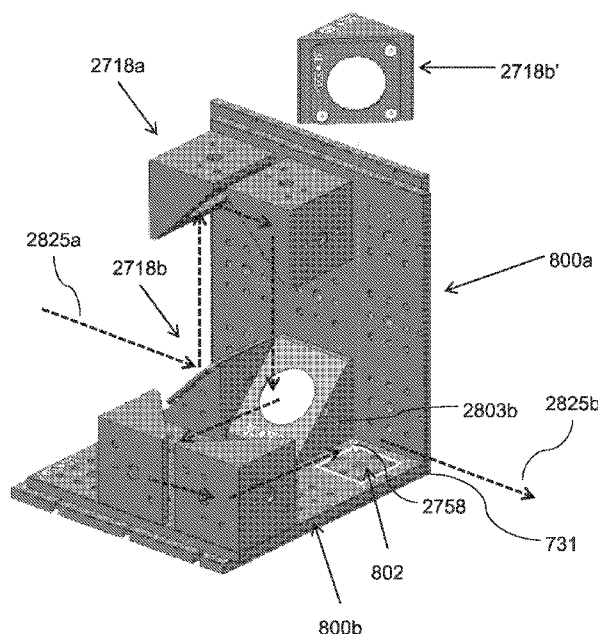




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- (71) Applicant: RAMOT AT TEL-AVIV UNIVERSITY LTD. [IL/IL]; P.O. Box 39296, 6139201 Tel-Aviv (IL).
- (72) Inventors: SUCHOWSKI, Haim; 17 Marva Street, 7685400 Kfar Mordechai (IL). LEVANON, Assaf; 7 Gershon Shershavski Street, 7680400 Mazkeret Batia (IL).
- (74) Agent: G. E. EHRLICH (1995) LTD. et al.; 11 Menachem Begin Road, 5268104 Ramat Gan (IL).
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FIG. 28



(57) Abstract: An optical setup, comprising one or more platforms having a plurality of fixation locations repeatedly arranged, and defining a discrete position coordinate system; and a plurality of modular optical units, each comprising an optical portion defining an optical axis fixedly attached to at least one mounting surface comprising complementary geometry to the fixation locations; wherein a releasable attachment of the plurality of modular optical units at the fixation locations defines a plurality of optical axes at least a portion of the optical axes overlapping across the discrete position coordinate system. In some embodiments, the modular optical units include standard optical elements. In some embodiments, the platform includes an attachment interface to an optical table and/or another platform. In some embodiments, laser pulses are synchronized by fixing a discrete path length over the fixation locations. In some embodiments the fixation locations are located on multiple planes in 3D space.



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## 3D MODULAR OPTICS FOR 3D OPTICAL ALIGNMENTS

RELATED APPLICATIONS

5           This application claims the benefit of priority under 35 USC §119(e) of U.S. Provisional Patent Application No. 62/427,194 filed 29 November 2016 and U.S. Provisional Patent Application No. 62/563,757 filed 27 September 2017, the contents of which are incorporated herein by reference in their entirety.

10 FIELD AND BACKGROUND OF THE INVENTION

The present invention, in some embodiments thereof, relates to an optical setup and, more particularly, but not exclusively, to a modular three-dimensional optical setup.

U.S. Patent No. US 5,825,558 discloses a three-dimensional Universal Mounting Component (UMC) system of UMC blocks provides general mounting for use in optical research  
15 in constructing layouts for experiments and breadboard-type prototypes. In such optical layouts laser beams or other light beams are directed about complex paths, often on several planes or levels. Use of the invention overcomes the problem of creating three-dimensional optical layouts with less standardized, and much more expensive, mounting adapters and posts. An economical, standardized set of UMC blocks, each with a number of holes in grid configurations, enables  
20 users to construct custom three-dimensional optical layouts.

U.S. Published Patent Application 2016/0033075 appears to disclose “kits for constructing an apparatus” ... “which, in some embodiments, can demonstrate desirable modularity, adjustability, and reconfigurability. A kit for constructing an apparatus described herein comprises a plurality of modular blocks and fastening sleeves, sleeve pins and coupling  
25 pins for connecting the modular blocks to one another. A modular block comprises a series of first apertures for receiving one or more of the fastening sleeves and series of second apertures for receiving the sleeve pins to secure the fastening sleeves in the first apertures, wherein the second apertures intersect the first apertures.”

U.S. Patent 5993283 appears to disclose “A modular building for a toy building set  
30 includes a planar member, or foundation, having raised ribs on its top and a wall member having a wall portion and a base portion. The wall portion of the wall member is substantially orthogonal to the base portion of the wall member. The base portion of the wall member has a cleft therein sized to receive one of the ribs of the foundation to removably attach the wall member to the foundations. A substantially planar coupler connects at least two or more of the foundation. The

coupler has at least two clefts therein. The clefts are sized to receive the ribs on each of the two foundations for removable attachment of the foundation to the coupler.

Additional background art which might be related includes Lazer Maze™ available from ThinkFun Inc. 1321 Cameron Street, Alexandria, VA 22314 USA  
5 www(dot)thinkfun(dot)com/products/laser-maze/, U.S. Patent No. 3,005,282, U.S. Patent No. 4,919,635, U.S. Patent No. 8,091,303, U.S. Patent Application No. US2005/0034413, U.S. Patent No. 8,049,881, U.S. Patent No. 8,201,370 and U.S. Patent No. 8,401,236.

### SUMMARY OF THE INVENTION

10 According to an aspect of some embodiments of the invention, there is provided a 3D optical setup, including: at least one base connected at an angle to at least one wall, each of the at least one base and at least one wall having a plurality of fixation locations repeatedly arranged, thereby defining a discrete 3D position coordinate system; a plurality of modular optical units, each including an optical portion defining an optical axis, the optical portion fixedly attached to  
15 at least one mounting surface including complementary geometry to the fixation locations; wherein a releasable attachment of some of the plurality of modular optical units at the fixation locations of the at least one base defines a first set of optical axes and a releasable attachment of some of the plurality of modular optical units at the fixation locations of the at least one wall defines a second set of optical axes; and wherein at least a portion of the first set of optical axes  
20 and at least a portion of the second set of optical axes overlap across the discrete 3D position coordinate system.

According to some embodiments of the invention, the base and the wall are fixedly connected.

25 According to some embodiments of the invention, the base and the wall are releasably connected.

According to some embodiments of the invention, the optical portion is at an angle to the mounting surface.

According to some embodiments of the invention, each of the at least one wall and at least one base comprise a first edge having complementary fitting with a second edge.

30 According to some embodiments of the invention, the complementary fitting includes at least one complementary threaded cavity in each of the first edge and the second edge.

According to some embodiments of the invention, the complementary fitting includes complementary interference fitting members.

According to some embodiments of the invention, the angle is 90 degrees.

According to some embodiments of the invention, the angle is between 45 to 90 degrees.

According to some embodiments of the invention, the angle is between 0 to 45 degrees.

According to some embodiments of the invention, the angle is between 90 to 135 degrees.

5 According to some embodiments of the invention, the angle is between 135 to 180 degrees.

According to some embodiments of the invention, the fixation locations comprise a plurality of fixation points.

According to some embodiments of the invention, the plurality of fixation points are radially symmetric.

10 According to some embodiments of the invention, the plurality of fixation points are axially symmetric.

According to some embodiments of the invention, the complementary surface of the modular optical units comprise a quadrangular shape.

15 According to some embodiments of the invention, the complementary surface of the modular optical units comprise a triangular shape.

According to some embodiments of the invention, the complementary surface of the modular optical units comprise a trapezoid shape.

According to some embodiments of the invention, the modular optical units comprise a cuboid shape.

20 According to some embodiments of the invention, at least one of the modular optical units comprises a prism shape.

According to some embodiments of the invention, the at least one unit includes a triangular face.

25 According to some embodiments of the invention, at least one face of the at least one unit is directed at 45 degrees to at least one the mounting surface of the at least one unit.

According to some embodiments of the invention, the at least one unit includes the at least one mounting surface and at least another mounting surface and wherein the at least one face is perpendicular to the at least another other mounting surface.

30 According to some embodiments of the invention, the optical portion of the at least one unit is mounted on the at least one face.

According to some embodiments of the invention, the complementary geometry connects with the fixation locations in at least one of a male-female connection, a male-male connection, a female-female connection, complementary screw holes, complementary holes for pins and a magnet.

According to some embodiments of the invention, the complementary surface fits across a plurality of the fixation locations.

According to some embodiments of the invention, the complementary surface fits across a portion of the fixation locations.

5 According to some embodiments of the invention, the setup further includes at least one ceiling, connected at a second angle to the at least one wall.

According to some embodiments of the invention, the setup further includes at least one translocator operably connected to the at least one base.

10 According to some embodiments of the invention, the attachment centers the optical element with respect to the fixation location.

According to some embodiments of the invention, the base is configured for connection to an optical table with a regular pattern of the plurality of fixation locations of the base coinciding with attachment locations of the optical table.

15 According to some embodiments of the invention, the optical set up includes 1" optical elements are 1" and a distance between fixation locations that is an integral multiple of 0.375".

According to some embodiments of the invention, the optical set up includes 1" optical elements are 1" and a distance between fixation locations that is an integral multiple of 0.333".

According to some embodiments of the invention, the optical set up includes 0.5" optical elements and a distance between fixation locations that is an integral multiple of 0.125".

20 According to some embodiments of the invention, the optical set up includes 2" optical elements and a distance between fixation locations that is an integral multiple of 0.125".

According to some embodiments of the invention, the optical set up includes 25 mm optical elements and the distance between fixation locations that are an integral multiple of 9.875mm.

25 According to some embodiments of the invention, the optical set up includes 12.5 mm optical elements and the distance between fixation locations that are multiples of one of 37.5 mm, 18.75 mm and 9.875 mm.

According to some embodiments of the invention, a modular optical unit of the plurality of modular optical units includes a mount for a standard optical element.

30 According to some embodiments of the invention, a synchronization light between a first path and a second path is preserved when the first path and the second path traverse an equal number of the fixation locations.

According to an aspect of some embodiments of the invention, there is provided a method for generating a 3D optical axis defined by a plurality of modular optical units, each modular

optical unit defining an optical line, including: connecting at an angle at least one wall to at least one base, each of the wall and the base having a plurality of fixation locations repeatedly arranged; releasably connecting a first set of the plurality of modular optical units at the fixation locations of the at least one base, defining a first set of optical axes; and releasably connecting a second set of the plurality of modular optical units at the fixation locations of the at least one wall, defining a second set of optical axes, thereby aligning at least a portion of the first set of optical axes and at least a portion of the second set of optical axes, generating a 3D optical axis.

According to some embodiments of the invention, the connecting at an angle at least one wall to at least one base includes fixedly connecting.

According to some embodiments of the invention, the connecting at an angle at least one wall to at least one base includes releasably connecting.

According to some embodiments of the invention, the method further includes connecting a plurality of the bases with a plurality of the walls.

According to some embodiments of the invention, the method further includes connecting at least one ceiling.

According to an aspect of some embodiments of the invention, there is provided a system of optical units including: a platform including a plurality of fixation locations, each fixation location having a respective connector an attachment interface for attachment to an optical table at a fixed location and direction; a modular optical unit including an optical element having an optical axis and a complementary connector for attachment to any respective connector on to retain the optical axis in one of a number of discrete directions and wherein for an element located at a first position of the plurality of fixation positions with a first optical axis directed in one of the number of discrete directions, the first optical axis overlaps a second optical axis of a second element at a second location of the fixation locations directed in a second direction for predetermined pairs of the second location and second direction.

According to some embodiments of the invention, the first location is on a first platform attached to the optical table at a first position and the second location is on a second platform connected to the optical table at a second position.

According to some embodiments of the invention, the first platform is does not contact the second platform.

According to some embodiments of the invention, for each of the predetermined pairs, a discrete path length from the first location to the second location is predetermined.

According to some embodiments of the invention, the first location and the second location fall on a grid and wherein the discrete path length is determined by a relative difference in coordinates on the grid between the first location and the second location.

According to an aspect of some embodiments of the invention, there is provided a system of optical units including: a first platform including 1st plurality of fixation locations, each fixation location having a connector a second platform including a 2nd plurality of fixation locations, each fixation location having a connector an attachment interface for attachment of the 1st platform to the 2nd platform with the 1st plurality of fixation locations aligned to the 2nd plurality of fixation locations; a plurality of modular optical units including an optical element and a complementary connector for attachment to the connector on the fixation location to retain the optical element in one of a discrete number of locations and/or directions on the platform.

According to some embodiments of the invention, the attachment between the modular optical units and the platform is reversible.

According to some embodiments of the invention, the attachment centers the optical element with respect to the fixation location.

According to some embodiments of the invention, the first platform is configured for connection to an optical table with a regular pattern of the fixation locations coinciding with attachment locations of the optical table.

According to some embodiments of the invention, including 1" optical elements are 1" and a distance between fixation locations that is a multiple an integral multiple of 0.375".

According to some embodiments of the invention, the optical set up includes 1" optical elements are 1" and a distance between fixation locations that is an integral multiple of 0.333".

According to some embodiments of the invention, the system includes the 0.5" optical elements and a distance between fixation locations that is an integral multiple of 0.125".

According to some embodiments of the invention, the system includes 2" optical elements and a distance between fixation locations that is an integral multiple of 0.125".

According to some embodiments of the invention, the system includes 25 mm optical elements and the distance between fixation locations that are multiples of one of 18.75mm, 12.5 mm and 9.875mm.

According to some embodiments of the invention, the system includes 12.5 mm optical elements and the distance between fixation locations that are multiples of one of 37.5 mm, 18.75 mm and 9.875 mm.

According to some embodiments of the invention, a modular optical units plurality of modular optical units includes a mount for a standard optical element.

According to some embodiments of the invention, a synchronization of light between a first path and a second path is preserved when the first path and the second path traverse an equal  
5 number of the fixation locations.

According to an aspect of some embodiments of the invention, there is provided an optical setup, including: A first platform and a second platform, each of the first platforms and the second platform having a plurality of fixation locations, to form repeatedly arranged, thereby defining a discrete position coordinate system; a plurality of modular optical units, each including  
10 an optical portion defining an optical axis, the optical portion fixedly attached to at least one mounting surface including complementary geometry to the fixation locations; wherein a releasable attachment of a first subset of the plurality of modular optical units at the fixation locations of the first platform defines a first set of optical axes; wherein a releasable attachment of a second subset of the plurality of modular optical units at the fixation locations of the second  
15 platform defines a second set of optical axes; and a single repeated arrangement of including the fixation locations of the first platform and the second platform and wherein at least a portion of the a first set of optical axes and at least a portion of the second set of optical axes overlap across the discrete position coordinate system.

According to some embodiments of the invention, each modular optical unit can be  
20 moved from a first the fixation location to a second the fixation location while preserving a relative geometry of the plurality of fixation locations.

According to some embodiments of the invention, each modular optical unit can be moved from a first the fixation location to a second the fixation location while preserving a relative geometry of each other of the plurality of modular optical units.

According to some embodiments of the invention, the first platform is reversibly attached  
25 to second platform.

According to some embodiments of the invention, the first platform and the second platform are reversibly attached to an optical table.

According to some embodiments of the invention, the attachment centers the optical  
30 element with respect to the fixation location.

According to some embodiments of the invention, the first platform is configured for connection to an optical table with a regular pattern of the fixation locations coinciding with attachment locations of the optical table.

According to some embodiments of the invention, the optical set up includes 1" optical elements are 1" and a distance between fixation locations that is an integral multiple of 0.375".

According to some embodiments of the invention, the optical set up includes 1" optical elements are 1" and a distance between fixation locations that is an integral multiple of 0.333".

5 According to some embodiments of the invention, the optical set up includes the 0.5" optical elements and a distance between fixation locations that is an integral multiple of 0.125".

According to some embodiments of the invention, the optical set up includes 2" optical elements and a distance between fixation locations that is an integral multiple of 0.125".

10 According to some embodiments of the invention, the optical set up includes 25 mm optical elements and the distance between fixation locations that are multiples of one of 18.75mm, 12.5 mm and 9.875mm.

According to some embodiments of the invention, the optical set up includes 12.5 mm optical elements and the distance between fixation locations that are multiples of one of 37.5 mm, 18.75 mm and 9.875 mm.

15 According to some embodiments of the invention, a modular optical unit of the plurality of modular optical units includes a mount for a standard optical element.

According to some embodiments of the invention, a synchronization light between a first path and a second path is preserved when the first path and the second path traverse an equal number of the fixation locations.

20 According to an aspect of some embodiments of the invention, there is provided a system of optical units including: a platform including a plurality of fixation locations, each fixation location having a respective connector a plurality of optical units each optical unit including an optical portion defining an optical axis, a complementary connector for attachment to any respective connector on to retain the optical axis in one of a number of discrete directions and  
25 wherein for an element located at a first position of the plurality of fixation positions with a first optical axis directed in one of the number of discrete directions, the first optical axis overlaps a second optical axis of a second element at a second location of the fixation locations directed in a second direction for predetermined pairs of the second location and second direction, and  
30 wherein at least one of the plurality of optical units including a mount for a standard optical element.

According to some embodiments of the invention, the first location is on a first platform attached to an optical table at a first position and the second location is on a second platform connected to the optical table at a second position.

According to some embodiments of the invention, the first platform does not contact the second platform.

According to some embodiments of the invention, for each of the predetermined pairs, a discrete path length from the first location to the second location is predetermined.

5 According to some embodiments of the invention, the first location and the second location fall on a grid and wherein the discrete path length is determined by a relative difference in coordinates on the grid between the first location and the second location.

According to some embodiments of the invention, the attachment between each of the plurality of optical units and the platform is reversible.

10 According to some embodiments of the invention, the attachment centers the optical element with respect to the fixation location.

According to some embodiments of the invention, the platform is configured for connection to an optical table with a regular pattern of the fixation locations coinciding with attachment locations of the optical table.

15 According to some embodiments of the invention, the standard optical element includes a 1" optical element and a distance between the fixation locations is an integral multiple of 0.375".

According to some embodiments of the invention, the optical set up includes 1" optical elements are 1" and a distance between fixation locations that is an integral multiple of 0.333".

20 According to some embodiments of the invention, the standard optical element includes a 0.5" optical element and a distance between the fixation locations is an integral multiple of 0.125".

According to some embodiments of the invention, the standard optical element includes a 2" optical element and a distance between the fixation locations is an integral multiple of 0.125".

25 According to some embodiments of the invention, the standard optical element includes a 12.5 mm optical element and a distance between the fixation locations is an integral multiple of 9.875mm.

According to some embodiments of the invention, the standard optical element includes a 25 mm optical element and a distance between the fixation locations is a multiple of at least one of 37.5 mm, 18.75 mm and 9.875 mm.

30 According to some embodiments of the invention, a synchronization of light between a first path and a second path is preserved when the first path and the second path traverse an equal number of the fixation locations.

According to some embodiments of the invention, the at least one optical unit can be moved from a first the fixation location to a second the fixation location while preserving a relative geometry of the plurality of fixation locations.

5 According to some embodiments of the invention, each at least one optical unit can be moved from a first the fixation location to a second the fixation location while preserving a relative geometry of each other of the plurality of optical units.

According to an aspect of some embodiments of the invention, there is provided a method of preserving synchronization of a first light source pulse traveling a first with a second laser pulse traveling a second path including: defining a discrete coordinate system of fixation  
10 locations located on a regular grid; releasably attaching a plurality of modular optical units at selected the fixation locations to define a plurality of optical axes wherein at least a portion of the optical axes overlap across the discrete coordinate system to define a first path and a second path; selecting the selected fixation locations to ensure that the first path and the second path traverse an equal number of grid spaces.

15 According to some embodiments of the invention, the method further includes: centering on a respective fixation location an optical element of each of the plurality of optical units.

According to an aspect of some embodiments of the invention, there is provided a connector for attaching a modular optical unit to a platform including: at least two holes configured to fit a mounting pin; at least one hole configured to fit a tightening element.

20 According to some embodiments of the invention, the method further includes: a hole for configured for attachment to an optical table.

According to some embodiments of the invention, the hole for configured for attachment to the optical table is centered with respect to the at least two holes configured to fit the mounting pin.

25 According to an aspect of some embodiments of the invention, there is provided a connector for attaching a modular optical unit to a platform including: at least two mounting pins and at least one tightening element.

According to an aspect of some embodiments of the invention, there is provided a kit for an interferometer including: at least four mounting platforms including at least two bases, at least  
30 two walls, each the mounting platform including a plurality of fixation locations repeatedly arranged, thereby defining a discrete position coordinate system; a plurality of modular optical units, including at least four modular mirror units each the mirror unit including an optical portion defining an optical axis, the optical portion fixedly attached to at least one mounting surface including complementary geometry to the fixation locations; and wherein a releasable

attachment of the plurality of modular mirror units at the fixation locations defines a first set of optical axes defining the interferometer.

According to some embodiments of the invention, the kit includes an instruction manual for assembling the interferometer.

5 According to some embodiments of the invention, the instruction manual includes a list of optomechanical parts and optical parts and a list of instruction assembly path.

According to some embodiments of the invention, the kit includes, a light source mounted on an optical table having a share optical axis with the interferometer.

10 According to some embodiments of the invention, the kit includes, one or more of the device selected from the group consisting of a characterization optical tool, a spectrometer optical apparatus, an imaging apparatus including at least two mounting platform, each the platform having a plurality of fixation locations repeatedly arranged, thereby defining a discrete position coordinate system; the at least two mounting platforms connected with the plurality of fixations on a first of the at least two mounting platforms arranged orthogonally to the plurality of fixations  
15 locations on a second of the at least two mounting platforms; a plurality of modular optical units, including at least four modular mirror units each including an optical portion defining an optical axis, the optical portion fixedly attached to at least one mounting surface including complementary geometry to the fixation locations; and wherein a releasable attachment of the plurality of modular mirror units at the fixation locations defines a first set of optical axes; and  
20 wherein the device and the interferometer are mounted on an optical chamber to form a compound device.

Example 1. A three dimensional (3D) optical setup, comprising at least one base connected at an angle to at least one wall, each of the at least one base and at least one wall having a plurality of fixation locations repeatedly arranged, thereby defining a discrete 3D  
25 position coordinate system; a plurality of modular optical units, each comprising an optical portion defining an optical axis, the optical portion fixedly attached to at least one mounting surface comprising complementary geometry to the fixation locations; wherein a releasable attachment of some of the plurality of modular optical units at the fixation locations of the at least one base defines a first set of optical paths and a releasable attachment of some of the plurality of  
30 modular optical units at the fixation locations of the at least one wall defines a second set of optical paths; and wherein at least a portion of the first set of optical paths and at least a portion of the second set of optical paths overlap across the discrete 3D position coordinate system.

Example 2. The setup of example 1, wherein the base and the wall are fixedly connected.

Example 3. The setup of example 1, wherein the base and the wall are releasably connected.

Example 4. The setup of any of examples 1-3, wherein the optical portion is at an angle to the mounting surface.

5 Example 5. The setup of any of examples 1-4, wherein each of the at least one wall and at least one base comprise a first edge having complementary fitting with a second edge.

Example 6. The setup of example 5, wherein the complementary fitting comprises at least one complementary threaded cavity in each of the first edge and the second edge.

10 Example 7. The setup of example 5, wherein the complementary fitting comprises complementary interference fitting members.

Example 8. The setup of any of examples 1-7, wherein the angle is 90 degrees.

Example 9. The setup of any of examples 1-8, wherein the fixation locations comprise a plurality of fixation points.

15 Example 10. The setup of example 9, wherein the plurality of fixation points are radially symmetric.

Example 11. The setup of example 9, wherein the plurality of fixation points are axially symmetric.

Example 12. The setup of any of examples 1-11, wherein the complementary surface of the modular optical units comprise a quadrangular shape.

20 Example 13. The setup of any of examples 1-12, wherein the complementary surface of the modular optical units comprise a triangular shape.

Example 14. The setup of any of examples 1-13, wherein the complementary surface of the modular optical units comprise a trapezoid shape.

25 Example 15. The setup of any of examples 1-14, wherein the modular optical units comprise a cuboid shape.

Example 16. The setup of any of examples 1-15, wherein the modular optical units comprise a prism shape.

Example 17. The setup of any of examples 1-15, wherein the complementary geometry connects with the fixation locations in a male-female connection.

30 Example 18. The setup of any of examples 1-17, wherein the complementary surface fits across a plurality of the fixation locations.

Example 19. The setup of any of examples 1-18, wherein the complementary surface fits across a portion of the fixation locations.

Example 20. The setup of any of examples 1-19, further comprising at least one ceiling, connected at a second angle to the at least one wall.

Example 21. The setup of any of examples 1-20, further comprising at least one translocator operably connected to the at least one base.

5 Example 22. A method for generating a 3D optical path defined by a plurality of modular optical units, each modular optical unit defining an optical line, comprising connecting at an angle at least one wall to at least one base, each of the wall and the base having a plurality of fixation locations repeatedly arranged; releasably connecting a first set of the plurality of modular optical units at the fixation locations of the at least one base, defining a first set of  
10 optical paths; and releasably connecting a second set of the plurality of modular optical units at the fixation locations of the at least one wall, defining a second set of optical paths, thereby aligning at least a portion of the first set of optical paths and at least a portion of the second set of optical paths, generating a 3D optical path.

Example 23. The method of example 22, wherein the connecting at an angle at least one  
15 wall to at least one base comprises fixedly connecting.

Example 24. The method of example 22, wherein the connecting at an angle at least one wall to at least one base comprises releasably connecting.

Example 25. The method of any of examples 22-24, further comprising connecting a plurality of the bases with a plurality of the walls.

20 Example 26. The method of any of examples 22-25, further comprising connecting at least one ceiling.

According to an aspect of some embodiments of the invention, there is provided a prismatic optical unit including: an angled face; an optical element mounted on the angled face; a first mounting surface at an angle of between 25 to 75 degrees to the angled face; a second  
25 mounting surface perpendicular to the angled face.

According to some embodiments of the invention, second mounting surface second mounting surface is triangular.

According to some embodiments of the invention, angled face is directed at 45 degrees to the first mounting surface.

30 According to some embodiments of the invention, the second mounting surface has a right triangular shape.

Unless otherwise defined, all technical and/or scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the invention pertains. Although methods and materials similar or equivalent to those described herein can be

used in the practice or testing of embodiments of the invention, exemplary methods and/or materials are described below. In case of conflict, the patent specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and are not intended to be necessarily limiting.

5 BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Some embodiments of the invention are herein described, by way of example only, with reference to the accompanying drawings. With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of embodiments of the invention. In this regard, the description taken with the drawings makes apparent to those skilled in the art how embodiments of the invention may be practiced.

In the drawings:

FIG. 1 is a block diagram illustration of a modular optical mounting system in accordance with an embodiment of the current invention;

15 FIG. 2 is a flow chart of a method of mounting modular optical units accordance with an embodiment of the current invention;

FIG. 3 is a block diagram illustration of a 3D modular optical mounting system in accordance with an embodiment of the current invention;

20 FIG. 4 is a flow chart of a 3D method of mounting modular optical units in accordance with an embodiment of the current invention;

FIG. 5A is a schematic drawing of reconfiguring a modular optical device in accordance with an embodiment of the current invention;

FIG. 5B is a schematic drawings of reconfiguring a modular optical device in accordance with an embodiment of the current invention;

25 FIGs. 6A-6C are perspective drawings of joining boards in for mounting modular optical units in one plane in accordance with an embodiment of the current invention;

FIGs. 7A-7B are perspective drawings of joining boards for mounting modular optical units in accordance with an embodiment of the current invention;

30 FIGs. 8A-8B are perspective drawings of joining boards for mounting modular optical units in two planes in accordance with an embodiment of the current invention;

FIG. 9 is a perspective drawing of a board for mounting modular optical units in accordance with an embodiment of the current invention;

FIG. 10 is perspective drawings of a polarization inverter built of modular units in accordance with an embodiment of the current invention;

FIG. 11 is perspective drawings of an alternative polarization inverter built of modular units in accordance with an embodiment of the current invention;

5 FIG. 12 is perspective drawings of a microscope built of modular units in accordance with an embodiment of the current invention;

FIGs. 13A-13B are schematic drawings of a multilayer optical devices built of modular units in accordance with an embodiments of the current invention;

10 FIG. 14 is a schematic drawing of a multilayer optical devices built of modular units in accordance with an embodiments of the current invention;

FIG. 15 is a schematic drawing of a multilayer optical devices built of modular units in accordance with an embodiments of the current invention;

FIG. 16 is a perspective drawing of a board for mounting modular units in accordance with an embodiment of the current invention;

15 FIGs. 17A-17B are photographs of multi-layer structures for mounting modular units in accordance with an embodiment of the current invention;

FIGs. 17C-17D are drawings of of multi-layer structures for mounting modular units in accordance with an embodiment of the current invention;

20 FIG. 18 is a perspective drawing of a modular unit with connectors for attaching to fixation locations in accordance with embodiments of the current invention;

FIG. 19 is a perspective drawing of a modular unit with connectors for attaching to fixation locations in accordance with embodiments of the current invention;

FIG. 20 is a perspective drawing of a modular unit with connectors for attaching to fixation locations in accordance with embodiments of the current invention;

25 FIG. 21 is a perspective drawing of a modular unit with connectors for attaching to fixation locations in accordance with embodiments of the current invention;

FIGs. 22A-22B are perspective drawings of fixed mirrors in accordance with embodiments of the current invention;

30 FIGs. 23A-23C are perspective views of an adjustable mirrors in accordance with embodiments of the current invention;

FIGs. 24A-24C are perspective drawings of optical units in accordance with embodiments of the current invention;

FIGs. 25A-25D are perspective drawings of modular units in accordance with embodiments of the current invention;

FIG. 26A-26B are perspective drawings of a modular units in accordance with embodiments of the current invention;

FIG. 27 is a parts list for a polarity reversing kit in accordance with an embodiment of the current invention;

5 FIG. 28 is a perspective view of a polarity inversion kit and attaching a fixed mirror perpendicular to a base in accordance with an embodiment of the current invention;

FIGs. 29A-29B are a perspective drawings of attaching a fixed mirror perpendicular to a wall in a polarity reversing kit in accordance with embodiments of the current invention;

10 FIGs. 30A-30B are a perspective drawings of attaching a fixed mirror at an angle to a wall in a polarity reversing kit in accordance with embodiments of the current invention;

FIG. 31 is a perspective drawing of attaching feet to a polarity reversing kit in accordance with an embodiment of the current invention;

FIGs. 32A-32B are a perspective drawings of attaching further walls to a polarity reversing kit in accordance with an embodiment of the current invention;

15 FIGs. 33A-33B are a perspective drawings of a dual path polarity retraining, polarity reversing kit in accordance with embodiments of the current invention;

FIGs. 34A-34H are perspective drawings of assembly of an autocorrelator kit in accordance with embodiments of the current invention;

20 FIGs. 35A-35E is a perspective drawing of assembly of an interferometer kit in accordance with embodiments of the current invention;

FIG. 36 is a perspective drawing of a frequency resolved optical gating (FROG) kit in accordance with embodiments of the current invention;

FIG. 37 is a perspective drawing of a nonlinear optical generation - Focusing apparatus kit in accordance with an embodiment of the current invention;

25 FIG. 38 is a photograph of modular devices integrated with conventional optical devices on an optical table in accordance with an embodiment of the current invention;

FIG. 39 is a perspective drawing of a board for fixing modular units to a conventional optical table in accordance with an embodiment of the current invention;

30 FIG. 40 is a photograph of an optical device for transferring a beam from a 1 inch optical element to a ½ inch optical element in accordance with an embodiment of the current invention;

FIG. 41 is a photograph of an adapter for transferring a beam from a 1 inch optical element to a ½ inch optical element in accordance with an embodiment of the current invention;

FIGs. 42A-42B are a photographs of an electro-mechanical-optical device for adjusting a path length in accordance with an embodiment of the current invention;

FIG. 43 is a photograph of a wall to an optical table in accordance with an embodiment of the current invention;

FIGs. 44A-44B are perspective drawings illustrating insertion of an optical element into a mount of a modular unit in accordance with an embodiment of the current invention;

5 FIG. 45A-45D are a perspective drawings illustrating insertion of an optical element into a mount of a modular unit in accordance with an embodiment of the current invention; and

FIG. 46 illustrates a discretization pattern for a platform configured for attachment to an optical table in accordance with an embodiment of the current invention.

## 10 DESCRIPTION OF SPECIFIC EMBODIMENTS OF THE INVENTION

The present invention, in some embodiments thereof, relates to an optical setup and, more particularly, but not exclusively, to a modular three-dimensional optical setup.

### **Overview**

Several embodiments of the invention relates to a system for generating an optical  
15 network. For example, the optical network may include a plurality of optical axes interconnecting a plurality of modular optical units. In some embodiments, the system includes a discrete set of fixation locations and a discrete set of directions. Optionally, interconnecting optical axes are defined by selecting a pair locations and/or directions from the discrete set. For example, a plurality of modular units (e.g. modular optical units) may each have a defined  
20 position and optical axis. Optionally, the units are arranged at the selected locations with the optical axes orient in the selected directions to form the network.

An aspect of some embodiments of the current invention relates to an expandable platform that defines a plurality of fixation locations. Optionally, releasable attachment of a modular optical unit at a fixation location defines a discrete set of directions for the optical axis  
25 of the unit (for example 4 or less directions and/or 8 or less directions and/or 16 or less directions and/or 32 or less directions and/or 64 or less directions). Optionally, discrete positional coordinates are provided by fixation locations repeatedly arranged over the expandable platform. For example, for a selected direction, an optical axis may intersect fixation locations at a defined discrete vector distance (for example defined as a number of fixation locations in one, two, or  
30 three directions).

In some embodiments, the discretization of path length may facilitate synchronizing pulses. For example, two synchronized pulses may be formed (e.g. by splitting a single pulse). Optionally, the two initially synchronized pulses may be sent of two separate paths. In some

embodiments, it may be desired to synchronize the two pulses as they leave the separate paths. For example, it may be desired to recombine the pulses and/or compare the pulses. Some embodiments of the present invention facilitate the formation of paths having discrete path lengths. Optionally, using discrete length paths may facilitate synchronization of pulses across multiple paths. For example, using the discrete length feature of some embodiments of the current invention it may make it easier to design two paths having equal lengths (for example each path having the same number of discrete sections). For example, two pulses pass along paths of equal length may retain their original synchronization. For example, the two pulses remain synchronized and/or may reach a sensor together at the end of the paths at the same time. For example the two pulses may simultaneously reach a combiner at the end of the paths and/or be combined.

In some embodiments, the modular optical units are modularly arranged in a 2D arrangement by releasable attachment to fixation locations. For example, fixation locations may be placed along surface to form a grid at fixed distances one from another. For example, fixation locations may be arranged along orthogonal axes. Optionally, lag distances between fixation locations may be equal in one or more directions and/or may vary by integral multiples.

In some embodiments, each discrete position comprises one fixation location. In some embodiments, a single fixation location comprises a plurality of fixation points. For example, a location may include at least two fixation points, or at least three, or at least four, or at least five fixation points. Optionally, the plurality of fixation points is arranged symmetrically across an area of the discrete position. In some embodiments, a symmetric arrangement comprises axis symmetry. Alternatively or additionally, a symmetric arrangement comprises rotational symmetry. Optionally, a unit attached to a fixation location may be oriented in one of a discrete set of orientations.

