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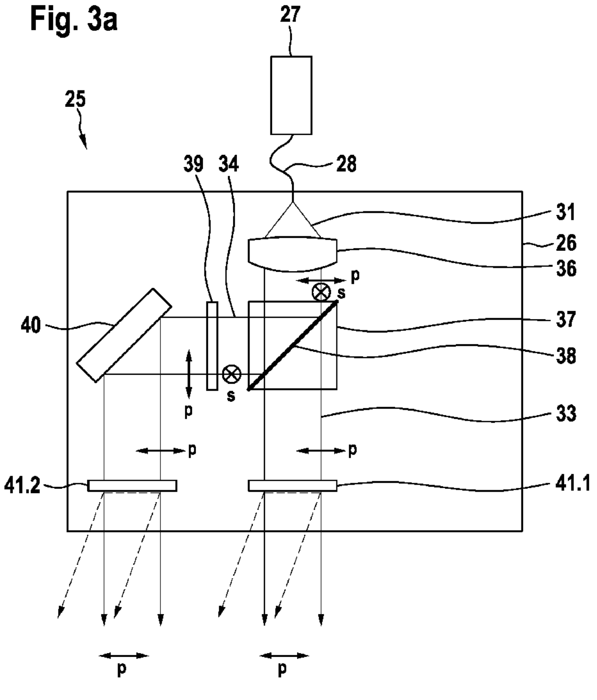
(54) **Title:** PROJECTION EXPOSURE APPARATUS COMPRISING A HEATING DEVICE AND A POLARIZER

Fig. 3a



(57) **Abstract:** The invention relates to a projection exposure apparatus (1) for semiconductor lithography, comprising a heating device (25) for heating optical elements (29) of the projection exposure apparatus (1) by means of heating radiation (31) and comprising a polarizer (37) for splitting the heating radiation (31) into at least two differently polarized heating beam portions (33, 34). Here, at least one polarization modulator (39) is present for modifying the polarization of at least one of the differently polarized heating beam portions (33, 34).

WO 2022/084066 A1

Projection exposure apparatus comprising a heating device and a polarizer

The present patent application claims the priority of the German patent application DE 10 2020213416.2, the content of which is fully incorporated by reference herein.

The invention relates to a projection exposure apparatus for semiconductor lithography comprising a heating device for heating optical elements of the projection exposure apparatus by means of heating radiation.

In relation to their imaging quality, projection exposure apparatuses for semiconductor lithography exhibit a behaviour that depends significantly on temperature. Both elements not involved directly in the optical imaging, such as, e.g., mounts and holders or housing parts, and optical elements themselves, such as for example lenses or, in the case of EUV lithography, mirrors, change their extent or their surface shape when heated up or cooled down, which has a direct effect on the quality of the imaging of a lithography mask, for example a phase mask, a so-called reticle, on a semiconductor substrate, a so-called wafer, as undertaken by the system.

In this case, the heating of the individual components of the apparatus during operation can be traced back to absorbing some of the radiation which is used to image the reticle onto the wafer and which is referred to as used radiation below. Particularly after a relatively long phase without used radiation, for example on account of maintenance work but also on account of a reticle exchange, the influence of heating up on the imaging quality is clearly in evidence until a constant temperature profile is formed. It is for this reason that the optical elements, i.e., the mirrors in the case of an EUV system, are heated in targeted fashion by additional heating devices before the used radiation is activated and also during exposure breaks.

Thus, the German patent application DE 102012216284 A1 by the applicant discloses such a heating device. Heat radiation provided by a laser is shaped and deflected by a deflection element embodied as a diffractive optical element, in such a way that a mirror surface is impinged with a desired intensity distribution. As a result of absorbing the heating radiation, the mirror is heated and can form a temperature profile which virtually corresponds to the temperature profile caused by the used radiation. A disadvantage of the heating device disclosed is that a large part of the non-polarized heating radiation is not absorbed by the mirror but reflected, firstly reducing the efficiency of the heating device and secondly heating other parts of the projection exposure apparatus by means of the reflected radiation, as a result of which the imaging quality may likewise be limited.

The object of the present invention is to provide a device that eliminates the disadvantages of the prior art.

This object is achieved by means of a device having the features of independent Claim 1. The dependent claims relate to advantageous developments and variants of the invention.

A projection exposure apparatus according to the invention for semiconductor lithography comprises a heating device for heating optical elements of the projection exposure apparatus by means of heating radiation and comprises a polarizer for splitting the heating radiation into at least two differently polarized heating beam portions. According to the invention, at least one polarization modulator is present for modifying the polarization of at least one of the differently polarized heating beam portions.

As a result, heating radiation polarized in parallel in relation to the optical element to be heated can be provided, which as a matter of principle can enter into the optical element in full if the suitable angle of incidence is chosen.

In particular, the polarization modulator can be set up to match the polarization of at least one heating beam portion to the polarization of at least one other heating beam portion.

As a result of this, a large part of the heating radiation provided on the part of the heating device can be effectively used to heat an optical element since this renders it possible to bring a large portion of the generated heating radiation into a polarization state that allows maximum absorption in the optical element to be heated. Furthermore, the reflection of heating radiation at the optical element is reduced by this measure, and so the above-described disturbing influences of the heating radiation do not arise.

By way of example, the polarizer can be a polarization beam splitter cube.

Furthermore, at least one deflection element can be present to deflect a heating beam portion leaving the polarization beam splitter cube. In this context and in an advantageous variant of the invention, the deflection element and the polarization beam splitter cube can be embodied as a common component part.

In particular, the polarization modulator can be a half-wave plate.

Furthermore, at least one deflection element can be present, for example a diffractive element for shaping at least one heating beam portion.

The deflection element can be arranged in the beam path upstream or downstream of the polarization modulator.

In particular, particularly high absorption of the heating radiation can be obtained by virtue of the heating radiation portions striking a surface of an optical element to be heated in the region of the Brewster angle.

Exemplary embodiments and variants of the invention are explained in more detail below with reference to the drawing, in which:

Figure 1	schematically shows a meridional section of a projection exposure apparatus for EUV projection lithography,
Figure 2	shows a heating device known from the prior art,
Figures 3a,b	show a first and second exemplary embodiment of a heating device according to the invention,
Figure 4	shows a further exemplary embodiment of the invention, and
Figure 5	shows a view to elucidate the use of the invention.

