



(51) International Patent Classification:
B29D 11/00 (2006.01)

(21) International Application Number:
PCT/EP2023/052847

(22) International Filing Date:
06 February 2023 (06.02.2023)

(25) Filing Language: English

(26) Publication Language: English

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(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,

AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ,
CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM,
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TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA,
ZM, ZW.

(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, CV,
GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST,
SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ,
RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ,
DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT,
LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE,
SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN,
GQ, GW, KM, ML, MR, NE, SN, TD, TG).

(54) Title: METHOD OF HANDLING A PLURALITY OF OPTICAL DEVICES, METHOD OF PROCESSING A PLURALITY OF
OPTICAL DEVICES, AND PROCESSING SYSTEM

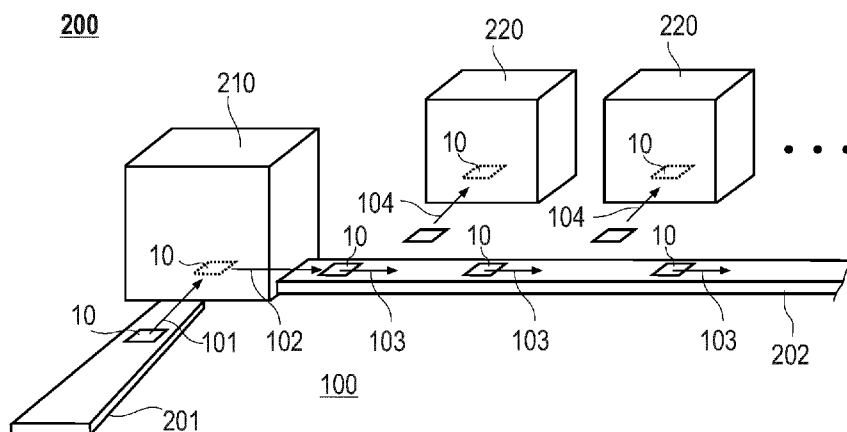


FIG. 1

(57) Abstract: A method (100) of handling a plurality of optical devices (10) in a processing system (200) is described. The method includes individually transporting (101) the optical devices (10) to a first processing module (210) without contacting a major surface (10M) of the optical devices (10) by using a first transportation apparatus (201). Additionally, the method includes transferring (102) the optical devices (10) from the first processing module (210) to a second transportation apparatus (202) connecting one or more further processing modules (220). Further, the method includes individually transporting (103) the optical devices to the one or more further processing modules (220) by using the second transportation apparatus (202), wherein during handling at least two of the plurality of optical devices (10) are provided in different processing modules at the same time. Moreover, a method of processing a plurality of optical devices and a processing system are described.

Published:

— *with international search report (Art. 21(3))*

**METHOD OF HANDLING A PLURALITY OF OPTICAL DEVICES,
METHOD OF PROCESSING A PLURALITY OF OPTICAL DEVICES,
AND PROCESSING SYSTEM**

FIELD

5 [0001] Embodiments of the present disclosure relate to handling methods, processing methods, and processing apparatuses for a plurality of optical devices, such as waveguides, wave guide combiners, flat optical devices, substrates having optical structures, cover glasses, lenses and the like.

BACKGROUND

10 [0002] Virtual reality is generally considered to be a computer-generated simulated environment in which a user has an apparent physical presence. A virtual reality experience can be generated in 3D and viewed with a head-mounted display (HMD) such as glasses or other wearable display devices that have near-eye display panels as lenses for displaying a virtual reality environment that replaces an actual
15 environment.

 [0003] Augmented reality, however, enables an experience in which a user can still see through the display lenses of the glasses or other HMD device to view the surrounding environment, yet also see images of virtual objects that are generated for display and appear as part of the environment. Augmented reality can include
20 any type of input, such as audio and haptic inputs, as well as virtual images, graphics, and video that enhances or augments the environment that the user experiences. As an emerging technology, augmented reality is accompanied by many challenges and design constraints.

 [0004] In order to allow for a computer-generated virtual image to be combined
25 with a real-world image of the environment so as to provide an augmented reality experience, optical combiners may be used. Such optical combiners may involve waveguides that include a substrate having a plurality of optical structures formed thereon. Since the optical structures are small (e.g. nano-sized), fragile structures that

are easily damaged or contaminated, the handling of waveguides may be challenging.

5 [0005] For example, a fast, automated processing of waveguides can be difficult, thus affecting the overall rate of productivity in the manufacture of display devices for augmented reality applications. Further, for manufacturing an augmented reality display device, it is often the case that an optical stack including one or more waveguides is to be formed, which may be subjected to further processing procedures. Due to the fact that waveguides need to be handled with great care, achieving high quality automated processing at high production rates can be
10 challenging.

[0006] In light of the above, it is beneficial to provide an improved handling method, improved processing method, and improved processing apparatuses suitable for handling and processing a plurality of optical devices.

SUMMARY

15 [0007] In light of the above, a method of handling a plurality of optical devices, a method of processing a plurality of optical devices, and a processing system for processing a plurality of optical devices according to the independent claims are provided. Further features, details, aspects, implementation and embodiments are shown in the dependent claims, the description and the drawings.

20 [0008] According to an aspect of the present disclosure, a method of handling a plurality of optical devices in a processing system is provided. The method includes individually transporting the optical devices to a first processing module without contacting a major surface of the optical devices by using a first transportation apparatus. Additionally, the method includes transferring the optical devices from
25 the first processing module to a second transportation apparatus connecting one or more further processing modules. Further, the method includes individually transporting the optical devices to the one or more further processing modules by using the second transportation apparatus. During handling, at least two of the

plurality of optical devices are provided in different processing modules at the same time.

[0009] According to another aspect of the present disclosure, a method of processing a plurality of optical devices in a processing system is provided. The method includes handling the plurality of optical devices according to the method of handling the plurality of optical devices according to any embodiments described herein. Additionally, the method includes carrying out a first processing procedure of one or more individual optical devices of the plurality of optical devices in the first processing module. Further, the method of processing includes carrying out one or more further processing procedures of one or more individual optical devices of the plurality of optical devices in the one or more further processing modules. During processing, at least two of the plurality of optical devices are processed in different processing modules at the same time.

[0010] According to a further aspect of the present disclosure, a processing system for processing a plurality of optical devices is provided. The processing system includes a first transportation apparatus for individually transporting the optical devices without contacting a major surface of the optical devices. Additionally, the processing system includes a first processing module for carrying out a first processing procedure of one or more individual optical devices of the plurality of optical devices. Further, the processing system includes a second transportation apparatus connecting one or more further processing modules. The second transportation apparatus is configured for individually transporting the optical devices. Additionally, the processing system includes a transfer apparatus for transferring the optical devices from the first processing module to the second transportation apparatus. Further, the processing system includes the one or more further processing modules which are configured for carrying out one or more further processing procedures of one or more individual optical devices of the plurality of optical devices.

[0011] Embodiments are also directed at apparatuses for carrying out the disclosed methods and include apparatus parts for performing each described method aspect. These method aspects may be performed by way of hardware components, a

computer programmed by appropriate software, by any combination of the two or in any other manner. Furthermore, embodiments according to the disclosure are also directed at methods for operating the described apparatus. The methods for operating the described apparatus include method aspects for carrying out every function of the apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments. The accompanying drawings relate to embodiments of the disclosure and are described in the following:

FIG. 1 shows a schematic perspective view of a processing system according to embodiments of the present disclosure;

FIGS. 2 and 3 show schematic top views of a processing system according to further embodiments of the present disclosure;

FIGS. 4A and 4B show block diagrams for illustrating a method of handling a plurality of optical devices according to embodiments described herein;

FIG. 4C shows a block diagram for illustrating a method of processing a plurality of optical devices according to embodiments described herein;

FIGS. 5A and 5B show schematic illustrations of a waveguide;

FIG. 6 shows a waveguide stack including several waveguides;

FIG. 7 shows a schematic view of a stacking module according to embodiments described herein;

FIG. 8 shows a schematic sectional view of a transportation apparatus for individually transporting optical devices without contacting a major

surface of the optical devices according to embodiments described herein;

5 FIG. 9 shows a schematic top view of a transportation apparatus for individually transporting optical devices without contacting a major surface of the optical devices according to embodiments described herein;

FIG. 10 shows a schematic sectional view of a transportation apparatus for individually transporting optical devices without contacting a major surface of the optical devices according to further embodiments described herein;

10 FIG. 11 shows a schematic top view of a further processing module according to embodiments described herein;

FIG. 12 shows a schematic perspective view of a transportation apparatus connecting one or more further processing modules according to embodiments described herein; and

15 FIG. 13 shows a schematic view of a suction holder according to embodiments described herein.

DETAILED DESCRIPTION OF EMBODIMENTS

[0013] Reference will now be made in detail to the various embodiments, one or more examples of which are illustrated in each figure. Each example is provided
20 by way of explanation and is not meant as a limitation. For example, features illustrated or described as part of one embodiment can be used on or in conjunction with any other embodiment to yield yet a further embodiment. It is intended that the present disclosure includes such modifications and variations. Within the following description of the drawings, the same reference numbers refer to the same or to
25 similar components. Generally, only the differences with respect to the individual embodiments are described. Unless specified otherwise, the description of a part or aspect in one embodiment can apply to a corresponding part or aspect in another embodiment as well.

[0014] With exemplary reference to FIGS. 1 to 4B, a method 100 of handling a plurality of optical devices 10 in a processing system 200 according to embodiments of the present disclosure is described. According to embodiments, which can be combined with any other embodiments described herein, the method 100 includes individually transporting (represented by arrow 101 in FIGS. 1 to 3 and operation 101 in FIGS. 4A and 4B) the optical devices 10 to a first processing module 210 without contacting a major surface of the optical devices 10 by using a first transportation apparatus 201. Additionally, the method 100 includes transferring (represented by arrow 102 in FIGS. 1 to 3 and operation 102 in FIGS. 4A and 4B) the optical devices 10 from the first processing module 210 to a second transportation apparatus 202 connecting one or more further processing modules 220. Further, the method 100 includes individually transporting (represented by arrow 103 in FIGS. 1 to 3 and operation 103 in FIGS. 4A and 4B) the optical devices to the one or more further processing modules 220 by using the second transportation apparatus 202. During handling, at least two of the plurality of optical devices 10 are provided in different processing modules at the same time. It is to be understood that the different processing modules refer to the first processing module 210 and the one or more further processing modules 220.

[0015] Accordingly, compared to the state of the art, an improved method of handling a plurality of optical devices in a processing system is provided. In particular, embodiments of the present disclosure beneficially provide for a more efficient transport and transfer of optical devices within a processing system having various processing modules. Further, embodiments as described herein beneficially provide for the possibility of handling optical devices of different form factors without the need for adaption to the various different specific form factors. Further, embodiments of the present disclosure have the advantage that multiple optical devices can be handled simultaneously. Accordingly, the method of handling as described herein is particularly well suited for in-line processing systems and high-volume manufacturing, for example of eyepieces.

[0016] Before various further embodiments of the present disclosure are described in more detail, some aspects with respect to some terms used herein are explained.

