array by the individual mirrors 27 can be at least 70%, in particular at least 80%, in particular at least 90%.

25 The used light 10 is reflected from the individual mirrors 27 of the facet mirror 13 toward the pupil facet mirror 14. The pupil facet mirror 14 has approximately 2000 static pupil facets. The latter are arranged in a plurality of concentric rings alongside one another, such that the pupil facets of the innermost ring are configured in sector-shaped fashion and the pupil facets

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of the rings directly adjacent thereto are configured in ring-sector-shaped fashion. In a quadrant of the pupil facet mirror 14, pupil facets can be present alongside one another in each of the rings 12. The pupil facets can be embodied in each case in a simply connected fashion. An arrangement
5 of the pupil facets that deviates therefrom is likewise possible. They can also be formed from a multiplicity of individual mirrors 27.

The used light 10 is reflected from the pupil facets toward a reflective reticle 30 arranged in the object plane 6. The projection optical unit 7 then
10 follows, as explained above. The individual mirrors 27 of the field facet mirror 13 and of the pupil facet mirror 14 bear multilayer coatings for optimizing their reflectivity at the wavelength of the used radiation 10. The temperature of the multilayer coatings should not exceed 425 K during the operation of the projection exposure apparatus 1.

15 The construction of the individual mirrors is explained by way of example below with reference to Figures 2 and 3. For further details of the construction of the individual mirrors 27 and the displaceability thereof, reference should be made to WO 2010/049 076 A1. Said document is
20 incorporated within its full scope in the present application as part thereof.

The individual mirrors 27 of the illumination optical unit 4 are accommodated in an evacuable chamber 32, of which a boundary wall 33 is indicated in Figure 2. The chamber 32 communicates with a vacuum
25 pump 31 via a fluid line 26, in which a shutoff valve 28 is accommodated.

The operating pressure in the evacuable chamber 32 is a few Pa (particular pressure H_2). The partial pressure of hydrogen is in particular at most 50 Pa, in particular at most 20 Pa, in particular at most 10 Pa, in

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particular at most 5 Pa. All other partial pressures are distinctly below 1×10^{-7} mbar. The chamber 32 can be evacuated in particular to high vacuum or ultra-high vacuum.

- 5 The mirror having the plurality of individual mirror 27, together with the evacuable chamber 32, is part of an optical component for guiding a beam of the EUV radiation 10. The individual mirror 27 can be part of one of the facet mirrors 13, 14.
- 10 Each of the individual mirrors 27 can have an impingable reflection surface 34 having dimensions of 0.5 mm $\times$ 0.5 mm or else of 5 mm $\times$ 5 mm or greater. The reflection surface 34 is part of a mirror body 35 of the individual mirror 27. The mirror body 35 bears the multilayer coating. The individual mirrors 27 or the reflection surface 34 thereof can also have
- 15 other dimensions. They are embodied as tiles, in particular, with which a two-dimensional area can be tiled. They are embodied in particular as triangular, quadrilateral, in particular square, or hexagonal. Their side lengths have in particular dimensions of at most 10 mm, in particular at most 5 mm, in particular at most 3 mm, in particular at most 1 mm, in
- 20 particular at most 0.5 mm, in particular at most 0.3 mm, in particular at most 0.1 mm. In particular, micromirrors can thus be involved. The latter should be understood to mean in particular mirrors having dimensions in the micrometers range.
- 25 The reflection surfaces 34 of the individual mirrors 27 complement one another to form a total mirror reflection surface of the field facet mirror 13. Correspondingly, the reflection surfaces 34 can also complement one

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another to form the total mirror reflection surface of the pupil facet mirror 14.

A carrying structure 36 or a substrate of the individual mirror 27 is
5 mechanically connected to the mirror body 35 via a heat conducting section 37 (cf. Figure 2). Part of the heat conducting section 37 is a flexure body 38 that permits the mirror body 35 to be tilted relative to the carrying structure 36. The flexure body 38 can be embodied as a flexure that permits the mirror body 35 to be tilted about defined degrees of freedom of tilting,
10 for example about one or about two tilting axes. The flexure body 38 has an outer holding ring 39 fixed to the carrying structure 36. Furthermore, the flexure body 38 has an inner holding body 40 connected to the holding ring 39 in an articulated manner. Said holding body is arranged centrally below the reflection surface 34. A spacer 41 is arranged between the central
15 holding body 40 and the mirror body 35.

The carrying structure 36 has cooling channels, through which an active cooling fluid is passed. For further details of the carrying structure 36 and in particular the thermal budget thereof, reference should again be made to
20 WO 2010/049 076 A1. Alternative embodiments of the flexure body 38 are known in particular from WO 2010/049 076 A1.

On that side of the holding body 40 which faces away from the spacer 41, an actuator pin 43, which continues the spacer 41 with a smaller external
25 diameter, is mounted on said holding body.

The carrying structure 36 is configured as a sleeve surrounding the actuator pin 43. The carrying structure 36 can be a silicon wafer, for example, on

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which is arranged an entire array of individual mirrors 27 of the type of the individual mirror 27 shown in Figure 2.

The individual mirrors 27 are each displaceable, that is to say positionable,
5 by means of an actuator device 50 having a plurality of
electromagnetically, in particular electrostatically, operating actuators. The
actuators can be produced in a batch process as a microelectromechanical
system (MEMS). For details, reference should again be made to
WO 2010/049 076 A1.

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A sum of the areas of the reflection surfaces 34 on the mirror bodies 35 is
greater than 0.5 times a total surface area occupied by the total reflection
surface area of the field facet mirror 13. In this case, the total surface area
is defined as the sum of the areas of the reflection surfaces 34 plus the area
15 occupied by the interspaces between the reflection surfaces 34. A ratio of
the sum of the areas of the reflection surfaces of the mirror bodies, on the
one hand, in relation to said total surface area is also designated as the
integration density. This integration density can also be greater than 0.6, in
particular greater than 0.7, in particular greater than 0.8, in particular
20 greater than 0.9.

With the aid of the projection exposure apparatus 1, at least one part of the
reticle 30 is imaged onto a region of a light-sensitive layer on the wafer for
lithographically producing a micro- and/or nanostructured component, in
25 particular a semiconductor component, e.g. a microchip. Depending on the
embodiment of the projection exposure apparatus 1 as a scanner or as a
stepper, the reticle 30 and the wafer are moved in a temporally
synchronized manner in the y-direction continuously in scanner operation
or step by step in stepper operation.

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The optical component in accordance with Figure 2 is preferably operated in high vacuum or ultra-high vacuum. In this case, a plasma 45, in particular a hydrogen plasma, can form in the region upstream of the individual mirrors 27, in particular upstream of the mirror bodies 35 having the reflection surfaces 34. The plasma 45 can be generated in particular by high-energy photons of the used radiation 10. The properties of the plasma 45 are thus dependent in particular on the properties of the radiation source 3, in particular the operating mode thereof, in particular the pulse frequency and/or pulse duration and/or intensity thereof, and the atmosphere in the chamber 32.

Three electrodes 62, 63, 64 are integrated in the sleeve of the carrying structure 36, which electrodes are arranged in a manner electrically insulated from one another and extending over approximately just less than 120° in each case in a circumferential direction around a center 59 of the actuator pin 43. The electrodes 62 to 64 constitute counterelectrodes with respect to the actuator pin 43, which is embodied as an electrode pin. The electrodes 62, 63, 64 are parts of an actuator device 50.

The actuator pin 43 can be embodied as a hollow cylinder. In a further embodiment of the actuator device 50, there can also be two, four or more electrodes instead of the three electrodes 62 to 64. The electrodes 62 to 64 can respectively interact with their matched electrodes 62' to 64' on the actuator pin 43.

In Figure 2 on the right, the individual mirror 27 is shown in a tilted position in which the counterelectrode 64 is connected at a positive potential V^+ relative to the negative potential V^- of the actuator pin 43. On

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account of this potential difference $V+/V-$, a force F_E arises, which draws the free end of the actuator pin 43 toward the counterelectrode 64, which leads to a corresponding tilting of the individual mirror 27. In this case, the resilient suspension provides for a compliant and controlled tilting of the individual mirror 27. Moreover, this resilient suspension provides for a high stiffness of the individual mirror 27 in relation to translational movements in the plane of the resilient suspension, which is also designated as high in-plane stiffness. This high stiffness completely or largely suppresses an undesired translational movement of the actuator pin 43, that is to say of the electrode pin, in the direction toward the electrodes 62 to 64. An undesired reduction of a possible tilting angle range of the actuator pin 43 and thus of the mirror body 35 is avoided in this way.