In some embodiments, the board may include an attachment feature for attachment to an optical table that is aligned with the fixation locations. For example, at least one of the discrete optical axes of fixation may be parallel to an axis of attachment locations on the optical table. Optionally two of the discrete optical axes fixation may be parallel to an axis of attachment locations on the optical table. In some embodiments at least one axis of fixation locations is aligned to an axis of attachment locations of the optical table. Additionally or alternatively, a sequence of axes of fixation locations is aligned to a sequence of axes of attachment locations of the optical table. For example, attachment locations of an optical table may be located along lines and/or rows one inch apart. Optionally, lines and/or rows of fixation locations on a board may arranged along lines and/or rows that are 1.5 inches apart and/or aligned with the columns and/or

rows of the optical table. For example, every third column and/or row of the board may coincide to every fourth row and/or column of the optical table when the board is attached to the table. For example a attachment location for the optical table may be centered on a fixation location on the board. In some embodiments, fixation locations and/or connectors and/or attachment locations for an optical table may be separated by a separation distance, for example 37.5 mm and/or 1" and/or 25 mm and/or 0.5" and/or 12.5 mm. Optionally, fixation locations and/or connectors and/or attachment locations for an optical table are distanced apart by a separation distance and/or by a multiple of separation distances.

In some embodiments two platforms may be attached to a table in alignment and/or at a fixed distance. For example the distance between the platforms may be fixed at a multiple of the distance between fixation locations on each board. For example, the two boards may be spatially synchronized (the fixation locations on one platform may be a continuation of the pattern the other platform). This spatial synchronization may occur in cases where the platforms are not directly attached to each other and/or are at a distance from each other. The alignment may be in the horizontal plane and/or in the vertical. For example multiple layers of two platforms may be aligned and/or may serve as continuations on of another. For example, optical units placed on discrete locations on separate boards may share an optical axis. Optionally alignment and/or sharing of an optical axis may be done over distance larger than the platform on which the devices are built and/or for disconnected platforms. In this way optical elements may be connected optically across a distance larger than the platform on which the elements are mounted and/or various units may be placed in discrete locations and/or share optical axes over different platforms.

In some embodiments, a path length may be synchronized across platforms. For example, paths from platform to platform and/or across distances greater than a single platform may have a discretized path length. For example, discretization may facilitate producing multiple paths of equal length. The discretization of path length may be used for example to synchronized pulses traveling different paths between two different platforms. For example, two pulses may travel different paths, cross different platforms. The arrival of the two pulses may optionally be synchronized, for example by ensuring the both pulses travel on paths of equal length. Designing equal length paths is optionally facilitated by discretization. For example, the initially synchronized pulses may travel down two equal length paths and/or the two pulses may arrive at one or more sensors at the same time. For example, the two pulses may arrive at the same time at a junction simultaneously and/or may be reunited. This may facilitate comparison of pulses and/or production of various compound pulses for various purposes.

In some embodiments, a modular unit includes a frame supporting a standard optical element. The frame is optionally configured to retain the optical element positioned in a way that is independent of the angle of fixation of the frame to the fixation location. For example the optical element may be centered on a fixation location. For example the optical element may be positioned symmetrically with respect to the discrete directions of alignment of the fixation locations.

In some embodiments, fixation points comprise geometrical elements suitable for an interference fit, such as a male-female fit. For example, it may be a protuberance, or a male portion, such as a pin, and/or a knob, and/or a bulge, and/or a projection. Alternatively or additionally, it may be a cavity, or a female portion, such as a hole, and/or a pit, and/or a socket, and/or a notch. Alternatively or additionally, the fixation points comprise interlocking members suitable for latch attachments, for example, a fastener, and/or a clasp, and/or a joint, and/or a hook, and/or a link.

Alternatively or additionally, the fixation locations comprise a geometrical mechanical alignment fit. For example, a groove and/or a protrusion having a defined geometrical shape boundary, such as a “+” sign, and/or a square, and/or a circle, and/or a trapezoid, and/or a hexagon, or any other geometrical shape. In such embodiments, the modular optical units complementary surface optionally comprises matching geometrical shapes fitting with the geometrical shape of the fixation location and complementary in direction, e.g. when a fixation location is provided with a groove, the complementary surface is provided with a protrusion, and vice versa.

In some embodiments, a complementary geometry comprises a plurality of complementary interference members, such as for example, complementary males and/or complementary female members. Alternatively or additionally, a complementary surface comprises complementary latch. Alternatively or additionally, the complementary surface comprises holes complementary in position to holes in the fixation locations. Optionally, the holes are threaded and suitable for a connection using a screw. Alternatively or additionally, a magnet and/or a pin may be used for connecting parts. Optionally the magnet and/or pin may be used in conjunction with a hole.

In some embodiments, one or more modular optical units may be added and/or removed from a platform without disturbing the spatial relationship between other units attached to the platform. For example, one unit may be removed and/or replaced at the same location by another unit. Optionally, multiple platforms may be connected together to form a single expanded arrangement of fixation locations. For example, the expanded arrangement may preserve

properties of the arrangement of one or more of the platforms. For example, a first optical system may be built on a first platform and a second optical system may be built on a second platform. The first and second optical systems may optionally be combined by attaching the first platform to the second platform and/or by providing a shared optical axis. For example, an output axis of  
5 the first platform may be directed to an input axis of the second platform and/or a combiner modular optical unit may be added to the first and/or second platform to combine an optical axis and/or a blocker element may be removed from the first and/or second platform to combine the networks.

In some embodiments, an attachment interface may be provided to platforms. For  
10 example, the interface may attach one platform to another platform. For example, the interface may attach an edge of a planar arrangement of fixation locations to an edge of a second planar arrangement to form a large integrated arrangement of fixation locations. Optionally, the attachment interface is configured for attachment while a platform remains in place. For example, a platform may have a rear face that is supported on a surface and a front face that is exposed.  
15 Attachment to a second platform may be achieved entirely from the exposed face. In some embodiments one or more platforms may be included in an optical bread board. Optionally, a platform of discrete fixation locations may be configured for attachment to a standard optical breadboard, standard modular optical units, breadboard components (for example handles and/or mounting brackets) and/or an optical table.

In some embodiments, the modular optical units are modularly arranged in a 2D  
20 arrangement by releasable attachment to a planar surface of a platform (e.g. a board) for example as explained above. In some embodiments, a plurality of platforms may be arranged into a 3D positional configuration. For example, a 3D box may comprise a base and/or at a wall fixedly connected to the base at an angle and/or a ceiling facing the base. In some embodiments, the  
25 modular optical units are attached at discrete position coordinates defined by the 3D box. Optionally, a plurality of optional units may be attached to each one of the base, ceiling and/or the wall of the 3D box. Optionally, a shared optical axis may be defined between units mounted on a base and/or a ceiling and/or wall by selecting a discrete vector distance between the units and a direction for each unit from the discrete set of directions. In some embodiments, the  
30 system may include multiple layers.

In some embodiments, a 3D modular system functions as an extendable 3D optical breadboard. For example the system may be moved onto and/or removed from an optical table. Optionally, the 3D system takes less space on a table than a similar 2D system.

In some embodiments, the modular optical unit further comprises threaded holes for securely screwing the units onto the 3D box. Optionally, the modular optical unit further comprises magnetic mounts on the complementary geometry.

In some embodiments, a modular optical unit has a 3D box shape, optionally cubic, cuboid or rectangular. Alternatively or additionally, a modular optical unit comprises a prism shape. Optionally, the prism comprises a right angle and/or isosceles angles. In some embodiments, the modular optical unit comprises an optical portion, optionally a frame protected reflector or mirror. Alternatively or additionally, the optical portion comprises a filter, or a camera, optionally frame protected. In some embodiments, an optical portion is provided on a separate wall of the 3D unit other than the complementary surface. In some embodiments, the optical element comprised in the optical portion of the modular optical unit is adjustable with respect to the mount mechanically holding the optical element.

In some embodiments, the modular optical unit defines an optical axis. In some embodiments, an optical axis comprises a propagating direction. In some embodiments, by positioning the modular optical units across a 3D box having discrete positions, an optical axis is generated between the modular optical units. In some embodiments, the positions are configured in such spaces as to enable an overlap between an optical axis generated on one plane, such as on the base, with an optical axis generated by a second plane, such as the wall. In some embodiments, an overlap is generated between an optical axis generated on a wall and an optical axis generated on a ceiling. Optionally, an optical axis generated on the ceiling is aligned with an optical axis generated on the base.

In some embodiments, at least a portion of a first set of optical axes created by releasably arranged modular optical units on a first plane and at least a portion of a second set of optical axes created by releasably arranged modular optical units on a second plane, overlap across the planes by defining in the planes a discrete 3D position coordinate system. In some embodiments, positioning across the positional system allows aligning optical axes which are much larger than the modular optical units themselves. For example, a modular optical unit may have dimensions of about  $10\text{ cm}^3$ , and an aligned optical axis may span over at least 10-15 meters.

In some embodiments, the complementary surface serves as a base, or a platform, upon which the optical portion is fixedly mounted. For example, a complementary surface may be a 3D quadrangular having two main surfaces and a height there between. Optionally, one surface comprises the complementary geometry or complementary members and the other surface comprises the mounted optical portion. In some embodiments, a mounted optical portion is in the form of another 3D quadrangular having two main surfaces and a height there between.

Optionally, the two surfaces define the frame which holds the optical element spanning across at least a portion of the height between the surfaces. In some embodiments, the angle between the complementary base and the mounted optical portion is 90 degrees. Alternatively, the angle between the complementary base and the mounted optical portion is more or less than 90 degrees, for example, ranging between about 90 and about 120, or ranging between about 90 and about 45 and/or ranging between 0 to 45 degrees. In some embodiments, the angle between the complementary base and the mounted optical portion is adjustable. Alternatively or additionally, boards may be attachable in the same plane, for example to extend a board while preserving an alignment and/or geometry of fixation locations.

In some embodiments, a complementary surface of a modular optical unit may span over a single fixation location. Alternatively or additionally, a complementary surface may span over a plurality of fixation locations, such as for example two, or three, or four. Alternatively, the complementary surface of a modular optical unit may span over a portion of the fixation location, for example, a prism shaped unit may span over a triangular portion which might be half of a square fixation location.

Optionally, the modular optical units comprise at least two complementary surfaces. In some embodiments, modular optical units are releasably attachable to each other. In some embodiments, the modular optical units are attached while being adjacent to one another on the same plane, such as for example for increasing the stability of the units. Alternatively or additionally, the units are attached one on top of the other, resulting in an optical axis which intersects with the plane defined by the board on which the modular optical units are assembled.

An aspect of some embodiments of the invention relates to a modular 3D position system suitable for discretely attaching optical elements, such that an optical axis transmitted through the optical elements overlaps with the positional coordinate system. In some embodiments, a 3D modular system comprises a 3D box having connecting units in the form of at least one base and/or at least one wall, and optionally at least one ceiling. In some embodiments, the 3D modular position system is modular in size, by increasing or decreasing the number of connecting units. In some embodiments, the 3D modular position system is modular in shape, such as by having a variable number of walls and optional ceiling.

In some embodiments, the connecting unit in a form of a base and/or a wall comprises a board having fixation locations in a repeated pattern across its surface. In some embodiments, a repeated pattern is a repetitive matrix of square positions, each position comprising one of the fixation locations. Alternatively, the repeated pattern is a repetitive pattern of another shape, such as a triangle, a hexagon and the like.

In some embodiments, the base and/or the wall comprise a limited number of fixation locations repetitions, such as for example, only 4, or only 9, or only 12, or only 16, or only 25 fixation locations, optionally arranged in a square or rectangular arrangement. A potential advantage of providing the board of the base and/or the wall having a limited number of repetitions is that the size of the 3D box being constructed from such boards is also modular. Alternatively, a base and/or a wall may be in another shape, such as a triangular shape, trapezoid, hexagon, and any shape which can be repeatedly matched.

In some embodiments, a base comprises at least one edge having complementary fitting with at least one edge of a second base. Optionally, each base comprises the two kinds of fittings, such that a base may connect and also be connected to. In some embodiments, at least two edges, optionally adjacent to each other, have a first complementary portion. In some embodiments, the complementary portions comprise a threaded cavity which can be secured by a screw. In some embodiments, a plurality of connecting units' arrangements is provided. For example, a matrix of 3x3 of connecting bases and/or walls and/or ceilings is provided, or a matrix of 9x9, or a matrix of 3x6, and/or a matrix of 6x6 and/or a matrix if 1x3 and/or 2x3 and/or a matrix if 1x4 or a matrix if 2x4 and/or any square or rectangular combination of 1, 2, 4, 5, 6, 7, 8, 9, 10 11, 12, and/or more and so forth.

In some embodiments, a wall comprises at least one edge suitable for fitting with another wall edge. In some embodiments, a board being a wall and/or a base comprises an extending edge projecting into a distinct plane than the plane defined by the surface of the board. In some embodiments, an extending edge is used for interconnecting a board with another board at an angle. Optionally, interconnecting is releasable and modular. Alternatively, interconnecting is fixed. Optionally, an angle between a base board and a wall board is about 90 degrees. Alternatively, an angle between a base board and a wall board is in a range larger than 90 degrees, for example, a range of 90-100 degrees, or a range of 100-120 degrees, or a range of 120-135 degrees, or a range from 135 to 180 degrees. Alternatively, an angle between a base board and a wall board is in a range smaller than 90 degrees, for example, a range of 90-60 degrees, or a range of 60-45 degrees, or a range from 45 to 0 degrees.

Alternatively or additionally, a connector is provided for connecting the base and the wall at an angle. In some embodiments, a connector may be an elongated member having two planes at a fixed angle, each plane having complementary fitting to an edge of a base and/or an edge of a wall.

Optionally, a 3D box comprises a ceiling. In some embodiments, a ceiling comprises a board, optionally similar to the boards comprising the base and/or the wall, which is connected at

an angle to a wall board. In some embodiments, the angle between the base and the wall is the same as the angle between the wall and the ceiling. Alternatively, the angle between the base and the wall is distinct than the angle between the wall and the ceiling, optionally, complementary to 180 degrees. For example, if an angle between the base and the wall is 120 degrees, the angle  
5 between the wall and the ceiling may be 60 degrees, such that the base and the ceiling are parallel to one another.

In some embodiments, base boards are connected to each other to create a larger board than a single unit of a base board. In some embodiments, wall boards are connected to each other larger board than a single unit of a wall board. In some embodiments, ceiling boards are  
10 connected to each other larger board than a single unit of a ceiling board. In such embodiments, the boards of the base, and/or wall, and/or ceiling are being used as building blocks for assembling a 3D box which is modular in size.

In some embodiments, more than one 3D box is provided. Optionally, two different devices may be supplied in interchangeable boxes. For example, two different devices may be  
15 supplied in identical 3D boxes and/or with identical input and output paths. For example, one device may be substituted for the other device in a system without changing the geometry of the system and/or without moving other parts of the system. Alternatively or additionally, two different devices will be supplied with identical path lengths. For example, the two devices may be substituted for one another in a system without changing the path length of the system. For  
20 example, one device may be placed in a path of a first pulse and the second device may be placed in a path of a second synchronized pulse and/or the synchronization of the pulses may be preserved. For example, each substitutable box may include a characterization optical tool (e.g. an autocorellator, a FROG), a spectrometer optical apparatus, an imaging apparatus (e.g. a microscope, a telescope) an interferometer and/or a pump-probe and/or a polarization rotator  
25 and/or another device. Alternatively, the boxes are distinct in size and/or in shape. In some embodiments, a translocator may axially translate a 3D box. Optionally, at least one 3D box is stationary while at least one other 3D box is movable.

In some embodiments one surface may overhang another surface. Optionally, in a multi-layer structure, one layer may extend past another layer. For example, a wall may extend further  
30 than a base. For example a base and/or a ceiling may extend beyond a wall and/or beyond an intermediated floor.

In some embodiments, an optical axis may cross a board. For example, a board may include a hole through which a beam can pass. Alternatively or additionally, a beam may pass a platform beyond an end therefore. Optionally the beam may be intercepted by an overhanging

element and redirected to an element attached to the board. For example, a beam may pass from an element mounted on a first board to an element on a far side of a board mounted parallel to the first board.

In some embodiments, fixation locations on different planes may be aligned. For example, where a base is oriented along an x-y plane, fixation locations on a wall and/or a ceiling may be aligned with the fixation locations of the base in the x-y plane. For example, the lag distance between repeated fixation locations may be the same on different planes and/or in different directions. Alternatively or additionally, the lag distance between repeated fixation locations on different planes and/or different directions may be integral multiples of one another. For example, the coordinate systems of different boards of a 3D structure may combine as an orthogonal coordinate system. For example, a base and/or a ceiling may lie in an x-y plane. A side wall may lie in an x-z plane and/or a front and/or rear wall may fall in a y-z plane.

In some embodiments, a box may include multiple layers of parallel boards. Optionally, a board may include fixation locations on multiple sides therefore. For example, a board may form a ceiling of a first layer and/or a base for a subsequent layer. Alternatively or additionally, a first board may be mounted as a ceiling and a second board may be placed back to back with the ceiling to form an upper floor (e.g. a base at a new level. Optionally fixation locations on one side of a two sided board and/or on opposite faces of two back to back boards fix optical elements to a ceiling of a first layer and/or fixation locations on a base of the subsequent layer.

In some embodiments, a modular unit may include an optical element and/or a connector on one face and/or a complementary connector on another face. For example, the first face may connect to a board and/or the second face may include a complementary fixation element to which another modular unit is attached. In some embodiments, a dimension of a modular unit may be equal to a lag distance between fixation elements of a board. Alternatively or additionally, a dimension of the modular unit may be equal to an integral multiple and/or factor of the distance between fixation elements of a board. For example, an element attached to a block may be aligned to a 3D coordinates of an element attached to orthogonal boards.

An aspect of several embodiments of the invention relates to a modular optical kit used for optical alignment during assembly of a specific device. In some embodiments, the modular apparatus is used in a variety of optical setups, such as, for example, auto-correlator and/or cross-correlator. For example, the modular apparatus may be used for a pump-probe apparatus and/or an interferometer and/or spectroscopy (for example time-resolved spectroscopy) and/or polarization rotation and/or Fourier transform infrared and/or a pulse shaper and/or a telescope and/or a microscope and/or any of their combinations. Optionally, modular devices may preserve

synchronization and/or modify timing of optical pulses according to a in a discretized manner. Optionally, the modular optical apparatus allows optical alignment in planar (2D) configuration. Alternatively or additionally, the modular optical apparatus allows optical alignment in 3D configurations. In some embodiments, the modular optical apparatus enables a fairly simple way  
5 for optical alignment in planar (2D) and/or 3D configurations. Optionally the system includes discretization in 4D (e.g. the position of an optical element and/or beam and/or pulse is discretized one, two or three spatial directions and/or the timing of a pulse is discretized (for example by discretizing the path length)). For example, discretization may simplify alignment in one, two, three or four dimensions.

10 In some embodiments, the apparatus includes at least two boxes. In some embodiments, the boxes are provided with a plurality of holes, optionally in fixed distances. In some embodiments, the apparatus includes a plurality of modular optical units, each having a plurality of elements sized and shaped to fit the plurality of holes. In some embodiments, the modular optical units serve as building blocks for optical system design. Alternatively or additionally, the  
15 modular optical units include a plurality of elements sized and shaped to fit with a plurality of holes provided in the optical system.

In some embodiments, the modular optical units in the modular design concept are screwed to reinforce the structure. Optionally, the modular optical units are connected by at least two screws for each modular optical unit, having the potential advantage of reducing movements.  
20 In some embodiments, the providence of screwing features offers assembly of different types of currently available and/or commercial optical setups (for example using pins and/or magnets). A potential advantage of using currently available optical setups, which could be complicated and/or expensive, with the modular optical setup herein is the robust and/or modular nature of the connection. Potentially, the modular design allows tunable assembly of complex setups which  
25 might provide an accurate optical setup by a non-expert in optics.

For example, at least one of the optic elements is a protected mirror, optionally in a triangle configuration, optionally non-dispersive and/or configurable and/or compact and/or extremely broadband (for example, spanning bandwidth in a range of 400-25000 nm). Optionally, a protected mirror is used for ultrashort pulses and/or broadband light and/or continuous wave  
30 alignment. Alternatively or additionally, at least one of a build-in delay line, and/or a beam splitter, and/or a filter, and/or an acoustic optic modulator can be part of the optic elements. A potential advantage of providing a variety of optic elements is increasing the variety of optical setups that can be assembled.

An aspect of some embodiment of the current invention relates to a prismatic in shaped modular optical unit. For example, an angled face of the unit may be at a non-square angle to at least one mounting surface of the optical unit. For example, the non-square angle may be 45 degrees and/or may range between 25 to 75 degrees. Optionally the prismatic unit may include a second mounting surface. For example, the angled face of the prism may be perpendicular to the second mounting surface. For example, the unit may have a right triangular prismatic shape. Optionally, an optical element is mounted on the angled face. For example the optical element may include a mirror. Optionally each mounting surface of the unit may include a connector for discrete connection to a platform.

An aspect of some embodiment of the current invention relates to a connector for attaching a modular optical element to a platform. The connector may include holes for at least two pins and at least one tightening element. For example, a pin and/or pin hole may fix the location of the modular unit along the surface of the platform and/or the tightening element may hold the unit to the pins and/or fix the unit in a direction normal to the surfaced of the platform. Optionally, the pins may be cylindrical and/or tapered and/or conical and/or press fit. For example a tightening element may include a screw and/or a threaded hole. For example the tolerance for positioning of the modular unit may range for example between 0.01 % to 0.07% and/or between 0.07% to 0.15% and/or between 0.15% to 1% and/or between 1% to 5% of the size of connector. For example the tolerance for positioning of the modular unit may range for example between 0.001 to 0.007 inch and/or between 0.007 to 0.015 inch and/or between 0.015 inch to .01 inch and/or between .01 to .05 inch and/or between 0.05 to 0.1 inch.

An aspect of several embodiments of the invention relates to precisely fixed optical elements configured for a modular 2D and/or 3D optical system configuration. In some embodiments, a specific typical distance in the system design is used, potentially aiding in alignment of the optical setup, especially in the alignment of ultrashort pulses and broadband light.

In some embodiments, a discrete number of optical elements serve as building blocks for the optical system. Optionally, each element is distinct in its optical role.

In some embodiments, the optical system including platforms and/or frames and/or modular units and/or optical elements is provided as a kit. Alternatively or additionally, the platforms and/or frames and/or modular units and/or optical elements are provided independently.

In some embodiments, standard optical elements are mounted to frames. For example, the frames may be configured for 1 inch optical elements, 0.5 inch optical elements, 2 inch optical

elements, 12.5 mm optical element and/or 25 mm optical elements and/or a combination thereof. For example, an optical element may include a disk of the specified diameter. For example an optical element may include a mirror and/or a lens, and/or a filter, and/or a beam splitter, and/or an iris. Also other optical elements, such as polarization cube, Brewster slabs, optical fibers, etc. can be combined with a modular optical system.

In some embodiments, the typical distance between interlocking fixation locations is fitted to a conventional optical elements size. For example:

1. Platform for Imperial (inch) optics:

a. 1'' optics platform:

- i. Platform distance between fixation locations - 1.5 inch and/or multiples thereof
- ii. frames – outer dimension 1.5inch\* 1.5inch\*1.5inch or less or multiples thereof
- iii. Freedom to locate the optical elements in discrete locations distanced by multiples of 1.5'' as well as 0.75'' and/or 0.375''

b. alternative 1'' optics platform:

- i. Platform distance between fixation locations - 1.33 inch and/or multiples thereof.
- ii. frames – outer dimension 1.33inch\* 1.33inch\*1.33inch or less or multiples thereof
- iii. Freedom to locate the optical elements in discrete locations distanced by multiples of 1.33'' as well as 0.66'' and/or 0.333''

c. 0.5'' optics platform:

- i. Platform distance between fixation locations - 1 inch and/or multiples thereof
- ii. frames – outer dimension 1inch\* 1inch\*1inch or less or multiples thereof
- iii. Freedom to locate the optical elements in discrete locations distanced apart by multiples of 1'' as well as 0.5'' and/or 0.25''

d. 2'' optics platform:

- i. Platform distance between fixation locations - 3 and/or 2.25 inch and/or multiples thereof
- ii. frames – outer dimension 3inch\* 3inch\*3inch and/or 2.25inch\* 2.25inch\*2.25inch or less or multiples thereof

iii. Freedom to locate the optical elements in discrete locations of distanced by multiples of 3'', 2.25'' and/or 1.5'' as well as 0.75'', 0.5 and/or 0.375''

e. Combination between these dimensions:

i. 0.5 inch optics in 1 inch platform.

5 ii. 0.5 inch optics in 2 inch platform

iii. 1 inch optics in 2 inch platform

f. There may be allowed error of up to 0.01 inch and/or 0.1 inch and/or 0.5 inch.

## 2. Metric optics

a. 25mm optics platform:

10 i. Platform distance between fixation locations – 37.5 mm and/or multiples thereof

ii. frames – outer dimension 37.5 mm \* 37.5 mm \*37.5 mm or less or multiples thereof

15 iii. Freedom to locate the optical elements in discrete locations of distanced by multiples of 37.5 mm as well as 18.75 mm and/or 9.875 mm

b. An alternative 25mm optics platform:

i. Platform distance between fixation locations – 33.87 mm and/or multiples thereof

20 ii. frames – outer dimension 33.87 mm \* 33.87 mm \* 33.87mm or less or multiples thereof

iii. Freedom to locate the optical elements in discrete locations of distanced by multiples of 33.87 mm as well as 16.93 mm and/or 8.467 mm

c. 12.5mm optics platform:

25 i. Platform distance between fixation locations – 25mm and/or multiples thereof

ii. frames – outer dimension 25mm \* 25mm \*25mm or less or multiples thereof

iii. Freedom to locate the optical elements in discrete locations of distanced by multiples of 25mm as well as 12.5mm and/or 6.75mm

30 d. 2'' optics platform:

i. Platform distance between fixation locations - 75mm or 56.25 mm and/or multiples thereof

- ii. frames – outer dimension 75mm \* 75mm \*75mm or less or multiples thereof and/or 56.25 mm \*56.25 mm \*56.25 mm or less or multiples thereof
- iii. Freedom to locate the optical elements in discrete locations of distanced by multiples of 75mm, 56.25mm, and/or 37.5mm as well as 18.75mm, 12.5 mm and 9.875mm
- 5
- e. Combination between all these dimensions:
- i. 12.5mm optics in 25mm platform.
- ii. 12.5mm optics in 50mm platform
- 10
- iii. 25mm optics in 50mm platform
- f. Examples will be given to the 25mm, There may be allowed error of ranging up to 0.025 mm and/or/or 0.25 mm and/or 0.5 mm.
- g. In some embodiments, adapters may have dimensions that are combinations of any of the different sizes listed herein above. Alternatively or additionally, an adapter may have a size that compensates between dimensions of different systems. For example, an adapter may fill a difference between dimensions of different systems. For example, an adapter may be sized to link optical axes between optical units of systems having sizes listed herein above. For, example an adaptor may align an optical path of a unit of one discrete size to an optical path of a unit of a different size. Alternatively or additionally units may have sizes that are not listed here.
- 15
- 20
- h. In some embodiments, back to back boards may have outward facing faces that are distance by a discretization distance of the fixation locations and/or an integral multiple of the discretization distance and/or an integral factor of the discretization distance (for example the multiple and/or factor may be 1, 2, 3, 4, 5, 6, 7, 8, or more). For example, the thickness of the boards may fit the discretization system of the fixation locations. For example, the thickness of each board may be an integral multiple of the discretization distance and/or an integral factor of the discretization distance (for example the multiple and/or factor may be 1, 2, 3, 4, 5,
- 25
- 30
- i. In some embodiments, the thickness of a board may be  $\frac{1}{2}$  the discretization distance between fixation locations. For example, two boards may be placed and/or attached back to back with the fixation location of one face

being located at one discretization distance from the fixation locations of the opposite face. Optionally the boards are attachable in alignment. For example, when two boards are attached back to back, the fixation locations on one board may be aligned in the plane of the board to the fixation locations of the opposite face of the other board. For example, for a 1" system with 1.5" fixation location discretization, the thickness of a board may be 0.75" and/or a multiple thereof. For example, for a 1" system with 1.33" fixation location discretization, the thickness of a board may be 0.66" and/or a multiple thereof. For example, for a 1/2" system with 1" fixation location discretization, the thickness of a board may be 0.5" and/or a multiple thereof. For example, for a 2" system with 3" or 2.25" fixation location discretization, the thickness of a board may be 1.5" and/or 1.125" and/or a multiple thereof. For example, for a 25mm system with 37.5 mm or 33.87 mm fixation location discretization, the thickness of a board may be 18.75 mm and/or 16.93 mm and/or a multiple thereof. For example, for a 12.5mm system with 25 mm fixation location discretization, the thickness of a board may be 12.5 mm and/or a multiple thereof. For example, for a 2" system with 75mm or 56.25mm fixation location discretization, the thickness of a board may be 37.5mm or 28.125 mm and/or a multiple thereof.

- ii. In some embodiments, the thickness of a board may be 1/4 the discretization distance between fixation locations. For example, two boards may be placed and/or attached back to back with the fixation location of one face being located at 1/2 discretization distance from the fixation locations of the opposite face. Optionally the boards are attachable in alignment. For example, when two boards are attached back to back, the fixation locations on one board may be aligned in the plane of the board to the fixation locations of the opposite face of the other board. For example, for a 1" system with 1.5" fixation location discretization, the thickness of a board may be 0.375" and/or a multiple thereof. For example, for a 1" system with 1.33" fixation location discretization, the thickness of a board may be 0.33" and/or a multiple thereof. For example, for a 1/2" system with 1" fixation location discretization, the thickness of a board may be 0.25" and/or a multiple thereof. For example, for a 2" system with 3" or

2.25" fixation location discretization, the thickness of a board may be 0.75" and/or 0.5625" and/or a multiple thereof. For example, for a 25mm system with 37.5 mm or 33.87 mm fixation location discretization, the thickness of a board may be 9.375 mm and/or 8.47 mm and/or a multiple thereof. For example, for a 12.5mm system with 25 mm fixation location discretization, the thickness of a board may be 6.25 mm and/or a multiple thereof. For example, for a 2" system with 75mm or 56.25mm fixation location discretization, the thickness of a board may be 18.75mm or 14.0625 mm and/or a multiple thereof.

- iii. In some embodiments, a board may have a thickness equal to the discretization distance between fixation locations. For example a board may have fixation locations on two opposite faces with the fixation location of one face being located at one discretization distance from the fixation locations of the opposite face. The fixation locations on one face may be aligned in the plane of the board to the fixation locations of the opposite face.
- iv. In some embodiments, thinner platforms may fit back to back with outwardly facing faces centered at discretization locations. For example a spacer and/or connector may be positioned between two boards mounted back to back.

Alternatively or additionally, a system may include a combination between dimensions for example, 12.5mm optics in a 25mm platform and/or 12.5mm optics in a 50mm platform and/or 25mm optics in 50mm platform. Error tolerance may range for example between 0.01 % to 0.07% and/or between 0.07% to 0.15% and/or between 0.15% to 1% and/or between 1% to 5%. A potential advantage of a conventional typical distance is compatibility with existing optical elements of other optical systems.

In some embodiments, a modular unit may be configured such that the position of an optical element is independent of the angle at which the unit is attached to a fixation location. For example, an optical element (and or a set of optical elements) may be mounted in a patten having optical symmetry. For example, the symmetry may be around an axis of the unit and/or an axis of a connector. For example, the modular unit may be configured such that when the unit is mounted to a fixation location, the optical element is centered with respect to the fixation location.

In some embodiments, a system may have one or more discretization distance. The discretization distance is defined as the largest distance which is a divisor of any portion of the optical path of a device between optical elements of different modular units. An x-axis discretization distance is defined as the largest distance which is a divisor of any portion of the optical path aligned with the x-axis of a device between optical elements of different modular units. A 2 orthogonal axis discretization distance is defined as the largest distance which is a divisor of any portion of the optical path aligned with either of two orthogonal axes of a device between optical elements of different modular units. A 3 orthogonal axis discretization distance is defined as the largest distance which is a divisor of any portion of the optical path aligned with one of three orthogonal axes of a device between optical elements of different modular units. A discretization distance between fixation locations along an axis will be a divisor of the distance between any two discretization locations located on a line parallel to the axis. For example, for a set of fixation locations, there may be a maximal discretization distance which is the maximum divisor of the distance between any two fixation locations along an axis and/or two orthogonal axes and/or three orthogonal axes.

In some embodiments, the discretization distance between fixation locations may be chosen so that multiple fixation locations are aligned and/or coincide to attachment holes on an optical table. For example, a modular optical system may be made to fit a one inch optical table. For example, the two axis fixation location discretization distance in the horizontal plane may be  $(n+1)/n * 1''$  such that for any integral  $n$  greater or equal to 1 such that a distance between every  $n+1$  discretization locations is an integral multiple of the  $1''$  spacing of the optical table. For example, for  $n=2$  the two axes discretization distance in the horizontal plane may be 1.5 inch such that every third fixation location fits to an attachment hole of the optical table. For example, for  $n=3$  the two axes discretization distance in the horizontal plane may be  $4/3$  inch such that every fourth fixation location fits to an attachment hole of the optical table. For example, for  $1''$  optical elements the discretization distance may be described by  $(n+1)/n * 1''$  for any integral  $n$  greater or equal to 1 or for  $n$  1, 2, 3, 4, 5, 6, 7, or 8. Optionally for different sized optical elements the discretization distance may be chosen to be slightly larger than the element. For example, for  $2''$  optical elements the discretization distance may be described by  $(n+1)/n * 2''$  for any integral  $n$  greater or equal to 1 or for  $n$  1, 2, 3, 4, 5, 6, 7, or 8. For example, for  $1/2''$  optical elements the discretization distance may be described by  $(n+1)/n * 1/2''$  for any integral  $n$  greater or equal to 1 or for  $n$  1, 2, 3, 4, 5, 6, 7, or 8.

In an example for an optical path in an interferometer:

The beam is directed to a 50%-50% beam-splitter (positioned in 45 degree) that divides the pulse into two beams – one which continues straight and the other which makes a 90 degrees turn. Each beam travels the same (discrete) distance and can be manipulate independently (e.g. one can change polarization; the other can travel in different media, etc.). With mirrors, the beams can be directed into another 50%-50% beam splitter that will combine the two separate beams.

After the combination, one can see an interference pattern between the beams that can be analyzed – and will possibly allow the retrieval of the optical response of materials.

In another example for a simpler apparatus for polarization:

The light beam has certain polarization in the input. With 5 mirrors that are located each in 45 degrees, the polarization can change its degree by 90 degrees – i.e. from Horizontal polarization to a vertical polarization (or vice versa).

Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not necessarily limited in its application to the details of construction and the arrangement of the components and/or methods set forth in the following description and/or illustrated in the drawings and/or the Examples. The invention is capable of other embodiments or of being practiced or carried out in various ways.