[0017] Embodiments described herein involve optical devices. A device may be considered an optical device if the optical properties of the device are relevant for the method or apparatus in which the device is used. At least a portion of an optical device can be made of a transparent material, such as glass or plastic. Some optical devices may be configured to change the properties, e.g. the propagation direction, of light. For example, an optical device may include optical structures for changing the propagation direction of light. Other optical devices may be unstructured and allow light to pass therethrough substantially unaltered. An optical device as described herein may be an optical device for use in augmented reality applications.

10 An optical device can also be called an optical element. Examples of optical devices include waveguides and transparent cover elements, such as cover glasses, as described herein.

[0018] An optical device as described herein, such as a waveguide or a transparent cover element, can be a thin piece of material. An optical device can be a plate element, including a plate element having a flat surface or a plate element having a curved surface. An optical device can have a first major surface and a second major surface opposite the first major surface. An optical device may be a substantially two-dimensional device, wherein a thickness of the optical device between the first major surface and the second major surface can be much smaller (e.g. 1 % or less) than a dimension, such as a length or width, of the first or second major surface. For example, the thickness of an optical device may be 1mm, 500µm or 300µm or less.

[0019] FIGS. 5A and 5B show an exemplary waveguide 12. As shown in FIG. 5A, the waveguide 12 may include a substrate 13, which may be a thin piece of transparent material, such as glass or plastic. At least one grating structure, such as a first grating structure 14 and a second grating structure 15, may be disposed on the substrate 13. The waveguide 12 may include an input coupling region 16 defined by the first grating structure 14. The waveguide 12 may include an output coupling region 17 defined by the second grating structure 15. Light, in particular light corresponding to a virtual, computer-generated image, may be coupled into the waveguide 12 at the input coupling region 16. The light may propagate through the waveguide 12 until the light reaches the output coupling region 17. At the output

coupling region 17, the light may exit the waveguide 12. Further, also at the output coupling region 17, light from the external, real-world surroundings may be transmitted through the waveguide 12 (as shown by the dashed line), allowing the user to see a combination of a virtual image and a real-world image. The waveguide 12 may be a waveguide combiner for providing an augmented reality experience to a user.

[0020] FIG. 5B shows a grating structure 18 of a waveguide 12 in more detail. The grating structure 18 may be the first grating structure 14 or the second grating structure 15 shown in FIG. 5B, and may accordingly serve to provide an input coupling region or an output coupling region of the waveguide 12. The grating structure 18 may be formed on a major surface 131 of the substrate 13. The grating structure 18 may include a plurality of optical structures 181. The optical structures 181 may be configured to change a propagation direction of light incident on the grating structure 18. The optical structures 181 may have dimensions, e.g. width and/or height, that lie in the sub-micron and even nanometer range. The optical structures may be arranged adjacent to each other with a gap in between. As shown in FIG. 5B, the optical structures 181 may be shaped, for example, as slanted fins.

[0021] The disclosure is not limited to the exemplary waveguide 10 shown in FIGS. 5A and 5B, and applies likewise to other waveguides. For example, a waveguide may have more than two grating structures (e.g. the waveguide may have one or more intermediate regions defined by further grating structures), the arrangement and shape of the optical structures 181 may be different from the example shown in FIG. 5B, the waveguide may have grating structures disposed on both sides of the waveguide, and so on.

[0022] A waveguide as described herein may include a substrate. A waveguide may include a plurality of optical structures formed on the substrate. The optical structures may have sub-micro-dimensions, e.g. nano-sized dimensions. The plurality of optical structures may form one or more grating structures on the substrate. A waveguide can be a waveguide combiner. A waveguide combiner may be configured for combining a virtual computer-generated image with a real-world

image of a surrounding environment. A waveguide may be an augmented reality waveguide combiner.

[0023] In an optical system, such as an augmented reality device, several waveguides may be stacked on top of each other to form a waveguide stack. For example, each waveguide in the waveguide stack may be configured for manipulating light at a respective wavelength range which is beneficial for providing color images.

[0024] FIG. 6 shows an example of an optical device being a waveguide stack 19. The waveguide stack 19 may include a first cover glass 191 (bottom cover glass), a first waveguide 12A, a second waveguide 12B, a third waveguide 12C and a second cover glass 192 (top cover glass) stacked in this order. A first adhesive 193A may be disposed between the first cover glass 191 and the first waveguide 12A. A second adhesive 193B may be disposed between the first waveguide 12A and the second waveguide 12B. A third adhesive 193C may be disposed between the second waveguide 12B and the third waveguide 12C. A fourth adhesive 193D may be disposed between the third waveguide 12C and the second cover glass 192. Each of the waveguides 12A, 12B and 12C may be a waveguide as described herein, such as a waveguide 12 shown in FIGS 5A and 5B.

[0025] A cover glass, such as the first cover glass 191 and/or the second cover glass 192, may be a protective glass. A cover glass may shield a surface of a waveguide adjacent to the cover glass, for example to prevent a grating formed on said surface from being contacted or contaminated. It may be the case that a cover glass itself does not have optical structures, such as a grating.

[0026] An adhesive, such as adhesives 193A-193D, may be configured to attach adjacent optical devices of a waveguide stack to each other. For example, the first adhesive 193A may be configured to attach the first cover glass 191 to the first waveguide 12A. The second adhesive 193B, the third adhesive 193C and the fourth adhesive 193D may be configured to attach the respective adjacent elements (12A, 12B, 12C, and 192) as exemplarily shown in FIG. 6. An adhesive may be a pressure sensitive adhesive (PSA). An adhesive may be a pre-formed adhesive, such as a pre-formed PSA. An adhesive may have an elongated shape. For example, an adhesive

may be an adhesive tape. An adhesive may function as a spacer providing a gap, particularly an air gap, between adjacent optical devices of the waveguide stack. Due to the adhesive, it may be the case that said adjacent optical devices do not contact each other.

5 [0027] The waveguide stack 19 shown in FIG. 6 includes a total of three waveguides. The disclosure is not limited thereto. A waveguide stack may include one or more, two or more, or three or more waveguides. For example, a waveguide stack may include one waveguide and one cover glass, e.g. in the case where optical
10 structures are provided on only one side of the waveguide and the cover glass is used to protect that optical structure. Typically, the cover glass is bonded to the waveguide by an adhesive as described herein. According to another example, a wave guide stack may include one or more of a total of two waveguides stacked between a first cover glass 191 and a second cover glass 192.

[0028] Further, it is to be noted that instead of cover glasses, transparent cover
15 elements made of materials other than glass may be used in a waveguide stack. Throughout the present disclosure, a cover glass may be replaced by a transparent cover element.

[0029] According to embodiments, which can be combined with any other
20 embodiments described herein, the method 100 of handling a plurality of optical devices further includes individually transferring (represented by arrow 104 in FIGS. 2 and 3 and operation 104 in FIG. 4B) the optical devices 10 from the second transportation apparatus 202 to a processing transportation apparatus 225 of the one or more further processing modules 220. Further, method 100 of handling a plurality
25 of optical devices typically further includes individually transferring (represented by arrow 106 in FIGS. 2 and 3 and operation 106 in FIG. 4B) the optical devices 10 from a processing transportation apparatus 225 of the one or more further processing modules 220 to the second transportation apparatus 202. In particular, individually
30 transferring the optical devices 10 from the second transportation apparatus 202 to a processing transportation apparatus 225 of the one or more further processing modules 220 and vice versa may include using a loading/unloading apparatus 240 as described herein, e.g. with reference to FIG. 11.

[0030] According to embodiments, which can be combined with any other embodiments described herein, the method 100 of handling a plurality of optical devices further includes individually transporting (represented by arrow 105 in FIGS. 2 and 3 and operation 105 in FIG. 4B) the optical devices 10 along a processing path 222 within the one or more further processing modules 220. Typically, at least one processing path 222 within the one or more further processing modules 220 is a circular processing path.

[0031] According to embodiments, which can be combined with any other embodiments described herein, individually transporting (represented by arrow 101 in FIGS. 1 to 3 and operation 101 in FIGS. 4A and 4B) the optical devices 10 to the first processing module 210 by the first transportation apparatus 201 includes contactlessly suspending the optical devices 10. In particular, contactlessly suspending the optical devices may include using a contactless suspension unit as described with reference to FIGS. 8 to 10.

[0032] According to embodiments, which can be combined with any other embodiments described herein, transferring (represented by arrow 102 in FIGS. 1 to 3 and operation 102 in FIGS. 4A and 4B) the optical devices 10 from the first processing module 210 to the second transportation apparatus 202 includes indirectly contacting the optical device through an air permeable material. In particular, transferring the optical devices 10 from the first processing module 210 to the second transportation apparatus 202 may include using a transfer apparatus 230 as described herein, e.g. with reference to FIG. 13.

[0033] According to embodiments, which can be combined with any other embodiments described herein, the method 100 of handling a plurality of optical devices further includes transferring (represented by arrow 107 in FIG. 3 and operation 107 in FIG. 4B) the optical devices 10 from the last processing module of the one or more further processing modules 220 to a third transportation apparatus 203 for individually transporting (represented by arrow 108 in FIG. 3) the optical devices 10 from a packaging area 40 into a logistic area 50. Typically, the packaging area 40 is provided in a first environment fulfilling higher standards with respect to cleanliness than a second environment wherein the logistic area 50 is

provided. In particular, the method 100 may include transferring individual vacuum sealed packages, each containing an individual optical device of the plurality of optical devices, from the last processing module to the third transportation apparatus 203. Typically, the last processing module of the one or more further processing modules 220 is a packaging module.

[0034] It is to be understood that the method 100 of handling a plurality of optical devices 10 according to embodiments described herein can be conducted by using a processing system 200 according to embodiments described herein.

[0035] With exemplary reference to FIG. 4C, a method 300 of processing a plurality of optical devices 10 in a processing system 200 is described. According to embodiments, which can be combined with any other embodiments described herein, the method 300 of processing includes handling (represented by operation 301 in FIG. 4C) the plurality of optical devices according to the method 100 of handling a plurality of optical devices according to any embodiments described herein. Further, the method 300 of processing includes carrying out (represented by operation 302 in FIG. 4C) a first processing procedure of one or more individual optical devices of the plurality of optical devices in the first processing module 210. Additionally, the method 300 of processing includes carrying out (represented by operation 303 in FIG. 4C) one or more further processing procedures of one or more individual optical devices of the plurality of optical devices in the one or more further processing modules 200. During processing, at least two of the plurality of optical devices 10 are processed in different processing modules at the same time. It is to be understood that the different processing modules refer to the first processing module 210 and the one or more further processing modules 220.

[0036] According to embodiments, which can be combined with any other embodiments described herein, the first processing procedure includes stacking one of the plurality of optical devices with one or more further optical devices.

[0037] According to embodiments, which can be combined with any other embodiments described herein, the one or more further processing procedures include one or more of a coating procedure, a curing procedure, a drying procedure, a testing procedure, and a packaging procedure.

