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(71) Applicant: CARL ZEISS MICROSCOPY GMBH [DE/DE]; Carl-Zeiss-Promenade 10, 07745 Jena (DE).

(72) Inventor: ZEIDLER, Dirk; Dreissentalstrasse 72, 73447 Oberkochen (DE).

(74) Agent: CARL ZEISS AG - PATENTABTEILUNG; Carl-Zeiss-Str. 22, 73447 Oberkochen (DE).

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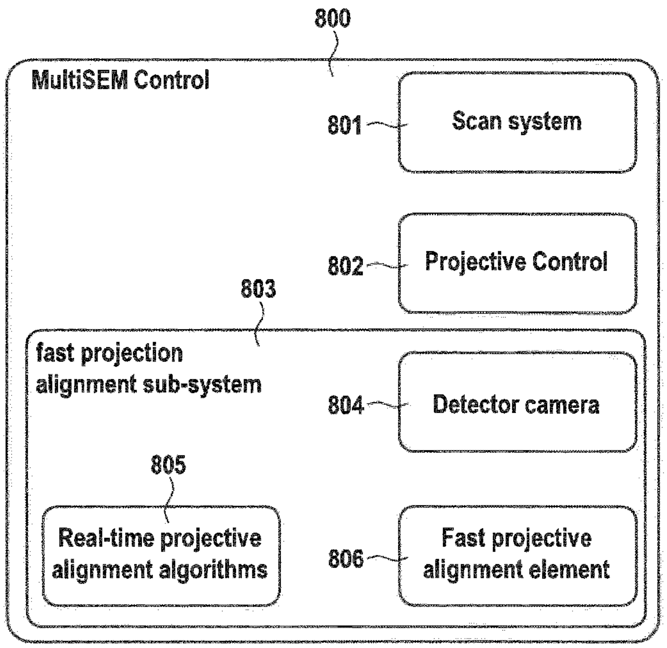

Fig. 3

(57) Abstract: The present invention relates to charged particle beam systems and methods. More particular the present invention relates to a multi beam charged particle beam system and related methods. Even more particular, the present invention relates to compensating sample charging in a multi beam charged particle beam system.

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Charged particle beam system and method

The present invention relates to charged particle beam systems and methods. More particular the present invention relates to a multi beam charged particle beam system and related methods.

A multi beam charged particle beam system is disclosed, for example, in WO2005024881A2 and in WO2016/124648.

For multi beam charged particle beam systems, such as multi beam electron microscopes, interaction products, i.e. secondary electrons, originating from different primary charged particle beams need to be imaged onto separate detectors by a projective system. To this end, electrostatic extraction fields can be used. A homogeneous extraction field ensures the imaging of the interaction products, such as secondary electrons, onto individual detectors and that a mapping between scan deflector voltages and respective beam positions at the individual detectors of the multi detector is faithful. The spot shape of the secondary electrons at a multi detector, for example a scintillator forming a component of the multi detector, critically depends on the homogeneity of the electrostatic extraction field. As one spot is imaged onto one corresponding detector, the homogeneity of the electrostatic extraction field governs the cross talk between beams and the corresponding detection signals.

In the presence of residual charges on the sample surface, the electrostatic extraction field can become distorted locally. Thereby, the imaging to separate detectors can become perturbed to an extent that a viable scan of the surface is not possible. Especially, the positioning of the beams at the detector can become strongly time-dependent and primary beam position dependent. Common methods for charge mitigation in scanning electron microscopes (SEM) are not straightforward to adapt to both the primary and secondary beam path of a multi beam scanning beam system, especially with respect to the extraction field homogeneity constraints for good secondary imaging. Available methods to realign the detectors in steady-state cases (i.e. between workflow runs or between recording of image frames) are not fast enough to steer the beams in a multi beam charged particle beam system.

One widely used strategy to faithfully image charging samples with charged particle beams is to pre-charge the sample with a second charged particle generator, a so-called flood gun, such that the surface potential after flooding is set to a value that the concurrent imaging step is performed at the yield-neutral point. The flood gun is either directed to the sample from the side, switching between imaging and flooding mode without moving the sample, or the flood gun is mounted on the chamber lid next to the imaging system, and flooding is performed by moving the sample between these two positions. For high-throughput charged particle beam imaging systems, none of these strategies is very desirable, as moving the sample back and forth between flooding and imaging position will reduce throughput. The large-FOV pole piece geometry of multi beam charged particle imaging systems makes pointing a flood gun at the location to be imaged challenging, as the distance between the lowest pols piece and the sample is approximately few mm or below, with a small cleft between the lowest pole piece and the sample over a large area. Even if one were to guide the flooding beam inside this cleft towards the imaging position, the electrostatic field present in this area will add further challenges to pointing the flooding beam faithfully.

The goal of the present invention is to provide a solution for operating a multi beam charged particle beam system also in cases in which the sample charges due to the impinging primary charged particle beams or beamlets. These and other objects are solved with a system with the features of claim 1 and a method with the features of claim 23. Advantageous embodiments are disclosed in the dependent claims.

The present invention relates to a charged particle beam system comprising at least a first charged particle source configured to generate a first charged particle beam, a multi beam generator configured to generate a plurality of charged particle beamlets from the incoming first charged particle beam, an objective lens, a projective system, a sample stage, a detector system comprising a plurality of individual detectors, and a control configured to control the operation of the multi beam generator, the objective lens and the projection system. The control provides a first mode of operation and a second mode of operation. In the first mode of operation the control controls the multi beam generator to be configured that each individual beamlet of the plurality of charged particle beamlets is spatially separated from other beamlets of the plurality of charged particle beamlets, and in the first mode of operation the control further controls the objective lens to be configured to focus incoming charged particle beamlets in a first plane in a manner that a first region in which a first individual beamlet of the plurality of charged particle beamlets impinges in the first plane is spatially separated from a second region in which a second individual beamlet of the plurality of charged particle beamlets impinges in the first plane, and in the first mode of operation the control controls the projective system to be configured to image interaction products leaving the first region within the first plane due to impinging charged particles onto a first one of the plurality of individual detectors and to image interaction products leaving the second region in the first plane due to impinging charged particles onto a second one of the plurality of individual detectors. In the second mode of operation the control controls the operation of the multi beam generator in combination with the objective lens to be configured that a single or plural defocused charged particle beam(s) is/are provided in the first plane.

Controlling the operation of the multi beam generator in combination in this disclosure means that the control either only changes the adjustment of the multi beam generator when switching between the first mode of operation and the second mode of operation, if changing only the adjustment of the multi beam generator is sufficient to achieve a sufficiently broad defocused charged particle beam in the first plane, or alternatively, the control changes the adjustment of the multi beam generator as well as the adjustment of the objective lens when switching between the first mode of operation and the second mode of operation, if this is necessary to achieve a sufficiently broad defocused charged particle beam in the first plane.

In an embodiment the charged particle beam system further comprises a voltage supply configured to supply a variable voltage to the sample stage, wherein in the first mode of operation the control controls a voltage supply of the objective lens and/or the voltage supply of the sample stage in a manner that the charged particles of the charged particle beamlets have a first average kinetic energy in the first plane, and wherein the control controls the voltage supply of the objective lens and/or the voltage supply of the sample stage in the second mode of operation in a manner that the charged particles have a second average kinetic energy in the first plane that is different from the first average kinetic energy. The first average kinetic energy can be larger than 400eV, alternatively larger than 1000eV, alternatively larger than 1500eV, or alternatively larger than 2000eV, depending on the type of sample imaged and desired sample contrast. The second average kinetic energy is smaller than 1000 eV, alternatively smaller than 500 eV, alternatively smaller than 200 eV, alternatively smaller than 50eV, depending on the sample composition and charging properties as a function of kinetic energy of the incoming charged particles. Especially the first average kinetic energy can be adjusted to any value in the range between 400 eV and 3000 eV. More preferable the first average kinetic energy can be adjusted to any value in the range between 200 eV and 5000 eV. The second average kinetic energy can be adjusted to any value in the range between 200 eV and 1000 eV. More preferable the second average kinetic energy can be adjusted to any value in the range between 50 eV and 2000 eV.

In another embodiment, in the second mode of operation the defocused charged particle beam has a second diameter in the first plane, wherein in the first mode of operation a minimum diameter of a circle surrounding an area onto which the plurality of charged particle beamlets impinge in the first plane has a first diameter, and wherein the second diameter is at least 1.2 times, more preferable 2 times, even more preferable 5 times, even more preferable 10 times, and most preferable 50 times the first diameter.

In another embodiment, in the second mode of operation the defocused charged particle beam illuminates a surface in the first plane having a second surface area, wherein in the first mode of operation a minimum surface area within which all beamlets of the plurality of charged particle beamlets impinge in the first plane has a first area, and wherein the second surface area is at least 1.5 times, more preferable 4 times, even more preferable 10 times, even more preferable 100 times, and most preferable 200 times the first surface area.

In an embodiment of the charged particle beam system, the multi beam generator comprises at least a first aperture plate, wherein the first multi aperture plate comprises a plurality of holes for forming the plurality of charged particle beamlets. The holes in first multi aperture plate can have a first hole diameter, and the first multi aperture plate can have has at least one second hole having a second hole diameter, wherein the second hole diameter is at least 5 times the first hole diameter.

In a further embodiment the first multi aperture plate can have, besides the first holes for forming the plurality of charged particle beamlets, more than one, i.e. two, three, or even more second holes having a second hole diameter, wherein the second hole diameter is at least 5 times the first hole diameter.

In an embodiment the first multi aperture plate is displaceable in a direction perpendicular to the direction of beam propagation of the charged particle beam. Switching between the first mode of operation in which the sample is scanned simultaneously by a plurality of charged particle beamlets, and flooding of the sample by an electron beam then is achieved by displacing the first multi aperture plate relative to the first charged particle beam so that the first charged particle beam impinges on one or more of the second holes.

In another embodiment the charged particle beam system further comprises a first single or double deflection system arranged between the charged particle source and the first multi aperture plate, and a second single or double deflection system arranged between the first multi aperture plate and the objective lens. In this embodiment, switching between the first mode of operation in which the sample is scanned simultaneously by a plurality of charged particle beamlets, and flooding of the sample by a defocused electron beam then is achieved by displacing the first charged particle beam by appropriate excitation of the single or double deflection system relative to the first multi aperture plate so that the first charged particle beam impinges on one or more of the second holes. Accordingly, in the second mode of operation, the control controls the first single or double deflection system and the second single or double deflection systems to pass the charged particle beam through the at least one second hole. The second single or double deflection system serves to realign the charged particle beams having passed the second holes to the axis of the charged particle beam system.

In an embodiment the charged particle beam system further comprises a beam splitter arrangement upstream of the objective lens to separate a primary beam path of the primary charged particle beamlets from the charged particle source to the first plane from a secondary beam path of interaction products, caused by the primary charged particle beamlets to leave a sample, from the sample to the detector system.

In another embodiment the charged particle beam system further comprises a second charged particle source providing a second charged particle beam, a deflection system and a beam stop, wherein the control is configured to control the deflection system to direct the second charged particle beam onto the beam stop in the first mode of operation and to direct the second charged particle beam to pass the beam stop in the second mode of operation.

The objective lens comprises an opening, for example an opening within the pole piece of a magnetic lens or several aperture openings of electrodes if the objective lens in an electrostatic lens, through which the primary charged particle beamlets pass in the first mode of operation. In an embodiments also the second charged particle beam passes through this opening in the objective lens in the second mode of operation before impinging defocused onto the sample.

The charged particle beam system can further comprise a flooding beam stop and a deflection system arranged upstream of the objective lens, and the control can be configured to control the deflection system to direct the primary charged particle beamlets to pass the flooding beam stop in the first mode of operation and to direct the charged particle beamlets to the flooding beam stop in the second mode or operation.

In a further embodiment of the charged particle beam system the projective system comprises a first subcomponent providing low-frequency adjustments and a second subcomponent providing high frequency adjustments. The subcomponent providing high frequency adjustments can comprise at least one of the group consisting of electrostatic lenses, electrostatic deflectors and electrostatic stigmators.

In a furthermore preferred embodiment the projective system comprises a current monitoring aperture in a cross-over plane.

In another embodiment the charged particle beam system can furthermore comprise a fast CCD camera.

In a furthermore preferred embodiment the charged particle beam system in addition comprises a computer system configured to analyze an actual state of the projective system and to manipulate the second subcomponent during scanning of a sample by the plurality of charged particle beamlets. The computer system can be configured to adjust the second subcomponent in a manner that positions of the interaction products on the individual detectors are kept constant also in the case of a sample charging. To achieve this, the computer can be configured to adjust the projective system in a two-step mode, whereby, in a first step the first component is adjusted while the second subcomponent is kept constant or switched-off, and, in a second step the second subcomponent is adjusted while the first subcomponent is kept constant.

In an embodiment the charged particle beam system can further comprise a projective beam stop between the first plane and the detector system and a deflection system between the first plane and detector system. The control can be configured to control the deflection system to direct interaction products from the charged particle beamlets to impinge onto the detector system in the first mode of operation and to direct the interaction products of the second defocused charged particle beams to the beam stop in the second mode or operation.