## 2D modular optic system

*FIG. 1* is a block diagram illustration of a modular optical system in accordance with an embodiment of the current invention. In some embodiments, a platform **100** includes a plurality of discrete fixation locations. Each fixation location includes a connector **101a**, **101b** defining a location and/or direction of an optical axis **104a**, **104b**. Optionally, multiple modular optical units **109a**, **109b** are configured to connect to the fixation locations. For example, each unit **109a**, **109b** includes a complementary connector **102a**, **102b** configured to connect to any of the connectors **101a**, **101b** of the platform **100**. Optionally, each modular optical unit **109a**, **109b** defines an optical axis **104a**, **104b**. In some embodiments, connection between each unit **109a**, **109b** and a connector **101a**, **101b** constrains the direction of the optical axis **104a**, **104b** to a discrete number of defined directions (for example one of four, six, eight, ten, twelve, sixteen, twenty, **32** directions and/or an intermediary number of directions and/or more directions). Optionally, the directions may be aligned to the locations. For example, fixation locations may fall along a row and/or a column on the platform and/or an optical axis **104a**, **104b** may pass along an axis of the row and/or column. Optionally an optical axis may intersect a fixed interval of locations. For example a 45 degree axis may intersect equidistant fixations locations by

moving an equal number of locations over a number of rows and up an equal number of columns. Optionally for row spacing that is double column spacing a 45 degree angle may be defined as one up and two over and so forth for other row and/or column spacing. Optionally for other angles other ratios of grid movements may apply.

5 In some embodiments, the interaction between optical axes **104a**, **104b** of two modular optical units **109a**, **109b** may be fixed by selecting one of a discrete number of locations and/or one of a discrete number of directions for each of the modular optical units **109a**, **109b**. Optionally, the platform has a planar face including a plurality of fixation locations. Optionally the fixation locations are located at regular intervals along one or more axes on the face. For  
10 example, the fixation locations may be located along a grid. For example, the fixation location may be located at every grid location along a regular grid. Alternatively or additionally, the fixation locations are located some but not necessarily all points along a regular grid. For example, the distances between fixation locations may be defined as multiples of some set base distance.

15 In some embodiments, a unit may be replaced without affecting other units and/or the board. For example, a unit **109a** may be replaced by another unit **109b** while the other units on a board remain aligned. For example, an optical axis **104a** of a unit **102a** may be aligned to a network of units. Optionally, unit **109a** may be replaced by another unit, for example new unit may be aligned to and/or connected to the network by selecting a location on the grid and/or a  
20 direction from a finite number of directions.

In some embodiments, the aligned fixation locations may all be on a surface of a single platform for example, on a planar surface of a single board. Alternatively or additionally, the aligned fixation locations may be on aligned surfaces of multiple inter connected platforms. For example, platforms may be directly connected one to another. For example, boards may be  
25 directly interconnected with aligned surfaces. Alternatively or additionally, disconnected platforms may be interconnected by an alignment object. For example, multiple boards may be attached at non-contiguous locations to an optical table. The connection to the optical table may align surface of the boards one to another. Optionally, each board will include mounts to the optical table that align the board to the table in one of a discrete number of alignment positions.

30 In some embodiments, a network of modular units may be expandable. For example, units may be added and/or removed. Optionally, alignment of units **102a**, **102b** is dependent on their respective orientations and/or positions on a board **100**. For example, addition or removal of one unit will not affect orientation of other units. Optionally, a board containing a plurality of units may be combined with another board to form a shared network. For example, boards may

connect to preserve a pattern of fixation locations over the combined boards. Optionally boards may have connector to attach them edge to edge (for example as illustrated in *FIGs. 6B, 6C*).

*FIG. 2* is a flow chart of a method of mounting modular optical units accordance with an embodiment of the current invention. In some embodiments, a plurality of discrete fixation locations and directions are defined **210**. For example, a platform may be supplied having a fixed pattern of fixation locations and/or a discrete set of fixation orientations. Optionally, a network of modular optical units is defined by selecting **211** locations and directions for each of a plurality of optical units within the pattern.

In some embodiments, multiple modular optical units may be provided **209**. For example, a modular optical unit may include an optical element (for example a mirror and/or an optical filter and/or a lens and/or an iris and/or a mirror). The modular optical unit optionally includes a fixation element (for example a complementary connector to a connector at a fixation location of a platform). For example, the connection may limit the optical element and/or an optical axis associated to the element to a finite number of discrete locations and/or directions. Optionally, the unit includes a frame including complementary connector to a platform and/or a standard mount for a standard optical element. For example, providing **209** the unit may include frame the optical element to the mount of the frame.

In some embodiments, optical axes of two modular optical units are aligned automatically according to a selection of discrete locations and directions. Optionally, units placed on the pattern are automatically aligned without requiring further adjustment. For example, parts may not include adjustable directions and/or positions outside of the discrete pattern. In some embodiments this makes it simple to place and/or replace **216** units in an optical network. For example, a unit may be changed (e.g. added, replaced and/or removed) independently. For example, changing a unit will not disturb relationships between other units in the network. Optionally, a new unit may be aligned to old units automatically based on the selection of discrete fixation location and/or direction.

In some embodiments, a pattern of fixation locations may be expanded **214**. For example, an expansion board may be added to an existing board. Optionally a new board may be connected to an old board. Alternatively or additionally, the fixation pattern may be expanded **214** by mounting the existing board and/or the expansion board may to an alignment object. For example, two boards may be interaligned by attachment to an optical table. Optionally, each board may include mounts that limit attachment to the optical table to discrete locations, heights and/or alignments. For example, alignment of optical axes across multiple boards may be determined by the choice of rows and/or columns of attachment locations on the optical table.

The alignment is optionally achieved without further calibration of the optical axes. For example, a coupling may be supplied to position and/or orient multiple boards to form a shared pattern. For example, an extension board may continue a pattern defined by the existing board. For example, a shared axis defined by a relationship between fixation locations on a board may  
5 on the board and/or between the board and additional board. In some embodiments, a first optical network and/or device on one board may be combined with a second optical network and/or device on a second board by interconnecting the boards. Optionally, the interconnection between the boards is delimited by a discrete set of positions and/or directions. For example, selecting a position and/or direction of each board from a discrete set automatically aligns and/or  
10 combines the boards. For example, alignment of boards does not require calibration of any continuous adjustment. Alternatively or additionally, the devices may be combined by adding and/or removing units at selected locations and/or directions selected from a discrete set. In some embodiments, boards may be interconnected and/or aligned without movement of an existing board. For example, where a new board is attached to an existing board, the attachment may be  
15 achieved with exposed surfaces of the existing board (e.g. without having to access a bottom of board that may be supported on a surface).

### 3D modular optic system

*FIG. 3* is a block diagram illustration of a 3D modular optical mounting system in accordance with an embodiment of the current invention. In some embodiments, a pattern of  
20 fixation locations and/or directions may be defined in a 3D space. For example, fixation locations may fall on multiple planes in 3D space.

In some embodiments, a pattern **100** of fixation locations may be defined on a first plane and/or a complementary pattern **300** may be defined on a second plane. Optionally, the relationship between fixation locations in different planes may be matched. For example, shared  
25 optical axes between modular optical units may be defined by discrete axes **304**, locations and/or directions with respect to the different planes by a set of discrete spacings and/or angles. For example, the spaces between fixation locations in different dimensions may be equal and/or related by simple multiples. For example, the first and second planes may be orthogonal and/or parallel. Optionally, a modular optical unit **309** may include an optical element having an optical  
30 axis **304** connected to a complimentary connector **302**. The modular optical unit **309** is optionally attached to a connector **301** at a fixation location within pattern **300** such that optical axis **304** intersects a modular optical unit **102b** on a pattern **100** on a different plane. In some embodiments, the intersection of axes **104a**, **104b**, **304** on one plane with units located on a different plane (and/or not located on the first plane) may be determined by a finite number of

discrete locations and/or directions. For example, a network of intersecting axes may be built by merely choosing locations and direction among a discrete set without further calibration. Alternatively or additionally, the length of the optical axis may be fixed by the number of fixation locations that it passes. For example, a length of intersecting axes may be determined by merely choosing locations and direction among a discrete set without further calibration. 5 Optionally the discretization of path length may facilitate synchronizing pulses. For example, two pulses formed at the same time (e.g. split from a single pulse) may be sent along two paths (for example a path may include elements that condition one of the two pulses). In order to synchronize the two pulses at the end of the two paths, the two paths may be designed to have equal path lengths. Discretizing path length, in accordance with embodiments of the current invention, may facilitate designing paths of specified (for example equal) lengths. For example, after two pulses travel on the two separate paths, a discrete addition may be added to the shorter path to make the two path lengths equal and/or to synchronize the pulses. For example, the synchronized pulses may reach a sensor and/or joiner at the same time. For example, 10 synchronization may facilitate combining and/or comparing the two pulses.

In some embodiments, a mount for a modular optical unit may include a complementary connector for connection to a platform on one surface and/or a connection for another modular optical unit on another surface. For example, the complementary connector may be configured for attaching a modular unit including a first optical element to a platform. Optionally, the connector on the other surface may be configured for attaching a second modular optical unit including a second optical element to the first optical unit. For example, a first modular optical unit may be attached to a base and a second modular optical unit attached to the top of the first unit. Optionally the second modular optical unit will be rotationally aligned to the base (for example directed in one of the discrete component directions defined by the base). Optionally, 20 the second modular optical unit will be aligned with a wall platform. For example the height of the first modular optical unit may be equal to the distance between fixation locations on a wall platform (and/or an integral multiple of that distance). In some embodiments a spacer unit may be used to raise a modular optical unit away from a board. For example, a spacer unit may be sized to hold a modular optical unit at a fixation location defined in 3D space by orthogonal platforms. 30

FIG. 4 is a flow chart of a 3D method of mounting modular optical units in accordance with an embodiment of the current invention. In some embodiments fixation locations may be supplied on multiple planes. For example, fixation locations may be organized on a 3D grid. A plurality of modular optical units may be attached to fixation locations on various planes.

Optical axes of the devices may intersect for example to build a network of interconnected devices.

In some embodiments, multiple platforms may be supplied **410**, each platform having a pattern of fixation locations. Optionally, the patterns on different platforms may match up. For example, the fixation locations may be arranged as a grid on each platform may have a simple integral ratio relationship to the locations on another platform. For example, grid spacing may be equal on different platforms and/or may have a simple multiple relationship (for example grid spacing on one platform may be twice that of another platform) and/or have an integral ratio (two spacings on one grid may equal three spacings on another grid).

In some embodiments, modular optical units may be attached **212** to each platform. For example, attachment **212** may be constrained to discrete location and/or discrete directions. Optionally, by designating locations and directions one may define a network of intersecting optical axes. Optionally, attaching **212** the units to the designated locations in the designated directions automatically aligns the optical axes, for example without need to calibrate the units.

In some embodiments, the different platforms are built **414** into a 3D structure with shared optical axes across platforms to form a large network. For example, a set of units and/or fixation locations and/or optical axes may all fall in a first plane. For example, a second set of units and/or fixation locations and/or optical axes may all fall in a second plane outside of the first plane. Optionally, the platforms are built **414** into a structure such there is at least one shared axis that intersects at least one unit the first set of units and at least one unit of the second set of units. Optionally, a beam and/or a pulse travels, between elements of the first set and then along the shared axis to the second set of elements and is transferred between units of the second set of units. For example, a platform containing the first set of units may be attached a platform containing the second set of units in a predetermined geometry to form the shared axis. Alternatively or additionally, the a platform containing the first set of units and the platform containing the second set of units may be attached to a joining element in a predetermined geometry to form the shared axis. For example, the two platforms may be attached to an optical table in the predetermined geometry.

In some embodiments an ultra-short pulse may be split along two paths. Optionally the paths contain discrete sections and/or the path length is determined by the number of fixation locations in each discrete section. For example, each path may pass and equal number of fixation locations. After being split to the two paths, the pulse may be reunited. Alternatively or additionally, distance between fixation locations may along different paths may be related by an integral ratio and/or the path may pass an equivalent ratio of locations before being reunited.

In some embodiments, platforms and/or patterns of elements and/or optical axes may be arranged along orthogonal surfaces and/or along parallel surfaces. For example, platforms may be built **414** into a structure having walls orthogonal to a base and/or a roof. Optionally a beam and/or a pulse will be transferred between paths along parallel and/or orthogonal surfaces. Alternatively or additionally, a single beam and/or pulse may be split and parts of the beam and/or pulse may travel along paths on various parallel and/or orthogonal surface. Subsequently the beam and/or pulse is optionally reunited.

In some embodiments, platforms may be built into boxes and/or stacked one on top of another. Optionally one or more shared axes will transfer a beam between units of different boxes. Optionally a unit and/or a network of units (for example a box) may be replaced while the rest of the network remains in place. Thus a new functional group may be added and/or removed from a complex laser device. Optionally, positioning of platforms and/or boxes is constrained to discrete positions and/or directions and/or distances. For example, coordination of shared axes and/or units and/or functional groups may be determined by choosing a discrete location and/or direction for each unit and/or group. Optionally the shared axes are joined by the discrete positioning without calibration. Alternatively or additionally, a calibration element (for example an adjustable mirror) may be supplied at an access point to adjust the shared axis between devices.

In some embodiments, a plurality of platforms may be built **414** into a 3D structure and then multiple modular optical units may be attached **212** to the platforms. For example the multiple modular optical units may form a 3D network and/or a shared pathway for a laser beam and/or pulse traveling between modular units attached to one or more of the platforms.

### **Example of modular optic units and relationships**

*FIGs. 5A and 5B* are schematic drawings of reconfiguring a modular optical device in accordance with an embodiment of the current invention. Optionally units may be reversibly attached to a grid of 16 fixation locations illustrated as boxes on each platform **500a**, **500b**. Optionally units can be attached on each grid in one of for orthogonal directions.

For example, *FIG. 5A* illustrates two disconnected platforms **500a** and **500b**. A laser light **504** is directed through an access path of platform **500a**. The light travels along a path **525** intersecting a first unit including a mirror **518b** directing the beam across an element **520a** (for example a filter). The light passes element **520a** and strikes a mirror **518a** which directs the light to an exit **522**. For example, in *FIG. 5A*, platform **500b** includes 4 mirrors and two elements that preserve direction.

In some embodiments, two platforms may be built into a compound device. For example, as illustrated in *FIG. 5B*, platform **500b** is connected to platform **500a** and/or mirror **518a** is moved up one grid space and rotated one rotation unit of 90 degrees to position **518a'**. Connecting the platforms and/or moving mirror **518a** optionally has no effect on the interconnections of other units on the two platforms. For example, after joining the boards **500a**,  
5 **500b** the same light **504** enters by the same access path **525**, is redirected by the same mirror **518b** and/or passes the same element **520a**. When the beam hits mirror **518a'** it is optionally directed along platform **500b** to mirror **518e**, mirror **518c**, mirror **518d**, through two elements **520b** and **520c**, to mirror **518f** and out exit **522**. The beam optionally enters and exits along the  
10 same path as before combination of platforms **500a** and **500b**, but has now passed through more elements **520b**, **520c** and/or a longer path length.

In some embodiments, the path length is discretized. For example, the path length may be determined by the number of fixation locations crossed. Optionally each fixation location is a square block. Optionally, each unit is centered on a fixation location. For example, beam **525**  
15 crosses half of the block fixation location **502** hitting mirror **518b** at the center of the block and then crosses half of the block before reaching the block of device **520a**. For example, the path in *FIG. 5A* crosses ten blocks and optionally has a length of ten units. For example, the path in *FIG. 5B* crosses **22** blocks and/or has a length of 22 units. For example if each block is square with a side length of 1.5 inches then the path length in *FIG. 5A* is 15 inches and/or the path length in  
20 *FIG. 5B* is 33 inches. Discretization of path length may facilitate constructing devices with exact path lengths which in some embodiments may facilitate joining pulses of light passing over separate paths. Optionally centering optical elements on a fixation location facilitates discretization of path length. For example, by centering mirror **518a** on a fixation location, the length of path entering and exiting the block of mirror **518a** is independent of the direction in  
25 which mirror **518a** is oriented.

*FIGs. 6A to 6C* are perspective drawings illustrating joining platforms for mounting modular optical units in one plane in accordance with an embodiment of the current invention. In some embodiments, a platform has the form of an optical breadboard with a two dimension pattern of discrete fixation locations on a surface thereof. For example the surface may be planar.  
30 Optionally, an attachment interface is supplied at some or all edges of the platform. For example, the interface facilitates connecting one platform to another platform. For example, the attachment interface may be configured to constrain attachments between platforms such that the fixation locations on the two platforms form a continuous pattern.

*FIG. 6A* illustrates an exemplary platform **600a** for attachment of modular optical units in accordance with an embodiment of the current invention. For example, platform **600a** includes 4 complete fixation locations **602** in a central section and **8** half fixation locations along the edges of the platform **600a** and four quarter fixation locations on the four corners of the platform **600a**.  
5 For example, each fixation location includes a square female connector **628** surrounded by four rectangular male connectors **626**. The male connectors optionally include holes **624a**. For example, some of holes **624a** may be threaded for screws and/or some of holes **624a** may be configured to hold a pin. Optionally along two edges of platform there are extension flanges **630a** and **630a'** for connection to an extension platform (for example platforms **600b** and/or  
10 **600c** as illustrated for example in *FIGs. 6B and 6C*). Extension flanges, **630a**, **630a'** optionally include holes **624b**. For example, some of holes **624b** may be threaded for screws and/or some of holes **624b** may be configured to hold a pin. The other two edges of platform **600a** include extension overhangs **630b** and **630b'**. Extension overhangs, **630b**, **630b'** optionally include holes **624c**. Optionally, each overhang **630b**, **630b'** is configured to attach to a flange (for  
15 example similar to flanges **630a**, **630a'**) of an extension board. Optionally, holes **624b** are positioned and/or configured for attachment to corresponding holes (e.g. similar to **624c**), for example by a screw and/or a pin.

*FIG. 6B* illustrates attaching a platform **600a** to a platform **600b** in accordance with an embodiment of the current invention. For example, an overhang of platform **600b** (for example  
20 similar to overhang **630b**) is placed over a flange **630a** of platform **600a**. A screw and/or a pin is optionally used to connect the platforms **600a** and **600b**. For example a screw and/or a pin may lock the two platforms together and/or the lock them into alignment. For example, a screw may be inserted through a hole in platform **600b** (for example similar to hole **624c**) and screwed into a hole **624b** in platform **600a**.

25 In some embodiments, holes may be arranged to allow attaching platforms together while they lie on a flat surface. For example, an extension (e.g. platform **600b**) may be added to an existing breadboard (e.g. platform **600a**) without disturbing the existing breadboard and/or without moving the existing breadboard and/or without disturbing modular optical units previously attached to the breadboard. For example, screws may be inserted through holes (e.g.  
30 holes **624c**) from the top of platform into corresponding holes (e.g. holes **624b**) of another platform while one or both platforms sit on a table.

*FIG. 6C* illustrates attaching a platform **600c** to the combined platforms **600a** and **600b** in accordance with an embodiment of the current invention. Optionally the fixation location all

remain with the same and/or a matching pattern. For example, modular optical units may be connected and/or optical networks built as described for example in *FIGs 1, 2 and 5*.

*FIGs. 7A and 7B* are perspective drawings joining boards for mounting modular optical units in accordance with an embodiment of the current invention. Exemplified are optional configurations for walls of the 3D box. Optionally walls may be connected with screws, pins and/or male-female connectors. Optionally a platform including for example a base, walls and/or a ceiling may be connected and or extended to any size. For example a platform **700a** may include an attachment interface with an overhang **630b** and/or a flange **630a**. Optionally, a flange may be connected to an overhang of another platform. For example the extension may extend a platform with a coplanar extension. Alternatively, an edge of platform **700a** may include an angle attachment interface **731**. For example attachment interface **731** may attach to a flange to form an out-of-plane connection between two platforms. In some, embodiments, a fixation location **702** may include a flat surface and/or a pattern of holes, for example four holes. In some embodiments, a separate joiner element may be supplied. For example, two platforms may be joined into a coplanar extension by employing one joiner element and/or the two platforms may be joined into an out-of-plane extension using a different joiner element.

*FIGs. 8A to 8B* are perspective drawings illustrating joining of platforms **700a**, **700b**, **700c** for mounting modular optical units in multiple planes in accordance with an embodiment of the current invention. In some embodiments, a platform **700a**, **700b**, **700c** may include a built in attachment interface (for example a flange and/or an overhang) for attaching to an extension. In some embodiments, the attachment interface may be configured for extension of a platform in a single plane (for example as illustrated in *FIG. 6A-6C*). In some embodiments, an attachment interface may be configured for attachment of platforms in different planes. Optionally, an attachment mechanism may be in integral part of a platform. For example, some platforms may be configured for use as a base (for example including only an in-plane attachment interface). For example, some platforms may be configured for use as a wall (for example including a connector for connection to a base at a 90 degree angle). Alternatively or additionally, there may be a generic board with a generic attachment interface. For example, use of joiner elements may allow connection of generic boards at different attitudes (for example a separate corner piece may join generic platforms orthogonally (for example at 90 degree angles).

*FIG. 8A* illustrates two platforms **800a** and **800b** in accordance with an embodiment of the current invention. Optionally, each platform **800a**, **800b** includes three rows and three columns of fixation locations **802**. Optionally, each fixation location includes holes for pins and/or screws. For example, some or all of the holes may be used to stabilize a modular optical

unit. In some embodiments, some of the holes pass through the platform to the rear face and/or some holes do not pass all the way through. For example, on board **630b** a front fixation surface is illustrated with nine holes. Some of the holes are for connection to a modular optical unit. For example, in the exemplary embodiment five of the nine holes pass through the platform to a rear  
5 face. An exemplary use of the various holes of fixation location **802** will be explained in more detail with respect to *FIGs. 9 and 27A-33B*.

In some embodiment a platform may include one or more attachment interfaces. For example, platform **800a** includes flanges **630a** and/or overhangs **630b**. For example, similar to the embodiment of *FIGs. 6A to 6C*, an overhang and a corresponding flange may be used to  
10 connect together coplanar platforms. Optionally, an attachment interface may be configured to connect platforms in multiple plains. For example, attachment interface **731** fits to an overhang (for example overhang **630b**) and to attach board **800a** to **800b** with surfaces at 90 degree angles.

*FIG. 8B* perspective drawings of boards **800a** and **800b** joined in two planes in  
15 accordance with an embodiment of the current invention. Optionally, platforms **800a** and **800b** may be attached together such that fixation locations on the two platforms **800a**, **800b** are aligned which each other in different planes. For example, the two platforms **800a**, **800b** may be connected orthogonally. Optionally one axis of platform **800a** may be independent from the plane of platform **800b**. Optionally along another axis boards **800a** and **800b** are aligned. For  
20 example, platform **800a** joins platform **800b** at a right angle. For example, *FIG. 8B*, each horizontal row of platform **800a** is aligned to a corresponding row of platform **800b**. Optionally, the columns of platforms **800a** and **800b** are independent. For example, changing a position of a modular optical unit from column to column on platform **800a** does not change a corresponding position on plane **800b**.

In some embodiments, screws **832** may be used to lock platforms together. Alternatively  
25 or additional, an attachment interface may include locking interference elements and/or a male/female connection and/or a track and/or a slot and/or a groove (for example a T-slot track) and/or a pin. In some embodiments, a connection may be designed to allow connection requiring access from only one side (for example this may allow extension of a bread board with the board  
30 remains supported on a surface).

*FIG. 9* is a perspective drawing of a front face of a platform for mounting modular optical units in accordance with an embodiment of the current invention. Optionally, a board may include two columns and/or three rows of fixation locations **802**. Optionally a platform may include one or more attachment interfaces.

In some embodiments, an arrangement of holes in a fixation location **802** may serve multiple functions. For example, a fixation location **802** may include a hole **924e** centered on the fixation location **802**. Alternatively or additionally, a fixation location may include one or more holes **925c** arranged at corners of the fixation location. Alternatively or additionally, a fixation location may include one or more holes **925d** arranged at edges (for example the center of each edge) of the fixation location. For example, as seen in the rear face of board **800a** in *FIGs. 8A, 8B*, holes **924d** may pass all the way through the platform and/or holes **924c** may not pass all the way through the platform. Optionally holes **924d** are used for pins. Optionally, holes **924d** are used for inserting screws, for example, from behind the board. Alternatively or additionally, screw holes may be configured for inserting screws from the front of the board. For example this may facilitate attaching units, detaching units and/or connection of platforms from the front face while the back face rests on a table without moving the platforms.

In some embodiments, a connector is invariant to rotation over a certain angle, for example 180 degrees, 90 degrees, 60 degrees 30 degrees. Optionally the connector of the fixation location **820** is invariant to 90 degree rotation. For example, each fixation location **802** includes a hole **924c** on each of the 4 corners and/or a hole **924d** on a center of each side. For example, a modular optical unit can be mounted to each fixation location platform **900** in any one of 4 orthogonal directions.

In some embodiments, a distance **923a** between holes of adjacent sides fixation locations is equal to a distance **923b** between opposite sides of a single fixation location. For example, a modular optical unit may be mounted centered on a fixation location and/or centered between two fixation locations.

In some embodiments, a platform may include an interface for mounting to an optical table. For example, an optical table may include grid of holes for screw located every one inch. Optionally, holes **924e** are located along a 1.5 inch grid across platform. Optionally, board **900** may be attached to a table by putting a screw through a corresponding hole of the platform to a corresponding hole of the table. For example, every third hole **924e** in the platform may correspond to every fourth hole of the grid of the table. Optionally, a spacer may be placed between the table and platform **900**. For example, the space may raise the platform off the table by a measured amount. For example, distance **923a** may be equal to **923b** may be equal to 0.75 inches.

In some embodiments, an attachment interface may include a flange **930a** and/or an overhang **930b** and/or an angled connector **931**. For example, an attachment interface may be on an edge of the platform.

FIG. 10 is a perspective drawing of a polarization inverter built of modular units in accordance with an embodiment of the current invention. In some embodiments a platform may include an opening. For example the opening may serve to allow a light beam and/or burst to pass therethrough.

5 In some embodiments, a set of modular optical units are attached to discrete fixation locations on one or more platforms **1000a**, **1000b** to form a functional device. For example, a set of six mirrors **1018a-1018f** may be used to reverse polarity of a light beam **1025a**.

In some embodiments a mirror may be mounted on a frame to form a modular optical unit **1018a – 1018f**. For example, each unit **1018a – 1018f** may be mountable to a fixation location on one of four faces and/or each face may be mountable to the fixation location in one of four directions. For example, each unit has two square faces and two triangular faces. Optionally each fixation location includes four holes for mounting to a modular optical unit. Optionally, each square face of a unit **1018a – 1018f** includes two holes. For example, two pins and/or two screws may be used to attach the square side to the fixation location in one of four directions. Optionally, each triangular face of a unit **1018a – 1018f** includes one hole. For example, a pin and/or a screw may be used to attach the triangular side to the fixation location in one of four directions.

In some embodiments, light beam **1025a** may enter the system, pass half a fixation locations and strike a first mirror **1018a**. Mirror **1018a** is optionally centered on the square fixation location. The modular unit is attached on a triangular side to the base platform **1000a**.  
20 Optionally, mirror **1018a** is oriented perpendicular to the plane of the base platform **1000a** and/or is directed 45 degrees to the left. For example, the beam enters the device in a forward direction, passes half a fixation location while entering the device and hits mirror **1018a** and is reflected at a 90 degree angle leftward, parallel to the base. The beam optionally crosses a total of two fixation locations and strikes mirror **1018b**.  
25 Optionally the modular unit of mirror **1018b** is connected on one of its square faces with mirror **1018a** facing leftward and at a 45 degree angle upward. When the beam hits mirror **1018b**, the beam is optionally reflected vertically upward. In some embodiments, the beam crosses a total of two fixation locations and strikes mirror **1018c**.  
30 Optionally the modular unit of mirror **1018c** is connected on one of its triangle faces to a left wall platform (not shown) and/or on a square face to a ceiling platform (not shown) with mirror **1018c** facing forward and at a 45 degree angle downward. When the beam hits mirror **1018c**, the beam is optionally reflected forward, parallel to base platform **1000a**. For example, the beam crosses a total of two fixation locations and strikes mirror **1018d**.  
Optionally the modular unit of mirror **1018d** is connected on one of its square faces to a front wall platform

**1000b** with mirror **1018d** facing backward and at a 45 degree angle downward. For example, when the beam hits mirror **1018d**, the beam is reflected downward, parallel to wall platform **1000b**. The beam optionally crosses a total of two fixation locations and strikes mirror **1018e**. For example, the modular unit of mirror **1018e** is connected on one of its triangular faces to a front wall platform **1000b** with mirror **1018e** facing rightward and at a 45 degree angle upward. When the beam hits mirror **1018d**, the beam is reflected rightward, parallel to base platform **1000a**. The beam crosses a total of two fixation locations and strikes mirror **1018f**. Optionally the modular unit of mirror **1018f** is connected on one of its triangular faces to a base platform **1000a** with mirror **1018f** facing leftward and at a 45 degree angle forward. When the beam hits mirror **1018d**, an exiting beam **1025b** is optionally reflected forward, parallel to base platform **1000a**. For example, the exiting beam **1025b** may be along the same line as the entering beam **1025a** except that the polarity has been reversed. Optionally beam **1025b** crosses half a fixation location and exits the device through an opening **1034** in front wall **1000b**. In the exemplary embodiment, from the time beam **1025a** enters the device until the beam **1025b** leaves the device, the beam has crossed exactly **12** fixation locations.

In some embodiment, a system may include 1" optics and/or every fixation location may form a 1.5" square. For example, in such an embodiment the beam has traveled exactly 18 inches from when it enters the device until it exits. The use of modular discrete optical units and fixation locations optionally makes it easy to construct a device with an exact and/or reproducible path length. Furthermore, in some embodiments the device has a three dimensional path of 18 inches but only takes up a 4.5 by 4.5 inch area on an optical table and/or fits in a box sized 4.5 inches by 4.5 inches by 4.5 inches. For example this may be much easier to move and/or to carry than a traditional 2D breadboard with a similar path length.

FIG. 11 is perspective drawings of an alternative polarization inverter built of modular units in accordance with an embodiment of the current invention. In the exemplary embodiment, the device includes five mirrors **1118** mounted on two platforms **1100a** and **1100b**. For example, platform **1100a** is a 3x3 rear wall and platform **1100b** is a 1x3 ceiling. For example the device may have a foot print of three by one fixation locations and/or a path length of seven fixation locations. In the exemplary embodiment of FIG. 11, the exiting beam **1125b** is parallel to the incoming beam **1125a** and/or on a different line and/or of opposite direction and/or polarity.

In some embodiments a kit may include parts and/or instructions for building a device, for example a polarity reversing device. Alternately or additionally, a single kit may include parts for building more than one alternative device. For example a kit may include 6 mirrors and/or three 3x3 platforms and/or a 1x3 platform. The instructions may include various designs

for polarity reversing devices of different foot prints, path lengths and/or input/output orientations (for example either in the geometry of the example of *FIG. 10* and/or of *FIG. 11*.

*FIG. 12* is perspective drawings of a microscope built of modular units in accordance with an embodiment of the current invention. In some embodiments, a device may include modular units of a height of two fixation locations (for example filter **1219a**, lenses **1221**, irises **1220d**, **1220e**, optical fiber mounts **1220f**, and/or **1220g**. Alternatively or additionally, a modular unit may be stacked on another unit, for example mirrors **1218h** and **1218i** are raised off a platform by block extenders **1254**. Alternatively or additionally, a modular unit may be attached to a wall, for example sample holder **1220j**. Alternatively or additionally, a modular unit may hang from a ceiling, for example mirrors **1218k** and **1218m**.

In some embodiments, a device may include a mechanically adjustable element, for example focusing stage **1200**. For example, movement may be driven by a manual manipulator, for example screw knob **1262**. Alternatively or movement may be driven by a motor and/or an actuator.

#### 15 **Multi-layer modular optic system**

*FIGs. 13a-15* are schematic drawings of a multilayer optical devices built of modular units in accordance with an embodiments of the current invention.

*FIG.13A* illustrates transferring a beam from one base platform **1300b** to another base platform **1300a** via a mirror **1318b** attached to a fixation location on a wall platform **1300c** in accordance with an embodiment of the current invention. For example a beam **1325a** enters at **3104a**, passes through an element **520** and is transferred by a mirror **1318a** upwards. The beam hits an overhanging mirror **1318b** attached to wall platform **1300c** beyond an edge of a second story base platform **1300b**. The beam is optionally reflected from mirror **1318b** along platform **1300b**, across an element **520** and out an exit **1322a**.

*FIG. 13B* illustrates transferring a beam from one base platform **1300e** to another base platform **1300f** via a mirror **1318k** attached to a fixation location on a ceiling platform **1300d** in accordance with an embodiment of the current invention. Optionally a platform **1300f** may have the thickness of a whole number of fixation locations and/or have two faces for mounting modular optical units on opposite sides of the platform **1300e**.

In some embodiments, a beam **1325b** enters at **3104b**, passes through an element **520** and is transferred by a mirror **1318c** upwards. The beam optionally then hits a mirror **1318d** attached to ceiling on a bottom face of platform **1300f**. The beam is optionally reflected from mirror **1318d** along a ceiling on a bottom face of a second story platform **1300f**, across an element **520** and to another mirror **1318g** which optionally transfers the beam back down to another mirror

**1318f** on base platform **1300e**. For example mirror **1318f** reflects the beam along base platform **1300e** across an optical element **520** to a mirror **1318k** attached to base platform **1300e** and/or underhanging beyond an edge of platform **1300f**. Optionally mirror **1318k** reflects the beam upward to a mirror overhanging beyond an edge of second story platform **1300f**. Mirror **1318h** optionally reflects the beam along ceiling platform **1300d** across and optical element **520** and to a mirror **1318i**. Optionally, mirror **1318i** reflects the beam downward to a mirror **1318j** attached to a top face of platform **1300f**. Mirror **1318j** optionally reflects the beam along the top face of platform **1300f** across an optical element **520** and/or out an exit **1322b**.

In some embodiment a thickness of a platform **1300f** may be a whole number of fixation location lengths (for example one). Optionally, modular units connected to a bottom face (for example mirrors **1318d** and **1318f**) preserve a pattern of fixation locations along with modular units (for example mirror **1318j**) attached to a top face of the platform **1300f**. Alternatively or additionally a path traveling on either and/or both faces of platform **1300f** may preserve a discrete length scale, for example similar to beams passing along a single platform the length of the path may be constrained to a finite number of discrete steps. Alternatively or addition, two platforms may be positioned back to back where the combined thickness is the length a whole number of fixation locations. The opposed faces may serve as a ceiling and a base and preserve a fixation location pattern and/or retain a discretized path length.

*FIG. 14* illustrates transferring a beam from one base platform **1400a** to another base platform **1400b** via overhanging mirrors **1418a** and **1418b** attached to the base platforms **1400a** and/or **1400b** via frames **1436a** and/or **1436b** in accordance with an embodiment of the current invention. For example a beam travels along platform **1400a** across an optical element **1420**, past an edge of platform **1500c** and then contacts mirror **1418a**. Optionally mirror **1418b** reflects the beam up to a mirror **1418a** which optionally is attached to and/or overhangs beyond a second story base platform **1418b**. For example the beam is reflected along platform **600b**, across element **1520** attached to platform **1418b** and out an exit **1422**.

*FIG. 15* illustrates transferring a beam from a lower base platform **1500a** to an upper base platform **1500b** via an opening **1534** in the upper floor base platform **1500b** in accordance with an embodiment of the current invention. For example a beam travels along platform **1500a** across an optical element **520**, and contacts mirror **1518b**. Optionally mirror **1518b** reflects the beam up through an opening **1534** in platform **1500b** to a mirror **1518b** which optionally is attached to platform **1500b** and/or overhangs opening **1534**. For example the beam is reflected along platform **1500b**, across element **520** and out an exit **1522**.