[0038] According to embodiments, which can be combined with any other embodiments described herein, individually transporting the optical devices 10 to the first processing module 210 may include transporting the optical devices at a first orientation O_1 . Further, carrying out one or more further processing procedures of one or more individual optical devices of the plurality of optical devices in the one or more further processing modules 220 may include processing the optical devices 10 at a second orientation O_2 different from the first orientation O_1 . In particular, the first orientation O_1 can be a substantially horizontal orientation and the second orientation O_2 can be a substantially vertical orientation. A substantially horizontal orientation can be understood as an orientation within a tolerance T of $T \leq \pm 15^\circ$, particularly $T \leq \pm 10^\circ$, from the perfect horizontal orientation. Accordingly, a substantially vertical orientation can be understood as an orientation within a tolerance T of $T \leq \pm 15^\circ$, particularly $T \leq \pm 10^\circ$, from the perfect vertical orientation. The perfect vertical orientation is an orientation along the perfect vertical direction which is defined by the force of gravity. The perfect horizontal orientation is perpendicular to the perfect vertical orientation.

[0039] It is to be understood that the method 300 of processing a plurality of optical devices 10 according to embodiments described herein can be conducted by using a processing system 200 according to embodiments described herein.

[0040] With exemplary reference to FIGS. 1 to 3 and 7 to 13, embodiments of a processing system 200 for processing a plurality of optical devices 10 are described. According to embodiments, which can be combined with any other embodiments described herein, the processing system 200 includes a first transportation apparatus 201 for individually transporting the optical devices 10 without contacting a major surface of the optical devices 10. Transporting the optical devices 10 without contacting a major surface of the optical devices 10 is beneficial for preventing damage to and contamination of the optical structures on a major surface of the optical devices 10. The major surfaces 10M of an optical device 10 as described herein are exemplarily indicated in FIGS. 8 and 10.

[0041] Additionally, the processing system 200 includes a first processing module 210 for carrying out a first processing procedure of one or more individual

optical devices of the plurality of optical devices 10. Further, the processing system 200 includes a second transportation apparatus 202 connecting one or more further processing modules 220. The second transportation apparatus 202 is configured for individually transporting the optical devices 10. Additionally, the processing system 200 includes a transfer apparatus 230 for transferring the optical devices 10 from the first processing module 210 to the second transportation apparatus 202. Further, the processing system 200 includes the one or more further processing modules 220. The one or more further processing modules 220 are configured for carrying out one or more further processing procedures of one or more individual optical devices of the plurality of optical devices.

[0042] According to embodiments, which can be combined with any embodiments of the method 100 of handling, the method 300 of processing, and the processing system 200 described herein, the one or more optical devices from the plurality of optical devices can be selected from the group consisting of: a waveguide, a wave guide combiner, a flat optical device, a substrate having optical structures, a cover glass, a lens, and a stack of at least one waveguide and at least one cover glass. Further, it is to be understood that typically the processing system 200 according to embodiments described herein can be used for conducting the method 100 of handling a plurality of optical devices according to embodiments described herein. Further, the processing system 200 according to embodiments described herein can be used for conducting the method of processing a plurality of optical devices according to embodiments described herein.

[0043] According to embodiments, which can be combined with any embodiments described herein, the processing system 200 includes two or more processing modules selected from the group consisting of a stacking module, a coating module, an edge blackening module, a module for treating a coating, a testing module, and a packaging module.

[0044] For instance, the first processing module 210 can be a stacking module 211. FIG. 7 shows a schematic view of a stacking module 211 according to embodiments described herein. For example, the stacking module 211 can be the first processing module 210 of the processing system as described herein.

[0045] The stacking module 211 may be connected to a first supply station 1212 for supplying optical devices. For examples, the first supply station 1212 may store a plurality of cover glasses (or other transparent cover elements). For example, the first supply station 1212 may store a plurality of trays each containing one or more cover glasses. Each cover glass supplied by the first supply station 1212 may serve as a bottom cover glass of a waveguide stack. The supply station 1212 may supply cover glasses to a first conveyor 1222. The first conveyor 1222 may be configured for conveying the cover glasses by side contact only. The first conveyor 1222 can be configured for providing the cover glasses to the first transportation apparatus 201 as described herein.

[0046] Further, the stacking module 211 may be connected to one or more second supply stations 1214 for supplying optical devices. For example, each of the one or more second supply stations 1214 may store a plurality of waveguides. For example, the one or more second supply stations 1214 may store a plurality of trays each containing one or more waveguides. In the exemplary embodiment of FIG. 7, one second supply station 1214 is shown. The disclosure is not limited thereto. For instance, the one or more second supply stations 1214 may include two, three or more supply stations. The number of second supply stations 1214 may depend on the number of waveguides that are to be included in each waveguide stack. The one or more second supply stations 1214 may be connected to the first transportation apparatus 201 via one or more second conveyors 1224. The one or more second conveyors 1224 may include two, three or more supply second conveyors 1224 depending on the number of waveguides that are to be included in each waveguide stack. Accordingly, the number of second conveyors 1224 may be equal to the number of second supply stations 1214. Each of the one or more second supply stations 1214 may supply waveguides to a corresponding second conveyor 1224. Each of the one or more second conveyors 1224 may be configured for conveying waveguides by side contact only.

[0047] According to embodiments, which can be combined with any embodiments, the stacking module 211 may be connected to a third supply station 1216 for supplying optical devices. For example, the third supply station 1216 may store a plurality of cover glasses. For example, the third supply station 1216

may store a plurality of trays each containing one or more cover glasses. Each cover glass supplied by the third supply station 1216 may serve as a top cover glass of a waveguide stack. The third supply station 1216 may supply cover glasses to a third conveyor 1226. The third conveyor 1226 may be configured for conveying the cover glasses by side contact only. Typically, the third conveyor 1226 is configured for providing the cover glasses to the first transportation apparatus 201 as described herein.

[0048] With exemplary reference to FIG. 7, it is to be understood that the first conveyor 1222, the one or more second conveyors 1224, and the third conveyor 1226 may be linked to the first transportation apparatus 201. Accordingly, the first transportation apparatus 201 can be configured to receive cover glasses from the first conveyor and the second conveyor and waveguides from the one or more supply second conveyors 1224. The first transportation apparatus 201 may be configured for conveying the cover glasses and waveguides by side contact only. For example, the first transportation apparatus 201 may be configured for conveying the cover glasses and the waveguides to a pick-up terminal 1232 provided in the stacking module 211. Typically, the pick-up terminal 1232 is adjacent to a positioning device 500. Typically, the positioning device 500 includes a gripper 510.

[0049] The gripper 510 may include a contactless suspension unit 511 that may be mounted to, or supported by, a gripper body. A contactless suspension unit 510 may be configured for contactlessly suspending the optical device 10. The term “contactlessly suspending” can be understood in the sense that the optical device is suspended, or levitated, in a floating state, wherein the contactless suspension unit does not include a mechanical support carrying the weight of the optical device by means of contact between the mechanical support and the optical device. While the optical device is contactlessly suspended by the contactless suspension unit, it may be the case that there is no contact between the optical device and the contactless suspension unit. The contactless suspension unit may exert a contactless action on the optical device that holds the optical device at a predetermined distance from the contactless suspension unit, for example a predetermined distance in a direction perpendicular to the first major surface or second major surface of the optical device. The predetermined distance may be adjustable by controlling a magnitude of a

contactless force exerted by the contactless suspension unit on the optical device. A contactless suspension unit may, for example, include an ultrasonic vibration generator, as described for the conveyor 1300 with reference to FIGS. 8 to 10 in the following. In the gripper 511, particularly the contactless suspension unit of the gripper may act on the optical device 10 from above the optical device 10.

[0050] It is to be understood that the positioning device may be configured for picking up cover glasses and waveguides from the first transportation apparatus 210 at the pick-up terminal 1232. Accordingly, the positioning device 500 may be a pick-and-place device. The positioning device 500 may include an arm 530 connected to the gripper 510, for example at an end of the arm 530. The positioning device 500 may include an actuator arrangement (not shown) including one or more actuators, e.g. motors, for moving and positioning the gripper 510. Using the actuator arrangement, at least one of an upward movement, a downward movement, a horizontal movement and an angular movement of the gripper may be provided. Accordingly, the gripper 510 can be configured for holding an optical device 10 at a tilting angle.

[0051] For example, the gripper 510 may place cover glasses and waveguides on support surfaces of a rotary support 810 in a first processing location for forming waveguide stacks, in collaboration with a further positioning device 844 that provides adhesives in a second processing location. The rotary support 810 may alternate between a first rotational position and a second rotational position. In a first rotational position of the rotary support 810, a first support surface 852 of the rotary support 810 may be arranged in the first processing location P_1 and, at the same time, a second support surface 854 of the rotary support 810 may be arranged in the second processing location P_2 . By rotating the rotary support, e.g. over an angle of about 180 degrees with respect to the first rotational position, the positions of the first support surface 852 and the second support surface 854 may be reversed. In a second rotational position of the rotary support 810, the first support surface 852 may be arranged in the second processing location P_2 and, at the same time, the second support surface 854 may be arranged in the first processing location P_1 . As exemplarily shown in FIG. 7, a fourth conveyor 842 configured for transporting adhesives, such as PSAs, can be provided. For example, each adhesive may be

supported by a carrier, such as a carrier sheet. The carrier with the adhesive attached thereto may be conveyed by the fourth conveyor 842.

[0052] With exemplary reference to FIG. 7, a transfer apparatus 230 for transferring the optical devices 10 from the stacking module 211 to the second transportation apparatus 202 can be provided. In particular, the transfer apparatus 230 can be a pick-and-place device for handling waveguide stacks. For example, the transfer apparatus 230 can include a Bernoulli gripper. The transfer apparatus 230 may pick up the waveguide stacks from the rotary support 810 and may place the waveguide stacks on the second transportation apparatus 202 as described herein. According to embodiments, which can be combined with any other embodiments described herein, the transfer apparatus 230 comprises a suction holder 231 for fastening an optical device, as exemplarily described with reference to FIG. 13 in the following.

[0053] Fig. 8 shows a conveyor 1300 according to embodiments described herein. The conveyor 1300 may be configured for a transportation of an optical device 10 by side contact only.

[0054] Typically, the two major surfaces 10M of the optical device 10 are not contacted by the conveyor 1300 during transportation of the optical device. The conveyor 1300 may include a contactless suspension unit for contactlessly suspending the optical device 10. The contactless suspension unit of the conveyor 1300 may include an ultrasonic vibration generator. The ultrasonic vibration generator may include a sonotrode 1314. The sonotrode 1314 may be mounted to a body portion 1302 of the conveyor 1300. Ultrasonic vibrations provided by the sonotrode 1314 may result in a repulsive contactless force pushing the optical device away from the sonotrode 1314. The ultrasonic vibration generator may include a resonating element 1312, such as a resonating plate, that may be connected to the sonotrode 1314. The resonating element 1312 may have a flat surface arranged for facing the optical device 10 that is supported by the conveyor 1300. The resonating element 1312 may be configured for transmitting the ultrasonic vibrations created by the sonotrode 1314 to an optical device receiving area of the conveyor 1300.