The present invention also relates to a method of operating a charged particle beam system, comprising the steps: in a first mode of operation, forming a plurality of charged particles beamlets of a multi beam charged particle beam system, scanning a sample with the charged particle beamlets and detecting interaction products leaving the sample due to the impinging plurality of charged particles beamlets, and, in a second mode of operation, flooding the sample with a defocused charged particle beam, switching between the first mode of operation and the second mode of operation several times while recoding an image of the sample, and changing at least one of the parameters of landing energy, focus, stage position and beam deflection of the charged particle beam system when switching between the first mode of operation and the second mode of operation.

In an embodiment of the method, in the second mode of operation the defocused charged particle beam has a second diameter in the first plane, wherein in the first mode of operation a minimum diameter of a circle surrounding an area onto which the plurality of charged particle beamlets impinge in the first plane has a first diameter, and wherein the second diameter is at least 1.2 times, more preferable 2 times, even more preferable 5 times, even more preferable 10 times, and most preferable 50 times the first diameter. A large second diameter ensures a homogenous charge compensation on the sample.

In another embodiment of the method, in the second mode of operation the defocused charged particle beam illuminates a surface in the in the first plane having a second surface area, wherein in the first mode of operation a minimum surface area within which all beamlets of the plurality of charged particle beamlets impinge in the first plane has a first area, and wherein the second surface area is at least 1.5 times, more preferable 4 times, even more preferable 10 times, even more preferable 100 times, and most preferable 200 times the first surface area.

In another embodiment of the method, the method further comprises, in the first mode of operation, directing interaction products form the charged particle beamlets to impinge onto a detector system, and in the second mode of operation, directing interaction products from a sample to a projective beam stop.

In another embodiment, the method further comprises the steps of: aligning the multi beam charged particle beam system with static methods and static charged particle optical elements, with a fast multi beam projective alignment method in an off state, and, activating a fast multi beam projective alignment system before a first image is recorded by controlling a state of a charged particle projective system for optimal imaging of interaction products onto a plurality of detectors and controlling the fast multi beam projective alignment system.

In an embodiment of the charged particle beam system the subcomponent providing high frequency adjustments comprises at least one of the group comprising electrostatic lenses, electrostatic deflectors and electrostatic stigmators. Ideally the subcomponent providing high frequency adjustments only consists of electrostatic elements, such as electrostatic lenses, electrostatic deflectors and electrostatic stigmators, but does not comprise any magnetic elements.

In an embodiment the subcomponent of the projective system providing high frequency adjustments can comprise a multi lens comprising at least one multi-aperture plate. Each aperture of this multi aperture plate can be surrounded by at least two, four or even more electrodes which are electrically insulated relative to each other as well as relative to the carrier of the multi aperture plate. By applying different electrical potentials to the electrodes each secondary charged particle beamlet of the interaction products can be adjusted individually to correct individual distortions of each secondary charged particle beamlet individually.

In another embodiment that comprises a fast CCD camera the fast CCD camera can be used to identify changes of the locations of the images of the interaction products in a detection plane due to a charging of the sample.

In a further embodiment of the charged particle beam system the computer system is configured to adjust the second (dynamic or high frequency) subcomponent of the projective system in a manner that positions of the interaction products on the individual detectors of the multi detector are kept constant.

In an embodiment of the charged particle beam system the computer is configured to adjust the projective system in a two-step mode, whereby, in a first step the first (low frequency) subcomponent is adjusted while the second (dynamic) subcomponent is kept constant or switched-off, and in a second step the second (dynamic) subcomponent is adjusted while the first subcomponent is kept constant.

In an embodiment the method can further comprises the steps: aligning a multi beam charged particle beam system with static methods and static charged particle optical elements, with a fast multi beam projective alignment method in an off state, rigging and starting a workflow and, activating a fast multi beam projective alignment system before a first image is recorded by controlling a state of a charged particle projective system for an optimal imaging of interaction products onto a plurality of detectors, and controlling the fast multi beam projective alignment system.

The alignment of the projective system by the aid of the dynamic subcomponent is carried out and repeated several times while the workflow of recording images of the sample is carried-out.

The fast projective system alignment to compensate for sample charging effects on detector collection efficiency and crosstalk can provide a synchronization of the scan system of the multi beam charged particle beam system and a fast detector camera and real-time projective system alignment algorithms as well as a low latency control of the projective system alignment elements.

The projective system can comprise a combination of a magnetic lens or several magnetic lenses with electrostatic elements. With the electrostatic elements hysteresis are eliminated and switching times of a few ms instead of seconds are achieved. In addition, a Larmor rotation during adjustment can be avoided by only changing electrostatic elements.

Electrostatic deflectors and/or electrostatic stigmators in the projective path of the interaction products provide the advantages of no eddy currents, no inductivity and adjustment times of µs instead of ms.

With a zoom aperture such as described in Figure 2 of WO2016/124648 a fast virtual change of an aperture size can be achieved. Additional fast deflectors in the secondary charged particle beam path of the interaction products provide the possibility of a fast alignment of the beam paths onto the detector system.

With the aid of a fast angle-resolved current monitor arranged in a crossover plane of the beam paths of the interaction products a centering of the crossover in real-time can be achieved.

The fast CCD camera and electrostatic alignment elements can be directly coupled by the computer system. Thereby latencies through the main control software that controls all other elements are avoided and in an off-mode of the electrostatic alignment elements the secondary electron projection is not effected by them at all. The computer system can comprise a graphic processing unit (GPU) and can be FPGA assisted. The alignment algorithms can be configured for achieving a fast spot position detection in the images recorded by the CCD camera. An optimal shift of the secondary electron beamlets can be achieved by using sensitivities of deflection elements of the excitation of deflectors, and can use a feedback loop for a direct optimization. In the case of image distortion an excitation of stigmators can be used for adjusting optimal shapes and/or positions of the secondary electrons by using sensitivities of stigmators on the shape and positions of the secondary electron beam spots and by using a feedback loop for direct optimization of the shape and/or position of the secondary electron beam spots.

With the alignment algorithms the excitation of stigmators are adjusted for an optimal spot shape and/or spot positions by using sensitivities of stigmators and by using feedback loops for direct optimization. The excitation of focusing elements and sample high voltage bias is adjusted for optimal spot shape and/or spot positions by using sensitivities of lenses, and also using feedback loops for direct optimization. For a crosstalk detection a virtual aperture size can be changed via a projective cross-over zoom system and the respective control algorithms for optimization of throughput (TPT) vs crosstalk in real time (once per frame).

The alignment algorithms can provide a fast switching from an image recording mode to a crossover monitoring mode, e.g. during flyback of the scanned electron beams, i.e. while, after a line or field on the sample has been scanned by the electron beamlets, the electron beamlets are moved back to the starting point of a new line or new frame; during such flyback normally no interaction products of the electron beamlets with the sample are recorded. An optimization of the crossover position can be achieved by a crossover monitoring in situ.

An alternative embodiment can comprise an aperture covered with a scintillating material and to detect with a fast camera the scintillation due to electrons impinging on the scintillating material. Also this alternative embodiment provides a cross-over monitor for a real-time centering.

A fast angle-resolved current detection on an aperture is advantageous for centering and/or alignment of the crossover by adjusting the electrostatic elements to achieve a minimized current or light emission detected by an angle-resolved current detector or the fast camera.

More details are disclosed with reference to the attached drawings. Thereby shows:

Fig. 1: A sketch of an embodiment of a multi beam charged particle system.

Fig. 2: A sketch of a detection system of a first embodiment.

Fig. 3: A block diagram of a portion of a multi beam projective control with a fast (dynamic) subcomponent for the projective system control in the beampaths of secondary electron beamlets.

Fig.4: A sketch of a projection path with additional electrostatic deflectors, electrostatic stigmators, electrostatic lenses, a beam splitter, a deflector and a starting energy HV supply.

Fig. 5a to Fig. 5f: An illustration of corrections achieved with the dynamic subcomponent of the projective systems in cases of particular distortions caused by sample charging.

Fig. 6: A diaphragm which can be provided in the projective system to achieve a filtering of the secondary electron beamlets.

Fig. 7: A an embodiment of a aperture diaphragm with cross-over monitoring capabilities for an angle dependent current readout for crossover position correction.

Fig 8: A further embodiment of a detector system.

Fig 9a: A sketch of the beam path in a multi beam charged particle beam system in a first mode of operation.

Fig. 9b: A sketch of the beam path in the multi beam charged particle beam system of Fig. 9a in a second mode of operation.

Fig. 10: A top view onto a multi aperture plate in the embodiment of Fig. 9a.

Fig. 11a: A sketch of a multi beam charged particle beam system having a second charged particle beam source for flooding in the first mode of operation.

Fig. 11b: A sketch of the multi beam charged particle beam system in Fig. 11a in the second mode of operation.

Fig. 12a: A sketch of a further embodiment of a multi beam charged particle beam system having a second charged particle beam source for flooding in the first mode of operation.

Fig. 12b: A sketch of the multi beam charged particle beam system in Fig. 12a in the second mode of operation.

In the exemplary embodiments described below, components similar in function and structure are indicated as far as possible by similar reference numerals.

The schematic representation of Figure 1 illustrates basic features and functions of a multi-beamlet charged-particle beam system 1. It is to be noted that the symbols used in the Figure do not represent physical configurations of the illustrated components but have been chosen to symbolize their respective functionality. The type of system shown is that of a scanning electron microscope (SEM) using a plurality of primary electron beamlets 3 for generating primary electron beam spots 5 on a surface of an object 7 located in an object plane 101 of an objective lens 102. It goes however without saying that the features and functions of system 1 can also be implemented using instead of electrons other types of primary charged particles such as ions and in particular helium ions, positrons, muons, and others.

The microscopy system 1 shown comprises a charged-particle multi-beamlet generator 300 for generating a plurality of primary charged-particle beamlets 3, a beam splitter unit 400 for separating the secondary charged-particle beam path 11 from the primary charged-particle beam path 13, an object irradiation unit 100 adapted to focus the primary charged-particle beamlets 3 onto the object plane 101, and a detection unit 200 for creating individual intensity signals for each of the secondary charged-particle beamlets 9.

In the embodiment illustrated, the primary beamlet generator 300 comprises an electron source 301, a collimating lens 303, a primary beamlet-forming unit 305, and a field lens 307.

The electron source 301 generates a diverging electron beam 309 that is collimated by the collimating lens to form a beam 311 incident on the primary beamlet-forming unit 305. Instead of an electron source generating just one diverging electron beam 309 as shown in Figure 1, an electron source creating two or more diverging electron beams may be used. The two or more electron beams are then collimated either by just one collimating lens 303 or by an appropriate number of collimating lenses 303, each collimating a subset or just one of the individual electron beams 309.

The beamlet-forming unit 305 basically comprises a first multi-aperture plate illuminated by the one or more electron beams 311 and a second multi-aperture plate located, with respect to the direction of movement of the electrons in beam 311, downstream of the first multi-aperture plate. The second multi-aperture plate is preferably set to a defined potential so that a focussing quality is conferred to the apertures and the second multi-aperture plate takes on the function of a micro lens array.

The primary electrons incident on object 7 at a beam spot 5 generate secondary electrons emanating from the surface of the object 7. The secondary electrons form secondary electron beamlets 9, which traverse the objective lens 102 and the beam splitter unit 400 and follow the secondary beam path 11. The beam splitter unit 400 separates the secondary beam path 11 from the primary beam path 13 usually by means of magnetic fields and directs the secondary beam path 11 to a detection unit 200.

The detection unit 200 comprises a projecting lens 205 for projecting the secondary electron beamlets 9 onto a surface plane 211 of an electron sensitive detector 207 of a detector arrangement 209. The electron sensitive detector 207 can be a single device or comprise more than one individual detectors. Irrespective of this, detector 207 provides an array of sensing areas arranged in a pattern compatible to the pattern of the secondary charged-particle beamlets 9 focussed by the projecting lens 205 onto the detector surface 211. This enables a detection of each individual secondary charged-particle beamlet 9 independent of the other secondary charged-particle beamlets 9 incident on the detector surface 211. Thus a plurality of electrical signals is created, whereby the value of each signal corresponds to the characteristics of just one of the secondary beamlets 9.

If the primary beamlet generator 300 allows not only to change the patterns of the primary beamlets 3 such that each pattern forms a sub-pattern of a basic pattern, but also to change the basic pattern, the detector arrangement 209 is preferably equipped with further detectors 207, each having its sensing areas arranged in a different basic pattern. Since the patterns of the secondary beamlets 9 correspond to the patterns of the primary beamlets 3 generated by the primary beamlet generator 300, the sensing area array pattern of each detector 207 preferably corresponds to one of the patterns available for the primary beamlets 3.

The object irradiation unit 100 comprises an objective lens 102 focussing the primary charged-particle beamlets 3 onto the object plane 101 in which the investigated surface of an object 7 is positioned by an object mount like for example a sample stage. The object mount is not shown in the Figures. The object irradiation system 100 further comprises a deflection system (not shown) by which the plurality of charged-particle beamlets can be deflected in a direction perpendicular to the direction of beam propagation in order to scan the surface of the sample concurrently with the plurality of focused charged particle beamlets.