With reference to Figure 1, the essential components of a microlithographic projection exposure apparatus 1 are initially described below in exemplary fashion. The description of the basic construction of the projection exposure apparatus 1 and its components are here not understood to be limiting.

An illumination system 2 of the projection exposure apparatus 1 has, besides a radiation source 3, an illumination optical unit 4 for the illumination of an object field 5 in an object plane 6. Here, a reticle 7 arranged in the object field 5 is exposed. The reticle 7 is held by a reticle holder 8. The reticle holder 8 is displaceable by way of a reticle displacement drive 9, in particular in a scanning direction.

A Cartesian xyz-coordinate system is shown in Figure 1 for explanation purposes. The x-direction extends perpendicular to the plane of the drawing. The y-direction extends horizontally, and the z-direction extends vertically. The scanning direction extends along the y-direction in Fig. 1. The z-direction extends perpendicularly to the object plane 6.

The projection exposure apparatus 1 comprises a projection optical unit 10. The projection optical unit 10 serves for imaging the object field 5 into an image field 11 in an image plane 12. The image plane 12 runs parallel to the object plane 6. Alternatively, an angle between the object plane 6 and the image plane 12 that differs from 0° is also possible.

A structure on the reticle 7 is imaged onto a light-sensitive layer of a wafer 13 arranged in the region of the image field 11 in the image plane 12. The wafer 13 is held by a wafer holder 14. The wafer holder 14 is displaceable by way of a wafer displacement drive 15, in particular along the y-direction. The displacement on the one hand of the reticle 7 by way of the reticle displacement drive 9 and on the other hand of the wafer 13 by way of the wafer displacement drive 15 can take place in such a way as to be synchronized with one another.

The radiation source 3 is an EUV radiation source. The radiation source 3 emits, in particular, EUV radiation 16, which is also referred to below as used radiation or illumination radiation. In particular, the used radiation has a wavelength in the range of between 5 nm and 30 nm. The radiation source 3 can be a plasma source, for example an LPP (“laser produced plasma”) source or a GDPP (“gas discharged produced plasma”) source. It may also be a synchrotron-based radiation source. The radiation source 3 can be a free electron laser (FEL).

The illumination radiation 16 emerging from the radiation source 3 is focused by a collector 17. The collector 17 can be a collector with one or more ellipsoid and/or hyperboloid reflection surfaces. The illumination radiation 16 may be incident on the at least one reflection surface of the collector 17 with grazing incidence (GI), i.e. at angles of incidence of greater than 45°, or with normal incidence (NI), i.e. at angles of incidence of less than 45°. The collector 17 can be structured and/or coated, firstly, for optimizing its reflectivity for the used radiation and, secondly, for suppressing extraneous light.

Downstream of the collector 17, the illumination radiation 16 propagates through an intermediate focus in an intermediate focal plane 18. The intermediate focal plane 18 may represent a separation between a radiation source module, having the radiation source 3 and the collector 17, and the illumination optical unit 4.

The illumination optical unit 4 comprises a deflection mirror 19 and, arranged downstream thereof in the beam path, a first facet mirror 20. The deflection mirror 19 may be a plane deflection mirror or, alternatively, a mirror with a beam-influencing effect that goes beyond a purely deflecting effect. As an alternative or in addition thereto, the mirror 19 can be embodied as a spectral filter separating a used light wavelength of the illumination radiation 16 from extraneous light having a wavelength that deviates therefrom. Provided the first facet mirror 20 is arranged in a plane of the illumination optical unit 4 which is optically conjugate to the object plane 6 as a field plane, this facet mirror is also referred to as a field facet mirror. The first facet mirror 20 comprises a multiplicity of individual first facets 21, which are also referred to below as field facets. Some of these facets 21 are shown in Figure 1 only by way of example.

The first facets 21 can be embodied as macroscopic facets, in particular as rectangular facets or as facets with an arcuate or partly circular edge contour. The first facets

21 may be embodied as plane facets or alternatively as convexly or concavely curved facets.

As known for example from DE 10 2008 009 600 A1, the first facets 21 themselves may also be composed in each case of a multiplicity of individual mirrors, in particular a multiplicity of micromirrors. The first facet mirror 20 may in particular be formed as a microelectromechanical system (MEMS system). For details, reference is made to DE 10 2008 009 600 A1.

The illumination radiation 16 travels horizontally, i.e., along the y-direction, between the collector 17 and the deflection mirror 19.

In the beam path of the illumination optical unit 4, a second facet mirror 22 is arranged downstream of the first facet mirror 20. If the second facet mirror 22 is arranged in a pupil plane of the illumination optical unit 4, it is also referred to as a pupil facet mirror. The second facet mirror 22 may also be arranged at a distance from a pupil plane of the illumination optical unit 4. In this case, the combination of the first facet mirror 20 and the second facet mirror 22 is also referred to as a specular reflector. Specular reflectors are known from US 2006/0132747 A1, EP 1 614 008 B1 and US 6,573,978.

The second facet mirror 22 comprises a plurality of second facets 23. In the case of a pupil facet mirror, the second facets 23 are also referred to as pupil facets.

The second facets 23 may likewise be macroscopic facets, which may for example have a round, rectangular or else hexagonal periphery, or alternatively be facets made up of micromirrors. In this respect, reference is likewise made to DE 10 2008 009 600 A1.

The second facets 23 may have planar or alternatively convexly or concavely curved reflection surfaces.

The illumination optical unit 4 consequently forms a twice-faceted system. This basic principle is also referred to as fly's eye integrator

It may be advantageous to arrange the second facet mirror 22 not exactly in a plane that is optically conjugate to a pupil plane of the projection optical unit 10.

With the aid of the second facet mirror 22, the individual first facets 21 are imaged into the object field 5 The second facet mirror 22 is the last beam-shaping mirror or else, in fact, the last mirror for the illumination radiation 16 in the beam path before the object field 5.

In a further embodiment of the illumination optical unit 4, not illustrated, a transfer optical unit can be arranged in the beam path between the second facet mirror 22 and the object field 5, said transfer optical unit contributing to the imaging of the first facets 21 into the object field 5, in particular. The transmission optical unit may have exactly one mirror or else alternatively two or more mirrors, which are arranged one behind the other in the beam path of the illumination optical unit 4. The transmission optical unit may in particular comprise one or two normal-incidence mirrors (NI mirrors) and/or one or two grazing-incidence mirrors (GI mirrors).