Depending on the choice of the relative potential of the counterelectrodes 62 to 64 with respect to the potential of the associated electrode 62' to 64' of the actuator pin 43, the individual mirrors 27 can be tilted by a predefined tilting angle. In this case, not just tilting angles which correspond to an inclination of the actuator pin 43 exactly toward one of the three counterelectrodes 62 to 64, but also, depending on a predefined potential combination of the counterelectrodes 62 to 64, any other tilting angle orientations are possible.

With regard to a method for producing the optical component and the actuator device 50 and the associated electronics for driving the actuator device 50 and the constructional details of said electronics, in particular of the corresponding control device, reference should again be made to WO 2010/049 076 A1. The control device for the actuator device 50 is integrated in particular into one or a plurality of application specific integrated circuits (ASICs) 60, which are merely illustrated schematically

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in Figure 2. An exemplary illustration of the contact structures, in particular of the electrical connections 65 for the actuator device 50, in particular the electrodes 62 to 64 and 62' to 64', is reproduced in Figure 4. This also schematically indicates that the contact structures are electrically
5 insulated from the carrying structure 36 by an insulation layer 66.

Further details of the facet mirror 13, 14 embodied as a multi-mirror array (MMA) are described below.

10 The multi-mirror arrangement (MMA) is produced by a sequence of microelectromechanical structuring steps (MEMS), in particular using lithographic method steps, such as, for example, etching, deposition, bonding or molding. It is produced in particular from a number of individual wafers which are bonded to one another after processing.

15

The individual mirrors 27 embodied as micromirrors are suspended on microscopic bending structures. The latter can be cut out or etched out from a thin silicon wafer or from a metallic membrane or the like. The bending structures can be embodied in particular two-dimensionally, that is
20 to say in a membrane-like fashion, or in a beam-type or cardan-type fashion.

The actuator is preferably electrostatic or electromechanical. Alternatives thereto are likewise possible, however.

25

The individual mirrors 27 can be pivoted by at least 80 mrad, in particular at least 100 mrad, in any radial direction.

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The number of individual mirrors 27 of the multi-mirror array (MMA) is in the range of 1 to 1 000 000. It can also be more than that, in principle. It can be chosen freely, in principle, depending on the requirement. The total number of individual mirrors 27 of the facet mirror 13, 14 can be in particular in the millions.

The electrical connections, in particular the circuits, can be produced as follows: the horizontally running electrical connections, that is to say those running in a direction parallel to a wafer surface, can be applied as thin metallic layers to the surface of the individual wafers. A printing or vapor deposition method can be provided for this purpose. The vertical electrical connections, that is to say the connections extending through the wafers, for example the carrying structure 36, can be produced by etching channels and/or opening and filling the same with metal, for example as so-called silicon plated-through holes. An MEMS method can be provided for this purpose, too.

An electronic control device 67 for control, in particular for closed loop control of the actuator device 50, is arranged on the rear side of the optical component, that is to say on the opposite side of the individual mirrors 27 relative to the reflection surface 34 thereof. The control device 67 comprises in particular the ASICs 60 already mentioned. The control device 67 is electrically conductively connected via the electrical connections 65 to the electrodes 62 to 64, 62' to 64' of each of the individual mirrors 27 or of the actuator device 50. The control device 67 can be embodied in an embedded fashion, in particular as a microscopically embodied integrated circuit (IC) or as a separate, external component. For details of how the electrical connections between the multi-mirror array, in particular between the actuator device 50 and the

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control device 67, are produced, reference should again be made to WO 2010/049 076 A1.

The optical component is operated in particular in the chamber 32 with
5 reduced pressure. The residual gas in the chamber 32 has a partial pressure of at most 50 Pa, in particular at most 30 Pa, in particular at most 10 Pa, preferably at most 5 Pa, during the operation of the projection exposure apparatus 1, in particular during the operation of the illumination system 2. The gas can be in particular hydrogen, helium or argon. Other gases are
10 also possible, in principle.

The surfaces of the actuator electrodes 62 to 64, 62' to 64' have to be shielded from the electrically charged plasma 45. This is achieved firstly by means of the mirror bodies 35 arranged between the plasma 45 and the
15 actuator electrodes 62 to 64, 62' to 64'. Moreover, as is illustrated schematically in Figure 5, a specific shielding element can be arranged in the region between the mirror bodies 35 and the actuator electrodes 62 to 64, 62' to 64'. This functionality can likewise be fulfilled by a corresponding embodiment of the holding elements 40. The shielding
20 element 68 can be embodied in a membrane-like, net-like or grating-like fashion. In the case of a net-like or grating-like embodiment, the free width is a maximum of 10 μm . It is also possible to arrange the individual mirrors 27 in such a way that their mutual distance d_m is less than 10 μm in particular less than 5 μm . In this case, it is possible, in principle, to
25 dispense with the shielding element 68 between the mirror body 35 and the actuator electrodes 62 to 64, 62' to 64'.

Moreover, precautions can preferably be taken to ensure that no stray light is incident on the surface of the actuator electrodes 62 to 64, 62' to 64'.

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The electronic control device 67 serves in particular for controlling the actuator device 50 having the actuator electrodes 62 to 64', 62' to 64'. It can be embodied as an open-loop control device or as a closed-loop control
5 device. In the latter case, it comprises a local and/or an external monitoring system, that is to say a sensor device, by means of which the displacement state, in particular the tilting, of each of the individual mirrors 27 can be monitored.

10 Moreover, a so-called bias potential V_{Bias} can be applied to the mirror body 35 itself by means of the control device 67. The supply leads required for this purpose can be integrated into the carrying structure 36 and into the flexure body 38. The bias potential V_{Bias} can be a constant potential, in particular in the range of -10 V to +10 V. The bias potential V_{Bias} can be set
15 in particular with an accuracy of a few mV or better. A voltage source 69, in particular a controllable voltage source 69, is provided for applying the bias potential V_{Bias} to the mirror bodies 35 of the individual mirrors 27. The voltage source 69 has a time constant, in particular a response time, which is shorter than the reciprocal of the pulse frequency of the radiation source
20 3.

By applying the potential to the mirror body 35 of the individual mirror 27, it is possible to prevent charges from the plasma 45 from being transferred to the mirror body 35. The charge transfer from the plasma 45 to the mirror
25 body 35 can at least be reduced by the application of the bias potential V_{Bias} to said mirror body. It is possible, in particular, to choose and set the exact value of the bias potential V_{Bias} in such a way that the charge transfer from the plasma 45 to the mirror body 35 of the individual mirror 27 is minimized. The bias potential V_{Bias} can also serve to compensate for the

losses of charge from the mirror surface into the surroundings, said losses occurring on account of the photoelectric effect. For this purpose, the bias potential V_{Bias} can be adapted to the operating conditions, in particular to the operating conditions of the radiation source 3, in particular the pulse
5 duration, pulse frequency and intensity thereof, and the atmosphere in the chamber 32. The control device 67 advantageously has a look-up table for this purpose. The method for setting the bias potential V_{Bias} is described in even greater detail below.

10 In accordance with the embodiment illustrated in Figure 5, moreover, a sensor device 70 is provided, by means of which the current flowing away from the plasma 45 through an individual mirror 27 is detectable. The current is dependent on a mirror potential, the V_{Mirror} , generated by a charge transfer from the plasma 45 to the mirror body 35, and the internal
15 electrical resistance between the mirror 27 and the control device 67 or a grounding. The current flow from the plasma 45 through the mirror 27 can be reduced, in particular minimized, in particular eliminated, by suitable setting of the bias voltage V_{Bias} to be applied to the mirror 27 by means of the control device 67 via the voltage source 69.

20 The sensor device 70 is preferably designed in such a way that it can detect the current respectively flowing away through the mirror 27 at any mirror potential V_{Mirror} occurring during the operation of the illumination system 2, with a resolution in the nanoamperes range.

25 In order to simplify the sensor system, it is also possible to provide a plurality of individual mirrors 27 together with a single sensor device 70. In this case, the sensor device 70 can detect either the average value or the sum or an individual value of the current flowing away through the mirrors

27. The sensor device 70 can be connected for example to two, three, four, six, nine or more individual mirrors 27.

The current measurement by means of the sensor device 70 can be effected
5 in particular with the aid of a voltage drop across a known resistor. The resistor can be integrated in particular into the MMA structure. It can be embodied for example as a resistive film with circuit connections. The resistor can preferably be integrated as near as possible to the coating of the mirror 27, in particular into said coating. For the further processing, the
10 voltage drop can be read out and converted into a current value.

