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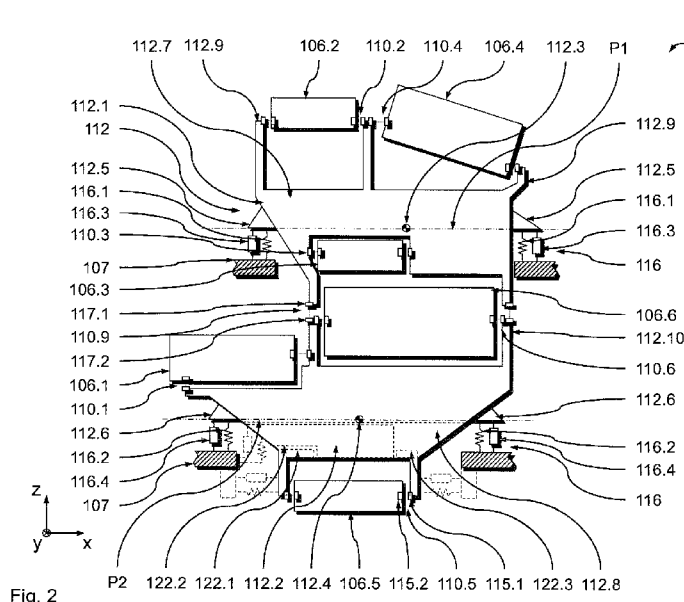


Fig. 2

(57) Abstract: The invention relates to an optical imaging arrangement comprising an optical projection system (102), a support structure system (102.1, 107, 111, 112), and a group of metrology devices (110). The optical projection system (102) comprises a group of optical elements supported by the support structure system (102.1, 107, 111, 112) and configured to transfer, in an exposure process using exposure light along an exposure light path, an image of a pattern of a mask (103.1) onto a substrate (104.1). The support structure system (102.1, 107, 111, 112) comprises a metrology support structure (112) and a load bearing structure (107). The metrology support structure (112; 212; 312) comprises a first metrology support substructure (112.1) and a second metrology support substructure (112.2) separately supported on the load bearing structure (107). The group of metrology devices (110) comprises an optical element metrology device (110.1 to 110.8) and a reference metrology device (110.9). The optical element metrology device (110.1 to 110.8) is functionally associated to an optical element of the group of optical elements. Furthermore, the optical element metrology device (110.1 to 110.8) is configured to capture optical element status information representative of a position and/or an orientation of the optical element in at least one degree of freedom up to all six degrees of freedom.

The reference metrology device (110.9) is functionally associated to the first metrology support substructure (112.1) and the second metrology support substructure (112.2). Furthermore, the reference metrology device (110.9) is configured to capture reference metrology information representative of a relative position and/or a relative orientation of a first reference part (112.11) of the first metrology support substructure (112.1) and a second reference part (112.12) of the second metrology support substructure (112.2) in at least one degree of freedom up to all six degrees of freedom. Finally, the support structure system (102.1, 107, 111, 112) comprises an active support device (116) supporting the first metrology support substructure (112.1) and/or the second metrology support substructure (112.2) on the load bearing structure (107) in a manner actively adjustable as a function of the reference metrology information.

OPTICAL IMAGING ARRANGEMENT WITH
ACTIVELY ADJUSTABLE METROLOGY SUPPORT UNITS

CROSS-REFERENCE TO RELATED APPLICATIONS

This patent disclosure claims benefit under 35 U.S.C. 119 of German Patent Application
5 Serial No. 10 2015 215 850.0 filed August 19, 2015, the entire contents of which are hereby
incorporated herein by reference.

BACKGROUND OF THE INVENTION

The invention relates to optical imaging arrangements used in exposure processes, in
particular to optical imaging arrangements of microlithography systems. It further relates to a
10 method of supporting a metrology device of an optical projection unit. The invention may be
used in the context of photolithography processes for fabricating microelectronic devices, in
particular semiconductor devices, or in the context of fabricating devices, such as masks or
reticles, used during such photolithography processes.

Typically, the optical systems used in the context of fabricating microelectronic devices such
15 as semiconductor devices comprise a plurality of optical element units comprising optical
elements, such as lenses and mirrors etc., arranged in the exposure light path of the optical
system. Those optical elements usually cooperate in an exposure process to transfer an
image of a pattern formed on a mask, reticle or the like onto a substrate such as a wafer.
The optical elements are usually combined in one or more functionally distinct optical
20 element groups. These distinct optical element groups may be held by distinct optical
exposure units. In particular with mainly refractive systems, such optical exposure units are
often built from a stack of optical element modules holding one or more optical elements.
These optical element modules usually comprise an external generally ring shaped support
device supporting one or more optical element holders each, in turn, holding an optical
25 element.

Due to the ongoing miniaturization of semiconductor devices there is, however, a permanent
need for enhanced resolution of the optical systems used for fabricating those semiconductor

devices. This need for enhanced resolution obviously pushes the need for an increased numerical aperture (NA) and increased imaging accuracy of the optical system.

One approach to achieve enhanced resolution is to reduce the wavelength of the light used in the exposure process. In the recent years, approaches have been taken using light in the extreme ultraviolet (EUV) range, typically using wavelengths ranging from 5 nm to 20 nm, in most cases about 13 nm. In this EUV range it is not possible to use common refractive optics any more. This is due to the fact that, in this EUV range, the materials commonly used for refractive optical elements show a degree of absorption that is too high for obtaining high quality exposure results. Thus, in the EUV range, reflective systems comprising reflective elements such as mirrors or the like are used in the exposure process to transfer the image of the pattern formed on the mask onto the substrate, e.g. the wafer.

The transition to the use of high numerical aperture (e.g. $NA > 0.4$ to 0.5) reflective systems in the EUV range leads to considerable challenges with respect to the design of the optical imaging arrangement.

One of the crucial accuracy requirements is the accuracy of the position of the image on the substrate, which is also referred to as the line of sight (LoS) accuracy. The line of sight accuracy typically scales to approximately the inverse of the numerical aperture. Hence, the line of sight accuracy is a factor of 1.4 smaller for an optical imaging arrangement with a numerical aperture $NA = 0.45$ than that of an optical imaging arrangement with a numerical aperture of $NA = 0.33$. Typically, the line of sight accuracy ranges below 0.5 nm for a numerical aperture of $NA = 0.45$. If double patterning is also to be allowed for in the exposure process, then the accuracy would typically have to be reduced by a further factor of 1.4. Hence, in this case, the line of sight accuracy would range even below 0.3 nm.

Among others, the above leads to very strict requirements with respect to the relative position between the components participating in the exposure process. Furthermore, to reliably obtain high-quality semiconductor devices it is not only necessary to provide an optical system showing a high degree of imaging accuracy. It is also necessary to maintain such a high degree of accuracy throughout the entire exposure process and over the lifetime of the system. As a consequence, the optical imaging arrangement components, i.e. the mask, the optical elements and the wafer, for example, cooperating in the exposure process must be supported in a well defined manner in order to maintain a predetermined spatial relationship between said optical imaging arrangement components as well to provide a high quality exposure process.

To maintain the predetermined spatial relationship between the optical imaging arrangement components throughout the entire exposure process, even under the influence of vibrations introduced, among others, via the ground structure supporting the arrangement and/or via internal sources of vibration disturbances, such as accelerated masses (e.g. moving components, turbulent fluid streams, etc.), as well as the under the influence of thermally induced position alterations, it is necessary to at least intermittently capture the spatial relationship between certain components of the optical imaging arrangement and to adjust the position of at least one of the components of the optical imaging arrangement as a function of the result of this capturing process.

In most conventional systems, this process of capturing the spatial relationship between components cooperating in the exposure process is done via a metrology system using a central support structure for the optical projection system and the substrate system as a common reference in order to be able to readily synchronize motion of the actively adjusted parts of the imaging arrangement.

On the other hand, an increase in the numerical aperture, typically, leads to an increased size of the optical elements used, also referred to as the optical footprint of the optical elements. The increased optical footprint of the optical elements used has a negative impact on their dynamic properties and the control system used to achieve the above adjustments. Furthermore, the increased optical footprint typically leads to larger light ray incidence angles. However, at such increased light ray incidence angles transmissivity of the multi-layer coatings typically used for generating the reflective surface of the optical elements is drastically reduced, obviously leading to an undesired loss in light power and an increased heating of the optical elements due to absorption. As a consequence, even larger optical elements have to be used in order to enable such imaging at a commercially acceptable scale.

These circumstances lead to optical imaging arrangements with comparatively large optical elements having an optical footprint of up to 1 m x 1 m and which are arranged very close to each other with mutual distances ranging down to less than 60 mm. Typically, in such a system with high numerical aperture NA requiring extremely low distortions, the optical path length reaches more than 2 m, while the object to image shift reaches 50 cm and more. These core figures essentially determine the overall size of the support structure, such as the optical element support structure for the optical elements as well as the metrology support structure for the metrology system. Typically, the overall dimensions of these support structures roughly reach 2 m x 1.2 m x 1.5 m.

One problem arising from the above situation is that such large structures are generally less rigid. Such less rigid support structures not only contribute to further restrictions of adjustment control performance, but also to residual errors due to quasi-static deformations of the respective structure caused by residual low frequency vibration disturbances. Such residual low frequency vibration disturbances may still be present despite the fact that the respective support structure is supported in a vibration isolated manner. Hence, the negative effects of such low frequency vibration disturbances become even more prominent.

One seemingly straightforward solution would be increasing the stiffness and, hence, the resonant frequency of the respective support structure. However, there are clear practical limits to such an approach. A crucial limitation is that methods for manufacturing such large structures from suitable materials required to achieve appropriate dynamic and thermal properties in such a high precision imaging arrangement are not readily available.

A further limitation in the ability to actively handle such residual low frequency vibration disturbances lies in the difficulties to practically capture such residual low-frequency accelerations at sufficient accuracy avoiding the negative effects of drift and noise, respectively.

An approach to tackle these problems is known from WO 2013/178277 A1 (the entire disclosure of which is incorporated herein by reference). According to this document, the metrology support structure is split into a plurality of separately supported, smaller metrology support substructures. Information on the respective spatial relation of these metrology support substructures is captured using reference metrology devices and the captured information is then taken into account in the control of the optical elements used in the exposure process.

Such a solution, however, on the one hand, has the disadvantage that the increased number of metrology support structures increases the effort for adjusting and calibrating the metrology system during manufacture. On the other hand, considerable effort still has to be taken to prevent sensor range problems of the reference metrology devices, e.g. situations where a reference metrology device capturing the spatial relation between two metrology support substructures falls out its useful sensor range due to excessive mutual motion between the metrology support substructures.

SUMMARY OF THE INVENTION

It is thus an object of the invention to, at least to some extent, overcome the above disadvantages and to provide good and long term reliable imaging properties of an optical imaging arrangement used in an exposure process.

- 5 It is a further object of the invention to reduce the effort necessary for an optical imaging arrangement while at least maintaining the imaging accuracy of the optical imaging arrangement used in an exposure process.

It is a further object of the invention to reduce the negative influence on imaging quality of residual low-frequency vibration disturbances introduced into the optical system of an optical
10 imaging arrangement.

These objects are achieved according to the invention which, according to one aspect, is based on the technical teaching that an overall reduction of the effort necessary for an optical imaging arrangement while at least maintaining the imaging accuracy of the optical imaging arrangement even under the presence of low-frequency vibration disturbances may be
15 achieved if the metrology support structure is split into a plurality of smaller separate metrology support substructures (at least in part supporting subgroups of the metrology devices used in the imaging arrangement), the spatial relation of at least two of these metrology support substructures is captured and at least one of the respective metrology support substructures is actively adjusted as a function of the captured spatial relation.

20 The split in separate smaller substructures has the great advantage that these substructures, due to their reduced size, may be more easily designed as components of increased rigidity and, hence, increased resonant frequency. Such increased rigidity and resonant frequencies lead to lower susceptibility of these support structures to low-frequency vibration disturbances, strongly reduced quasi-static deformation of the respective support structure
25 and, ultimately, improved imaging accuracy.

It should be noted that the reference metrology device typically will have to determine the spatial relation between the metrology support substructures in all degrees of freedom (DOF) in space, which are relevant for the imaging quality in the specific imaging process performed (i.e. in at least one or more degrees of freedom, typically in all six degrees of freedom). The
30 active adjustment of the respective metrology support substructure will then typically have to ensue as a function of the captured spatial relation in all these relevant degrees of freedom.

However, the additional effort for the active support is largely outweighed by the benefit achieved due to the active support. In particular, the active support greatly reduces the effort for, both, the reference metrology devices and the support of the metrology support substructures.

5 More precisely, under one aspect, the effort for the respective reference metrology device and the arrangement of its components at the respective metrology support substructure itself is reduced, since sensor range requirements are relaxed. This is due to the possibility to adjust the respective metrology support substructure (e.g. to maintain a given spatial relation in the one or more relevant or critical degrees of freedom) such that a given sensor
10 range is always observed.

Moreover, under a further aspect, the overall support for the respective metrology support substructure is facilitated, since, overall, less expense has to be made to avoid the introduction of vibration disturbances or the like into the metrology support substructure. This is due to the possibility to adjust the respective metrology support substructure such that
15 disturbances introduced into the respective metrology support substructure can be actively counteracted or damped, respectively. For example, less effort may be necessary regarding the vibration behavior of cooling systems of the optical imaging arrangement.

Finally, with certain optical projection systems having one or more large and heavy optical elements, support of such heavy optical elements is facilitated insofar as the requirements
20 for the adjustment of these heavy optical elements are relaxed. More precisely, with the actively adjustable support of the metrology support substructures, rather than trying to obtain broadband active support of the large and heavy optical element, it is even possible to passively support such an optical element and to have the associated metrology support substructure(s) follow motions of the optical element.

25 It will be appreciated that control of the active support of the respective metrology support substructure may also ensue in a proactive manner, e.g. in that certain disturbances influencing the respective metrology support substructure are captured. The captured disturbance can then, for example, be used to generate a forecast of the motion of the respective metrology support substructure resulting from this disturbance. The forecast can
30 then be used to initiate appropriate counteractions to the disturbance. Such a counteraction may, for example, include an appropriate action of the active support of the respective metrology support substructure. Nevertheless, in addition or as an alternative, it may also include other measures, such as countermeasures directly influencing the disturbance itself.

Such a proactive control of the respective metrology support substructure is typically realized using suitable numerically and/or empirically generated models of the relevant parts of the optical imaging arrangement. It will be appreciated that such a model may immediately yield suitable control parameters for the control of the respective metrology support substructure in response to an input of the respective information relating to the captured disturbance. It will be further appreciated that the disturbance may be of any type, which influences the state of the respective metrology support substructure and can be at least partially counteracted by a spatial adjustment of the respective metrology support substructure. Typically, such disturbances are vibrational disturbances. However, other disturbances such as, for example, thermal disturbances may also be of relevance in this respect.

Hence, despite the additional effort for the active support, the overall expense for the metrology system, its support and the vibration behavior of the entire optical imaging arrangement can be reduced.

Thus, according to a first aspect of the invention there is provided an optical imaging arrangement comprising an optical projection system, a support structure system, and a group of metrology devices. The optical projection system comprises a group of optical elements supported by the support structure system and configured to transfer, in an exposure process using exposure light along an exposure light path, an image of a pattern of a mask onto a substrate. The support structure system comprises a metrology support structure and a load bearing structure. The metrology support structure comprises a first metrology support substructure and a second metrology support substructure separately supported on the load bearing structure. The group of metrology devices comprises an optical element metrology device and a reference metrology device. The optical element metrology device is functionally associated to an optical element of the group of optical elements. Furthermore, the optical element metrology device is configured to capture optical element status information representative of a position and/or an orientation of the optical element in at least one degree of freedom up to all six degrees of freedom. The reference metrology device is functionally associated to the first metrology support substructure and the second metrology support substructure. Furthermore, the reference metrology device is configured to capture reference metrology information representative of a relative position and/or a relative orientation of a first reference part of the first metrology support substructure and a second reference part of the second metrology support substructure in at least one degree of freedom up to all six degrees of freedom. Finally, the support structure system comprises an active support device supporting the first metrology support substructure

and/or the second metrology support substructure on the load bearing structure in a manner actively adjustable as a function of the reference metrology information.

It will be appreciated that the control may be configured to adjust the position and/or the orientation of the first metrology support substructure and/or the second metrology support substructure in space with respect to any desired reference of the optical imaging device. Preferably, the active support device is configured to adjust, as a function of the reference metrology information, a relative position and/or a relative orientation of the first metrology support substructure and the second metrology support substructure in at least one degree of freedom up to all six degrees of freedom. This yields a particularly simple control concept with reduced errors.

It will be further appreciated that either of the first and second metrology support substructure may be actively adjusted in the relevant degrees of freedom in space. Here, the same adjustment frequency ranges may be selected for both metrology support substructures.

However, with certain embodiments with metrology support substructures having noticeably different masses and/or moments of inertia (including their respective supported components) in the respective relevant degree of freedom, different (eventually overlapping) adjustment frequency ranges may be selected. Hence, for example, a more inert metrology support substructure may be unadjusted or adjusted within a lower frequency range than a less inert metrology support substructure. Moreover, such a more inert metrology support substructure may serve as an inertial reference and one or more less inert metrology support substructures may be actively adjusted to follow its motions.

Hence, with certain embodiments, the active support device is configured to adjust the first metrology support substructure in such a manner that the first metrology support substructure at least partially follows a motion of the second reference part of the second metrology support substructure in at least one degree of freedom. In addition or as an alternative, the active support device may be configured to adjust the first metrology support substructure in such a manner that a predeterminable relative position and/or a predeterminable relative orientation of the first metrology support substructure with respect to the second reference part is at least partially maintained in at least one degree of freedom. By either of these variants a particularly simple, efficient, rapid and dynamically advantageous active adjustment may be achieved

With embodiments, which are particularly simple to implement, the active support device comprises a control device and an actuator device. The control device is connected to the reference metrology device and the actuator device. The control device is further configured to control the actuator device as a function of the reference metrology information received from the reference metrology device to adjust the first metrology support substructure and/or the second metrology support substructure in at least one degree of freedom.

It will be appreciated that the reference metrology information may be obtained in any suitable way via a direct or indirect measurement involving the respective reference parts of the first and second metrology support substructure. Preferably, a first reference metrology unit of the reference metrology device is located at the first reference part of the first metrology support substructure and a second reference metrology unit of the reference metrology device is located at the second reference part of the second metrology support substructure. The reference metrology device is then configured to capture information representative of a relative position and/or a relative orientation of the first reference metrology unit and the second reference metrology unit as the reference metrology information.

It will be appreciated that a metrology device used in the context of the present invention may operate according to any desired operating principle. For example, it may operate according to an encoder principle, i.e. a principle, where a sensor head emits a sensor light beam towards a structured surface and detects a reading light beam reflected from the structured surface of the reference element. The structured surface may be, for example, a grating comprising a series of parallel lines (one-dimensional grating) or a grid of mutually inclined lines (two-dimensional grating) etc. Positional alteration is basically captured from counting the lines passed by the sensor beam which may be derived from the signal achieved via the reading beam.