In the illustrated example, the primary charged particle source is implemented in form of an electron source 301 featuring an emitter tip 310 and an extraction electrode 302. When using primary charged particles other than electrons, like for example helium ions, the configuration of the primary charged-particle source 301 may be different to that shown.

The electron source 301 emits a divergent electron beam 309, which is collimated in the shown example by collimating lens 303 to form a collimated beam 311. The collimating lens 303 is usually formed by one or more electrostatic or magnetic lenses, or by a combination of electrostatic and magnetic lenses. The use of a collimating lens is not imperative, but it is preferred when the multi-aperture plates used in the beamlet-forming unit 305 have a planar configuration, i.e. a configuration where the apertures 315 are arranged in a non-curved plane. When no collimating lens 303 is used, the apertures 315 of the multi-aperture plates 313 and 320 are preferably arranged in a curved plane which curvatures are adapted to the divergence of the primary beam 309 as e.g. described in document WO 2007/028596 A1, which is hereby incorporated by reference.

The collimated beam 311 (or the non-collimated beam, if no collimating lens is used) is incident on the multi-aperture selector plate 313 of the primary beamlet-forming unit 305. The multi-aperture plate selector 313 has two or more aperture arrays 317 formed therein. Each aperture array comprises one or more apertures 315 formed in the multi aperture selector plate 313. The apertures of a multi-aperture array may be arranged in a one-dimensional or in a two-dimensional pattern, whereby two-dimensional patterns are preferred for a fast inspection of an object's surface.

The detection system further comprises a filter 208 with the aid of which interaction products leaving the sample 7 in the first plane 101 (for example secondary electrons) can be filtered according to their trajectories or beam paths. An example of a respective detection system with a filter is shown in Figure 2.

The multi beam system further comprises a computer system or controller 10 which is configured to control the individual charged particle beam components as well as for evaluating and analyzing images recorded with multi detector 209. In addition the controller 10 is configured to generate images based on the detection signals gathered with multi detector 209 on a display.

The detection system 200 in Figure 2 comprises in addition to the projection lens 205 and the multi detector 209 two additional charged particle lenses 210, 211. The first additional charged particle lens 210 forms a crossover in a crossover plane 214. In this crossover plane the beam paths of the interaction products which leave the first plane 101 in different regions, i.e. the beam paths of the secondary electron beamlets, are superimposed. The second additional charged particle lens 211is operated so that its focal plane substantially coincides with the crossover plane 214 of the first additional charged particle lens 210. The beam paths of the interaction products leaving the first plane 101 then run separated from each other downstream of the second additional charged particle lens 211 and are projected by projection lens 205 onto separate detection regions 215 of the multi detector 209.

In the crossover plane 214 or in the neighborhood thereof a diaphragm 216 is arranged with the aid of which the interaction products can be filtered according to their beam paths. A first embodiment for a diaphragm is shown in Figure 6 which comprises a circular opening 218. The circular opening 218 is transmissive for interaction products while an outer portion of the diaphragm 216 is non-transmissive for the interaction products. With such kind of bright-field diaphragm in the crossover plane of the projective system a crosstalk between different individual detection fields, i.e. a crosstalk between the beam paths of interaction products leaving the first plane 101in a first region and a detector assigned to interaction products leaving the first plane 101 in a second region different from the first region, can be avoided or at least reduced.

Regarding further details of the system shown in Figure 2 and the diaphragm shown in Figure 6, reference is made to the description of the respective Figures in WO2016/124648 the disclosure of which with respect to the respective figures 2 and 6 thereof is hereby incorporated by reference.

An alternative embodiment for a diaphragm in a detection system 200 is shown in Figure 7. The diaphragm 1213 also has a circular opening 1214 which is transmissive for interaction products. However the circular opening is surrounded in a radial direction by a couple of electrodes 1215a to 1215h which are electrically insulated with respect to each other as well as with respect to the body of the diaphragm. The electrodes can serve as current detectors. Each electrode comprises a signal line via which an electrical current induced within each electrode can be detected. By detecting asymmetries in the currents or charges induces in the set of electrodes 1215a to 1215h a decentering of the charged particle beamlets passing the aperture of the diaphragm can be detected.

In an alternative embodiment, instead of electrodes being arranged around the circular opening 1214 a scintillating material can be provided on the surroundings of the circular opening, and furthermore light detectors are provided to detect light emitted by the scintillating material due to impinging electrons. By detecting asymmetries in the light emission of the scintillating material a decentering of the charged particle beamlets passing the diaphragm 1213 can be detected.

The diaphragm shown in Figure 7 as well as the above described alternative embodiment for a diaphragm can be used as a in-situ crossover monitor if arranged in the crossover plane 214 of the detection system shown in Figure 2 or the crossover plane 238 of Figure 8. Accordingly, the projective system comprises a current monitoring aperture in a crossover plane.

Figure 8 shows an alternative of a detection system providing the possibility of filtering interaction products according to their beam paths. Figure 8 is identical to Figure 4 in WO2016/124648 and regarding a description of this detection system and its capabilities and advantages it is referred to the respective description of Figure 4 in WO2016/124648, which is hereby incorporated by reference. It should especially be noted that the system shown in Figure 8 (or Figure 4 in WO2016/124648) forms a crossover-zoom system as this also is described in more detail in WO 2016/124648.

Figure 3 is a block diagram of a portion of the control system 800 (which corresponds to the control system 10 in Figure 1) of the multi beam charged particle beam system. The control system 800 comprises a scan system control component 801 and a control 802 for the static or low frequency subcomponents of the projective system for adjusting the charged particle beam lenses and multipoles. The control system 800 further comprises a fast projective alignment sub-system comprising a detector camera 804 (corresponding to the spatially resolved detection system 290 in Figure 4), real-time projective alignment algorithms 805 and one or more fast projective alignment element(s). The control system shown in Figure 3 especially can be used for controlling, inter alia, a projective system as shown in Figure 4 and described in more detail hereinafter.

The projective system 200 in Figure 4 comprises a set of static (or low frequency) electron optical elements 250, 270, and 285, and a set of dynamic (or high frequency) electron optical elements 260, 280, and 288. The static electron optical elements are used for imaging of secondary electrons (SE) 3 from sample 7 onto the detection plane 209a. These can comprise one or more electron optical lenses 251, deflectors 271, and/or stigmators 286. As slow alignment times are sufficient in the static case, magnetic lenses, magnetic deflectors, and magnetic stigmators are used. A controller 160 controls the static electron optical elements 250, 270, and 285, as well as the static sample potential via a static voltage supply 150. To this end, the controller uses a spatially resolving detection system 290 that uses a fraction of the signal impinging onto the detection plane 209a. For example, a spatially resolved detection system 290 can comprise a fast CCD camera that images a fraction of the light emanating from spots from the detection plane 209a, where a plate made of a scintillating material placed onto a transparent carrier can be arranged to form a multi detector 209. Most of the signal produced in the detection plane 209a is used for feeding into the image acquisition system. The image acquisition system also forms part of the multi detector.

As described above, in the detection plane 209a a scintillator plate 209 is arranged onto which the secondary electron beamlets are directed by the projective system 200. The projective system 200 comprises, when integrated in the multi-beam inspection system of Figure 1, electron-optical components forming the electron beamlets 9, i.e., for example the objective lens 102 guiding the electron beamlets towards the multi electron-detector, the beam splitter 400 and components focusing the electron beamlets 9 onto the surface of the scintillator plate 209 such as the lens 263. The electron beamlets 9 are incident onto the scintillator plate 209 at locations of incidence 213. Also if the electron beamlets 9 are focused onto the surface of the scintillator plate 209, beam spots are formed on the surface, the diameter of which cannot be arbitrarily small. The centers of the beam spots may be considered as the locations of incidence 213 disposed from each other at the distance P2 (see Figure 1).

The scintillator plate 209 comprises a scintillator material emitting light beams when excited by the incident electrons of the electron beamlets 9. Therefore, at each of the locations of incidence 213 a source of light beams is disposed. In Figure 4, only a single such light beam 221 is shown emitted from the location of incidence 213 of one of the three depicted electron beamlets 9. The light beam 221 propagates through light optics comprising a first lens 306, a mirror 291, a second lens 292, a third lens 293 and a beam splitter 294 and is then incident onto a light receiving area 330 of the image acquisition system. The light receiving area 330 is formed by a front side of a bundle of glass fibers 295 into which a major portion of the light beam 221 is coupled and guided to light detectors 296, 297, 298, 299, 331. The light detectors may comprise, for example, photo multipliers, avalanche-photodiodes, photodiodes or other kinds of suitable light detectors. The light optics are configured so that it optically images the surface of the scintillator plate 209 arranged in the detection plane 209a into a region where the light receiving area 330 is disposed. Due to this optical imaging optical images of the locations of incidence 213 are formed in the light receiving area 330. For each of the locations of incidence 213 a separate light receiving area 330 of the image acquisition system is provided. Each of the further light receiving areas 330 is formed by a front side of a light guide 295 guiding the light coupled into the front side to a separate respective light detector 296, 297, 298, 299, 331. Due to the optical imaging each of the locations of incidence 213 is associated with a light receiving area 330 wherein the light incident onto each of the light receiving areas 330 is detected by a separate one of the light detectors 296, 297, 298, 299, 331. The light detectors 296, 297, 298, 299, 331output detection signals via electric signal lines. The detection signals represent intensities of the electron beamlets 9.

It should be mentioned that in Figure 4, for simplification, only five light detectors 296, 297, 298, 299, 331 are shown. In a realistic embodiment the number of light detectors 296, 297, 298, 299, 331 corresponds at least to the number of primary charged particle beamlets and the number of secondary electron beamlets 9. In a preferred embodiment the image acquisition system comprises even more light detectors 296, 297, 298, 299, 331 than the number of primary charged particle beams, for example five, ten or twenty light detectors for each secondary electron beamlet. A number of more than one light detector for each primary electron beamlet provides additional flexibility in assigning light detectors to a particular secondary charged particle beam.

A small portion of the light beam 221 transmits the beam splitter 294 and impinges onto the spatially resolving detection system 290 which can be a fast CCD camera.

In the embodiment elucidated herein, the light detectors 296, 297, 298, 299, 331 are disposed at a distance from the light receiving areas onto which the light optics (comprising the first lens 306, the mirror 291, the second lens 292, the third lens 293 and the beam splitter 294) image the scintillator plate 209 and the received light is guided to the light detectors by glass fibers. However, it is also possible that the light detectors 296, 297, 298, 299, 331 are directly disposed where the light optics generate the image of the scintillator plate 209 and the light sensitive areas are thus formed by the light receiving areas.

The secondary electron beamlets 9 propagate in a vacuum and, accordingly, also the surface of the scintillator plate 209 onto which the electron beamlets impinge is disposed in the vacuum. The light optics 306, 291, 292, 293, 294 may be disposed outside the vacuum wherein, then, a vacuum window is provided in the beam path of the light beam 221, the vacuum window being traversed by the beam 221 and separates the vacuum from the environment.

The electron beams incident onto the scintillator plate 209 may ionize residual gas molecules in the region in front of the scintillator plate resulting in electric charges at the locations of incidence 213 and the charges may, in turn, attract residual gaseous contaminant in the vacuum so that the contaminant is deposited at the locations of incidence 213 on the scintillator plate 209 and result in the deterioration of the properties of the scintillator material so that the intensity of the light beams 221 caused by the incident electron beamlets 9 decreases over time. This problem can be coped with by displacing the locations of incidence 213 in a direction orthogonal to a surface normal of the scintillator plate 209, the direction being oriented orthogonal to a normal of a surface of the scintillator plate 209, i.e. within the detection plane 209a. With this, the electron beamlets 9 are not always incident onto the surface of the scintillator plate at the same locations of incidence 213 but are moved over the surface of the scintillator plate 209 and, therefore, moved to ever new locations on its surface. A contamination occurring at distinct locations on the surface of the scintillator plate 209 then does not hinder the generating of light at the locations of incidence 213 caused by the incident electron beamlets 9.

The dynamic electron optical elements are used for dynamically correcting residual imaging errors of secondary electrons (SE) 3 from sample 7 onto the detection plane 209a that are not accounted for by the static imaging system. These residual imaging errors can occur during the scanning of charging surfaces where the imaging properties and constraints, such as starting energy of the SE's or starting angle distribution of the SE's can change within one frame of imaging. These dynamic elements can comprise one or more electron optical lenses 260, deflectors 280, and stigmators 288. As fast alignment times are required in the dynamic case, only electrostatic lenses, electrostatic deflectors, and/or electrostatic stigmators are preferably used. A dynamic controller 170 controls the dynamic electron optical elements 260, 280, and 288, as well as the dynamic sample potential added to the static potential via voltage supply 151. To this end, the dynamic controller 170 uses the spatially resolving detection system 290 that uses a fraction of the signal impinging onto the detection plane 209a. The beam splitting device 400 consists of magnetic sectors that are statically aligned. A fast electrostatic deflection element 410 within the beam splitting device 400 is controlled as well by dynamic controller 170.

A further controller 160 controls the static or low frequency properties and components.

A final lens 263 for producing the spots on the detection plane 209a can be either of the static or dynamic type and controlled by controller 160 or 170, respectively.