The sensor device 70 can be connected to an electrical interface 71 in a data-transferring manner. For its part, the electrical interface 71 can be connected in a data-transferring manner firstly to the control device 67, and
15 secondly to an external open-loop or closed-loop control device 72. The external control device 72 can comprise software or hardware components.

The bias potential V_{Bias} to be applied to the individual mirrors 27 can be determined experimentally. It can be determined in particular offline, in
20 particular before the illumination system 2 is started up. In particular, a look-up table can be created for this purpose. A method for creating such a look-up table is illustrated schematically in Figure 6. Firstly, in a providing step 73, an illumination system 2 is provided. The illumination system 2 is brought in particular to a state ready for operation. For this purpose, by
25 way of example, the chamber 32 is at least partly evacuated by means of the vacuum pump 31. In an actuating step 74, the individual mirrors 27 are then brought to the desired position, that is to say positioned, by means of targeted activation of the actuator device 50. Afterward, in a repeated measuring method 75, firstly, a bias potential V_{Bias} is applied to the

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individual mirror 27 in an applying step 76, the voltages applied to the actuator electrodes 62 to 64, 62' to 64' are adapted in a compensation step 77, the radiation source 3 is activated in an activation step 78, and the current flowing through the individual mirror 27 is measured in a
5 measuring step 79.

The compensation step 77 serves for adapting the actuation voltages in order to reestablish the positioning of the individual mirror 27 as set in the actuating step 74 after the bias voltage V_{Bias} has been applied to said
10 individual mirror in the applying step 76. The application of the bias voltage V_{Bias} to the individual mirror 27 generally necessitates such a compensation.

The measuring method 75 is repeated for different values of the bias
15 potential V_{Bias} . In principle, the measuring method 75 can also be repeated for different positioning of the individual mirrors 27. Moreover, the measuring method 75 can be repeated for different operating modes of the radiation source 3.

20 The optimum value, for the respective conditions, of the bias potential V_{Bias^*} to be applied to the individual mirror 27 is subsequently determined in an optimization step 80. The optimization step 80 can comprise an interpolation step.

25 According to the invention it has been found that the optimized bias potentials V_{Bias^*} depend for example on the pulse frequency of the radiation source 3. The optimized bias potential V_{Bias^*} increases in particular as the frequency of the radiation source 3 increases. The optimized bias potential V_{Bias^*} is determined with an accuracy of 10 mV or better. According to the

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invention it has been found that the disturbance caused by the plasma 45, that is to say the radiation-induced influence on the positioning of the individual mirror 27, could be reduced to a tilting of less than 10 μ rad.

- 5 The above-described calibration method for determining the optimized bias voltage V_{Bias^*} can preferably be performed in a fully automated manner. It can be carried out in particular independently at a predefined point in time. It can be carried out in particular at regular intervals. It is possible, in particular, to adapt the optimized bias voltages V_{Bias^*} to slow, long-term
- 10 changes in the radiation source 3, in particular the intensity thereof. Advantageously, the devices necessary for the calibration method, in particular the electronic devices, are integrated, in particular embedded, into the MMA. The optimized bias potentials V_{Bias^*} are in particular in the range of -10 V to +10 V, in particular in the range of -5 V to +5 V.

- 15 By applying the bias voltage V_{Bias} to the individual mirrors 27, it is possible to reduce, in particular minimize, in particular eliminate, the interaction between individual mirrors 27 or the actuator device 50 thereof and the surroundings thereof, in particular the plasma 45. In order to
- 20 address dynamic aspects of the activation of the radiation source 3, preferably a dynamic control, in particular a time-dependent control, can also be provided. This is advantageous in particular if the radiation source 3 is operated in a pulsed manner. A dynamic control of the bias potential V_{Bias} or generally of the means for reducing the radiation-induced influence
- 25 on the positioning of the individual mirror 27 is advantageous in particular if the electrical properties of the surroundings of the mirrors 27 or of the actuator device 50 are variable, in particular if said properties vary during the operation of the radiation source 3, in particular between two pulses thereof. Dynamic, in particular transient, effects can occur even after the

radiation source 3 is switched on or after a relatively long pause. By way of example, time-dependent variations of the plasma 45 can also occur in the interval between the exposure of two wafers. In order to be able to take account of such a time-dependent variation of the plasma 45, provision can
5 be made for measuring the current flowing away via the individual mirror 27 by means of the sensor device 70 and for determining from the measured current a time-dependent compensation potential $V_{\text{Bias}}(t) = V_{\text{Comp}}$, which, when said potential is applied to the individual mirror 27, leads to a reduction, in particular to a minimization, in particular to an
10 elimination, of the current flowing away through the individual mirror 27.

In order that the measured current reproduces as well as possible the dynamic range of the electrical interaction between the individual mirror 27 and the surroundings thereof, the mirror 27 and the sensor device 70 are
15 embodied in such a way that the characteristic time constant of the corresponding equivalent circuit is significantly shorter than the characteristic time of the external electrical disturbances. The time constant of the equivalent circuit of the individual mirror 27 or of the MMA is in particular shorter than 100 msec, in particular shorter than 30 msec, in
20 particular shorter than 10 msec, in particular shorter than 3 msec, in particular shorter than 1 msec, in particular shorter than 0.3 msec, in particular shorter than 0.1 msec, in particular shorter than 10^{-5} sec, in particular shorter than 10^{-6} sec.

25 As is illustrated schematically in Figure 7, the compensation potential V_{Comp} can be determined offline. In this case, in particular each individual mirror 27 can be calibrated in accordance with the flow chart illustrated schematically in Figure 7. For the purpose of calibration, in particular a providing step 73 is again provided, in which the illumination system 2 is

- provided and brought to operating conditions. By way of example, the chamber 32 can again be evacuated by means of the vacuum pump 31. Afterward, provision is again made for displacing the individual mirrors 27 in an actuating step 74, that is to say for positioning said individual mirrors, that is to say for bringing them to the desired position by the activation of the actuator device 50. The radiation source 3 is then activated in an activation step 78. This is followed by the determination of the compensation potential $V_{\text{Comp}} = V_{\text{Bias}}(t)$. The determination comprises a measuring step 79 and a calculating step 81. The temporal profile of the current flowing away via the mirror 27 can be measured in the measuring step 79. From these measurement data, the temporal profile of the desired compensation voltage $V_{\text{Comp}} = V_{\text{Bias}}(t)$ is determined in the calculating step 81. In a subsequent storage step 82, the function $V_{\text{Bias}}(t)$ is stored in free form or in a parameterized fashion.
- V_{Comp} can be a periodic function. It can have in particular the same periodicity as the radiation source 3. It can also have higher frequency components. It can also have a transient component, in particular for the interval directly after the radiation source 3 is switched on. It can also have a transition region that takes account of the time duration until the radiation source 3 has reached steady-state conditions. In principle, the function $V_{\text{Bias}}(t)$ can also be calculated for the entire duration of the activation of the radiation source 3.
- For a correction during the operation of the illumination system, provision is made for applying the compensation voltage $V_{\text{Comp}} = V_{\text{Bias}}(t)$ to the individual mirror 27. The required time dependence of the compensation potential to be applied can be generated with the aid of electronic devices, for example function generators, amplifiers, inverters. The devices can be

digital or analog. An external electronic open-loop or closed-open control device or an internal electronic open-loop or closed-loop control device, that is to say one which is integrated into the MMA, can be provided for generating the compensation potential V_{Comp} and/or for applying the latter to the individual mirror 27.

As is illustrated schematically in Figure 8, the function of the compensation potential $V_{\text{Comp}} = V_{\text{Bias}}(t)$ is directed from a storage device 83 to a function generator 84. The function generator 84 is synchronized with the radiation source 3 by means of a synchronization unit. The synchronization unit 85 can be triggered in particular by the radiation source 3. The signal generated by the function generator 84 is forwarded to a voltage amplifier 86. The voltage amplifier 86 is electrically conductively connected to the individual mirror 27. In particular, an electrical connection 65 is provided for this purpose.