[0055] In the conveyor 1300, the contactless suspension unit may act on the optical device 10 from below the optical device. The sonotrode 1314 and/or the resonating element 1312 may be disposed below an optical device receiving area of the conveyor 1300. The repulsive force provided by the ultrasonic vibration generator may be an upward force.

[0056] By the combination of the repulsive upward contactless force provided by the ultrasonic vibration generator of the conveyor 1300 and the downward action of gravity on the optical device 10 (i.e. the weight of the optical device), a contactless suspension of the optical device can be provided. Due to the upward repulsive contactless force provided by the ultrasonic vibration generator, an air cushion is created, preventing the optical device, that is forced downwards by the action of gravity, from contacting the ultrasonic vibration generator. The optical device 10 may be maintained in a floating state without there being contact between the optical device 10 and the contactless suspension unit. The vertical position of the suspended optical device (e.g. the distance between the optical device and the resonating element 1312) can be adjusted by controlling the magnitude of the repulsive contactless force exerted by the ultrasonic vibration generator, particularly by controlling the magnitude of the ultrasonic vibrations generated by the sonotrode 1314.

[0057] According to some embodiments described herein, the contactless suspension unit of the conveyor 1300 may include a suction circuit, such as a vacuum circuit (not shown in Fig. 8). The suction circuit may be disposed, for example, in the resonating element 1312. The suction circuit may be configured for providing a suction force, or negative pressure, to attract the optical device towards the body portion 1302. The suction force may be a downward contactless force acting on the optical device. The suction force may help to further compensate (in addition to the weight of the optical device 10) the upward repulsive force provided by the ultrasonic vibration generator. By controlling the suction force, the distance of the optical device 10 with respect to the body portion 1302 can be further controlled.

[0058] The conveyor 1300 may be configured for providing the suspended optical device 10 at a tilting angle 1320 with respect to a horizontal plane. This may

be achieved by arranging the contactless suspension unit, and possibly the body portion 1302, of the conveyor 1300 in an inclined orientation, as shown in FIG. 8. The tilting angle 1320 may be 15 degrees or less, 10 degrees or less, or 5 degrees or less. For example, the tilting angle 1320 may be about 2-5 degrees.

5 [0059] However, it is to be understood that according to an alternative embodiment (not explicitly shown), the conveyor 1300 may be configured for providing the suspended optical device 10 at a tilting angle with respect to a vertical plane. This may be achieved by arranging the contactless suspension unit of the conveyor 1300 in different inclined orientations, particularly a vertically inclined
10 orientation, having an inclination angle α with respect to the vertical direction. It is to be understood that the vertical direction is defined by the vector of gravity. For instance, the inclination angle α can be selected from a range of $0^\circ < \alpha < 75^\circ$, particularly $0^\circ \leq \alpha < 45^\circ$, more particularly $2^\circ \leq \alpha \leq 30^\circ$. For example, the inclination angle α may be about 5-15 degrees.

15 [0060] The tilting angle 1320 may be an adjustable angle. The conveyor 1300 may be movable from a horizontal, or non-tilted, orientation to a tilted orientation at the tilting angle 1320. For example, the conveyor 1300 may include one or more actuators for adjusting the tilting angle 1320 and/or for moving the conveyor from a horizontal orientation to a tilted orientation, e.g. by moving the body portion 1302
20 or a portion thereof over an angle. The actuator may be connected to a controller, so that the magnitude of the tilting angle 1320 may be controlled. In other implementations, the tilting angle 1320 may be adjusted manually. Alternatively, the tilting angle 1320 may be a fixed angle. The tilted orientation of the conveyor 1300 may be stationary, i.e. non-adjustable.

25 [0061] As exemplarily shown in FIG. 8, the conveyor 1300 may include one or more side supports 1340, which may be mounted to the body portion 1302 and/or may be coupled to the contactless suspension unit of the conveyor 1300. The one or more side supports 1340 may be adjacent to an optical device receiving area of the conveyor 1300, i.e. adjacent to the suspended optical device 10. The one or more
30 side supports 1340 may be a single side support or a plurality of side supports. Due to the tilted orientation of the suspended optical device 10, gravity acting on the

optical device 10 causes the optical device 10 to move downwards along the tilted plane of the optical device 10. The one or more side supports 1340 support a side surface 10S of the tilted optical device 10, so that a downwards movement of the optical device 10 due to the action of gravity is prevented. The one or more side supports 1340 may be arranged for securing, or fixing, a position of the side surface 10S of the optical device 10. The side surface 10S of the tilted optical device 10 may abut against the one or more side supports 1340. Due to the action of gravity acting on the tilted optical device 10, the side surface 10S may remain in a position abutted against the one or more side supports 1340.

10 [0062] The conveyor 1300 may be configured to transport the optical device 10 in a transport direction. The transport direction may be a horizontal direction. The transport direction may be defined by a length of the conveyor 1300. In FIG. 8, the transport direction may be perpendicular to the drawing plane.

15 [0063] Typically, the conveyor 1300 includes a plurality of contactless suspension units. Each contactless suspension unit may include a sonotrode 1314 and resonating element 1312. The plurality of contactless suspension units may be arranged according to a linear arrangement extending in the transport direction of the conveyor 1300.

20 [0064] FIG. 9 shows a top view of a conveyor 1300 according to embodiments described herein. The conveyor 1300 may include a conveyor belt 1410. The conveyor belt 1410 may be an endless conveyor belt. The conveyor belt 1410 may extend in the transport direction of the conveyor 1300. The transport direction is indicated in FIG. 9 by arrow 1450. The conveyor belt 1410 may be configured for transporting an optical device 10 in the transport direction while the optical device is held in a floating state using a contactless suspension unit of the conveyor 1300.

25 [0065] As shown in FIG. 9, the conveyor belt 1410 may be arranged laterally with respect to an optical device receiving area of the conveyor 1300. The conveyor belt 1410 may be arranged for contacting a side surface 10S of an optical device 10 transported by the conveyor 1300. The conveyor belt 1410 may include a plurality of protrusions 1420, e.g. 10 or more, or 30 or more protrusions. The protrusions 1420 may protrude from the conveyor belt 1410 in a direction transversal to, particularly

perpendicular to, the transport direction. Each protrusion 1420 may be a side support 1340 of the conveyor 1300, as described herein. Each protrusion 1420 may be configured for supporting a side surface 10S of an optical device 10 that is held in a floating state using a contactless suspension unit of the conveyor 1300, particularly an optical device 10 that is held at a tilting angle 1320.

[0066] In operation, the protrusions 1420 move in the transport direction of the conveyor 1300 owing to the motion of the conveyor belt 1410. While an optical device 10 is held in a floating state using one or more contactless suspension units of the conveyor 1300 (particularly in a tilted orientation as described herein), a static friction between the side surface 10S of the optical device 10 and the protrusion(s) 1420 supporting said side surface 10S may result in a movement of the optical device 10 in the transport direction. The optical device 10 may be transported by the conveyor 1300 due to friction between the optical device and one or more protrusions 1420. During transportation, the major surfaces of the optical device 10 are not contacted.

[0067] The protrusions 1420 may be beneficial, for example, for supporting an optical device 10 having a curved side surface 10S, as shown in FIG. 9.

[0068] The conveyor belt 1410 is not limited to a conveyor belt including the protrusions 1420. The protrusions 1420 may be omitted. In some embodiments, the conveyor belt 1410 may have a flat side surface that directly contacts a side surface 10S of an optical device 10, resulting in a transportation of the optical device 10 due to static friction between the flat side surface of the conveyor belt 1410 and the optical device 10, analogous to the function of the protrusions 1420. In such embodiments, portions of the side surface of the conveyor belt 1410 may correspond to the side supports 1340 as described herein.

[0069] During the movement of the optical device 10 in the transport direction, the contactless suspension unit(s) of the conveyor 1300 may be stationary. During transportation of an optical device, the optical device may be transferred from one contactless suspension unit to the next. The optical device may remain in a suspended state during transportation due to the action of one or more contactless suspension units that are stationary.

[0070] In light of the above, the conveyor 1300 may be configured for transporting an optical device 10 by side contact only. The optical device 10 is maintained at a tilting angle by the contactless suspension unit(s) of the conveyor 1300, and the movement of the optical device 10 in the transportation direction is caused by friction between the side surface 10S of the optical device 10 and the conveyor belt 1410, either directly or via the protrusions 1420. The two major surfaces of the optical device 10 are not contacted during transportation.

[0071] With exemplary reference to FIG. 10, the conveyor 1300 may have an alternative configuration. The conveyor shown in FIG. 10 may include any of the features discussed in relation to the conveyor as described with reference to FIGS. 8 and 9, and the discussion of said features will not be repeated here.

[0072] A difference between the conveyor of FIG. 10 and the conveyor of FIGS. 8 and 9 is that in the case of the former conveyor, the contactless suspension unit may act on the optical device 10 from above the optical device 10. The sonotrode 1314 and/or the resonating element 1312 may be disposed above an optical device receiving area of the conveyor 1300. The repulsive force provided by the ultrasonic vibration generator may be a downward force. With exemplary reference to FIG. 10, the contactless suspension unit of the conveyor 1300 may include a suction circuit 1550, such as a vacuum circuit. The suction circuit may be provided, for example, in the resonating element 1312. The suction circuit may be configured for providing a suction force, or negative pressure, to attract the optical device 10 towards the resonating element 1312 and/or body portion 1302. The suction force may be an upward contactless force acting on the optical device 10. Due to the repulsive contactless force acting on the optical device 10 by means of the ultrasonic vibration generator, an air cushion is created between the resonating element 1312 and the optical device 10, preventing the optical device 10 that is attracted by the suctioning force from contacting the ultrasonic vibration generator. By means of the combination of the repulsive downward contactless force provided by the ultrasonic vibration generator and the attractive upward contactless force provided by the suction circuit 1550, a contactless suspension of the optical device 10 can be provided. The distance between the optical device 10 and the resonating element 1312 can be adjusted by controlling the magnitude of the

repulsive contactless force exerted by the ultrasonic vibration generator, and/or by controlling the magnitude of the suctioning force provided by the suction circuit.

[0073] According to embodiments which can be combined with any other embodiment described herein, the conveyor 1300 may include a Bernoulli portion 1560 functioning as a Bernoulli gripper for picking up the optical device 10 without contacting the major surfaces of the optical device 10, and possibly even without contacting the optical device at all. The Bernoulli portion 1560 may be included in the resonating element 1312. After being picked up, the optical device 10 may be transported by the conveyor 1300. During transportation, one or more contactless suspension units of the conveyor 1300 act on the optical device 10 from above the optical device 10. At a location where two conveyors meet, the optical device 10 may be transferred from one conveyor to another conveyor.

[0074] With exemplary reference to FIG. 10, according to embodiments which can be combined with any other embodiment described herein, the conveyor 1300 may include a pressurized air outlet 1570 for transferring the optical device 10 from one conveyor to another conveyor without contacting the major surfaces of the optical device, and possibly without contacting the optical device at all.