In the embodiment shown in Figure 1, the illumination optical unit 4 has exactly three mirrors downstream of the collector 17, specifically the deflection mirror 19, the field facet mirror 20 and the pupil facet mirror 22.

The deflection mirror 19 can also be dispensed with in a further embodiment of the illumination optical unit 4, and so the illumination optical unit 4 can then have exactly two mirrors downstream of the collector 17, specifically the first facet mirror 20 and the second facet mirror 22.

As a rule, the imaging of the first facets 21 into the object plane 6 by means of the second facets 23 or using the second facets 23 and a transmission optical unit is only approximate imaging.

The projection optical unit 10 comprises a plurality of mirrors Mi, which are consecutively numbered in accordance with their arrangement in the beam path of the projection exposure apparatus 1.

In the example illustrated in Figure 1, the projection optical unit 10 comprises six mirrors M1 to M6. Alternatives with four, eight, ten, twelve or any other number of mirrors Mi are similarly possible. The penultimate mirror M5 and the last mirror M6 each have a through opening for the illumination radiation 16. The projection optical unit 10 is a double-obscured optical unit. The projection optical unit 10 has an image-side numerical aperture which is greater than 0.5 and which can also be greater than 0.6 and, for example, be 0.7 or 0.75.

Reflection surfaces of the mirrors Mi can be embodied as free-form surfaces without an axis of rotational symmetry. Alternatively, the reflection surfaces of the mirrors Mi may be designed as aspherical surfaces with exactly one axis of rotational symmetry of the reflection surface form. Just like the mirrors of the illumination optical unit 4, the mirrors Mi may have highly reflective coatings for the illumination radiation 16. These coatings may be designed as multilayer coatings, in particular with alternating layers of molybdenum and silicon.

The projection optical unit 10 has a large object image offset in the y-direction between a y-coordinate of a centre of the object field 5 and a y-coordinate of the centre of the image field 11. In the y-direction, this object-image offset can be approximately the same size as a z-distance between the object plane 6 and the image plane 12.

In particular, the projection optical unit 10 may have an anamorphic form. In particular, it has different imaging scales βx, βy in the x- and y-directions. The two imaging scales βx, βy of the projection optical unit 10 preferably lie at (βx, βy) = (+/- 0.25, /+- 0.125). A positive imaging scale β means imaging without an image reversal. A negative sign for the imaging scale β means imaging with an image reversal.

The projection optical unit 10 consequently leads to a reduction in size with a ratio of 4:1 in the x-direction, i.e. in a direction perpendicular to the scanning direction.

The projection optical unit 10 leads to a reduction in size of 8:1 in the y-direction, i.e. in the scanning direction.

Other imaging scales are similarly possible. Imaging scales with the same sign and the same absolute value in the x-direction and y-direction are also possible, for example with absolute values of 0.125 or of 0.25.

The number of intermediate image planes in the x-direction and in the y-direction in the beam path between the object field 5 and the image field 11 may be the same or, depending on the embodiment of the projection optical unit 10, may differ. Examples of projection optical units with different numbers of such intermediate images in the x- and y-directions are known from US 2018/0074303 A1.

Respectively one of the pupil facets 23 is assigned to exactly one of the field facets 21 for the purposes of forming respectively one illumination channel for illuminating the object field 5. In particular, this can yield illumination according to the Köhler principle. The far field is decomposed into a multiplicity of object fields 5 with the aid of the field facets 21. The field facets 21 produce a plurality of images of the intermediate focus on the pupil facets 23 respectively assigned thereto.

By way of a respectively assigned pupil facet 23, the field facets 21 are imaged onto the reticle 7 in a manner superposed on one another for the purposes of illuminating the object field 5. In particular, the illumination of the object field 5 is as homogeneous as possible. It preferably has a uniformity error of less than 2%. The field uniformity can be achieved by way of the superposition of different illumination channels.

The illumination of the entrance pupil of the projection optical unit 10 can be defined geometrically by way of an arrangement of the pupil facets. The intensity distribution in the entrance pupil of the projection optical unit 10 can be set by selecting the illumination channels, in particular the subset of the pupil facets which guide light. This intensity distribution is also referred to as illumination setting.

A likewise preferred pupil uniformity in the region of sections of an illumination pupil of the illumination optical unit 4 that are illuminated in a defined manner can be achieved by a redistribution of the illumination channels.

Further aspects and details of the illumination of the object field 5 and in particular of the entrance pupil of the projection optical unit 10 are described below.

In particular, the projection optical unit 10 may have a homocentric entrance pupil. The latter may be accessible. It may also be inaccessible.

The entrance pupil of the projection optical unit 10 cannot be exactly illuminated using the pupil facet mirror 22 on a regular basis. In the case of imaging the projection optical unit 10 in which the centre of the pupil facet mirror 22 is telecentrically imaged onto the wafer 13, the aperture rays often do not intersect at a single point. However, it is possible to find an area in which the distance of the aperture rays determined in pairs becomes minimal. This area represents the entrance pupil or an area in real space that is conjugate thereto. In particular, this area has a finite curvature.

It may be that the projection optical unit 10 has different positions of the entrance pupil for the tangential beam path and for the sagittal beam path. In this case, an imaging element, in particular an optical component part of the transmission optical unit, should be provided between the second facet mirror 22 and the reticle 7. With the aid of this optical element, the different position of the tangential entrance pupil and the sagittal entrance pupil can be taken into account.

In the arrangement of the components of the illumination optical unit 4 illustrated in Figure 1, the pupil facet mirror 22 is arranged in an area conjugate to the entrance pupil of the projection optical unit 10. The field facet mirror 20 is arranged in tilted fashion with respect to the object plane 6. The first facet mirror 20 is arranged in tilted fashion with respect to an arrangement plane defined by the deflection mirror 19.

The first facet mirror 20 is arranged so as to be tilted in relation to an arrangement plane defined by the second facet mirror 22.