FIG. 16 is a perspective drawing of a front face of a board for mounting modular units in accordance with an embodiment of the current invention. In some embodiments a platform **1600** (including for example a flat board) may include fixation locations **802** arranged along a regular grid. For example, platform **1600** includes a three by three grid of locations. Optionally, connectors for modular optical units are positioned on only some of the grid points. For example, the top row and left column of platform **1600** include five fixation locations **802**. Each fixation location optionally includes a connector for a modular optical unit. For example, a connector for a modular unit may include screw holes **924c** and/or pin holes **924d**. Alternatively or additionally, fixation locations may include a mounting hole **924e**. For example, the mounting hole **924e** may be used to connect to an optical table (for example as explained with reference to *FIG. 9*). Alternatively or additionally, some grid locations, for example the four lower right grid locations, may not include a connector for a modular optical unit. For example, the four lower right grid locations of platform **1600** include openings **1634**. Optionally, openings **1634** may be used to pass a beam through the platform **1600**. Alternatively or additionally, openings **1634** may be used for manual access to parts in a box and/or to pass a power cord through platform **1600** for example to power an elector mechanical part of the device.

In some embodiments, a platform may include an attachment interface. For example, an attachment interface may include a flange **1630**. Flange **1630**, is optionally used to attach platform **1600** to another platform. Optionally flange **1630** includes side mounting screw holes **1624**. For example, when a rear face of the board is supported on a table, a wall platform may be attached to flange **1630** with screws entering holes **1624** from back of the wall on the side of the box. Optionally, inserting the screws from the side facilitates construction of a box with platform **1600** as a base while platform **1600** remains stationary and/or lying on the support surface.

*FIGs. 17A – 17B* are photographs of multi-layer stand for mounting modular units in accordance with an embodiment of the current invention.

For example, a stand is illustrated in *FIG. 17A*. A stand optionally includes a plurality of platforms **1700a**, **1700b**, **1700c**, **1700d**, **1700e**, **1700f**, **1700g**, **1700h**, **1700i**, **1700j**. The stand is shown, optionally supported on but not aligned to and/or not attached to an optical table 1766.

Optionally, the stand may be attached to and/or aligned with the optical table. For example, screws could be put through holes **924e** into holes in optical table 1766.

In some embodiments a stand may include walls. For example, wall may include of set of connected 1x3 platforms including for example platforms **1700i**, **1700h**, **1700f**, **1700g**. In some locations a wall may project outward, for example, a 3x3 platform **1700e**. In some embodiments,

a ceiling may be formed having a face for mounting modular optical units facing downward. For example, the downward facing face of the ceiling may be aligned with fixation locations on a wall. For example, the 3x1 platform **1700d** forms a ceiling. For example, the downward face of platform **1700d** is aligned with fixation locations on walls **1700g** and/or **1700h**. In some  
5 embodiments, a platform may be supported on a base sitting on a surface (for example platform **1700c** is supported for example on table 1766). A base may project at a higher level. For example, platforms **1700a** and/or **1700b** are base platforms with an upper surface vertically aligned to fixation locations on walls **1700g**, **1700h** and **1700i**.

*FIG. 17B* illustrated an exemplary stand. In some embodiments, a wall may include one  
10 or more attachment interfaces, for example, attachment interfaces may facilitate connection to a base and/or a ceiling. For example, a slit **1740a** and/or a flange **1740b** may support a base platform and/or a ceiling platform. For example slit **1740a** in platform **1700m** and flange **1700b** in platform **1700n** support platform **1700k**.

*FIG. 17C* is a drawing of a 1x3 platform **1700o** in accordance with an embodiment of the  
15 current invention. For example, platform **1700o** includes three fixation locations and/or connectors **802** for attachment to modular optical units. Optionally, platform **1700o** includes attachment interfaces for orthogonal attachment of platform **1700o** to other platforms, for example a flange **1740b** and a slit **1740a**. Optionally screw holes **1724a** are included through the sides of slits **1740a**, for example to lock platforms together. Optionally screw holes **1724b** are  
20 included through an inner surface of flange **1740b**, for example to lock platforms together. For example, a screw may be inserted into hole **1724b** from an inner face of a platform. For example, inserting a screw from an inner face may facilitate screwing together platforms even when an outer surface is obscured, for example by being placed on a table.

*FIG. 17D* is a drawing illustrating a stand including a ceiling platform **1700p**, a bottom  
25 base platform **1700q**, an intermediate base platform **1700r** and/or a projecting base platform **1700s** in accordance with an embodiment of the current invention.

#### **Alternative fixation location geometries**

*FIG. 18* is a perspective drawing of connectors for attaching square and triangular faces  
of a modular mirror **1818** to fixation locations in accordance with an embodiment of the current  
30 invention. For example a connector **1802** at a fixation location on a platform **1800** may include a square female component and/or **4** screw holes. A square face **1803a** of the modular mirror **1818** optionally includes a square male component and/or **4** screw holes. A triangular face **1803b** of the modular mirror **1818** optionally includes a triangular male component and/or **2** screw holes. Optionally, the location of the center of mirror is invariant to rotation and/or which face is

attached to the fixation location. For example, the center of the mirror is always centered with regard to the fixation location. Optionally other types of modular optical units may be supplied with square and/or triangular faces of the same type.

*FIG. 19* is a perspective drawing of connectors for attaching square and triangular faces of a prismatic modular unit **1918** to fixation locations in accordance with an embodiment of the current invention.

In some embodiments an optical unit may include an angled face **1903c**. Optionally, face **1903c** is at a non-square angle to at least one mounting surface (for example face **1903b**) of the optical unit. For example, the non-square angle may be 45 degrees. Alternatively or additionally, the non-square angle may range between 25 to 75 degrees. Optionally the prismatic unit **1918** may include a second mounting surface (for example on a face **1903a**). Optionally, angled face **1903a** is perpendicular to the second mounting surface (e.g. on face **1903a**). Optionally, an optical element **1987** is mounted on the angled face **1903c** of unit **1918**. For example the optical element **1987** may include a mirror.

In some embodiments, unit **1918** is a right triangular prism. Optionally the angled face of the prism may be perpendicular a triangular base of the prism (for example face **1903a**). Optionally the angled face of the prism may be at an angle ranging between 25 to 75 degrees (for example 45 degrees) to a lateral side of the prism (for example face **1903b**). Alternatively or additionally, a prismatic unit may a shape other than a right triangular prism.

In some embodiments, a connector **1902** at a fixation location on a platform **1900** may include crisscrossing tracks and two screw holes. Square face **1903a** of the modular unit **1918** optionally includes a cross male component. Triangular face **1903b** of the modular unit **1918** optionally includes a 90 degree angled male component. Optionally, the location of the center of optical element **1987** is invariant to rotation and/or which face is attached to the fixation location. For example, the center of the element **1987** is centered with regard to the fixation location when either face **1903a**, **1903b** is attached to the fixation location. Optionally, other types of modular optical units may be supplied with a prismatic unit. Optionally other types of connectors may be used to connect a prismatic unit to a platform.

*FIG. 20* is a perspective drawing of connectors for attaching square and triangular faces of a modular mirror **2018** to fixation locations in accordance with an embodiment of the current invention. For example a connector **2002** at a fixation location on a platform **2000** may include a square female component and/or 2 screw holes. A square face **2003a** of the modular mirror **2018** optionally includes a square male component and/or 2 screw holes. A triangular face **2003b** of the modular mirror **2018** optionally includes a triangular male component and/or 1 screw holes.

Optionally, the location of the center of mirror is invariant to rotation and/or which face is attached to the fixation location. For example, the center of the mirror is always centered with regard to the fixation location. Optionally other types of modular optical units may be supplied with square and/or triangular faces of the same type.

5            *FIG. 21* is a perspective drawing of connectors for attaching square and triangular faces of a modular mirror **2118** to fixation locations in accordance with an embodiment of the current invention. For example a connector **2102** at a fixation location on a platform **2100** may include 2 screw holes. A square face **2103a** of the modular mirror **2118** optionally includes 2 screw holes. A triangular face **2103b** of the modular mirror **2118** optionally includes 1 screw hole.

10          Optionally, the location of the center of mirror is invariant to rotation and/or which face is attached to the fixation location. For example, the center of the mirror is always centered with regard to the fixation location. Optionally other types of modular optical units may be supplied with square and/or triangular faces of the same type.

#### **Exemplary Modular optical units**

15            Reference is now made to *Figures 22a-26B* illustrating in a way of example, some of the basic units, configurations and modular optical units which may be used with the optical set up described herein. Each unit would now be given a brief description. It is important to note that these are only a few examples of a variety of optical and mechanical components that can be incorporated in the modular design disclosed in the present invention.

20            *FIGs. 22A and 22B* are perspective drawings of fixed mirrors in accordance with embodiments of the current invention. For example, modular unit **2218a** includes a 1 inch mirror mounted to a 1.5 inch frame. Optionally the mirror is centered with respect to the frame of unit **2218a**. For example, modular unit **2218b** includes multiple optical units in a single modular unit. For example, two 1/2 inch mirrors mounted to a 1.5 inch frame. Optionally the mirrors are not

25          centered with respect to the mounting of unit **2218b**. Others numbers and/or configurations of multi-optical-units are possible on a modular unit in embodiments of the current invention. In some multi-unit units, the pattern of the optical elements may be symmetric across certain planes and/or invariant to certain rotations.

            In some embodiments, a basic modular optical unit is a protected mirror. In some

30          embodiments, the optical element is in a triangle configuration. Optionally the protected mirror is non-dispersive, and/or configurable, and/or compact and/or broad (for example, spanning at a bandwidth between about 400 nm and about 25000 nm). Optionally such a protected mirror is suitable for ultrashort pulses and/or broadband light alignment.

*FIGs. 23A and 23B* are perspective drawings of adjustable mirrors in accordance with embodiments of the current invention. For example a 1 inch mirror mount **2342a** is movably connected to a prismatic unit **2318a** (for example a right Triangle (45°- 45°- 90°) shape of prism) with a square attachment face **2303a** and/or a triangular attachment face **2303b**. Optionally, the angle of the mirror may be adjusted by moving the mirror mount **2342a** with respect to the attachment faces **2303a** and **2303b**.

*FIGs. 23C* is a photograph of an adjustable mirror in accordance with embodiments of the current invention. Optionally, the unit allows degrees of freedom into a reinforced structure and/or a tunable triangle mirror. For example a 1 inch mirror mount **2342b** is movable connected to a prismatic unit **2318b** with a square attachment face and/or a triangular attachment face. For example the attachment faces may be configured for attachment to a fixation location. Optionally, the angle of the mirror may be adjusted by moving the mirror mount **2342a** with respect to the attachment faces **2303a** and **2303b** by means of screws **2332**. Unit **2318b** is shown connected to an exemplary platform **2300**.

Alternatively or additionally, a modular optical unit comprises a build-in delay line, and/or beam splitter, and/or filter and/or acoustic optic modulator.

*FIGs. 24A and 24C* are perspective drawings of filters in accordance with embodiments of the current invention. For example, unit **2444a** includes a filter on a base with a complimentary connector for a fixation location. For example, unit **2444b** includes a dichroic filter on a prismatic base with a complimentary connector for a fixation location. For example, unit **2444c** includes an end mirror on a prismatic base with a complimentary connector for a fixation location. In some embodiments, optical elements are standard (for example 1 inch disks). In some embodiments optical elements are reversible mounted to modular units. In some embodiments optical elements are permanently mounted to modular units.

*FIGs. 25A and 25D* are perspective drawings of modular units in accordance with embodiments of the current invention. Optionally many commercial accessories, such as irises **2548**, sample holders **2552** optionally including micrometers, objectives **2546** optical fiber modular units **2550** are mounted to modular units with complementary connectors for discrete connection to a fixation location. For example, modular units may hold a CCD camera, acoustics optic modulators, microscope objectives, crystal materials holder and other units.

*FIGs. 26A and 26B* are perspective drawings of an extension block **2654** and modular units **2648** and **2650** in accordance with embodiments of the current invention. For example extension block **2654** may be used to raise a modular unit away from a fixation location. For example, the unit may be raised a distance equal to the size of the fixation unit and/or a multiple

thereof. Optionally, a modular unit connected to the block extender may retain the discrete directional limitation of the fixation location.

### Optical kits

*FIG. 27* is a parts list for a polarity reversing kit in accordance with an embodiment of the current invention. For example a kit may contain five fixed mirror units **2718a**, two adjustable mirror units **2618b**, two 3x3 platforms **800b** with interface for angled attachment to another platform, two 3x3 platforms **800a** with interface in plane angled to an extension platform, **4** legs **2756**, **12** attachment interface screws **832**, nine pins **2758** and/or **14** modular optical unit mounting screws **2732**.

*FIG. 28* is a perspective view of a polarity reversing kit in accordance with an embodiment of the current invention. Optionally, instructions for the kit illustrate attaching a fixed mirror perpendicular to a base. Optionally, the device is assembled on two perpendicular platforms, for example platform **800a** and **800b** as illustrated in *FIGs. 8A, 8B and 27*. Optionally, the kit includes instructions for attaching mirrors **2718a**, **2718b** and **2718b'** to the board as illustrated.

In some embodiments simple instructions illustrate how to assemble an optical device from modular units. Examples of instructions for assembling various (but not necessarily all) parts of a polarization reversal device are illustrated herein. An optional order of assembly of the exemplary *FIGs.* is as follows: assemble platforms **800a** and **800b** into two sides of a box as illustrated for example in *FIGs. 8A and 8B*; add an interface for an optical table (e.g. feet) for example as illustrated in *FIG. 31*; attach one by one modular optical units as illustrated for example in *FIGs. 29A, 29B, 30A, 30B and 28*; and add two more sides to the box, as illustrated for example in *FIGs. 32A and 32B*.

*FIG. 28* illustrates attaching an adjustable mirror unit **2718b'** to the box in accordance with an embodiment of the current invention. Optionally, instructions designate which face (e.g. a triangular face) of which modular optical unit (e.g. unit **2718b'**) to attach to which fixation location on the box (e.g. location **802** on platform **800b**) and in which discrete direction (e.g. with the mirrored face of mirror unit **2718b'** facing outward and rightward).

In some embodiments, instructions for positioning of a modular unit consist of designating a face of a finite number of attachment faces of the unit to be attached to a designated fixation location of the discrete locations on the platforms directed in a designated direction of the discrete possible directions of attachment. For example, by designating a discrete face, a discrete position and a discrete direction positioning of a modular unit, the optical axis of an optical element is entirely determined. Optionally, no calibration is necessary. For example,

positioning of each mirror unit **2718a** consists of placing the a designated face of the four attachment faces of a mirror unit **2718a** onto a designated fixation location of the 18 discrete locations on the two platforms **800a** and **800b** directed in a designated direction of the four discrete possible directions of attachment.

5 In some embodiments, adjustable units, for example adjustable mirrors **2718b'** and **2718b**, are placed at the light entrance and light exit of the device. For example, the adjustable units allow the device to be calibrated according to incoming light which is optionally not limited to the discrete directions of the modular system.

10 In some embodiments, a designated fixation location is illustrated in an instruction manual. For example a location **802** for mirror unit **2718'** is designated in *FIG. 28* by a bright outline. The attachment face is designated, for example, by showing a triangular face of block **2718b'** facing the designated location **802** with an arrow toward joining them. The designated direction is illustrated, for example in *FIG. 28*, by showing the mirrored face of mirror unit **2718b'** facing outward and rightward with the face of the mirror vertical.

15 In some embodiments, the designated face of mirror unit **2718b'** is optionally locked to the designated location **802** with one or more screws (for example two screws may be inserted from the bottom of platform **800b** for example exactly analogous to inserting screws illustrated in *FIG. 29B*). In the exemplary embodiment, light output **2825b** from the device is on the same line and direction as light input **2825a** to the device (with possible adjustments using adjustable mirrors **2718b** and **2718b'**) and with reversed polarity (for example due to the convoluted path through the device as illustrated by the dashed arrows in *FIG. 28*).

20 In some embodiments, connectors of multiple fixation locations and/or attachment faces of multiple modular optical units are inter compatible and/or exchangeable. For example, every attachment face of every modular unit **2718a**, **2718b** may be attached to any of the 18 attachment of locations of the embodiment illustrated in *FIG. 28*.

FIGs. 29A and 29B are perspective drawings of attaching a fixed mirror perpendicular to a wall in a polarity reversing kit in accordance with embodiments of the current invention. Optionally, the illustrated attachment of a triangular face of fixed mirror unit **2718a** to wall platform **800a** is exactly the same procedure as attachment of the triangular face of adjustable mirror unit **2718b'** to base platform **800b** as illustrated for example, in *FIG. 28*.

30 *FIGs. 30A and 30B* are perspective drawings of attaching a fixed mirror to a wall in a polarity reversing kit in accordance with embodiments of the current invention. For example, *FIGs. 30A and/or 30B* illustrated attaching a square face of a mirror unit **2718a** to wall platform **800a** with two pins **2758** and two screws **2732**.

*FIGs. 31* is a perspective drawing of attaching feet **2756** to a polarity reversing kit in accordance with an embodiment of the current invention. Optionally feet **2756** are positioned, matching the positions of holes in a standard 1 inch optical table (for example at 3 inch intervals). Optionally, feet **2756** are a designated length for easy integration of the exemplary polarity reversing device with other devices. For example, feet **2756** may raise platform **800b** by exactly the width of one fixation location **802**. Optionally, feet **2756** are configured for attachment to an optical table (for example each foot **2756** includes a threaded hole in the bottom with may be attached via a screw to the table).

*FIGs. 32* is a perspective drawing of attaching extra walls to a polarity reversing kit in accordance with an embodiment of the current invention. The extra walls optionally protect a user from exposure to dangers laser light and/or add rigidity to the box and/or may be used to add more optical units to the device, for example to interface with another device.

*FIGs. 33A and 33B* are perspective drawings of a dual path polarity retaining, polarity reversing kit in accordance with embodiments of the current invention. For example, device **3390b** includes the polarization reverser device illustrated in *FIG. 11*. For example, device **3390a** includes a device with a path length exactly equal to device **3390b**, but which does not reverse polarity. For example, an ultra-short laser pulse is split into two partial pulses. One partial pulse is put through device **3390a** and another partial pulse is put through device **3390b**. The two partial pulses remain synchronized, but have opposite polarities. In some embodiments, preserving synchronization of the partial pulses (for example due to the equal path lengths) may facilitate recombining of the partial pulses. In some embodiments, discretization of path length in accordance with the current invention may facilitate producing multiple devices with the same path length and/or facilitate conditioning and/or recombining laser pulses.

*FIGs. 34A through 34H* are perspective drawings illustrating assembly of an autocorrelator (e.g. pump probe) kit in accordance with embodiments of the current invention.

*FIGs. 35A-35E* illustrate assembly of a Michelson interferometer kit in accordance with an embodiment of the current invention.

*FIG. 35A* illustrates assembling a base in accordance with an embodiment of the current invention. The base optionally includes a fixed platform **3577** and a mobile platform **3578**. For example, the fixed platform **3577** includes four boards of 3x3 fixation locations interconnected and interaligned into an L-shape. The mobile platform optionally includes one 3x3 board **3500** which is mounted via a linear translator **3591**. Linear translator move board freely **3500** horizontally such that rows of board **3500** remain aligned with row of a board **3500'** which forms the leg of the L of platform **3577**.

*FIG. 35B* illustrates further assembly of the interferometer in accordance with an embodiment of the current invention. For example, a wall **3500''** is attached to base **3500** of mobile platform **3578** and a second wall **3500'''** is attached to base **3500'** of fixed platform **3577**. Angled mirror units **3518** are optionally attached to board **3500'''** and board **3500''**, for example as illustrated and/or two iris units **3520** are attached to fixed platform **3577**. A block extender **3554** is optionally attached to mobile platform **3578**.

*FIG. 35C* illustrates further assembly of the interferometer in accordance with an embodiment of the current invention. For example, another angled mirror is attached to fixed platform **3577**. A flat mirror **3518'** unit is optionally placed on block extender **3554**. Optionally, a beam splitter **3517** is attached to board **3500'''**.

*FIG. 35D* illustrates further assembly of the interferometer in accordance with an embodiment of the current invention. For example, a photodetector **3550** and sample mount **3552** are attached to fixed platform **3577** and wall board **3500'''** respectively. For example, an incoming beam is split into a fixed and a variable path length portion. The fixed length portion optionally passes through a fixed length path and/or the variable length portion optionally passes to mirror **3518'**. The length of the variable length portion is optionally changed by moving movable platform **3578**. Light from both portions is recombined reflected off of a target. The resulting reflected light and interference due to the recombining is optionally measured by detector **3550**.

*FIGs. 36* is a perspective drawing of a frequency resolved optical gating (FROG) kit in accordance with an embodiment of the current invention.

*FIGs. 37* is a perspective drawing of a nonlinear optical generation - Focusing apparatus kit in accordance with an embodiment of the current invention.

### **Interface to other optical mounting systems**

*FIG. 38* is a photograph of a device attached to an optical table in accordance with an embodiment of the current invention. For example, optical devices **3890a** and **3890b** are attached to a standard optical table **3866** and/or optical bread board **3867**. The modular device **3890a** and/or **3890b** are optionally aligned to table **3866**. Optionally, table **3866** aligns device **3890a** to device **3890b**. For example there may be a shared optical axis between device **3890a** to **3890b**. For example, output of device **3890a** may serve as input to device **3890b**. For example, a laser pulse may be split into two sub pulses, one sub pulse may be conditioned by device **3890a** and/or another sub pulse may be conditioned by device **3890b**, and/or the sub pulses may be recombined. Optionally, optical table **3866** aligns device **3890a** and/or **3890b** with another device **3891**.

FIG. 39 is a perspective drawing of a platform **3900** configured for attachment to a standard **1"** optical table in accordance with an embodiment of the current invention. For example, platform **3900** includes three equally spaced rows and three columns equally of grid points (for example spacing may be 1.5 inches). The inner column optionally includes three  
5 fixation locations and connectors **802** for modular optical units. Each connector **802** may optionally include an interface for an optical table, for example as explained with regards to *FIG. 9*. Optionally, the two outer columns of platform **3900** include six holes **924e** configured to interface to an optical table. For example, the four corner holes are all 3 inches apart and/or facilitate connection to a one inch optical table.

10 FIG. 40 is a photograph of transferring a beam between 1 inch and  $\frac{1}{2}$  inch optics in accordance with an embodiment of the current invention. In some embodiments, system for optics of different sizes may include spacing of modular units that differs. For example, modular units in a system for 1 inch optics may be spaced 1.5 inches apart in both the horizontal and vertical axes. For example, modular units for  $\frac{1}{2}$  inch optics may be spaced 1.0 inches apart on  
15 the vertical and horizontal axes. In some embodiments, an adapter will fit to a system of optics of a first size and/or transfer a beam at a position that fits a different system. For example, the embodiment of *FIG. 40* includes two platforms **800a**, **800b** with fixation locations and connectors **802** for module units with 1 inch optics. For example, the distance between fixation locations may be 1.5 inches. A module mirror unit **1118** of **1"** optics is illustrated connected to platform **800a**. Optionally, a modular mirror unit **4018** is configured for a  $\frac{1}{2}$  inch mirror. For  
20 example, unit **4018** has a width of 1 inch and includes a complementary connector to fit a platform of 1 inch fixation locations. Optionally, an adapter **4072** connects between unit **4018** to connector **802**. Optionally, adapter **4072** moves unit **4018** over 0.25 inches such that the mirror of unit **4018** is centered in the 1.5 inch fixation location in the horizontal direction. For example,  
25 unit **4018** catches a light beam from unit **1118** and reflects it parallel to the surface of platform **800b** at a height of 0.5 inches off the board (fit for a board of 1 inch fixation locations that may be receive the beam).

In some embodiment an adapter may transfer a beam between systems of other sizes. For example, an adapter may transfer a beam between systems based on **1"** and **2"** optics and/or  
30 between 25 mm and 12.5 mm and/or between **1"** and 12.5 mm and/or any other combination thereof. In some embodiments, a  $\frac{1}{2}$ " unit and/or adapter may be used with a 12.5 mm optical system. In some embodiments, a **1"** unit and/or adapter may be used directly with a 25 mm optical unit and/or system or vice versa. In some embodiments, a  $\frac{1}{2}$  inch adapter may be used directly with a 12.5 mm optical unit and/or system.

*FIG. 41* is a close up view of adapter **4072** in accordance with an embodiment of the current invention. For example, adapter **4072** may include connectors for both 1” modular optical units and/or 1/2” modular optical units.

*FIGs. 42A and 42B* are photographs of an electro-mechanical-optical device for adjusting a path length in accordance with an embodiment of the current invention. For example a motorized actuator may be used with a modular optical system in accordance with an embodiment of the current invention. Alternatively or additionally, a manual actuator may be used (for example as illustrated in *FIG. 12*). For example, a standard actuator **4076** and/or motor **4074** may be used to move a mobile platform **4078** with respect to a fixed platform **4077** and/or a table **4066**. Optionally the system will include clips and/or a guide for wires (for example for a power cord and/or control wires). Alternatively or additionally, modular actuators, controllers and/or motors may be supplied. In some embodiments a cooling element such as a fan and/or a heat sink and/or a channel for cooling fluid may be added.

*FIG. 43* is a photograph of an addition to an optical table in accordance with an embodiment of the current invention. In some embodiments, modular optical units may be included in an optical table. Optionally units may be mounted reversibly and/or permanently to the table.

In some embodiments, a wall including connectors for modular optical units may be positioned on an optical table. Optionally, a platform **800a** including fixation locations and/or connectors is mounted vertically on an edge of an optical table **4366**. For example, platform **800a** is located directly in front an outlet of an ultrashort pulsed laser light source **4681**. Optionally, platform **4681** may prevent laser light from passing beyond an edge of an optical table and injuring a passerby. In some embodiments, platform **4681** is a convenient place to add preliminary conditioning to a laser pulse. For example, paths of known length can be defined easily to various parts of the table. Optionally this may facilitate using a larger portion of the table. Optionally, by moving a few module units a laser pulse may be redirected to another part of the table and/or by replacing the modular units, the pulse may be returned to the previous location with the same path length and optical parameters as previously. For example this may facilitate setting up multiple devices and/or experiments on a single table and/or switching back and forth between different apparatuses when needed.

In some embodiments, a platform may be connected permanently or temporarily to an optical table. For example, platform **800b** may be attached to a side wall of the table. For example, adding a platform may add to the useful space of the table. In some embodiments the platform may include a fixation location and/or a connector for a modular optical unit in

accordance with embodiments of the current invention. In some embodiments, a platform for a modular system according to the current invention may be added as an extra level (e.g. a floor and/or ceiling) to an optical table. Alternatively or additionally, a fixation location and/or a connector for a modular optical unit in accordance with embodiments of the current invention may be added permanently or reversible to the surface of an optical table.

### Assembly of a modular optical unit

*FIGs. 44A-B* illustrates assembly of a modular optical unit in accordance with an embodiment of the current invention. In some embodiments an optical element **4487** may be attached to a modular frame. Optionally, an optical element may include a standard optical element. Optionally, the frame may include a standard mount for the optical element and/or one or more complementary connectors to for connection to a connector of a fixation location. Optionally the optical element may be reversibly mounted to the frame. Alternatively or additionally the optical element may be permanently mounted to the frame.

In some embodiments, a disk shaped optical element **4487** (for example a mirror) having a standard diameter and/or thickness may be mounted to a modular frame **4493**. Optionally, the frame may include one or more complementary connectors for connection to a connector **4403** at a fixation location. In some embodiments a locking element may be included, for example an adjustment screw **4491** that facilitates tightening and/or adjusting element **4487** in mount **4489**. For example element, **4487** may be locked into mount **4489** such that the element oriented and/or positioned with respect to a complementary connector **4403** such that optical element **4487** is centered with respect to a fixation location when complementary connector **4403** is connected to a connector at the fixation location. Optionally, a tightening and/or adjustment element may include a screw and/or a locking ring and/or adhesive and/or a chuck. In some embodiments, a tightening and/or adjustment element may be configured to avoid interfering with connection to a fixation location. For example, screw **4491** may be shorter than the hole into which it is inserted such that after tightening, screw **4491** is optionally sunk into the frame and/or does not protrude from the frame. In some embodiments, a tightening and/or adjustment element protrude from a face of the device that is not mounted to a fixation locations, for example similar to adjustment screws **4532**, for example as illustrated in *FIG. 45C* and/or adjustment screws **2332** for example as illustrated in *FIG. 23C*. In some embodiments, a tightening and/or adjustment element protrude from a location on a face that corresponds to a hole in the fixation location. In some embodiments mount **4489** is configured to retain the optical element **4487** positioned in a way that is independent of the angle of fixation of the frame **4493** to the fixation location. For example the optical element **4487** may be centered on a fixation location. In some embodiments,

element mount **4489** is made to hold optical element in a precise position and orientation without calibration.

*FIGs. 45A-45D* illustrate assembly of a modular optical unit including an adjustable element in accordance with an embodiment of the current invention. For example an adjustable element may allow the degrees of freedom, for example for calibration with another modular unit and/or with an external optical device. Optionally a mirror **4487** is mounted into a reinforced structure, to produce a unique tunable triangle modular mirror unit **4518**. For example, mirror **4487** is inserted into a mount **4589**. Optionally, a face plate **4591** may retain and/or fix mirror **4587** in mount **4589**. In some embodiments, adjusting screws **4532** may hold face plate **4591** in place and/or adjust the angle of mirror **4487**.

FIG. 46 illustrates a discretization pattern for a platform configured for attachment to an optical table in accordance with an embodiment of the current invention. Optionally, regularly spaced rows and/or columns of fixation locations coincide with rows and/or columns of attachment locations of the optical table. Optionally the spacing between fixation locations will be greater than the width of an optical element. Alternatively or additionally, a modular optical unit may straddle more than one fixation location and/or include an optical element that is larger than the spacing between fixation locations.

FIG 46 illustrates a scheme for an optical table with attachment locations (e.g. fixation locations for example holes) spaced on a regular square grid with grid spacing of 1" in accordance with an embodiment of the current invention. Optionally, the distance between every  $n+1$  rows or columns is an even number of inches (the spacing between attachment locations on the optical table). In this embodiment, this means that each set of  $n+1$  rows or columns will have the same relationship to the attachment locations on the table. For example every  $n+1$  row or column of fixation locations on the platform will be coaxial with a row or column of the table. For example, every  $n+1$  fixation location will be centered on a hole in the optical table. For example, the distance between  $n+1$  rows and/or columns of fixation locations on the platform will be an even number of inches. Optionally the distance between fixation locations will be greater than the width of an optical element. For example, for 1" inch optical elements and 1" hole spacing on an optical table the discretization distance between fixation locations may be  $(n+1)/n * 1$ " for  $n$  and integer greater or equal to 1. For example, (as illustrated for example in FIGs. 8A, 8B, 9, 16, 17A, 31, 38 and 39) for  $n=1$  the fixation locations are 1.5" apart and every third fixation location will correspond to every fourth row or column on the table. For example, for  $n=2$  the fixation locations are 1.333" apart and every fourth fixation location will correspond to every fifth row or column on the table. Alternatively for 25 mm optics and a 25 mm optical

table the discretization distance between fixation locations may be given by  $(n+1)/n * 25$  mm. In some embodiments it may be desired that rows and columns of the table and the modular platform coincide over small distances (for example, a smaller coincidence distance may facilitate using smaller platforms and/or give more flexibility in placement and/or alignment of platforms on the table). For example, in some embodiments,  $n$  may be kept less than 4 and/or less than 8.

In some embodiments, different sized optical elements may be used with the same platform or optical table. For example, 25 mm optics may be used with a table having 1" spacing between holes. Alternatively or additionally, 1" optics may be used with a 25 mm table. For example, a modular optical unit including connectors for a platform having 1.5 inch fixation location spacing may include a mount for an optical element of any size. The optical element may for example, be held centered on the fixation location and/or distanced from the surface of the platform to center the optical element with regard to a fixation location on an orthogonal platform.

In some embodiments, a system may be designed for 1/2 inch optical element on a 1" optical table. For example, the spacing of fixation locations may be  $(n+1)/n * 0.5$ ". Alternatively or additionally, the fixation location scale described above for 1" optics can also be used for 1/2" optics (in some embodiments using the 1" scale has the advantage of facilitating the use of 1" and 1/2" optics together, in some embodiments using the smaller 1/2" scaling has the advantage of allowing more optical units in a smaller space, for example facilitating a more compact device).

### ***Submodules***

In some embodiments, a sub-platform will be provided. For example, a group of optical elements may be mounted on a sub-platform that can be added or removed from a platform as a single unit. Optionally, elements on the sub-platform may be mounted outside of the discrete pattern of the platform. Alternatively or additionally, optical axes within the sub-platform may be outside of the discrete scheme of directions and/or positions of the platform. Optionally the sub-platform will have an input and/or output optical axis that conforms to the discrete pattern of locations and/or directions of the platform. In some embodiments elements may be added removed and/or replaced in the sub-platform without changing the position of the sub-platform on the platform and/or without changing other elements of the platform and/or without changing the input/output axis of the sub-platform. Optionally the direction of an input and/or output of the platform may be changed. For example, a direction of the input and/or output axis may be changed without changing the platform and/or the elements within the sub-platform and/or the

position of the sub-platform on the platform. Optionally, the sub-platform includes a complementary connector for connection to a fixation location of the platform.

### *Markings*

5 In accordance with some embodiments of the current invention, a modular optical system may include a marker. For example, a marker may be non-functional and/or not include an optical element. For example, a marker may not affect an optical path passing the marker position. Optionally a marker may be permanently placed on a fixation location. Alternatively or additionally, a marker may be reversibly connected to a fixation location.

10 In some embodiments, a kit for building a device may include a marker. For example, one or more platforms within the kit may be marked. For example, a fixation location may be marked for connection to a modular unit and/or the mark may indicate which modular unit is connected to the location and/or in which direction the optical axis is pointed. Optionally, a modular unit may be marked and/or differentiated from other modular units. Alternatively or additionally, a marking on a platform may differentiate one platform from another platform  
15 and/or may show where an attachment interface connects to one platform to another platform and/or to which platform the interface is to be attached. In some embodiments, a platform may include multiple sets of marking, for example each set may be part of instructions to assemble different devices. Optionally a marker may show a location of other aspects of a system. For example, a marker may indicate an input and/or output location and/or a location of a cord (for  
20 example a power cord) and/or a preferred path for a connection (for example a wire).

In some embodiments, marker may be reversibly connected to a platform. For example, when designing a system, a user may place markers in various places to envision the system before assembling optical units. Optionally, the user may change the geometry of the markers to arrive at a desired assembly. For example, subsequently the user may assemble the device  
25 according to the markers.

In some embodiments, a marker may be used to mark a transitory element in a system and/or a location where a transitory element may be placed. For example, in some assemblies a transitory element may include a debug element. For example, the debug element may be used for initial testing and/or subsequent error correction (for example, a debug element may include  
30 a status indicator and/or an output port). Alternatively or additionally, a transitory element may include a transition element that transforms a function of a device and/or redirects an optical path. Optionally the transitory element may be marked to facilitate its identification and/or removal. Optionally, the place of a transitory element may be marked to facilitate addition of the transitory element when desired.

