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(54) Title: IMAGING OPTICAL SYSTEM, PROJECTION EXPOSURE INSTALLATION FOR MICRO-LITHOGRAPHY COMPRISING AN IMAGING OPTICAL SYSTEM OF THIS TYPE, AND METHOD FOR PRODUCING A MICROSTRUCTURED COMPONENT WITH A PROJECTION EXPOSURE INSTALLATION OF THIS TYPE

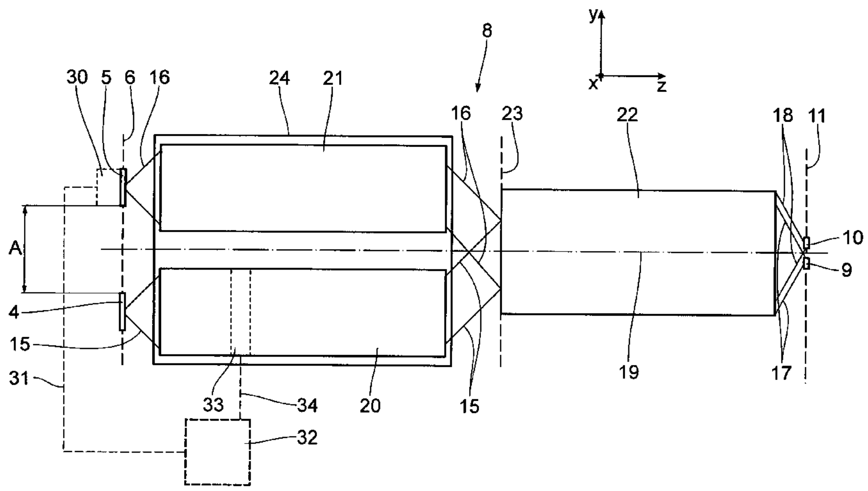

Fig. 2

(57) Abstract: One embodiment of an imaging optical system (8) has exclusively mirrors as beam-guiding optical components. The imaging optical system (8) images at least one object field (4, 5) in at least one object plane (6) into at least one image field (9, 10) in at least one image plane (11). In the imaging optical system (8), there are two object fields (4, 5) which are spatially separated from one another and with which two image fields (9, 10), which are likewise spatially separated from one another, are associated. This results in an imaging optical system with increased flexibility of use.

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Imaging optical system, projection exposure installation for microlithography comprising an imaging optical system of this type, and method for producing a microstructured component with a projection exposure installation of this type

The invention relates to an imaging optical system according to the preamble of claims 1 and 2. The method further relates to a projection exposure installation according to claim 19 and a method for producing a microstructured component according to claims 21, 22, 23, 24 and 25.

Imaging optical systems, which may be used in particular in projection exposure installations for microlithography, are known from US 7,046,335 B2, US 2007/0153247 A1, US 6,600,608 B1 and US 6,631,036 B2.

An object of the present invention is to develop an imaging optical system of the type mentioned at the outset in such a way that the flexibility of use thereof is increased.

This object is achieved according to the invention by an imaging optical system with the features of claim 1 and by an imaging optical system with the features of claim 2.

In the solution according to the invention of claim 1, the exclusive use of mirrors results in an optical system which provides the possibility of a broadband use and in which two object fields and two image fields can be used simultaneously with a compact construction. Thus, use is not made of two imaging optical systems, as is the case for example in US 2007/0153247 A1, but use is made of precisely one imaging optical system, with at least one optical component which is used jointly by the two imaging light paths between the two object fields and the two image fields, this single imaging optical system comprising two object fields and two image fields. The overall result is a compact imaging construction.

In the solution according to the invention according to claim 2, a folded light path can be dispersed with because of the inline construction. The light paths which are associated with the two object fields preferably extend reflectionally symmetrically in relation to the optical axis. The inline arrangement simplifies the production of the imaging optical system as a whole and likewise contributes to a compact system being achieved.

The distance between the at least two object fields is preferably at least 50 mm, more preferably at least 100 mm, even more preferably at least 150 mm and yet more preferably at least 164 mm. The distance between the at least two image fields results from the distance of the at least two object fields and the imaging factor of the imaging optical system. A distance of at least 100 mm between the at least two object fields and a reduction imaging scale of 10 results, for example, in a distance of 10 mm between the at least two image fields.

With particular mirror constructions, used off-axis, of imaging optical systems, the construction can be widened using the solution according to the invention in such a way that by using two object fields, the object field originally used with the construction and thus also the image field double in size.

In a construction according to claim 3, there are always at least two field component groups and at least one aperture component group in each case. The field component groups may be associated with the at least two object fields, the at least two image fields, or even intermediate image fields of the imaging optical system. The two field component groups may be configured so as to be constructionally separated from one another. This makes it possible to provide these two field component groups with different qualities of optical systems and also with different additional components, for example as regards an actuator for displacing individual imaging components or a sensor for measuring, for example, optical parameters of the imaging optical system.

A mirror group according to claim 4 can be configured in a broadband form and allows in particular light with a wavelength for which transmissive materials do not exist in a sufficient quality to be guided.

A relative aperture size according to claim 5 leads to a compact construction of the imaging optical system, spatial separation between the optically effective surfaces of the beam-guiding components of the field component groups being possible nevertheless.

A configuration according to claim 6 allows a constructional separation of components associated with the two object fields to be achieved. This broadens the possibilities for the use of these two object fields. These may in particular be used by entirely different units, for example a reticle on the one hand and an optical sensing means on the other hand. The opposite arrangement, with two field components which are associated with the two image fields and with an aperture component between the object fields and the two field component groups, is also possible.

An arrangement according to claim 7, with four field component groups, allows of the imaging properties of the field component groups to be influenced in diverse and mutually independent ways.

A configuration of the imaging optical system according to claim 8 makes it possible, in particular, to act upon a field component group with a different wavelength to that used for the other field component group. This can be made use of in numerous ways, in particular for preparation and measurement purposes. The very same imaging optical system can, for example, be used for EUV exposure and simultaneously for preparation or measurement in the UV range or in the visible wavelength range. Beam-guiding optical components which are used jointly by both wavelengths may have coatings which optimise the passage of light through the imaging optical system and are tuned to both the wavelengths being used.

Object planes which are at a distance from one another according to claim 9 again lead to an increase in the flexibility of use of the imaging optical system. For example, when using different wavelengths, it is possible in this way to compensate chromatic effects. This can be used to compensate the chromatic variations which are induced by coatings of the beam-guiding optical components of the imaging optical system. Different imaging criteria may be used in the two partial systems, which are associated with mutually distanced object planes, of the imaging optical system. This can then be used for imaging rough structures by means of a first imaging light path, with which one of the object fields is associated, for example at a reduction scale of 2x, and for imaging fine structures by means of a further imaging light path, with which another of the object fields is associated, at a higher reduction scale, for example of 16x. Alternatively, it is possible to image-scan various layers, which are distanced from one another by the distance of the two object planes, of the same object, which is moved parallel to the two object planes between the object fields.

An optical sensing means according to claim 10 allows the imaging properties in the light path, starting from the associated image field, to be measured. In this way, the image properties of an aperture group can, for example, be controlled online during a projection of an object arranged in the other object field. The measurement result of the optical sensing means can be used as a control value for adjusting the imaging properties of the imaging optical system. A CCD camera in particular may be used as an optical sensing means. This can be acted on by measurement light of which the wavelength is different from that of the illumination light used for the actual imaging.

A configuration according to claim 11 provides the possibility of readjusting the imaging properties of the imaging optical system in a closed control circuit.

An arrangement according to claim 12 makes it possible to influence the image properties on the image field side for the two image fields separately. This can also be made use of in numerous ways.

Image fields which, in accordance with claim 13, are not arranged in a plane increase the flexibility of use of the imaging optical system.

Image fields which, in accordance with claim 14, are parallel to and at a distance from one another allow imaging of objects arranged in the two object fields in different layer positions of a substrate arranged in the region of the image fields. This can in particular be used for three-dimensional structuring in the production of microstructured components.

An arrangement according to claim 15 can for example be used for an imaging optical system with an imaging scale of 1:1. Individual alterations, i.e. alterations associated with the respective fields of the field component groups, in the imaging properties of the imaging optical system are then possible both on the object field side and on the image field side.

An arrangement according to claim 16 leads to an individual separation of the light paths between the aperture component groups for each field. This can be used to analyse one of the two separated light paths, i.e. to use it as a reference light path, or to manipulate one of the two light paths independently of the other. This arrangement may also be configured in such a way as to result in 1:1 imaging.

A configuration of the field component groups according to claim 17 reduces the production costs of the beam-guiding optical components from which they are constructed. For example, each pair of mirrors can be produced together.

An aperture component group according to claim 18 enables an imaging optical system with a high numerical aperture to be achieved.

At least one ring field according to claim 19 allows the field shape to be fitted well to the construction of the imaging optical system for given imaging requirements. If two object fields configured as ring fields and/or two image fields configured as ring fields are used, they may be partial rings of the same ring, and this symmetrises the construction of the imaging optical system. In the case of a ring field, it is preferable for all the fields of the imaging optical system, i.e. both the two object fields and the two ring fields, to be configured as ring fields.

The advantages of a projection exposure installation according to claims 20 and 21 correspond to those previously discussed with regard to the imaging optical system according to the invention. The light source of the projection exposure installation may be in the form of a broadband light source and may have, for example, a bandwidth greater than 1 nm, greater than 10 nm or greater than 100 nm. In addition, the projection exposure installation may be constructed in such a way that it can be operated with light sources of different wavelengths, which in particular are associated with the different object fields. Light sources for other wavelengths, in particular wavelengths used for microlithography, can be used in conjunction with the imaging optical system according to the invention, for example light sources with wavelengths of 365 nm, 248 nm, 193 nm, 157 nm, 126 nm and 109 nm, and in particular also with wavelengths which are less than 100 nm.

A further object of the invention is to specify methods for the production of a microstructured component in which the flexibility of use, which is obtained because of the projection exposure installation according to the invention, is particularly useful.

This object is achieved according to the invention by the methods with the method steps specified in claims 22 to 26.

A production method according to claim 22 allows the creation of constructions of a critical dimensions which are smaller than those achieved in a single-exposure procedure of the light-sensitive layer of the wafer.

The methods according to claims 23 and 24 have corresponding advantages.

A method according to claim 25 allows online correction to take place before the projection step, which is decisive in the production of the microstructured component. In this method, one of the image fields is used as a measurement image field and the other as a projection image field. As a function of the measured wafer topography, alterations can still be made, for example, in the imaging properties of the field component group which is associated with the projection image field. It is possible alternatively or additionally to further adjust the positioning of the wafer in the projection image field. This is also known as a line of sight correction.

In the method according to claim 26, online-monitoring of the success of the projection step is possible. In this way, it is possible to achieve a quick quality control check of the operation of the projection exposure installation.