In Figures 5a to 5f circles 551 depict the areas on the spatially resolved detection system 290 that correspond to the sensitive areas of the corresponding detectors of the image acquisition system and, accordingly, to the ideal positions of the secondary electron beamlets in the detection plane 209. The mapping between these areas on spatially resolved detection system 290 and the sensitive areas of the image acquisition detectors is fix and can be calibrated upfront (for reference, see US 9,336,982 B2 and references therein, which are hereby incorporated by reference). Circles 550 depict the position distribution of the secondary electron beamlets imaged by projection system 200 onto the detection plane 209a. Fig. 5a depicts a shift between the position distribution of the secondary electron beamlets 550 and the sensitive areas 551. Using fast deflection systems 280, this can be corrected to yield the correct positioning of the secondary electron beamlets 550 onto the sensitive areas 551 shown in Fig. 5f. To achieve this, the shift between the position distribution of the secondary electron beamlets 550 and the sensitive areas 551 is determined by recording and analyzing an image recorded by the spatially resolved detection system 290. Appropriate deflection potentials for the fast deflection system 280 are determined by the real-time projective alignment algorithms

805 by analyzing the recorded image, and the thus determined deflection potentials are applied to the fast deflection system 280 by dynamic controller 170. The deflection potentials are determined in a manner that with the appropriate potentials applied to the fast deflection system 280 the positions of the secondary electrons 550 coincide with the centers of the sensitive areas 551as shown in Fig. 5f.

Fig. 5b depicts a distortion of the position distribution of the secondary electron beamlets 550 relative to the sensitive areas 551. Using fast stigmation systems 285, this can be corrected to yield the correct positioning of the secondary electron beamlets 550 onto the sensitive areas 551 shown in Fig. 5f. To achieve this, the distortion of the position distribution of the secondary electron beamlets 550 is determined by recording an image by the spatially resolved detection system 290, analyzing the image recorded by the spatially resolved detection system 290 by real-time projective alignment algorithms 805 and determining, based on the image analysis, appropriate stigmator voltages for the fast stigmation system 285. The stigmator voltages are determined by the real-time projective alignment algorithms 805 in a manner that with the appropriate voltages applied to the fast stigmation system 285 the positions of the secondary electron beamlets 550 coincide with the centers of the sensitive areas 551as shown in Fig. 5f. The respectively determined stigmator voltages are applied to the fast stigmation system 285 by dynamic controller 170.

Fig. 5c depicts a defocus of the secondary electron beamlets 550 with respect to the sensitive areas 551. Using fast lens systems 260, this can be corrected to yield the correct positioning of the secondary electron beamlets 550 onto the sensitive areas 551 shown in Fig. 5f. To achieve this, the defocus of the secondary electron beamlets 550 at the sensitive areas 551 is determined by recording and analyzing, by real-time projective alignment algorithms 805, an image recorded by the spatially resolved detection system 290. Appropriate voltages for the fast lens systems 260 are determined by the real-time projective alignment algorithms 805 and applied to the fast lens systems 260 by dynamic controller 170 in a manner that with the appropriate voltages applied to the fast lens systems 260 the positions of the secondary electron beamlets 550 coincide with the centers of the sensitive areas 551and the diameters of the light spots on the spatially resolved detection system 290 are minimized or have the appropriate dimensions as shown in Fig. 5f.

Fig. 5d depicts an astigmatic imaging of the secondary electron beamlets 550 onto the sensitive areas 551. Using fast stigmation systems 285, this can be corrected to yield the correct positioning of the secondary electron beamlets 550 onto the sensitive areas 551 shown in Fig. 5f. Keeping the spot positions correct at the same time requires the use of at least two stigmators, as described in great detail in US 20150357157 A1 which is hereby incorporated by reference. To achieve stigmation, the distortion of the stigmatic imaging of the secondary electron beamlets 550 is determined by recording and analyzing an image recorded by the spatially resolved detection system 290. Appropriate stigmator voltages for the fast stigmation system 285 are determined by the real-time projective alignment algorithms 805 and such stigmator voltages are applied to the fast stigmation system 285 by dynamic controller 170. The stigmator voltages are determined, based on the image analysis, in a manner that with the appropriate voltages applied to the fast stigmation system 285 the form of the beam spots of the secondary electron beamlets 550 become circular with their centers in the centers of the sensitive areas 551as shown in Fig. 5f.

Fig. 5e depicts a magnification change in the imaging of the secondary electron beamlets 550 with respect to the sensitive areas 551. Using fast lens systems 260, this can be corrected to yield the correct positioning of the secondary electron beamlets 550 onto the sensitive areas 551 shown in Fig. 5f. Keeping the spot positions correct at the same time requires the use of at least two lenses, as described in great detail in US 20150357157 A1 which is hereby incorporated by reference. To achieve this, the magnification change of the secondary electron beamlets 550 at the sensitive areas 551 is determined by recording and analyzing an image recorded by the spatially resolved detection system 290. Appropriate voltages for the fast lens systems 260 are determined by the real-time projective alignment algorithms 805, based on the image analysis, and applied to the fast lens systems 260 by dynamic controller 170. The appropriate voltages are determined by the real-time projective alignment algorithms 805 in a manner that with the appropriate voltages applied to the fast lens systems 260 the positions of all the secondary electron beamlets 550 coincide with the centers of the sensitive areas 551 and the diameters of the light spots on the spatially resolved detection system 290 are minimized or have the appropriate dimensions as shown in Fig. 5f.

Above, with respect to Fig. 5a to 5f only the correction of individual distortions is described. However, the real-time projective alignment algorithms 805 advantageously are configured also to determine appropriate potentials and voltages for the fast alignment components if the images recorded with the spatially resolved detection system 290 show combinations of the described distortions. Appropriate voltages for the electrostatic lenses, the electrostatic stigmators and the electrostatic deflectors then are determined by the real-time projective alignment algorithms 805 concurrently or sequentially in iterative steps.

The recording of the images with the spatially resolved detection system 290 takes place before an image of the sample is recorded by the aid of the multi detector or while portions of the image of the sample are recorded by the aid of the multi detector, for example after a predetermined number of lines has been scanned by the plurality of primary electron beamlets.

The charged particle beam system in Fig. 9a has a similar design as the system shown in Figure 1. In Figure 9a the charged particle source is depicted with the reference numeral 900. In the beam path of the charged particles emitted by the charged particle source 900 at least one collimating lens 901 is arranged. Following in the direction of emission of charged particles downstream of the collimating lens, a multi aperture plate 904 having a plurality of holes is arranged for generating a plurality of charged particle beamlets 904a to 904c from the charged particle beam emitted by the charged particle source 900. Between the collimating lens 901 and the multi aperture plate a first deflection system 902 is arranged. The first deflection system 902 can either be a single deflection system or a double deflection system having two deflectors 902, 903.

Between the multi aperture array 904 and the field lens 907 a further, second deflection system 905 is arranged. Also this second deflection system can be either a single deflection system or a double deflection system having two deflectors 905, 906. The first deflection system 902 and the second deflection system 905 serve to switch between the first mode of operation, i.e. recording of images of a sample by concurrently scanning the sample by a multitude of charged particle beamlets and detecting interaction products leaving the sample due to the impinging primary charged particle beamlets, and the second mode of operation in which the sample is flooded with an defocused charged particle beam to compensate for sample charging.

As described already in combination with Fig. 1, following downstream in the direction of propagation of the primary charged particles a beam splitter 908 and an objective lens 909 are arranged. By the objective lens 909 the primary charged particle beamlets are focused on a sample 910 to be arranged in a sample plane (first plane).

In the secondary beam path, i.e. in the beam path of interaction products leaving the sample 910 due to the impinging primary charged particles between the projective system 911 and the multi detector 912 with the separate detecting regions 912a to 912e a projective stop 913 is arranged. Also, between the objective lens 909 and the beam splitter 908 or following downstream of the beam splitter a further deflector 914 is arranged.

In the first mode of operation, the control of the multi beam charged particle beam system controls the first and second deflection system 902 and/or 903, 905 and/or 906 so that a plurality of charged particle beamlets impinge on the sample. To achieve this, the first deflection system 902/903 directs the incoming charged particle beam to impinge onto the plurality of holes 1001, 1002 (see Fig. 10) of the multi aperture plate 904 having a diameter d1. In the second mode of operation the control of the multi beam charged particle beam system controls the first and second deflection system 902/903, 905/906 so that the incoming charged particle beam is directed onto the larger holes 103 (see Fig. 10) of the multi aperture plate 904 having a diameter d2. As described above, d2 is at least 5 times d1. In the second mode of operation concurrently with deflecting the primary beam to impinge onto the plurality of holes 1001, 1002 the control controls the projective system 911, e.g. by means of deflector 914, to direct all, or at least the majority of interaction products caused to leave the sample 910 due to the impinging primary charged particles to impinge onto the projective stop 913 (see Fig. 9b). In both modes of operation, the beams pass through the objective lens 909 onto the sample 910.

The embodiment in Figures 11a and 11b is similar to the embodiment shown in Figure 9a. Components identical to components in Fig 9a are depicted with identical reference numerals and regarding their design and functions reference is made to the above description of Figures 9a and 9b. The embodiment in Figure 11 has a second charged particle source 921 serving only for flooding the sample. Following downstream of the second charged particle source 921 a deflection system 922 and a beam stop 923 are arranged. In addition, a second beam stop 920 can be provided between the beam splitter 908 and the objective lens 909.

In the first mode of operation the control of the charged particle beam system controls the deflector 922 in the beam path of the second charged particle beam emitted by the second charged particle source 921 to impinge onto the beam stop 923. Concurrently, the control controls the multi beam generator to generate a plurality of primary charged particle beamlets to impinge onto the sample 910. In this mode of operation the sample 910 is scanned by the plurality of charged particle beamlets and interaction products caused to leave the sample due to the primary beamlets are detected by multi detector 912. In the second mode of operation the control controls the multi beam generator, for example by a different excitation of the deflection system 902 (and/or the deflections system 903, and/or the deflections system 905/906 in Fig. 9a) to direct the charged particle beamlets onto the stop 920 arranged between the beam splitter 908 and the objective lens. The beam stop 920 can also be placed between the multi aperture plate 904 and the beam splitter 908, or deflection system 902/903 can be used to deflect the primary beam illuminating the multiple holes of the first multi aperture plate in the first mode to an area without holes as shown in Fig. 11b. Concurrently, the control controls the deflector 922, and/or the objective lens 909 and/or the sample position so that the charged particles emitted by the second charged particle source 921 pass through the opening in the beam stop 923 and impinge onto the sample 910 in a defocused manner. Then, the charged particles emitted by the second charged particle source impinge onto a large area on a surface of the sample 910 in a defocused manner. Again, in both the first and the second mode of operation, the charged particle beams traverse through the objective lens hole.

Figures 12a and 12b show a second embodiment of a charged particle beam system with the second charged particle source 921. Identical components in Figures 11a and 11b as well as 12a and 12b are assigned identical reference numerals. In the embodiments shown in Figures 12a and 12b the first multi aperture plate 904 itself serves as a beam stop for the charged particles emitted by charged particle source 900. In the first mode of operation the deflections systems 902, 903 upstream of the multi aperture plate 904 are excited to deflect the charged particle beam emitted by charged particle source 900 to a region with the plurality of hole in the multi aperture plate 904 to generate the multiple charged particle beamlets 904a to 904c. The deflection system 905, 906 downstream of the multi aperture plate is excited to re-align the charged particle beamlets with an optical axis of the objective lens 909. Concurrently the deflection system 922 in the beam path emitted by the second charged particle beam source 921 is excited to deflect the charged particle beam emitted by the second charged particle beam source 922 to impinge onto the beam stop 923.

In the second mode of operation illustrated in Fig. 12b the deflection system 902, 903 arranged upstream of the multi aperture plate 904 is excited to deflect the charged particle beam emitted by charged particle source 900 to impinge onto a region of the multi aperture plate 904 without any hole. Concurrently the deflection system 922in the beam path emitted by the second charged particle beam source 921 is excited to deflect the charged particle beam emitted by the second charged particle beam source 922 to pass through a hole in the beam stop 923. Concurrently the deflection system 914 in the projective beam path is excited to deflect all or the majority of interactions products leaving the sample 910 due to the impinging charged particles to impinge onto the beam stop 913 in the secondary beam path.

In an embodiment the above described methods for charge compensation by flooding the sample with a defocused charged particle beam and for controlling a dynamic subcomponent of the projective system to eliminate beam disturbances due to charging of the sample are combined.

Claims:

1. A charged particle beam system comprising:
at least a first charged particle source configured to generate a first charged particle beam,
a multi beam generator configured to generate a plurality of charged particle beamlets from the incoming first charged particle beam,
an objective lens,
a projective system,
a sample stage
a detector system comprising a plurality of individual detectors, and
a control configured to control the operation of the multi beam generator, the objective lens and the projective system, wherein the control provides a first mode of operation and a second mode of operation,
wherein in the first mode of operation the control controls the multi beam generator to be configured that each individual beamlet of the plurality of charged particle beamlets is spatially separated from other beamlets of the plurality of charged particle beamlets,
wherein in the first mode of operation the control further controls the objective lens to be configured to focus incoming charged particle beamlets in a first plane in a manner that a first region in which a first individual beamlet of the plurality of charged particle beamlets impinges in the first plane is spatially separated from a second region in which a second individual beamlet of the plurality of charged particle beamlets impinges in the first plane,
wherein in the first mode of operation the control controls the projective system to be configured to image interaction products leaving the first region within the first plane due to impinging charged particles onto a first one of the plurality of individual detectors and to image interaction products leaving the second region in the first plane due to impinging charged particles onto a second one of the plurality of individual detectors, and
wherein in the second mode of operation the control controls the operation of the multi beam generator in combination with the objective lens to be configured that a single or plural defocused charged particle beam(s) is/are provided in the first plane.