It will be appreciated however that, with other embodiments of the invention, apart from the encoder principle any other type of contactless measurement principle (such as e.g. an interferometric measurement principle, a capacitive measurement principle, an inductive measurement principle etc.) may be used alone or in arbitrary combination. However, it will also be appreciated that, with other embodiments of the invention, any suitable contact based metrology arrangement may be used as well. As contact based working principles magnetostrictive or electrostrictive working principles etc. may be used for example. In particular, the choice of the working principle may be made as a function of the accuracy requirements.

With certain embodiments of particularly suitable and simple design, the optical element metrology device comprises a first optical element metrology unit located at the first metrology support substructure and a second optical element metrology unit located at the optical element. Here, the reference metrology device is configured to capture information representative of a relative position and/or a relative orientation of the first optical element metrology unit and the second optical element metrology unit as the optical element status information.

It will be appreciated that the positions of either two components of the optical element metrology device, the reference metrology device and the active support device at the same metrology support substructure preferably should be as close to each other as possible in order to reduce errors caused by a deformation of the metrology support substructure as far as possible. Hence, typically, the first metrology support substructure has a maximum substructure dimension in space and a volume center of gravity, and the first optical element metrology unit is preferably spaced from the first reference metrology unit by less than 100% to 50%, preferably less than 10% to 5%, more preferably 3% to 1%, of the maximum substructure dimension.

In addition or as an alternative, the first metrology support substructure is supported by the active support device at at least one support location, the at least one support location being spaced from the first optical element metrology unit and/or the first reference metrology unit by less than 100% to 50%, preferably less than 10% to 5%, more preferably 3% to 1%, of the maximum substructure dimension.

Furthermore, in addition or as an alternative, the first metrology support substructure is supported by the active support device at one support location, the support location being spaced from the volume center of gravity by less than 100% to 50%, preferably less than 10% to 5%, more preferably 3% to 1%, of the maximum substructure dimension.

It will be appreciated that control of the active adjustment of the respective metrology support substructure may be performed solely on the basis of the respective reference metrology information. However, with preferred embodiments yielding particularly good imaging properties with reduced imaging errors, a proactive control concept as generally outlined above is implemented. Such a proactive control concept may use disturbance information that is captured and relates to actual disturbances propagating towards or already acting on the optical imaging arrangement. The disturbance information may then be used to generate a preventive control of the active adjustment of the respective metrology support

substructure to keep the impact of the disturbance on the imaging properties as low as possible.

Any type of disturbance may be captured and counteracted in such an (eventually proactive) control concept. With certain embodiments, vibration disturbances are captured and used.

5 Such a vibration disturbance may be captured by any suitable means allowing sufficiently precise determination of the disturbance. For example, a motion sensor may be used to yield suitable vibration information. With particularly simple variants of the invention, acceleration sensors are used to capture the disturbance information.

Hence, in certain preferred embodiments, eventually incorporating such a proactive control
10 concept, the active support device comprises an acceleration sensor device, which is arranged and configured to capture acceleration information representative of an acceleration acting, in at least one degree of freedom up to all six degrees of freedom, on an accelerated component of the optical imaging arrangement. The active support device is then configured to adjust, as a function of the acceleration information, a relative position
15 and/or a relative orientation of the first metrology support substructure and the second metrology support substructure in at least one degree of freedom up to all six degrees of freedom.

As outlined above, the acceleration information (i.e. the disturbance information) may be captured at any suitable location allowing proper determination of the disturbance to be
20 expected at the respective metrology support substructure and, consequently, proper proactive control of the active adjustment of the respective metrology support substructure. For example, the acceleration information may be captured at any component of the optical imaging apparatus (e.g. at its illumination unit, the mask unit, the optical projection unit or the substrate unit). Preferably, the accelerated component is a component of the optical
25 projection system (e.g. one of the optical elements) and/or a component of the support structure system (e.g. the load bearing structure or one of the metrology support substructures). In case of the active adjustment of the first metrology support substructure, for example, the accelerated component may be the second metrology support substructure.

With particularly simple embodiments, the active support device comprises a control device
30 and an actuator device, the control device being connected to the acceleration sensor device and the actuator device. The control device is further configured to control the actuator device as a function of the acceleration information received from the acceleration sensor

device to adjust the first metrology support substructure and/or the second metrology support substructure in at least one degree of freedom.

With particularly advantageous embodiments allowing particularly good compensation of the disturbance, the control device uses a numerical model to control the actuator device, the
5 numerical model having been previously established and being representative of a motion of the first metrology support substructure and/or the second metrology support substructure in response to the acceleration acting on the accelerated component. By this means particularly rapid reaction to such disturbances may be achieved.

In addition or as an alternative, the control device may be configured to control the actuator
10 device to counteract a motion of the first metrology support substructure and/or the second metrology support substructure, the motion resulting from a disturbance generating the acceleration acting on the accelerated component. Furthermore, in addition or as an alternative, the control device may be configured to control the actuator device to actively damp a motion of the first metrology support substructure and/or the second metrology
15 support substructure, the motion resulting from a disturbance generating the acceleration acting on the accelerated component. In any of these cases particularly beneficial reduction of the imaging errors resulting from such disturbances may be achieved.

It will be appreciated that the support of the respective metrology support substructure may be designed in any suitable way. Preferable, the first metrology support substructure is
20 supported on the load bearing structure via a first vibration isolation device and the second metrology support substructure is supported on the load bearing structure via a second vibration isolation device to achieve good primary vibration behavior of the support. Preferably, the first vibration isolation device and/or the second vibration isolation device, in particular, having a vibration isolation resonant frequency in a range from 10 Hz to 3 Hz,
25 preferably from 1 Hz to 0.5 Hz, more preferably from 0.3 Hz to 0.1 Hz. This yields particularly beneficial vibration behavior of the support.

With certain embodiments, the second metrology support substructure is a simple reference substructure free from any optical element metrology devices functionally associated to one of the optical elements. Such a simple reference structure, due to the fact that it doesn't
30 have to carry the weight of such optical element metrology devices, has the advantage that it may be executed as a simple, lightweight and highly rigid component, which is less susceptible to residual quasi-static deformation and, hence, perfectly suited as a reference for other actively adjusted metrology support substructures.

With other embodiments, the second metrology support substructure may also carry parts of such an optical element metrology device. In these cases, preferably, a first optical element metrology unit of a further optical element metrology device is located at the second metrology support substructure and a second optical element metrology unit of the further optical element metrology device is located at a further optical element of the group of optical elements, the further optical element metrology device being configured to capture further optical element status information representative of a position and/or an orientation of the further optical element in at least one degree of freedom.

It will be appreciated that the metrology support structure may be split into any desired number of metrology support substructures. In other words, two or more metrology support substructures may be provided. Apparently, an increased number of metrology support substructures yields smaller substructures, which, typically, may be of more rigid design, which is preferable under dynamic aspects as well as with regard to reduced residual quasi-static deformations.

With certain such embodiments, the metrology support structure comprises a third metrology support substructure separately supported on the load bearing structure. Here, a further reference metrology device is functionally associated to the first metrology support substructure or the second metrology support substructure and the third metrology support substructure. The further reference metrology device is configured to capture further reference metrology information representative of a relative position and/or a relative orientation of the first metrology support substructure or the second metrology support substructure and the third metrology support substructure in at least one degree of freedom up to all six degrees of freedom.

Here again, the third metrology support substructure may be a simple reference structure without any components of an optical element metrology device. With other embodiments, however, a fifth optical element metrology unit of a further optical element metrology device is located at the third metrology support substructure and a sixth optical element metrology unit of the further optical element metrology device is located at a further optical element of the group of optical elements, the further optical element metrology device being configured to capture further optical element status information representative of a position and/or an orientation of the further optical element in at least one degree of freedom.

It will be appreciated that any desired number of the optical elements of the group of optical elements of the optical projection system may each have its own separate metrology support

substructure. In particular, each of the optical elements may have its own separate metrology support substructure (carrying the respective parts of the optical element metrology device assigned to the optical element). In other cases, a metrology support substructure may be assigned to more than one of the optical elements.

5 It will be appreciated that the metrology support substructures may be made of any desired and suitable material. Particularly beneficial dynamic and static properties are achieved if at least one of the metrology support substructures is made from a material selected from a material group, the material group consisting of steel, aluminum (Al), titanium (Ti), an Invar-alloy, a tungsten alloy, a ceramic material, silicon infiltrated silicon carbide (SiSiC), silicon
10 carbide (SiC), silicon (Si), carbon fiber reinforced silicon carbide (C/CSiC), aluminum oxide (Al_2O_3), tungsten carbide (WC) and Cordierite, while Zerodur®, ULE® glass and quartz would be possible but less preferred due to their lower rigidity,.

It will be further appreciated that, with certain embodiments, a control device is provided and configured to use the optical element status information to control an active component of the
15 optical imaging arrangement, e.g. to provide active support of the respective optical element.

It will be further appreciated that the invention may be used in the context of any desired optical imaging process at any desired exposure light wavelength. Particularly beneficial results are achieved in the context of microlithography. Hence, with certain embodiments, the optical imaging arrangement is configured to be used in microlithography using exposure
20 light at an exposure light wavelength in a UV range, in particular, an EUV range. Preferably, the exposure light has an exposure light wavelength ranging from 5 nm to 20 nm. Furthermore, the optical elements of the group of optical elements preferably are reflective optical elements.

Preferably, to be able to perform an exposure process, the optical imaging arrangement
25 further comprises an illumination unit, a mask unit and a substrate unit. The illumination unit is configured to illuminate the mask received within the mask unit with the exposure light and the substrate unit is configured to receive the substrate to receive the image transferred by the optical projection system.

According to a second aspect of the invention there is provided a method of supporting a
30 metrology device of an optical imaging arrangement comprising an optical projection system with a group of optical elements configured to transfer, in an exposure process using exposure light along an exposure light path, an image of a pattern of a mask onto a

substrate. The method comprises supporting a first metrology support substructure and a second metrology support substructure separately on a load bearing structure. The method further comprises functionally associating an optical element metrology device to an optical element of the group of optical elements and capturing, via the optical element metrology device, optical element status information representative of a position and/or an orientation of an optical element of the group of optical elements in at least one degree of freedom up to all six degrees of freedom. The method further comprises functionally associating a reference metrology device to the first metrology support substructure and the second metrology support substructure, and capturing, via the reference metrology device, reference metrology information representative of a relative position and/or a relative orientation of a first reference part of the first metrology support substructure and a second reference part of the second metrology support substructure in at least one degree of freedom up to all six degrees of freedom. The method finally comprises actively adjusting the first metrology support substructure and/or the second metrology support substructure with respect to the load bearing structure as a function of the reference metrology information. With this method, the objects, variants and advantages as outlined above in the context of the optical imaging arrangement according to the present invention may be achieved to the same extent, such that insofar explicit reference is made to the statements made in the foregoing.

It will be appreciated that active support of the metrology support substructure according to the present invention furthermore greatly facilitates manufacturing, in particular calibration, of the optical imaging arrangement. This is due to the fact that the actively adjusted metrology support substructure has only to be coarsely adjusted during manufacture at such a precision that the assigned reference metrology device is within its sensor range. Subsequent calibration, i.e. fine adjustment to the specification, can then be made via the active support device of the metrology support substructure. This greatly reduces manufacturing time, in particular calibration time.

Hence, according to a third aspect of the invention there is provided a method of calibrating a metrology system of an optical imaging arrangement comprising an optical projection system with a group of optical elements configured to transfer, in an exposure process using exposure light along an exposure light path, an image of a pattern of a mask onto a substrate. The method comprises supporting the optical projection system and the metrology system on a load bearing structure, at least one optical element metrology unit of the metrology system being supported on a metrology support substructure. The method further comprises, in a coarse adjustment step, performing a coarse spatial adjustment of the metrology support substructure, and, in a calibrating step, performing a fine spatial

adjustment by adjusting said metrology support substructure using a method of supporting a metrology device according to the invention. With this method, the objects, variants and advantages as outlined above in the context of the optical imaging arrangement according to the present invention may be achieved to the same extent, such that insofar explicit
5 reference is made to the statements made in the foregoing.

Furthermore, according to a fourth aspect of the invention there is provided an optical imaging method comprising transferring, in an exposure process using the exposure light, the image of the pattern onto the substrate, wherein, during the exposure process, the first metrology support substructure and/or the second metrology support substructure is actively
10 adjusted using a method of supporting a metrology device according to the invention. Preferably, during the exposure process, an active component of the optical imaging arrangement is controlled using the optical element status information. With this method as well, the objects, variants and advantages as outlined above in the context of the optical imaging arrangement according to the present invention may be achieved to the same
15 extent, such that insofar explicit reference is made to the statements made in the foregoing.

Further aspects and embodiments of the invention will become apparent from the dependent claims and the following description of preferred embodiments which refers to the appended figures. All combinations of the features disclosed, whether explicitly recited in the claims or not, are within the scope of the invention.

20 BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic representation of a preferred embodiment of an optical imaging arrangement according to the invention with which preferred embodiments of methods according to the invention may be executed;

25 Figure 2 is a schematic representation of a part of the optical imaging arrangement of Figure 1;

Figure 3 is a mechanical block diagram of the part of the optical imaging arrangement of Figure 2;

Figure 4 is a schematic representation of the part of the optical imaging arrangement of Figure 2 in a pre-assembled testing state;

Figure 5 is a block diagram of a preferred embodiment of a method of determining status information of a group of optical elements according to the invention including a preferred embodiment of a method of supporting a metrology system according to the invention which may be executed with the optical imaging arrangement of Figure 1;

Figure 6 is a further schematic representation of a part of the optical imaging arrangement of Figure 2;

Figure 7 is a schematic representation of a part of the optical imaging arrangement of Figure 6;

Figure 8 is a schematic representation of a part a further preferred embodiment of an optical imaging arrangement according to the invention with which further preferred embodiments of methods according to the invention may be executed;

Figure 9 is a mechanical block diagram of the part of the optical imaging arrangement of Figure 8;

Figure 10 is a mechanical block diagram of a part of a further preferred embodiment of an optical imaging arrangement according to the invention;

DETAILED DESCRIPTION OF THE INVENTION

First Embodiment

In the following, a preferred first embodiment of an optical imaging arrangement 101 according to the invention with which preferred embodiments of methods according to the invention may be executed will be described with reference to Figures 1 to 7. To facilitate understanding of the following explanations a xyz coordinate system is introduced in the Figures, wherein the z-direction designates the vertical direction (i.e. the direction of gravity).

Figure 1 is a highly schematic and not-to-scale representation of the optical imaging arrangement in the form of an optical exposure apparatus 101 operating in the EUV range at a wavelength of 13 nm. The optical exposure apparatus 101 comprises an optical projection unit 102 adapted to transfer an image of a pattern formed on a mask 103.1 (located on a mask table 103.2 of a mask unit 103) onto a substrate 104.1 (located on a substrate table

104.2 of a substrate unit 104). To this end, the optical exposure apparatus 101 comprises an illumination system 105 illuminating the reflective mask 103.1 with exposure light (represented by its chief ray 105.1) via an appropriate light guide system 105.2. The optical projection unit 102 receives the light reflected from the mask 103.1 and projects the image of the pattern formed on the mask 103.1 onto the substrate 104.1, e.g. a wafer or the like.

To this end, the optical projection unit 102 holds an optical element unit group 106 of optical element units 106.1 to 106.6. This optical element unit group 106 is held within an optical element support structure 102.1. The optical element support structure 102.1 may take the form of a housing structure of the optical projection unit 102, which, in the following, is also referred to as the projection optics box structure (POB) 102.1. It will be appreciated, however, that this optical element support structure does not necessarily have to form a complete or even (light and/or fluid) tight enclosure of the optical element unit group 106. Rather it may also be partially formed as an open structure as it is the case with the present example.

It will be appreciated that, in the sense of the present invention, an optical element unit may merely consist of an optical element, such as a mirror. However, such an optical element unit may also comprise further components such as a holder holding such an optical element.

The projection optics box structure 102.1 is supported in a vibration isolated manner on a load bearing structure 107, which in turn, is supported on a ground or base structure 111. The load bearing structure 107 is supported on the ground or base structure 111 in a vibration isolated manner at a vibration isolation resonant frequency that ranges from 0.05 Hz to 8.0 Hz, preferably from 0.1 Hz to 1.0 Hz, more preferably from 0.2 Hz to 0.6 Hz. Furthermore, typically, a damping ratio is selected that ranges from 5% to 60%, preferably from 10% to 30%, more preferably from 20% to 25%. In the present example a vibration isolation resonant frequency of 0.25 Hz to 2 Hz at a damping ratio of 15% to 35% is selected for the vibration isolated support of the load bearing structure 107.

The ground or base structure 111 (in a vibration isolated manner) also supports the mask table 103.2 via a mask table support device 103.3 and the substrate table 104.2 via a substrate table support device 104.3. It will be appreciated however that, with other embodiments of the invention, the load bearing structure 107 may also support (preferably in a vibration isolated manner) the mask table 103.2 and the substrate table 104.2.

It will be appreciated that the projection optics box structure 102.1 may be supported in a cascaded manner via a plurality of vibration isolation devices and at least one intermediate support structure unit to achieve good vibration isolation. Generally, these vibration isolation devices may have different isolation frequencies to achieve good vibration isolation over a wide frequency range.

The optical element unit group 106 comprises a total of six optical element units, namely a first optical element unit 106.1, a second optical element unit 106.2, a third optical element unit 106.3, a fourth optical element unit 106.4, a fifth optical element unit 106.5 and a sixth optical element unit 106.6. In the present embodiment, each of the optical element units 106.1 to 106.6 consists of an optical element in the form of a mirror, also referred to as mirrors M1 to M6 in the following.

In the present embodiment, mirror 106.2 (M2), mirror 106.3 (M3) and mirror 106.4 (M4) form a first optical element subgroup 106.7 in the sense of the present invention, while mirror 106.1 (M1), mirror 106.5 (M5) and mirror 106.6 (M6) form a second optical element subgroup 106.8.

It will be appreciated however that, with other embodiments of the invention, (as mentioned above) the respective optical element unit may also comprise further components (beyond the optical element itself) such as, for example, aperture stops, holders or retainers holding the optical element and eventually forming an interface for the support unit connecting the optical element unit to the support structure.

It will be further appreciated that, with other embodiments of the invention, another number of optical element units may be used. Preferably, four to eight optical element units are provided.

Each one of the mirrors 106.1 (M1) to 106.6 (M6) is supported on the support structure formed by the projection optics box structure 102.1 by an associated support device 108.1 to 108.6. Each one of the support devices 108.1 to 108.6 is formed as an active device such that each of the mirrors 106.1 to 106.6 is actively supported at a defined control bandwidth.

In the present example, the optical element unit 106.6 is a large and heavy component forming a first optical element unit of the optical element unit group 106 while the other optical element units 106.1 to 106.5 form a plurality of second optical element units of the optical element unit group 106. The first optical element unit 106.6 is actively supported at a

low first control bandwidth, while the second optical element units 106.1 to 106.5 are actively supported at a second control bandwidth to substantially maintain a given spatial relationship of each of the second optical element units 106.1 to 106.5 with respect to the first optical element unit 106.6 as it is disclosed in WO 2013/004403 A1 (the entire disclosure of which is
5 incorporated herein by reference).