In one advantageous embodiment, the control device 67 is fast enough to detect the current through the mirror 27 and to calculate and generate the compensation potential $V_{\text{Comp}} = V_{\text{Bias}}(t)$ in real time. In this embodiment, the compensation potential is calculated with a clock rate that is greater than the pulse frequency of the radiation source 3. The clock rate for calculating the compensation potential V_{Comp} is in particular at least double the magnitude, in particular at least 5 times the magnitude, in particular at least 10 times the magnitude, in particular at least 20 times the magnitude, in particular at least 50 times the magnitude, of the pulse frequency of the radiation source 3.

Part of the method for a real-time correction is illustrated schematically in Figure 9. In this case, the current through the mirror 27 is measured by

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means of a closed-loop control unit in the measuring step 79. The measured value is then present as an analog signal 87. The analog signal 87 is forwarded to an analog-to-digital converter (ADC) 88 and is then present as a digital real-time sample 89. The required compensation potential

5 $V_{\text{Comp}} = V_{\text{Bias}}(t)$ can be determined from said sample 89 in the calculating step 81. The determination can be effected in particular in a software-based manner. The correction value determined in this way is forwarded to a digital-to-analog converter (DAC) 90. The digital-to-analog converter 90 generates an analog signal $V_{\text{Bias}}(t)$ in real time and forwards said signal to

10 the voltage amplifier 86, from where the signal is in turn forwarded to the mirror 27.

In addition thereto, it is possible to adapt the actuator voltage applied to the actuator electrodes 62 to 64, 62' to 64'. This can be advantageous in

15 particular if the average value of the compensation potential V_{Comp} is not equal to zero. The actuator voltages can be adapted in particular in such a way that the voltage differences between the mirror 27 and the actuator electrodes 62 to 64, 62' to 64' are not influenced by the application to the mirror 27, but rather remain constant over time.

20

A further embodiment of a means for reducing a radiation-induced influence on the positioning of the individual mirrors 27 is described below with reference to Figures 10 and 11.

25 The basic construction of the multi-mirror array (MMA) comprising a multiplicity of individual mirrors 27 corresponds to the exemplary embodiment in accordance with Figure 2, to the description of which reference is hereby made.

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In the case of the embodiment in accordance with Figure 10, the facet mirror 13, which serves as a concrete example of the optical component according to the invention, comprises a shielding element 91. The shielding element 91 comprises a grating 92. The grating 92 can be surrounded
5 marginally by a mask in the form of a metal sheet 93. The grating 92 serves for electrostatically shielding the individual mirrors 27 and the underlying electronics, in particular the ASICs 60.

The grating 92 is composed of an electrically conductive material. The
10 metal sheet 93 surrounding the grating 92 is also composed of an electrically conductive material.

The grating 92 is geometrically adapted to the embodiment of the individual mirrors 27 and the arrangement thereof relative to one another.
15 The individual grating webs form in particular meshes having a width w corresponding to the side length l of the individual mirrors 27 increased by the distance d_m between two adjacent individual mirrors 27 and reduced by the thickness d_g of the grating webs.

20 The grating 92 is arranged at a distance from the individual mirrors 27. It is arranged in particular in the region between the radiation source 3, in particular between the plasma 45, and the individual mirrors 27. It is arranged at a distance h upstream of the individual mirrors 27. In this case, the following holds true:

25 $h \geq l + d_m$. The grating 92 is arranged relative to the individual mirrors 27 in particular in such a way that its image in the case of a normal projection in the direction of the optical axis on the mirrors 13 is incident in the region between the individual mirrors 27 (see Figure 11). The thickness d_g of the grating webs is in particular less than the distance d_m between two adjacent

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individual mirrors 27. The following holds true, in particular: $d_g \leq 0.5 d_m$, in particular $d_g \leq 0.3 d_m$, in particular $d_g \leq 0.2 d_m$, in particular $d_g \leq 0.1 d_m$, in particular $d_g \leq 0.05 d_m$, in particular $d_g \leq 0.03 d_m$, in particular $d_g \leq 0.02 d_m$, in particular $d_g \leq 0.01 d_m$.

5

The grating 92 is held by means of spacers 94 relative to the multi-mirror array (MMA) having the individual mirrors 27. The spacers 94 have a diameter d_a that is less than the distance d_m between two adjacent individual mirrors 27. The following holds true, in particular: $d_a \leq 0.5 d_m$.

10

The spacers 94 are led through the carrying structure 36. They are led through the carrying structure 36 in particular in through openings. The spacers 94 are electrically insulated in particular from the rest of the carrying structure 36.

15

The spacers 94 are fitted to the carrying structure 36 in the region between the individual mirrors 27. They are designed and arranged in such a way that they do not influence the displacement, in particular the tilting, of the individual mirrors 27.

20

The grating 92 is designed in particular in such a way that it does not lead to any shading of the used radiation 10 from the radiation source 3 upon the impingement thereof on the individual mirrors 27.

25 Moreover, the grating 92 is designed in particular in such a way that diffraction effects thereof on the used radiation 10 are negligible.

At least one of the spacers 94 is embodied as a contact pin 94*. It is composed of an electrically conductive material. The contact pin 94* is

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electrically conductively connected to a voltage source 95. For its part, the voltage source 95 is controllable by means of a control device 96.

- Via the contact pin 94*, an electrical shielding potential V_{Grating} can be
- 5 applied to the grating 92. The value of the shielding potential applied to the grating 92 is controllable by means of the control device 96. It is in the range of -100 V to +100 V, in particular. It is preferably relatively low, that is to say more negative than -10 V.
- 10 In order to ensure good results, the following values of the shielding voltage are preferred: a shielding voltage of more negative than -10 V for individual mirrors 27 having a side length l of 600 μm given a thickness d_g of 20 μm and a distance d_m of less than 100 μm . A shielding voltage of more negative than -30 V for individual mirrors 27 having a side length l of
- 15 1 mm given a thickness d_g of 20 μm and a distance d_m of less than 100 μm . For individual mirrors 27 having a side length l of less than 1 mm and a grating 92 with d_g less than 100 μm , negative potentials of up to -100 V have brought about effective shielding.
- 20 The shielding potential V_{Grating} to be applied to the grating 92 can be defined before the operation of the illumination system 2. It can also be determined experimentally. It can be determined and set in particular during the operation of the illumination system 2.
- 25 With the aid of the shielding element 91 it is possible to prevent free electrons or ions from the plasma 45, which can lead to a disturbance of the positioning of the individual mirrors 27, from being able to pass to the individual mirrors 27 and/or the actuator device 50.

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While in Figure 10 the grating 92 is embodied as a two-dimensional grating having a mesh structure, it is also possible for the grating 92 to be embodied as a one-dimensional grating in which all the grating webs run parallel to one another.

5

While the grating 92 in the embodiment in accordance with Figure 10 is connected to the carrying structure 36, it can also be embodied as a separate device, independently of the multi-mirror array. It can be arranged in particular as a separate device in an adjustable manner in the beam path upstream of the mirror 13.

10

A further means for reducing a radiation-induced influence on the positioning of the individual mirrors 27 consists in applying a bias voltage to the actuator device 50, in particular the actuator electrodes 62 to 64, 62' to 64'.

15

Preferably, in each case two, three or more of the actuator electrodes 62 to 64, 62' to 64' are arranged and/or connected to the control device 67 in such a way that they can be operated differentially. The bias voltage is correspondingly applied to at least two of the actuator electrodes 62 to 64, 62' to 64' in such a way that the effects of the bias voltage on the positioning of the individual mirrors 27 in each case mutually compensate for one another.

20

According to the invention it has been recognized that, by applying the bias voltage, it is possible to reduce the effective elasticity constant of the individual mirrors 27 in the sense of an excitable mechanical system, in particular in the sense of an excitable oscillator. Likewise, by applying a bias voltage, it is possible to reduce the resonant frequency of the

25

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individual mirrors 27. In other words, the application of the bias voltage leads to an improved damping of the individual mirrors 27.

5 The applied bias voltage can be constant, in particular. Its amplitude is in particular at least equal to the maximum actuation voltage provided for pivoting the individual mirrors 27.

For the purpose of applying the bias voltage to the actuator electrodes 62 to 64, 62' to 64', the control device 67 can have a separate voltage source.

10 This can be a DC voltage source.

The different means for reducing a radiation-induced influence on the positioning of the individual mirrors 27 can also be combined with one another.