2. The charged particle beam system of claim 1, wherein the objective lens comprises an opening, wherein the primary charged particle beamlets pass though the opening of the objective lens in the first mode of operation, and wherein in the second mode of operation the charged particle beam or beams pass though the opening in the objective lens.

3. The charged particle beam system of claim 1 or 2, further comprising a voltage supply configured to supply a variable voltage to the sample stage, wherein in the first mode of operation the control controls the objective lens and/or a voltage supply of the sample stage in a manner that the charged particles of the charged particle beamlets have a first average kinetic energy in the first plane, and wherein the control controls the objective lens and/or the voltage supply of the sample stage in the second mode in a manner that the charged particles have a second average kinetic energy in the first plane that is different from the first average kinetic energy.

4. The charged particle beam system of claim 3, wherein the first average kinetic energy is larger than 400eV, alternatively larger than 1000eV, alternatively larger than 1500eV, or alternatively larger than 2000eV and wherein the second average kinetic energy is smaller than 1000 eV, alternatively smaller than 500eV, alternatively smaller than 200eV, or alternatively smaller than 50eV.

5. The charged particle beam system of one of claims 1 to 4, wherein in the second mode of operation the defocused charged particle beam has a second diameter in the first plane, wherein in the first mode of operation a minimum diameter of a circle surrounding an area onto which the plurality of charged particle beamlets impinge in the first plane has a first diameter, and wherein the second diameter is at least 1.2 times the first diameter, more preferable at least 2 times the first diameter, even more preferable at least 5 times the first diameter, even more preferable at least 10 times the first diameter, and most preferable at least 50 times the first diameter.

6. The charged particle beam system of one of claims 1 to 4, wherein in the second mode of operation the defocused charged particle beam illuminates a surface in the first plane having a second surface area, wherein in the first mode of operation a minimum surface area within which all beamlets of the plurality of charged particle beamlets impinge in the first plane has a first area, and wherein the second surface area is at least 1.5 times, more preferable 4 times, even more preferable 10 times, even more preferable 100 times, and most preferable 200 times the first surface area.

7. The charged particle beam system of one of claims 1 to 6, the multi beam generator comprising at least a first multi aperture plate, wherein the first multi aperture plate comprises a plurality of holes for forming the plurality of charged particle beamlets.

8. The charged particle beam system of claim 7, wherein the holes in first multi aperture plate have a first hole diameter, and wherein the first multi aperture plate has at least one second hole having a second hole diameter, and wherein the second hole diameter is at least 5 times the first hole diameter.

9. The charged particle beam system of claim 8, wherein the first multi aperture plate is displaceable in a direction perpendicular to the direction of beam propagation of the charged particle beam.

10. The charged particle beam system of claim 7 or 8, wherein the charged particle beam system further comprises a first single or double deflection system arranged between the charged particle source and the first multi aperture plate, and a second single or double deflection system arranged between the first multi aperture plate and the objective lens.

11. The charged particle beam system of claim 10, wherein in the second mode of operation the control controls the first single or double deflection system and the second single or double deflection systems to pass the charged particle beam through the at least one second hole.

12. The charged particle beam system of claims 1 to 11, further comprising a beam splitter arrangement upstream of the objective lens.

13. The charged particle beam system of one of claims 1 - 12, further comprising a second charge particle source providing a second charged particle beam, a deflection system and a beam stop, wherein the control is configured control the deflection system to direct the second charged particle beam onto the beam stop in the first mode of operation and to direct the second charged particle beam to pass the beam stop in the second mode of operation.

14. The charged particle beam system of claim 13, further comprising an flooding beam stop and a deflection system, and wherein the control is configured to control the deflection system to direct the charged particle beamlets to pass the flooding beam stop in the first mode of operation and to direct the charged particle beamlets to the flooding beam stop in the second mode or operation.

15. The charged particle beam system of one of claims 1 to 14, wherein the projective system comprises a first subcomponent providing low-frequency adjustments and a second subcomponent providing a high frequency adjustments.

16. The charged particle beam system of claim 15, wherein the subcomponent providing high frequency adjustments comprises at least one of the group consisting of electrostatic lenses, electrostatic deflectors and electrostatic stigmators.

17. The charged particle beam system of one of claims 14 to 16, wherein the projective system comprises a current monitoring aperture in a cross-over plane.

18. The charged particle beam system of one of claims 1 – 17, further comprising a fast CCD camera.

19. The charged particle beam system of one of claims 15 – 18, further comprising a computer system configured to analyze an actual state of the projective system and to manipulate the second subcomponent during scanning of a sample by the plurality of charged particle beamlets.

20. The charged particle beam system of claim 19, wherein the computer system is configured to adjust the second subcomponent in a manner that positions of the interaction products on the individual detectors are kept constant.

21. The charged particle beam system of claim 20, wherein the computer is configured to adjust the projective system in a two-step mode, whereby,
   a. in a first step the first component is adjusted while the second subcomponent is kept constant or switched-off, and
   b. in a second step the second subcomponent is adjusted while the first subcomponent is kept constant.

22. The charged particle beam system of claims 1 to 21, further comprising an projective beam stop between the first plane and the detector system and a deflection system

between the first plane and the detector system, wherein the control is configured to control the deflection system to direct emission products form the charged particle beamlets to impinge onto the detector system in the first mode of operation and to direct the emission products of the second charged particle beamlets to the beam stop in the second mode or operation.

23. A method of operating a charged particle beam system, comprising the steps:
in a first mode of operation, forming a plurality of charged particle beamlets of a multi beam charged particle beam system, scanning a sample with the charged particle beamlets and detecting interaction products leaving the sample due to the impinging plurality of charged particles beamlets, and
in a second mode of operation, flooding the sample with a defocused charged particle beam,
switching between the first mode of operation and the second mode of operation several times while recording an image of the sample, and
changing at least one of the parameters of landing energy, focus, stage position and beam deflection of the charged particle beam system when switching between the first mode of operation and the second mode of operation.

24. The method of claim 23, wherein in the first mode of operation and in the second mode of operation the charged particle beams pass through an identical aperture in an objective lens of the charged particle beam system.

25. The method of one of the claims 23 or 24, wherein in the second mode of operation the defocused charged particle beam has a second diameter in the first plane, wherein in the first mode of operation a minimum diameter of a circle surrounding an area onto which the plurality of charged particle beamlets impinge in the first plane has a first diameter, and wherein the second diameter is at least 1.2 times the first diameter, more preferable 2 times the first diameter, even more preferable 5 times the first diameter , even more preferable 10 times the first diameter, and most preferable 50 times the first diameter.

26. The method of one of the claims 23 or 24, wherein in the second mode of operation the defocused charged particle beam illuminates a surface in the in the first plane having a second surface area, wherein in the first mode of operation a minimum surface area within which all beamlets of the plurality of charged particle beamlets impinge in the first plane has a first area, and wherein the second surface area is at least 1.5 times, more preferable 4 times, even more preferable 10 times, even more preferable 100 times, and most preferable 200 times the first surface area.

27. The method of one of the claims 23 to 26, the method further comprising, in the first mode of operation, directing emission products form the charged particle beamlets to impinge onto a detector system, and in the second mode of operation, directing emission products from an sample to a projective beam stop.

28. The method of one of claim 23 to 27, further comprising the steps of:

aligning the multi beam charged particle beam system with static methods and static charged particle optical elements, with a fast multi beam projective alignment method in an off state, and

activating a fast multi beam projection alignment system before a first image is recorded by controlling a state of a charged particle projective system for optimal imaging of interaction products onto a plurality of detectors and controlling the fast multi beam projective alignment system.

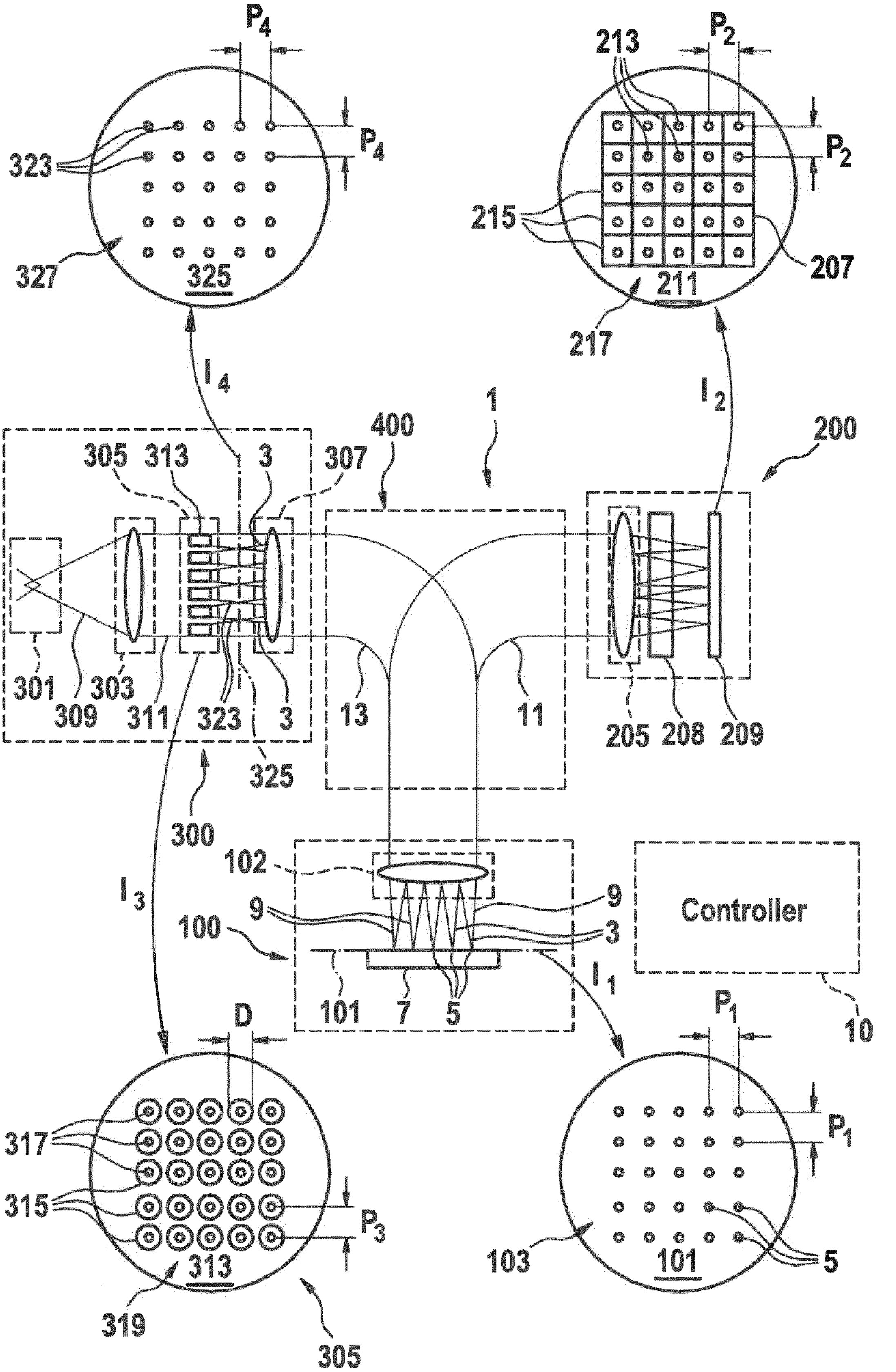
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Fig. 1