In the present example, a similar active support concept is chosen for the mask table support device 103.3 and the substrate table support device 104.3 both also actively supported at a third and fourth control bandwidth, respectively, to substantially maintain a given spatial relationship of the mask table 103.2 and the substrate table 104.2, respectively, with respect
10 to the first optical element unit 106.6. It will be appreciated however that, with other embodiments of the invention, another support concept may be chosen for the mask table and/or the substrate table.

As will be explained in further detail below, control of the active support devices 108.1 to 108.6, 103.3 and 104.3 is performed by a control device 109 as a function on the signals of a
15 metrology arrangement 110. Adjustment control of the components participating in the imaging process is performed the following way.

To achieve the active low bandwidth support the first optical element unit 106.6 (M6), the first support device 108.6 of the first optical element unit 106.6 is configured and controlled to provide adjustment of the first optical element unit 106.6 with respect to a component of the
20 metrology arrangement 110 at a first adjustment control bandwidth ranging from 5 Hz to 100 Hz, preferably from 40 Hz to 100 Hz.

Furthermore, to achieve the active support the second optical element units 106.1 to 106.5, the mask table 103.2 and the substrate table 104.2, respectively, each of the second support devices 108.1 to 108.5 of the second optical element units 106.1 to 106.5 as well as the
25 mask table support device 103.3 and the substrate table support device 104.3, respectively, is configured and controlled to provide adjustment of the respective associated optical element unit 106.1 to 106.5, the mask table 103.2 and the substrate table 104.2, respectively, at a second, third and fourth adjustment control bandwidth, respectively, ranging from 5 Hz to 400 Hz, preferably from 200 Hz to 300 Hz. It will be appreciated that,
30 with certain embodiments of the invention, the second control bandwidth may vary among the second support devices 108.1 to 108.5.

The present embodiment hence follows a support strategy according to which the large and heavy first optical element unit 106.6 posing the most severe problems in reaching the high control bandwidth typically required in EUV microlithography is actively supported in a controlled manner at a low bandwidth (at which control may be readily achieved for this optical element unit 106.6) while the other components participating in the exposure process, i.e. the second optical element units 106.1 to 106.5, the mask table 103.2 and the substrate table 104.2, are controlled to maintain a sufficiently stable and accurate spatial relation with respect to the first optical element unit 106.6 and, hence, with respect to each other.

Hence, despite the fact that, in the present example, all components participating in the imaging process (i.e. the mirrors 106.1 to 106.6, the mask 103.1 and the substrate 104.1) are actively controlled, the greatly relaxed requirements for the adjustment control bandwidth of the first optical element unit 106.6 largely outweigh the increased expense for the active support of the individual components. In particular, adjustment control of a large optical footprint component such as the sixth mirror 106.6 (which may have an optical footprint of up to 1.5 m x 1.5 m and a mass of up to 350 kg) is greatly facilitated compared to conventional systems where, typically, an adjustment control bandwidth of 200 Hz to 300 Hz is used and considered necessary (a control bandwidth that can hardly be reached for such large optical footprint components due to their low resonant frequency).

It will be appreciated however that, with other embodiments of the invention, another support strategy of the optical element units 106.1 to 106.6, the mask table 103.2 and the substrate table 104.2 may be followed.

The image of the pattern formed on the mask 103.1 is usually reduced in size and transferred to several target areas of the substrate 104.1. The image of the pattern formed on the mask 103.1 may be transferred to the respective target area on the substrate 104.1 in two different ways depending on the design of the optical exposure apparatus 101. If the optical exposure apparatus 101 is designed as a so called wafer stepper apparatus, the entire image of the pattern is transferred to the respective target area on the substrate 104.1 in one single step by irradiating the entire pattern formed on the mask 103.1. If the optical exposure apparatus 101 is designed as a so called step-and-scan apparatus, the image of the pattern is transferred to the respective target area on the substrate 104.1 by progressively scanning the mask table 103.2 and thus the pattern formed on the mask 103.1 under the projection beam while performing a corresponding scanning movement of the substrate table 104.2 and, thus, of the substrate 104.1 at the same time.

In both cases, a given spatial relationship between the components participating in the exposure process (i.e. between the optical elements of the optical element unit group 106, i.e. the mirrors 106.1 to 106.6, with respect to each other as well as with respect to the mask 103.1 and with respect to the substrate 104.1 has to be maintained within predetermined limits to obtain a high quality imaging result.

During operation of the optical exposure apparatus 101, the relative position of the mirrors 106.1 to 106.6 with respect to each other as well as with respect to the mask 103.1 and the substrate 104.1 is subject to alterations resulting from, both, intrinsic and extrinsic, disturbances introduced into the system. Such disturbances may be mechanical disturbances, e.g. in the form vibrations resulting from forces generated within the system itself but also introduced via the surroundings of the system, e.g. the load bearing structure 107 (which itself is supported on a ground structure 111). They may also be thermally induced disturbances, e.g. position alterations due to thermal expansion of the parts of the system.

In order to keep the above predetermined limits of the spatial relation of the mirrors 106.1 to 106.6 with respect to each other as well as with respect to the mask 103.1 and the substrate 104.1, each one of the mirrors 106.1 to 106.6 is actively positioned in space via their support devices 108.1 to 108.6, respectively. Similarly, the mask table 103.2 and the substrate table 104.2 are actively positioned in space via the respective support devices 103.3 and 104.3, respectively.

In the following, the control concept for the spatial adjustment of the components 106.1 to 106.6, 103.1 and 104.1 participating in the imaging process will be described with reference to Figures 1 and 2. As mentioned above, control of the adjustment of the components 106.1 to 106.6, 103.1 and 104.1 in all six degrees of freedom is done using the control device 109 connected and providing corresponding control signals to each one of the support devices 108.1 to 108.6, 103.3 and 104.3 (as it is indicated in Figure 1 by the solid and dotted lines at the control device 109 and the respective support device) at the specific adjustment control bandwidth as outlined above.

It will be appreciated however that, with other embodiments of the invention, it may not be necessary to provide active adjustment control in all six degrees of freedom for specific ones or even all the components participating in the imaging process. For example, given a specific design of the imaging arrangement with an imaging error behavior having a relevant sensitivity to alterations (of individual or even all components participating in the imaging

process) only in certain degrees of freedom, it may be sufficient to only consider and, if necessary, control adjustment of the relevant components in these specific degrees of freedom, while other degrees of freedom, due to their lacking influence on imaging quality, may be neglected.

5 In the present example, the control device 109 generates its control signals as a function of the metrology signals of the metrology arrangement 110 which captures, as a status information in the sense of the present invention, an information representative of the position and orientation of each one of the components 106.1 to 106.6, 103.1 and 104.1 in all six degrees of freedom (as it is indicated by the dotted lines in Figure 1 and 2).

10 As mentioned above, the metrology arrangement 110 uses the large optical footprint sixth mirror 106.6 as an inertial reference (i.e. as a reference optical element unit) to which all further components 106.1 to 106.5, 103.1 and 104.1 participating in the imaging process are referred to. As can be seen from Figure 1, the sixth mirror 106.6, in the light path, is the ultimate mirror unit hit last by the exposure light 105.1 when transferring the image of a
15 pattern formed on the mask 103.1 onto the substrate 104.1.

To this end, the metrology arrangement 110 comprises a group of metrology devices 110.1 to 110.6 mechanically connected to a projection system metrology support structure 112 which in turn is supported by the load bearing structure 107 as well as further metrology devices 113 and 114 associated to the mask table 103.2 and the substrate table 104.2,
20 respectively as it is (highly schematically) indicated in Figure 1.

In the present embodiment, each metrology device 110.1 to 110.6 comprises a plurality of sensor heads 115.1 mechanically connected to the projection system metrology support structure 112, and cooperating with an associated reference element 115.2 mechanically connected directly to the respective mirror 106.1 to 106.6. Similar applies to the metrology
25 devices 113 and 114, respectively.

The term "mechanically connected directly", in the sense of the invention, is to be understood as a direct connection between two parts including (if any) a short distance between the parts allowing to reliably determine the position of the one part by measuring the position of the other part. In particular, the term may mean without the interposition of further parts
30 introducing uncertainties in the position determination, e.g. due to thermal or vibration effects. It will be appreciated that, with certain embodiments of the invention, the reference element 115.2 may not be a separate component connected to the mirror but may be

directly or integrally formed on a surface of the mirror, e.g. as a grating or the like formed in a separate process upon manufacture of the mirror.

In the present embodiment, the metrology devices 110.1 to 110.6, 113 and 114 operate according to an encoder principle, i.e. the sensor head emits a sensor light beam towards a structured surface and detects a reading light beam reflected from the structured surface of the reference element. The structured surface may be, for example, a grating comprising a series of parallel lines (one-dimensional grating) or a grid of mutually inclined lines (two-dimensional grating) etc. Positional alteration is basically captured from counting the lines passed by the sensor beam which may be derived from the signal achieved via the reading beam.

It will be appreciated however that, with other embodiments of the invention, apart from the encoder principle any other type of contactless measurement principle (such as e.g. an interferometric measurement principle, a capacitive measurement principle, an inductive measurement principle etc) may be used alone or in arbitrary combination. However, it will also be appreciated that, with other embodiments of the invention, any suitable contact based metrology arrangement may be used as well. As contact based working principles magnetostrictive or electrostrictive working principles etc may be used for example. In particular, the choice of the working principle may be made as a function of the accuracy requirements.

The metrology device 110.6 associated to the sixth mirror 106.6 (M6), in all six degrees of freedom, captures the first spatial relationship between the projection system metrology support structure 112 and the sixth mirror 106.6 (M6) which forms the inertial reference. Furthermore, the metrology devices 110.1 to 110.5, 113 and 114 associated to the other components 106.1 to 106.5, 103.1 and 104.1 participating in the imaging process (in all six degrees of freedom) capture the second spatial relationship between the projection system metrology support structure 112 and the associated component 106.1 to 106.5, 103.1 and 104.1.

Finally, the metrology arrangement 110 determines the spatial relationship between the sixth mirror 106.6 and the respective further component 106.1 to 106.5, 103.1 and 104.1 using the first spatial relationship and the second spatial relationship. Corresponding metrology signals are then provided to the control device 109 which in turn generates, as a function of these metrology signals, corresponding control signals for the respective support device 108.1 to 108.6, 103.3 and 104.3.

It will be appreciated that, with other embodiments of the invention, direct measurement of the spatial relation between the central reference element (e.g. the sixth mirror M6) and any one of the respective further component (e.g. mirrors 106.1 to 106.5, mask 103.1 and substrate 104.1) participating in the imaging process may also be provided. Depending on the spatial boundary conditions an arbitrary combination of such direct and indirect measurements may also be used.

In the embodiment shown, as a function of the metrology signals representative of the first spatial relationship between the metrology structure and the sixth mirror 106.6, the control device 109 generates corresponding control signals for the support device 108.6 of the sixth mirror 106.6 (i.e. the reference element in the sense of the present invention) to adjust the sixth mirror 106.6 at the above first adjustment control bandwidth (ranging from 5 Hz to 100 Hz, preferably from 40 Hz to 100 Hz) with respect to the projection system metrology support structure 112 of the metrology arrangement 110.

This low bandwidth control of the critical first optical element unit 106.6 provides low bandwidth drift control of the first optical element unit 106.6 with respect to the metrology support structure 112. In other words, it allows the first optical element unit 106.6 to follow corresponding low-frequency motions of the metrology support structure 112 of the metrology device 110.6 capturing the spatial relationship between the first optical element unit 106.6 and the projection system metrology support structure 112. By this means excessive relative motion between the first optical element unit 106.6 and the projection system metrology support structure 112 of the metrology arrangement 110 going beyond the capturing range of the capturing devices of the metrology arrangement 110 or, in other words, sensor range problems may be avoided in a very beneficial way.

It will be appreciated that the spatial relationship between the substrate table 104.2 and the substrate 104.1 is known, e.g. due to a measurement operation immediately preceding the exposure process. The same applies to the spatial relationship between the mask table 103.2 and the mask 103.1. Hence, the respective reference element connected to the mask table 103.2 and the substrate table 104.2, respectively, also allows capturing the spatial relationship between the reference mirror 106.6 and the mask 103.1 and the substrate 104.1, respectively.

As a consequence, despite the fact that, typically, all components participating in the exposure process now have to be actively controlled, the requirements for the control bandwidth of the most critical first optical element unit 106.6 are greatly relaxed in a highly

beneficial way. This positive effect, generally, largely outweighs the increased expense for the active support of all components.

Hence, for example, compared to conventional systems where, typically, an adjustment control bandwidth of 200 Hz to 300 Hz is used and considered necessary for each individual optical element unit, with the present invention a considerably lower adjustment control bandwidth, e.g. between 5 Hz to 100 Hz, preferably between 40 Hz to 100 Hz, may be used for the critical first optical element unit 106.6, while all other components participating in the imaging process (i.e. optical element units 106.1 to 106.5, mask unit 103.1 and substrate unit 104.1) may be readily controlled at the conventionally desired higher adjustment control bandwidth of, for example, 200 Hz to 400 Hz, to provide proper alignment with respect to the inertial reference formed by the first optical element unit 106.6.

It will be further appreciated that the above (indirect) measurement concept has the advantage that the instantaneous rigid-body position and orientation of the projection system metrology support structure of the metrology unit 110.1, in particular, vibration disturbances introduced into the metrology structure of the metrology unit 110.1, are essentially irrelevant as long as the projection system metrology support structure 112.1 is sufficiently rigid to largely avoid deformation of the metrology support structure 112. In particular, less effort has to be made for stabilizing the position and/or orientation of the projection system metrology support structure 112 in space. Typically, however, as in the present embodiment, the projection system metrology support structure 112 may nevertheless be supported in a vibration isolated manner.

According to the present invention, optical performance of the system 101 is further improved by further reducing or vastly eliminating the influence of low-frequency vibration leading to quasi-static deformation of the projection system metrology support structure 112 by splitting the projection system metrology support structure 112 into a plurality of separate metrology support substructures, namely a first metrology support substructure 112.1 and a second metrology support substructure 112.2, each supporting a subgroup of the metrology devices 110.1 to 110.6, each subgroup of the metrology devices 110.1 to 110.6 being associated to a subgroup of the mirrors 106.1 to 106.6.

More precisely, as can be seen from Figure 2 (showing only parts of the projection system 102 relevant in this context), in the present example, a first metrology device subgroup 110.7 (comprising metrology devices 110.2, 110.3 and 110.4) is associated to a first optical element subgroup 106.7 (comprising mirrors 106.2, 106.3 and 106.4) and is supported by the

first metrology support substructure 112.1. A second metrology device subgroup 110.8 (comprising metrology devices 110.1, 110.5 and 110.6) is associated to a second optical element subgroup 106.8 (comprising mirrors 106.1, 106.5 and 106.6) and is supported by the second metrology support substructure 112.2.

- 5 This split of the projection system metrology support structure 112 into separate smaller substructures 112.1 and 112.2 has the great advantage that these substructures 112.1 and 112.2, due to their reduced size, may be more easily designed as components of increased rigidity and increased resonant frequency.

Such increased rigidity and resonant frequencies of the substructures 112.1 and 112.2, compared to conventional single piece rigid structure designs of the projection system metrology support structure (where, for example, support structure 112 would be made of a monolithic component or from a plurality of rigidly connected components), lead to remarkably lower susceptibility of these support substructures 112.1 and 112.2 to low-frequency vibration disturbances, which typically leads to a so called quasi-static deformation of the respective support substructure 112.1 and 112.2.

For example, a rectangular plate structure having a length dimension a , a width dimension b , a thickness dimension h , a density ρ , and a compliance B , the resonant frequency ω_{mn} , for the mode numbers m, n , calculates as:

$$\omega_{mn} = \pi^2 \cdot \left[\left(\frac{m}{a} \right)^2 + \left(\frac{n}{b} \right)^2 \right] \cdot \sqrt{\frac{B}{\rho \cdot h}} = k_{mn}^2 \cdot \sqrt{\frac{B}{\rho \cdot h}}. \quad (1)$$

- 20 Furthermore, the deformation D of such a plate is directly proportional to the resonant frequency ω_{mn} , i.e. the following holds:

$$D \sim \omega_{mn}. \quad (2)$$

Consequently, with equation (1), the deformation D is inversely proportional to the square of the respective length dimension a and width dimension b , respectively. In other words, reducing each of the length dimension a and width dimension b by 50% leads to a reduction of the deformation D by 75% (i.e. to a quarter of the original deformation). This is schematically illustrated in Figure 5 showing the first metrology support substructure 112.1 and the second metrology support substructure 112.2 under quasi-static deformation

compared to a single piece metrology support structure under such quasi-static deformation (indicated by the double-dot-dashed contour).

Consequently, low-frequency vibration induced quasi-static deformation of the respective support substructure 112.1 and 112.2 is greatly reduced compared to conventional single piece rigid metrology support structure. This reduces measurement errors due to alterations of the position and/or orientation of the metrology devices 110.1 to 110.6 resulting from such quasi-static deformation of the projection system metrology support structure 112, which improves the measurement accuracy achieved with the metrology devices 110.1 to 110.6. This, ultimately, in a beneficial way leads to an improved accuracy of the control process and, hence, improved overall imaging accuracy of the imaging arrangement 101.

As can be further seen from Figure 2, the split design of the projection system metrology support structure 112, compared to conventional single piece rigid body designs, allows a comparatively lightweight design where the respective first and second metrology support substructure 112.1 and 112.2 only comprises a core structure and a plurality of support arms protruding from this core structure.

More precisely, the first metrology support substructure 112.1 comprises a first core structure 112.7, while the second metrology support substructure 112.2 comprises a second core structure 112.8. The first core structure 112.7 carries a plurality of first support arms 112.9, while the second core structure 112.8 carries a plurality of second support arms 112.10.

Each of the first support arms 112.9, in the region of its free end, carries one or more of the sensor heads 115.1 of the first metrology device subgroup 110.7. In order to provide a good dynamic behavior and, hence, a highly stable support of the sensor heads 115.1, each first support arm 112.9 is designed as a comparatively short and rigid component.

To this end, each first support arm 112.9 has a first maximum arm dimension which ranges from 5% to 150% of a first maximum core structure dimension of the first core structure 112.7. Preferably, the first maximum arm dimension ranges from 20% to 120% of the first maximum core structure dimension, more preferably from 30% to 100% of the first maximum core structure dimension.

Similar applies to the respective second support arm 112.10. Hence, preferably, each second support arm 112.10 has a second maximum arm dimension which ranges from 5% to 150% of a second maximum core structure dimension of the second core structure 112.8.

Preferably, the second maximum arm dimension ranges from 20% to 120% of the second maximum core structure dimension, more preferably from 30% to 100% of the second maximum core structure dimension.

Apparently, compared to conventional designs, with this split design of the metrology support structure 112, in particular, in the central region where the two metrology substructures 112.1 and 112.2 are located adjacent to each other, a considerable amount of structural components or materials may be omitted. There is only a need for the respective core structure 112.7 and 112.8, respectively, to provide basic structural stability of the respective metrology support substructure 112.1 and 112.2, while, apart from the comparatively slender and lightweight but highly rigid support arms 112.9 and 112.10, respectively, any further structural elements or components may be dispensed with. Hence, compared to conventional single piece designs, a considerably more lightweight and, ultimately, more rigid structure may be achieved.