Embodiments of the invention will be described in the following in greater detail with reference to the drawings, in which:

Fig. 1 is a schematic view of a projection exposure installation for EUV microlithography;

Fig. 2 is a schematic view of an imaging optical system of the projection exposure installation comprising two field mirror groups, each between one of two object fields and an entrance pupil plane of the imaging optical system, and an aperture mirror group, between the entrance pupil plane and two image planes respectively associated with the object planes;

Fig. 3 is a meridional section of a first variant of an optical construction of the imaging optical system of Fig. 2;

Fig. 4 and 5 are meridional sections of further variants of optical constructions of the embodiment of Fig. 2;

Fig. 6 is a schematic view, similar to Fig. 2, of a further embodiment of an imaging optical system comprising two field mirror groups, each between one of two object fields and an entrance pupil plane of the imaging optical system, an aperture mirror group between the entrance pupil plane and an exit pupil plane of the imaging optical system, and two further field mirror groups, in each case between the exit pupil plane and one of the two image planes;

Fig. 7 is a schematic view, similar to Fig. 2, of a further variant of an imaging optical system comprising an aperture mirror group between two object fields and an entrance pupil plane of the imaging optical system, two separated field mirror groups, each between the entrance pupil plane and an exit pupil plane of the imaging optical system, and a further aperture mirror group, between the exit pupil plane and two separated image planes;

Fig. 8 is a schematic view, similar to Fig. 2, of a further variant of an imaging optical system with mirror groups arranged comparably to the embodiment of Fig. 2, the object field plane of a first object field, associated with the first field mirror group, being arranged to as to be at a distance from and parallel to the object field plane of a second image field, associated with the second field mirror group,

Fig. 9 is a schematic view of two ring fields to illustrate a definition of the distance between them; and

Fig. 10 is a schematic view of two rectangular fields to illustrate a definition of the distance between them.

A projection exposure installation 1 for microlithography, schematically shown in Fig. 1, has a light source 2 for illumination light. The light source 2 is a EUV light source which produces light in a wavelength range in particular of between 5 nm and 30 nm. Other EUV wavelengths are also possible. In general, any desired wavelengths, for example visible wavelengths or any other wavelengths which are used for example in microlithography and are available for the appropriate laser light sources and/or LED light sources, for example 365 nm, 248 nm, 193 nm, 157 nm, 129 nm or 109 nm, are possible for the illumination light guided in the projection exposure installation 1. A light path of the illumination light 3 is very schematically shown in Fig. 1.

In order to aid the description of the projection exposure installation 1 and the components thereof, an xyz Cartesian coordinate system is provided in the drawings and shows the respective locations of the components shown in the figures. In Fig. 1, the x direction extends perpendicular to and into the drawing plane. The y direction extends to the right and the z direction extends downwards.

The illumination light 3 exposes two object fields 4, 5, which are spatially separated from one another in the y direction by a distance A (cf. also Fig. 9 and 10), and which lie in a common object plane 6, which is perpendicular to the drawing plane in Fig. 1. The object fields 4, 5 may be ring fields or also rectangular fields.

A lens system 7 guides the illumination light 3 from the light source 2 to the object fields 4, 5. With a projection optical system 8, i.e. an imaging optical system, the two object fields 4, 5 are imaged in two image fields 9, 10 associated therewith, which are likewise arranged so as to spaced from one another, in a common image plane 11 with a pre-specified reduction scale. The image plane 11 lies parallel to the object plane 6. In Fig. 1, the image fields 9, 10 are so small that they are not shown spatially extended in the image plane 11. One of the embodiments shown in the following figures can be used for the projection optical system 8. The projection optical system 8 has for example a reduction factor of 8. Other imaging factors or reduction scales are also possible, for example 4x, 5x, or even reduction scales that are greater than 8x. 1:1 imaging is also possible. An imaging magnification level of 8x is particularly suitable for the illumination light 3 with an EUV wavelength, since the object-side angle of incidence on a reflection mask 12 can thus remain small. An imaging magnification level of 8x does not require, in addition, unnecessarily large masks to be used. The projection optical system 8 images portions of the reflection mask 12, also referred to as a reticle, which coincide with the object fields 4, 5.

The image fields 9, 10 are curved in an arc shape in the image plane 11, the distance between the two arc curves which delimit the image fields 9, 10 being 1 mm. 1 mm is also the side length of the straight side edges which delimit the image fields 9, 10 between the two arc curves and which extend parallel to one another and to the y-axis. The drawing plane of Fig. 1 extends parallel to these side edges of the image planes 9, 10. These two straight side edges of the image fields 9, 10 are at a distance of 13 mm from one another. The area of the two curved image fields 9, 10 corresponds to a rectangular image field with edge-lengths of 1 mm x 13 mm . Rectangular image fields of this type are also possible instead of the image fields 9, 10. Rectangular image fields as produced for example when using catoptric systems with free-form surfaces as reflection surfaces or when using catadioptric systems.

Imaging takes place on the surface of a substrate 13 in the form of a wafer which is supported by a substrate support 14. Fig. 1 schematically shows, between the reticle 12 and the projection optical system 8, light beams 15, 16, entering these, of the illumination light 3. In this case, the light beam 15 departs from the object field 4 and the light beam 16 from the object field 5. Between the projection optical system 8 and the substrate 13, two light beams 17, 18 of the illumination light exiting from the projection optical system 8 are shown. The light beam 17 exposes the image field 9 and the light beam 18 exposes the image field 10.

The paths of the light beams 15 to 18 are shown very schematically in Fig. 1. In particular, the light beams 15 and 17 on one side and 16 and 18 on the other may extend symmetrically in relation to an assigned axis of the projection optical system 8, in particular symmetrically in relation to the optical axis thereof.

The projection exposure installation 1 is a scanner-type device. Both the reticle 12 and the substrate 13 are scanned in the y direction during the operation of the projection exposure installation 1. Alternatively, the projection exposure installation 1 can be a stepper-type device. In this case, the substrate support 14 and a reticle support (not shown), which is associated with the reflection mask 12, are displaced stepwise between individual exposes in the y direction.

Fig. 2 shows schematically a variant of the projection optical system 8 of the projection exposure system 1. Components which correspond to those which have been previously explained with reference to Fig. 1 like reference numerals and will not be discussed in detail again.

Fig. 2 shows schematically the construction of a first embodiment of the projection optical system 8. This is configured as an inline system. All beam-guiding components of the projection optical system 8 may be associated with the same continuous optical axis 19, which thus extends without bends, throughout.

The projection optical system 8 of Fig. 2 has three component groups 20, 21, 22, which are each constructed as beam-guiding optical components.

The two component groups 20, 21 shown on the left in Fig. 2 are field groups, in which the light beams 15, 16, which proceed respectively from the object planes 4, 5, are guided. The light beams 15, 16 are guided separately from one another in the two field groups 20, 21.

In Fig. 2, the field group 20 is arranged below the field group 21. The field group 20 lies between the object field 4 and a pupil plane 23 of the projection optical system 8. The two light beams 15, 16 exiting the field groups 20, 21 overlap in the pupil plane 23.

The component group 22 shown on the right in Fig. 2 is an aperture group, in which the light beams 15, 16, i.e. the imaging rays which proceed from all of the object planes 4, 5, are guided. The aperture group 22 is arranged between the pupil plane 23 and the two image fields 9, 10.

The component groups 20 to 22 of the embodiment of Fig. 2 are pure mirror groups or catoptric groups, i.e. component groups which comprise exclusively mirrors as beam-guiding optical components. In principle, the component groups 20 to 22 may also be catadioptric or dioptric groups.

The two field groups 20, 21 may be constructionally completely separate from one another, but may however be integrated to form one constructional unit, as is indicated in Fig. 2, with a common housing 24.

Fig. 3 shows a first constructional variant of the projection optical system 8. Components which correspond to those which have been previously explained with reference to Fig. 1 and 2 have like reference numerals and will not be discussed in detail again.

The light path of each of three individual rays 25, which proceed in each case from two object field points, at a distance from one another in the y direction in Fig. 3, of the object fields 4 and 5, is shown. The three individual rays 25, which belong to one of these in total four object field points, are each associated with three different illumination means for the image field point. Principal rays 16, which extend through the centre of the pupil plane 23 of the projection optical system 8, are included in Fig. 3 only for illustrative reasons, as these are not real imaging light paths of the projection optical system 8.

The individual rays 15, in each case associated with the same illumination angle of a field point, extend divergently from the respective object plane 4, 5. This is referred to in the following as a negative back focal length of the entrance pupil. An entrance pupil of the projection optical system 8 of Fig. 3 lies not inside the projection optical system 8 but before the object planes 4, 5 in the light path. Alternatively, a positive back focal length of the entrance pupil or a telecentric light path on the object side is possible, for example when using a ray divider element for illuminating a reflection mask or when using a transmission mask. This makes it possible, for example, to arrange a pupil component of the illumination optical system 7 in the entrance pupil of the projection optical system 8, before the projection optical system 8 in the light path, without further imaging optical components having to be present between these pupil components and the object planes 4, 5.

The field group 20 of the projection optical system 8 has two mirrors M1a, M2a. The field group 21 of the projection optical system 8 likewise has two mirrors M1b and M2b. Where, in the following, the references M1, M2 are used instead of the references M1z/b, M2a/b within a field group, for example, they refer in each case to both mirrors M1a/b, M2a/b. The numbering of the mirrors of the projection optical system 8 are numbered in the sequence of the light path, proceeding from the object fields 4 and 5. The mirrors M1a and M1b and the mirrors M2a and M2b each have reflection surfaces which are arranged on the same surface, which is rotationally symmetric about the optical axis 19. The mirrors M1a and M1b on the one hand and M2a and M2b on the other hand may therefore be portions of one and the same mirror. However, this is not compulsory. The mirrors M1a, M1b, M2a, M2b may equally all be arranged spatially separated from one another.

After the mirrors M1a/b and M2a/b, the projection optical system 8 also comprises four further mirrors M3, M4, M5 and M6, which belong to the aperture group 22.

Fig. 3 shows only the reflection surfaces of the mirrors M1 to M6. The reflection surfaces of the mirrors M1 to M6 are as a whole at least portions in each case of a surface which is rotationally symmetrical in relation to the optical axis 19. The mirrors M1, M4, M5 and M6 are formed as concave mirrors. The mirrors M2 and M3 are formed as convex mirrors.

The optical data for the projection optical system 8 of Fig. 3 are shown in the following by means of two tables.

In the column "radius", the first table shows in each case the reciprocal of the curvature c of the mirrors M1 to M6. The third column (thickness) describes the distance from the object plane 6 to the following surface in each case.

The second table describes the precise surface form of the reflection surfaces of the mirrors M1 to M6, where the constants K and A to G are to be put into the following equation for the sagittal height:

$$z(h) = \frac{ch^2}{1 + SQRT\{1 - (1+K)c^2h^2\}} + Ah^4 + Bh^6 + Ch^8 + Dh^{10} + Eh^{12} + Fh^{14} + Gh^{16}$$

In this case, h represents the distance from the optical axis 19. Therefore: $h^2 = x^2 + y^2$. The reciprocal of "radius" is used for c.