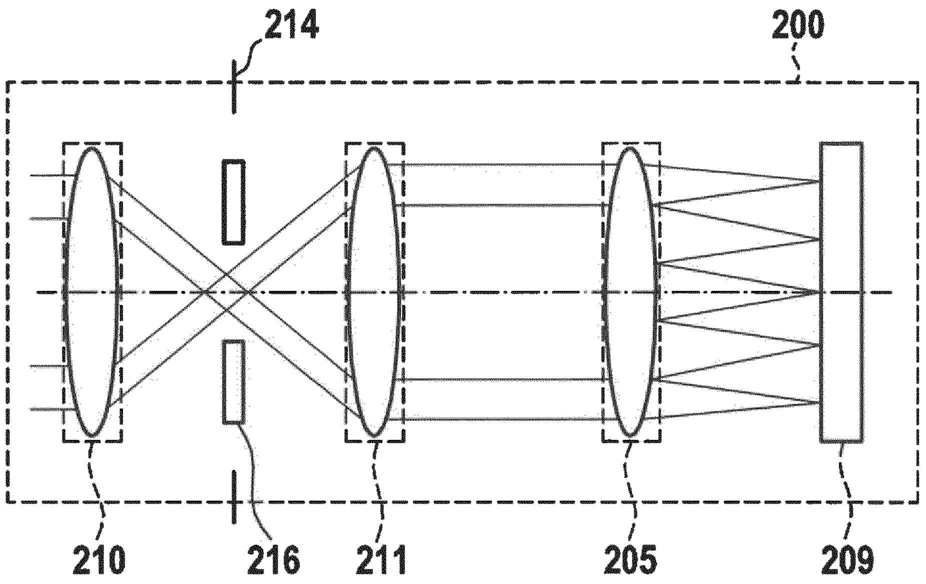
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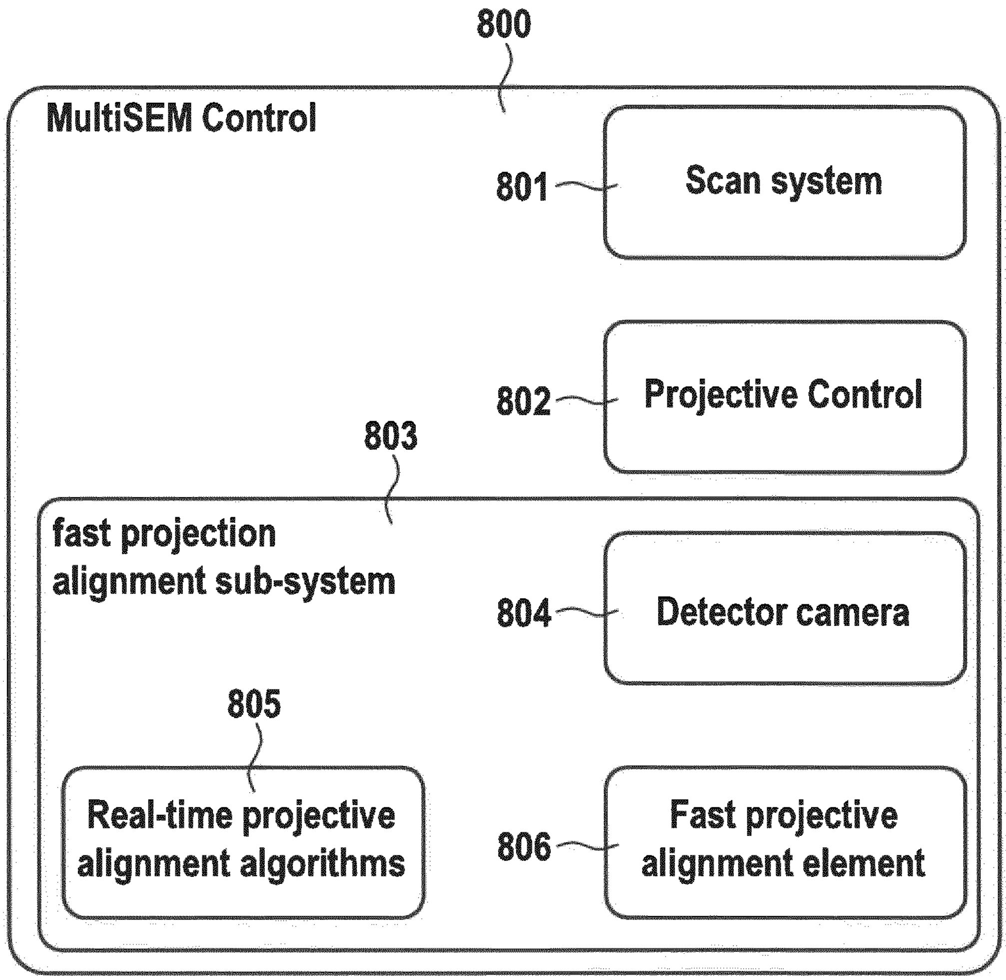
Fig. 2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MultiSEM Control
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Scan system
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Projective Control
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fast projection alignment sub-system
804
Detector camera
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Real-time projective alignment algorithms
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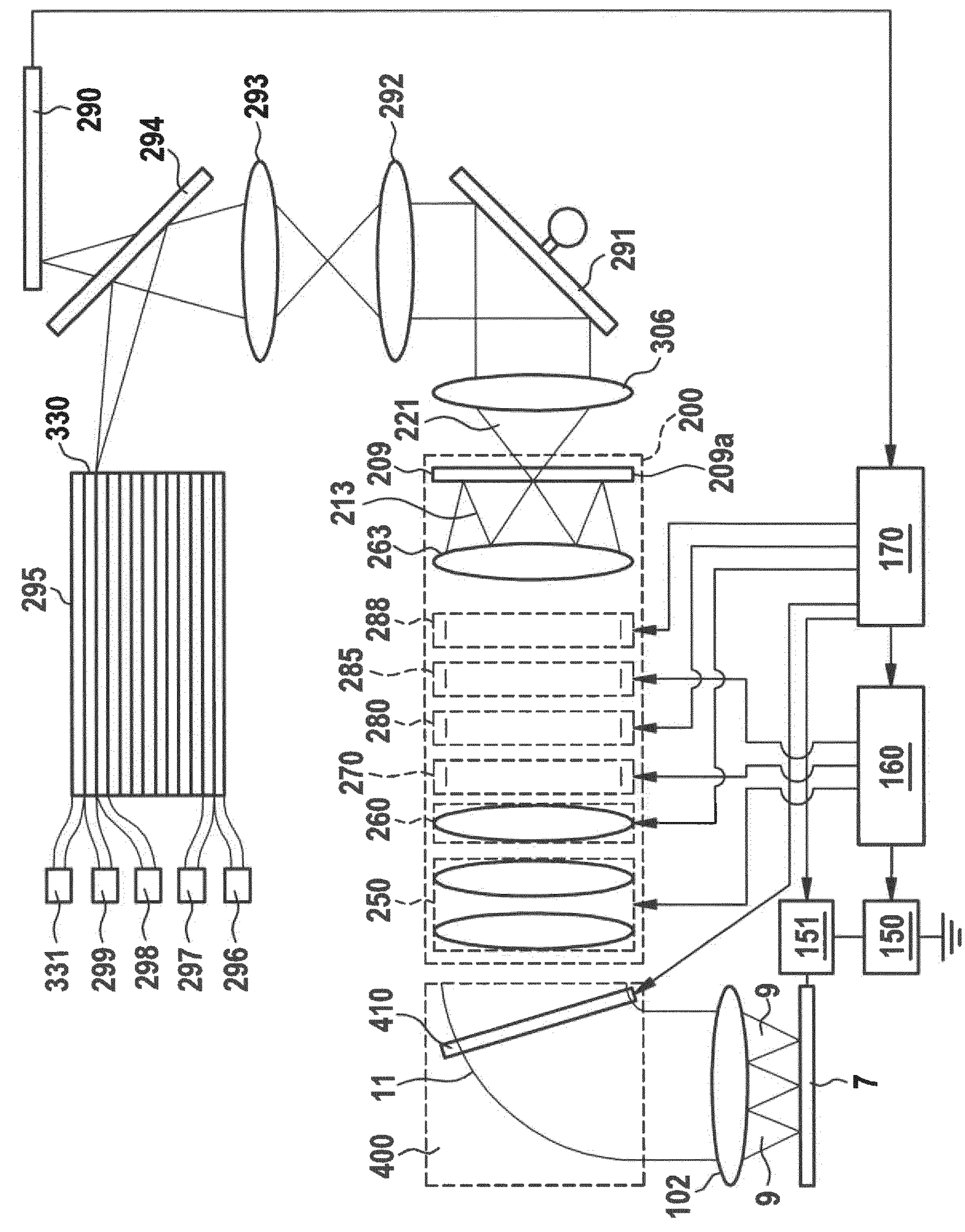
Fast projective alignment element

Fig. 3

Fig. 4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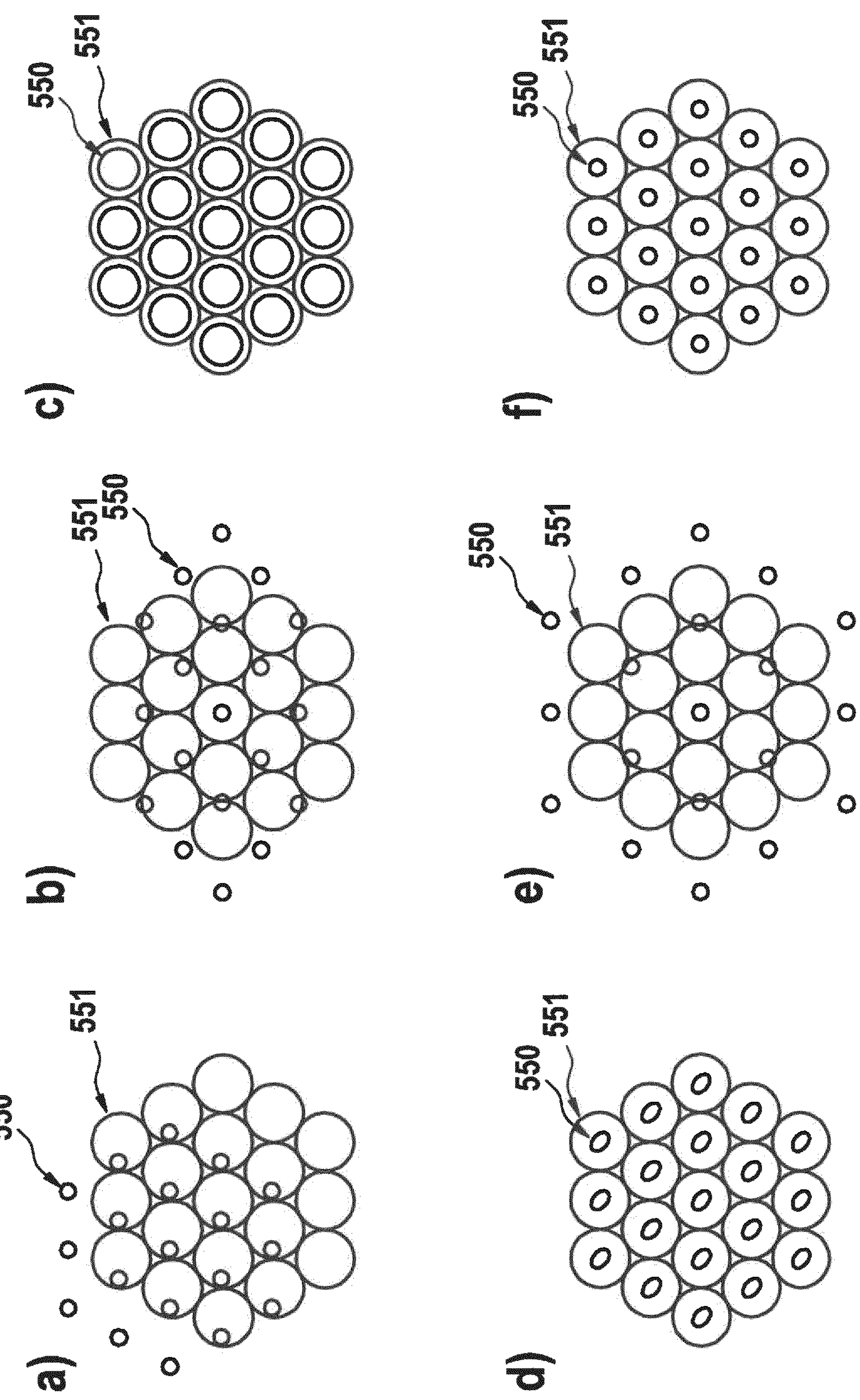