Figure 2 shows a side view of a mirror 29, which may for example correspond to one of the mirrors M1 to M6 of the projection exposure apparatus 1 described in Figure 1 and which comprises a heating device 24 known from the prior art. The heating device 24 comprises a heating radiation source which is embodied as a laser 27 in the example shown and which is connected by way of a fibre 28 to the housing 26 of the heating device 24. The heating radiation 31 is shaped in the heating device 24 by way of a diffractive optical element (not illustrated) for example, and so the heating radiation 31 shaped thus is incident on the mirror 29 with a desired intensity distribution. As a result, a temperature distribution is formed in the region of a mirror surface 30 irradiated by the heating radiation 31, and so the mirror 29 already has a preferred temperature distribution before it is impinged by the used radiation (not illustrated) used for imaging the structures, as a result of which the aberrations arising due to the mirror 29 heating up can be minimized.

Figure 3a shows a first embodiment of a heating device 25 according to the invention, which likewise comprises a laser 27 which couples into a fibre 28, and a housing 26. The fibre 28 is guided into the housing 26 and emits divergent unpolarized heating radiation 31 at its end, with the parallel and perpendicular polarization direction of the heating radiation 31 being represented in each case by a double-headed arrow in the plane of the drawing and perpendicular to the plane of the drawing. Subsequently, the heating radiation 31 passes through a collimator 36 and is shaped by the latter to form collimated heating radiation 31 which still is unpolarized. The collimated heating radiation 31 now strikes a polarizer which is embodied as a polarization beam splitter cube 37 and which comprises a partly transmissive mirror 38 that is arranged at 45° with respect to the beam direction of the heating radiation 31. Said mirror passes the parallel polarized portion 33 of the heating radiation 31 and reflects the perpendicular polarized portions 34 of the heating radiation 31, i.e., output-couples a part 34 of the heating radiation 31. The direction of the polarization (double-headed arrow, s, p) of the two heating beam portions 33, 34 illustrated in Figure 3a relates to the planes of incidence of the optical elements 37, 40, 41.1, 41.2 of the heating device 25 and not to the plane of incidence, relevant to the absorption, of the mirror to be heated. The perpendicular polarized heating beam portion 34 subsequently passes through a polarization modulator 39 which is embodied as a half-wave plate and which rotates the polarization direction through 90° such that the perpendicular polarized heating beam portion 34 likewise has a parallel polarization after passing through the half-wave plate 39. Subsequently, this heating beam portion 34 is reflected at a deflection element 40, which is embodied as a deflection mirror, in such a way that the two heating beam portions 33, 34 run parallel to one another. Both heating beam portions 33, 34 are now each guided through a deflection element embodied as a diffractive optical element 41.1, 41.2, said deflection elements having a different embodiment for the two heating beam portions 33, 34 and shaping and deflecting the latter. The heating beam portions 33, 34 are shaped in such a way that a desired intensity profile forms on a surface of a mirror to be heated (not illustrated). The structures of the diffractive elements 41.1, 41.2 are determined in advance on the basis of the desired intensity profile on the mirror, substantially by way of a Fourier transform. Additionally, the heating beam portions 33, 34 are deflected by the diffractive optical elements 41.1, 41.2 in such a way that the polarization direction of the heating beam portions 33, 34 is polarized in parallel in relation to the plane of incidence (not illustrated) of the mirror surface of the mirror (not illustrated).

Furthermore, the heating device 25 is arranged in such a way that the heating beam portions 33, 34 strike the mirror surface at the Brewster angle or at least in the region of the Brewster angle in order to achieve maximum absorption in the mirror. In addition to high efficiency of the heating device 25, this also leads to an advantageous lower reflection, which would act as thermal interference in a projection optical unit 10 as described in Figure 1.

Alternatively, the diffractive optical elements 41.1, 41.2 can also be arranged upstream of the half-wave plates, wherein the polarization effect of the half-wave plates depends on the angle of incidence of the beams and hence the arrangement illustrated in the exemplary embodiment, within the scope of which collimated light passes through the half-wave plates 39, should be preferred.

Figure 3b shows a second embodiment of the invention likewise illustrating a heating device 25 with a housing 26. This embodiment differs from the embodiment described in Figure 3a in that the heating beam portion 33 which passes the partly transmissive mirror 38 of the polarization beam splitter cube 37 and which has parallel polarization downstream of the polarization beam splitter cube 37 is subsequently rotated through 90° by a half-wave plate 39 and consequently strikes the following diffractive element 41.1 with a perpendicular polarization. The heating beam portion 34 output-coupled in the polarization beam splitter cube 37 is merely reflected by a deflection mirror 40, in such a way that it runs parallel to the first heating beam portion 33. Thus, the heating beam portions 33, 34 emerging from the heating device 25 have a perpendicular polarization in relation to the optical elements 38, 40, 41.1, 41.2

of the heating device. The parallel polarization of the heating radiation 31 required for effective heating power on the mirror surface (not illustrated) is achieved by an appropriate arrangement of the heating device 25 in relation to the mirror (not illustrated). In this respect, see also the description of Figure 5.

Figure 4 shows a further embodiment of the invention in which a heating device 25 is illustrated, the latter substantially corresponding to the heating devices 25 described in Figure 3a and Figure 3b in respect of the beam profile and the arrangement of the polarising components In contrast with the heating device 25 described in Figure 3a, the polarization beam splitter cube 42 comprises the deflection mirror 40 for the output-coupled heating beam portion 34; the two elements are thus formed as one component part. Reducing the interfaces between optical material and the surroundings, for example a vacuum in the beam path in the case of an EUV projection exposure optical unit, further increases the efficiency of the heating device as a result of lower losses due to reflection at interfaces. Additionally, one half-wave plate 39 is arranged in each of the beam paths of the two heating beam portions 33, 34, in such a way that in the exemplary embodiment shown the polarization of the two heating beam portions 33, 34 is at 45° in relation to the plane of incidence of the diffractive elements 41.1, 41.2 in the heating device 25. The illustrated angle of 45° is exemplary and should elucidate that the polarization direction can be set as desired in order in conjunction with the arrangement of the heating device 25 in relation to a mirror to be heated (not illustrated) to be able to set a polarization that is parallel to the plane of incidence of the mirror. Furthermore, telescopes 43 are arranged downstream of the diffractive elements 41.1, 41.2 and as a result of the magnifying effect these facilitate a reduction in the beam deflection caused by the diffractive elements 41.1, 41.2. This can keep the beam deflection small in the diffractive optical elements 41, which additionally increases the diffraction efficiency of the diffractive optical elements 41.1, 41.2 and thus increases the efficiency of the heating device 25. Additionally, the production of diffractive elements 41 with smaller deflection angles is easier, as a result having an advantageous effect on the production costs of the apparatus according to the invention.