Patent Claims

1. Optical component (13; 14) comprising
 - a. at least one optical device (27),
 - 5 b. at least one actuator device (50) for displacing the at least one optical device (27), and
 - c. at least one means for reducing a radiation-induced influence on and/or a dynamic disturbance of the positioning of the at least one optical device (27).
- 10 2. Optical component (13; 14) according to Claim 1, **characterized in that** the at least one means for reducing a radiation-induced influence on the positioning of the at least one optical device (27) comprises a control device (67) for the targeted application of an electrical bias
15 potential (V_{Bias}) to the at least one optical device (27) and/or for the targeted application of an electrical bias voltage to the at least one actuator device (50).
- 20 3. Optical component (13; 14) according to Claim 2, **characterized in that** the control device (67) has a look-up table for determining the bias potential (V_{Bias}) to be applied to the at least one optical device (27).
- 25 4. Optical component (13; 14) according to either of Claims 2 and 3, **characterized in that** the control device (67) is embodied as a closed-loop control device with at least one sensor (70).
5. Optical component (13; 14) according to any of the preceding claims, **characterized in that** the at least one means for reducing a radiation-

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induced influence on the positioning of the at least one optical device (27) comprises at least one shielding element (91).

- 5 6. Optical component (13; 14) according to Claim 5, **characterized in that** the at least one shielding element (91) comprises a grating (92) and/or a mask (93).
- 10 7. Optical component (13; 14) according to either of Claims 5 and 6, **characterized in that** the at least one shielding element (91) comprises a control device (96) for the targeted application of an electrical potential to said at least one shielding element.
- 15 8. Method for positioning at least one optical device (27) comprising the following steps:
 - 15 a. providing an optical component (13; 14) according to any of Claims 1 to 7,
 - b. applying an electrical potential to the at least one optical device (27) and/or the at least one actuator device (50) and/or at least one shielding element (91).
- 20 9. Illumination optical unit (4) for a projection exposure apparatus (1) comprising at least one optical component (13; 14) according to any of Claims 1 to 7.
- 25 10. Illumination system (2) comprising
 - a. an illumination optical unit (4) according to Claim 9 and
 - b. a radiation source (3).

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11. Projection exposure apparatus (1) comprising an illumination optical unit (4) according to Claim 9.

12. Method for producing a micro- or nanostructured component

5 comprising the following steps:

- providing a wafer, to which a layer composed of a light-sensitive material is at least partly applied,
 - providing a reticle (30) having structures to be imaged,
 - providing a projection exposure apparatus (1) according to
- 10 Claim 11,
- projecting at least one part of the reticle (30) onto a region of the layer of the wafer with the aid of the projection exposure apparatus (1).