Surface	Radius	Thickness	Operating mode
Object plane	INFINITY	683.665	
M1	-694.834	-271.324	REFL
M2	-411.527	1372.036	REFL
M3	346.281	-1100.613	REFL
M4	1469.502	2005.780	REFL
M5	-722.731	-41.563	REFL
STOP	INFINITY	-272.149	
M6	544.465	370.467	REFL
Image plane	INFINITY	0.000	

Surface	K	A	B	C
M1	7.396949	-8.591818E-11	2.958631E-15	-1.515085E-19
M2	-4.696303E-01	-1.639186E-09	-1.894486E-14	-4.136066E-18
M3	-5.224549E-01	-2.010111E-09	-1.293006E-14	-2.918315E-20
M4	-3.021297E-02	9.250522E-14	5.057734E-20	4.887335E-28
M5	-3.126684E+00	2.153833E-09	1.799694E-14	-1.892202E-20
M6	6.984230E-01	-1.682769E-10	-1.422157E-15	1.234832E-20
Surface	D	E	F	G
M1	4.091038E-24	-5.790509E-29	3.296826E-34	8.178384E-41
M2	1.255234E-21	-1.379809E-25	5.435466E-30	-4.566966E-36
M3	1.475407E-23	-5.835055E-28	1.288505E-32	-3.671165E-37
M4	4.320243E-35	4.670696E-39	-4.109431E-45	2.963010E-51
M5	-6.296522E-25	2.964336E-29	6.191151E-34	-1.998284E-38
M6	-1.683381E-25	8.658821E-31	-3.676860E-36	-5.905802E-41

The mirrors M1a/b and M2a/b of the two field groups 20, 21 are used in the shape of ring segments and off-axis in relation to the optical axis 19. The employed optical reflection surface of the mirrors M1 and M2 thus lies at a distance from the optical axis 19.

The employed optical reflection surface of the mirror M3 is approximately centred on the optical axis 19.

The pupil plane 23 lies in the imaging light path of the projection optical system 8 in the region of the reflection of the individual rays 25 on the mirror M3. In the imaging light path between the mirrors M4 and M5, spatially in between the mirrors M6 and M5, lies an intermediate image plane 26 of the projection optical system 8.

Between the mirrors M2a/b and M3, the individual rays 25 pass through a through-opening 27 in the mirror M4. The mirror M4 is used around the through-opening 27. The mirror M4 is thus an obscured mirror. As well as the mirror M4, the mirrors M5 and M6 are also obscured and both likewise comprise a through-opening 27.

The mirror M3, i.e. the fourth last mirror in the light path before the image fields 9 and 10, is not obscured. An outer edge 28 of the optically effective reflection surface of the mirror M3 provides a central shadowing of the projection optical system 8, i.e. of the imaging optical system, in an exit pupil plane 29 in the imaging light path in the region of the reflection on the mirror M5. The mirror M3 thus defines the pupil obscuration of the projection optical system 8. The mirror M3 therefore shadows the light path between the mirrors M4 and M5.

The distance between the fourth last mirror M3 and the last mirror M6 is equal to approximately 22 % of the distance of the object plane 6 from the image plane 11 in the embodiment of the projection optical system 8 of Fig. 3.

The projection optical system 8 of Fig. 3 has a numerical aperture of 0.55 on the image side. The projection optical system 8 of Fig. 3 has a maximum root mean square (rms) wavefront error of 1.4 nm. The maximum distortion is 1.4 nm. The pupil obscuration is 16.8 %.

The light beams 15, 16 of the two imaging light paths, which until now have been guided on separate mirrors M1a/b, M2a/b, overlap in the aperture group 22, i.e. on the mirrors M3 to M6

In the projection optical system 8 of Fig. 3, the distance A (cf. also Fig. 9 and 10) between the two object fields 4, 5 is 164 mm.

The projection optical system 8 can be used within the projection exposure installation 1 in the production of a microstructured component in the following manner: Initially, the reticle 12 and the wafer 13 are prepared. Subsequently, a structure, arranged in the first object field 4, on the reticle 12 is projected onto a light-sensitive layer of the wafer 13 in the first image field 9. The exposed light-sensitive layer is then displaced in the positive y direction from the first image field 9 to the second image field 10 by displacing the wafer 13 by means of the substrate support 14. Subsequently, a structure, arranged in the second object field 5, on the reticle 12 is projected onto the previously exposed light-sensitive layer of the wafer 13 in the second image field 10. In this way, a microstructure is produced on the wafer 13. As far as the basic procedure is concerned, but not the use of the optical components shown here, this method is known as a "double exposure" method and allows a smaller structures than would be possible with a conventional "single exposure" method to be microstructured. A double exposure method which can be used with the projection exposure installation 1 is disclosed, for example, in the professional article A. Poonawala, Y. Borodovsky, and P. Milanfar, "ILT for Double Exposure Lithography with Conventional and Novel Materials", Proceedings of the SPIE Advanced Lithography Symposium, Feb 2007. In this professional article, the use of a second field region for receiving the topography of a wafer, as discussed below, is also explained. Further wafer-monitoring methods which can be used with the disclosed variants of the projection exposure installation 1 are explained in US 2007/0080281 A1 and in US 5,268,744.

In an alternatively or additionally possible application of the projection optical system 8 within the projection exposure installation 1, after the preparation of the reticle 12 and of the wafer 13, a light-sensitive layer of the wafer 13 in the first image field 9 is initially exposed with a preparation light of a first light wavelength, which is coupled into the first image field 9 via the first object field 4 and the field group 20. Subsequently, the light-sensitive layer prepared in this manner is displaced from the first image field 9 to the second image field 10, as explained previously in the above. Subsequently, a structure, arranged in the second object field 5, on the reticle 12 is projected onto the prepared light-sensitive layer of the wafer 13 in the second image field 10. In this way, a microstructure is produced on the wafer 13. In a variant of the method, the reticle 12 does not cover the first object field 4. Alternatively, it is possible to prepare the reticle 12 only after the preparation of the light-sensitive layer with the preparation light in the location of the object field 5.

Irradiation with preparation light may for example be used to make the light-sensitive layer on the wafer 13 more sensitive for the subsequent irradiation process with the illumination light 3.

In an alternatively or additionally possible application of the projection optical system 8 within the projection exposure installation 1, the sequence of the exposure of the wafer 13, on the one hand with preparation light and on the other hand with illumination light, is reversed as compared to the method explained above. In the first image field 9, the light-sensitive layer on the wafer 13 is initially exposed with the illumination light 3. After the displacement of the previously exposed light-sensitive layer on the wafer 13 to the second image field 10, the previously exposed light-sensitive layer is irradiated with the preparation light in the second image field 10.

In a further application of the projection optical system 8 within the projection exposure installation 1, the projection optical system 8 has additional components, which are shown in broken lines in Fig. 2. This includes an optical sensing means 30, which may for example be a CCD camera. The optical sensing means 30 is arranged in such a way that the optically sensitive surface thereof encompasses the object field 5 of the field group 21. The optical sensing means 30 thus encompasses the imaging rays between the image field 10 and the object field 5. The optical sensing means 30 is in a signal connection with a central control means 32 of the projection exposure installation 1 via a signal line 31.

Furthermore, for this further application, the projection optical system 8 has within the projection exposure installation 1 a correction means 33 for the correction of the imaging properties of the field group 20, i.e. of the field group which is not directly associated with the optical sensing means

30. In turn, the correction means 33 is in a signal connection with the control means 32 via a signal line 34.

The correction means 33 may for example be a mirror, which is displaceable by means of at least one actuator (not shown), or an adjustable stop or filter element.

In an application of the projection optical system 8 within the projection exposure installation 1 where the components 30 to 34 are used, the reticle 12 is prepared in the region of the object field 4 and the wafer 13 in the region of the two image fields 9 and 10. Subsequently, the topography of the wafer is measured in the image field 10 by means of the optical sensing means 30. By means of the measured topography and the corresponding topography data conveyed from the optical sensing means 30 to the control means 32, the control means 32 calculates a correction value. Subsequently, the imaging properties of the projection optical system 8 are corrected on the basis of the calculated correction value by actuating the correction means 33. Finally, the structure which is arranged in the object field 4, on the reticle 12, is projected onto a light-sensitive layer of the wafer 13 in the image field 9 with the corrected projection optical system 8.

In an alternatively or additionally possible application of the projection optical system 8 with the additional components 30 to 32, i.e. with the optical sensing means 30, the control means 32 and the associated signal line 31, the reticle is again prepared in the object field 4 and the wafer in the image fields 9 and 10. Subsequently, the structure which is arranged in the first object field 4, on the reticle 12, is projected onto a light-sensitive layer of the wafer 13 in the image field 9 with the projection optical system 8. Subsequently, the wafer 13 is displaced in such a way that the portion initially lying in the image field is transferred into the image field 10. Subsequently, the topography, affected by the aforementioned projection, of the wafer 13 in the image field 10 of the projection optical system 8 is measured by means of the optical sensing means 30, which is arranged in the object field 5. In this way, the result of the projection step can be subjected to an immediate check.

Fig. 4 shows a further embodiment of a projection optical system 8 for use in the projection exposure installation 1. Components which correspond to those which have been previously explained with reference to Fig. 1 to 3 have like reference numerals and will not be discussed in detail again. The applications of the projection optical system of Fig. 4 also correspond to those which were previously explained in the above, unless otherwise indicated below.

The first field group 20 comprises a total of four mirrors M1a, M2a, M3a and M4a in the embodiment of Fig. 4. The second field group 21 comprises the mirrors M1b, M2b, M3b and M4b, which lie, comparably with the mirrors M1 and M2 of the embodiment of Fig. 3, on portions, which are arranged symmetrically in relation to the optical axis 19, of a reflection surface which is rotationally symmetric about the optical axis 19 and on which the mirrors M1a, M2a, M3a and M4a also lie in portions respectively spatially separated therefrom. The reflection surfaces of the mirrors M1a and M1b, the mirrors M2a and M2b, the mirrors M3a and M3b and the mirrors M4a and M4b thus lie pairwise on the same surface, arranged rotationally symmetrically in relation to the common optical axis 19. The separation between the mirrors M4a and M4b is in this case relatively small as compared to the separations of the mirrors M1 to M3.

The aperture group 22 comprises the following mirrors M5 to M8, of the projection optical system 8 of Fig. 4, in the imaging light path.

The mirrors M3a and M3b on the one hand and M6 on the other hand are arranged back to back as regards the reflection surfaces thereof. The same applies to the mirrors M1a and M1b on the one hand and M4a and M4b on the other hand.

The pupil plane 23 lies in the light path between the mirrors M5 and M6 close behind the reflection of the individual rays 25 on the mirror M5. The intermediate image plane 26 lies in the light path between the mirrors M6 and M7. This plane lies spatially in between the mirrors M5 to M8, which are likewise used back-to-back as regards the reflection surfaces thereof. In the embodiment of Fig. 4, the exit pupil plane 29 is in the region of the reflection of the individual rays 25 on the mirror M7.

The projection optical system 8 of Fig. 4 has a root mean square (rms) maximum wavefront error of 0.6 nm, a distortion which is less than 1nm, and a pupil obscuration of 6 %.

The mirrors M1, M4 and M5 are convex. The mirrors M2, M3, M6, M7 and M8 are concave. The mirrors M5 to M8 each comprise a central through-opening 27, and are therefore obscured.

The projection lens system 8 of Fig. 4 also has a reduction scale of 8. The image-side numerical aperture of the projection lens system 8 of Fig. 4 is 0.60.

The optical data for the projection optical system 8 of Fig. 4 are shown in the following by means of two tables, which correspond in terms of their layout to the tables for Fig. 3.