Figure 5 shows an exemplary arrangement of a heating device 25, in which the heating device 25 and a mirror 29 heated thereby are illustrated. Once again, the heating device 25 is connected using a fibre 28 to the heating radiation source embodied as a laser 27. In the exemplary embodiment shown, the two heating beam portions 33, 34 illuminate the same surface component of a surface 30 of the mirror 29. As described further above in relation to Figure 3a, this is brought about by the different embodiment of the diffractive elements (not shown). Alternatively, the surface components illuminated by the heating beam portions 33, 34 may also be complementary or only partly overlap. The heating device 25 facilitates very efficient heating of the mirror 29 with its mirror surface 30. In addition to saving power, this also reduces the power radiated into the surroundings, which advantageously reduces the thermal interference on the imaging quality of the projection optical unit, which reacts sensitively to changes in temperature. For further illustrative purposes, the plane of incidence 32, which coincides with the plane of the sheet in the illustrated example, is illustrated in Figure 5.

List of reference signs

1	Projection exposure apparatus
2	Illumination system
3	Radiation source
4	Illumination optical unit
5	Object field
6	Object plane
7	Reticle
8	Reticle holder
9	Reticle displacement drive
10	Projection optical unit
11	Image field
12	Image plane
13	Wafers
14	Wafer holder
15	Wafer displacement drive
16	EUV radiation
17	Collector
18	Intermediate focal plane
19	Deflection mirror
20	Facet mirror
21	Facets
22	Facet mirror
23	Facets
24	Heating device (prior art)
25	Heating device
26	Housing
27	Laser
28	Fibre
29	Mirror

30	Mirror surface
31	Heating radiation
32	Plane of incidence
33	First heating beam portion
34	Second heating beam portion
35	Plane of incidence
36	Collimator
37	Polarization beam splitter cube
38	Partly transmissive mirror
39	Half-wave plate
40	Deflection mirror
41.1, 41.2	Diffractive optical element
42	Polarization beam splitter cube with mirror
43	Telescope
s	Perpendicular polarization
p	Parallel polarization

Claims

1. Projection exposure apparatus (1) for semiconductor lithography, comprising a heating device (25) for heating optical elements (29) of the projection exposure apparatus (1) by means of heating radiation (31) and comprising a polarizer (37) for splitting the heating radiation (31) into at least two differently polarized heating beam portions (33, 34),

characterized in that

at least one polarization modulator (39) is present for modifying the polarization of at least one of the differently polarized heating beam portions (33, 34).

2. Projection exposure apparatus (1) according to Claim 1,

characterized in that

the polarization modulator (39) is set up to match the polarization of at least one heating beam portion (34) to the polarization of at least one other heating beam portion (33).

3. Projection exposure apparatus (1) according to Claim 1 or 2,

characterized in that

the polarizer (37) is a polarization beam splitter cube.

4. Projection exposure apparatus (1) according to Claim 3,

characterized in that

at least one deflection element (40) is present for deflecting a heating beam portion leaving the polarization beam splitter cube (37).

5. Projection exposure apparatus (1) according to Claim 4,

characterized in that

the deflection element (40) and the polarization beam splitter cube (37) are embodied as a common component part.

6. Projection exposure apparatus (1) according to any one of Claims 1 to 5,

characterized in that

the polarization modulator (39) is a half-wave plate.

7. Projection exposure apparatus (1) according to any one of Claims 1 to 6,

characterized in that
at least one deflection element (41.1, 41.2) is present for shaping at least one heating beam portion (33, 34).

8. Projection exposure apparatus (1) according to Claim 7,
characterized in that
the deflection element (41.1, 41.2) is a diffractive element.

9. Projection exposure apparatus (1) according to Claim 7 or 8,
characterized in that
the deflection element (41.1, 41.2) is arranged in the beam path downstream of the polarization modulator (39).

10. Projection exposure apparatus (1) according to Claim 7 or 8,
characterized in that
the deflection element (41.1, 41.2) is arranged in the beam path upstream of the polarization modulator (39).

11. Projection exposure apparatus (1) according to any one of the preceding claims,
characterized in that
the heating beam portions (33, 34) strike a surface (30) of an optical element (29) to be heated in the region of the Brewster angle.