[0075] Embodiments described above involve conveyors that are configured to transport an optical device, such as a waveguide, in a tilted orientation. Such a tilted orientation is particularly beneficial, for example, when the conveyors are used in conjunction with a gripper that holds optical devices in a tilted orientation. According to other embodiments, a conveyor may be provided that transports the waveguide without contacting the major surfaces thereof, while not necessarily holding the waveguide at a tilting angle. For example, the conveyor may hold the waveguide in a horizontal orientation. Apart from the absence of a tilting angle, the conveyor may have a similar design as described with reference to FIGS. 8 to 10. Particularly, the waveguide may be provided in a suspended state by contactless suspension device(s), e.g. in a horizontal orientation of the waveguide. If there is no tilting angle, gravity may not cause the waveguide to abut against the one or more side supports 1340, and the transportation of the waveguide may not operate on the basis of static friction between the side supports 1340 and the waveguide. Instead, a

set of side supports surrounding the waveguide may be provided, so that the position of the waveguide is contained within an area defined by said set of side supports. The set of side supports may be moveable in the transport direction, and the waveguide may be transported together with the side supports. For example, as the side supports move in the transport direction, at least some of the side supports may push horizontally against a side surface of the waveguide, resulting in a transportation of the waveguide by the conveyor.

[0076] It is to be understood that one or more of the first transportation apparatus 201, the second transportation apparatus 202, the third transportation apparatus 203, the first conveyor 1222, the second conveyor 1224, and the third conveyor 1226 can be a conveyor 1300 as described with reference to FIGS. 8, 9 and 10.

[0077] Accordingly, according to embodiments which can be combined with any other embodiments described herein, the first transportation apparatus 201 includes a contactless suspension unit for contactlessly suspending the optical device. The contactless suspension unit may be configured as described with reference to the conveyor 1300 of FIGS. 8, 9 and 10.

[0078] According to embodiments, which can be combined with any other embodiments described herein, the first transportation apparatus 201 is configured for transporting the optical devices 10 at a first orientation O_1 . Further, at least one of the one or more further processing modules 220 can be configured for processing the optical devices 10 at a second orientation O_2 different from the first orientation O_1 . For example, the first orientation O_1 can be a substantially horizontal orientation within a tolerance T of $T \leq \pm 15^\circ$, particularly $T \leq \pm 10^\circ$. The second orientation O_2 can be a substantially vertical orientation within a tolerance T of $T \leq \pm 15^\circ$, particularly $T \leq \pm 10^\circ$.

[0079] With exemplary reference to FIG. 11, an exemplary configuration of the one or more further processing modules 220 is described. The one or more further processing modules 220 may include one or more of processing modules selected from the group consisting of a coating module, an edge blackening module, a module for treating a coating, a testing module, and a packaging module. A coating module

can be understood as a processing module configured for providing a coating on one or more surfaces of an optical device as described herein. An edge blackening module can be understood as a processing module configured for providing coating of optically absorbent material on an edge of an optical device as described herein.

5 A module for treating a coating can be understood as a processing module configured for curing and/or drying a coating provided on an optical device as described herein. A testing module can be understood as a module configured for measuring optical performance characteristics of an optical device as described herein. A packaging module can be understood as a processing module configured for packaging an
10 optical device as described herein. In particular, the packaging module can be configured for individually packing optical devices in individual vacuum sealed packages.

[0080] As exemplarily shown in FIG. 11, according to embodiments which can be combined with any other embodiments described herein, at least one of the one
15 or more further processing modules 220 include a processing transport apparatus 225. The processing transport apparatus 225 can be configured for individually transporting the optical devices 10 along a processing path 222, particularly a circular processing path. For instance, the processing transport apparatus 225 may include a rotary table having one or more supports 226 configured
20 for individually supporting one or more optical devices 10 as described herein. Further, as schematically shown in FIG. 11, one or more processing stations 224 can be provided along the processing path 222. It is to be understood that the processing stations 224 may be selected according to the process to be carried out by the respective processing module. Accordingly, the processing stations 224 may include
25 one or more coating stations, one or more an edge blackening stations, one or more coating treatment stations, one or more testing stations, and one or more packaging stations.

[0081] With exemplary reference to FIG. 11, according to embodiments which can be combined with any other embodiments described herein, the one or more
30 further processing modules 220 include a loading/unloading apparatus 240 configured for transferring the optical devices 10 from the second transportation apparatus 202 to the processing transport apparatus 225 and vice versa. Typically,

the loading/unloading apparatus 240 is arranged between the second transportation apparatus 202 and the processing transport apparatus 225, as exemplarily shown in FIG. 11. For instance, the loading/unloading apparatus 240 may include a gripper 241 configured for removing an optical device from the second transportation apparatus 202 and arranging the optical device on a support 226 of the processing transport apparatus 225. The gripper 241 can be coupled to a robot 242, particularly a selective compliance assembly robot arm (SCARA) or a cartesian robot.

[0082] With exemplary reference to FIG. 12, exemplary embodiments of the second transportation apparatus 202 according to the present disclosure are described.

[0083] According to embodiments, which can be combined with any other embodiments described herein, the second transportation apparatus 202 includes one or more sleds 20 for individually moving the optical devices 10 to the one or more further processing modules 220. Typically, the one or more sleds 20 are movable along a rail 23. As exemplarily shown in FIG. 12, the transfer apparatus 230 can be coupled to the second transportation apparatus 202, particularly to the one or more sleds 20. For instance, the transfer apparatus 230 can be coupled to the second transportation apparatus 202 via a movable shuttle 21. Typically, as indicated by the double-sided arrow 22, the movable shuttle 21 is movable in a cross-direction with respect to a transport direction T for transporting the optical devices 10 to the one or more further processing modules 220. In particular, the cross-direction is perpendicular to the transport direction T.

[0084] Typically, the transfer apparatus 230 includes a suction holder 231 which is exemplarily shown in FIG. 13. The suction holder 231 is configured for fastening an individual optical device 10 as described herein. As exemplarily indicated by arrow 22 in FIG. 12, the suction holder 231 may be pivotable. Accordingly, the transfer apparatus 230 can be configured for picking up and providing optical devices at different orientations. FIG. 12 shows an example wherein an optical device 10 is picked up from a rotary support 810 at a horizontal orientation and which is to be transported to another processing transport apparatus 225 being configured as a

rotary support having a vertical support 226 to which the optical device is to be handed over. However, it is to be understood that the pick-up orientation and the hand-over orientation can be different from the exemplary orientation shown in FIG. 12

5 [0085] According to embodiments, which can be combined with any other embodiments described herein, the suction holder 231 includes an air permeable material 232 configured to be in contact with the optical device 10. In some
10 embodiments, the air permeable material 232 may include at least one material selected from the group consisting of paper, textile, perforated polymeric film, and foam. According to the present disclosure, any material that allows air to pass through and is suitable for usage with an optical device 10 can be an air permeable material 232 as described herein. In particular, any material that allows air to pass through and being soft for the use with an optical device, i.e., preventing damage such as scratches on the optical device, is an air permeable material as described
15 herein.

[0086] For example, the air permeable material 232 may be a cleanroom paper, e.g., a low particulate cleanroom paper. In some embodiments, the air permeable material 232 may be a cleanroom textile. The use of cleanroom paper or cleanroom textile prevents contamination of the optical device 10 with particles.

20 [0087] The air permeable material 232 prevents direct contact between the suction holder 231, particularly a suction plate 233 of the suction holder 231, and the optical device 10. Accordingly, beneficially the optical device 10 is not damaged due to manipulation with the suction holder 231 during the handling of the optical device 10. Further, since the air permeable material 232 may be made of a material
25 selected from the group consisting of paper, textile, perforated polymeric film, and foam, the air permeable material 232 may be a soft material that prevents damage to the surface of the optical device 10. Furthermore, since the air permeable material 232 allows air to pass through, the suction force provided by suction holder 231, particularly by one or more through-holes 234 of the suction plate 233
30 and/or the at least one vacuum supply, acts upon the optical device 10, i.e., not only

the air permeable material 232 but also the optical device 10 can be fastened by providing the appropriate suction force.

[0088] Accordingly, typically the suction holder 231 includes a suction plate 233. The suction plate 233 includes a surface 235 configured to indirectly
5 contact the optical device 10 through the air permeable material 232. Furthermore, the suction plate 233 includes one or more through-holes 234. Although FIG. 13 shows a suction plate 233 having a circular shape, the suction plate 233 may have any shape such as a round shape or polygonal shape. Typically, the suction holder 231 further includes one or more vacuum channels 236 connected at one end
10 to at least one vacuum supply (not shown) and at the other end with the one or more through-holes 234. For the sake of simplicity, FIG. 13 shows only two of the one or more vacuum channels 236 as an example. In addition, the one or more through-holes 234 and/or the at least one vacuum supply can be configured to provide at least one suction force at the surface 235 of the suction plate 233. The surface 235 of the
15 suction plate 233 may be smaller than any of the first major surface and the second major surface of the optical device 10. In this manner, the suction holder 231 can be a universal one-size-fit-all end-effector, i.e., a suction holder useful for optical devices having different sizes and shape.

[0089] In some embodiments, the suction holder 231 may further include a
20 housing 237 enclosing the one or more vacuum channels 236. However, each of the one or more vacuum channels 236 may correspond to an independent tube or pipe and the housing 237 may be omitted.

[0090] In some embodiments, the one or more through-holes 234 may have a circular cross section or a polygonal cross section. In some embodiments, a
25 maximum width of the one or more through-holes 234 can be 2 mm or less, particularly 1.5 mm or less, and particularly 0.5 mm or less.

[0091] In view of the embodiments described herein, it is to be understood that, compared to the state of the art, an improved method of handling a plurality of optical devices, an improved method of processing a plurality of optical devices, and an
30 improved processing system are provided. In particular, embodiments of the present disclosure beneficially provide for a more efficient transport and transfer of optical

devices within a processing system having various processing modules. Further, embodiments as described herein beneficially provide for the possibility of handling optical devices of different form factors without the need for adaption to the various different specific form factors. Further, embodiments of the present disclosure have the advantage that multiple optical devices can be handled simultaneously with great care in an automated manner such that high quality processing at high production rates can be achieved. Accordingly, the method of handling as described herein is particularly well suited for in-line processing systems and high-volume manufacturing, for example of eyepieces.

10 [0092] While the foregoing is directed to implementations of the present disclosure, other and further implementations of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

CLAIMS

1. A method (100) of handling a plurality of optical devices (10) in a processing system (200), comprising:
 - individually transporting (101) the optical devices (10) to a first processing module (210) without contacting a major surface of the optical devices (10) by
5 using a first transportation apparatus (201);
 - transferring (102) the optical devices (10) from the first processing module (210) to a second transportation apparatus (202) connecting one or more further processing modules (220); and
10 - individually transporting (103) the optical devices to the one or more further processing modules (220) by using the second transportation apparatus (202), wherein during handling at least two of the plurality of optical devices (10) are provided in different processing modules at the same time.
2. The method (100) of claim 1, further comprising individually transferring (104)
15 the optical devices (10) from the second transportation apparatus (202) to a processing transportation apparatus of the one or more further processing modules (220).
3. The method (100) of claim 1 or 2, further comprising individually transporting (105) the optical devices (10) along a processing path (222) within the one or
20 more further processing modules (220).
4. The method (100) of claim 3, wherein at least one processing path (222) within the one or more further processing modules (220) is a circular processing path.
5. The method (100) of any of claims 1 to 4, wherein individually transporting (101) the optical devices (10) to the first processing module (210) comprises
25 contactlessly suspending the optical devices (10).