Surface	Radius	Thickness	Operating mode
Object plane	INFINITY	182.885	
M1	312.514	-135.045	REFL
M2	461.057	514.193	REFL
M3	-989.211	-295.490	REFL
M4	-210.779	875.015	REFL
M5	760.298	-545.015	REFL
M6	698.490	798.704	REFL
M7	-576.011	-19.744	REFL
STOP	INFINITY	-173.945	
M8	347.848	224.078	REFL
Image plane	INFINITY	0.000	

Surface	K	A	B	C
M 1	0.000000E+00	2.054833E-08	-4.009641E-13	7.171735E-17
M 2	0.000000E+00	3.334553E-10	-7.634038E-15	1.024823E-19
M 3	0.000000E+00	-5.191038E-10	-4.805715E-16	1.117253E-19
M 4	0.000000E+00	-8.530524E-08	-7.872800E-12	-8.643400E-16
M 5	0.000000E+00	-9.493122E-10	-4.519746E-14	2.842871E-19
M 6	0.000000E+00	1.067524E-10	3.344389E-16	8.381905E-22
M 7	0.000000E+00	3.431647E-10	-3.006760E-15	1.681919E-19
M 8	0.000000E+00	-5.212207E-09	-4.936095E-14	3.981107E-19

Surface	D	E	F	G
M 1	-2.913353E-21	1.088107E-25	0.000000E+00	0.000000E+00
M 2	-9.460244E-25	3.872599E-30	0.000000E+00	0.000000E+00
M 3	-1.418804E-24	9.313360E-30	0.000000E+00	0.000000E+00
M 4	-1.810090E-20	-3.582650E-23	0.000000E+00	0.000000E+00
M 5	-9.298310E-24	-1.362975E-28	0.000000E+00	0.000000E+00
M 6	2.378219E-27	2.644241E-33	3.062582E-38	0.000000E+00
M 7	-1.186133E-24	2.512989E-29	0.000000E+00	0.000000E+00
M 8	3.278180E-24	-3.575793E-29	0.000000E+00	0.000000E+00

In the projection optical system 8 of Fig. 4, the distance A (cf. also Fig. 9 and 10) between the two object fields 4, 5 is 88.308 mm.

A further embodiment of a projection optical system 8 is disclosed in the following by means of Fig. 5. Components which correspond to those which have been previously explained with reference to Fig. 1 to 4 have like reference numerals and will not be discussed in detail again. The applications of the projection optical system of Fig. 5 also correspond to those which were previously explained in the above, unless otherwise indicated below.

Proceeding from the object fields 4, 5, the projection optical system 8 of Fig. 5 first has two field groups 20, 21 with mirrors M1a, M2a on one side and M1b, M2b on the other, which are similar in construction to the field groups 20, 21 of the embodiment of Fig. 3.

The embodiment of Fig. 5 has, arranged after the two field groups 20, 21, two further field groups 35, 36, respectively comprising four mirrors M3a, M4a, M5a, M6a on one side and M3b, M4b, M5b, M6b on the other. The field group 35 is in this case arranged after the field group 20 in the light path of the individual rays 25 proceeding from the object field. The field group 36 is arranged after the field group 21 in the light path of the individual rays 25 proceeding from the object field 5. In Fig. 5, the field group 35 lies above the optical axis 19 and the field group 36 lies below the optical axis 19. In turn, the mirrors M1 to M6 of the field groups 20, 21, 35, 36 each comprise two mirrors a/b which are outside the axis and of which the reflection surfaces lie on a common surface which is rotationally symmetrical in relation to the common optical axis 19.

A first pupil plane 37 of the projection optical system 8 of Fig. 5 lies between the field groups 20 and 35 on the one hand and 21 and 36 on the other hand. After the first pupil plane 37, the beams of individual rays associated with the two object fields 4, 5 separate completely again, in such a way that the following first mirrors M3a/b of the field groups 35, 36 are also spatially separated from one another.

The mirrors M1a and M1b on the one hand and M4a and M4b on the other lie back to back as regards the reflection surfaces thereof. The same applies to the mirrors M3a and M3b on the one hand and M6a and M6b on the other hand.

The mirrors M1, M4, M5, M8, M9 and M10 are concave. The mirrors M2, M3, M6 and M7 are convex.

The mirrors M7 to M10 belong to the aperture group 22 of the projection optical system of Fig. 5. The mirrors M7 to M10 each comprise a central through-opening 27, and are therefore obscured.

In the light path between the mirrors M5a and M6a on the one hand and M5b and M6b on the other lies a first intermediate image plane 38 of the projection optical system 8. In the vicinity of the reflection of the individual rays 25 on the mirror M7 lies a further pupil plane 39, which corresponds approximately to the pupil plane 23 of the embodiment of Fig. 4..
In the light path between the mirrors M8 and M9 lies a further intermediate image plane 40 of the projection optical system 8 of Fig. 5. This further intermediate image plane 40 lies spatially in between the mirrors M7 and M10.

As regards the reflection surfaces thereof, the mirrors M5a and M5b on the one hand and M8 on the other hand are arranged back-to-back relative to one another. As regards the reflection surfaces thereof, the mirrors M7 and M10 are arranged back-to-back relative to one another.

The exit pupil plane 29 is arranged in the vicinity of the reflection of the individual rays 25 on the mirror M9.

The projection optical system 8 of Fig. 5 has reduction scale of 8x and a numerical aperture of 0.80. The root mean square (rms) of a wavefront error is 2 nm. The distortion is at most 1.5 nm and the pupil obscuration is 9 %.

The optical data for the projection optical system 8 of Fig. 5 are shown in the following by means of two tables, which correspond in terms of their layout to the tables for Fig. 3.

Surface	Radius	Thickness	Operating mode
Object plane	INFINITY	231.437	
M1	-288.093	-103.544	REFL
M2	-377.155	292.180	REFL
M3	448.302	-138.636	REFL
M4	454.8	523.231	REFL
M5	-589.203	-216.254	REFL
M6	-145.829	1018.283	REFL
M7	2703.619	-649.781	REFL
M8	912.571	920.886	REFL
M9	-812.217	-31.279	REFL
STOP	INFINITY	-179.826	
M10	359.686	256.105	REFL
Image plane	INFINITY	0.000	

Surface	K	A	B	C
M1	0.000000E+00	-2.770331E-09	-1.945643E-13	1.458478E-17
M2	0.000000E+00	-5.212535E-09	1.710190E-12	-8.085597E-16
M3	0.000000E+00	-3.752077E-08	5.246057E-14	-6.894048E-17
M4	0.000000E+00	-2.462750E-09	-3.344608E-14	-1.092346E-19
M5	0.000000E+00	-5.521295E-10	-4.038243E-14	6.719521E-19
M6	0.000000E+00	-3.262600E-07	-1.087971E-10	-1.914029E-14
M7	0.000000E+00	4.368648E-10	-1.436480E-15	-9.017326E-21
M8	0.000000E+00	4.738372E-11	6.475997E-17	8.529830E-23
M9	0.000000E+00	1.300125E-09	-3.133782E-15	2.232463E-19
M10	0.000000E+00	-1.582356E-09	-1.336421E-14	-2.713010E-20

Surface	D	E	F	G
M1	-1.046226E-21	5.585585E-26	-2.261643E-30	4.656384E-35
M2	5.785045E-19	-1.744933E-22	3.203600E-26	-2.339477E-30
M3	1.505618E-20	-1.372039E-24	6.258658E-29	-1.139523E-33
M4	-1.945640E-23	1.214453E-28	3.518208E-33	-1.581797E-37
M5	-1.134436E-23	2.244576E-28	-2.347477E-33	1.853695E-39
M6	8.830341E-18	-1.561330E-20	6.912490E-24	-8.162979E-27
M7	8.083936E-26	-5.639881E-30	3.439245E-35	-4.819066E-40
M8	1.142674E-28	4.929596E-35	2.814036E-40	5.135289E-46
M9	-3.720192E-24	5.185605E-29	-4.428414E-34	1.816673E-39
M10	4.748659E-25	-1.040642E-29	5.109331E-35	-4.742038E-41

In the projection optical system 8 of Fig. 5, the distance A (cf. also Fig. 9 and 10) between the two object fields 4, 5 is 104 mm.

Fig. 6 shows a further embodiment of a projection optical system 8, in a view similar to that of Fig. 2. Components which correspond to those which have been previously explained with reference to Fig. 1 to 5 have like reference numerals and will not be discussed in detail again. The same applies to the applications of the projection optical system 8 of Fig. 6.

In the embodiment of Fig. 6, the two object fields 4, 5 and the two image fields 9, 10 are spatially separated from one another. The arrangement of the two field groups 20, 21 on the object field side corresponds to the arrangement of Fig. 2. The projection optical system 8 of Fig. 6 has an aperture group 41, between the first pupil plane 23 and a further pupil plane 42, as a third component group. Between the further pupil plane 42 and one of the two image fields 9, 10 in each case lie two further field groups 43, 44. In the schematic view of the projection optical system 8 of Fig. 6, the arrangement of the component groups 20, 21, 41, 43, 44 is thus reflectionally symmetric in relation to an xy-plane intersecting the aperture group 41 centrally.

The field group 44 may, as is shown in broken lines in Fig. 6, be configured in such a way that an image plane 11a of the field group 44 is separated from the image plane 11 of the image field 9 by a distance ΔF. In the embodiment of Fig. 6, the image plane 11a of the image field 10a is displaced in the positive z direction relative to the image plane 11 of the image field 9. This displacement ΔF may for example only be a few micrometres. It is thus possible to produce images at different depths in the light-sensitive layer on the wafer 13, within the scope of a double exposure method as described above. In this way, it is possible to produce a three-dimensional structure in the wafer 13 by means of appropriately selected reticle constructions in the object fields 4 and 5.

Fig. 7 shows a further embodiment of a projection optical system 8, in a view similar to that of Fig. 2. Components which correspond to those which have been previously explained with reference to Fig. 1 to 6 have like reference numerals and will not be discussed in detail again. The same applies to the applications of the projection optical system 8 of Fig. 7.

In the projection optical system 8 of Fig. 7, between the object fields 4 and 5 and the field groups 20, 21, there first lies an aperture group 45, in which the light beams 15, 16 are guided together. The light beams 15, 16 separate only after a first pupil plane 46, and then enter the field group 20, 21.

The field group 21, for example, may in turn contain an optical correction means 33, the function of which is identical to that which has already been explained in relation to the projection optical system 8 of Fig. 2.

Fig. 8 shows a further embodiment of a projection optical system 8, in a view similar to that of Fig. 2. Components which correspond to those which have been previously explained with reference to Fig. 1 to 7 have like reference numerals and will not be discussed in detail again. The same applies to the applications of the projection optical system 8 of Fig. 8.

In the embodiment of Fig. 8, the two field groups 20, 21 belong to object fields 4a, 5a, of which the object planes 6a, 6b extend parallel to one another and are at a distance from one another. The field group 20 is configured, in terms of the optical construction thereof, for a different wavelength to that of the field group 21, for example for preparation or measurement light. In this case, the light beam 15 is preparation light, which may have a different wavelength to that of the illumination light, i.e. the light beam 16.

The projection optical system 8 of Fig. 8, which is otherwise constructed in the same way as the one in Fig. 2, is suitable in particular for the method previously disclosed above for correcting imaging properties by means of measured topography data and for checking, after a projection exposure procedure, the topography produced thereby on the substrate 13.

In general, the field groups have a smaller aperture than the aperture groups within one of the previously disclosed embodiments of the projection optical system 8.

Fig. 9 and 10 serve to illustrate a definition of the distance A between the object fields 4, 5. Fig. 9 thus shows the case where the object fields 4, 5 are ring fields, and Fig. 10 shows the case where the object fields 4, 5 are rectangular fields.