As becomes further apparent from Figure 2, the project system metrology support structure 112 defines a set of three orthogonal directions, namely width direction (x-axis), the depth direction (y-axis) and the height direction (z-axis). Apparently, the height dimension of the projection system metrology support structure 112 is the maximum dimension of the projection system metrology support structure 112 in one of these three orthogonal directions. Hence, the height direction represents a direction of maximum dimension in the sense of the present invention.

In the present example, the split line between the metrology support substructures 112.1 and 112.2 is selected such that the first metrology support substructure 112.1 and the second metrology support substructure 112.2 are located mutually adjacent in this direction of maximum dimension. Consequently, in the present example, the first metrology support substructure 112.1, in the height direction (being the direction), is located above the second metrology support substructure.

It will be appreciated however that, with other embodiments of the invention, another location of the split line between the metrology support substructures may be selected. For example, in the most prominent dimension of the metrology support structure was in the width direction (i.e. the x-axis being the direction of maximum dimension) and/or in the depth direction (i.e. the y-axis being the direction of maximum dimension), the split would preferably be such that the first and second metrology support substructure are located side-by-side at the same height level.

As can be seen from Figure 2, the first metrology support substructure 112.1 and the second metrology support substructure 112.2, respectively, in the height direction (i.e. in the direction of the z-axis being the direction of maximum dimension), has a dimension that is only a fraction of its dimension in the other two orthogonal directions (i.e. in the direction of the x-axis and of the y-axis). Preferably, this fraction ranges from 20% to 80%, more preferably from 30% to 70%, even more preferably from 40% to 60%, thereby achieving a good compromise between structural stability and lightweight design.

It will be appreciated that any desired and appropriate material may be selected for the respective support structure, in particular for the projection system metrology support structure 112. For example, metals like aluminum may be used for the respective support structure, in particular, for support structures requiring a comparatively high rigidity at a comparatively low weight. It will be appreciated that the material for the support structures is preferably selected depending on the type or function of the support structure.

In particular, for the projection optics box structure 102.1 steel, aluminum (Al), titanium (Ti), so called Invar-alloys (i.e. iron nickel alloys with 33% to 36% of Ni, e.g. Fe₆₄Ni₃₆) and appropriate tungsten alloys (such as e.g. DENSIMET® and INERMET® composite materials, i.e. heavy metals with a tungsten content greater than 90% and a NiFe or NiCu binder phase) are preferably used.

Furthermore, for the projection system metrology support structure 112 materials such as silicon infiltrated silicon carbide (SiSiC), silicon carbide (SiC), silicon (Si), carbon fiber reinforced silicon carbide (C/CSiC), aluminum oxide (Al₂O₃), tungsten carbide (WC), Cordierite (a magnesium iron aluminum cyclosilicate) or another ceramic material with low coefficient of thermal expansion and high modulus of elasticity may also be beneficially used. Materials like Zerodur® (a lithium aluminosilicate glass-ceramic), ULE® glass (a titania silicate glass) and quartz could eventually also be used but would be less preferred due to their lower level rigidity.

In the present example, the projection optics box structure 102.1 is made from steel as a first material having a first rigidity. By this means, compared to conventional support structures being made, for example, from aluminum, the weight increases by a factor of three, what would typically not be favored in conventional systems. However, due to the non-conventional support strategy followed in the present example, the increased weight of the projection optics box structure 102.1 is beneficial in terms of the vibration behavior.

Furthermore, the projection metrology support structure 112 is made from a second material having a second rigidity that is higher than the first rigidity of the steel material of the projection optics box structure 102.1. Such a high rigidity of the projection metrology support structure 112.1 is beneficial as it has been outlined above.

5 The first metrology support substructure 112.1 and the second metrology support structure 112.2, in the present example, are supported separately on the load bearing structure 107 in an actively individually adjustable and individually vibration isolated manner by an active support device 116 of the support structure system. More precisely, the first metrology support substructure 112.1 is supported on the load bearing structure 107 via a first vibration
10 isolation device 116.1, while the second metrology support substructure 112.2 is supported on the load bearing structure 107 via a second vibration isolation device 116.2.

The first vibration isolation device 116.1 and the second vibration isolation device 116.2 each has a vibration isolation resonant frequency in a vibration isolation resonant frequency range from 0.5 Hz to 8.0 Hz. Preferably, the respective vibration isolation resonant frequency
15 ranges from 1.0 Hz to 6.0 Hz, more preferably from 2.0 Hz to 5.0 Hz. Furthermore, typically, a damping ratio is selected that ranges from 5% to 60%, preferably from 10% to 30%, more preferably from 20% to 25%. In the present example a vibration isolation resonant frequency of 2.0 Hz to 6.0 Hz at a damping ratio of 15% to 35% is selected for the first vibration isolation device 116.1 and the second vibration isolation device 116.2. With these frequency
20 ranges and damping ratios particularly good low-frequency vibration isolation of the respective metrology support substructure 112.1 and 112.2 is achieved, further beneficially reducing the influence of low-frequency vibration.

It is particularly advantageous to introduce the support forces into the respective metrology support substructure 112.1 and 112.2 as close to its mass center of gravity 112.3 and 112.4,
25 respectively, as possible. Such a support typically leads to reduced low-frequency vibration amplitudes.

Hence, to achieve a particularly good low-frequency vibration behavior of the respective metrology support substructure 112.1 and 112.2, in the present example, the first metrology support substructure 112.1 has a plurality of first load bearing interface devices 112.5
30 contacting the first vibration isolation device 116.1 and, hence, serving to introduce support forces into the first metrology support substructure 112.1 when supporting the latter on the load bearing structure 107.

Furthermore, the second metrology support substructure 112.2 has a plurality of second load bearing interface devices 112.6 contacting the second vibration isolation device 116.2 and, hence, serving to introduce support forces into the second metrology support substructure 112.2 when supporting the latter on the load bearing structure 107.

5 To achieve the beneficial support as outlined above, the first load bearing interface devices 112.5 are arranged such that they define a first load bearing interface plane P1, which is located to substantially coincide with the mass center of gravity 112.3 of the first metrology support substructure 112.1. Likewise, the second load bearing interface devices 112.6 are arranged such that they define a second load bearing interface plane P2, which is located to
10 substantially coincide with the mass center of gravity 112.4 of the second metrology support substructure 112.2.

It should be noted that the separate (preferably vibration isolated) support of the metrology support substructures 112.1 and 112.2, during operation of the optical imaging apparatus 101, typically, would lead to a drift between the separate metrology support substructures
15 112.1 and 112.2 and, hence, between the respective metrology device subgroups 110.7 and 110.8 supported thereon in one or more degrees of freedom which are relevant to the imaging error of the optical imaging apparatus 101.

To largely avoid or reduce such a mutual drift of the metrology support substructures 112.1 and 112.2, in the present example, the first metrology support substructure 112.1 is further
20 supported in an actively adjustable manner on the load bearing structure 107 via a first actuator device 116.3, while the second metrology support substructure 112.2 is supported on the load bearing structure 107 in an actively adjustable manner via a second actuator device 116.4.

In the present example, these actuator devices 116.3 and 116.4 are used to adjust the
25 position and/or the orientation of the first metrology support substructure 112.1 and the second metrology support substructure 112.2 in space in any desired degree of freedom up to all six degrees of freedom. It will be appreciated that, typically, adjustment only needs to be provided in those degrees of freedom, which have a noticeable impact on the imaging process, more precisely, on the imaging quality to be achieved.

30 In the present example, the active support device 116 is configured to adjust the relative position and/or the relative orientation of the first metrology support substructure 112.1 and the second metrology support substructure 112.2 as a function of reference metrology

information representative of the spatial relation between the first and second metrology support substructure 112.1 and 112.2 captured in at least one degree of freedom up to all six degrees of freedom. Apparently, the reference metrology information is typically captured at least in those degrees of freedom in which adjustment of these metrology support
5 substructures 112.1, 112.2 is provided.

To capture this reference metrology information, in the present example, some additional metrology arrangement is provided, which is configured to determine the spatial relation between the metrology device subgroups supported by the respective metrology support substructures in all degrees of freedom (DOF) in space which are relevant for the imaging
10 quality in the specific imaging process performed with the imaging apparatus 101 (i.e. in at least one or more degrees of freedom, typically in all six degrees of freedom). The reference metrology information captured is then used to control the active support via the actuator devices 116.3 and 116.4 of the active support device 116 as will be explained further below.

It will be appreciated that, as mentioned above, this additional effort for the metrology system
15 110 and the active support system 116 is largely outweighed by the benefit achieved due to the strongly reduced quasi-static deformation of the respective support substructure 112.1 and 112.2 as well as its clear benefits in terms of imaging accuracy. Furthermore, the present solution has the advantage that the requirements regarding eventual vibration isolated support of the respective substructures 112.1 and 112.2 are greatly relaxed. More
20 precisely, noticeably less effort has to be made for the vibration isolation itself and/or the introduction of a larger amount of vibration may be accepted due to the reduced sensitivity of the system to such vibration. This is not least due to the fact that the active support of the respective support substructure 112.1 and 112.2 avoids sensor range problems, in particular, sensor range problems of those metrology devices capturing the spatial relation between the
25 first and second metrology support substructures 112.1 and 112.2.

As can be seen from Figure 2 and 3, in the present embodiment, there is provided a reference metrology device 110.9 configured to capture first reference metrology information RMI12 representative of the relative position (also referred to as the reference position) and the relative orientation (also referred to as the reference orientation) between the first
30 metrology support substructure 112.1 and the second metrology support substructure 112.2 in all six degrees of freedom.

Using this reference metrology information RMI12, the control device 109 may calculate the actual relative position and relative orientation of all the metrology devices 110.1 to 110.6 in

all six degrees of freedom. It will be appreciated that this calculation may be made under the assumption of infinitely rigid first and second metrology support substructures 112.1 and 112.2. Such an approach may be viable where the reduced quasi-static deformation of the respective metrology support substructure 112.1 and 112.2 is low enough, such that the impact of the error (involved with this assumption) on the imaging accuracy of the optical imaging process is negligible.

It will be appreciated however that, with other embodiments of the invention, the actual quasi-static deformation of either of the first and second metrology support substructure 112.1 and 112.2 may be taken into account in this calculation. For example, based on an (empirically and/or theoretically) established model of the first and second metrology support substructure 112.1 and 112.2 and the actual loads acting on the optical imaging apparatus 101, in particular, on the first and second metrology support substructure 112.1 and 112.2, the control device 109 may determine the actual quasi-static deformation of either of the first and second metrology support substructure 112.1 and 112.2 and take the latter into account in the calculation.

As can be seen from Figure 2, the reference metrology device 110.9 comprises a first reference metrology unit 117.1 and a second reference metrology unit 117.2 configured to cooperate in providing this reference metrology information. More precisely, the first reference metrology unit 117.1 comprises a plurality of sensor heads mechanically connected to a first reference part 112.11 of the first metrology support substructure 112.1 each of which cooperates with an associated reference element of the second reference metrology unit 117.2 mechanically connected directly to a second reference part 112.12 of the second metrology support substructure 112.2.

The sensor heads 117.1 and the associated reference elements 117.2 are designed in the same manner and provide the same functionality as the sensor heads 115.1 and reference elements 115.2 as described above. Hence, to avoid repetitions, reference is made to the explanations given above in the context of these components 115.1 and 115.2.

It will be appreciated that, here as well, with other embodiments of the invention, apart from the encoder principle, any other type of contactless measurement principle (such as e.g. an interferometric measurement principle, a capacitive measurement principle, an inductive measurement principle etc.) may be used alone or in arbitrary combinations. However, it will also be appreciated that, with other embodiments of the invention, any suitable contact based metrology arrangement may be used as well. As contact based working principles

magnetostrictive or electrostrictive working principles etc. may be used for example. In particular, the choice of the working principle may be made as a function of the accuracy requirements.

Furthermore, it will be appreciated that, with certain embodiments, the first reference metrology unit 117.1 may eventually only be a passive component as well. For example, the first reference metrology unit 117.1 may then comprise one or more simple reflective elements guiding the respective measurement light beam towards the second reference metrology unit 117.1 and a sensor head unit (as indicated by the dashed contour 117.3 in Figure 7) comprising one or more associated sensor heads located at the load bearing structure 107, respectively.

In this case, the first reference metrology unit 117.1 and the associated sensor head unit 117.3 may be used to determine the relative position and/or orientation of the first metrology support substructure 112.1 with respect to the load bearing structure 107 as first spatial relation information. Using this first spatial relation information, the first reference metrology unit 117.1, the second reference metrology unit 117.2 and the sensor head unit 117.3 may then be used to determine the relative position and/or orientation of the first metrology support substructure 112.1 with respect to the second metrology support substructure 112.2.

Such a solution has the advantage that no active components of the reference metrology device 110.9 have to be supported by the respective metrology support substructure 112.1 and 112.2. This allows a more lightweight and more rigid design of the respective metrology support substructure 112.1, 112.2, yielding even higher resonant frequencies and even less quasi-static deformation.

It will be further appreciated that either of the first and second metrology support substructure 112.1 and 112.2 may be actively adjusted in the relevant degrees of freedom in space within the same adjustment frequency ranges, which are adapted to the optical imaging process performed by the optical imaging arrangement 101, more precisely to the imaging accuracy to be achieved in this optical imaging process. This may, in particular, be the case where both metrology support substructures 112.1 and 112.2 have comparable masses and/or moments of inertia (including their respective supported components) in the respective relevant degree of freedom.

However, with certain embodiments comprising metrology support substructures 112.1 and 112.2 having noticeably different masses and/or moments of inertia (including their

respective supported components) in the respective relevant degree of freedom, different (eventually overlapping) adjustment frequency ranges may be selected for the respective degree of freedom. Hence, for example, a more inert metrology support substructure (e.g. the second metrology support substructure 112.2) may even be unadjusted or adjusted within a frequency range FR2 that is lower than a frequency range FR1 used for a less inert metrology support substructure (e.g., the first metrology support substructure 112.1). Moreover, such a more inert metrology support substructure may serve as an inertial reference and one or more (less inert) metrology support substructures may be actively adjusted to follow its motions.

Hence, with certain embodiments, the control device 109 (using the reference metrology information RMI12) controls the active support device 116 to adjust the first metrology support substructure 112.1 in such a manner that the first metrology support substructure 112.1 at least partially (preferably completely) follows a motion of the second reference part 112.12 of the second metrology support substructure 112.2 in at least one degree of freedom (up to all six degrees of freedom). In the present example, the actuator device 116.1 (under the control of the control device 109) adjusts the first metrology support substructure 112.1 in such a manner that a predeterminable relative position and/or a predeterminable relative orientation of the first metrology support substructure 112.1 with respect to the second reference part 112.12 is at least partially (preferably fully) maintained in at least one degree of freedom (up to all six degrees of freedom).

As can be seen from Figure 5, this active support of the first metrology support substructure 112.1 has the advantage that the latter maintains the predeterminable relative position and/or a orientation with respect to the second reference part 112.12 irrespective of a deformation of the load bearing structure 107 (as it is indicated by the dashed contours in Figure 5 showing the load bearing structure 107 its undeformed state and the location of the first metrology support substructure in case of an inactive actuator device 116.1, respectively). Hence, sensor range problems with the reference metrology device 110.9 are virtually excluded in a beneficial way.

It will be appreciated that, in the present embodiment, the metrology arrangement 110 further captures second reference metrology information RMIR2 representative of the relative position (also referred to as the reference position) and the relative orientation (also referred to as the reference orientation) between a metrology support substructure reference and the second metrology support substructure 112.2 in all six degrees of freedom. In the present example, the large optical footprint sixth mirror 106.6 (serving as the inertial reference for the

entire optical projection system) forms this metrology support structure system substructure reference. Hence, the second reference metrology information RMIR2 is the first spatial relationship captured by the metrology device 110.6 as it has been described above.

- 5 It will be appreciated however that, with other embodiments of the invention, any other suitable part of the optical imaging arrangement 101, for example a separate reference structure, may be used as the metrology support substructure reference.

In the embodiment shown, as a function of the second reference metrology information RMIR2, the control device 109 generates corresponding control signals for the actuator
10 device 116.4 to adjust the second metrology support substructure 112.2 at the above first adjustment control bandwidth (ranging from 5 Hz to 100 Hz, preferably from 40 Hz to 100 Hz) with respect to the first optical element unit 106.6 (i.e. the metrology support substructure reference).

This low bandwidth control of the second metrology support substructure 112.2 also provides
15 low bandwidth drift control of the spatial relation between the first optical element unit 106.6 (forming the inertial reference for the entire optical system in the present embodiment) and the second metrology support substructure 112.2. In other words, it allows the second metrology support substructure 112.2 to follow low-frequency motions of the first optical element unit 106.6. By this means excessive relative motion between the first optical
20 element unit 106.6 and the second metrology support substructure 112.2 going beyond the capturing range of the capturing devices of the metrology device 110.6 or, in other words, sensor range problems may be avoided in a very beneficial way.

It will be appreciated that, with certain embodiments of the invention, the low bandwidth control of the first optical element unit 106.6 may even be omitted, such that the low
25 bandwidth drift control of the spatial relation between the first optical element unit 106.6 and the second metrology support substructure 112.2 is exclusively provided via the active adjustment of the second metrology support substructure 112.2. Such a solution has the advantage that the effort for the support of the (large and heavy) first optical element unit 106.6 is greatly reduced. For example, even a simple passive support of the first optical
30 element unit 106.6 may then be sufficient. Eventually, appropriate vibration isolation of the first optical element unit 106.6 may be provided.

As can be seen from Figure 6 and 7, the optical element metrology device 110.3 comprises a first optical element metrology unit formed by sensor heads 115.1 located at the first metrology support substructure 112.1 and a second optical element metrology unit formed by reference element 115.2 located at the optical element 106.3. As outlined above, the optical element metrology device 110.3 captures information representative of a relative position and/or a relative orientation of the first optical element metrology unit 115.1 and the second optical element metrology unit 115.2 as the optical element status information.

The positions of either two components of the optical element metrology device 110.3, the reference metrology device 110.9 and the active support device 116 at the first metrology support substructure 112.1 preferably should be as close to each other as possible in order to reduce errors caused by a deformation of the first metrology support substructure 112.1 as far as possible. In the present example, this goal is achieved by implementing corresponding dimensions D1 to D4 as a function of a maximum substructure dimension SD_{max} of the first metrology support substructure 112.1 as they will be explained in the following with reference to Figure 7.

More precisely, in the present example, the first optical element metrology unit 115.1 is spaced from the first reference metrology unit 117.1 by a distance D1, which is less than 100% to 50%, preferably less than 10% to 5%, more preferably 3% to 1%, of the maximum substructure dimension SD_{max} .

Furthermore, the first metrology support substructure 112.1 is supported by the active support device 116.3 at a support location 112.13, which is spaced from the first optical element metrology unit 115.1 by a distance D2 and spaced from the first reference metrology unit 117.1 by a distance D3. In the present example, either of the distances D2 and D3 is less than 100% to 50%, preferably less than 10% to 5%, more preferably 3% to 1%, of the maximum substructure dimension SD_{max} .

Finally, the support location 112.13 is spaced from the volume center of gravity 112.3 of the first metrology support substructure 112.1 by a distance D4, which is less than 100% to 50%, preferably less than 10% to 5%, more preferably 3% to 1%, of the maximum substructure dimension SD_{max} .

It will be appreciated that control of the active adjustment of the respective metrology support substructure 112.1 and 112.2 may be performed solely on the basis of the respective reference metrology information RMI12 and RMIR2.