In accordance with some embodiments of the current invention, a naming convention may facilitate reference to a fixation location and/or modular optical unit. For example, an indicator may indicate a reference point (for example an origin) and/or a direction (for example a direction of an axis and/or a positive direction on an axis). Alternatively or additionally an indicator may differentiate platforms and/or modular optical units. Additionally or alternatively, fixation locations on a board and/or a box and/or a platform may be indexed. For example, the naming convention may facilitate to description of a system and/or defining positioning of optical units orally and/or textually. For example, the naming convention may be used by a user to describe a system to an assistant. For example, the naming convention may be used by an assistant to describe changes to the system (for example repairs and/or improvements) to a user. For example, the naming convention may be used for communication between an automated design system and a user.

***Computerized planning, design and/or analysis***

In some embodiments, a modular optical system may include features to facilitate computer assisted planning, design and/or analysis. For example, locations on a platform may be marked and/or modular optical units may be marked for automated recognition. For example, markings may be visible and/or there may be an automated image processing procedure. For example, the procedure may identify a structure of the optical system from an image of the system. Alternatively, non-visible markers may be included, for example magnetic markers and/or wireless markers (for example an RFID) and/or a platform may include a logically addressable system to identify locations and/or connections and/or identities of modular units. Optionally, a control system may facilitate an automated control and/or adjustment of an optical element.

In some embodiments, a processor may be configured to assist in design and/or analysis of a modular optical system. For example, the processor may be programed to output a plan for a system to fulfill a required functionality under a set of constraints (for example constraints may include space limitations and/or budgetary limitations and/or availability of parts and/or time constraints for assembly of the system and/or time constraints for running of programs (experiments) and/or constraints on external resources for example cooling and/or input light sources and/or sensors).

In some embodiments, a processor may be programed for debugging a system. For example when a fault occurs the processor may supply suggested tests to determine the source of the problem and/or suggested interventions for fix the problem. For example input to the debug program may include the structure of the optical system and/or behavior of the system.

Optionally, the processor may include inventory control functions. For example the processor may track the location and/or availability of modular units and/or schedule their use and/or remind a user when and/or where to return a part. For example, the processor may track the availability and/or demand of parts. For example, the processor may recommend substitutes for missing parts and/or acquisition of high demand parts. Optionally the inventory functions may be linked to security systems (for example tracking presence of personnel to a room and/or a storage area and/or the presence of equipment).

### General

It is expected that during the life of a patent maturing from this application many relevant light pipes will be developed and the scope of the term light pipe is intended to include all such new technologies *a priori*.

As used herein the term "about" refers to  $\pm 25\%$ .

The terms "comprises", "comprising", "includes", "including", "having" and their conjugates mean "including but not limited to".

The term "consisting of" means "including and limited to".

The term "consisting essentially of" means that the composition, method or structure may include additional ingredients, steps and/or parts, but only if the additional ingredients, steps and/or parts do not materially alter the basic and novel characteristics of the claimed composition, method or structure.

As used herein, the singular form "a", "an" and "the" include plural references unless the context clearly dictates otherwise.

Throughout this application, various embodiments of this invention may be presented in a range format. It should be understood that the description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the invention. Accordingly, the description of a range should be considered to have specifically disclosed all the possible subranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed subranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

Whenever a numerical range is indicated herein, it is meant to include any cited numeral (fractional or integral) within the indicated range. The phrases "ranging/ranges between" a first indicate number and a second indicate number and "ranging/ranges from" a first indicate

number “to” a second indicate number are used herein interchangeably and are meant to include the first and second indicated numbers and all the fractional and integral numerals therebetween.

It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single  
5 embodiment. Conversely, various features of the invention, which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable subcombination or as suitable in any other described embodiment of the invention. Certain features described in the context of various embodiments are not to be considered essential features of those embodiments, unless the embodiment is inoperative without those elements.

10 Although the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims.

All publications, patents and patent applications mentioned in this specification are herein  
15 incorporated in their entirety by reference into the specification, to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated herein by reference. In addition, citation or identification of any reference in this application shall not be construed as an admission that such reference is available as prior art to the present invention. To the extent that section headings are used, they should not be construed  
20 as necessarily limiting.

## WHAT IS CLAIMED IS:

1. A 3D optical setup, comprising:
  - at least one base connected at an angle to at least one wall, each of said at least one base and at least one wall having a plurality of fixation locations repeatedly arranged, thereby defining a discrete 3D position coordinate system;
  - a plurality of modular optical units, each comprising a mount for an optical portion defining an optical axis, said mount fixed to at least one mounting surface comprising complementary geometry to said fixation locations;
  - wherein a releasable attachment of some of the plurality of modular optical units at said fixation locations of said at least one base defines a first set of optical axes and a releasable attachment of some of the plurality of modular optical units at said fixation locations of said at least one wall defines a second set of optical axes; and
  - wherein at least a portion of said first set of optical axes and at least a portion of said second set of optical axes overlap across said discrete 3D position coordinate system.
2. The setup of claim 1, wherein said base and said wall are connected in at least one manner selected from fixedly and reversibly.
3. The setup of claim 1, wherein said base and said wall are releasably connected.
4. The setup of any of claims 1-3, wherein said angle is at least one of 90 degrees and 45 degrees.
5. The setup of any of claims 1-4, wherein at least one face at least one unit of said plurality of modular optical units is directed at 45 degrees to at least one said mounting surface of said at least one unit and wherein said at least one unit includes at least one other mounting surface and wherein said at least one face is perpendicular to said at least one other mounting surface and wherein said mount of said at least one unit is on said at least one face.
6. The setup of any of claims 1-5, further comprising at least one ceiling, connected at a second angle to said at least one wall.

7. The optical set up of any of claims 1 to 6 wherein said attachment centers said mount with respect to at least one of said fixation location.
8. The setup of any of claims 1 to 6, wherein said base is configured for connection to an optical table with a regular pattern of said plurality of fixation locations of the base coinciding with respective attachment locations of the optical table.
9. The optical set up of any of claims 1 to 7 wherein said mount is configured to hold a 1" optical elements and a distance between fixation locations that is an integral multiple of at least one of 0.375" and 0.333".
10. The optical set up of any of claims 1 to 7 wherein said mount is configured to hold at least one of 0.5" optical elements and 2" optical elements and a distance between fixation locations that is an integral multiple of 0.125".
11. The optical set up of any of claims 1 to 7 wherein said mount is configured to hold at least one of 25 mm optical elements and 12.5 mm optical elements and the distance between fixation locations that are an integral multiple of 9.875mm.
12. The optical set up of any of claims 1 to 11, further including an optical element attached to said mount with an optical axis of said optical element corresponding to said optical axis of said mount.
13. The setup of any of claims 1-11, wherein a synchronization light between a first path and a second path is preserved when said first path and said second path traverse an equal number of said fixation locations.
14. A method for generating a 3D optical axis defined by a plurality of modular optical units, each modular optical unit defining an optical line, comprising:
  - connecting at an angle at least one wall to at least one base, each of said wall and said base having a plurality of fixation locations repeatedly arranged;
  - releasably connecting a first set of the plurality of modular optical units at said fixation locations of said at least one base, defining a first set of optical axes; and

releasably connecting a second set of the plurality of modular optical units at said fixation locations of said at least one wall, defining a second set of optical axes, thereby aligning at least a portion of said first set of optical axes and at least a portion of said second set of optical axes, generating a 3D optical axis.

15. A system of optical units comprising:

one or more platforms, each of said one or platforms including

a plurality of fixation locations, each fixation location having a respective connector

an attachment interface for attachment to an optical table at a fixed location and direction;

a modular optical unit including

a mount for an optical element having an optical axis and

a complementary connector for attachment to any said respective connector on to retain said optical axis in one of a number of discrete directions and wherein for an element located at a first position of said plurality of fixation positions with a first optical axis directed in one of said number of discrete directions, said first optical axis overlaps a second optical axis of a second element at a second location of said fixation locations directed in a second direction for predetermined pairs of said second location and second direction.

16. The system of claim 15, wherein said one or more platforms includes a first platform attached to said optical table at a first position and a second platform connected to said optical table at a second position and wherein said first location is on said first platform and said second location is on said second platform and wherein said first platform is does not contact said second platform.

17. The system of any of claims 15 to 16, wherein said first location and said second location fall on a grid and wherein for each of said predetermined pairs, a discrete path length from said first location to said second location is determined by a relative difference in coordinates on said grid between said first location and said second location.

18. A system of optical units comprising:

a first platform including 1st plurality of fixation locations, each fixation location having a connector

a second platform including a 2nd plurality of fixation locations, each fixation location having a connector

an attachment interface for attachment of said 1st platform to said 2nd platform with said 1st plurality of fixation locations aligned to said 2nd plurality of fixation locations;

a plurality of modular optical units including

a mount for an optical element and

a complementary connector for attachment to said connector on said fixation location to retain said mount in one of a discrete number of locations and/or directions on said platform.

19. The system of claim 18, wherein said attachment between said modular optical units and said platform is reversible.

20. The system of any of claims 18-19, wherein said attachment centers said mount with respect to at least one of said fixation location.

21. The system of any of claims 18 to 20, wherein said first platform is configured for connection to an optical table with a regular pattern of said fixation locations coinciding with respective attachment locations of the optical table.

22. The system of any of claims 18 to 20, wherein including 1" optical elements are 1" and a distance between fixation locations that is a multiple an integral multiple of at least one of 0.375" and of 0.333".

23. The system of any of claims 18 to 20, wherein a synchronization of light between a first path and a second path is preserved when said first path and said second path traverse an equal number of said fixation locations.

24. An optical setup, comprising:

A first platform and a second platform, each of said first platforms and said second platform having a plurality of fixation locations, to form repeatedly arranged, thereby defining a discrete position coordinate system;

a plurality of modular optical units, each comprising a mount for an optical portion defining an optical axis, said mount spatially fixedly in relation to at least one mounting surface comprising complementary geometry to said fixation locations;

wherein a releasable attachment of a first subset of the plurality of modular optical units at said fixation locations of said first platform defines a first set of optical axes;

wherein a releasable attachment of a second subset of the plurality of modular optical units at said fixation locations of said second platform defines a second set of optical axes; and

a single repeated arrangement including said fixation locations of said first platform and said second platform and wherein at least a portion of said a first set of optical axes and at least a portion of said second set of optical axes overlap across said discrete position coordinate system.

25. The optical set up of claim 24, wherein each said modular optical unit can be moved from a first said fixation location to a second said fixation location while preserving a relative geometry of said plurality of fixation locations.

26. The optical set up of any of claim 24 to 25, wherein each said modular optical unit can be moved from a first said fixation location to a second said fixation location while preserving a relative geometry of each other of said plurality of modular optical units.

27. The optical set up of any of claim 24 to 26, wherein said first platform are said second platform are held in a fixed mutual spatial relation in at least one manner include reversibly attaching said first platform to said second platform and reversibly attaching said first platform and said second platform to an optical table.

28. The optical set up of any of claims 24 to 27 wherein said attachment centers said mount with respect to said fixation location.

29. The system of any of claims 24 to 28, wherein said first platform is configured for connection to an optical table with a regular pattern of said fixation locations coinciding with respective attachment locations of the optical table.

30. The optical set up of any of claims 24 to 27, wherein a synchronization light between a first path and a second path is preserved when said first path and said second path traverse an equal number of said fixation locations.

31. A kit for an interferometer comprising:

at least four mounting platforms including at least two bases, at least at least two walls, each said mounting platform including a plurality of fixation locations repeatedly arranged, thereby defining a discrete position coordinate system;

a plurality of modular optical units, including at least four modular mirror units each said mirror unit comprising an optical portion defining an optical axis, said optical portion fixedly attached to at least one mounting surface comprising complementary geometry to said fixation locations; and

wherein a releasable attachment of the plurality of modular mirror units at said fixation locations defines a first set of optical axes defining said interferometer.

32. The kit of claim 31 further comprising, a light source mounted on an optical table having a shared optical axis with said interferometer.

33. The kit of claim 31 further comprising:

one or more of device selected from the group consisting of a characterization optical tool, a spectrometer optical apparatus, an imaging apparatus including

at least two mounting platforms, each platform of said at least two mounting platforms having a plurality of fixation locations repeatedly arranged, thereby defining a discrete position coordinate system; said at least two mounting platforms connected with said plurality of fixation locations on a first of said at least two mounting platforms arranged orthogonally to said plurality of fixations locations on a second of said at least two mounting platforms;

a plurality of modular optical units, including at least four modular mirror units each of said plurality of modular optical units comprising an optical portion defining an optical axis, said optical portion fixedly attached to at least one mounting surface comprising complementary geometry to said fixation locations; and

wherein a releasable attachment of the plurality of modular mirror units at said fixation locations defines a first set of optical axes; and

wherein said device and said interferometer are mounted on an optical chamber to form a compound device.

34. A system of optical units comprising:

a platform including a plurality of fixation locations, each fixation location having a respective connector

a plurality of optical units each said optical unit comprising

- an optical portion defining an optical axis,
- a complementary connector for attachment to any said respective connector on to retain said optical axis in one of a number of discrete directions and wherein for an element located at a first position of said plurality of fixation positions with a first optical axis directed in one of said number of discrete directions, said first optical axis overlaps a second optical axis of a second element at a second location of said fixation locations directed in a second direction for predetermined pairs of said second location and second direction, and
- wherein at least one of said plurality of optical units comprising a mount for a standard optical element.

35. The system of claim 34, wherein said first location is on a first platform attached to an optical table at a first position and said second location is on a second platform connected to said optical table at a second position and said first platform is not in direct contact said second platform.

36. The system of claim 34, wherein said first location and said second location fall on a grid and wherein for each of said predetermined pairs, a discrete path length from said first location to said second location is determined by a relative difference in coordinates on said grid between said first location and said second location.

37. The system of any of claims 34 to 36, wherein said attachment between each of said plurality of optical units and said platform is reversible.

38. The system of any of claims 34 to 36, wherein said attachment centers said optical element with respect to at least one of said fixation location.

39. The system of any of claims 34 to 38, wherein said platform is configured for connection to an optical table with a regular pattern of said fixation locations coinciding with respective attachment locations of the optical table.

40. The system of any of claims 34 to 39, wherein a synchronization of light between a first path and a second path is preserved when said first path and said second path traverse an equal number of said fixation locations.

41. The system of any of claims 34 to 36, wherein said at least one optical unit can be moved from a first said fixation location to a second said fixation location while preserving a relative geometry of said plurality of fixation locations.

42. The optical set up of any of claims 34 to 36, wherein each said at least one optical unit can be moved from a first said fixation location to a second said fixation location while preserving a relative geometry of each other of said plurality of optical units.

43. A method of preserving synchronization of a first light source pulse traveling a first with a second laser pulse traveling a second path comprising:

defining a discrete coordinate system of fixation locations located on a regular grid;

releasably attaching a plurality of modular optical units at selected said fixation locations to define a plurality of optical axes wherein at least a portion of said optical axes overlap across said discrete coordinate system to define a first path and a second path;

selecting said selected fixation locations to ensure that said first path and said second path traverse an equal number of grid spaces.

44. The method of claim 43, further comprising:

centering on a respective fixation location an optical element of each of said plurality of optical units.

45. A connector for attaching a modular optical unit to a platform comprising:

at least two holes configured to fit a mounting pin;

at least one hole configured to fit a tightening element.

46. The connector of claim 45, further comprising:

a hole for configured for attachment to an optical table.

47. The connector of claim 46, wherein said hole for configured for attachment to the optical table is centered with respect to said at least two holes configured to fit said mounting pin.

48. A connector for attaching a modular optical unit to a platform comprising:

at least two mounting pins;

at least one tightening element.

49. A prismatic optical unit comprising:  
an angled face;  
an optical element mounted on said angled face;  
a first mounting surface at an angle of between 25 to 75 degrees to said angled face;  
a second mounting surface perpendicular to said angled face.
50. The prismatic optical unit of claim 49, wherein angled face is directed at 45 degrees to said first mounting surface.

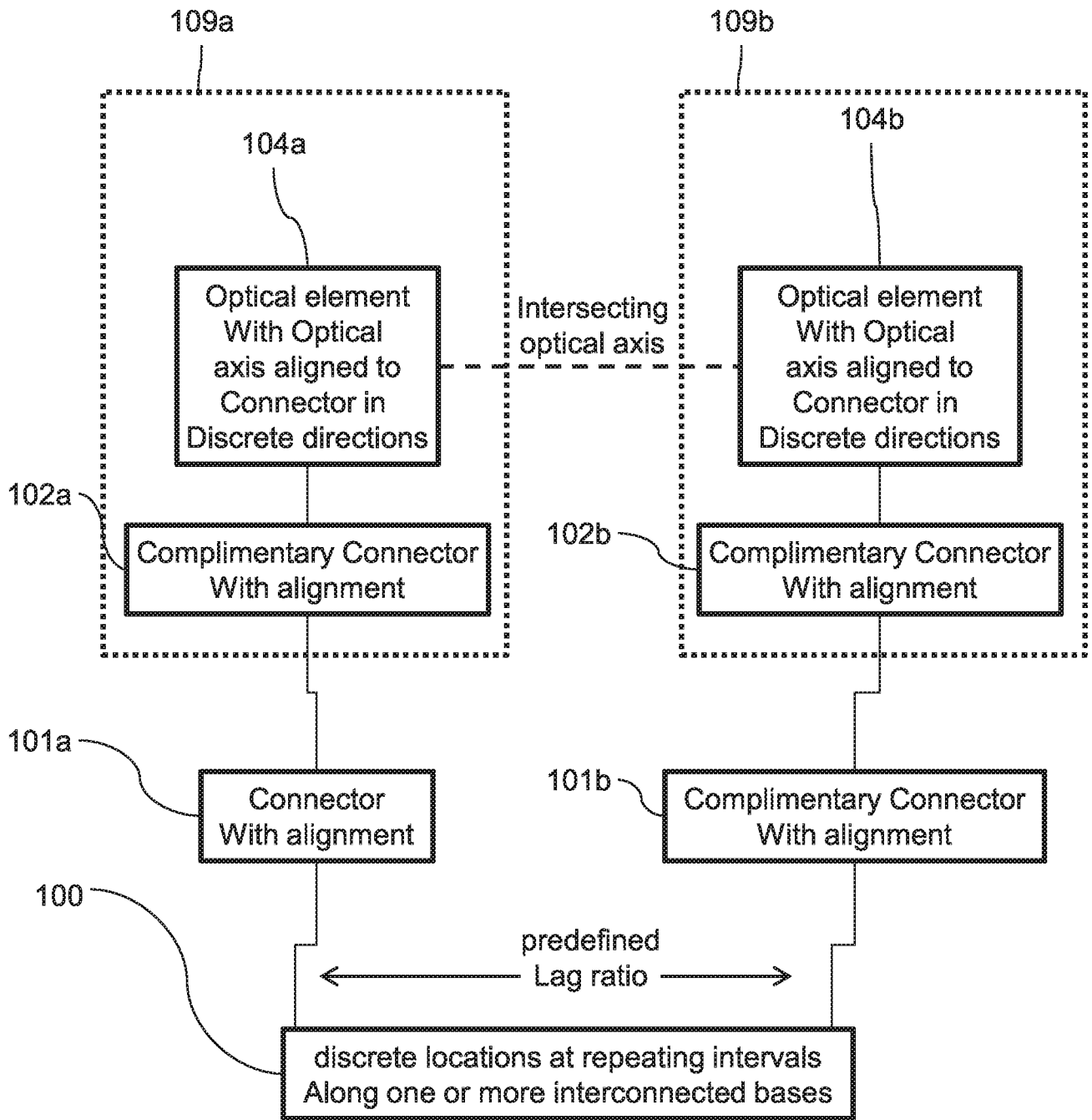
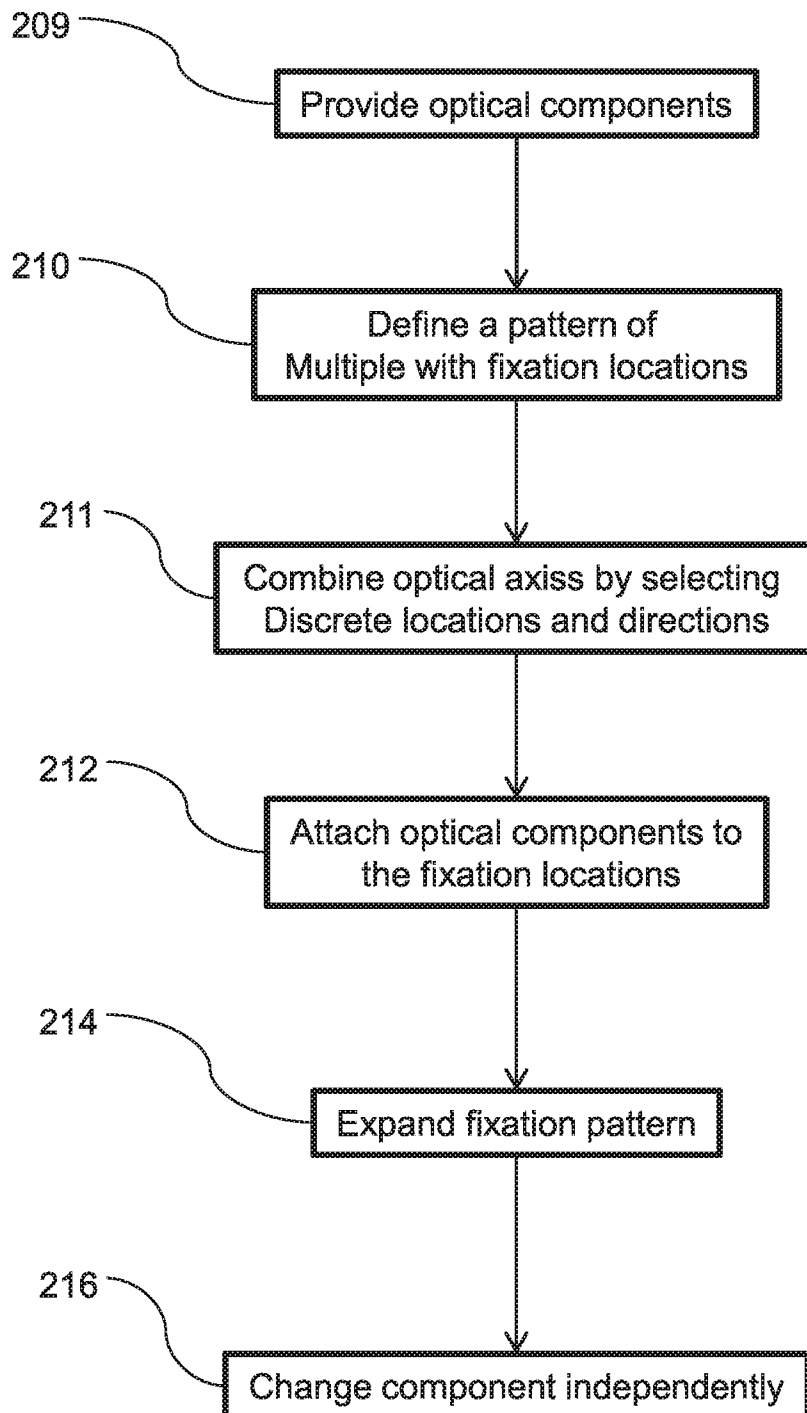


FIG. 1

**FIG. 2**

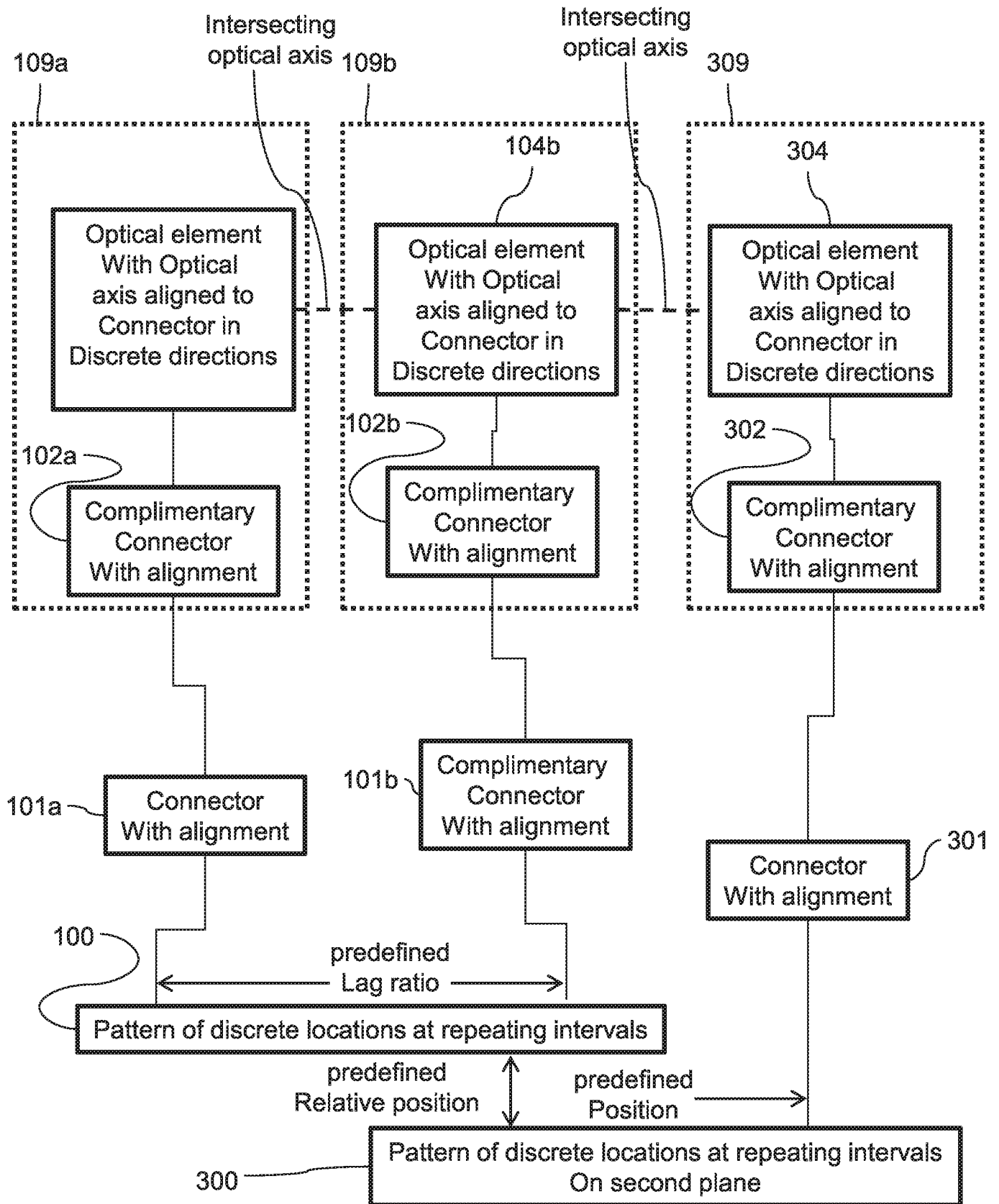
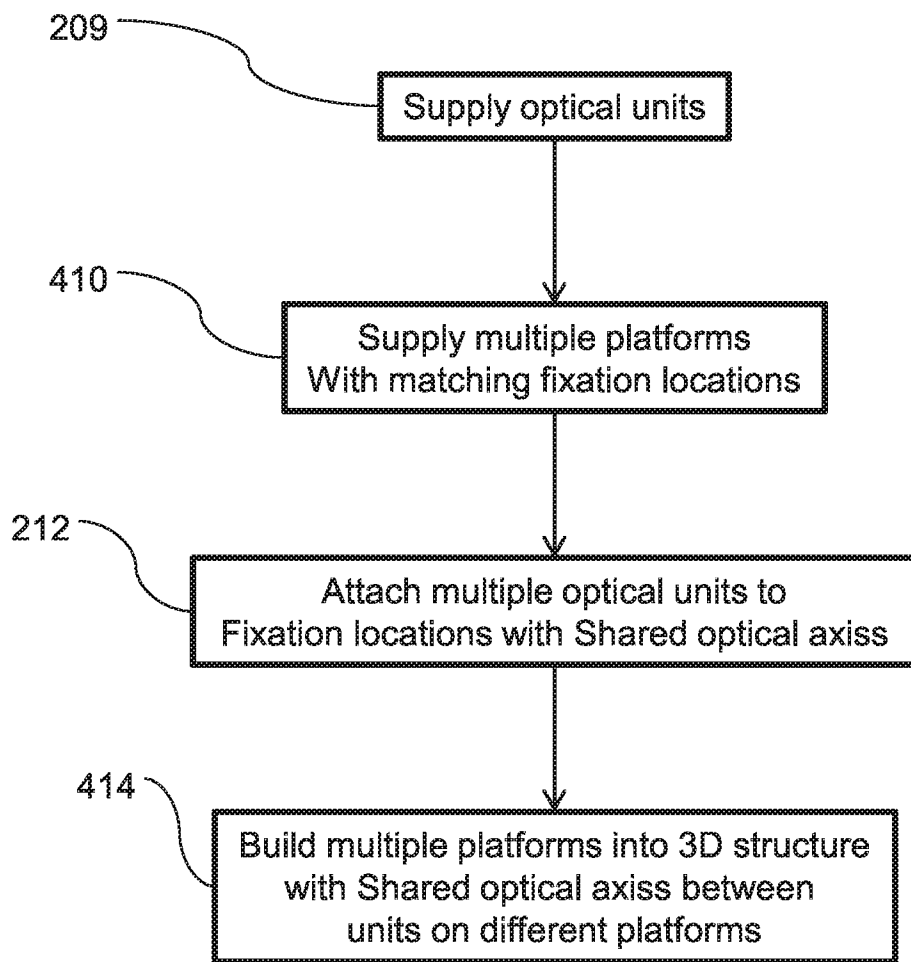
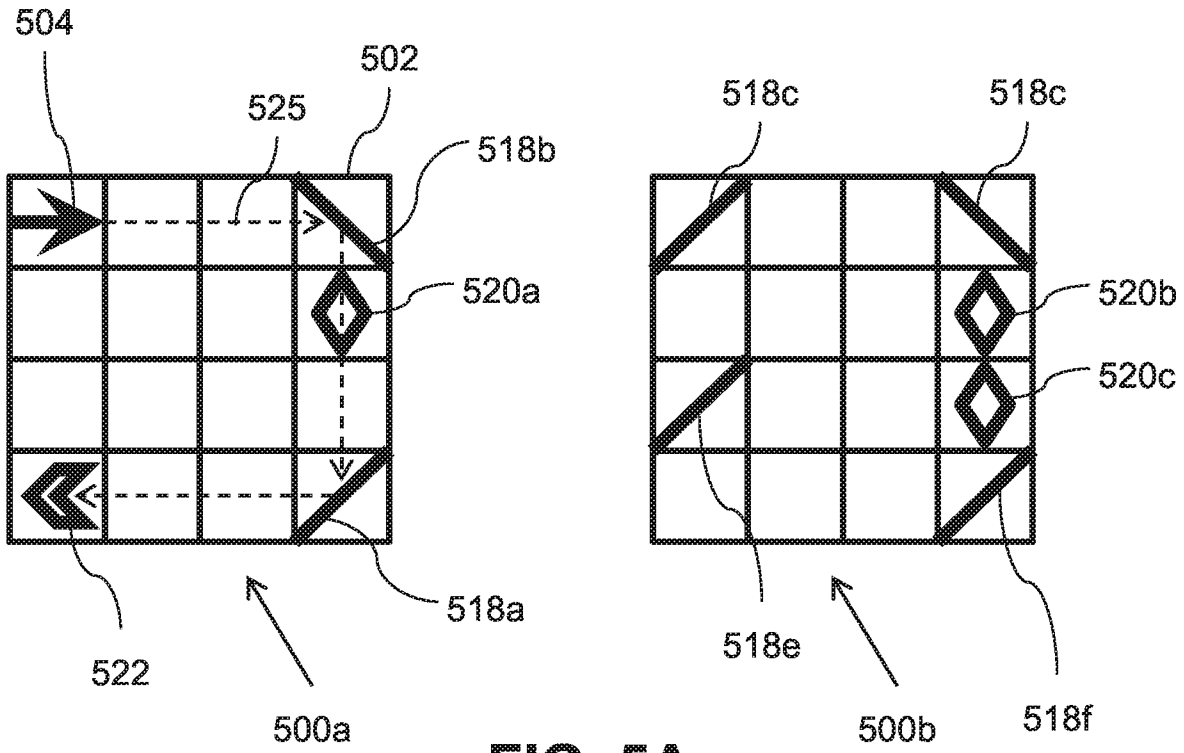