In the case of ring fields, where the object fields 4, 5 are thus delimited inter alia by inner arcs which face the optical axis 19, the distance A is defined as the distance between the two points, on the two arcs, at the central height ($x = 0$) in the object fields 4, 5. In the case where the two inner arcs are concentric about the optical axis 19, this distance A is accordingly defined as twice the radius R of the inner arcs which delimit the ring fields. In the case of the rectangular object fields 4, 5, the distance A is defined as the distance between the two longitudinal edges, facing one another, of the object fields 4, 5.

Claims

1. Imaging optical system (8), which comprises exclusively mirrors as beam-guiding optical components (M1 to M6; M1 to M8; M1 to M10) and images at least one object field (4, 5) in at least one object plane (6; 6a, 6b) into at least one image field (9, 10) in at least one image plane (11; 11, 11a),
characterised by at least two object fields (4, 5; 4a, 5a), which are spatially separated from one another and with which two image fields (9, 10; 9a, 10a), which are likewise spatially separated from one another, are associated, there being at least one optical component (M3 to M6; M5 to M8; M7 to M10) of the imaging optical system (8) which is used jointly by the imaging light paths, which are separate at least in portions and which are present between the object fields (4, 5; 4a, 5a), which are arranged separately from one another, and the image fields (9, 10; 9a, 10a), which are arranged separately from one another.

2. Imaging optical system (8), which is configured as an inline system, of which the components (M1 to M6; M1 to M8; M1 to M10) can therefore all be associated with one and the same continuous optical axis (19), and which images at least one object field (4, 5; 4a, 5a) in at least one object plane (6; 6a, 6b) into at least one image field (9, 10; 9, 10a) in at least one image plane (11; 11, 11a),
characterised by at least two object fields (4, 5; 4a, 5a), which are spatially separated from one another and with which two image fields (9, 10; 9a, 10a), which are likewise spatially separated from one another, are associated, the imaging light paths between the at least two object fields and the at least two image fields jointly using at least one pupil plane of the imaging optical system.

3. Imaging optical system according to either claim 1 or claim 2, **characterised by** a construction consisting of at least three component groups (20, 21, 22; 20, 21, 41, 43, 44; 45, 20, 21, 22; 35, 36), each of the component groups (20, 21, 22; 20, 21, 41, 43, 44; 45, 20, 21, 22; 35, 36) being able to be associated with a type from the two following groups:
   - a field type (20, 21; 20, 21, 43, 44; 35, 36), in which imaging rays (25) proceeding from precisely one object field (4, 5; 4a, 5a) are guided;
   - an aperture type (22; 41; 45), in which imaging rays (25), proceeding from all object fields (4, 5; 4a, 5a) are guided.

4. Imaging optical system according to claims 2 and 3, **characterised in that** at least one of the component groups (20, 21, 22; 20, 21, 41, 43, 44; 45, 20, 21, 22; 35, 36) comprises exclusively mirrors (M1 to M6; M1 to M8; M1 to M10).

5. Imaging optical system according to either claim 3 or claim 4, **characterised in that** the at least one field component group (20, 21; 20, 21, 43, 44; 35, 36) has a lower numerical aperture than the at least one aperture component group (22; 41).

6. Imaging optical system according to any one of claims 3 to 5, **characterised by** precisely two object fields (4, 5; 4a, 5a), precisely two image fields (9, 10) and at least three component groups (20, 21, 22; 20, 21, 41, 43, 44; 45, 20, 21, 22; 35, 36),
   - two field component groups (20, 21) each being arranged between one of the two object fields (4, 5; 4a, 5a) and a pupil plane (23) of the imaging optical system (8), and

- an aperture component group (22) being arranged between the pupil plane (23) and the two image fields (9, 10).

7. Imaging optical system according to claim 6, **characterised in that**
   - two field component groups (20, 21) are each arranged between one of the two object fields (4, 5) and a pupil plane (37) of the imaging optical system (8),
   - two further field component groups (43, 44) are arranged between this pupil plane (37) and a further pupil plane (39) of the imaging optical system (8),
   - an aperture component group (23) is arranged between the further pupil plane (39) and the two image fields (9, 10).

8. Imaging optical system according to any one of claims 1 to 7, **characterised in that** the imaging optical system (8) is configured for a different wavelength of imaging rays (25) in the light path between the first object field (4; 4a) and the associated first image field (9) from those in the light path between the second object field (5; 5a) and the associated second image field (10; 10a).

9. Imaging optical system according to any one of claims 1 to 8, **characterised in that** the two object fields (4a, 5a) are arranged in object planes (6a, 6b) which are at a distance from one another.

10. Imaging optical system according to any one of claims 1 to 9, **characterised in that** a two-dimensional optical sensing means (30) is arranged in one of the two object fields (5) and senses imaging rays (16) between the image field (10) associated with this object field (5) and said object field (5).

11. Imaging optical system according to claim 10, **characterised by**
    - a correction means (33) for correcting the imaging properties of a component group (20) of the imaging optical system (8) in the imaging light path between the object field (4) and the image field (9) in which the optical sensing means (30) is not arranged,
    - a control means (32), which is in a signal connection (31, 34) with the optical sensing means (30) and the correction means (33).

12. Imaging optical system according to any one of claims 1 to 11, **characterised by** precisely two object fields (4, 5), precisely two image fields (9, 10; 9, 10a) and at least three component groups (20, 21, 41, 43, 44), one aperture component group (41) being arranged between the two object fields (4, 5) and a pupil plane (42), and
    - at least two field component groups (43, 44) each being arranged between the pupil plane (42) and one of the two image fields (9, 10; 9, 10a).

13. Imaging optical system according to claim 12, **characterised in that** the two field component groups (43, 44) are configured in such a way that the second image field (10a) is arranged at a distance from the image plane (11) of the first image field (9).

14. Imaging optical system according to claim 13, **characterised in that** the two field component groups (43, 44) are configured in such a way that the image field plane (11a) of the second image field (10a) is arranged parallel to and at a distance from the image field plane (11) of the first image field (9).

15. Imaging optical system according to any one of claims 1 to 14, **characterised by** precisely two object fields (4, 5), precisely two image fields (9, 10; 9, 10a), and precisely five component groups (20, 21, 41, 43, 44),
    - two field component groups (20, 21) each being arranged between one of the two object fields (4, 5) and a pupil plane (23) of the imaging optical system (8),
    - an aperture component group being arranged between this pupil plane (23) and a further pupil plane (42) of the imaging optical system (8), and
    - two further field component groups (43, 44) each being arranged between the further pupil plane (42) and one of the two image fields (9, 10; 9, 10a).

16. Imaging optical system according to any one of claims 1 to 11, **characterised by** precisely two object fields (4, 5), precisely two image fields (9, 10) and precisely four component groups (45, 20, 21, 22),
    - an aperture component group (45) being arranged between the two object fields (4, 5) and a first pupil plane (46) of the imaging optical system (8),
    - two field component groups (20, 21) each being arranged between this pupil plane (46) and a further pupil plane (23) of the imaging optical system (8),
    - a further aperture component group (22) being arranged between the further pupil plane (23) and the two image fields (9, 10).

17. Imaging optical system according to any one of claims 4 to 16, **characterised in that** reflection surfaces of the mirrors (M1a/b, M2a/b, M3a/b, M4a/b, M5a/b, M6a/b) of field mirror groups (20, 21; 20, 21,

35, 36; 20, 21, 43, 44) are in each case configured as pairs of surface portions of a surface which is rotationally symmetric in relation to a common axis (19).

18. Imaging optical system according to any one of claims 4 to 17, **characterised in that** the at least one aperture component group (22; 41; 22; 45) is configured as an obscured-pupil system, i.e. as a mirror group with internal pupil shadowing.

19. Imaging optical system according to any one of claims 1 to 18, **characterised in that** at least one of the fields (4, 5, 9, 10; 4a, 5a; 9, 10a) is configured as a ring field.

20. Projection exposure installation (1) for microlithography

- comprising an imaging optical system (8) according to any one of claims 1 to 19,
- comprising a light source (2) for illumination and imaging light (3), and
- comprising an illumination optical system (7) for guiding the illumination light (3) to at least one of the object fields (4, 5) of the imaging optical system (8).

21. Projection exposure installation according to claim 20, **characterised in that** the light source (2) is configured as an EUV light source.

22. Method for the production of a microstructured component with the projection exposure installation (1) according to either claim 20 or claim 21, comprising the following steps:

- providing a reticle (12) and a wafer (13),

- projecting a structure, arranged in the first object field (4), on the reticle (12) onto a light-sensitive layer of the wafer (13) in the first image field (9),
- displacing the exposed light-sensitive layer from the first image field (9) to the second image field (10; 10a)
- projecting a structure, arranged in the second object field (5), on the reticle (12) onto a previously exposed light-sensitive layer of the wafer (13) in the second image field (10; 10a),
- producing a microstructure on the wafer (13).

23. Method for the production of a microstructured component with the projection exposure installation (1) according to either claim 20 or claim 21, comprising the following steps:
    - providing a reticle (12) and a wafer (13),
    - Exposing a light-sensitive layer of the wafer (13) in the first image field (9) with the imaging optical system (8) with preparation light (15),
    - Displacing the prepared light-sensitive layer from the first image field (9) to the second image field (10; 10a),
    - projecting a structure, arranged in the second object field (5), on the reticle (12) onto the prepared light-sensitive layer of the wafer (13) in the second image field (10; 10a) with the projection exposure installation (1),
    - producing a microstructure on the wafer (13).

24. Method for the production of a microstructured component with the projection exposure installation (1) according to either claim 20 or claim 21, comprising the following steps:
    - providing a reticle (12) and a wafer (13),

- projecting a structure, arranged in the first object field (4), on the reticle (12) onto a light-sensitive layer of the wafer (13) in the first image field (9),
- displacing the exposed light-sensitive layer from the first image field (9) to the second image field (10; 10a)
- exposing the previously exposed light-sensitive layer of the wafer (13) in the second image field (10; 10a) with the imaging optical system (8) with preparation light (16),
- producing a microstructure on the wafer (13).

25. Method for the production of a microstructured component with the projection exposure installation (1) according to either claim 20 or claim 21, with an imaging optical system according to claim 11, comprising the following steps:
- providing a reticle (12) and a wafer (13),
- measuring the topography or a position of the wafer (13) in a first one of the image fields (10) using the optical sensing means (30), which is arranged a further object field (5) associated with this image field (10),
- calculating a correction value in the control means (32) by means of the topography data or position data conveyed from the optical sensing means (30),
- correcting imaging properties of the imaging optical system (8) by controlling the correction means (33) on the basis of the calculated correction value,
- projecting a structure, arranged in the first object field (4) of the imaging optical system (8), on the reticle (12) onto a light-sensitive layer of the wafer (13) in the associated image field (9) with the corrected imaging optical system (8).

26. Method for the production of a microstructured component with the projection exposure installation (1) according to either claim 20 or claim 21, with an imaging optical system according to claim 10, comprising the following steps:
    - providing a reticle (12) and a wafer (13),
    - projecting a structure, arranged in the first object field (4) of the imaging optical system (8), on the reticle (12) onto a light-sensitive layer of the wafer (13) in the associated image field (9) with the corrected imaging optical system (8),
    - displacing the exposed light-sensitive layer of the wafer (13) to the second image field (10),
    - measuring the topography, influenced by the projection procedure, of the wafer (13) in the second image field (10) of the imaging optical system (8), by means of the optical sensing means (30) which is arranged in the object field (5), associated with the second image field (10), of the imaging optical system (8).