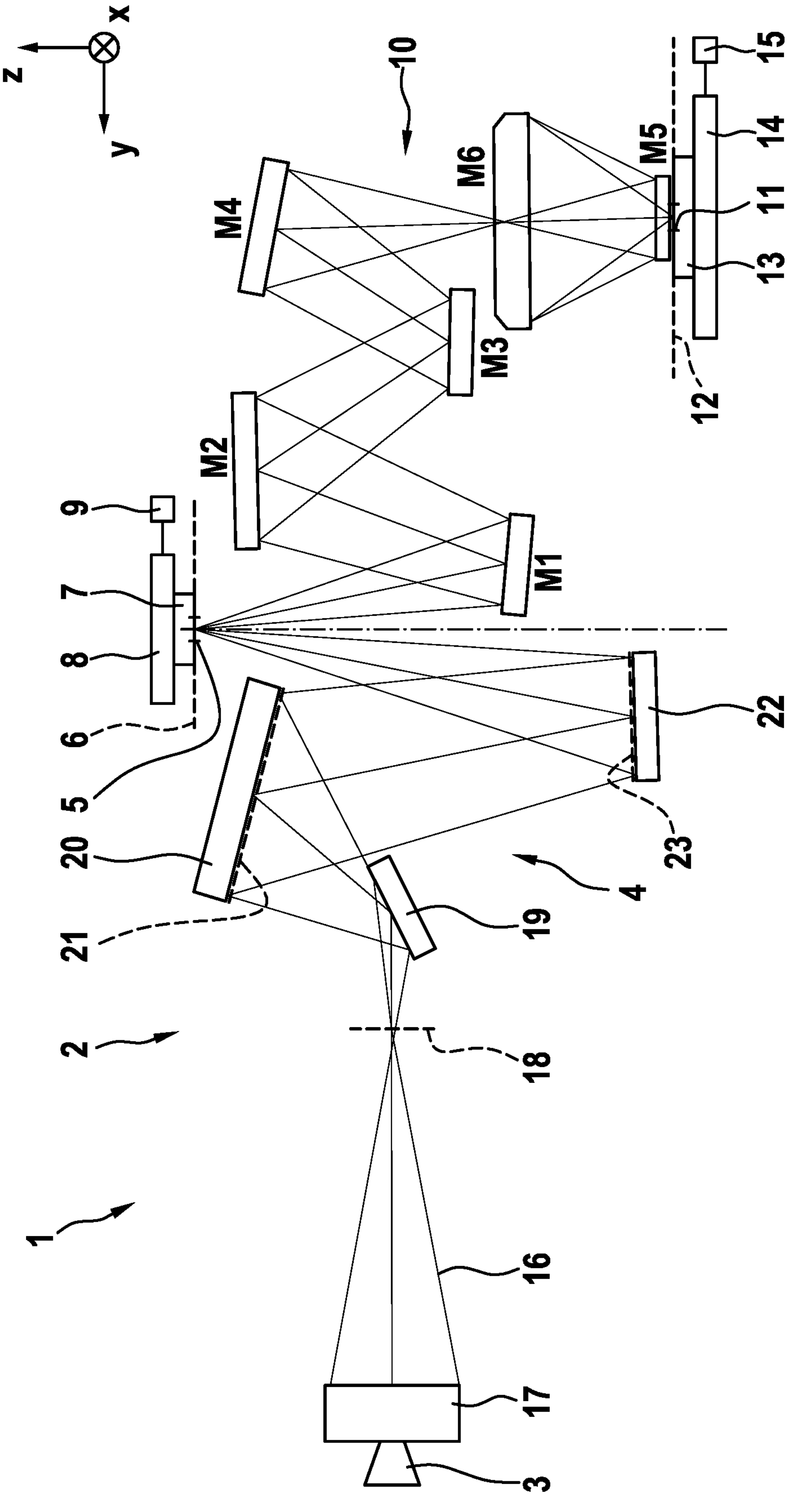

z
x
y
10
15
M4
M6
M5
14
11
13
M3
12
M2
9
7
8
6
M1
5
22
20
23
4
21
19
2
18
1
16
17
3