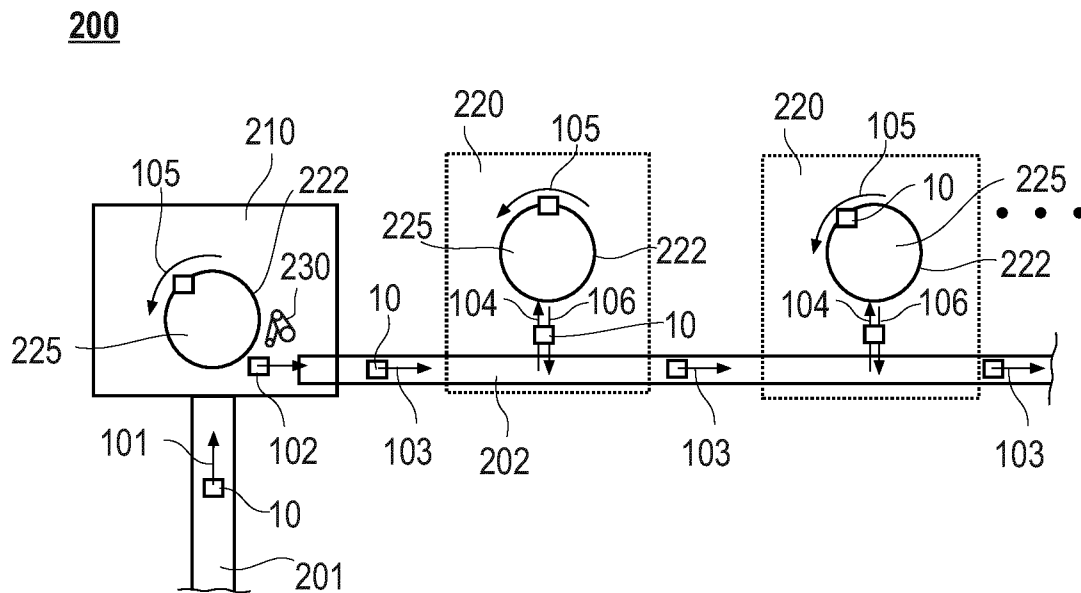
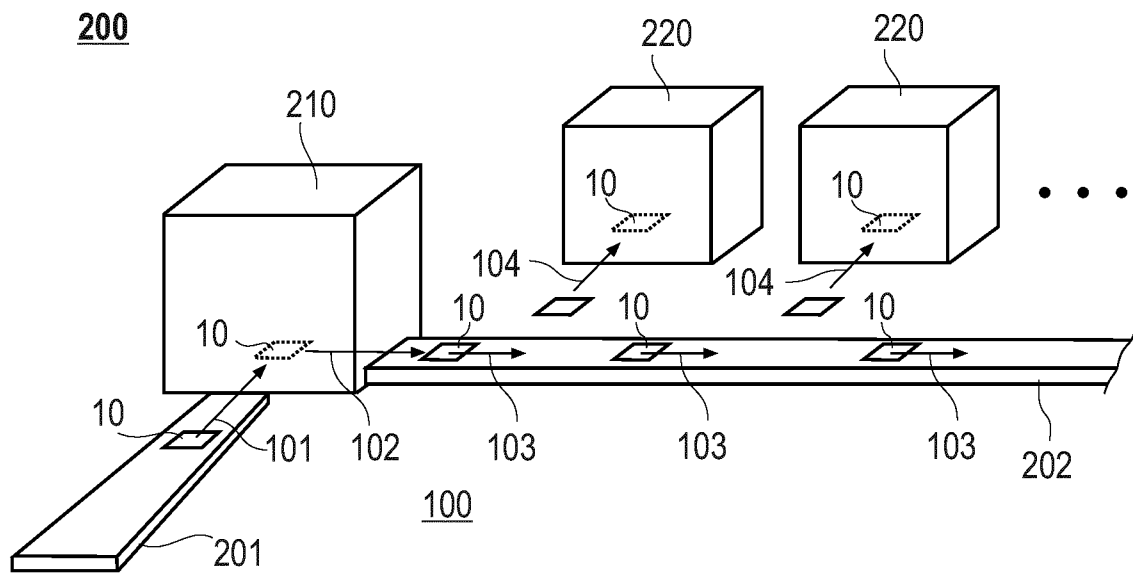
6. The method (100) of any of claims 1 to 5, wherein transferring (102) the optical devices (10) from the first processing module (210) to the second transportation apparatus (202) comprises indirectly contacting the optical device through an air permeable material.
- 5 7. The method (100) of any of claims 1 to 6, further comprising transferring (107) the optical devices (10), particularly individual packages containing the individually vacuum sealed optical devices, from the last processing module of the one or more further processing modules (220) to a third transportation apparatus (203) for individually transporting the optical devices (10), particularly
10 the individual packages, from a packaging area (40) into a logistic area (50), particularly the last processing module being a packaging module.
8. A method (300) of processing a plurality of optical devices (10) in a processing system (200), comprising:
- 15 - handling (301) the plurality of optical devices according to the method (100) of any of claims 1 to 7;
- carrying out a first processing procedure (302) of one or more individual optical devices of the plurality of optical devices in the first processing module (210); and
- 20 - carrying out one or more further processing procedures (303) of one or more individual optical devices of the plurality of optical devices in the one or more further processing modules, wherein during processing at least two of the plurality of optical devices are processed in different processing modules at the same time.
9. The method (300) of claim 8, wherein the first processing procedure comprises
25 stacking one of the plurality of optical devices with one or more further optical devices.

10. The method (300) of claim 8 or 9, wherein the one or more further processing procedures include one or more of a coating procedure, a curing procedure, a drying procedure, a testing procedure, and a packaging procedure.
11. The method (300) of any of claims 8 to 10, wherein one or more optical devices
5 from the plurality of optical devices (10) are selected from the group consisting of: a waveguide, a wave guide combiner, a flat optical device, a substrate having optical structures, a cover glass, a lens, and a stack of at least one waveguide and at least one cover glass.
12. The method (300) of any of claims 8 to 11, wherein individually transporting
10 (101) the optical devices (10) to the first processing module (210) comprises transporting the optical devices at a first orientation O_1 , wherein carrying out one or more further processing procedures (303) of one or more individual optical devices of the plurality of optical devices in the one or more further processing modules (200) comprises processing the optical devices (10) at a second
15 orientation O_2 different from the first orientation O_1 , particularly wherein the first orientation O_1 is a substantially horizontal orientation within a tolerance T of $T \leq \pm 15^\circ$, and particularly wherein the second orientation O_2 is a substantially vertical orientation within a tolerance T of $T \leq \pm 15^\circ$.
13. A processing system (200) for processing a plurality of optical devices (10),
20 comprising:
- a first transportation apparatus (201) for individually transporting the optical devices (10) without contacting a major surface (10M) of the optical devices (10);
- a first processing module (210) for carrying out a first processing procedure of one or more individual optical devices of the plurality of optical devices (10);
25 - a second transportation apparatus (202) connecting one or more further processing modules (220), the second transportation apparatus (202) being configured for individually transporting the optical devices (10);
- a transfer apparatus (230) for transferring the optical devices (10) from the first processing module (210) to the second transportation apparatus (202); and

- the one or more further processing modules (220) being configured for carrying out one or more further processing procedures of one or more individual optical devices of the plurality of optical devices.
14. The processing system (200) of claim 13, wherein the first transportation apparatus (201) comprises a contactless suspension unit for contactlessly suspending the optical device.
15. The processing system (200) of claim 13 or 14, wherein the transfer apparatus (230) comprises a suction holder for fastening an optical device, particularly the suction holder comprising an air permeable material configured to be in contact with the optical device and a suction plate including a surface configured to indirectly contact the optical device through the air permeable material.
16. The processing system (200) of any of claims 13 to 15, wherein the second transportation apparatus (202) comprises one or more sleds for individually moving the optical devices (10) to the one or more further processing modules (220).
17. The processing system of any of claims 13 to 16, wherein the transfer apparatus (230) is coupled to the second transportation apparatus (202), particularly via a movable shuttle, particularly the movable shuttle being movable in a cross-direction to a transport direction (T) for transporting the optical devices (10) to the one or more further processing modules (220).
18. The processing system of any of claims 13 to 17, wherein at least one of the one or more further processing modules (220) includes a processing transport apparatus (225) for individually transporting the optical devices (10) along a circular processing path.
19. The processing system (200) of any of claims 13 to 18, wherein the first transportation apparatus (201) is configured for transporting the optical devices (10) at a first orientation O_1 , and wherein at least one of the one or more

further processing modules (220) is configured for processing the optical devices (10) at a second orientation O_2 different from the first orientation O_1 .

20. The processing system (200) of claim 19, wherein the first orientation O_1 is a substantially horizontal orientation within a tolerance T of $T \leq \pm 15^\circ$, particularly $T \leq \pm 10^\circ$, and wherein the second orientation O_2 is a substantially vertical orientation within a tolerance T of $T \leq \pm 15^\circ$, particularly $T \leq \pm 10^\circ$.



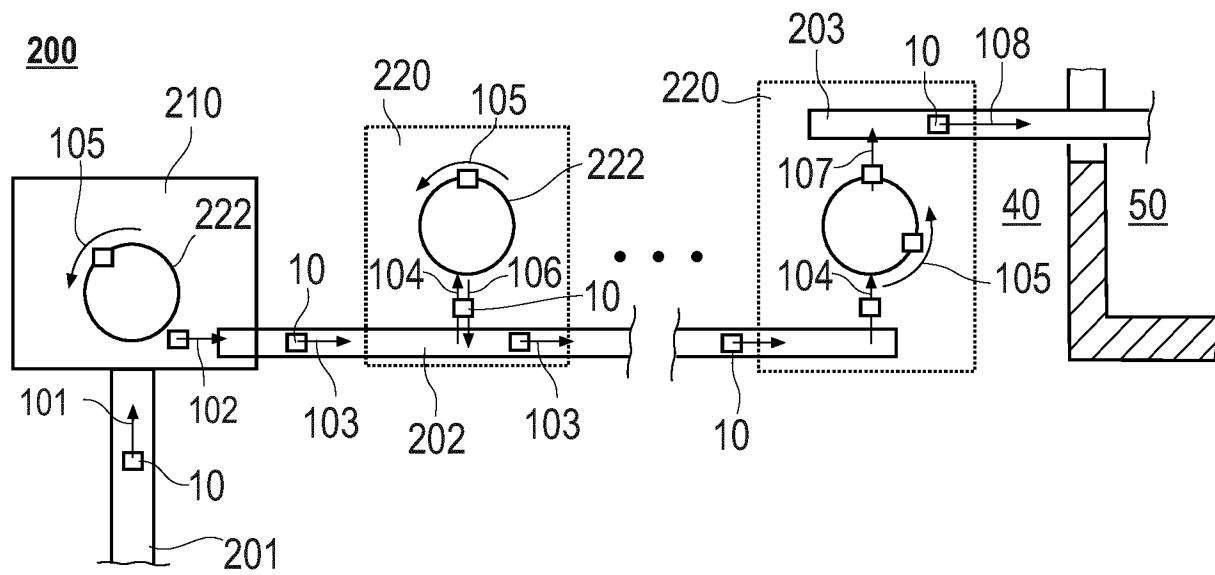


FIG. 3

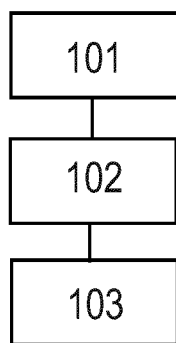
100

FIG. 4A

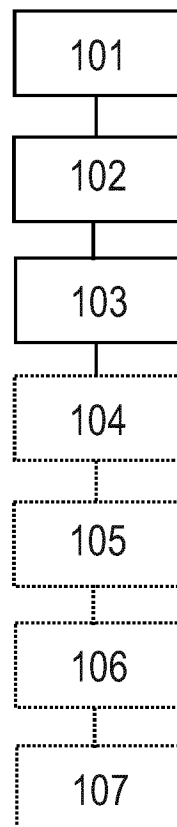
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FIG. 4B