Fig. 5

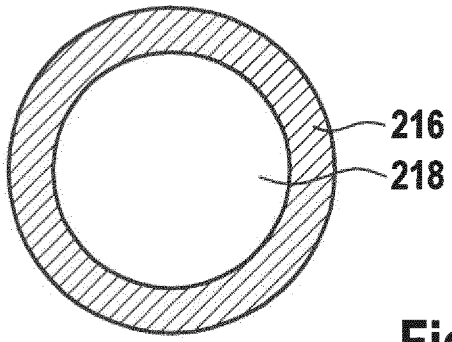

Fig. 6

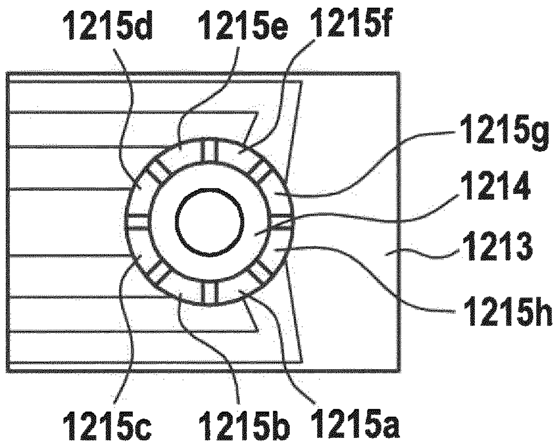

Fig. 7

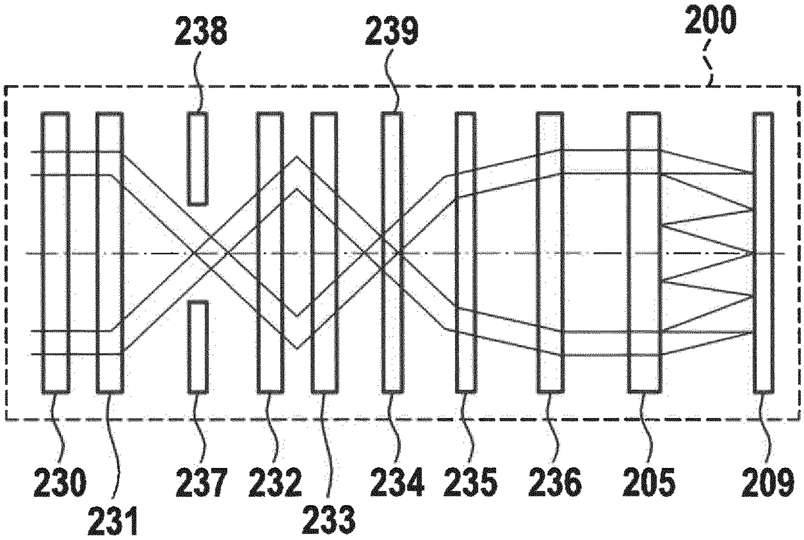

Fig. 8

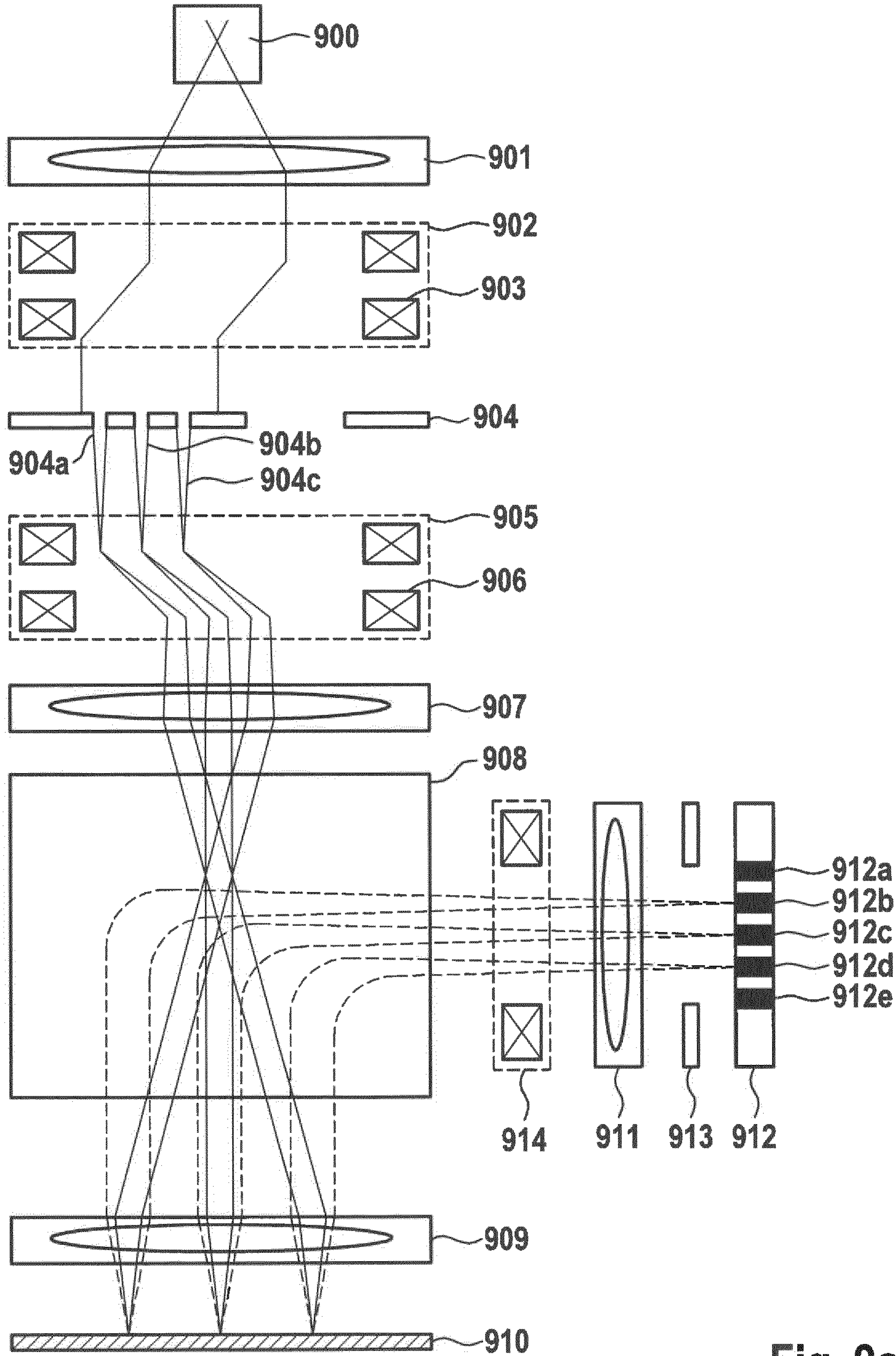
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Fig. 9a

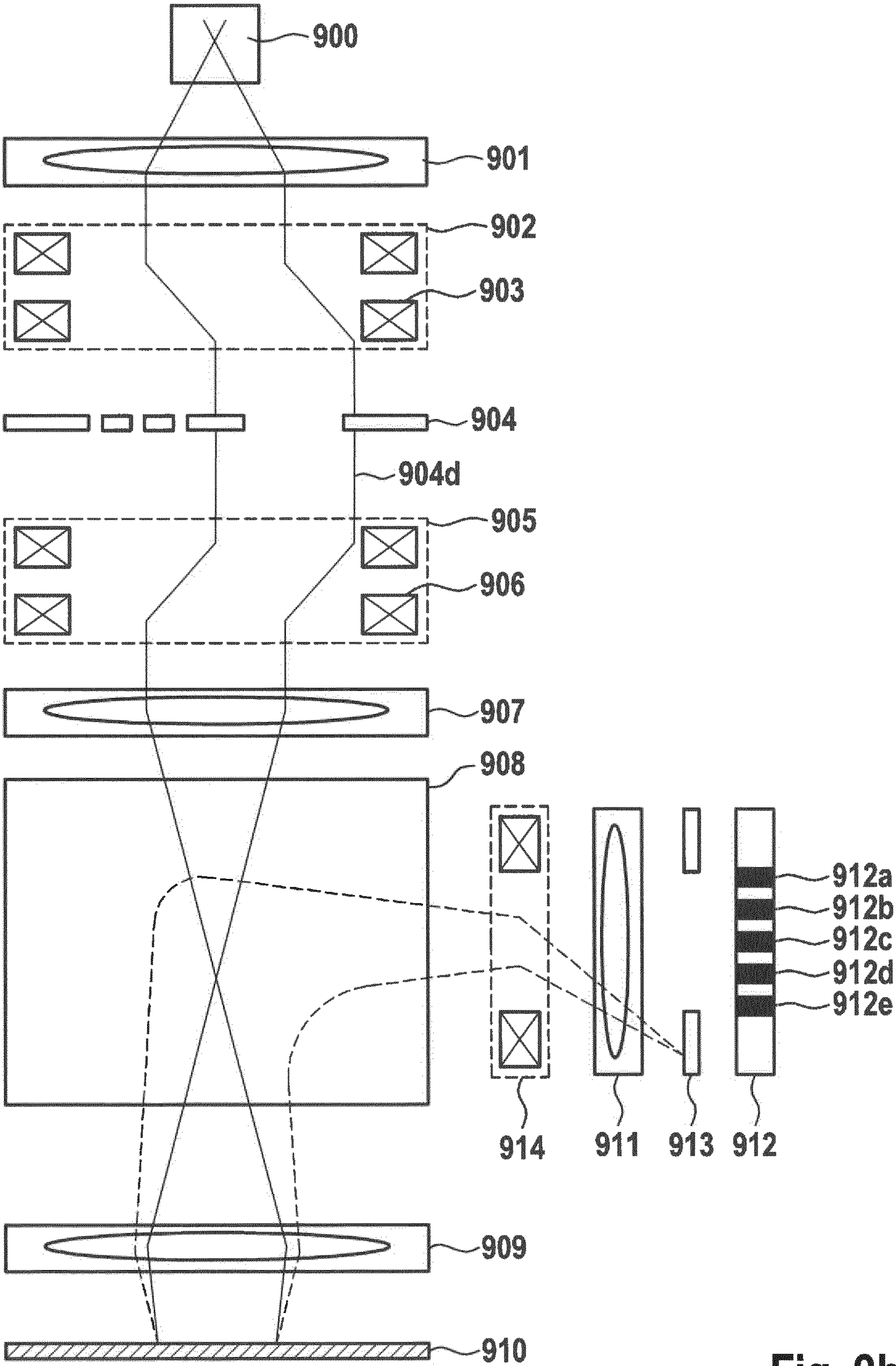
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Fig. 9b

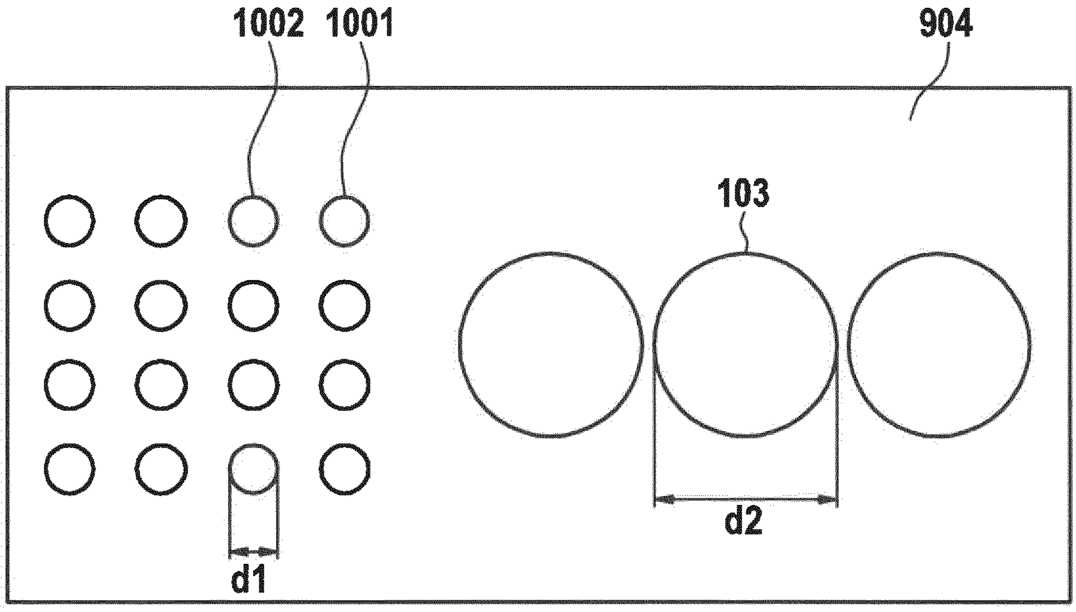

Fig. 10

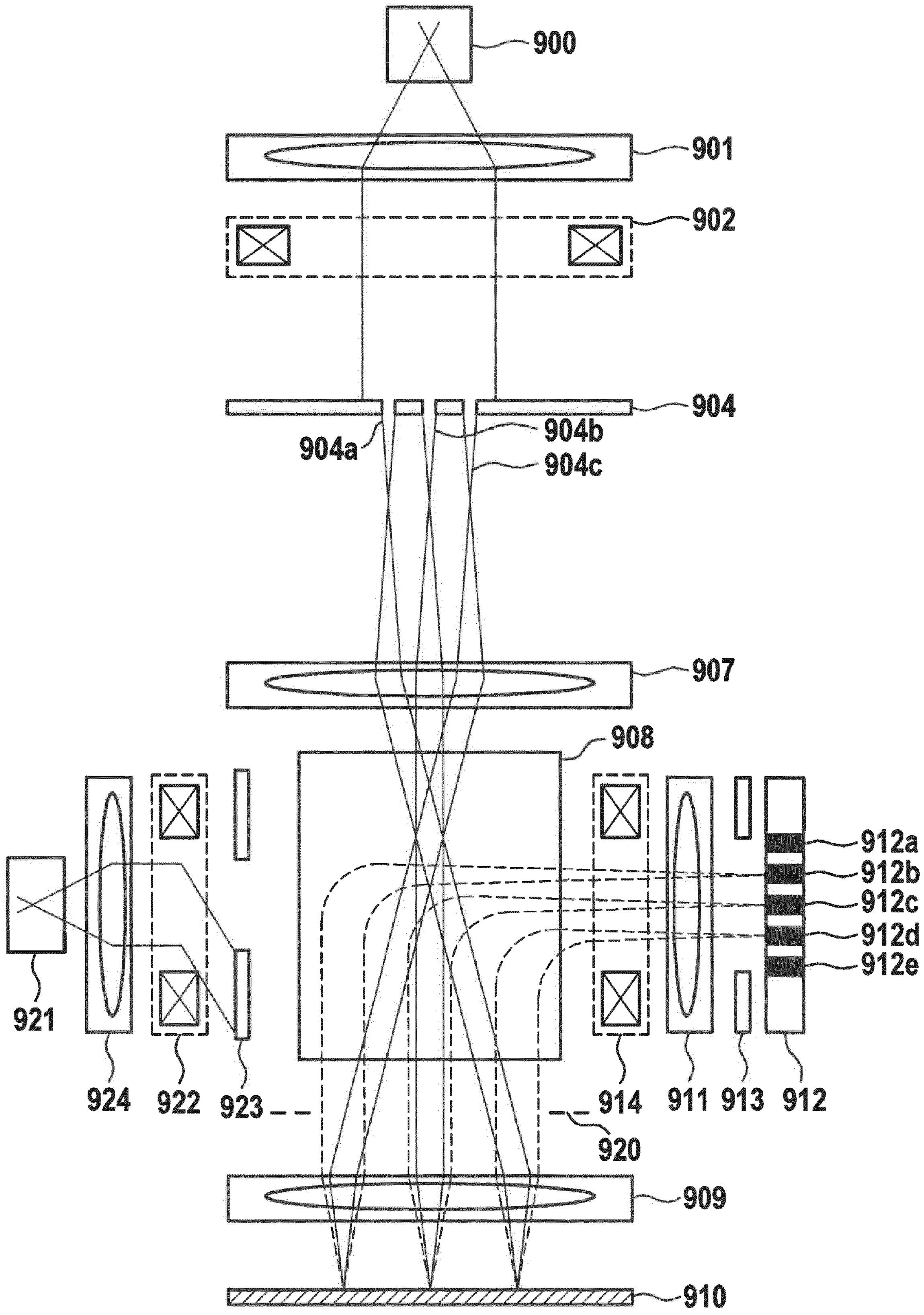
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Fig. 11a