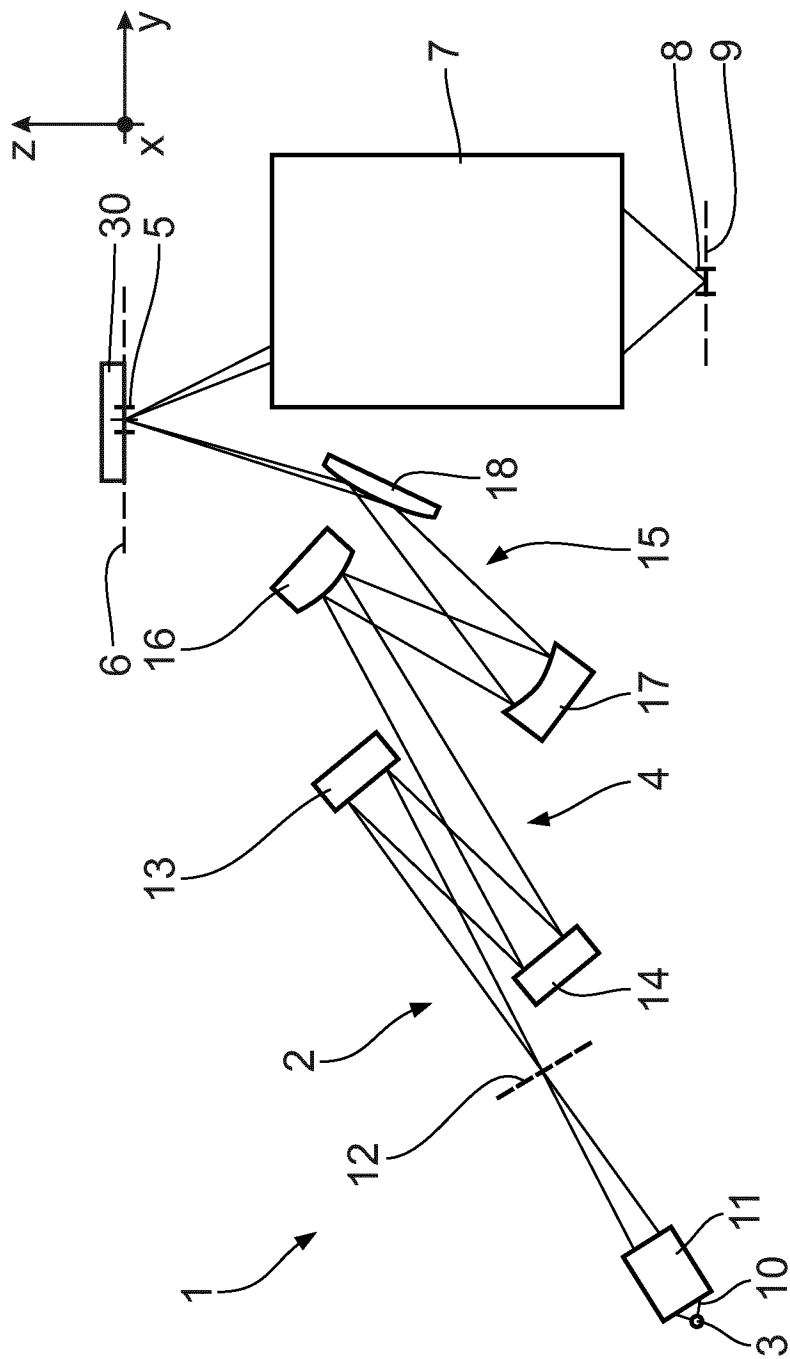


Fig. 1

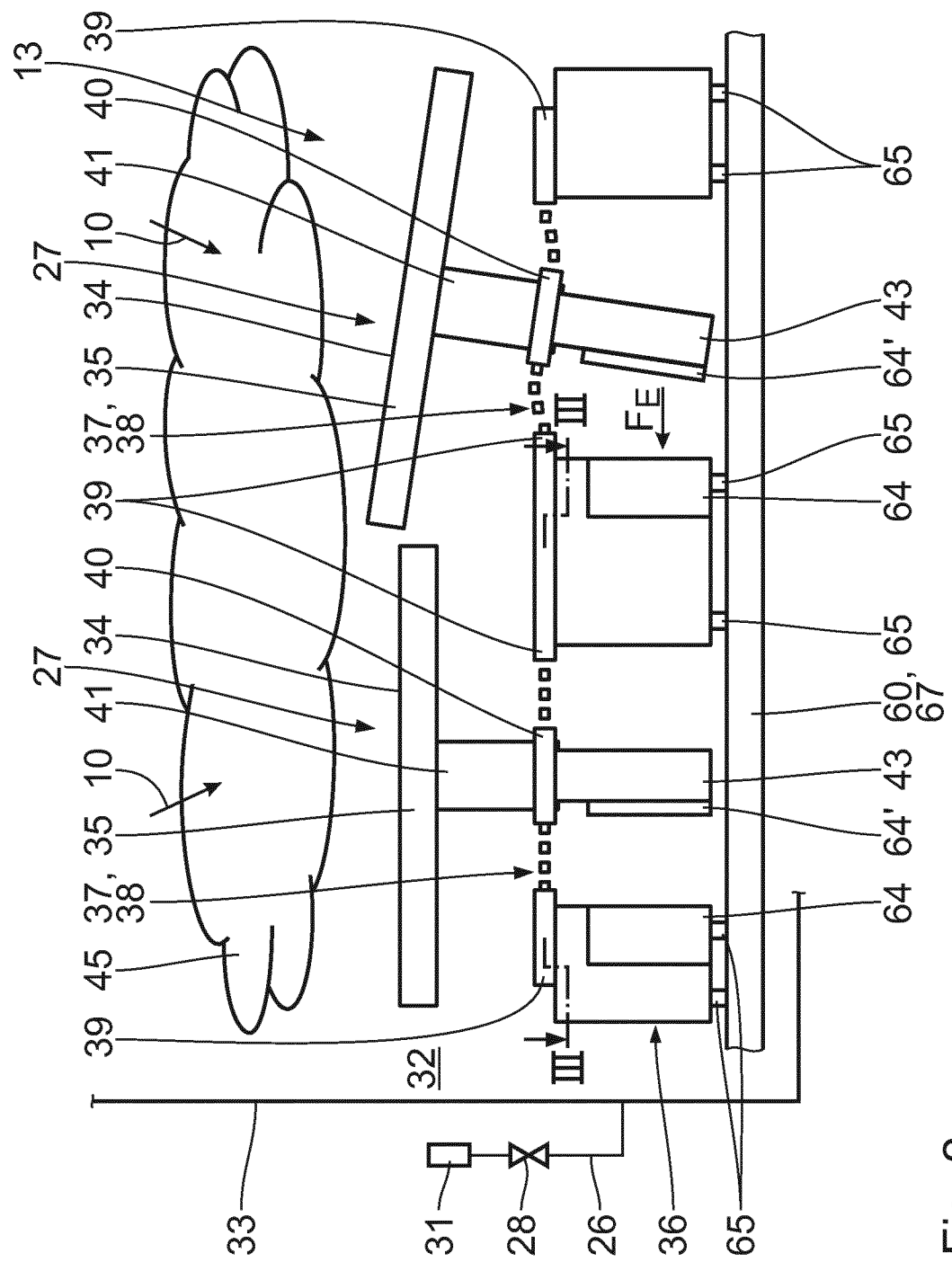


Fig. 2

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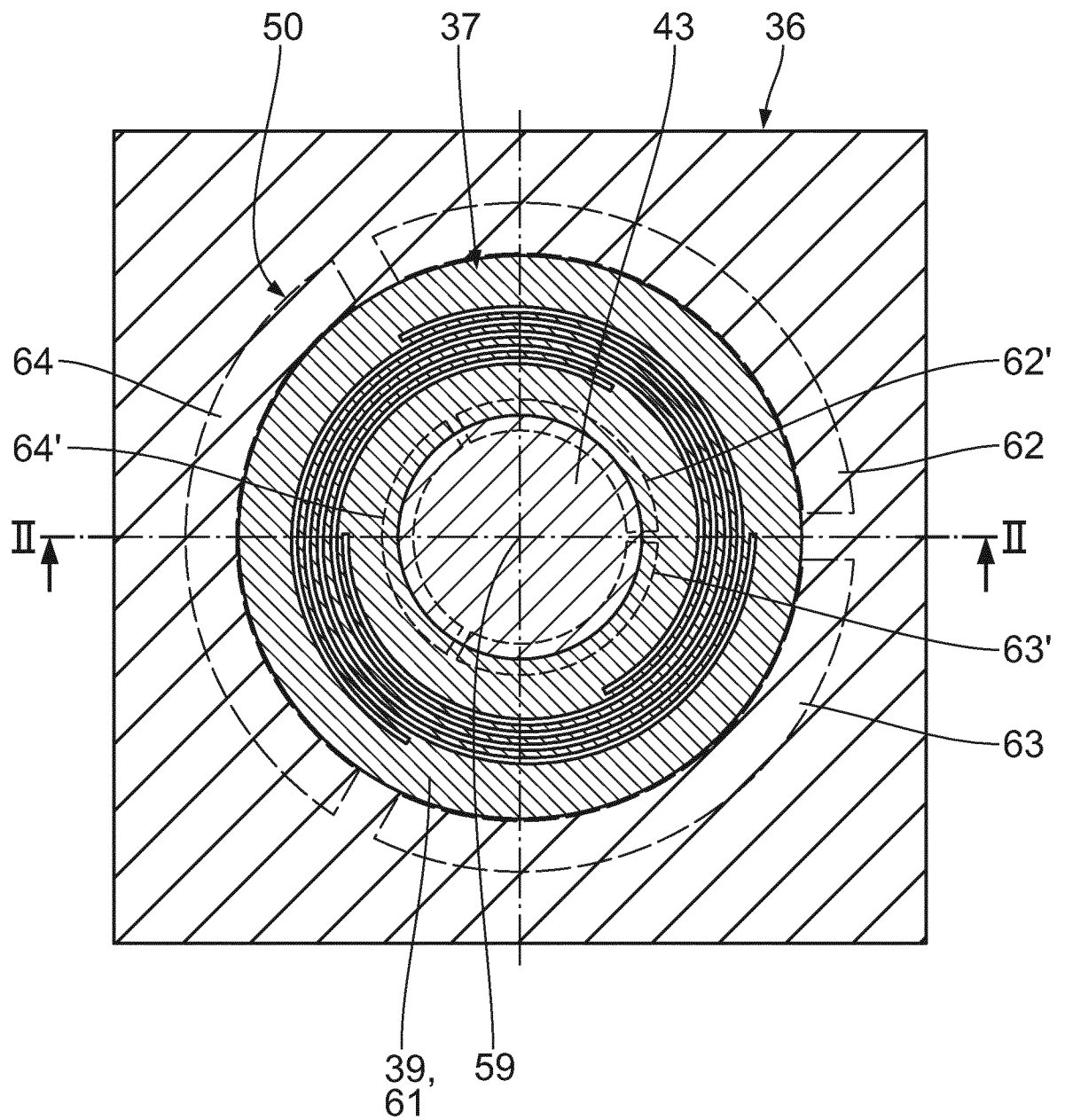


Fig. 3

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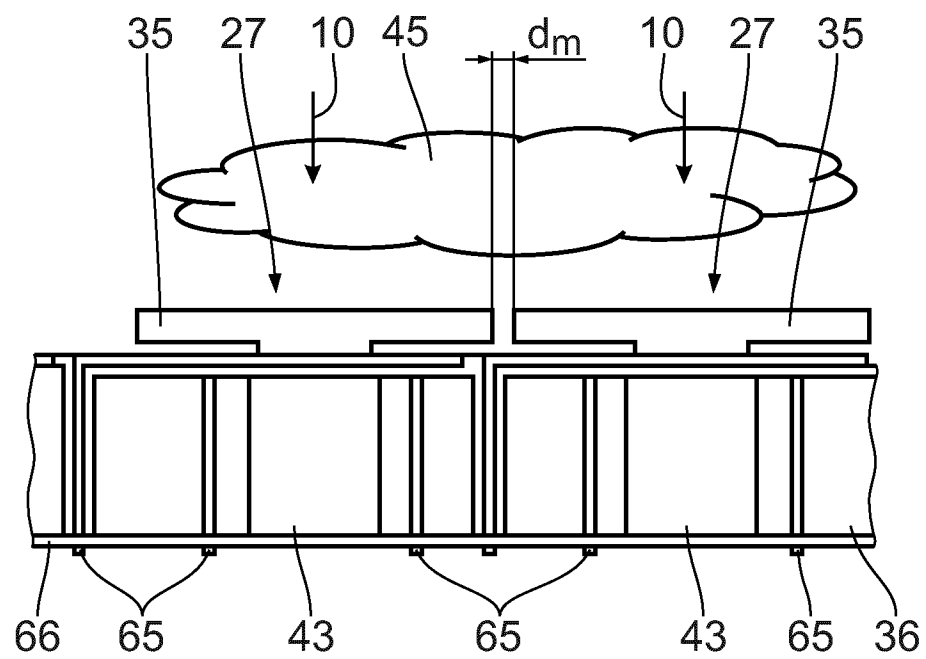