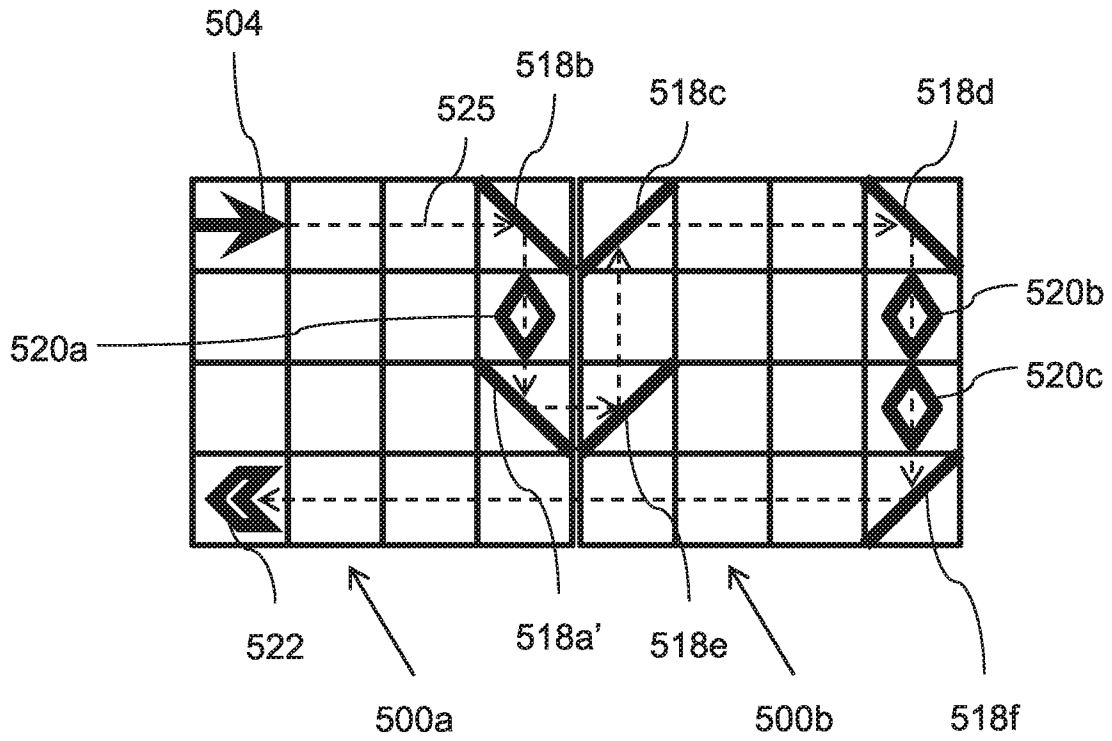
FIG. 3



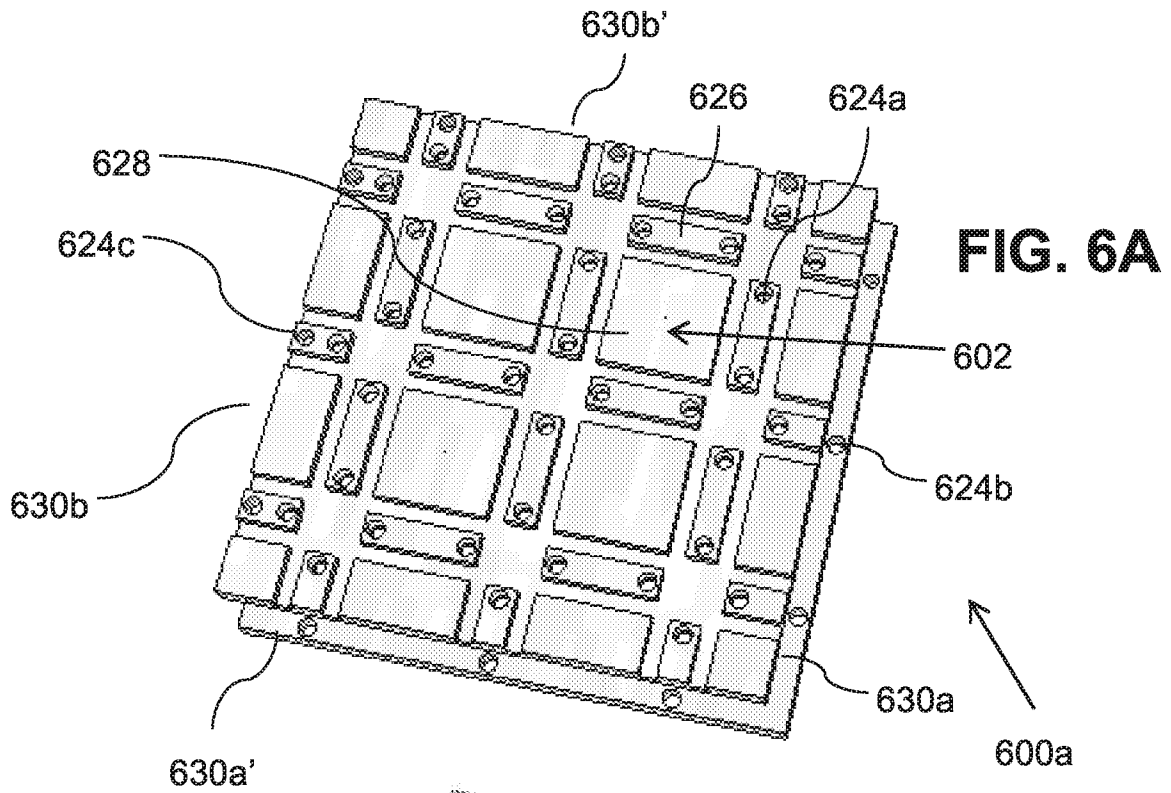
**FIG. 4**



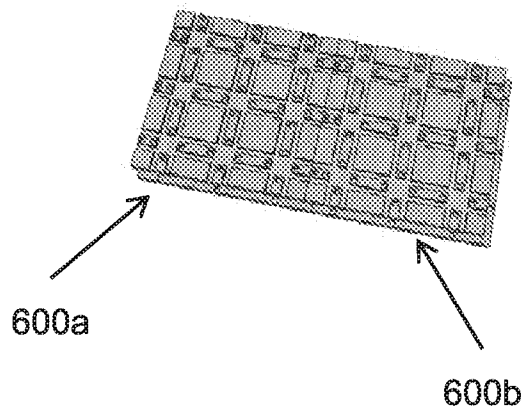
**FIG. 5A**



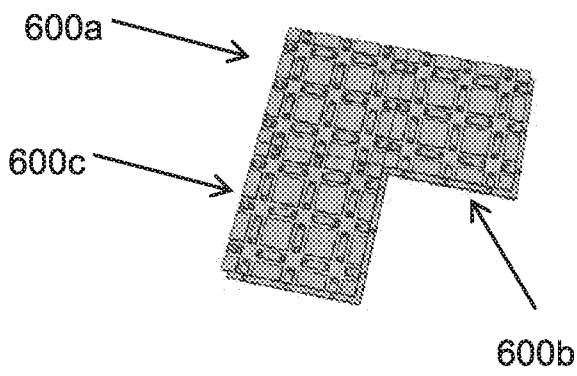
**FIG. 5B**



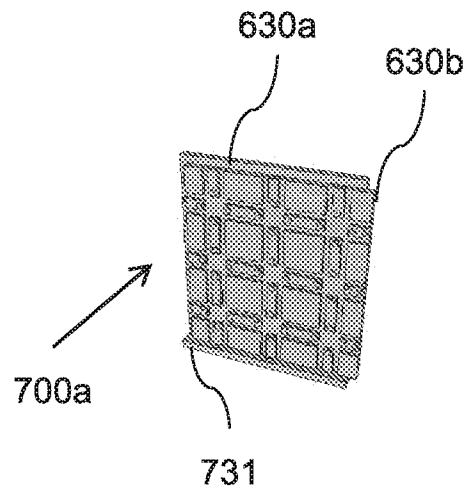
**FIG. 6A**



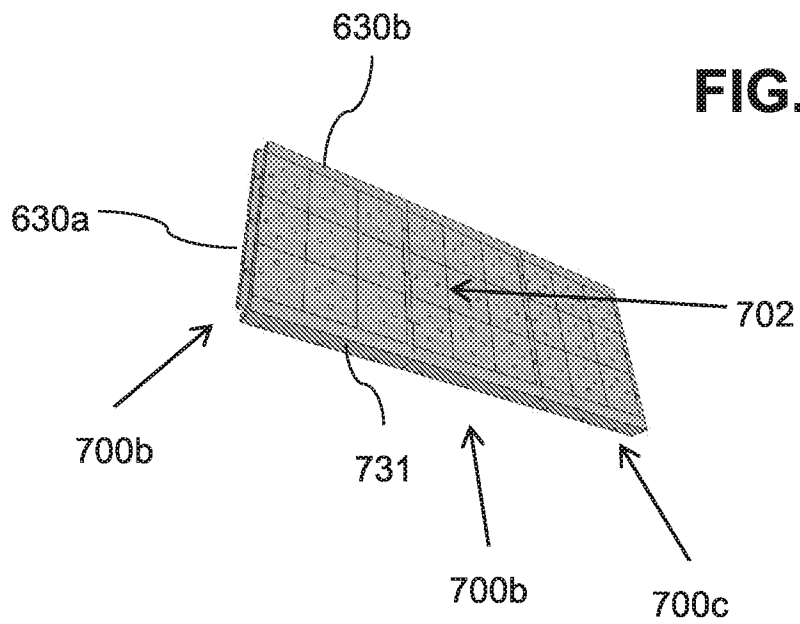
**FIG. 6B**



**FIG. 6C**



**FIG. 7A**



**FIG. 7B**

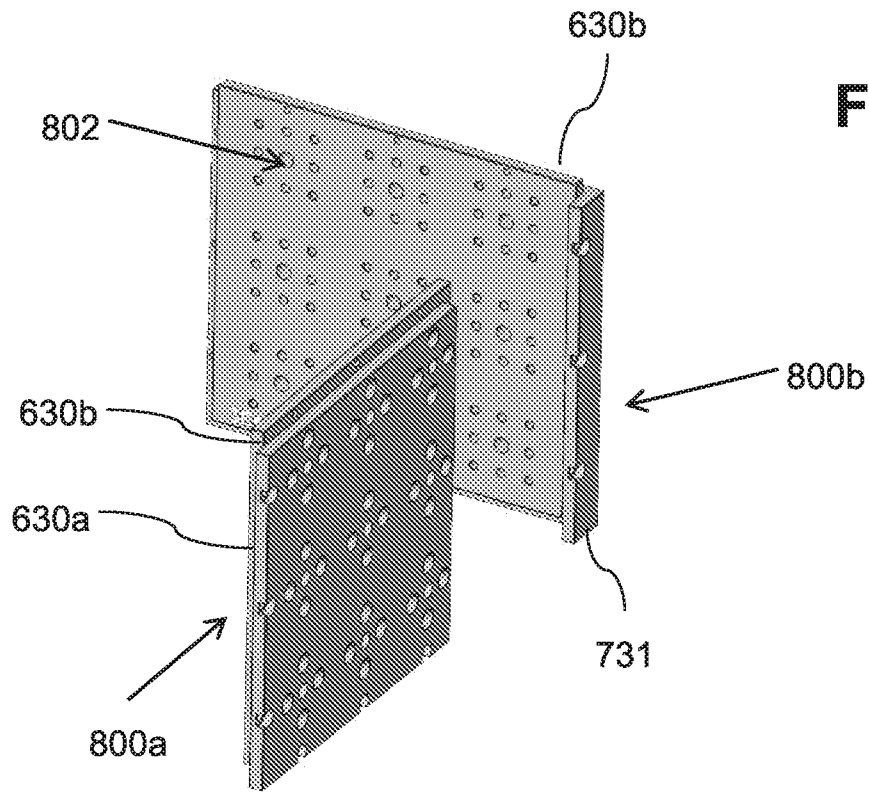


FIG. 8A

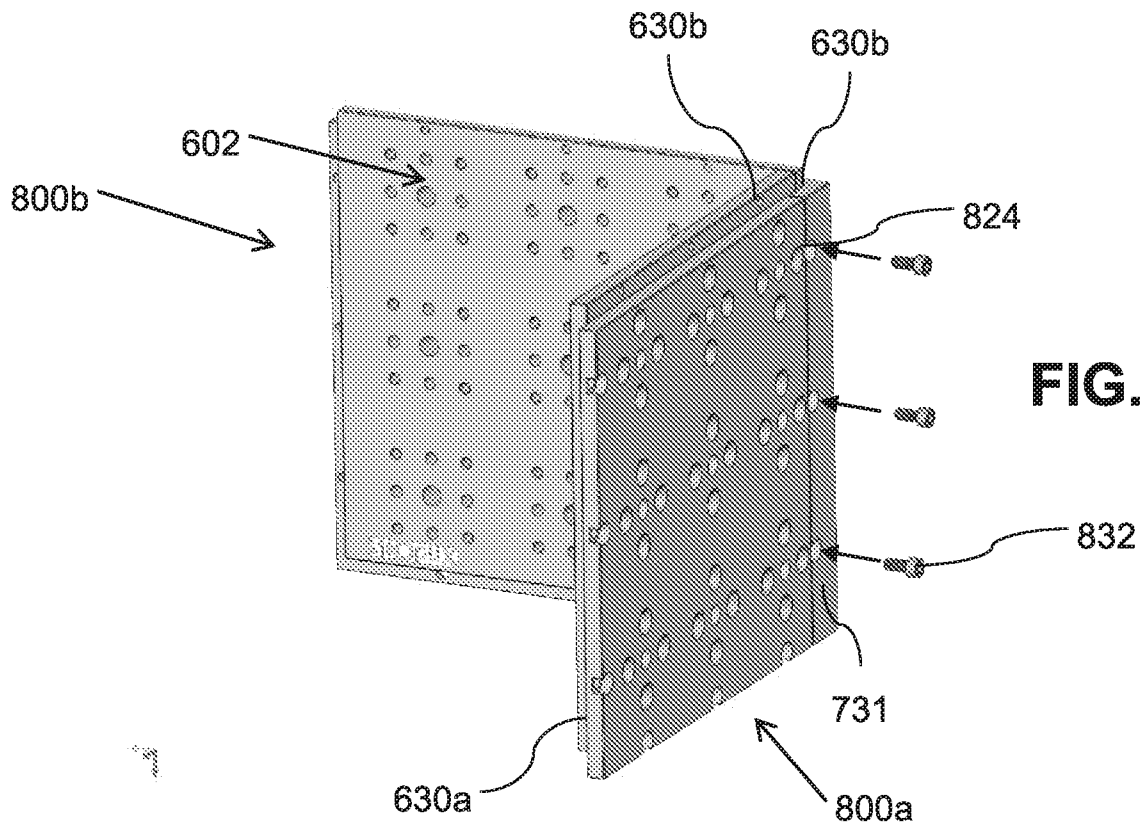


FIG. 8B

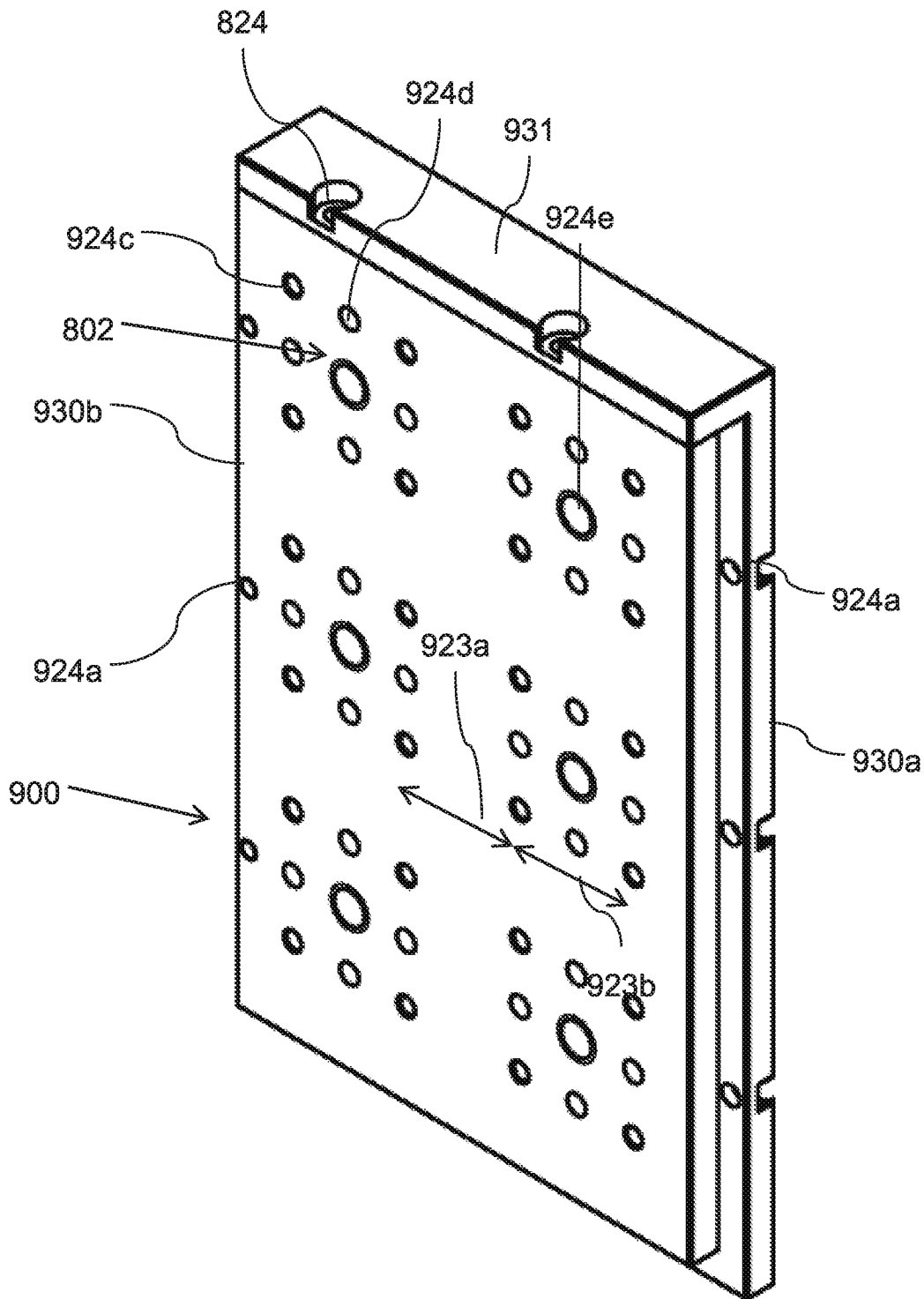
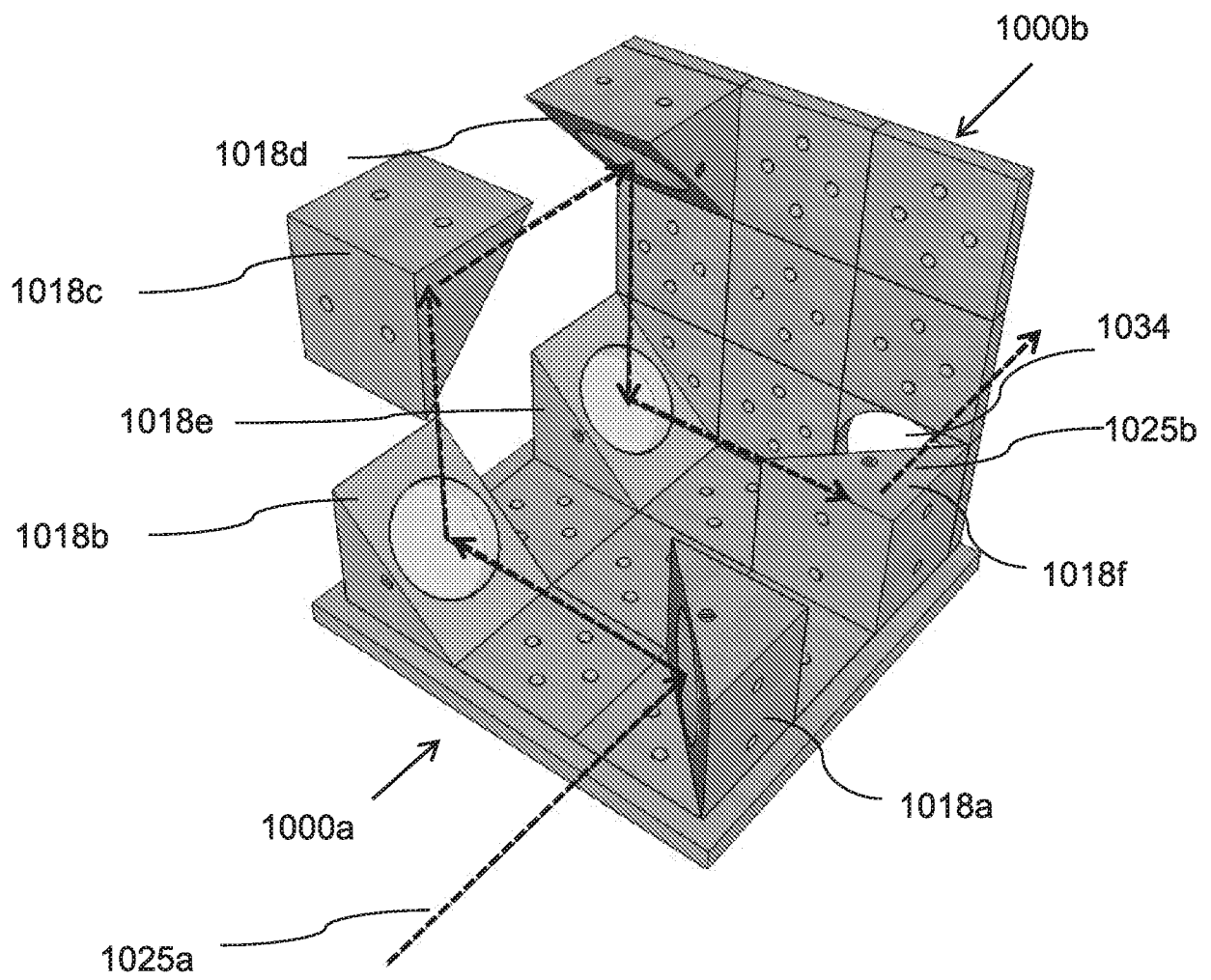
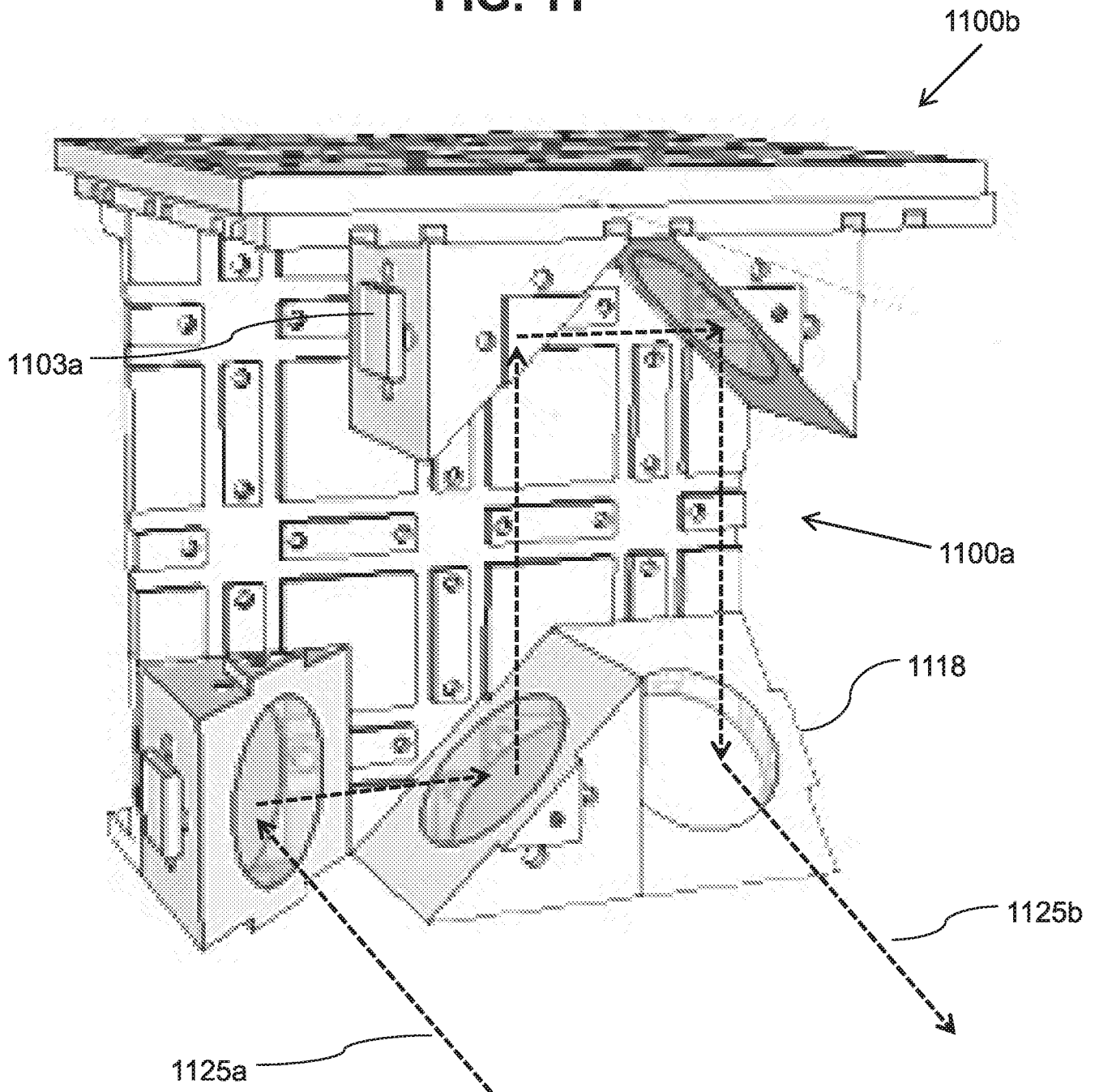


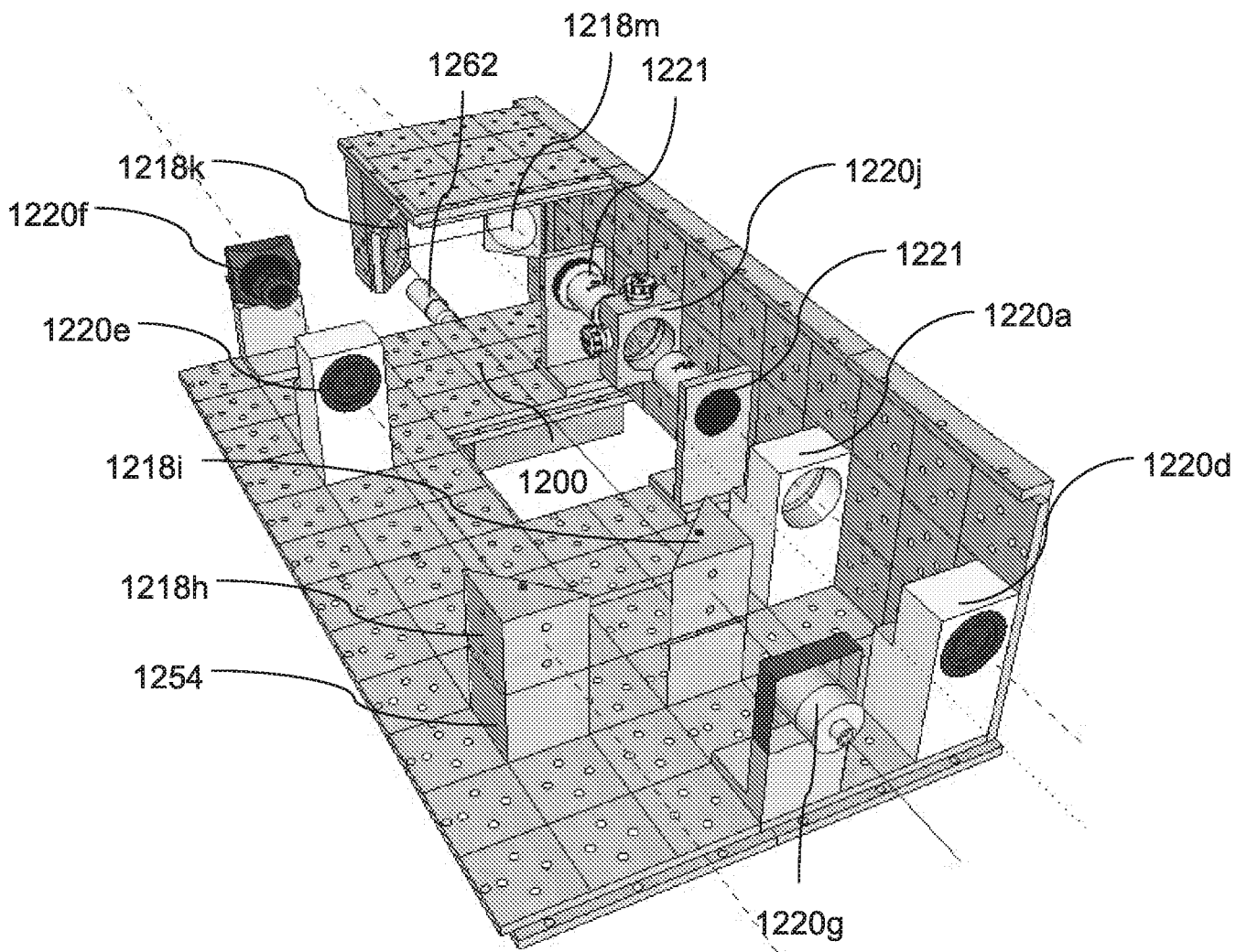
FIG. 9



**FIG. 10**

FIG. 11





**FIG. 12**



FIG. 14

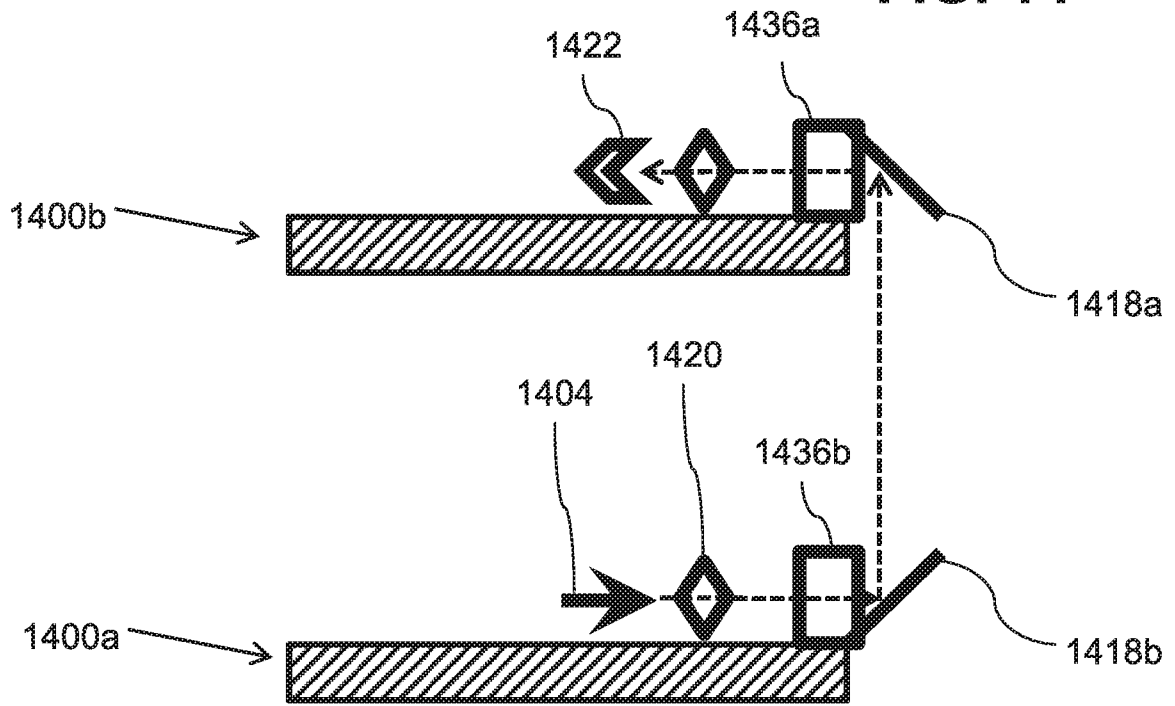


FIG. 15

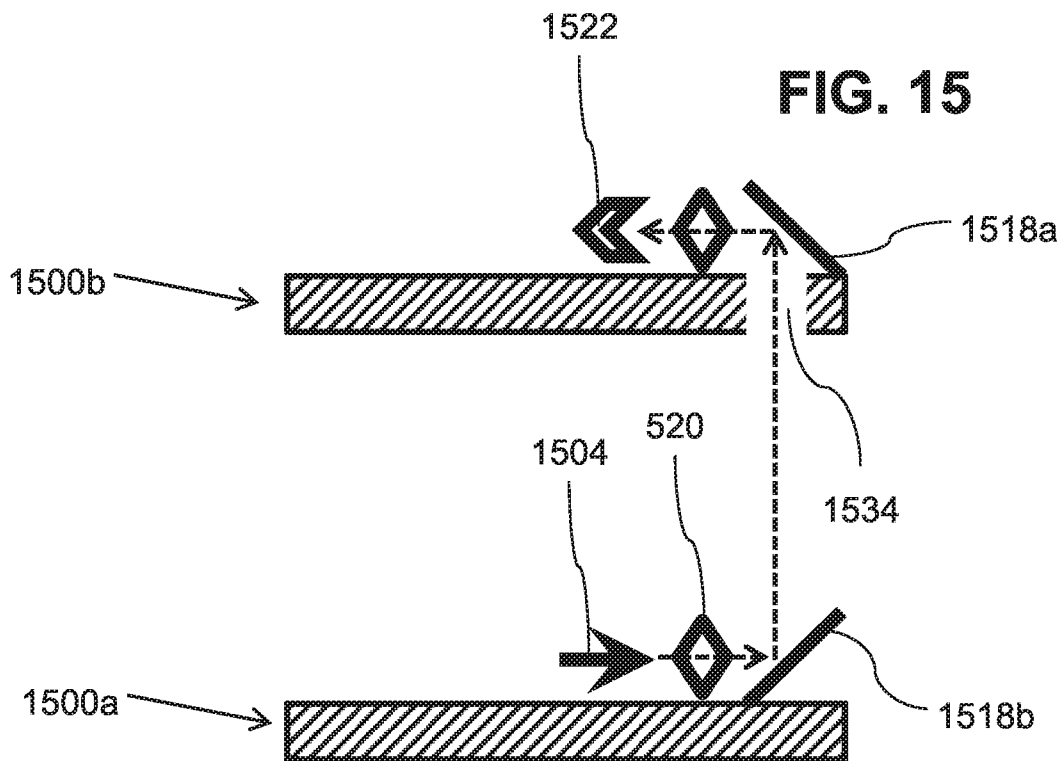
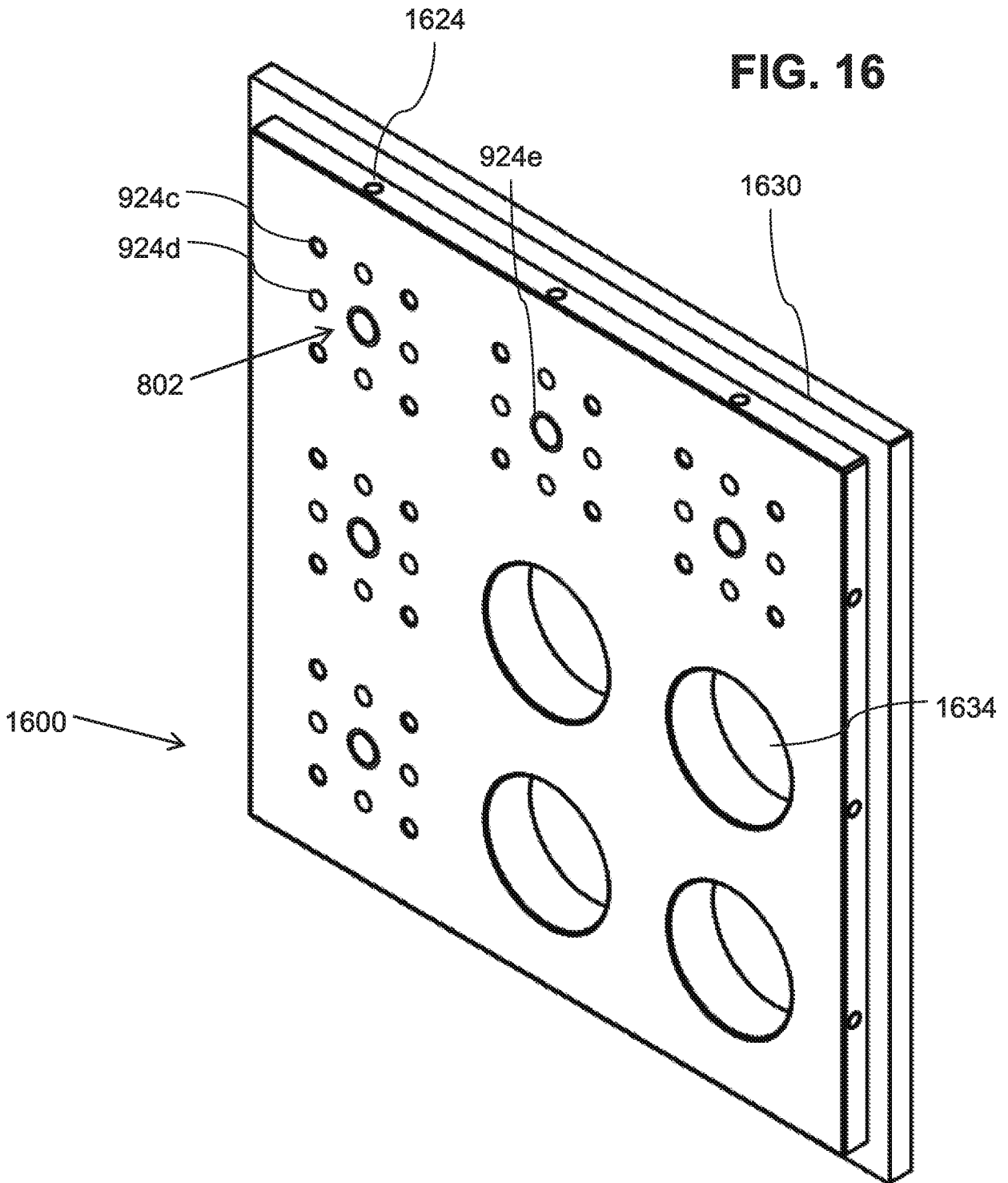
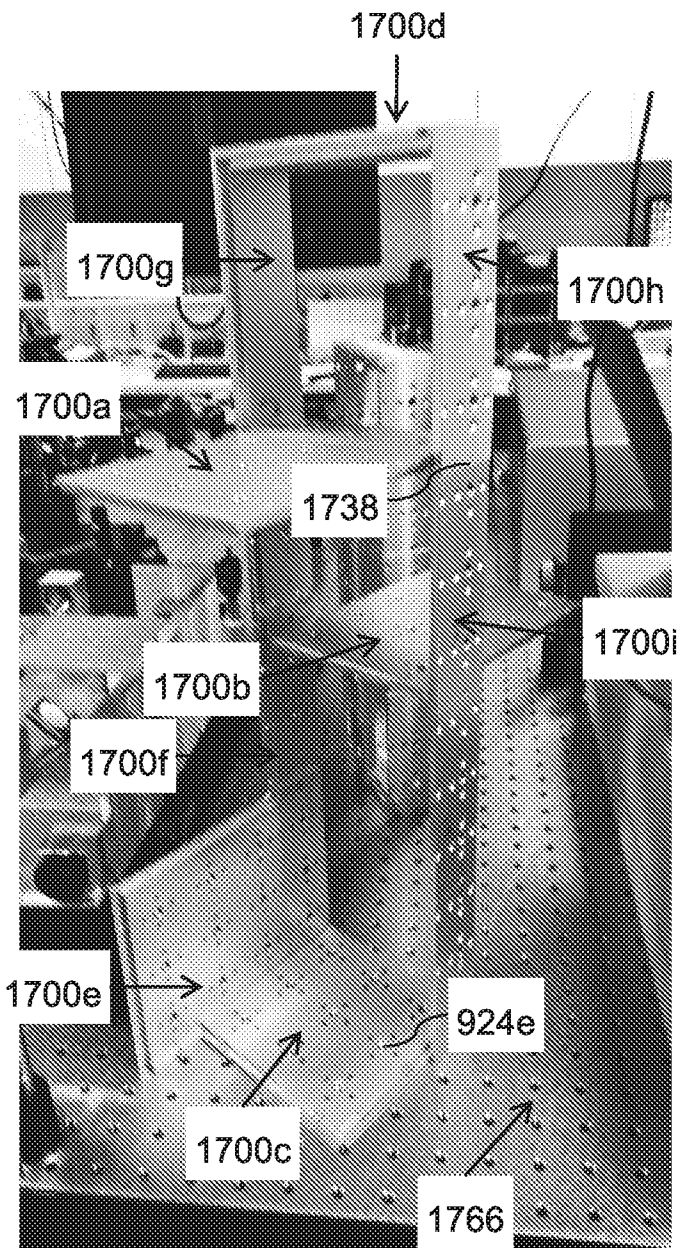