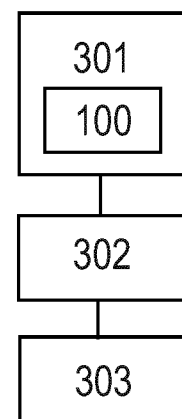
300

FIG. 4C

12

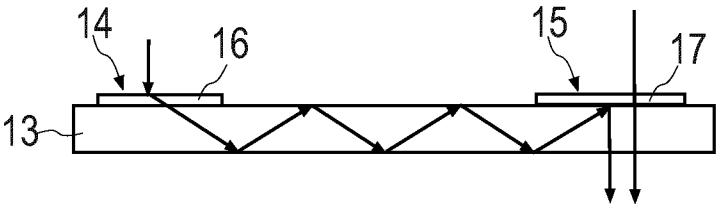


FIG. 5A

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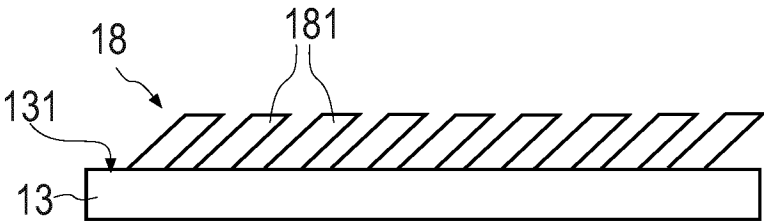


FIG. 5B

19

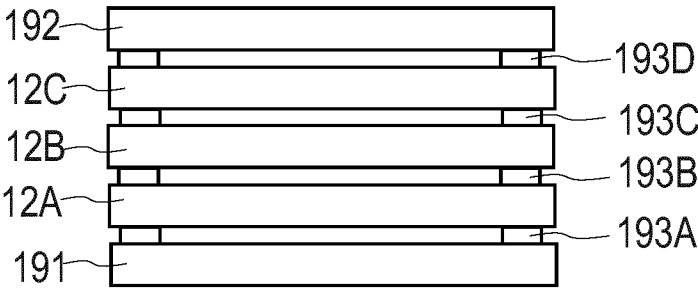


FIG. 6

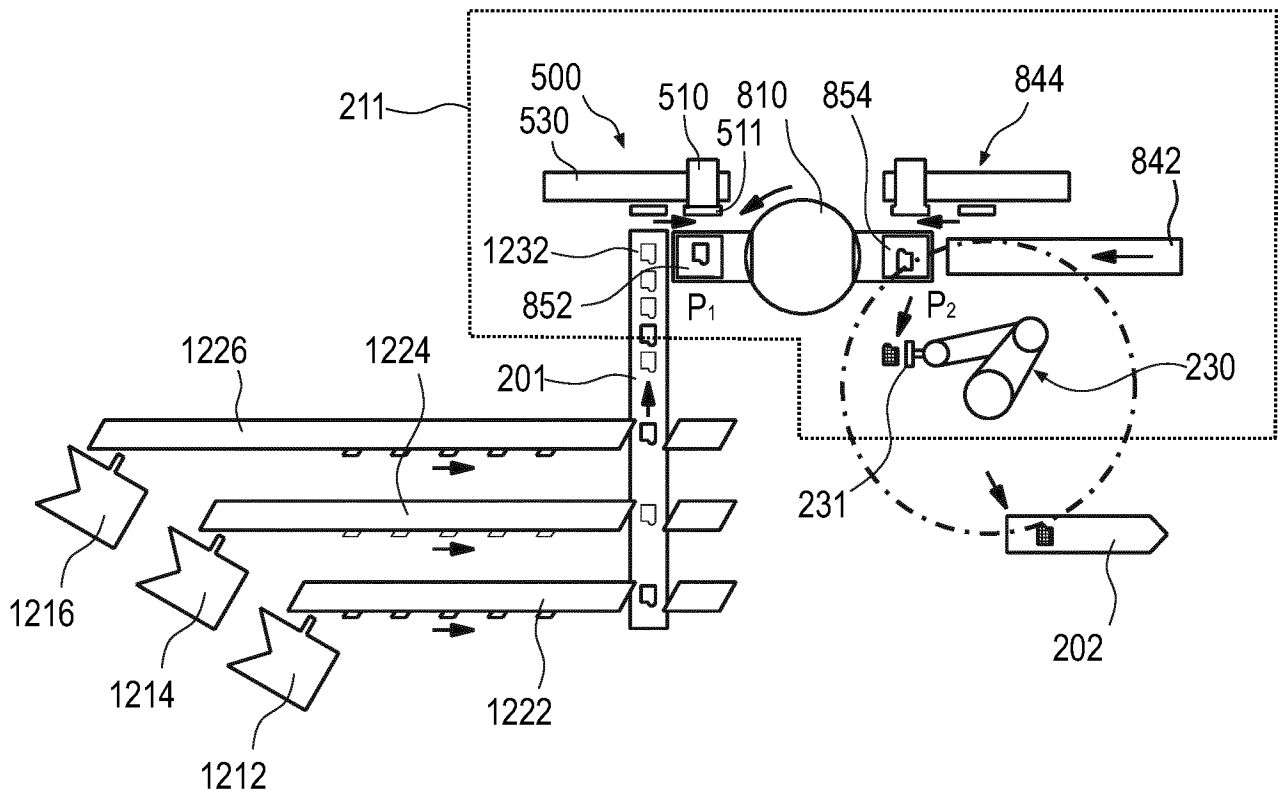


FIG. 7

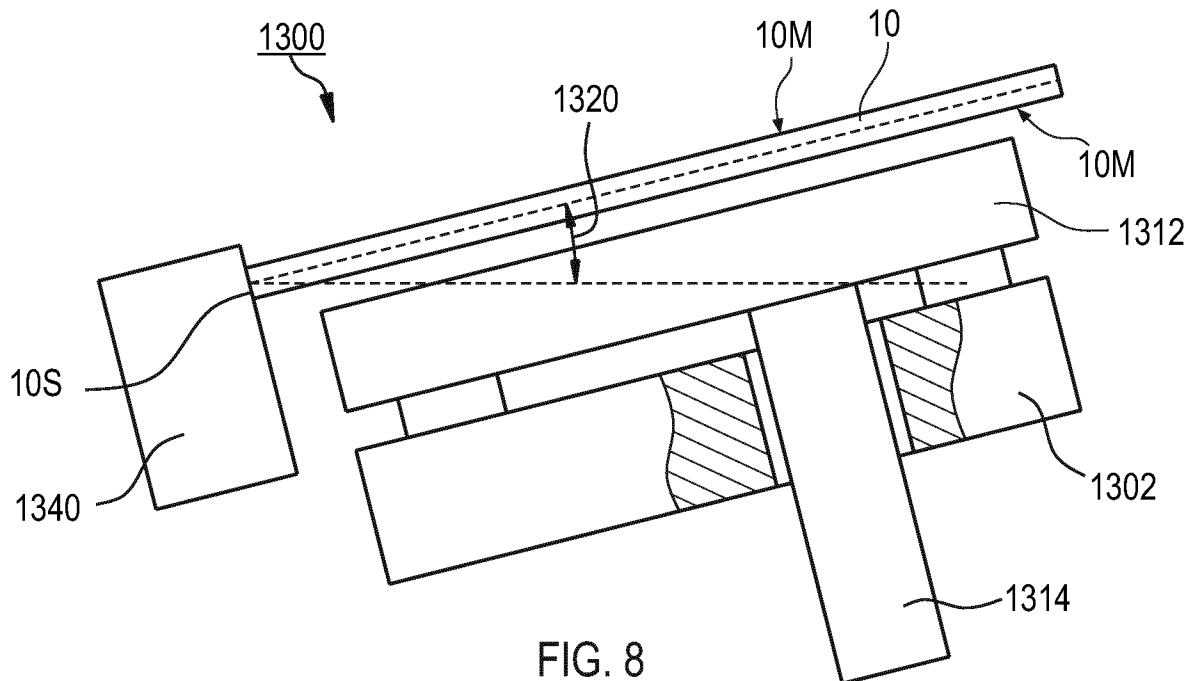


FIG. 8

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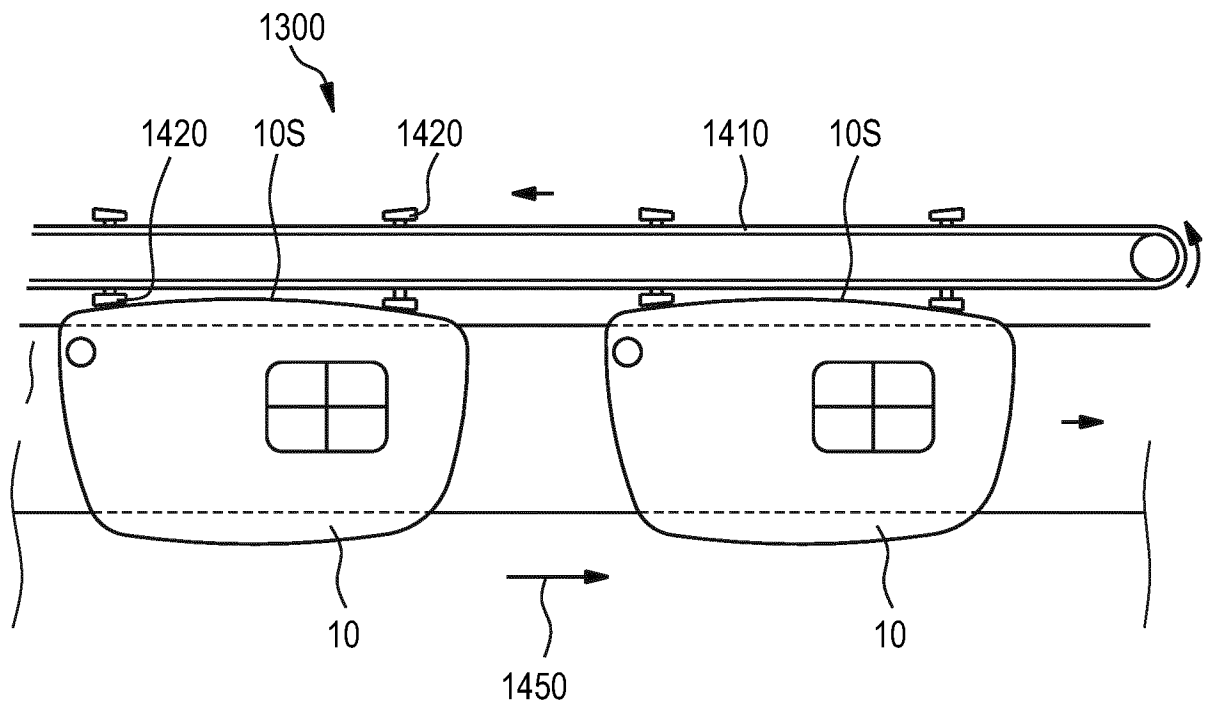