However, in the present example, a proactive control concept as generally outlined above is implemented via the control device 109. In the present example, the proactive control concept uses disturbance information DI that is captured and relates to actual disturbances propagating towards or already acting on the optical imaging arrangement 101. The disturbance information DI is then used to generate a preventive control of the active adjustment of the respective metrology support substructure 112.1 and 112.2 to keep the impact of the disturbance on the imaging properties as low as possible.

In the present example, vibration disturbances VD are captured and used in this proactive control concept for the metrology support substructures 112.1 and 112.2. Such a vibration disturbance VD may be captured by any suitable means allowing sufficiently precise determination of the disturbance VD. For example, a motion sensor may be used to yield suitable vibration information VI as the disturbance information DI. In the present example, an acceleration sensor device 110.10 comprising one or more acceleration sensors is used to capture the disturbance information DI.

In the present example, the acceleration sensor device 110.10 captures acceleration signals forming acceleration information AI, which is representative of an acceleration acting, in at least one degree of freedom up to all six degrees of freedom, on an accelerated component of the optical imaging arrangement 101. The acceleration sensor device 110.10 is connected to the control device 109 and provides the acceleration information AI to the control device 109. The control device 109, in turn, controls the active support device 116 to adjust the relative position and/or the relative orientation of the first metrology support substructure 112.1 and the second metrology support substructure 112.2 in at least one degree of freedom (up to all six degrees of freedom) as a function of the acceleration information AI.

As outlined above, the acceleration information AI (i.e. the disturbance information DI) may be captured at any suitable location of the optical imaging arrangement 101 allowing proper determination of the disturbance to be expected at the respective metrology support substructure 112.1 and 112.2. This allows proper proactive control of the active adjustment of the respective metrology support substructure 112.1 and 112.2 as a function of the disturbance to be expected.

For example, the acceleration information AI may be captured at any component of the optical imaging apparatus 101 (e.g. at its illumination unit 105, the mask unit 103, the optical projection unit 102 or the substrate unit 104). Preferably, the accelerated component is a

component of the optical projection system 106 (e.g. one of the optical elements of the optical element units 106.1 to 106.6). In addition or as an alternative, the accelerated component may be a component of the support structure system 107, 102.1, 111, 112 (e.g. the load bearing structure 107 or one of the metrology support substructures 112.1, 112.2).

5 In case of an active adjustment of the first metrology support substructure 112.1, for example, the accelerated component may be the second metrology support substructure 112.2.

In the present example, the control device 109 uses a numerical model NM to control the respective actuator device 116.3 and 116.4. The numerical model NM has been previously
10 established (empirically and/or theoretically) and is representative of a motion of the first metrology support substructure 112.1 and the second metrology support substructure 112.2 in response to the acceleration acting on the accelerated component (as the result of a vibration disturbance) and captured by the acceleration sensor device 110.10. By this means particularly rapid reaction to such vibration disturbances may be achieved.

15 In the present example, the control device 109 controls the respective actuator device 116.3 and 116.4 to counteract a motion of the first metrology support substructure 112.1 and the second metrology support substructure 112.2, respectively, the motion resulting from the disturbance generating the acceleration acting on the accelerated component. It will be appreciated that this counteracting action may be such that any motion of the first metrology
20 support substructure 112.1 and/or the second metrology support substructure 112.2 resulting from such a disturbance is substantially completely suppressed. With certain embodiments, however, a counteracting action may be sufficient, which only damps such disturbance induced motion to an extent necessary in view of the imaging errors acceptable in the optical imaging process performed with the optical imaging apparatus 101.

25 It will be appreciated that, with the microlithography apparatus 101 of the present embodiment, a line of sight accuracy may be obtained which is below 100 pm in all the relevant degrees of freedom, typically in the x direction and the y direction.

As becomes apparent from Figure 4, with the split design of the projection system metrology support structure 112 according to the present invention, it is possible to implement a
30 pretesting routine for the first and second metrology device subgroups 110.7 and 110.8 mounted to the respective first and second metrology support substructure 112.1 and 112.2.

This may be done in a first testing assembly 118 where the mirrors 106.2, 106.3 and 106.4 of the first optical element group 106.7 already including all the reference elements 115.2 are mounted to a testing support structure (not shown) identical to the corresponding part of the projection optics box structure 102.1. The fully preassembled first metrology support
5 substructure 112.1 including all components of the first metrology device subgroup 110.7 is then supported on a test load bearing structure 119 identical to the load bearing structure 107.

The same applies to a second testing assembly 120 where the mirrors 106.1, 106.5 and 106.6 of the second optical element group 106.8 already including all the reference elements
10 115.2 are mounted to a testing support structure (not shown) identical to the corresponding part of the projection optics box structure 102.1. The fully preassembled second metrology support substructure 112.2 including all components of the second metrology device subgroup 110.8 is then supported on a test load bearing structure 121 identical to the load bearing structure 107.

In a test procedure a testing routine is run on the first and second metrology device
15 subgroups 110.7 and 110.8 under real operating conditions. The split design of the projection system metrology support structure 112 provides easy accessibility to centrally located metrology devices such as, in particular, the ones for the third mirror 106.3 (M3) and the sixth mirror 106.6 (M6) which, in a conventional single piece design of the metrology
20 support structure would (if at all) only hardly be accessible. This greatly facilitates adjustment and calibration of the metrology device subgroups 110.7 and 110.8.

Moreover, the active support of the metrology support substructures 112.1 and 112.2 greatly facilitates manufacturing, in particular calibration, of the optical imaging arrangement 101. This is due to the fact that, in a preferred embodiment of the method of calibrating a
25 metrology system according to the invention, the actively adjusted metrology support substructures 112.1 and 112.2 only have to be coarsely adjusted during manufacture at such a precision that the reference metrology device 110.9 is within its sensor range. Subsequent calibration, i.e. fine adjustment to the specification of the optical imaging process, can then be made via the active support device 116 of the metrology support substructures 112.1 and
30 112.2. This greatly reduces manufacturing time, in particular calibration time.

With the optical imaging apparatus 101 of Figure 1 and 2 a method of transferring an image of a pattern onto a substrate may be executed using a preferred embodiment of a method of

supporting a metrology device according to the invention as it will be described in the following with reference to Figures 1 to 7.

In a transferring step of this method, an image of the pattern formed on the mask 103.1 is transferred onto the substrate 104.1 using the optical projection unit 102 of the optical
5 imaging arrangement 101.

To this end, in a capturing step S3 of said transferring step, the spatial relationship between the components 106.1 to 106.6, 103.1 and 104.1 participating in the imaging process is captured using a method of capturing a spatial relationship between an optical element unit and a reference unit as a status information as it has been outlined above. During this
10 capturing step S3 the metrology devices 110.1 to 110.6 are supported using a method according to the invention as it has also been outlined above.

In a controlling step S4 of the transferring step, the position and/or orientation of the substrate table 104.2, the mask table 103.2 and the other mirrors 106.1 to 106.5 with respect to the sixth mirror 106.6 as well as the relative position and/or relative orientation of the sixth
15 mirror 106.6 and the metrology support substructures 112.1 and 112.2 of the metrology unit 110.1 is controlled as a function of the respective spatial relationship previously captured in the capturing step S3 as it has been outlined above. In an exposure step, immediately following or eventually overlapping the controlling step S4, the image of the pattern formed on the mask 103.1 is then exposed onto the substrate 104.1 using the optical imaging
20 arrangement 1.

In a partial step of the controlling step S4, the mask unit 103 with the mask 103.1 and the substrate unit 104 with the substrate 104.1 previously provided are adjusted in space. It will be appreciated that the mask 103.1 and the substrate 104.1 may also be inserted into the mask unit 103 and the substrate unit 104, respectively, at a later point in time prior to the
25 actual position capturing or at an even later point in time prior to the exposure step.

According to a preferred embodiment of a method of supporting components of an optical projection unit according to the invention, in a step S1, the components of the optical projection unit 102 are first provided and then supported in a step S2 as it has been outlined above. To this end, in said step S2, the mirrors 106.1 to 106.6 of the optical projection unit
30 102 are supported and positioned within the projection optics box structure 102.1 of the optical projection unit 102. In step S4, the mirrors 106.1 to 106.6 are then actively supported

at the respective control bandwidth in the projection optics box structure 102.1 to provide a configuration as it has been described above in the context of Figures 1 and 2.

In the capturing step S3 the metrology arrangement 110 (previously provided in a configuration as it has been described above in the context of Figures 1 to 7) is used. It will be appreciated that the reference elements 115.2 may already have been provided at an earlier point in time together with the respective mirror 106.1 to 106.6 on which they are located. However, with other embodiments of the invention, the reference elements 115.2 may be provided together with the other components of the metrology arrangement 110 at a later point in time prior to the actual position capturing.

In the capturing step S3, the actual spatial relationship between the sixth mirror 106.6 as a central inertial reference of the optical imaging arrangement 101 and the substrate table 104.2, the mask table 103.2 as well as the other mirrors 106.1 to 106.5 is then captured as it has been outlined above.

It will be appreciated that the actual spatial relationship between the sixth mirror 106.6 and the substrate table 104.2, the mask table 103.2 and the other mirrors 106.1 to 106.5 as well as the actual spatial relationship of the sixth mirror 106.6 with respect to the metrology support structure 112 and the actual spatial relationship between the metrology support substructures 112.1 and 112.2 may be captured continuously throughout the entire exposure process. In the controlling step S4, the most recent result of this continuous capturing process is then retrieved and used.

As described above, in the controlling step S4, the spatial relation of the substrate table 104.2, the mask table 103.2, the mirrors 106.1 to 106.6 and the metrology support substructures 112.1 and 112.2 is then controlled as a function of the respective spatial relationship previously captured before, in the exposure step, the image of the pattern formed on the mask 103.1 is exposed onto the substrate 104.1.

Second embodiment

In the following, a second preferred embodiment of an imaging arrangement 201 according to the invention with which preferred embodiments of the methods according to the invention may be executed will be described with reference to Figure 8 and 9. The optical imaging arrangement 201 in its basic design and functionality largely corresponds to the optical imaging arrangement 101 such that it is here mainly referred to the differences. In particular,

identical components have been given the identical reference, while like components are given the same reference numeral increased by the value 100. Unless explicitly deviating statements are given in the following, explicit reference is made to the explanations given above in the context of the first embodiment with respect to these components.

- 5 The optical imaging arrangement 201 differs from the optical imaging arrangement 101 in the deviating concept of using the reference metrology device 210.9 of the metrology arrangement 210. It will be appreciated that the metrology arrangement 210 may simply replace the metrology arrangement 110 in the optical imaging arrangement 101.

As can be seen from Figure 8 and 9, instead of directly capturing the relative position and
10 relative orientation between the first metrology support substructure 212.1 and the second metrology support substructure 212.2 (using a reference metrology unit having sensor heads 117.1 connected to the first metrology support substructure 212.1 and associated reference elements 117.2 connected to the second metrology support substructure 212.2 as it is indicated by the dashed contours) the determination of the relative position and relative
15 orientation between the first metrology support substructure 212.1 and the second metrology support substructure 212.2 in all six degrees of freedom is done in an indirect way.

To this end, the reference metrology device 210.9 comprises a first relative reference metrology unit formed by a plurality of sensor heads 222.1, a second relative reference metrology unit formed by a plurality of associated reference elements 222.2, a third relative
20 reference metrology unit formed by the sensor heads 115.1 of the sixth metrology device 210.6 and a fourth relative reference metrology unit formed by the associated reference elements 115.2 of the sixth metrology device 210.6.

The sensor heads 222.1 of the first relative reference metrology unit are connected to the first metrology support substructure 112.1, while the associated reference elements 222.2 of
25 the second relative reference metrology unit are connected to the sixth mirror 106.6 (M6) forming a reference unit in the sense of the present invention. The sensor heads 222.1 and the associated reference elements 222.2 cooperate in the same manner as the sensor heads 115.1 and the associated reference elements 115.2 as it has been outlined in greater detail above. Hence, in this respect, reference is only made to the explanations given above in the
30 context of the first embodiment.

Thus, the sensor heads 222.1 of the first relative reference metrology unit and the associated reference elements 222.2 of the second relative reference metrology unit cooperate to

provide first relative reference metrology information RMIR1 representative of a first relative position (also referred to as first relative reference position) and a first relative orientation (also referred to as first relative reference orientation) between the first metrology support substructure 112.1 and the sixth mirror 106.6 (M6) in all six degrees of freedom.

5 The sixth metrology device 210.6 operates in the same manner as described in the context of the first embodiment. Hence, the third relative reference metrology unit formed by the sensor heads 115.1 of the sixth metrology device 210.6 and the fourth relative reference metrology unit formed by the associated reference elements 115.2 of the sixth metrology device 210.6 again cooperate to provide second relative reference metrology information
10 RMIR2 representative of the second relative position (also referred to as second relative reference position) and the second relative orientation (also referred to as second relative reference orientation) between the second metrology support substructure 212.2 and the sixth mirror 106.6 (M6) in all six degrees of freedom.

The control device 109 then derives the reference metrology information RMI12
15 (representative of the relative position and orientation of the first and second metrology support substructure 212.1 and 212.2 in all six degrees of freedom) from said first relative reference metrology information RMIR1 and said second relative reference metrology information RMIR2. Again, as described above in the context of the first embodiment, the control device 109 then uses this reference metrology information RMI12 to control the
20 actuator device 216.3 to adjust the first metrology support substructure 112.1.

It will be appreciated that, in the present example (and other than with the first embodiment), the second metrology support substructure 212.2 is not supported in an actively adjustable manner on the load bearing structure 107. In this case, the support may be provided via a vibration isolation device or even a simple substantially rigid connection. Here, preferably,
25 reference drift control is again provided via the active support of the sixth mirror 106.6 (M6). However, with other embodiments, the second metrology support substructure 212.2 may again be supported in an adjustable manner as it has been described in the context of the first embodiment (and as is indicated by the dashed contours 216.4 in Figure 8 and 9).

It will be appreciated that, with other embodiments of the invention, the reference unit does
30 not necessarily have to be the largest and most inert optical element of the optical system. Rather, any other suitable, preferably sufficiently dynamically stabilized component of the imaging apparatus 101 may be used. Preferably, in such cases, the reference unit is formed by any such suitable component external to the metrology support structure 112. For

example, as mentioned above, it may be one of the optical elements of the optical projection system. Furthermore, preferably, the reference unit may be the optical element of the optical projection system which is supported to exhibit maximum inertia (and hence tends to be the dynamically most stabilized component) among the optical elements.

- 5 Preferably, the reference unit it is formed by a component of the imaging apparatus which results in the least average of metrology or sensor cascades (over the entire optical projection system) necessary to determine the relative position and orientation between all optical elements of the optical projection system in all six degrees of freedom.

10 It will be appreciated that, with certain embodiments, the remaining outlay of the metrology system 210 may be identical to the metrology system 110 of the first embodiment. Hence, the first metrology support substructure 212.1 may further carry the first metrology device subgroup 210.7 associated to the first optical element subgroup 206.7. The second metrology support substructure 212.2 may carry a second relative reference metrology unit formed by metrology device 210.6 associated to the central reference unit (formed by the
15 optical element 106.6) as well as a metrology device subgroup 210.10 (of the second metrology device subgroup 210.8) associated to the remaining optical element subgroup 206.9 of the second optical element subgroup 206.8.

To keep the sensitivity of the metrology system 210 to deformations of the reference unit formed by the sixth mirror 106.6 (M6) as low as possible, the fourth relative reference
20 metrology unit (formed by the sensor heads 115.1) and spatially associated second relative reference metrology unit (formed by the sensor heads 222.1) are located as close together as possible. Preferably, they are located at a distance which ranges from 0% to 20% of a maximum dimension of the reference unit 106.6. Preferably the distance ranges from 0% to 10%, more preferably from 0% to 5% of this maximum dimension of the reference unit 106.6.
25 In any case, preferably the absolute distance ranges from 0 mm to 80 mm, preferably from 0 mm to 50 mm, more preferably from 0 mm to 20 mm.

it will be appreciated that, with certain embodiments of the invention, in certain degrees of freedom, the indirect determination of the relative position and/or orientation information as described in the context of the present embodiment may also be combined with the direct
30 determination as described in the context of the first embodiment. To this end, sensor heads 117.1 and associated reference elements 117.2 (as described in the context of the first embodiment) may also be used for certain degrees of freedom (as is indicated by the dashed contours in Figure 8).

The optical imaging arrangement 201 further differs from the optical imaging arrangement 101 in the deviating split design of the projection system metrology support structure 212. As can be seen from Figure 8 and 9, the projection system metrology support structure 212 is split into three substructures, namely the first metrology support substructure 212.1, the second metrology support substructure 212.2, and a third metrology support substructure 212.14.

The third metrology support substructure 212.14 carries a third metrology device subgroup 210.12, which is associated to a third optical element subgroup 206.10 and determines the relative position and/or orientation between the third metrology support substructure 212.14 and the optical elements of the third optical element subgroup 206.10 in at least one degree of freedom up to all six degrees of freedom.

Furthermore, the second metrology support substructure 212.2 carries a further reference metrology unit 210.11 determining third reference metrology information RMI23 representative of the relative position and orientation between the second metrology support substructure 212.2 and the third metrology support substructure 212.14 in all six degrees of freedom (in the same manner as it has been described above in the context of the first embodiment for the reference metrology unit 110.9).

As an alternative, as indicated by the dashed contour 210.12 in Figure 9, the reference metrology unit 210.11 may be omitted and the third metrology support substructure 212.14 may carry a further reference metrology unit 210.13 determining the relative position and orientation between the third metrology support substructure 212.14 and the central reference unit formed by the optical element 106.6 in all six degrees of freedom (in the same manner as it has been described above in the context of the second embodiment for the reference metrology unit 210.9).

Finally, as a further alternative, as indicated by the dashed contour 210.13 in Figure 9, the reference metrology unit 210.11 may be omitted and the first metrology support substructure 212.1 (or the third metrology support substructure 212.14) may carry a further reference metrology unit 210.13 determining the relative position and orientation between the third metrology support substructure 212.14 and first metrology support substructure 212.1 in all six degrees of freedom (in the same manner as it has been described above in the context of the first embodiment for the reference metrology unit 110.9).

As with all the other embodiments, the third metrology support substructure 212.14 is supported in a vibration isolated and actively adjustable manner separately from the first and second metrology support substructures 212.1 and 212.2 on the load bearing structure 107. Here, active adjustment of the third metrology support substructure 212.14 is provided via an actuator device 216.5, which is controlled by the control device 109. The active adjustment is done in a similar manner as it has been described in the context of the first embodiment for the first metrology support substructure 112.1. Hence, the actuator device 216.5 is controlled as a function of the spatial relation between the second and third metrology support substructure 212.2 and 212.14, which is captured via the reference metrology unit 210.11.

It will be appreciated that, any desired number of optical elements may be used. For example, in the present embodiment, an optical element group 206 comprising eight optical elements may be provided. Furthermore, in the present embodiment, as highly schematically indicated in Figure 9, the split between the first and second metrology support substructure 212.1 and 212.2 is such that they are located above each other in the height direction (z-axis), while the split between the second and third metrology support substructure 212.2 and 212.14 is such that they are located adjacent to each other (at substantially the same height level) in the horizontal plane (xy-plane). Furthermore, it will be appreciated that, with other embodiments of the invention, any other split into any desired number of metrology support substructures may be chosen.