FIG. 16



**FIG. 17A**



**FIG. 17B**

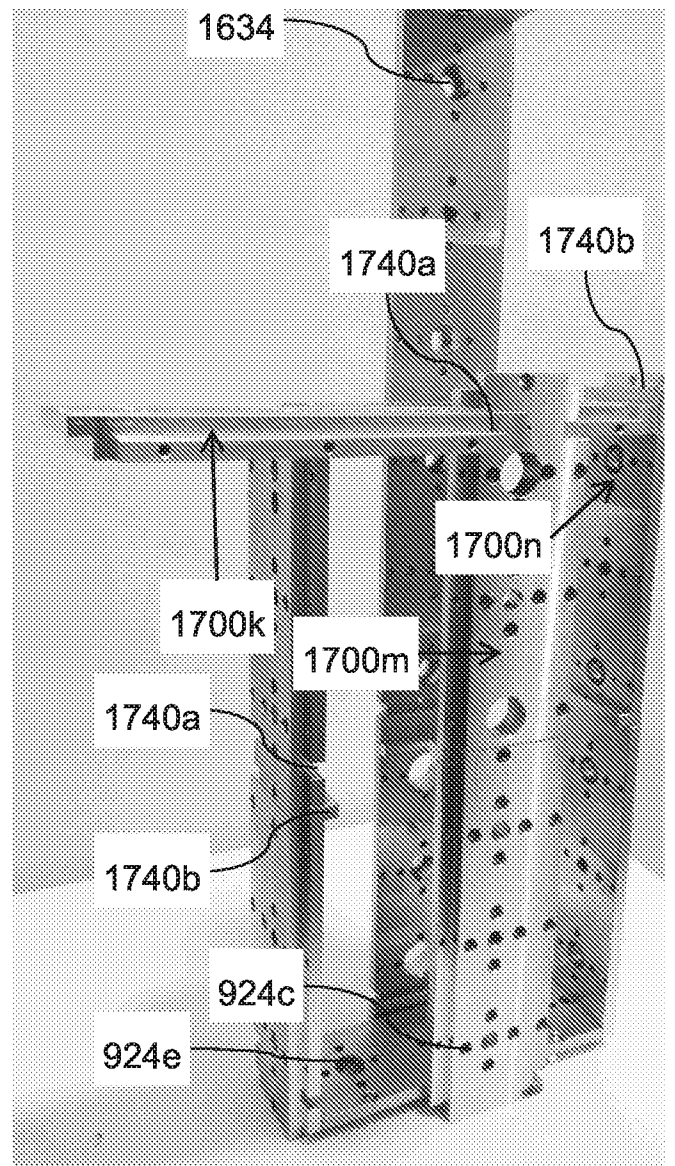


FIG. 17C

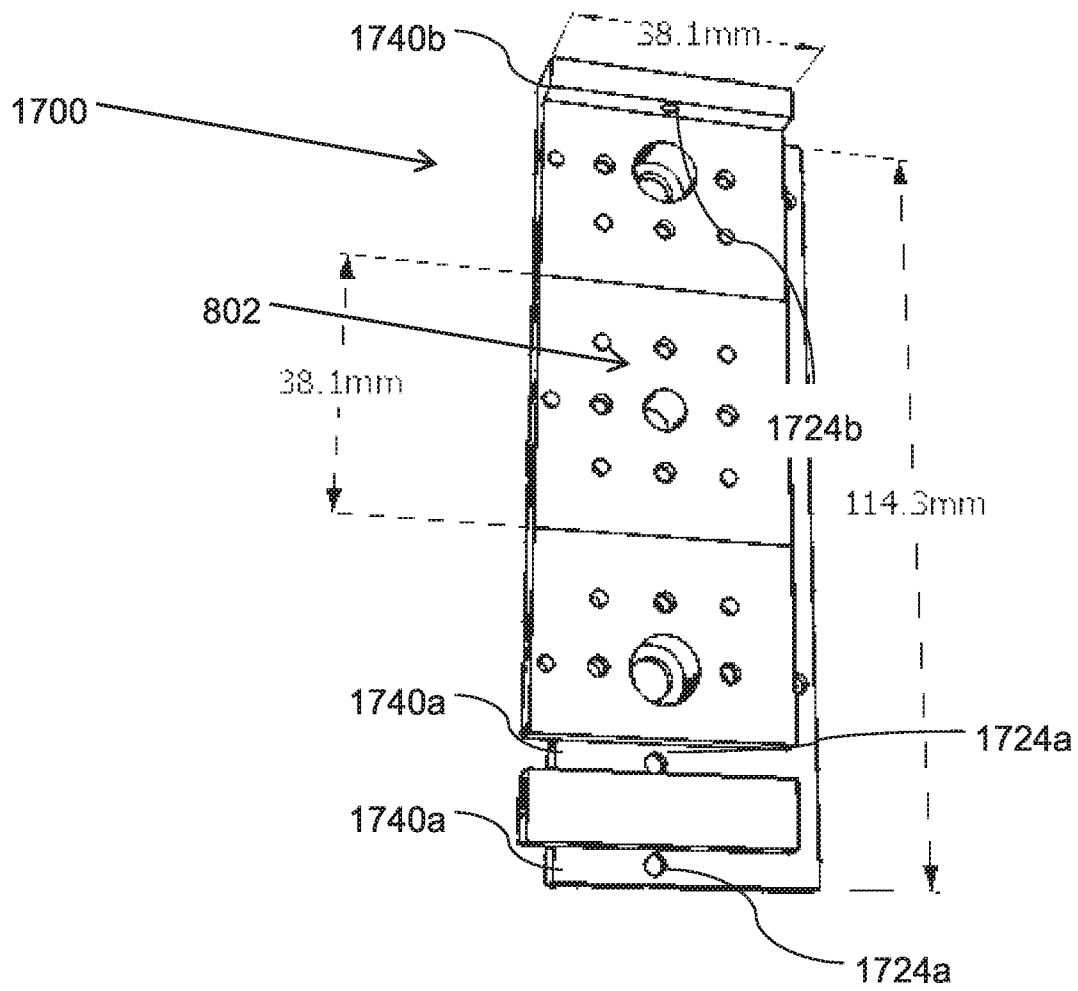
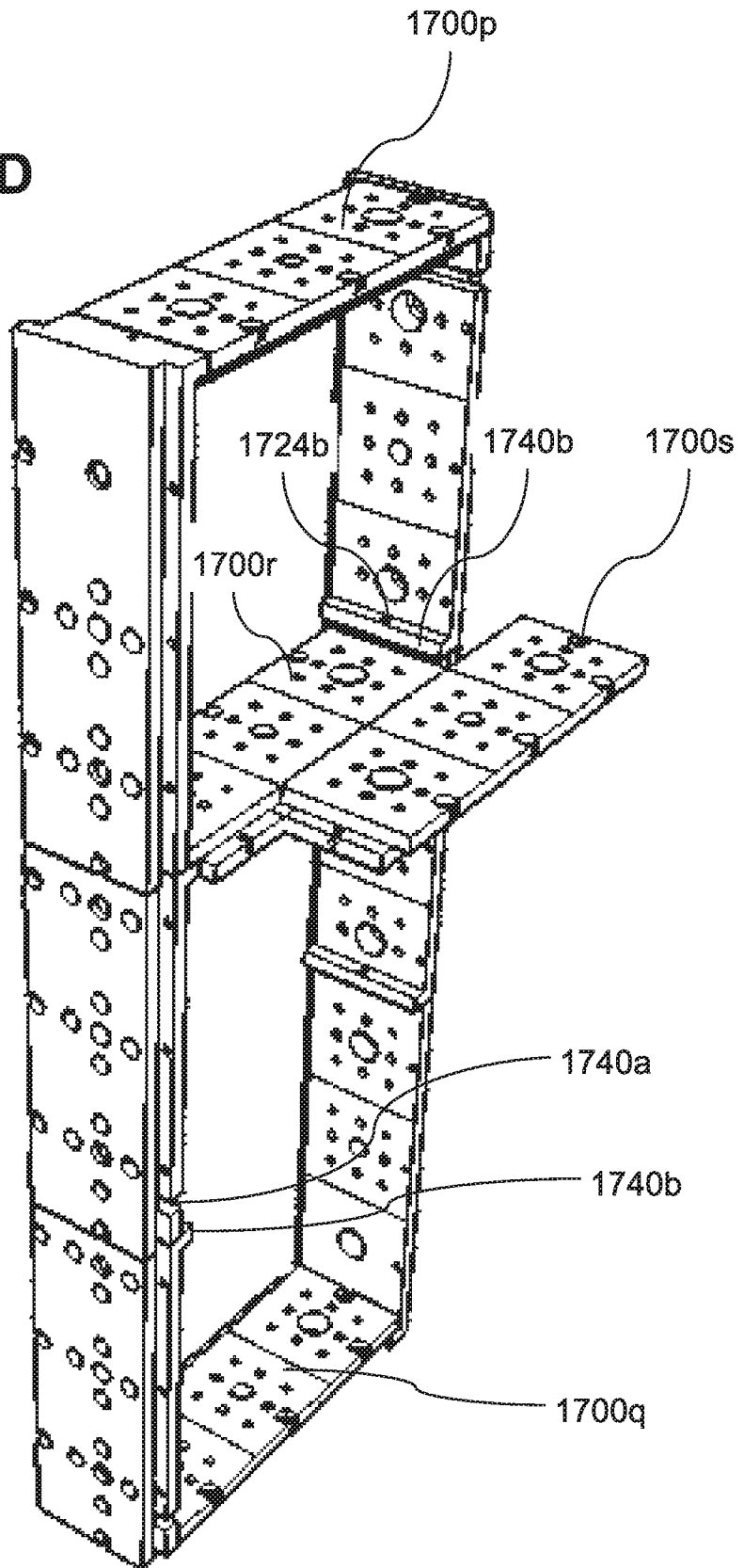
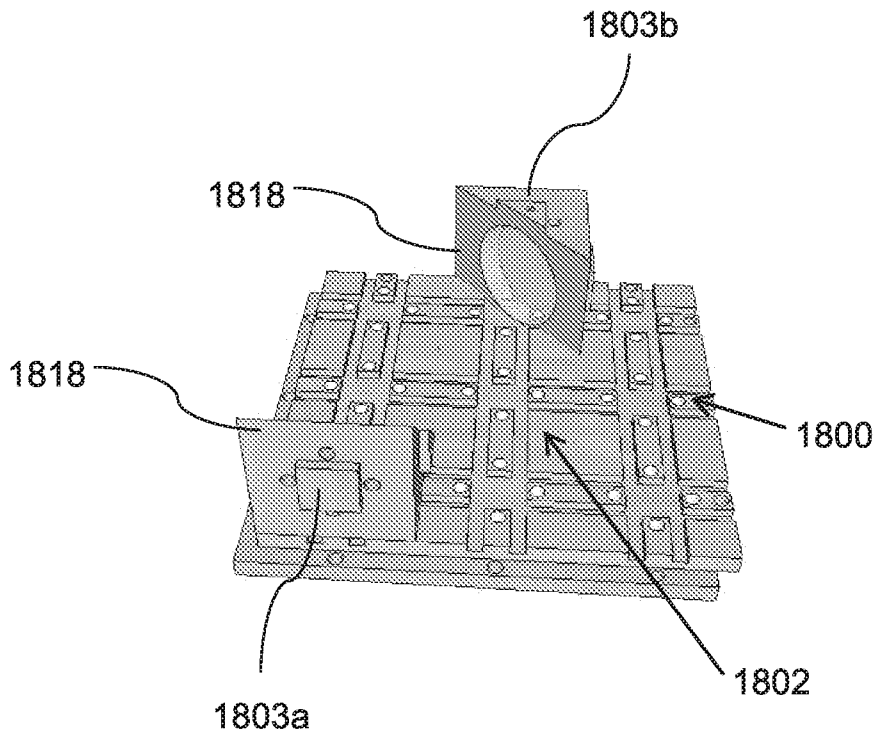


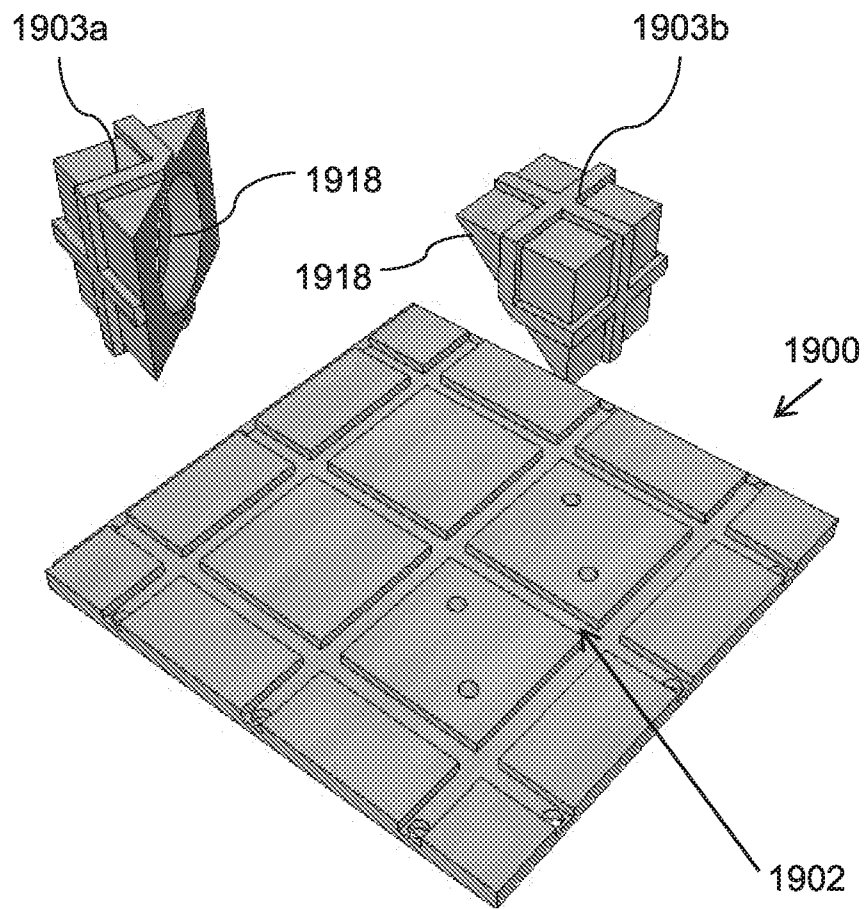
FIG. 17D



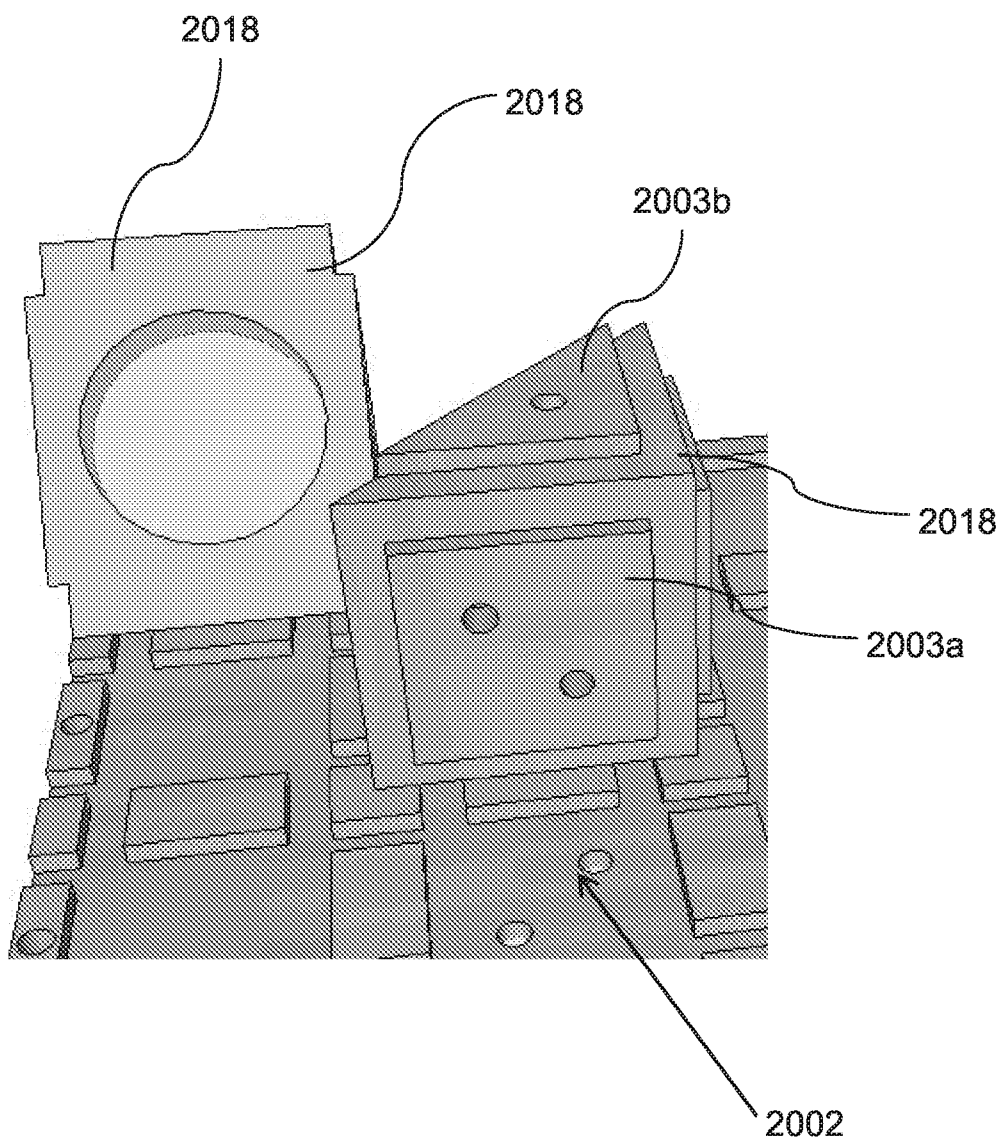


**FIG. 18**

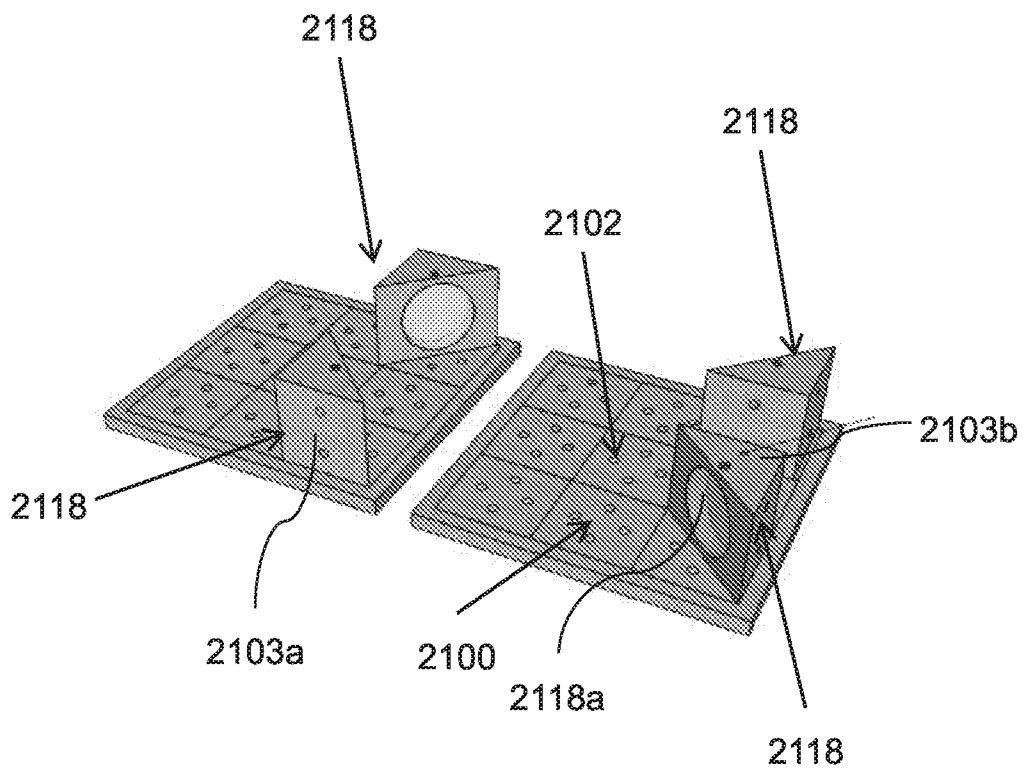
FIG. 19



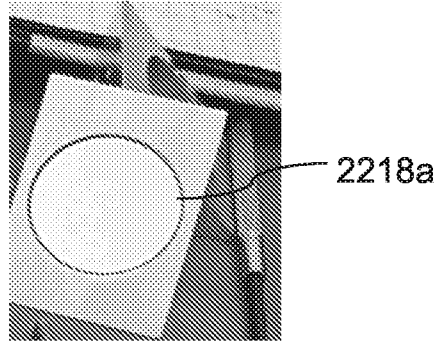
**FIG. 20**



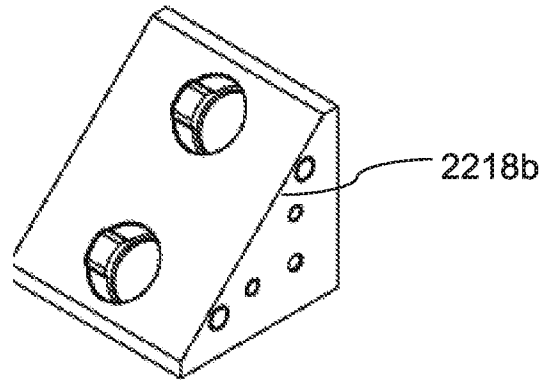
**FIG. 21**

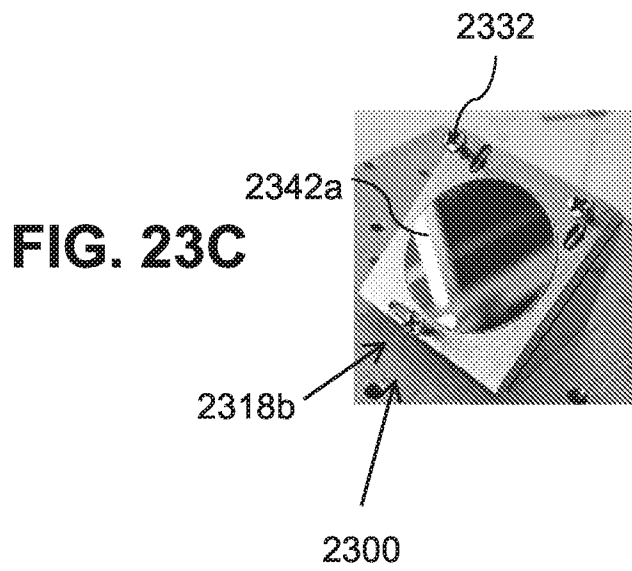
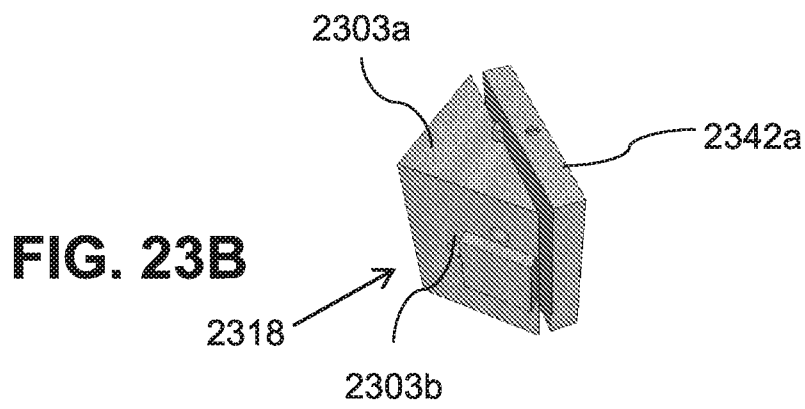
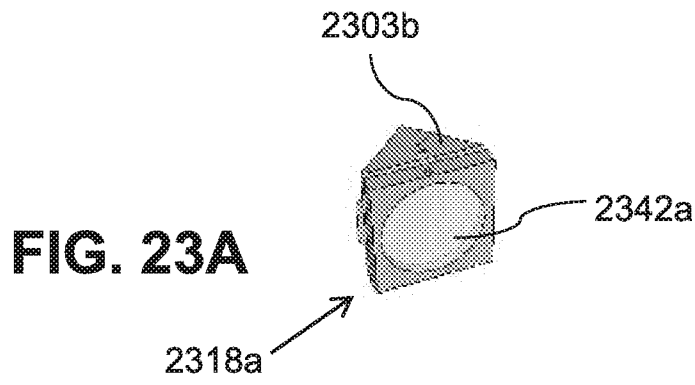