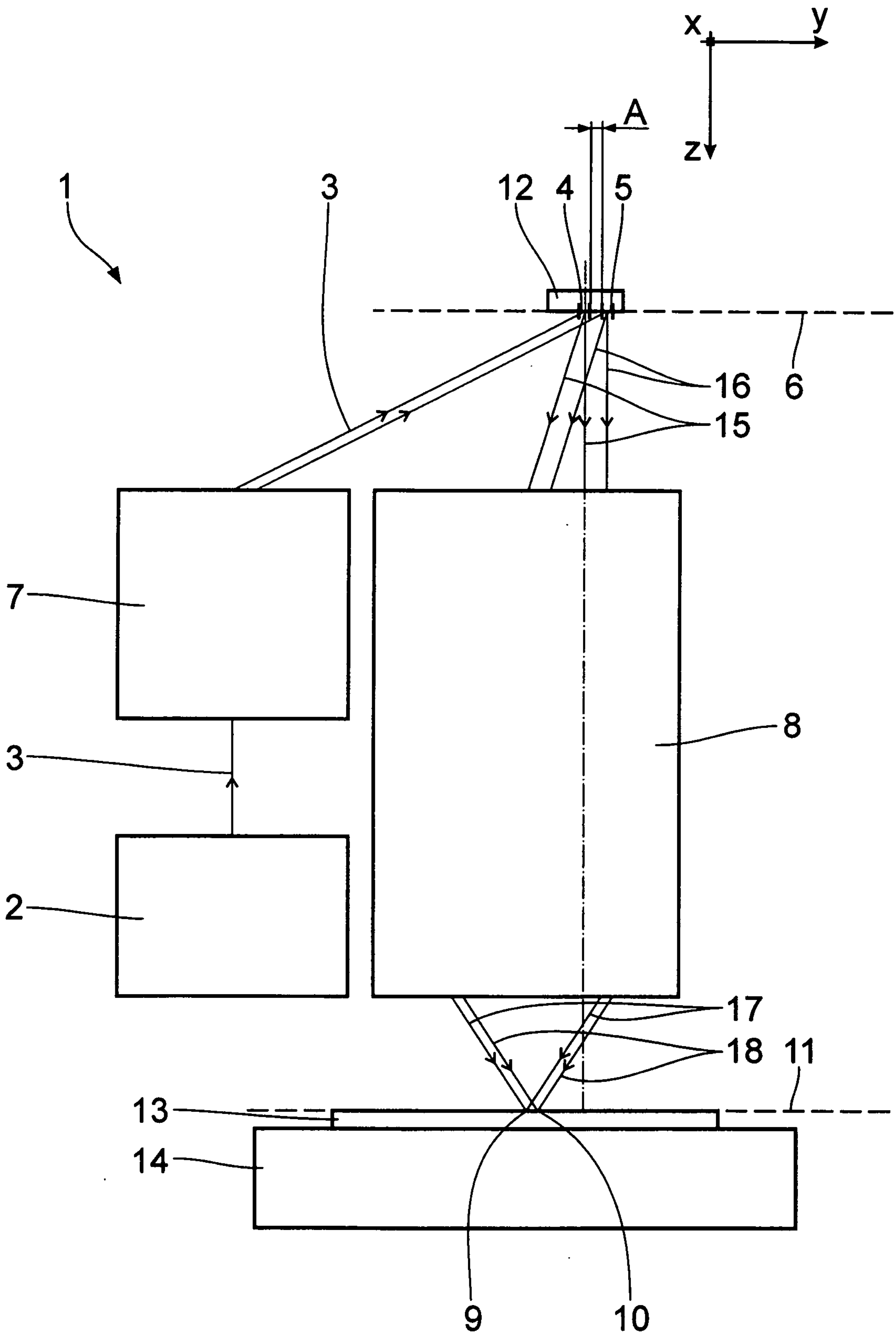
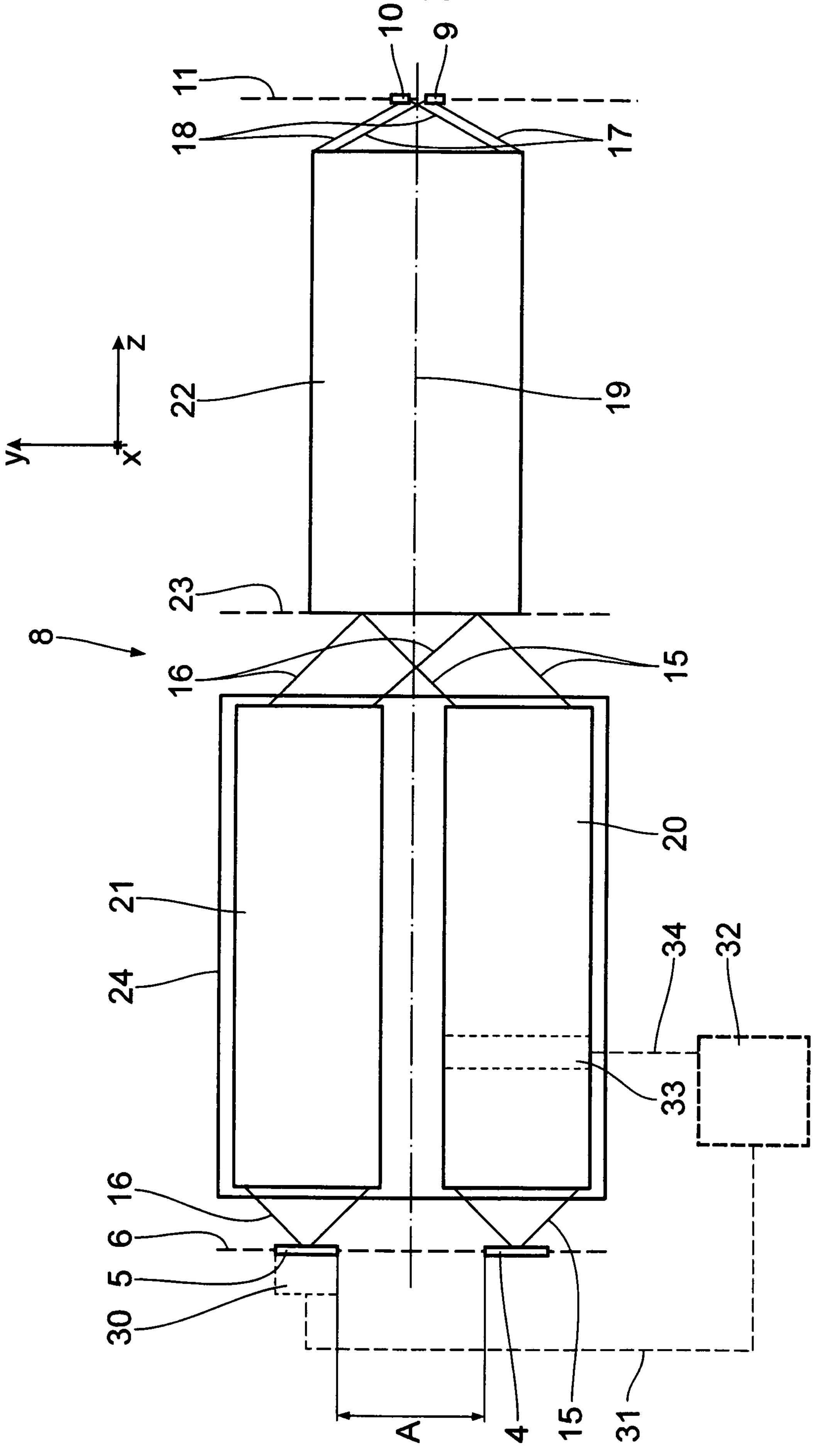
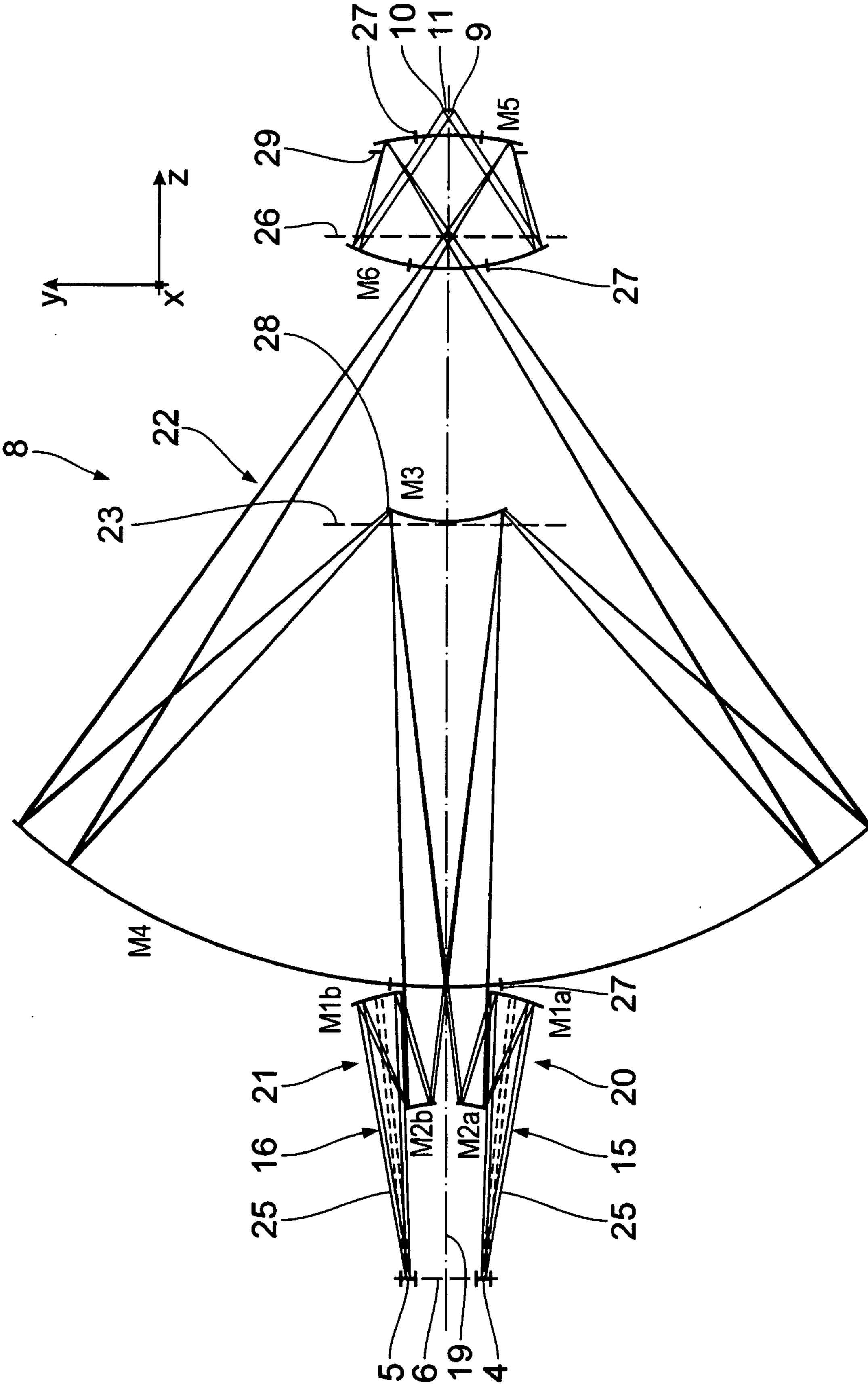