It will be appreciated that, with the microlithography apparatus 201 of the present embodiment, a line of sight accuracy may be obtained which is below 1 nm in all the relevant degrees of freedom, typically in the x direction and the y direction.

It will be further appreciated that, here as well, the methods according to the invention as described above in the context of Figure 5 may also be executed with the microlithography apparatus 201.

Third embodiment

In the following, a third preferred embodiment of an optical imaging arrangement 301 according to the invention with which preferred embodiments of the methods according to the invention may be executed will be described with reference to Figure 10. The optical imaging arrangement 301 in its basic design and functionality largely corresponds to the optical imaging arrangement 101 such that it is here mainly referred to the differences. In

particular, identical components have been given the identical reference, while like components are given the same reference numeral increased by the value 200. Unless explicitly deviating statements are given in the following, explicit reference is made to be explanations given above in the context of the second embodiment with respect to these components.

The main difference between the optical imaging arrangement 301 and the optical imaging arrangement 101 lies within the deviating split design of the projection system metrology support structure 312 which is selected as a result of a slightly different arrangement of the first and second optical element subgroups 306.7 and 306.8. More precisely, mirror M3 of the first optical element subgroup 306.7 is shifted upward (in the z-direction) to be located considerably closer to mirrors M3 and M4 (than in the first embodiment as shown e.g. in Figure 2), while mirrors M1 and M6 are shifted downward (in the z-direction) to be located considerably closer to mirror M5 (than in the first embodiment as shown e.g. in Figure 2). Hence, a large essentially void area is created between the first and second optical element subgroups 306.7 and 306.8.

As can be seen from Figure 10, the projection system metrology support structure 312 is split into three substructures, namely a first metrology support substructure 312.1, a second metrology support substructure 312.2, and a third metrology support substructure 312.14. The third metrology support substructure 312.14 is located between the first metrology support substructure 312.1 and the second metrology support substructure 312.2 to bridge the gap or void area between them.

Hence, as in the first embodiment, the first metrology support substructure 312.1 carries a first metrology device subgroup 310.7 associated to the first optical element subgroup 306.7 as well as a first reference metrology device 310.9 determining reference metrology information RMI13 representative of the relative position and orientation between the first metrology support substructure 312.1 and the third metrology support substructure 312.11 in all six degrees of freedom (in the same manner as it has been described above in the context of the first embodiment for the reference metrology unit 110.9).

Furthermore, in a manner similar to the first embodiment, the third metrology support substructure 312.14 carries a further reference metrology device 310.14 determining reference metrology information RMI23 representative of the relative position and orientation between the second metrology support substructure 312.2 and the third metrology support substructure 312.14 in all six degrees of freedom (in the same manner as it has been

described above in the context of the first embodiment for the reference metrology unit 110.9). As an alternative, the second metrology support substructure 312.2 may carry the further reference metrology device 310.14.

Finally, also similar to the first embodiment, the second metrology support substructure 312.2 carries a second metrology device subgroup 310.10 associated to the second optical element subgroup 306.8.

Hence, the third metrology support substructure 312.11 has no metrology device subgroup associated to any optical elements but merely serves as a lightweight and highly rigid bridging unit spanning the gap or void area between the first metrology support substructure 312.1 and the second metrology support substructure 312.2.

In a manner similar to the first embodiment, the first metrology support substructure 312.1, the second metrology support substructure 312.2, and the third metrology support substructure 312.14 each is separately supported in a vibration isolated and actively adjustable manner on the load bearing structure 107 via an active support device 316 (in a manner similar to the active support device 116). Here as well, with other embodiments, at least one of the first, second and third metrology support substructures 312.1, 312.2 and 312.14 may not be actively adjustable. This applies particularly to the lightweight and highly rigid third metrology support substructure 312.11.

It will be appreciated that, here as well any desired number of optical elements may be used. For example, in the present embodiment, an optical element group comprising eight optical elements may also be provided.

Furthermore, it will be appreciated that, with other embodiments of the invention, any other split into any desired number of metrology support substructures may be chosen. Hence, a split into four or even more metrology support substructures may be chosen (as it is indicated e.g. by the dashed contours in Figure 7 and 8). In particular, a separate metrology support substructure may be provided for each optical element of the optical projection system.

Moreover, eventually, it may even be provided that, for one or more (up to all) optical elements of the optical projection system, two or more separate metrology support substructures are provided for the individual optical element (as it is indicated by the dashed contours 122.1 to 122.3 in Figure 2). Here, as indicated by contours 122.1 to 122.3, the lower part of metrology support substructure 112 may be split off and the split-off part itself

may again be split into three separate metrology support substructures 122.1 to 122.3 associated to optical element 106.5 (here mirror M5). As shown, each of these separate metrology support substructures 122.1 to 122.3 associated to optical element 106.5 may be individually supported in an actively adjustable manner as it has been described above.

5 Moreover, only the two metrology support substructures 122.1 and 122.3 carry parts of the optical element metrology device 110.5 associated to optical element 106.5, while metrology support substructure 122.2 only carries reference metrology devices. Hence, similar to metrology support substructure 312.11 of the third embodiment, metrology support substructure 122.2 carries no metrology device subgroup associated to any optical element
10 but merely serves as a lightweight and highly rigid bridging unit spanning the gap or void area between the metrology support substructures 122.1 and 122.3.

It should again be noted that, eventually, each of these separate metrology support substructures as outlined above may be supported in an actively adjustable manner as it has been described above.

15 It will be appreciated that, with the microlithography apparatus 301 of the present embodiment, a line of sight accuracy may be obtained which is below 1 nm in all the relevant degrees of freedom, typically in the x direction and the y direction.

It will be further appreciated that, here as well, the methods according to the invention as described above in the context of Figure 5 may also be executed with the microlithography
20 apparatus 301.

Although, in the foregoing, embodiments of the invention have been described where the optical elements are exclusively reflective elements, it will be appreciated that, with other embodiments of the invention, reflective, refractive or diffractive elements or any combinations thereof may be used for the optical elements of the optical element units.

25 Furthermore, it will be appreciated that the present invention, although mainly described in the context of microlithography in the foregoing, may also be used in the context of any other type of optical imaging process, typically requiring a comparably high level of imaging accuracy. In particular, the invention may be used in the context of any other type of optical imaging process operating at different wavelengths.

CLAIMS

1. An optical imaging arrangement comprising:

- an optical projection system (102),
- a support structure system (102.1, 107, 111, 112; 212; 312), and
- 5 - a group of metrology devices (110; 201; 310);
- said optical projection system (102) comprising a group of optical elements supported by said support structure system (102.1, 107, 111, 112; 212; 312) and configured to transfer, in an exposure process using exposure light along an exposure light path, an image of a pattern of a mask (103.1) onto a substrate
- 10 (104.1);
- said support structure system (102.1, 107, 111, 112; 212; 312) comprising a metrology support structure (112; 212; 312) and a load bearing structure (107);
- said metrology support structure (112; 212; 312) comprising a first metrology support substructure (112.1; 212.1; 312.1) and a second metrology support
- 15 substructure (112.2; 212.2; 312.2) separately supported on said load bearing structure (107);
- said group of metrology devices (110; 201; 310) comprising an optical element metrology device (110.1 to 110.8; 210.6, 210.7, 210.9, 210.10, 210.12; 310.7, 310.8) and a reference metrology device (110.9; 210.6, 210.9; 210.11; 310.9,
- 20 310.14);
- said optical element metrology device (110.1 to 110.8; 210.6, 210.7, 210.9, 210.10, 210.12; 310.7, 310.8) being functionally associated to an optical element of said group of optical elements and being configured to capture optical element status information representative of a position and/or an orientation of said optical
- 25 element in at least one degree of freedom up to all six degrees of freedom;
- said reference metrology device (110.9; 210.6, 210.9; 310.9) being functionally associated to said first metrology support substructure (112.1; 212.1; 312.1) and said second metrology support substructure (112.2; 212.2; 312.2) and being configured to capture reference metrology information representative of a relative
- 30 position and/or a relative orientation of a first reference part (112.11) of said first metrology support substructure (112.1; 212.1; 312.1) and a second reference part (112.12) of said second metrology support substructure (112.2; 212.2; 312.2) in at least one degree of freedom up to all six degrees of freedom;

characterized by

- said support structure system (102.1, 107, 111, 112; 212; 312) comprising an active support device (116; 216; 316) supporting said first metrology support substructure (112.1; 212.1; 312.1) and/or said second metrology support substructure (112.2; 212.2; 312.2) on said load bearing structure (107) in a manner actively adjustable as a function of said reference metrology information.

2. The optical imaging arrangement according to claim 1, wherein

- said active support device (116; 216; 316) is configured to adjust, as a function of said reference metrology information, a relative position and/or a relative orientation of said first metrology support substructure (112.1; 212.1; 312.1) and said second metrology support substructure (112.2; 212.2; 312.2) in at least one degree of freedom up to all six degrees of freedom;

wherein

- said active support device (116; 216; 316), in particular, is configured to adjust said first metrology support substructure (112.1; 212.1; 312.1) in such a manner that said first metrology support substructure (112.1; 212.1; 312.1) at least partially follows a motion of said second reference part (112.12) of said second metrology support substructure (112.2; 212.2; 312.2) in at least one degree of freedom;

and/or

- said active support device (116; 216; 316), in particular, is configured to adjust said first metrology support substructure (112.1; 212.1; 312.1) in such a manner that a predeterminable relative position and/or a predeterminable relative orientation of said first metrology support substructure (112.1; 212.1; 312.1) with respect to said second reference part (112.12) is at least partially maintained in at least one degree of freedom.

3. The optical imaging arrangement according to any one of claims 1 and 2, wherein,

- said active support device (116; 216; 316) comprises a control device (109) and an actuator device (116.3, 116.4; 216.3, 216.4, 216.5);
- said control device (109) being connected to said reference metrology device (110.9; 210.6, 210.9; 210.11; 310.9, 310.14) and said actuator device (116.3, 116.4; 216.3, 216.4, 216.5);

- said control device (109) being configured to control said actuator device (116.3, 116.4; 216.3, 216.4, 216.5) as a function of said reference metrology information received from said reference metrology device (110.9; 210.6, 210.9; 210.11; 310.9, 310.14) to adjust said first metrology support substructure (112.1; 212.1; 312.1) and/or said second metrology support substructure (112.2; 212.2; 312.2) in at least one degree of freedom.

4. The optical imaging arrangement according to any one of claims 1 to 3, wherein,

- a first reference metrology unit of said reference metrology device (110.9; 210.6, 210.9; 210.11; 310.9, 310.14) is located at said first reference part (112.11) of said first metrology support substructure (112.1; 212.1; 312.1);
- a second reference metrology unit of said reference metrology device (110.9; 210.6, 210.9; 210.11; 310.9, 310.14) is located at said second reference part (112.12) of said second metrology support substructure (112.2; 212.2; 312.2); and
- said reference metrology device (110.9; 210.6, 210.9; 210.11; 310.9, 310.14) is configured to capture information representative of a relative position and/or an relative orientation of said first reference metrology unit and said second reference metrology unit as said reference metrology information.

5. The optical imaging arrangement according to claim 4, wherein,

- said optical element metrology device (110.1 to 110.8; 210.6, 210.7, 210.9, 210.10, 210.12; 310.7, 310.8) comprises a first optical element metrology unit (115.1) located at said first metrology support substructure (112.1; 212.1; 312.1) and a second optical element metrology unit (115.2) located at said optical element;
- said reference metrology device (110.9; 210.6, 210.9; 210.11; 310.9, 310.14) is configured to capture information representative of a relative position and/or a relative orientation of said first optical element metrology unit (115.1) and said second optical element metrology unit (115.2) as said optical element status information;
- said first metrology support substructure (112.1; 212.1; 312.1) has a maximum substructure dimension in space and a volume center of gravity;

wherein

- said first optical element metrology unit (115.1) is spaced from said first reference metrology unit by less than 100% to 50%, preferably less than 10% to 5%, more preferably 3% to 1%, of said maximum substructure dimension;

and/or

- said first metrology support substructure (112.1; 212.1; 312.1) is supported by said active support device (116; 216; 316) at at least one support location (112.13), said at least one support location (112.13) being spaced from said first optical element metrology unit (115.1) and/or said first reference metrology unit by less than 100% to 50%, preferably less than 10% to 5%, more preferably 3% to 1%, of said maximum substructure dimension;

and/or

- said first metrology support substructure (112.1; 212.1; 312.1) is supported by said active support device (116; 216; 316) at one support location (112.13), said support location (112.13) being spaced from said volume center of gravity by less than 100% to 50%, preferably less than 10% to 5%, more preferably 3% to 1%, of said maximum substructure dimension.

6. The optical imaging arrangement according to any one of claims 1 to 5, wherein,

- said active support device (116; 216; 316) comprises an acceleration sensor device (110.10);

- said acceleration sensor device (110.10) is arranged and configured to capture acceleration information representative of an acceleration acting, in at least one degree of freedom up to all six degrees of freedom, on an accelerated component of said optical imaging arrangement; and

- said active support device (116; 216; 316) is configured to adjust, as a function of said acceleration information, a relative position and/or a relative orientation of said first metrology support substructure (112.1; 212.1; 312.1) and said second metrology support substructure (112.2; 212.2; 312.2) in at least one degree of freedom up to all six degrees of freedom;

- said accelerated component, in particular, being one of a component of said optical projection system (102) and a component of said support structure system (102.1, 107, 111, 112; 212; 312);

- said accelerated component, in particular, being said second metrology support substructure (112.2; 212.2; 312.2).

7. The optical imaging arrangement according to claim 6, wherein,

- said active support device (116; 216; 316) comprises a control device (109) and an actuator device (116.3, 116.4; 216.3, 216.4, 216.5);
- said control device (109) being connected to said acceleration sensor device (110.10) and said actuator device (116.3, 116.4; 216.3, 216.4, 216.5);
- said control device (109) being configured to control said actuator device (116.3, 116.4; 216.3, 216.4, 216.5) as a function of said acceleration information received from said acceleration sensor device (110.10) to adjust said first metrology support substructure (112.1; 212.1; 312.1) and/or said second metrology support substructure (112.2; 212.2; 312.2) in at least one degree of freedom;

wherein

- said control device (109), in particular, uses a numerical model to control said actuator device (116.3, 116.4; 216.3, 216.4, 216.5), said numerical model having been previously established and being representative of a motion of said first metrology support substructure (112.1; 212.1; 312.1) and/or said second metrology support substructure (112.2; 212.2; 312.2) in response to said acceleration acting on said accelerated component;

and/or

- said control device (109), in particular, is configured to control said actuator device (116.3, 116.4; 216.3, 216.4, 216.5) to counteract a motion of said first metrology support substructure (112.1; 212.1; 312.1) and/or said second metrology support substructure (112.2; 212.2; 312.2), said motion resulting from a disturbance generating said acceleration acting on said accelerated component;

and/or

- said control device (109), in particular, is configured to control said actuator device (116.3, 116.4; 216.3, 216.4, 216.5) to actively damp a motion of said first metrology support substructure (112.1; 212.1; 312.1) and/or said second metrology support substructure (112.2; 212.2; 312.2), said motion resulting from a disturbance generating said acceleration acting on said accelerated component.

8. The optical imaging arrangement according to any one of claims 1 to 7, wherein,

- said first metrology support substructure (112.1; 212.1; 312.1) is supported on said load bearing structure (107) via a first vibration isolation device (116.1) and said

second metrology support substructure (112.2; 212.2; 312.2) is supported on said load bearing structure (107) via a second vibration isolation device (116.2);

- said first vibration isolation device (116.1) and/or said second vibration isolation device (116.2), in particular, having a vibration isolation resonant frequency in a range from 10 Hz to 3 Hz, preferably from 1 Hz to 0.5 Hz, more preferably from 0.3 Hz to 0.1 Hz;

9. The optical imaging arrangement according to any one of claims 1 to 8, wherein

- said second metrology support substructure (112.2; 212.2; 312.2) is a reference substructure free from any optical element metrology devices functionally associated to one of said optical elements;

or

- a first optical element metrology unit (115.1) of a further optical element metrology device (110.1 to 110.8; 210.6, 210.7, 210.9, 210.10, 210.12; 310.7, 310.8) is located at said second metrology support substructure (112.2; 212.2; 312.2) and a second optical element metrology unit (115.2) of said further optical element metrology device (110.1 to 110.8; 210.6, 210.7, 210.9, 210.10, 210.12; 310.7, 310.8) is located at a further optical element of said group of optical elements, said further optical element metrology device (110.1 to 110.8; 210.6, 210.7, 210.9, 210.10, 210.12; 310.7, 310.8) being configured to capture further optical element status information representative of a position and/or an orientation of said further optical element in at least one degree of freedom.

10. The optical imaging arrangement according to any one of claims 1 to 9, wherein

- said metrology support structure (112; 212; 312) comprises a third metrology support substructure (212.3; 312.3) separately supported on said load bearing structure (107);
- a further reference metrology device (110.9; 210.6, 210.9; 210.11; 310.9, 310.14) being functionally associated to said first metrology support substructure (112.1; 212.1; 312.1) or said second metrology support substructure (112.2; 212.2; 312.2) and said third metrology support substructure (212.3; 312.3) and being configured to capture further reference metrology information representative of a relative position and/or a relative orientation of said first metrology support substructure (112.1; 212.1; 312.1) or said second metrology support substructure (112.2; 212.2;

312.2) and said third metrology support substructure (212.3; 312.3) in at least one degree of freedom up to all six degrees of freedom;

wherein, in particular,

- a fifth optical element metrology unit of a further optical element metrology device (110.1 to 110.8; 210.6, 210.7, 210.9, 210.10, 210.12; 310.7, 310.8) is located at said third metrology support substructure (212.3; 312.3) and a sixth optical element metrology unit of said further optical element metrology device (110.1 to 110.8; 210.6, 210.7, 210.9, 210.10, 210.12; 310.7, 310.8) is located at a further optical element of said group of optical elements, said further optical element metrology device (110.1 to 110.8; 210.6, 210.7, 210.9, 210.10, 210.12; 310.7, 310.8) being configured to capture further optical element status information representative of a position and/or an orientation of said further optical element in at least one degree of freedom.

11. The optical imaging arrangement according to any one of claims 1 to 10, wherein

- at least one of said metrology support substructures is made from a material selected from a material group;
- said material group consisting of steel, aluminum (Al), titanium (Ti), an Invar-alloy, a tungsten alloy, a ceramic material, silicon infiltrated silicon carbide (SiSiC), silicon carbide (SiC), silicon (Si), carbon fiber reinforced silicon carbide (C/CSiC), aluminum oxide (Al_2O_3), tungsten carbide (WC), Zerodur®, ULE® glass, quartz, and Cordierite.

12. The optical imaging arrangement according to any one of claims 1 to 11, wherein

- a control device (109) is provided and configured to use said optical element status information to control an active component of said optical imaging arrangement;

and/or

- said optical imaging arrangement is configured to be used in microlithography using exposure light at an exposure light wavelength in a UV range, in particular, an EUV range;

and/or

- said exposure light has an exposure light wavelength ranging from 5 nm to 20 nm;

and/or

- said optical elements of said group of optical elements are reflective optical elements.

and/or

- an illumination unit, a mask unit and a substrate unit are provided, said illumination unit being configured to illuminate said mask (103.1) received within said mask unit with said exposure light and said substrate unit being configured to receive said substrate (104.1) to receive said image transferred by said optical projection system (102).