FIG. 9

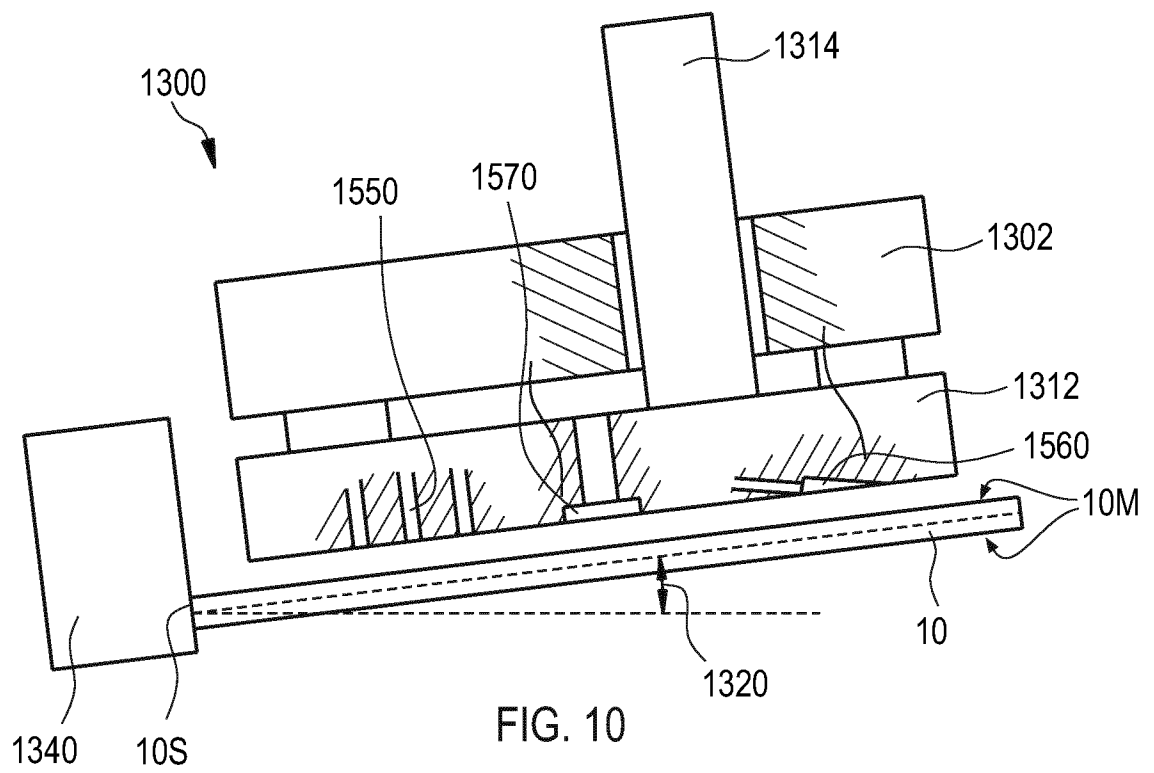


FIG. 10

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220

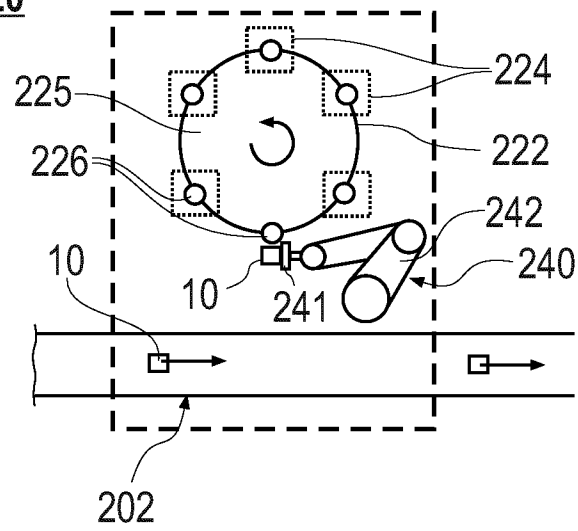


FIG. 11

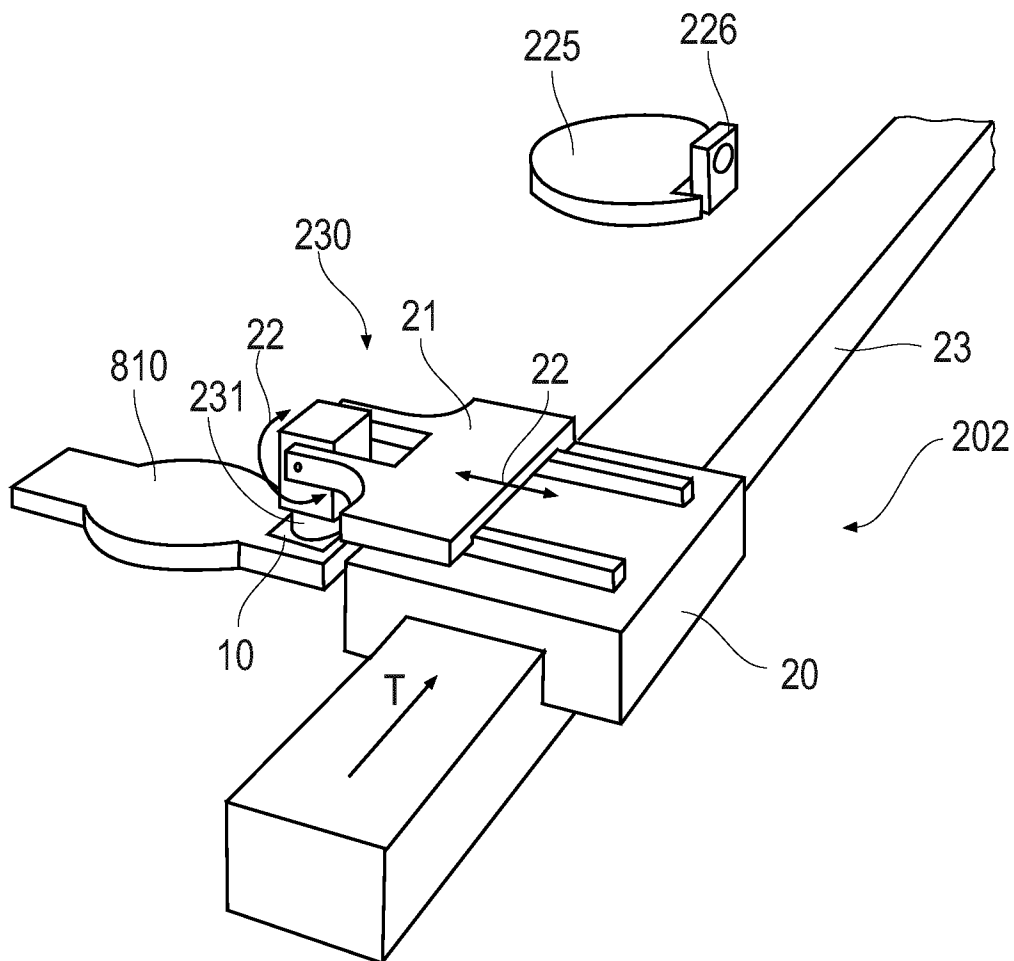


FIG. 12

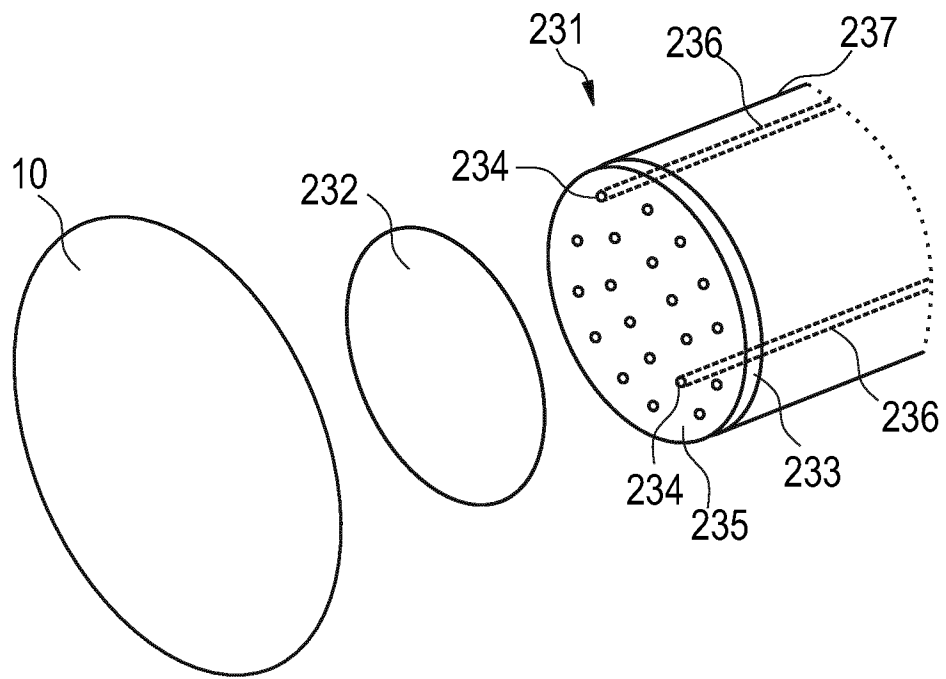


FIG. 13

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2023/052847

A. CLASSIFICATION OF SUBJECT MATTER**INV. B29D11/00****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)

B29D B65G H01L

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**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2006 176255 A (MURATA MACHINERY LTD) 6 July 2006 (2006-07-06) abstract figures 1-8 paragraphs [0018] - [0024], [0026], [0032] - [0034] -----	1-20
A	US 2019/136367 A1 (PETER MARC [CH] ET AL) 9 May 2019 (2019-05-09) abstract figures 1-3 -----	1-20
A	US 2004/070221 A1 (HOEHN MICHAEL [DE] ET AL) 15 April 2004 (2004-04-15) abstract figures 1-8 ----- -/-	1-20



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See patent family annex.

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Date of the actual completion of the international search

22 August 2023

Date of mailing of the international search report

30/08/2023

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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