Fig. 1



ig. 2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9
M5
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z
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y
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M6
27
28
22
8
M3
23
M4
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M1a
21
20
M2b
M2a
16
15
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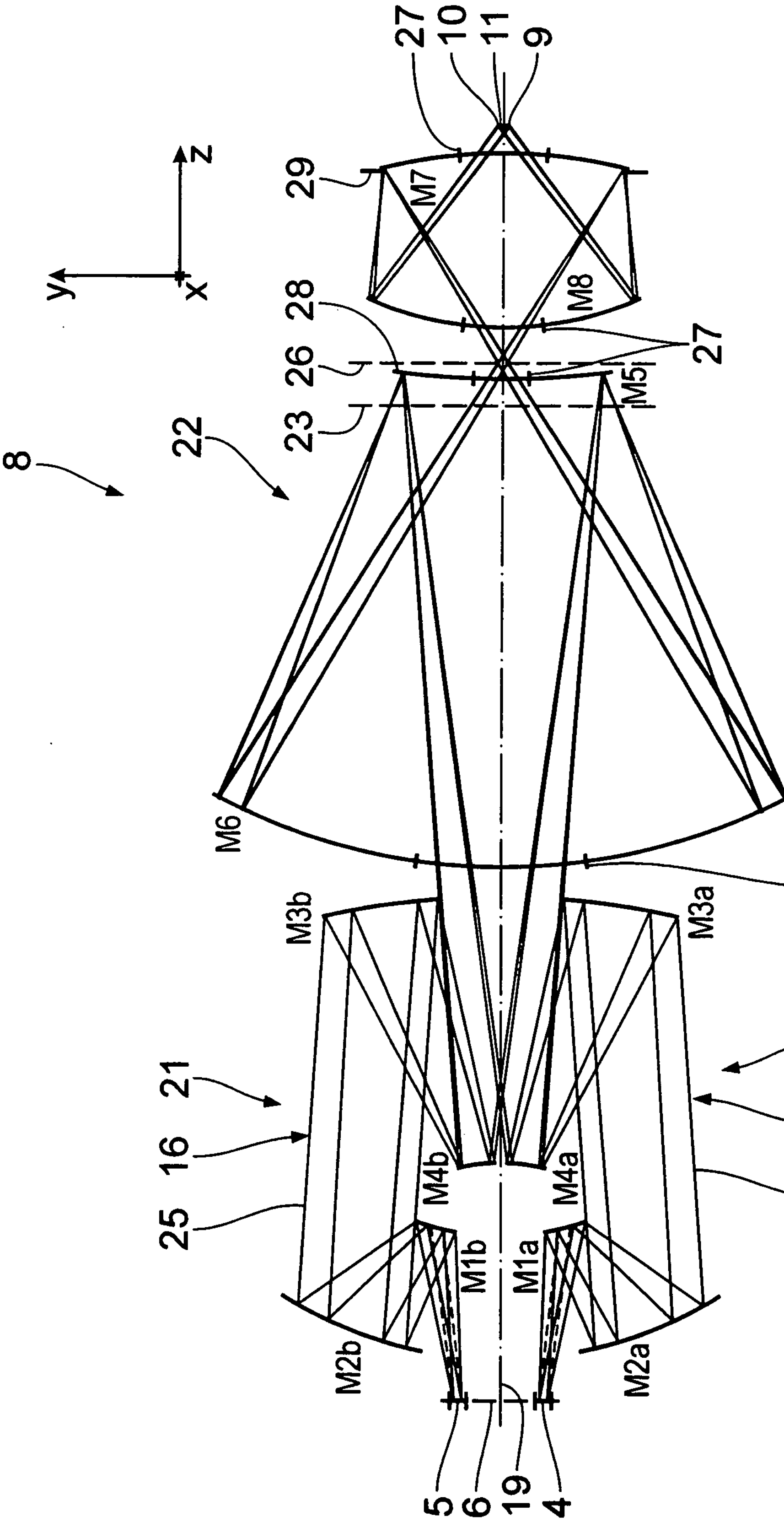
25
5
6
19
4

Fig. 3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M3a
21
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M1a
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19
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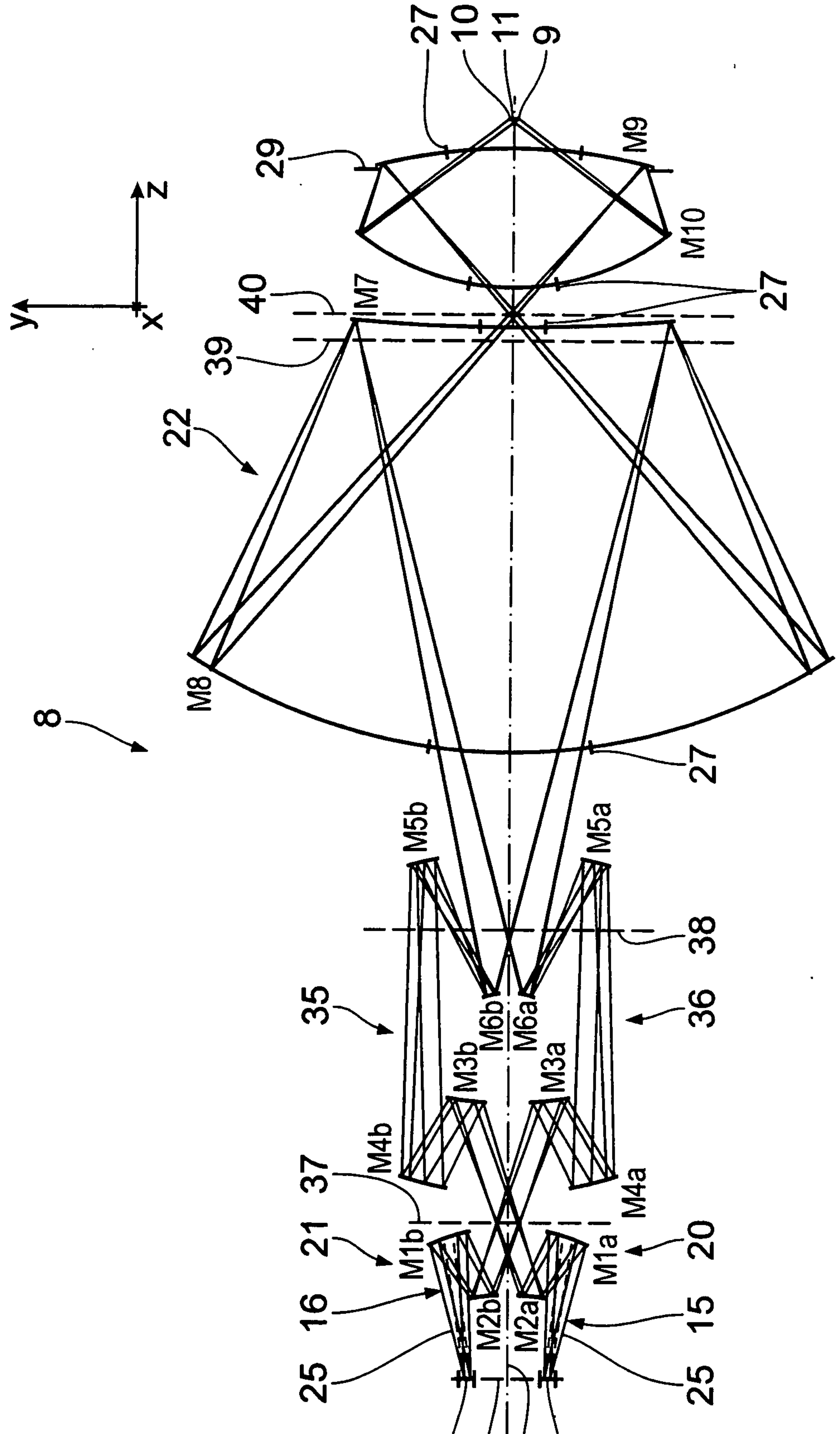
Fig. 4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M5a
38
35
M6b
M6a
36
M3b
M3a
M4b
37
M4a
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M1a
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4