13. A method of supporting a metrology device of an optical imaging arrangement comprising an optical projection system (102) with a group of optical elements configured to transfer, in an exposure process using exposure light along an exposure light path, an image of a pattern of a mask (103.1) onto a substrate, said method comprising

- supporting a first metrology support substructure (112.1; 212.1; 312.1) and a second metrology support substructure (112.2; 212.2; 312.2) separately on a load bearing structure (107);
- functionally associating an optical element metrology device (110.1 to 110.8; 210.6, 210.7, 210.9, 210.10, 210.12; 310.7, 310.8) to an optical element of said group of optical elements and capturing, via said optical element metrology device (110.1 to 110.8; 210.6, 210.7, 210.9, 210.10, 210.12; 310.7, 310.8), optical element status information representative of a position and/or an orientation of an optical element of said group of optical elements in at least one degree of freedom up to all six degrees of freedom;
- functionally associating a reference metrology device (110.9; 210.6, 210.9; 210.11; 310.9, 310.14) to said first metrology support substructure (112.1; 212.1; 312.1) and said second metrology support substructure (112.2; 212.2; 312.2), and capturing, via said reference metrology device (110.9; 210.6, 210.9; 210.11; 310.9, 310.14), reference metrology information representative of a relative position and/or a relative orientation of a first reference part (112.11) of said first metrology support substructure (112.1; 212.1; 312.1) and a second reference part (112.12) of said second metrology support substructure (112.2; 212.2; 312.2) in at least one degree of freedom up to all six degrees of freedom;

characterized by

- actively adjusting said first metrology support substructure (112.1; 212.1; 312.1) and/or said second metrology support substructure (112.2; 212.2; 312.2) with respect to said load bearing structure (107) as a function of said reference metrology information.

5 14. The method according to claim 13, wherein

- a relative position and/or a relative orientation of said first metrology support substructure (112.1; 212.1; 312.1) and said second metrology support substructure (112.2; 212.2; 312.2) is adjusted, as a function of said reference metrology information, in at least one degree of freedom up to all six degrees of freedom;

10 wherein

- said first metrology support substructure (112.1; 212.1; 312.1), in particular, is adjusted in such a manner that said first metrology support substructure (112.1; 212.1; 312.1) at least partially follows a motion of said second reference part (112.12) of said second metrology support substructure (112.2; 212.2; 312.2) in at least one degree of freedom;

15

and/or

- said first metrology support substructure (112.1; 212.1; 312.1), in particular, is adjusted in such a manner that a predeterminable relative position and/or a predeterminable relative orientation of said first metrology support substructure (112.1; 212.1; 312.1) with respect to said second reference part (112.12) is at least partially maintained in at least one degree of freedom.

20

15. The method according to any one of claims 13 and 14, wherein,

- a control device (109) receives said reference metrology information from said reference metrology device (110.9; 210.6, 210.9; 210.11; 310.9, 310.14), and
- said control device (109) controls an actuator device (116.3, 116.4; 216.3, 216.4, 216.5) as a function of said reference metrology information to adjust said first metrology support substructure (112.1; 212.1; 312.1) and/or said second metrology support substructure (112.2; 212.2; 312.2) in at least one degree of freedom.

25

16. The method according to any one of claims 13 to 15, wherein,

- a first reference metrology unit of said reference metrology device (110.9; 210.6, 210.9; 210.11; 310.9, 310.14) is located at said first reference part (112.11) of said first metrology support substructure (112.1; 212.1; 312.1);
- a second reference metrology unit of said reference metrology device (110.9; 210.6, 210.9; 210.11; 310.9, 310.14) is located at said second reference part (112.12) of said second metrology support substructure (112.2; 212.2; 312.2); and
- said reference metrology device (110.9; 210.6, 210.9; 210.11; 310.9, 310.14) captures information representative of a relative position and/or an relative orientation of said first reference metrology unit and said second reference metrology unit as said reference metrology information.

17. The method according to claim 16, wherein,

- a first optical element metrology unit (115.1) of said optical element metrology device (110.1 to 110.8; 210.6, 210.7, 210.9, 210.10, 210.12; 310.7, 310.8) is located at said first metrology support substructure (112.1; 212.1; 312.1) and a second optical element metrology unit (115.2) of said optical element metrology device (110.1 to 110.8; 210.6, 210.7, 210.9, 210.10, 210.12; 310.7, 310.8) is located at said optical element; and
- said reference metrology device (110.9; 210.6, 210.9; 210.11; 310.9, 310.14) captures information representative of a relative position and/or a relative orientation of said first optical element metrology unit (115.1) and said second optical element metrology unit (115.2) as said optical element status information;
- said first metrology support substructure (112.1; 212.1; 312.1) having a maximum substructure dimension in space and a volume center of gravity;

wherein

- said first optical element metrology unit (115.1) is spaced from said first reference metrology unit by less than 100% to 50%, preferably less than 10% to 5%, more preferably 3% to 1%, of said maximum substructure dimension;

and/or

- said first metrology support substructure (112.1; 212.1; 312.1) is actively supported at at least one support location (112.13), said at least one support location (112.13) being spaced from said first optical element metrology unit (115.1) and/or

said first reference metrology unit by less than 100% to 50%, preferably less than 10% to 5%, more preferably 3% to 1%, of said maximum substructure dimension;

and/or

- said first metrology support substructure (112.1; 212.1; 312.1) is supported by said active support device (116; 216; 316) at one support location (112.13), said support location (112.13) being spaced from said volume center of gravity by less than 100% to 50%, preferably less than 10% to 5%, more preferably 3% to 1%, of said maximum substructure dimension.

18. The method according to any one of claims 13 to 17, wherein,

- an acceleration information representative of an acceleration acting, in at least one degree of freedom up to all six degrees of freedom, on an accelerated component of said optical imaging arrangement is captured; and
- a relative position and/or a relative orientation of said first metrology support substructure (112.1; 212.1; 312.1) and said second metrology support substructure (112.2; 212.2; 312.2) is adjusted, as a function of said acceleration information, in at least one degree of freedom up to all six degrees of freedom;
- said accelerated component, in particular, being one of a component of said optical projection system (102) and a component of said support structure system (102.1, 107, 111, 112; 212; 312);
- said accelerated component, in particular, being said second metrology support substructure (112.2; 212.2; 312.2).

19. The method according to claim 18, wherein,

- a control device (109) receives said acceleration information, and
- said control device (109) controls an actuator device (116.3, 116.4; 216.3, 216.4, 216.5) as a function of said acceleration information to adjust said first metrology support substructure (112.1; 212.1; 312.1) and/or said second metrology support substructure (112.2; 212.2; 312.2) in at least one degree of freedom;

wherein

- said control device (109), in particular, uses a numerical model to control said actuator device (116.3, 116.4; 216.3, 216.4, 216.5), said numerical model having been previously established and being representative of a motion of said first

metrology support substructure (112.1; 212.1; 312.1) and/or said second metrology support substructure (112.2; 212.2; 312.2) in response to said acceleration acting on said accelerated component;

and/or

- 5 - said control device (109), in particular, controls said actuator device (116.3, 116.4; 216.3, 216.4, 216.5) to counteract a motion of said first metrology support substructure (112.1; 212.1; 312.1) and/or said second metrology support substructure (112.2; 212.2; 312.2), said motion resulting from a disturbance generating said acceleration acting on said accelerated component;

10 and/or

- said control device (109), in particular, controls said actuator device (116.3, 116.4; 216.3, 216.4, 216.5) to actively damp a motion of said first metrology support substructure (112.1; 212.1; 312.1) and/or said second metrology support substructure (112.2; 212.2; 312.2), said motion resulting from a disturbance
15 generating said acceleration acting on said accelerated component.

20. The method according to any one of claims 13 to 19, wherein,

- said first metrology support substructure (112.1; 212.1; 312.1) is supported on said load bearing structure (107) via a first vibration isolation device (116.1) and said second metrology support substructure (112.2; 212.2; 312.2) is supported on said
20 load bearing structure (107) via a second vibration isolation device (116.2);
- said first vibration isolation device (116.1) and/or said second vibration isolation device (116.2), in particular, having a vibration isolation resonant frequency in a range from 10 Hz to 3 Hz, preferably from 1 Hz to 0.5 Hz, more preferably from 0.3 Hz to 0.1 Hz;

25 21. The method according to any one of claims 13 to 20, wherein

- a first optical element metrology unit (115.1) of a further optical element metrology device (110.1 to 110.8; 210.6, 210.7, 210.9, 210.10, 210.12; 310.7, 310.8) is located at said second metrology support substructure (112.2; 212.2; 312.2) and a second optical element metrology unit (115.2) of said further optical element
30 metrology device (110.1 to 110.8; 210.6, 210.7, 210.9, 210.10, 210.12; 310.7, 310.8) is located at a further optical element of said group of optical elements, and

- said further optical element metrology device (110.1 to 110.8; 210.6, 210.7, 210.9, 210.10, 210.12; 310.7, 310.8) captures further optical element status information representative of a position and/or an orientation of said further optical element in at least one degree of freedom.

5 22. The method according to any one of claims 13 to 21, wherein

- a third metrology support substructure (212.3; 312.3) is separately supported on said load bearing structure (107), and
- a further reference metrology device (110.9; 210.6, 210.9; 210.11; 310.9, 310.14) is functionally associated to said first metrology support substructure (112.1; 212.1; 312.1) or said second metrology support substructure (112.2; 212.2; 312.2) and said third metrology support substructure (212.3; 312.3) and captures further reference metrology information representative of a relative position and/or a relative orientation of said first metrology support substructure (112.1; 212.1; 312.1) or said second metrology support substructure (112.2; 212.2; 312.2) and said third metrology support substructure (212.3; 312.3) in at least one degree of freedom up to all six degrees of freedom;

wherein, in particular,

- a first optical element metrology unit (115.1) of a further optical element metrology device (110.1 to 110.8; 210.6, 210.7, 210.9, 210.10, 210.12; 310.7, 310.8) is located at said third metrology support substructure (212.3; 312.3) and a second optical element metrology unit (115.2) of said further optical element metrology device (110.1 to 110.8; 210.6, 210.7, 210.9, 210.10, 210.12; 310.7, 310.8) is located at a further optical element of said group of optical elements, said further optical element metrology device (110.1 to 110.8; 210.6, 210.7, 210.9, 210.10, 210.12; 310.7, 310.8) capturing further optical element status information representative of a position and/or an orientation of said further optical element in at least one degree of freedom.

23. A method of calibrating a metrology system of an optical imaging arrangement comprising an optical projection system (102) with a group of optical elements configured to transfer, in an exposure process using exposure light along an exposure light path, an image of a pattern of a mask (103.1) onto a substrate (104.1), said method comprising

- supporting said optical projection system (102) and said metrology system on a load bearing structure (107), at least one optical element metrology unit of said metrology system being supported on a metrology support substructure,
- in a coarse adjustment step, performing a coarse spatial adjustment of said metrology support substructure; and,
- in a calibrating step, performing a fine spatial adjustment of said metrology support substructure using a method according to any one of claims 13 to 22.

24. An optical imaging method comprising

- transferring, in an exposure process using said exposure light, said image of said pattern onto said substrate (104.1), wherein,
- during said exposure process, said first metrology support substructure (112.1; 212.1; 312.1) and/or said second metrology support substructure (112.2; 212.2; 312.2) is actively adjusted using a method according to any one of claims 13 to 22, wherein
- during said exposure process, in particular, an active component of said optical imaging arrangement is controlled using said optical element status information.