Fig. 4

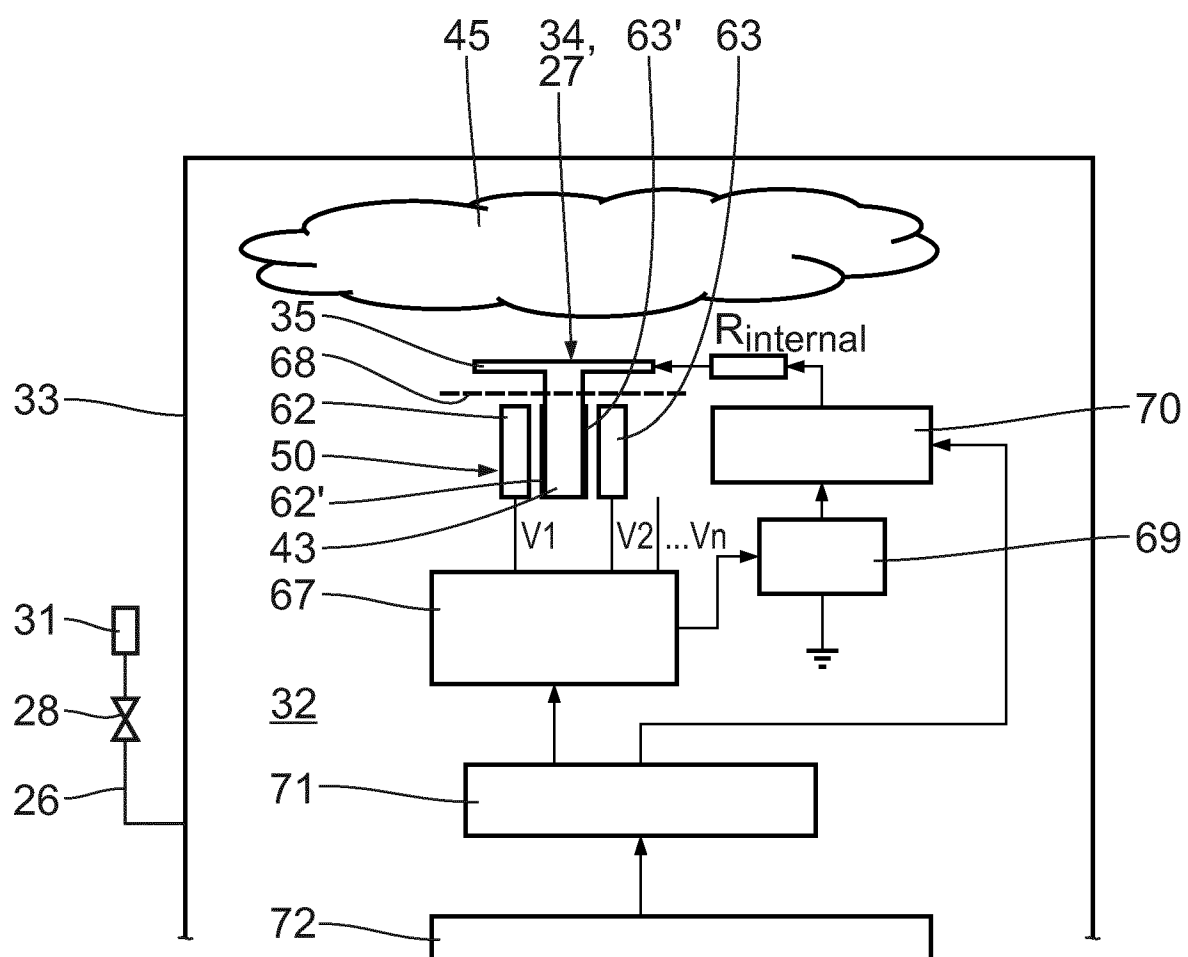


Fig. 5

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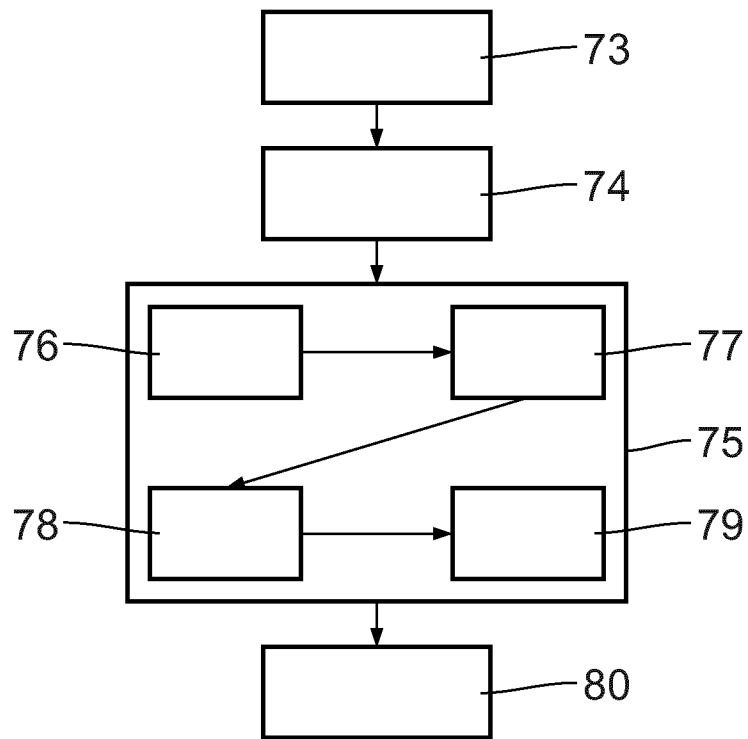


Fig. 6

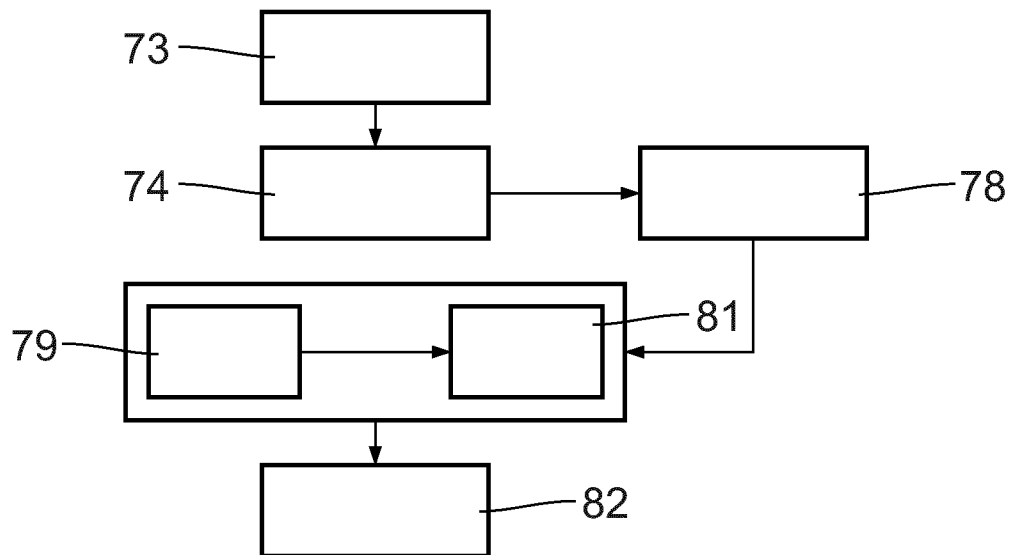


Fig. 7

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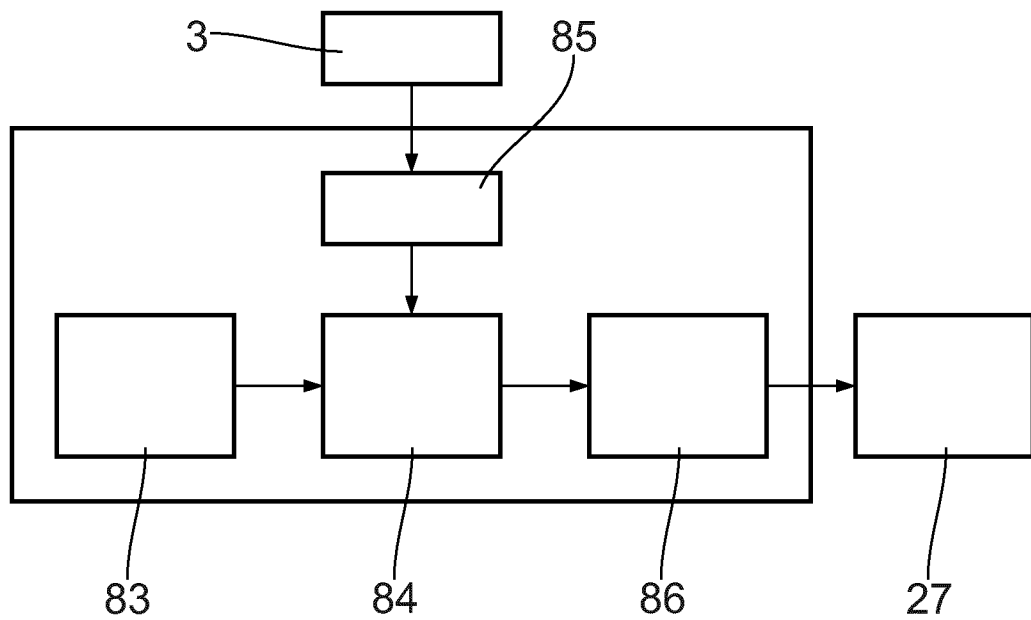