Fig. 1

Fig. 2

Stand der Technik

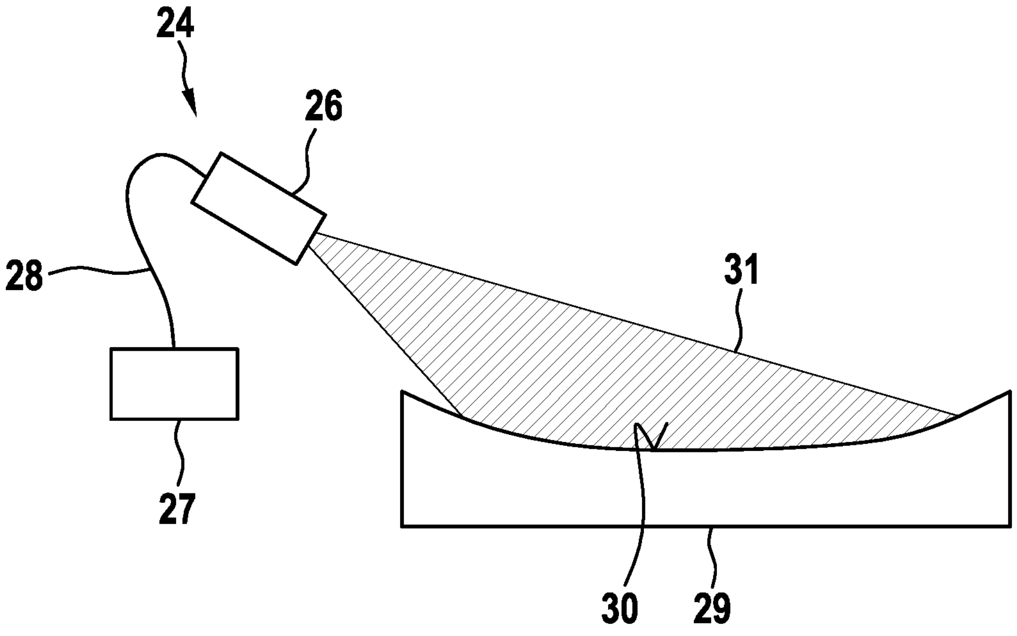


Fig. 3a

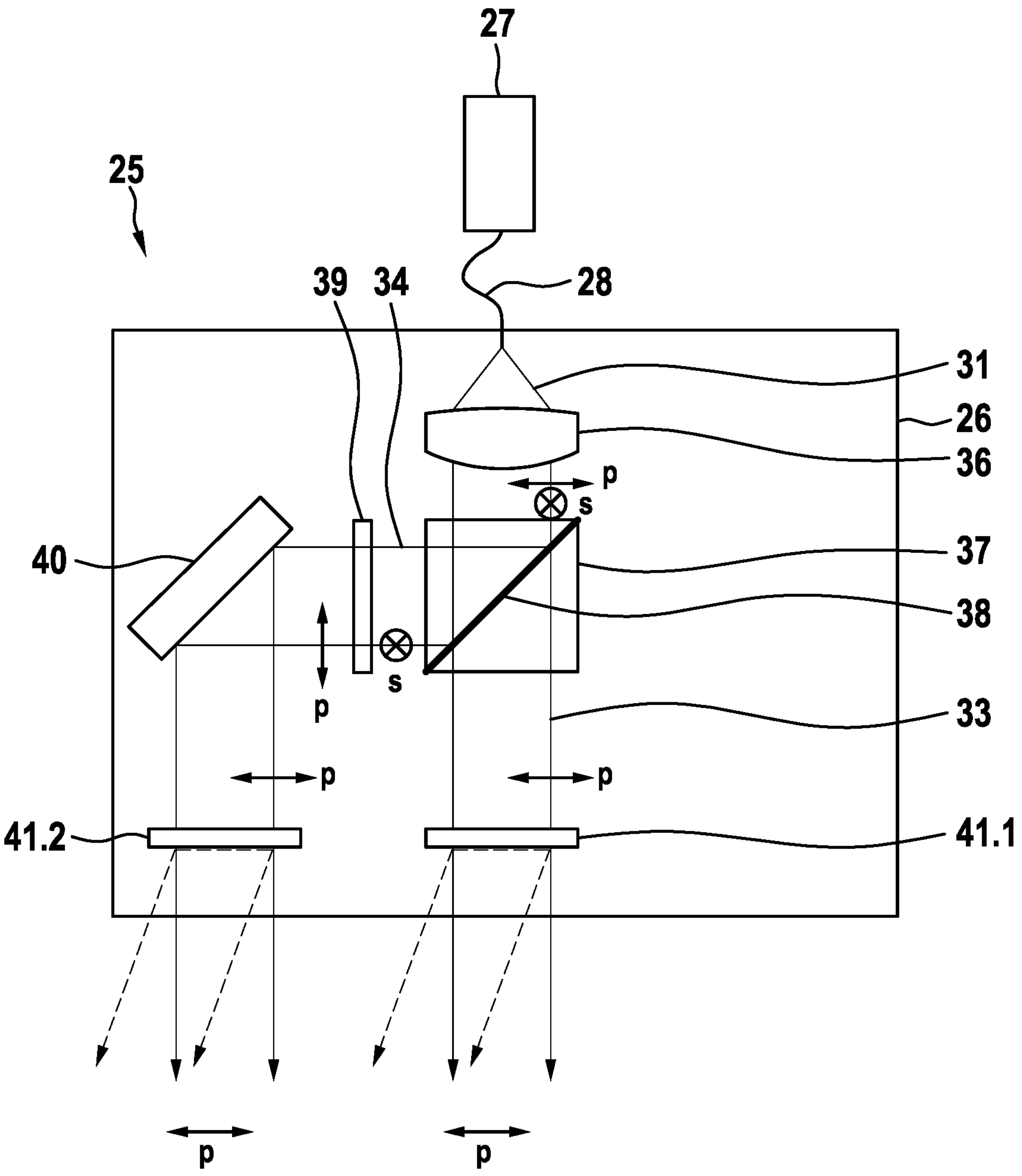


Fig. 3b

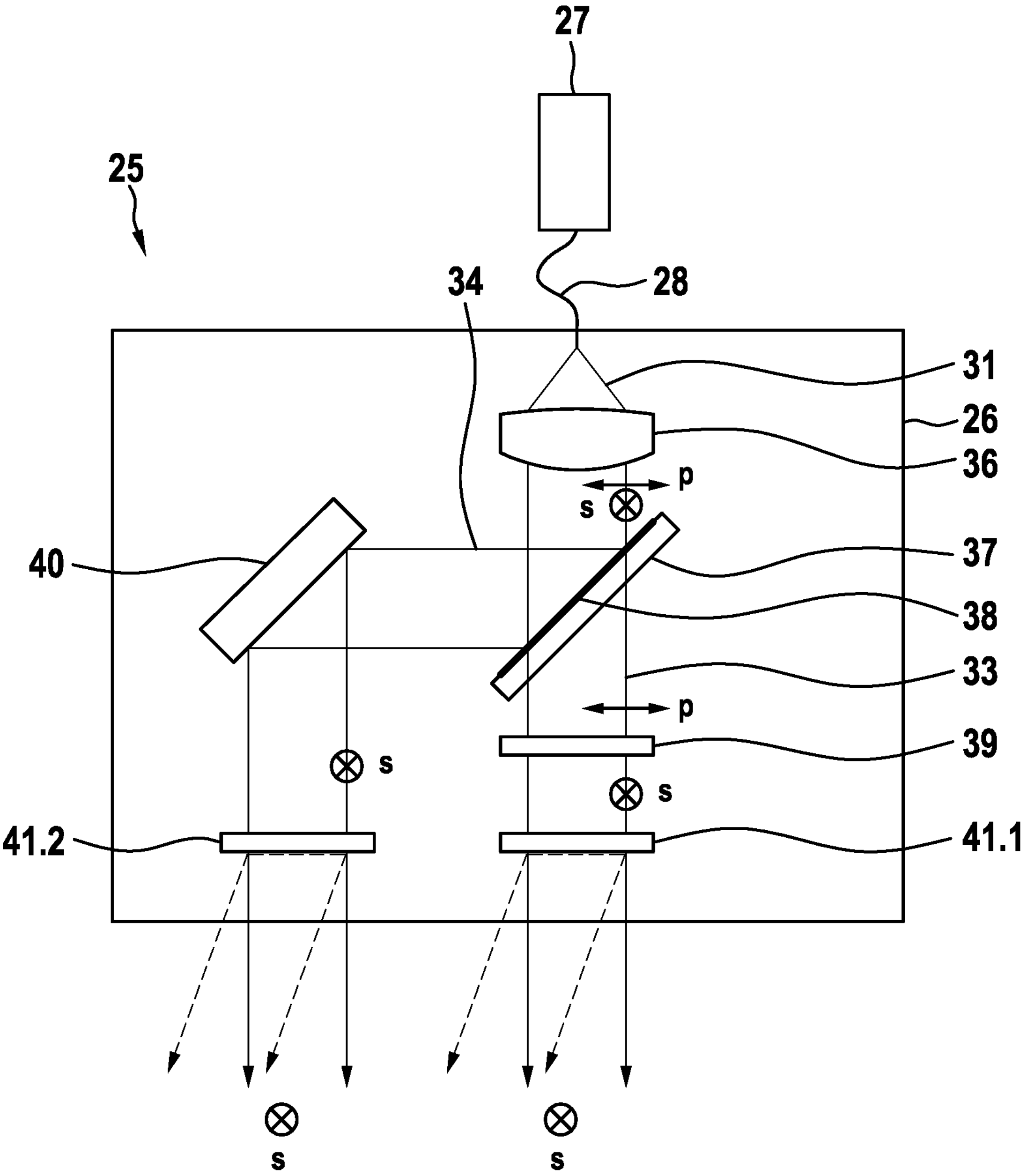


Fig. 4

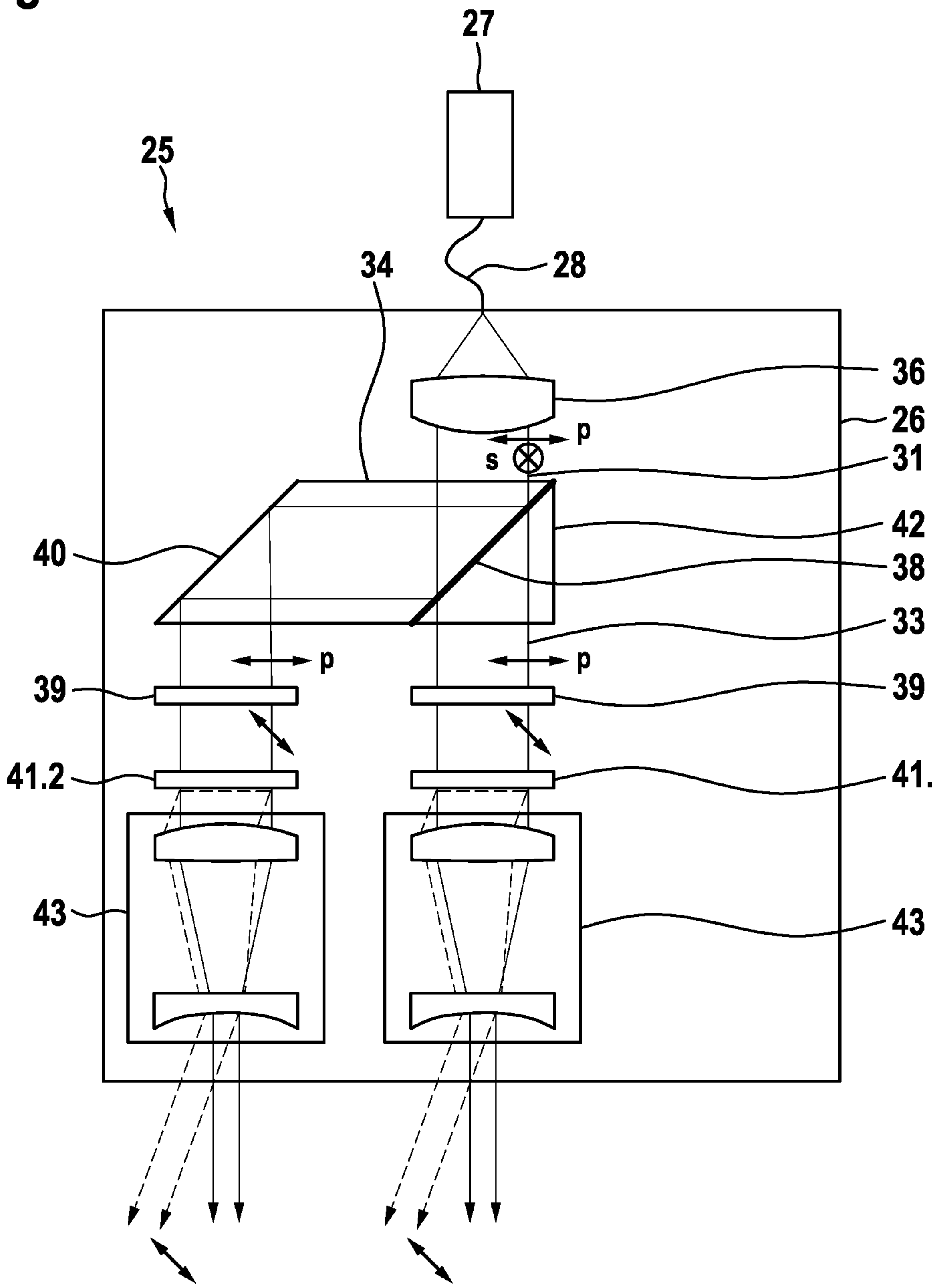
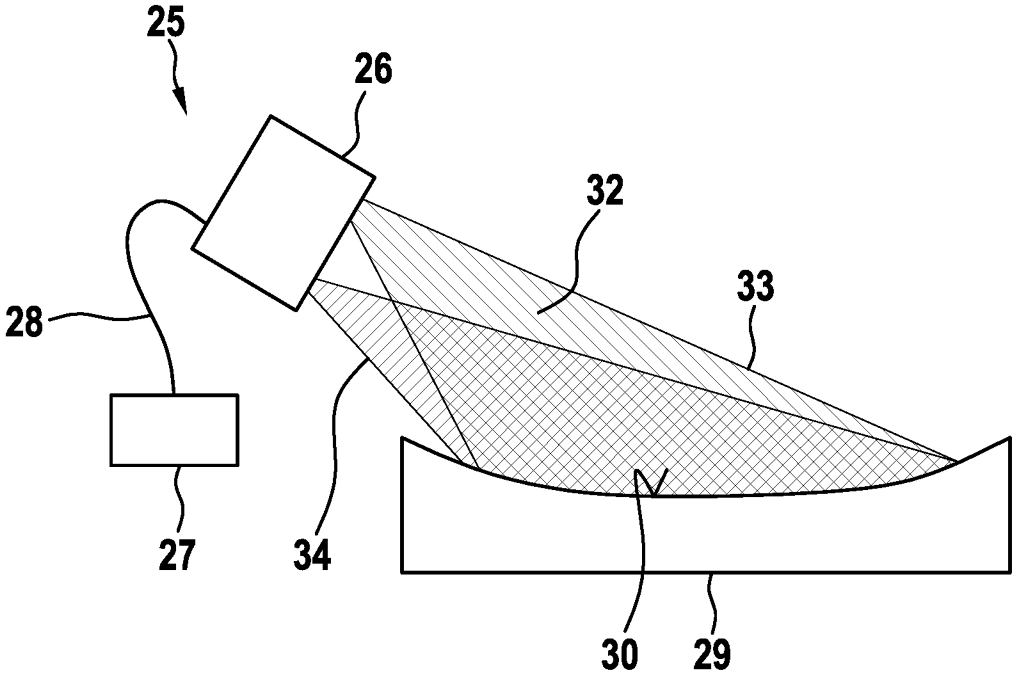


Fig. 5



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2021/077824

A. CLASSIFICATION OF SUBJECT MATTER
INV. 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)
G03F G02B

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.
Y	US 2020/201197 A1 (JANSSEN FRANCISCUS JOHANNES JOSEPH [NL] ET AL) 25 June 2020 (2020-06-25)	1-9,11
A	abstract figures 1,6A paragraphs [0002], [0051], [0052], [0060], [0061], [0078], [0087], [0096] - [0101] -----	10
Y	US 2008/246933 A1 (UCHIKAWA KIYOSHI [JP]) 9 October 2008 (2008-10-09)	1-9,11
A	abstract figure 10 paragraphs [0001], [0019] - [0022], [0090], [0096], [0098], [0122] - [0128] -----	10

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search 18 January 2022	Date of mailing of the international search report 26/01/2022
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Andersen, Ole

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2021/077824

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