* * * * *

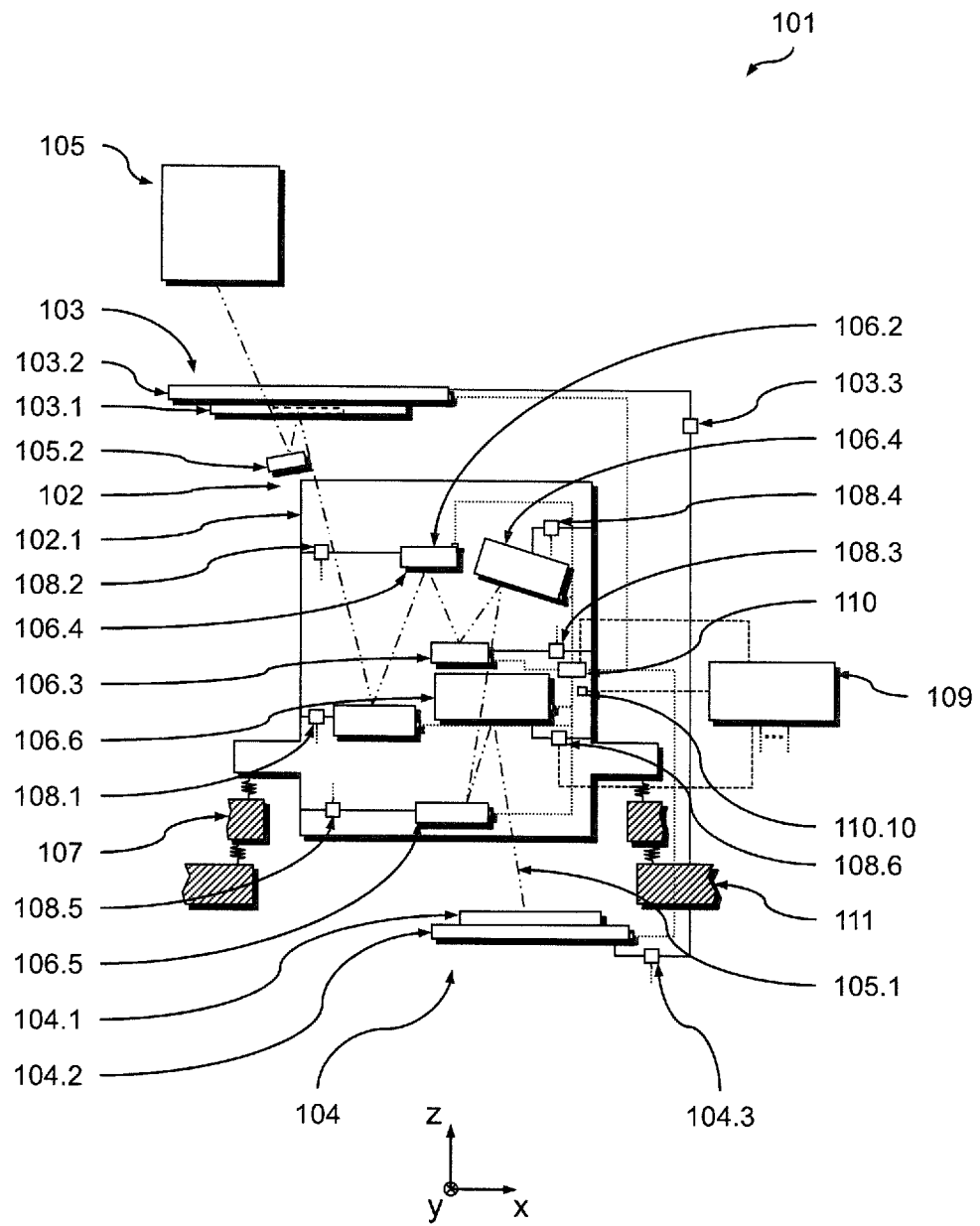


Fig. 1

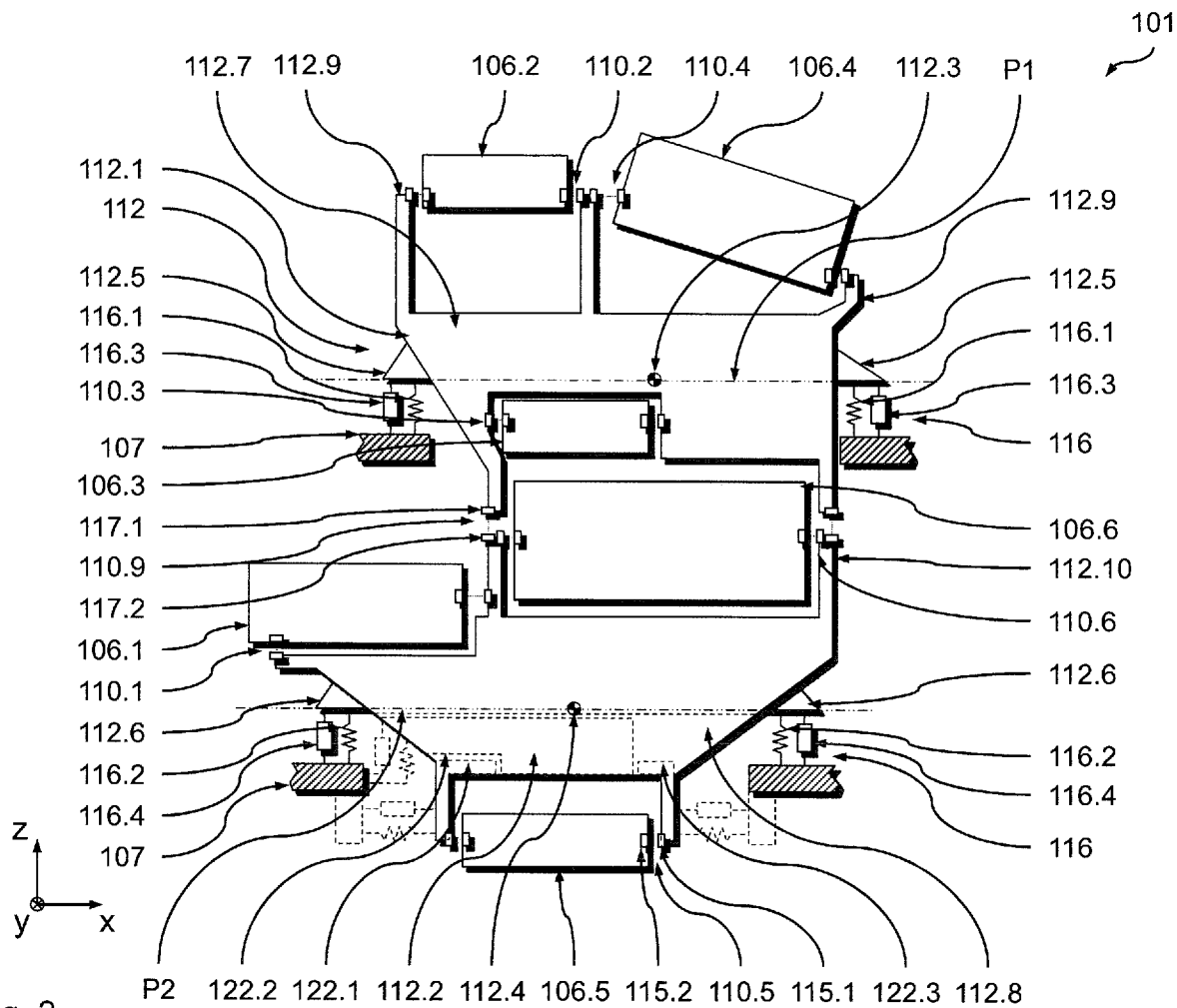


Fig. 2

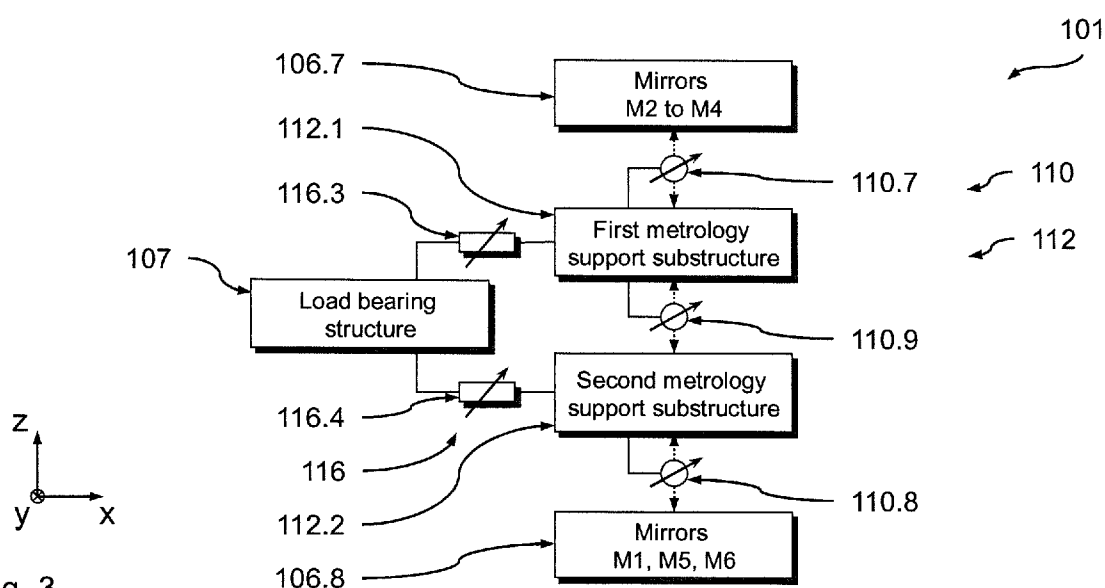


Fig. 3

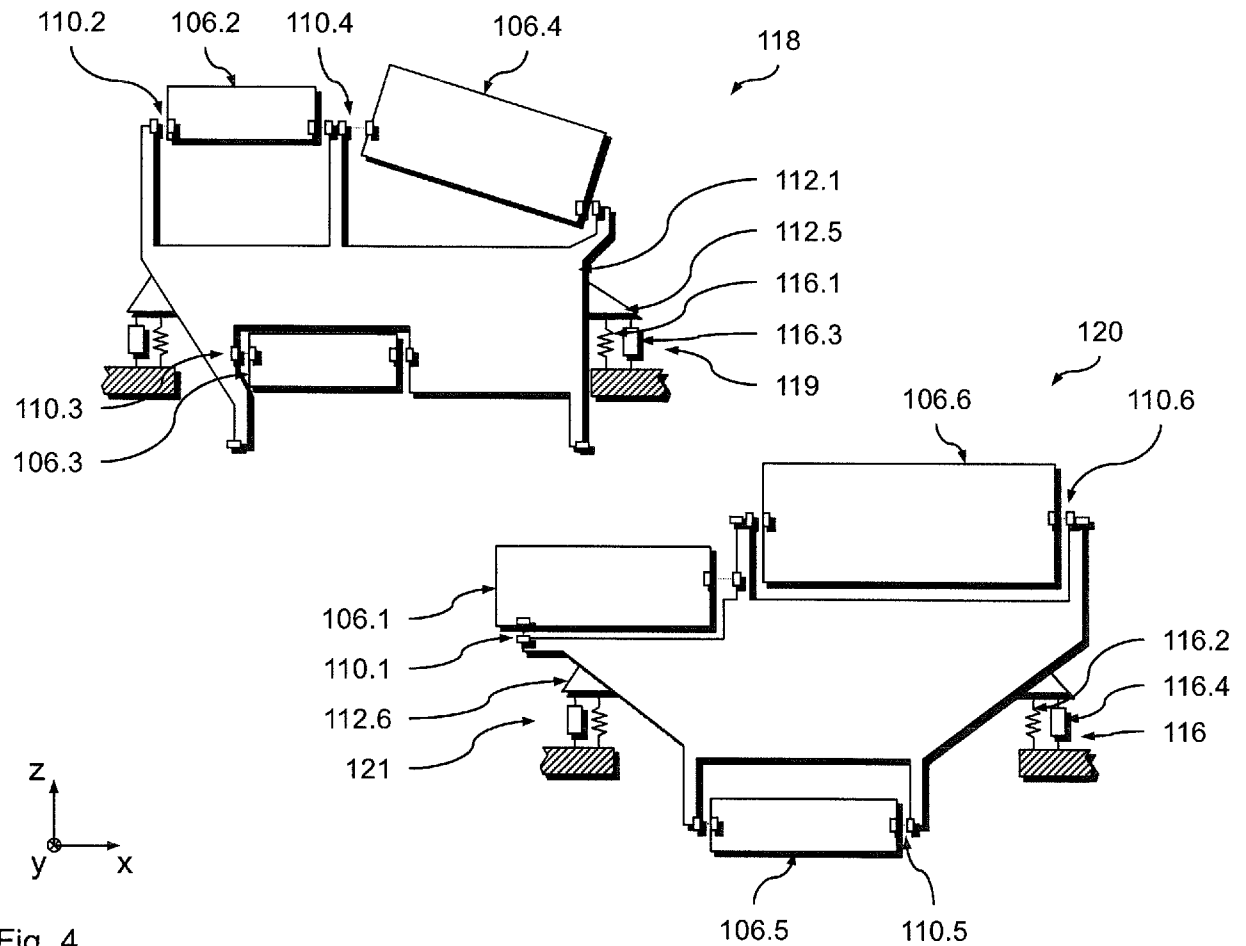


Fig. 4

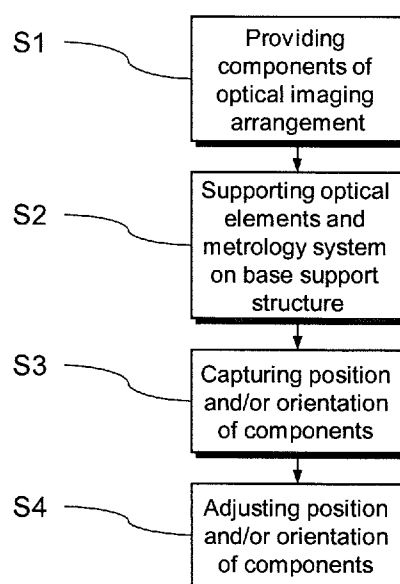
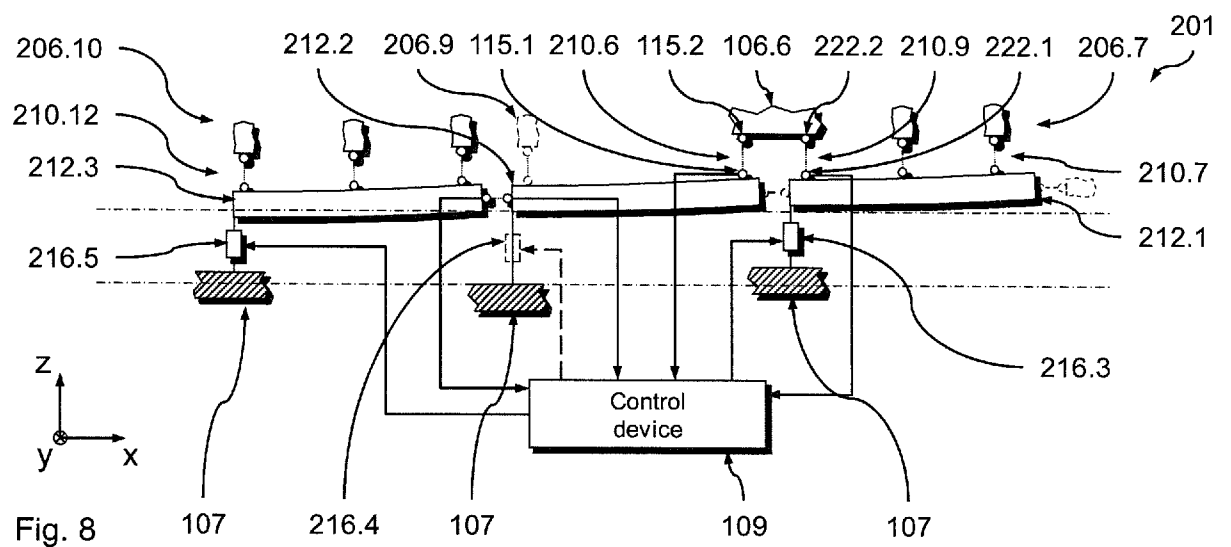
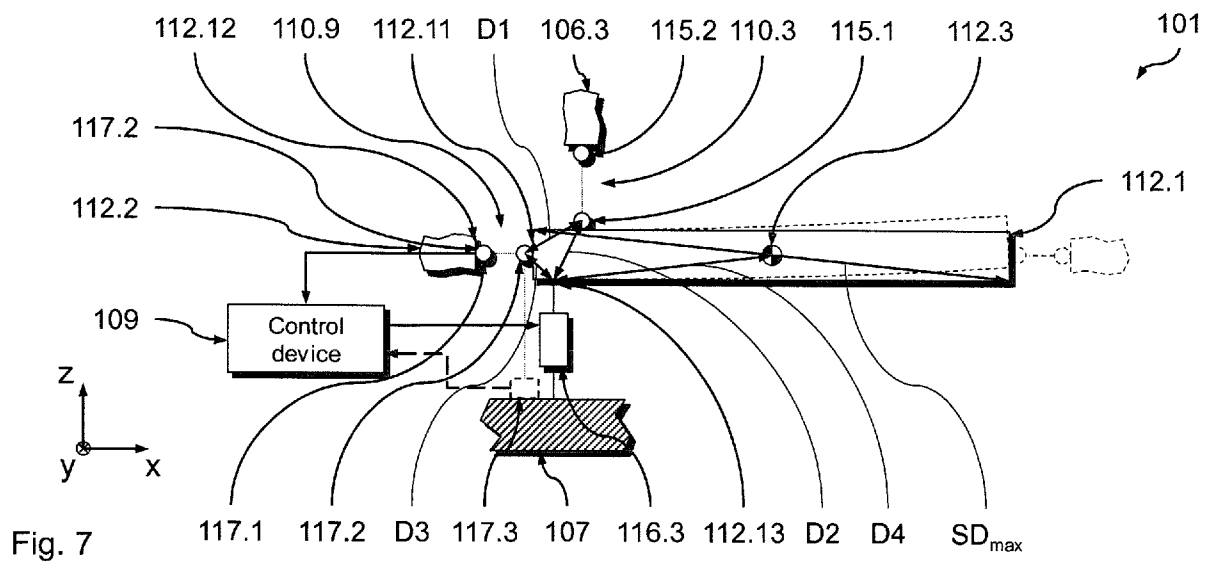
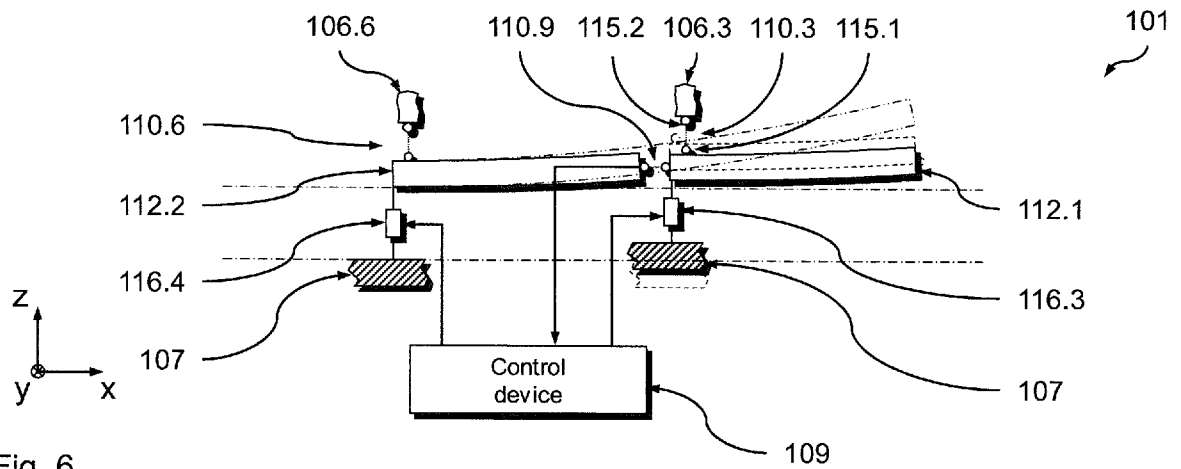


Fig. 5



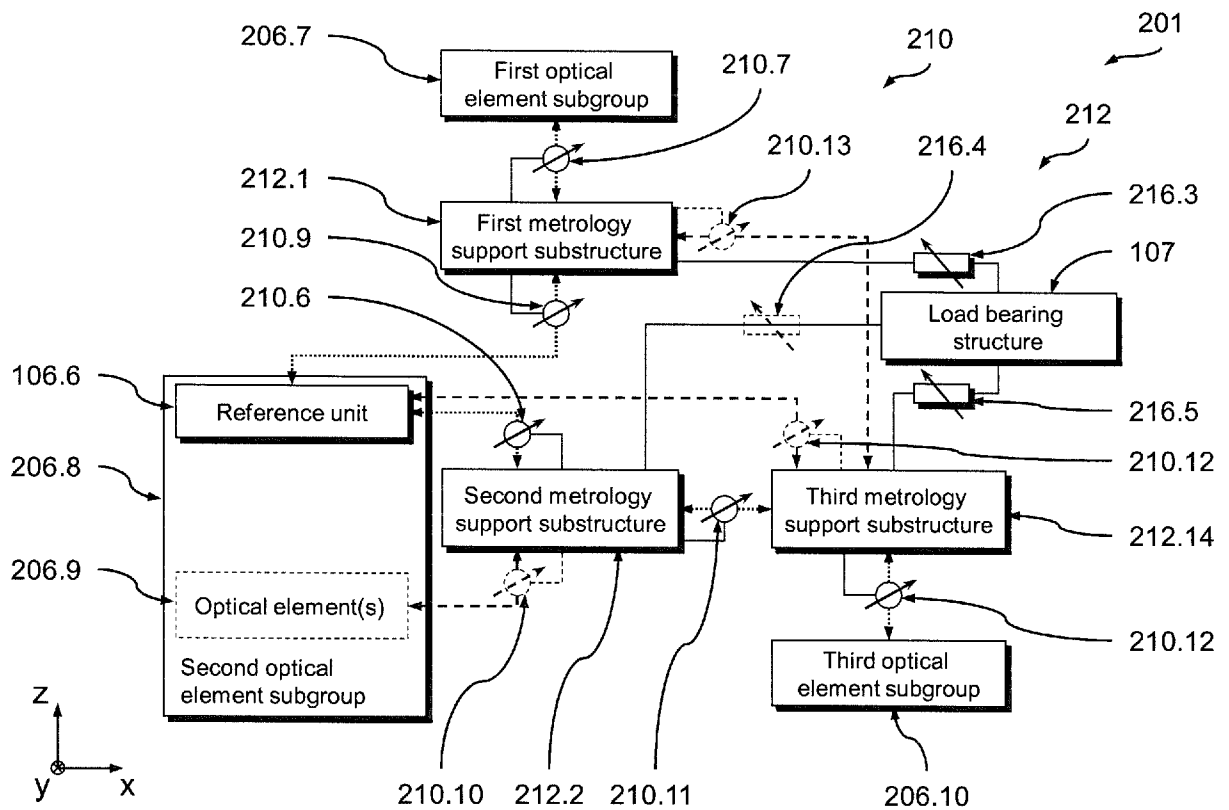


Fig. 9

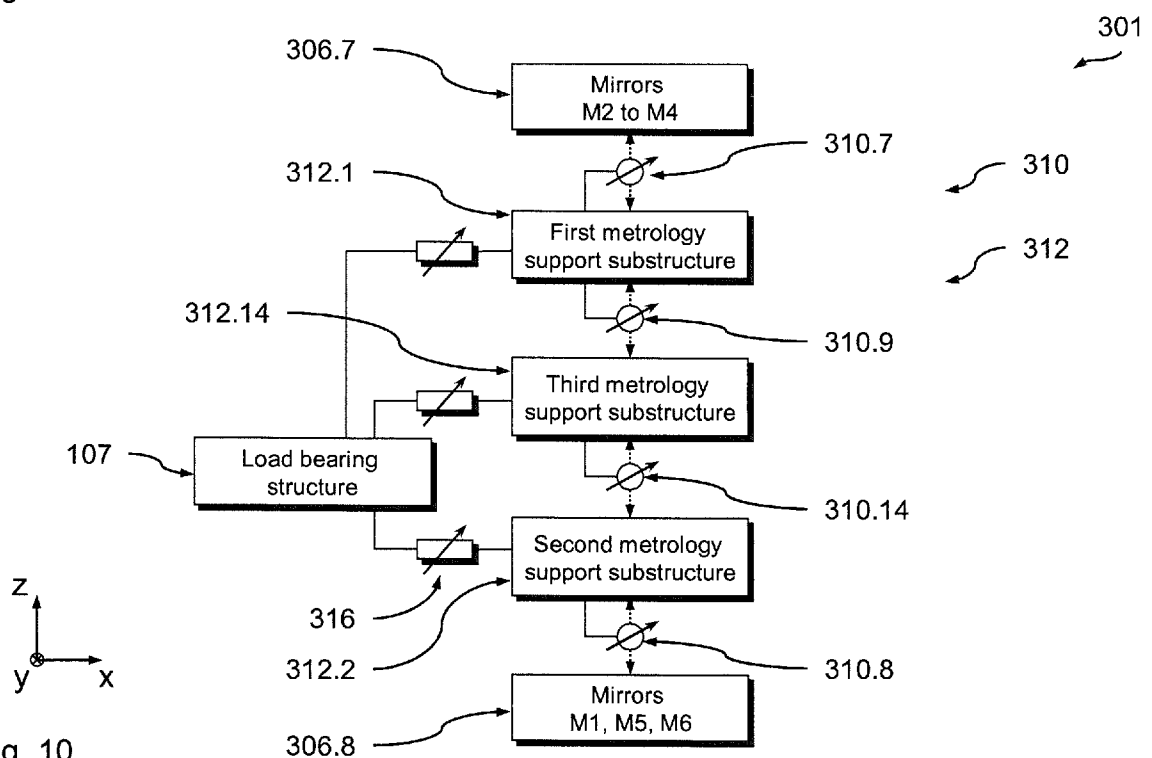


Fig. 10

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2016/068777

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

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	WO 2013/178277 A1 (ZEISS CARL SMT GMBH [DE]; KWAN YIM-BUN PATRICK [DE]; RUINEMANS ERIK [N] 5 December 2013 (2013-12-05) page 9, paragraph 5 - page 31, paragraph 4 figures 1-5 -----	1-24
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Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

17 November 2016

Date of mailing of the international search report

24/11/2016

Name and mailing address of the ISA/

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Authorized officer

Meixner, Matthias

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/068777

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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