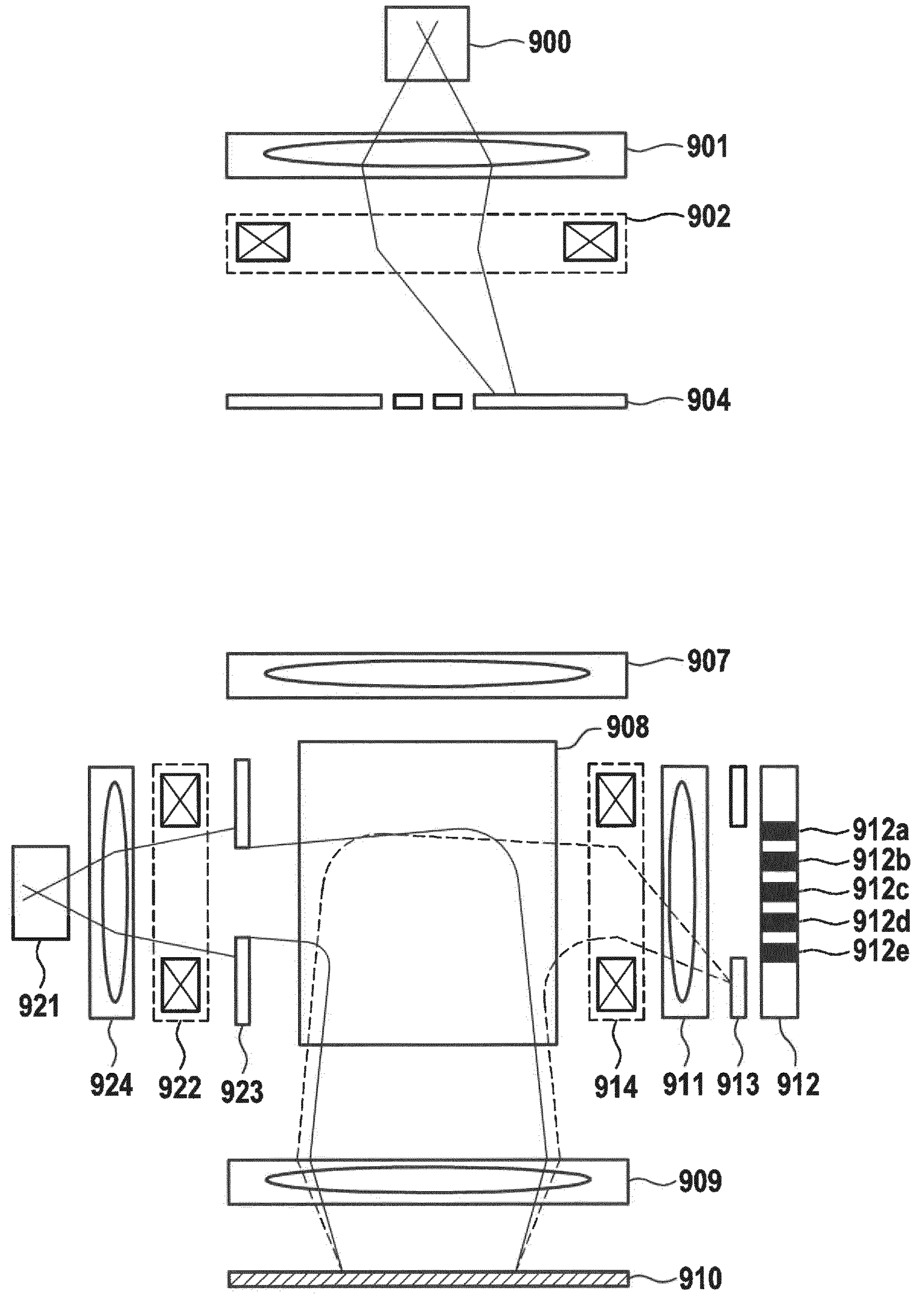
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Fig. 11b

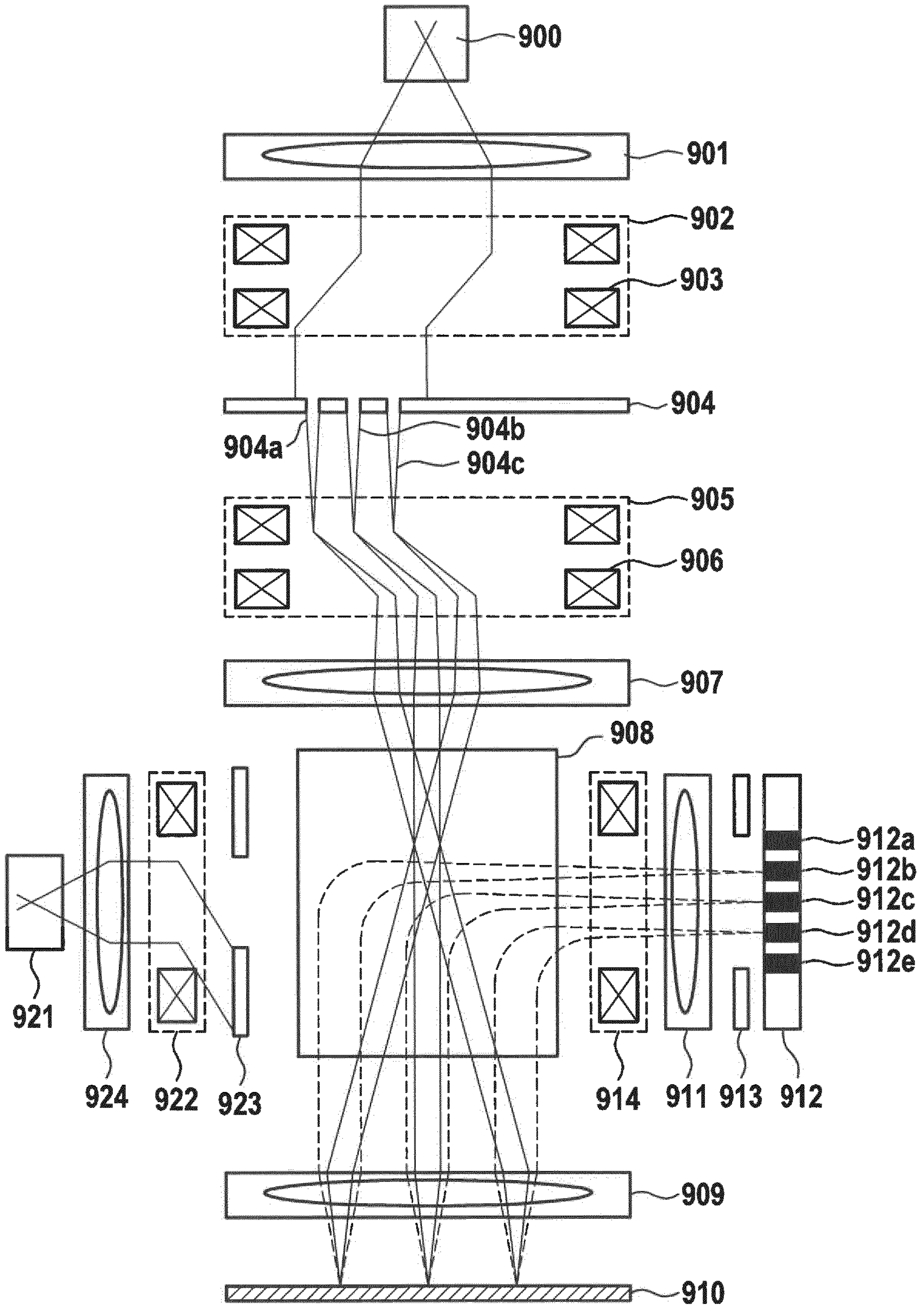
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Fig. 12a

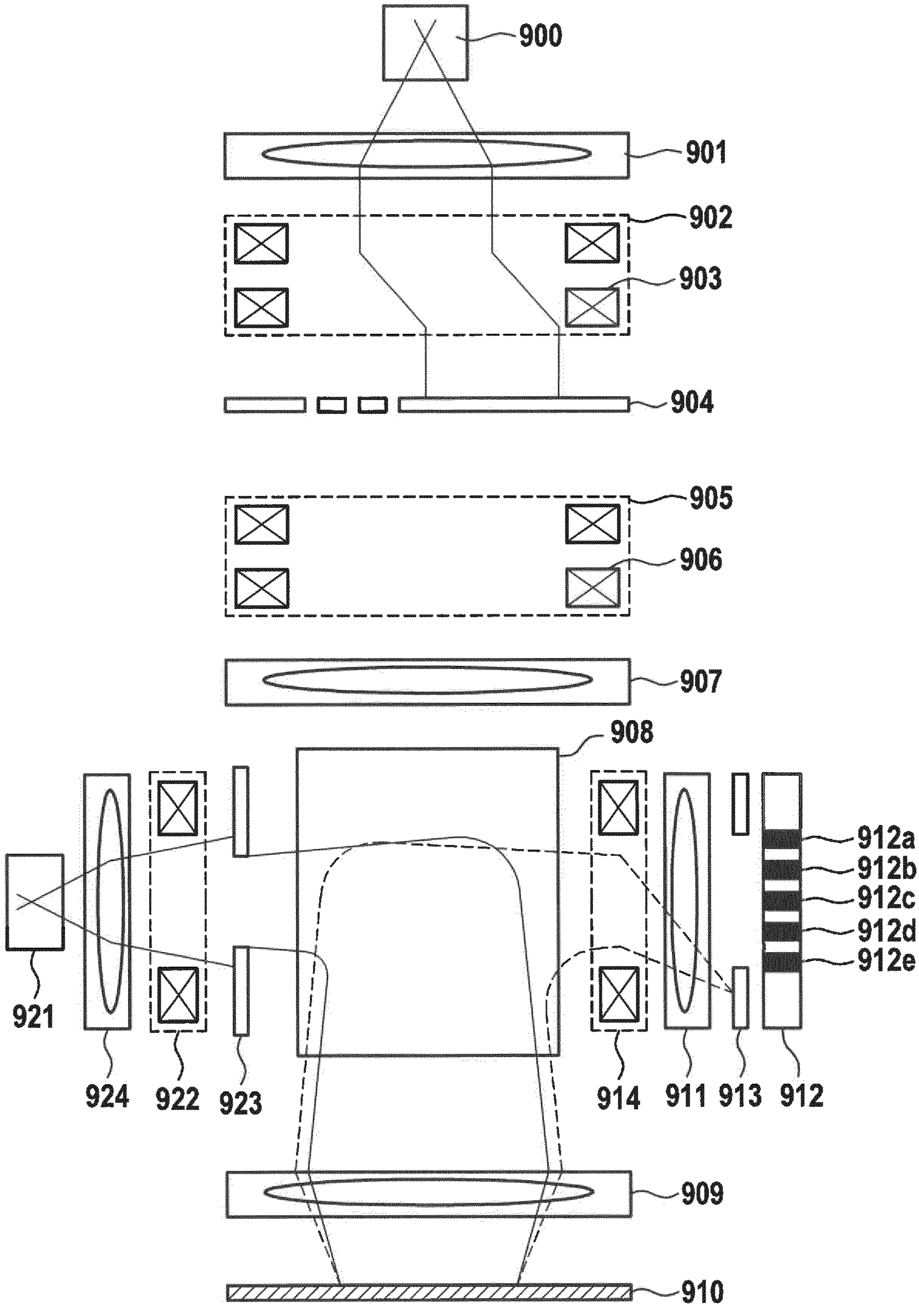
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Fig. 12b