Fig. 5

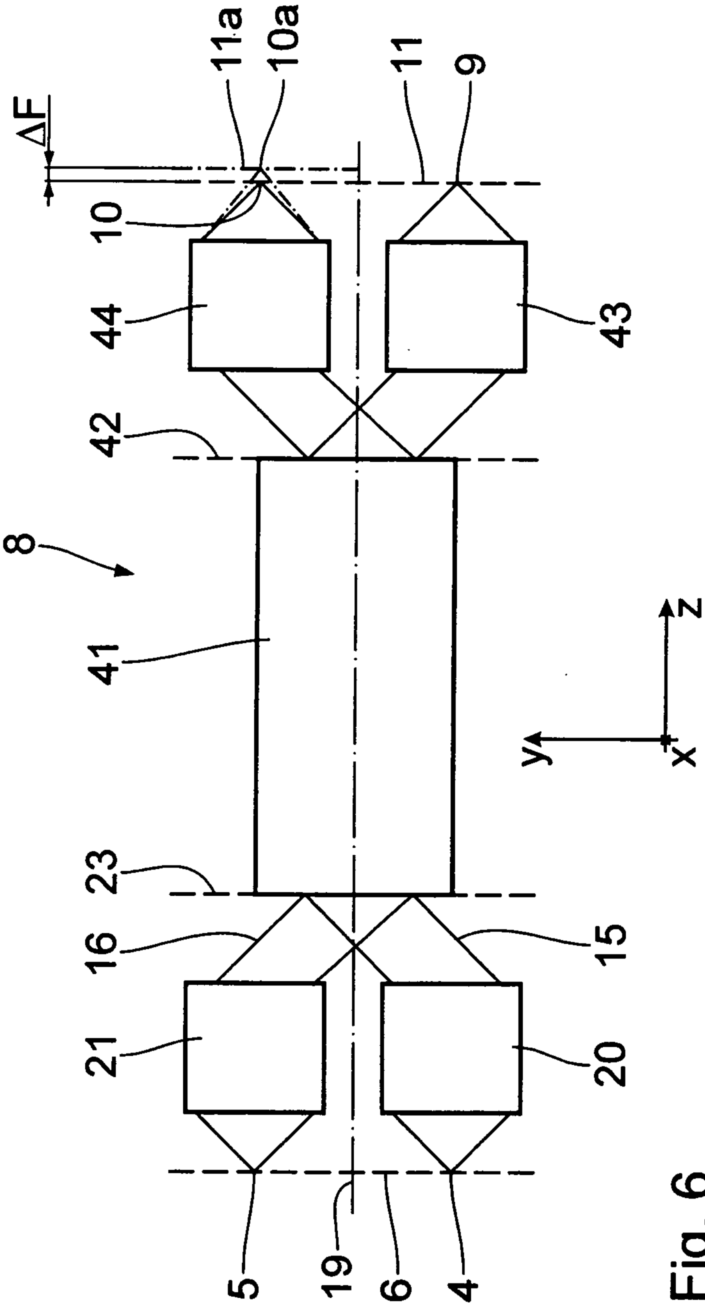

Fig. 6

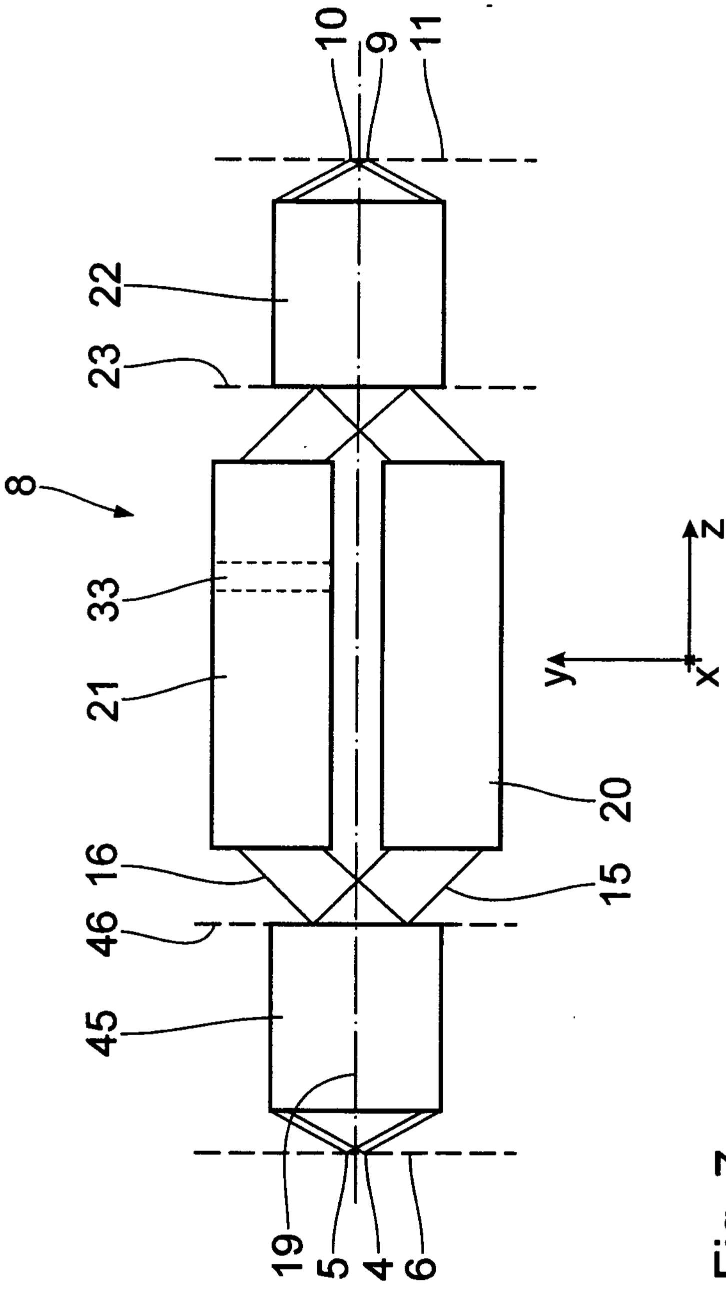

Fig. 7

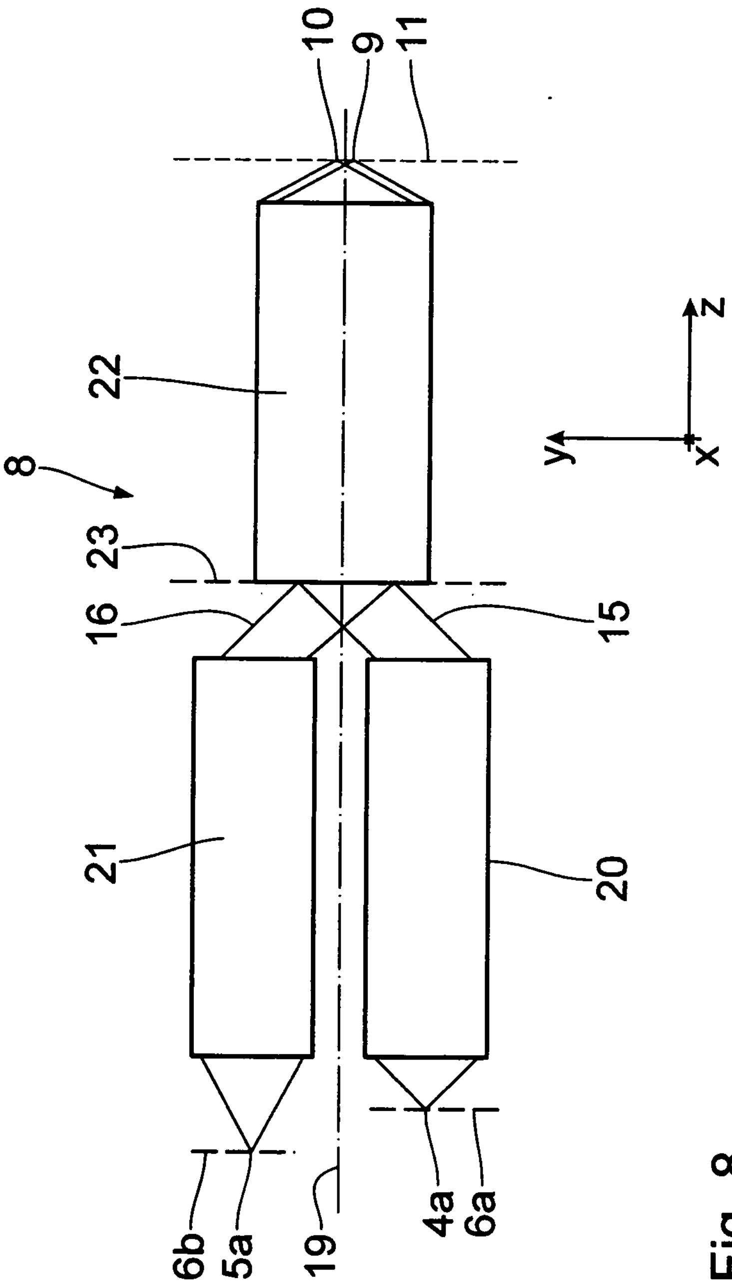

Fig. 8

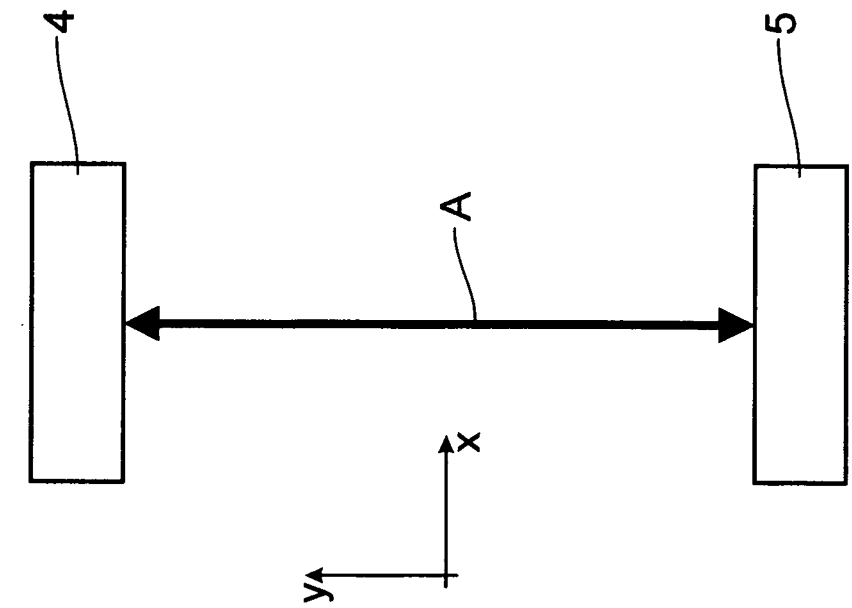

Fig. 10

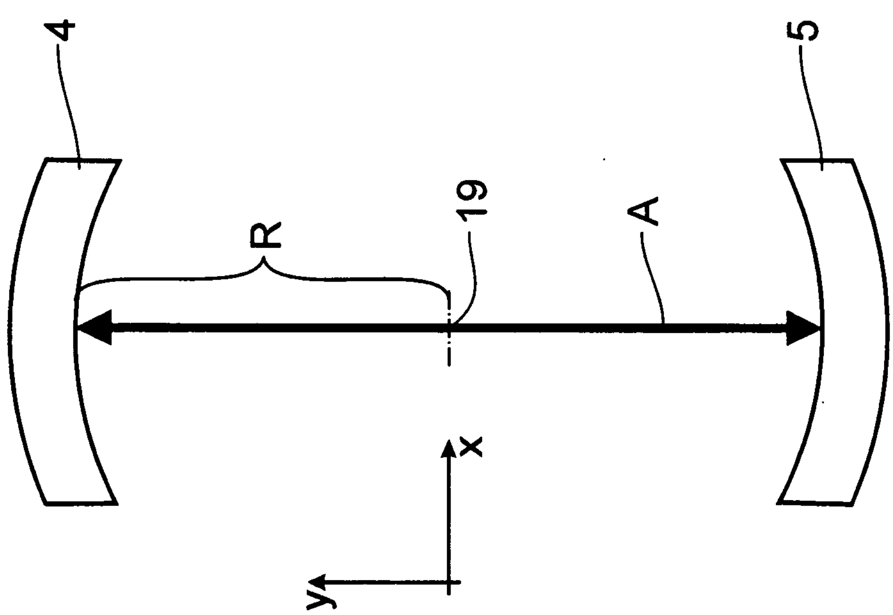

Fig. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2008/008336

A. CLASSIFICATION OF SUBJECT MATTER
INV. G02B17/06 G03F7/20

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 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 practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2007/242244 A1 (NAGASAKA HIROYUKI [JP]) 18 October 2007 (2007-10-18)	1,3-5, 20,21
Y	paragraphs [0031], [0088]; figure 1	6,7
Y	WO 2007/119466 A (NIPPON KOGAKU KK [JP]; SHIGEMATSU KOJI [JP]) 25 October 2007 (2007-10-25) figure 4	6,7

[ ] Further documents are listed in the continuation of Box C.

[X] 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 document 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	Date of mailing of the international search report
15 December 2008	18/03/2009

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Daffner, Michael

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2008/008336

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 allsearchable 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 reportcovers 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.:

see annex

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, 3-7, 20, 21

   The group defines the arrangement of field component groups and aperture component groups.

   ---

2. claims: 2 - 26

   Defines an inline system.
   Claims 3 - 26 are only regarded as forming a part of this group of claims as far as the claims refer back to claims of this group. See also the comment in paragraph 4 below.

   ---

3. claim: 8

   A configuration for different wavelengths.

   ---

4. claims: 9, 12 - 14

   The group defines the arrangement of the two object fields in different object planes or of the two image fields in different image planes.

   ---

5. claims: 10, 11, 25, 26

   The group defines the sensing of image rays and the correction.

   ---

6. claims: 15, 16

   The claims define alternative optical systems with precisely five or four component groups.

   ---

7. claims: 17 -19

   The group defines the symmetry of the mirror system and the field

   ---

8. claims: 22-24

   This group defines a method for producing a microstructured component comprising the step of displacing the exposed light sensitive layer from the first image field to the second image field.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2008/008336

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 2007242244	A1	18-10-2007	EP	1993121 A1	19-11-2008
			WO	2007100087 A1	07-09-2007
			KR	20080107363 A	10-12-2008
WO 2007119466	A	25-10-2007	EP	2009677 A1	31-12-2008
			US	2008246932 A1	09-10-2008