Fig. 8

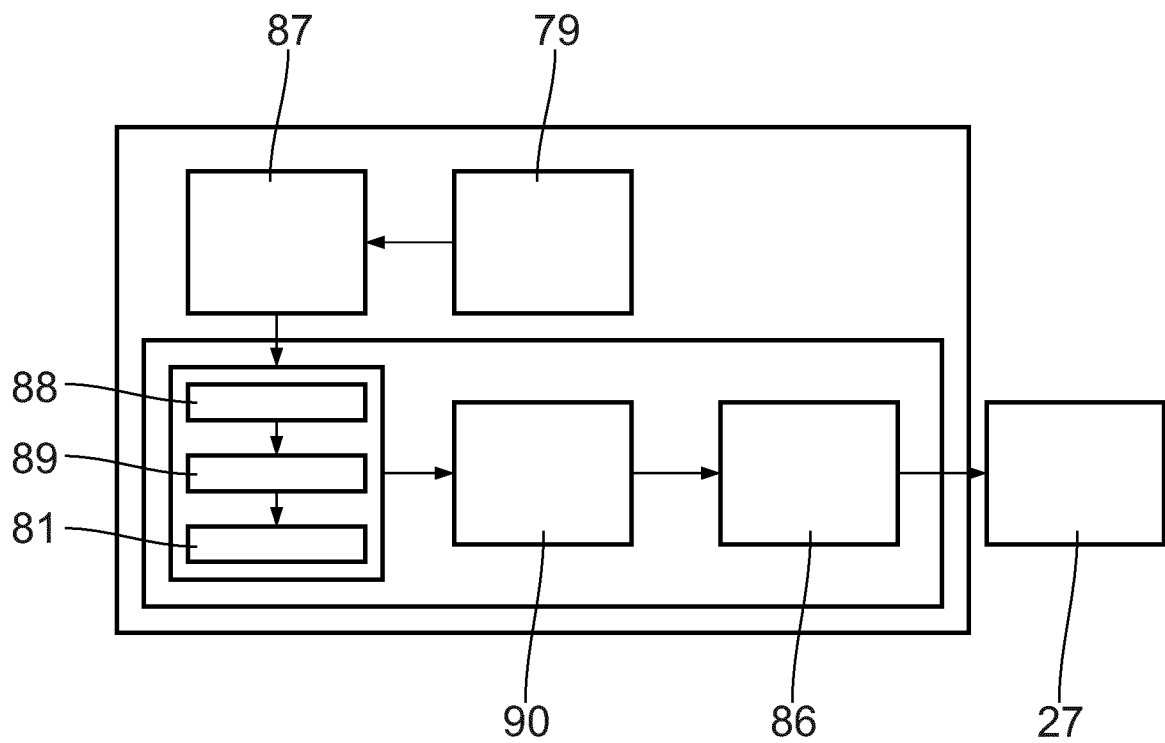


Fig. 9

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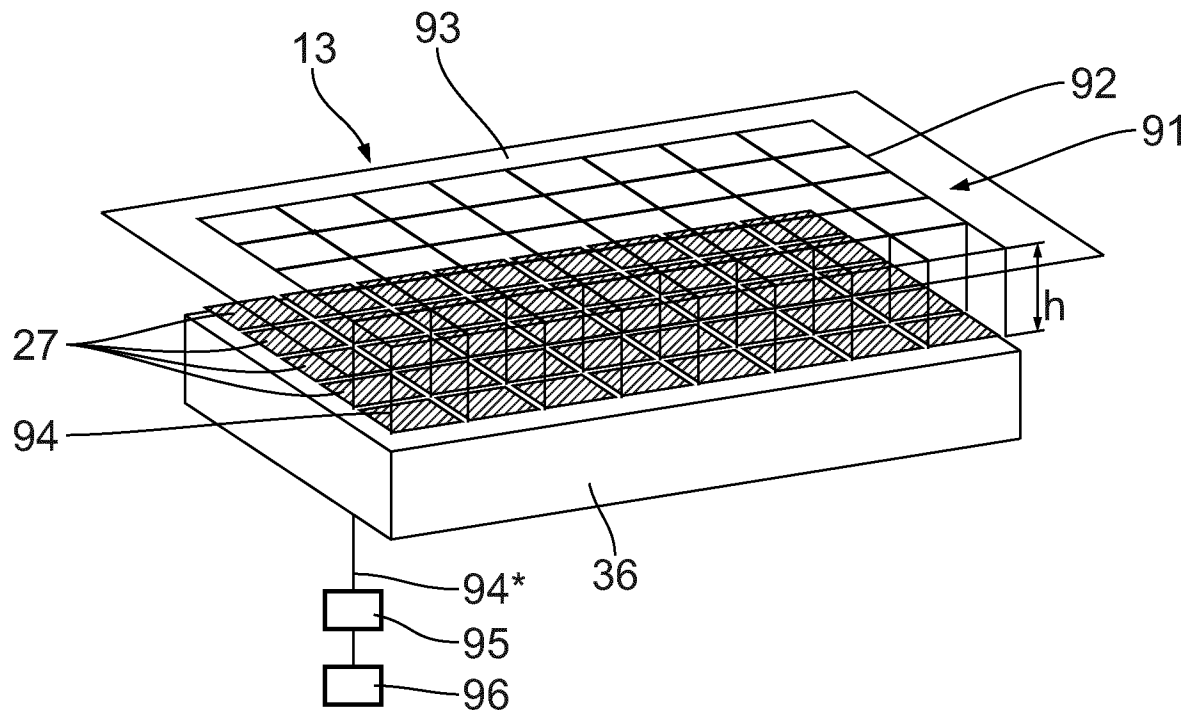


Fig. 10

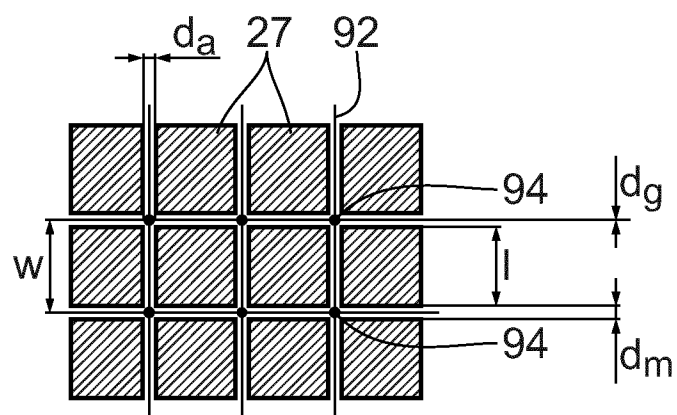


Fig. 11

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/056532

A. CLASSIFICATION OF SUBJECT MATTER

INV. G02B26/08 G02B17/08 G09G3/00 G03F7/20
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G02B G09G G03B G03F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 771 851 B1 (YANG XIAO [US]) 3 August 2004 (2004-08-03)	1,8
Y	figures 2-5 column 3 - column 5	2,4
X	WO 2010/049076 A2 (ZEISS CARL SMT AG [DE]; HAUF MARKUS [DE]; WALDIS SEVERIN [DE]; NOELL W) 6 May 2010 (2010-05-06)	1,8-12
Y	page 5 figures 1-25	2-4
Y	WO 02/059680 A1 (NAYNA NETWORKS INC [US]) 1 August 2002 (2002-08-01) page 18 - page 19 figures 4-12	2,3
	----- -/-	



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

6 June 2014

Date of mailing of the international search report

20/08/2014

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
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Authorized officer

Beutter, Matthias

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/056532

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2004/061619 A1 (KIM JUNG SANG [US] ET AL) 1 April 2004 (2004-04-01) paragraph [0035] -----	2
A	US 2009/231707 A1 (EHM DIRK HEINRICH [DE] ET AL) 17 September 2009 (2009-09-17) paragraph [0049] - paragraph [0051] -----	1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2014/056532

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-4, 8-12

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-4, 8-12

An optical component comprising an optical device, an actuator device and means for reducing radiation-induced influence on said optical device wherein said means comprise a control device to apply a bias voltage to said actuator device.

2. claims: 5-7

An optical component comprising an optical device, an actuator device and means for reducing radiation-induced influence on said optical device wherein said means comprise a shielding element.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2014/056532

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6771851	B1	03-08-2004	NONE
WO 2010049076	A2	06-05-2010	CN 102257421 A 23-11-2011
			JP 5355699 B2 27-11-2013
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			CN 101968609 A 09-02-2011
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			KR 20090057368 A 05-06-2009
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			WO 2008034582 A2 27-03-2008