**FIG. 22A**

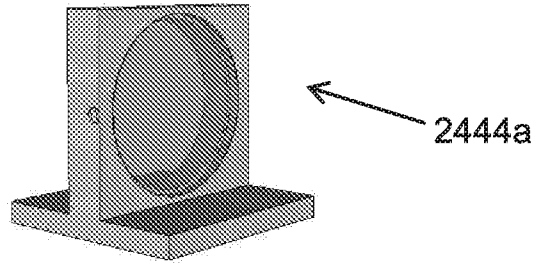


**FIG. 22B**

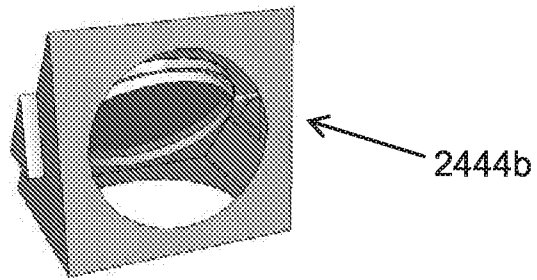




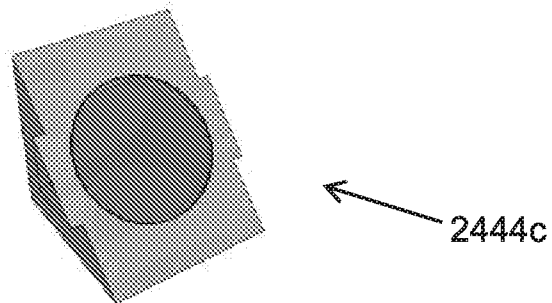
**FIG. 24A**



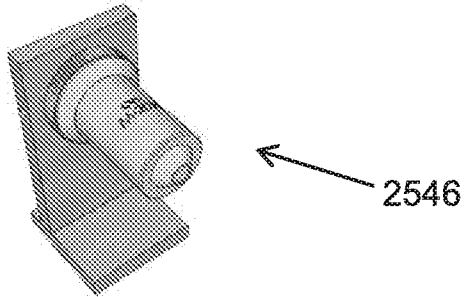
**FIG. 24B**



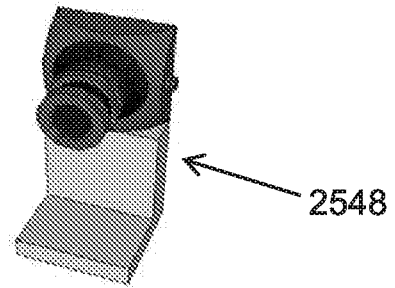
**FIG. 24C**



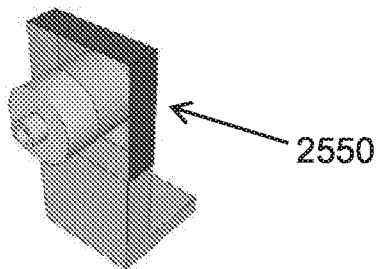
**FIG. 25A**



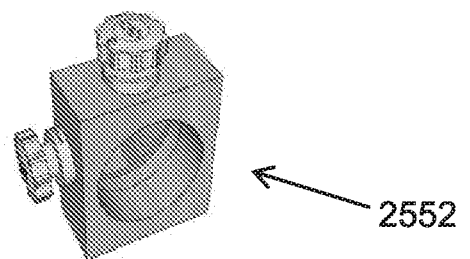
**FIG. 25B**



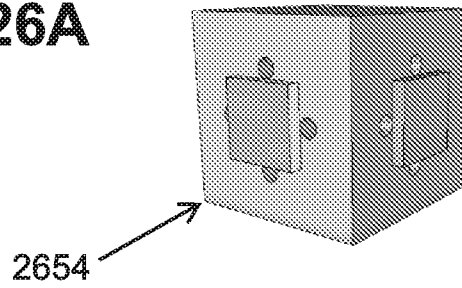
**FIG. 25C**



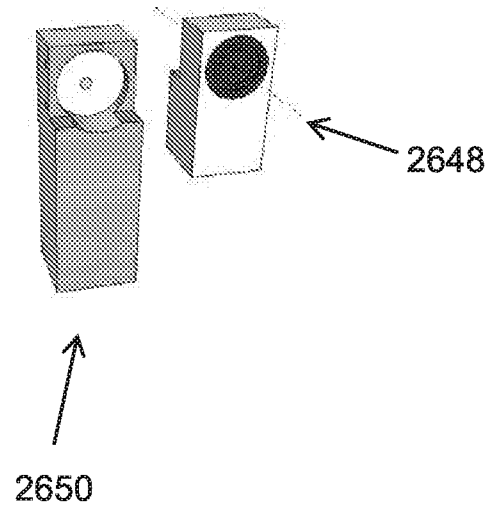
**FIG. 25D**



**FIG. 26A**



**FIG. 26B**



**FIG. 27**

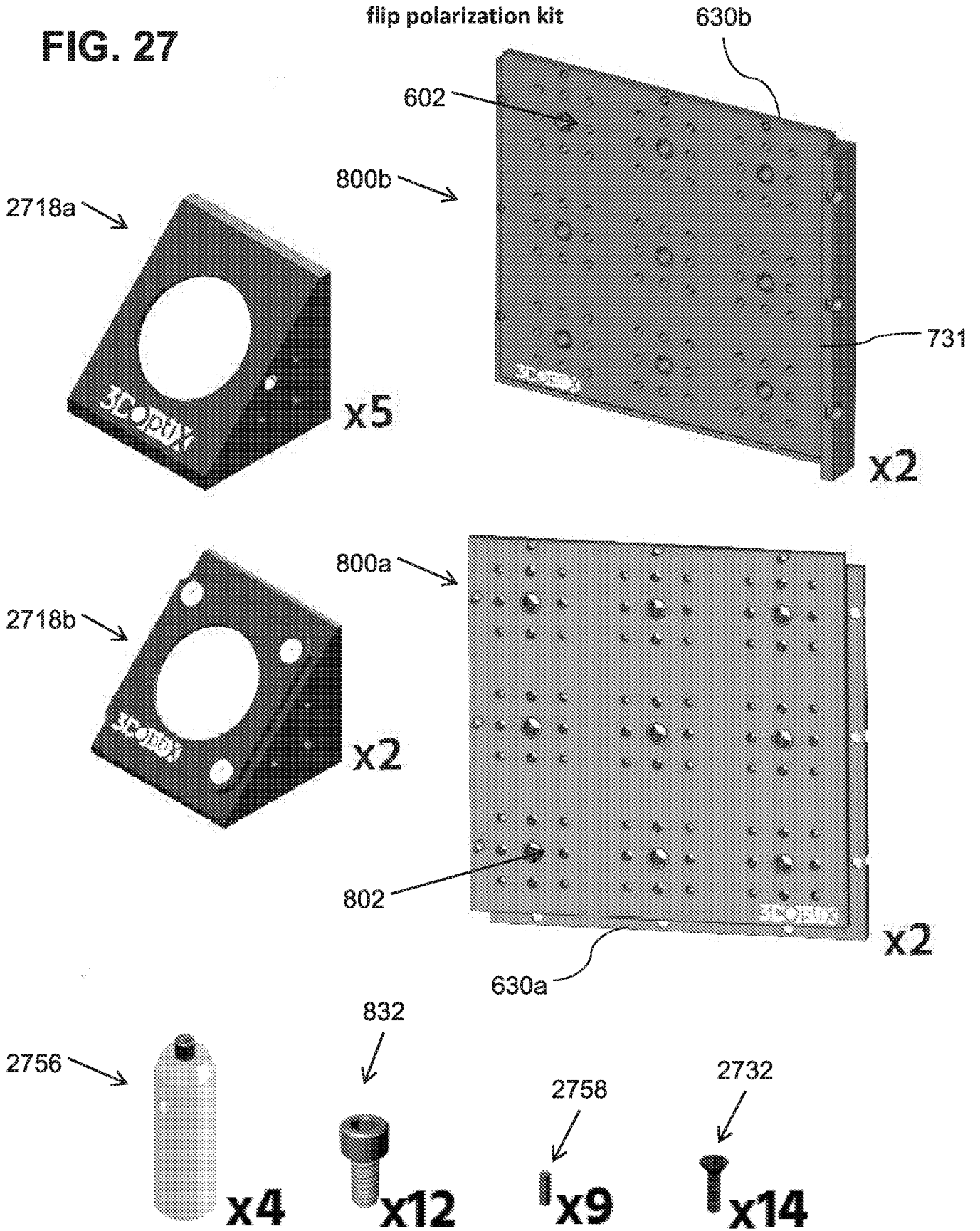


FIG. 28

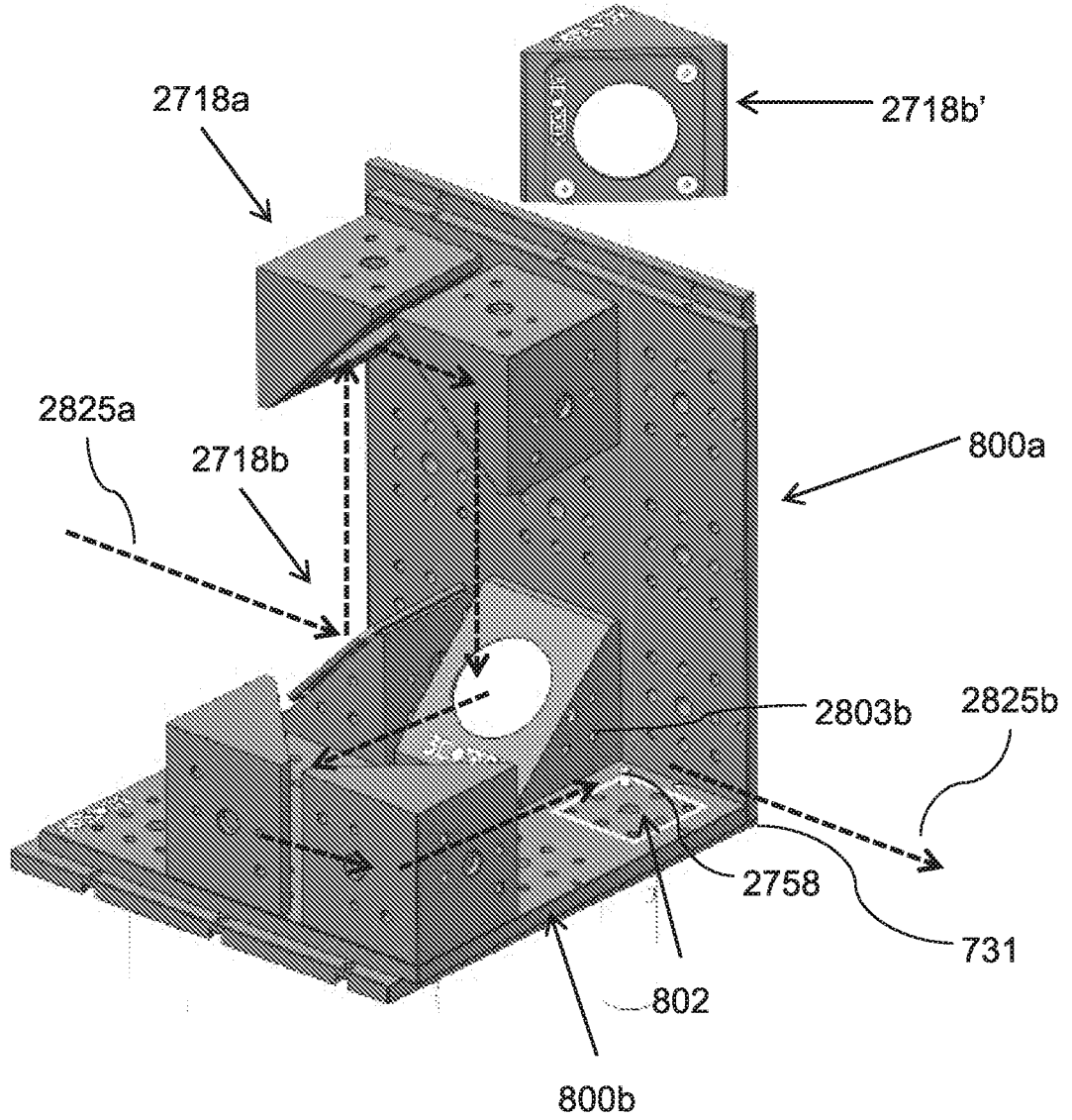


FIG. 29A

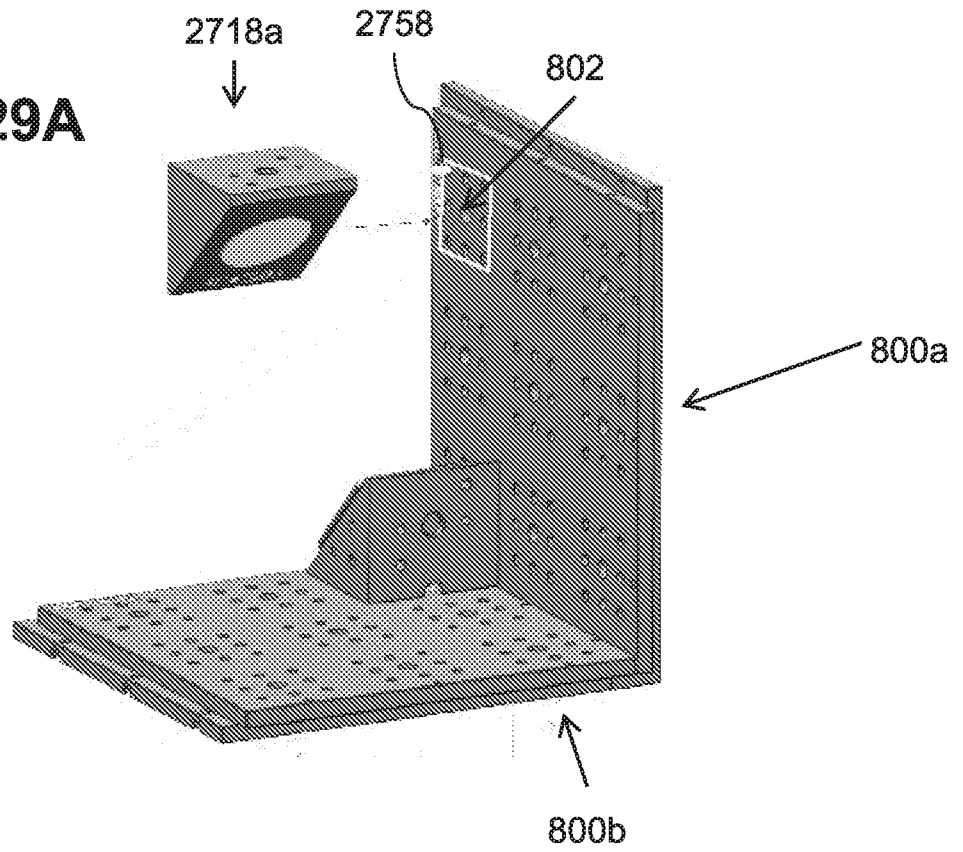
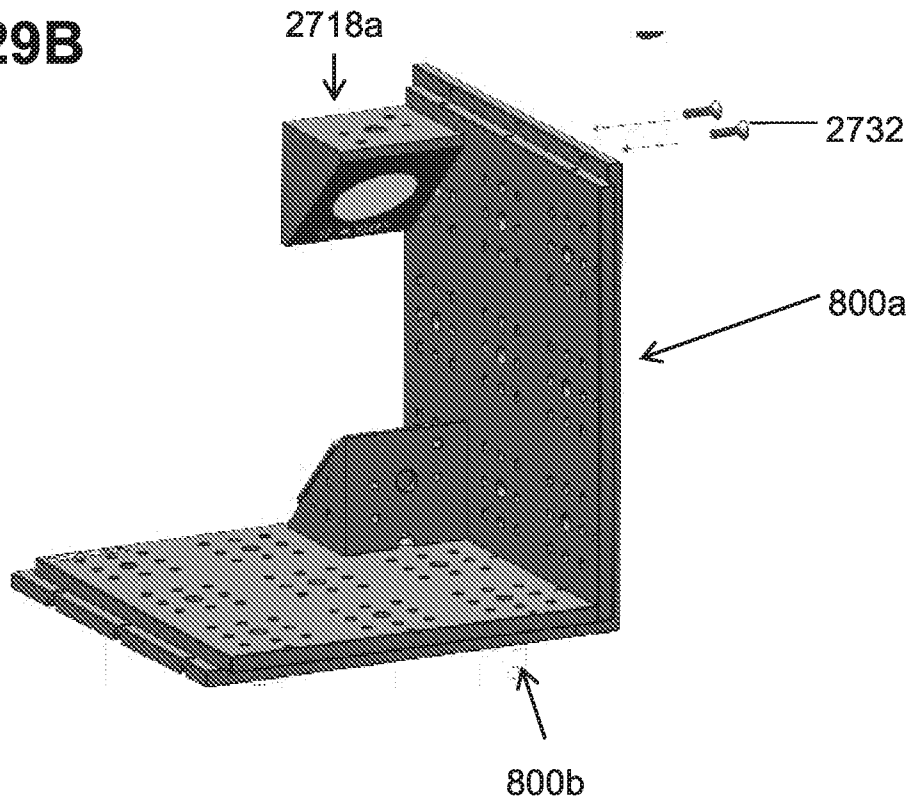
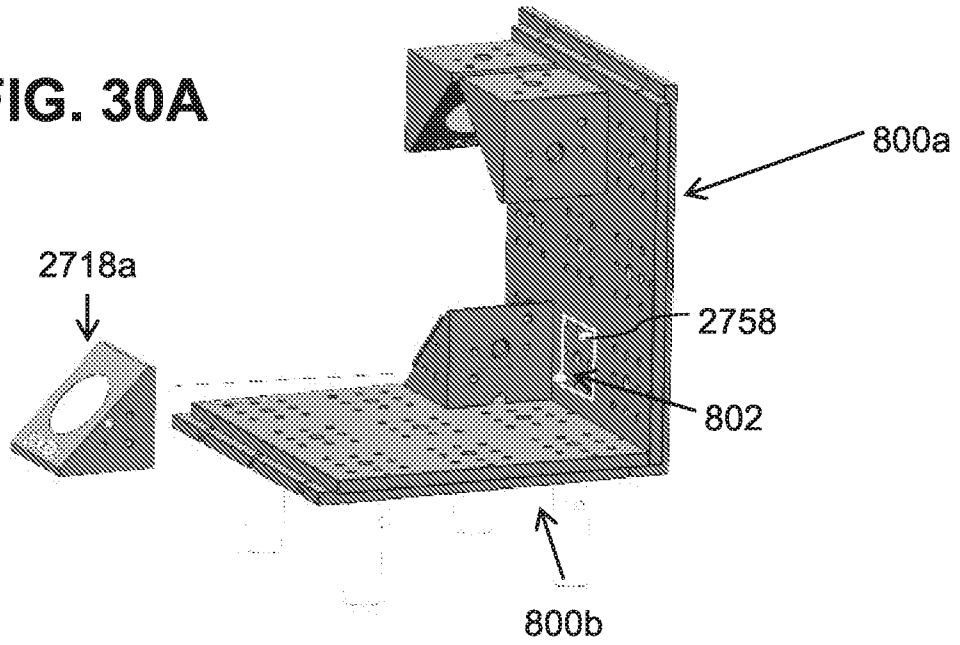


FIG. 29B



**FIG. 30A**



**FIG. 30B**

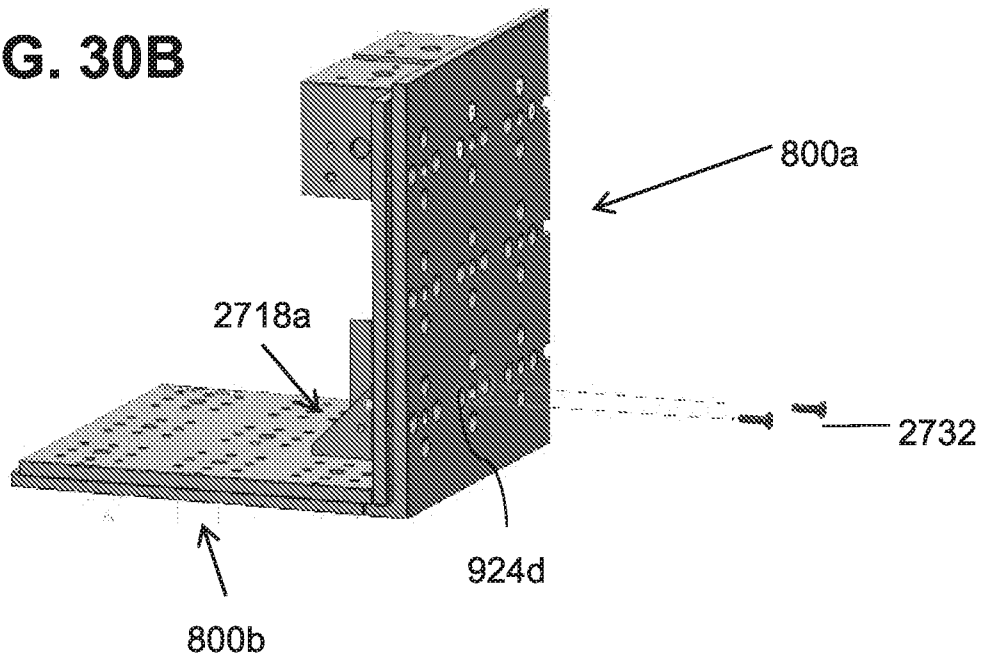
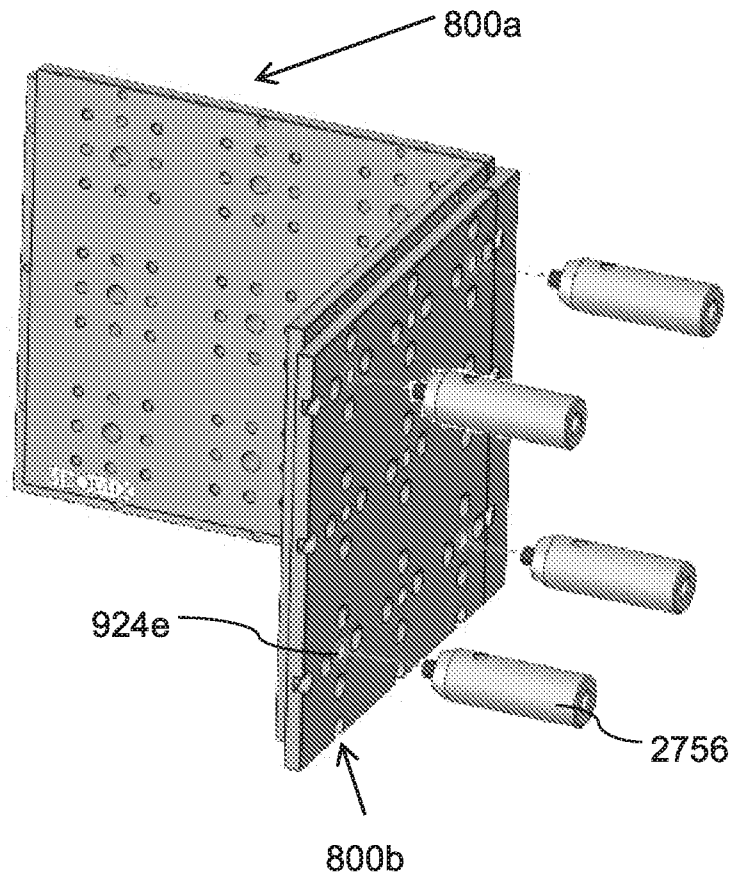
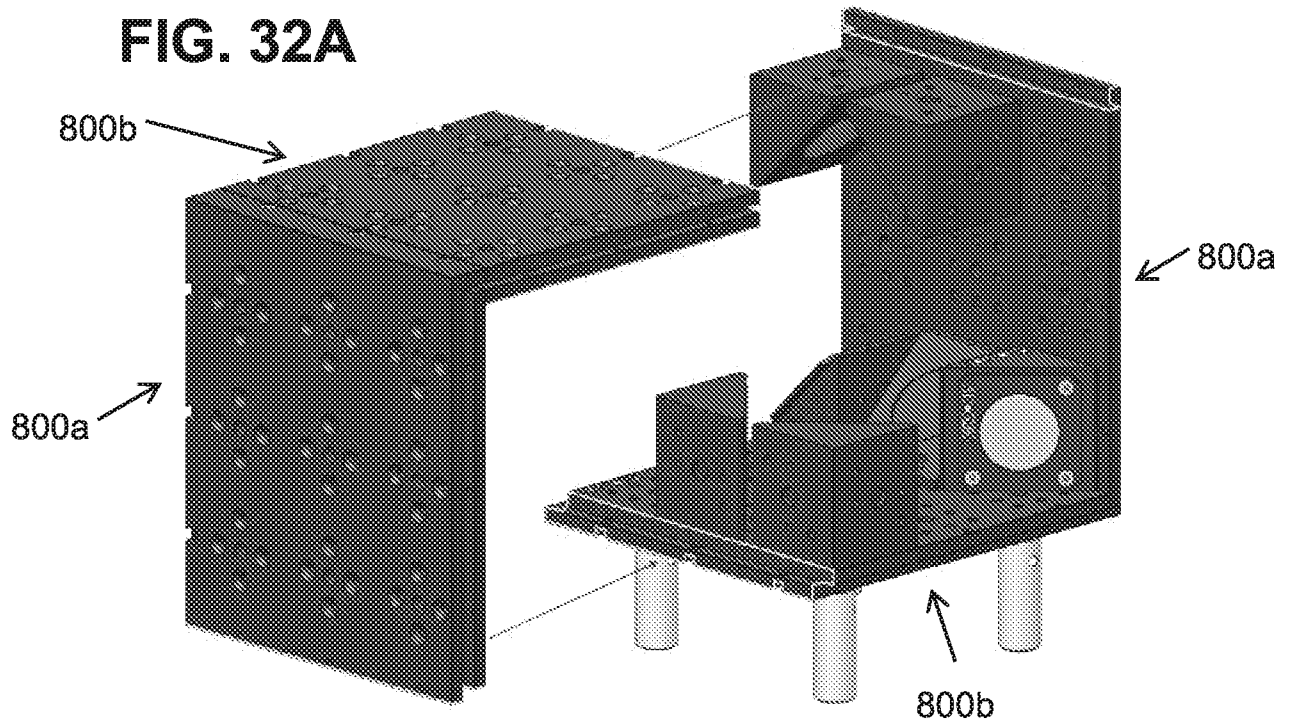


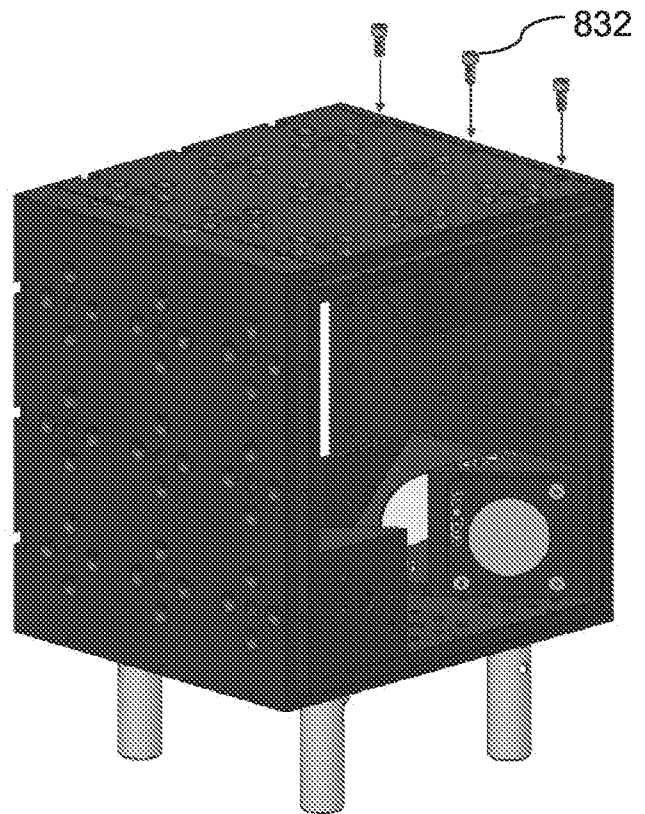
FIG. 31



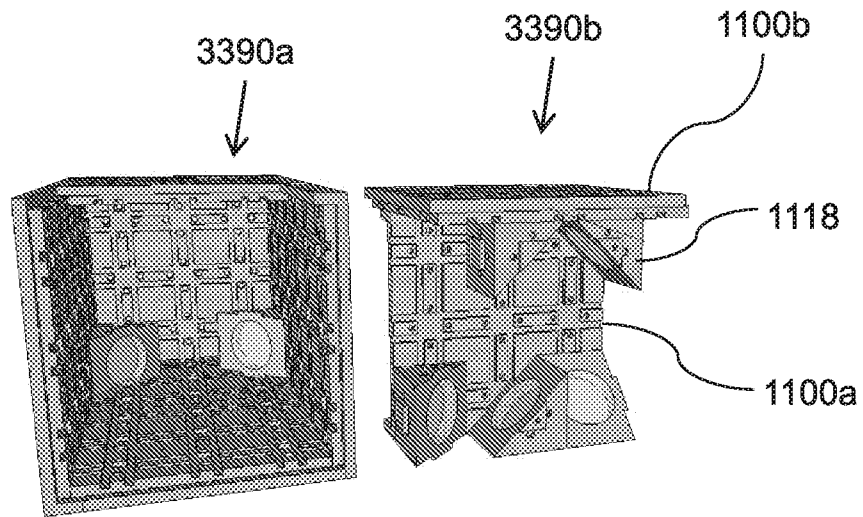
**FIG. 32A**



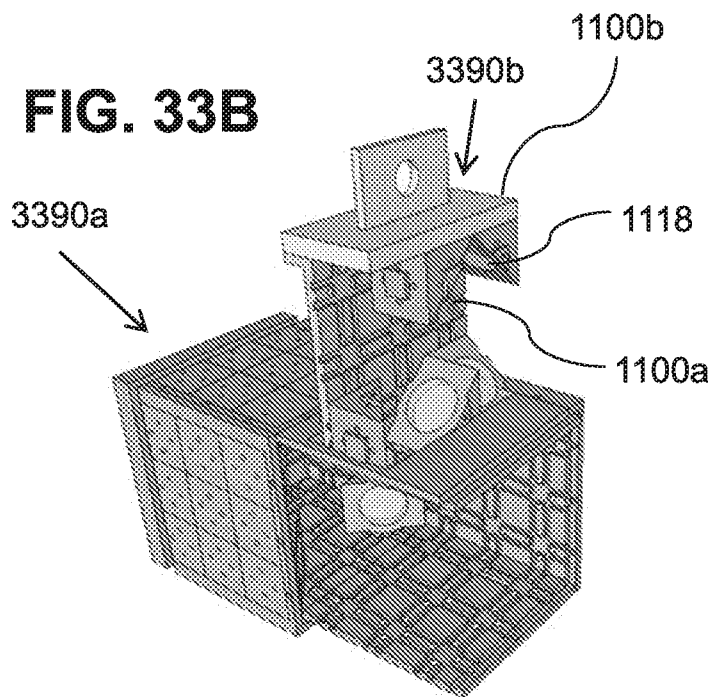
**FIG. 32B**

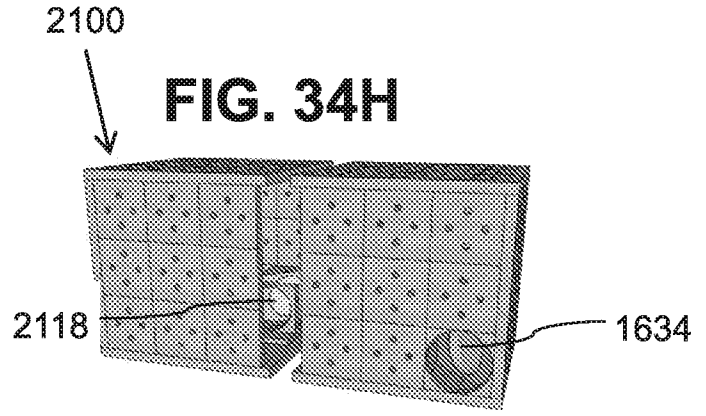
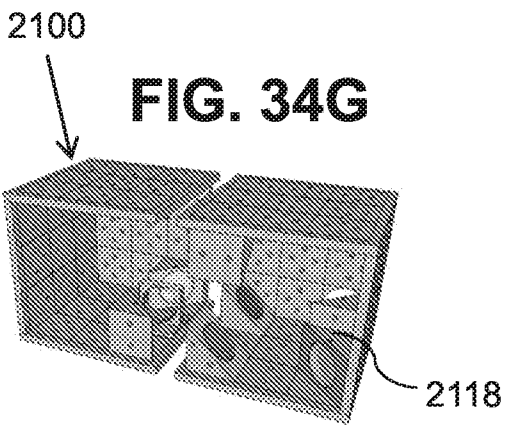
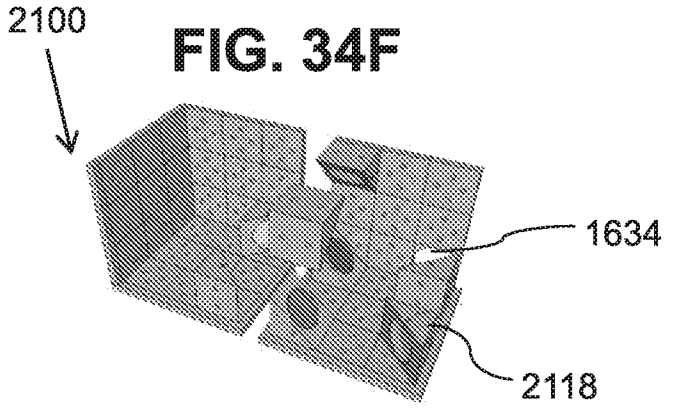
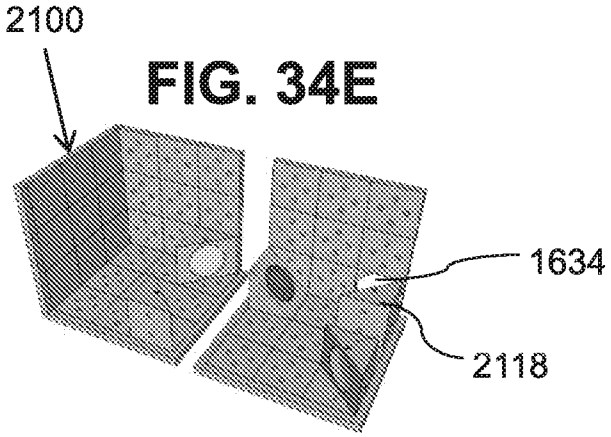
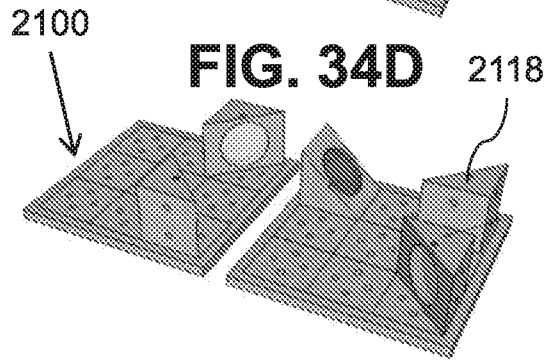
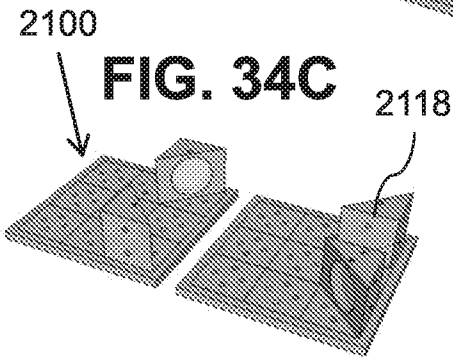
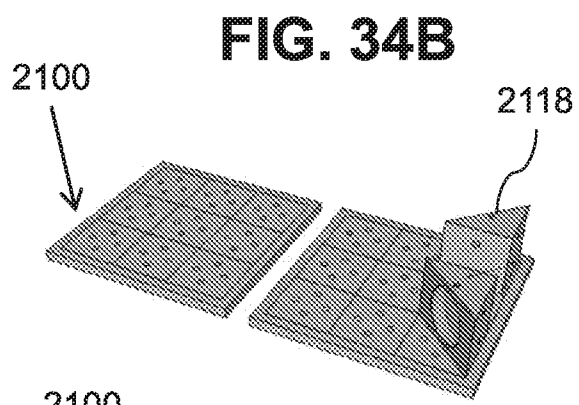
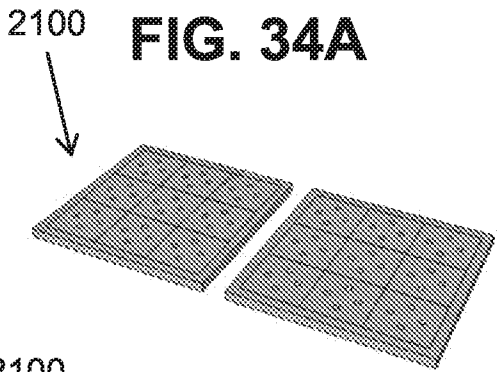


**FIG. 33A**

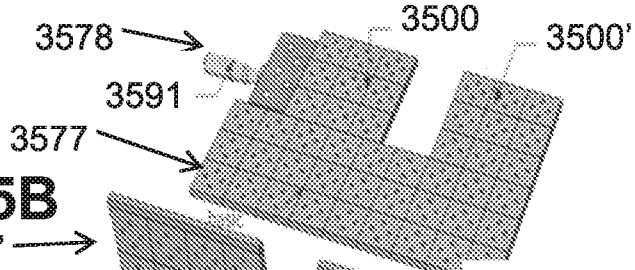


**FIG. 33B**

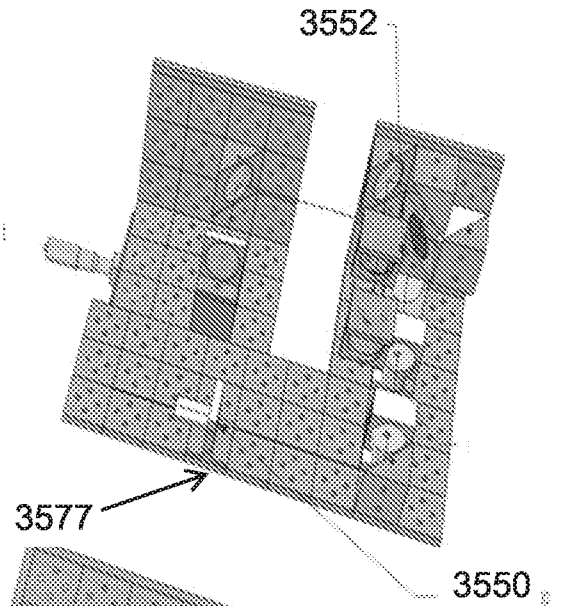




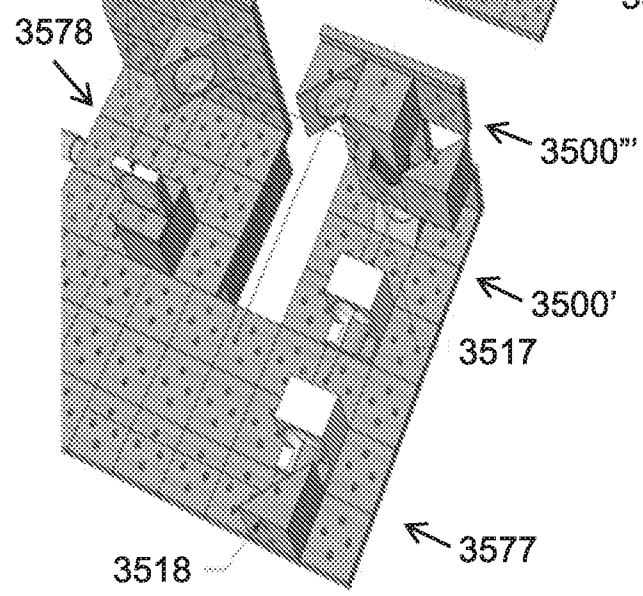
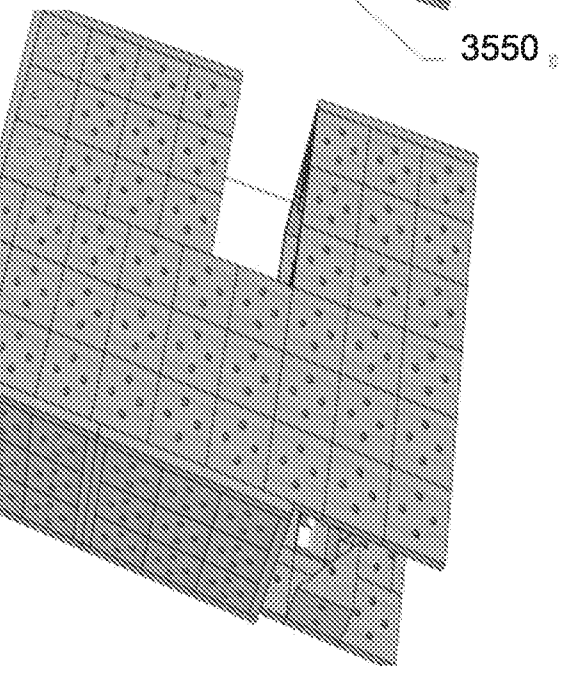
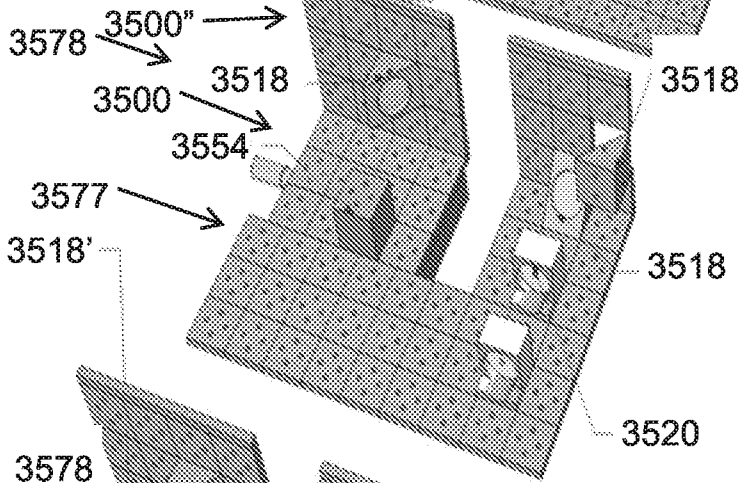
**FIG. 35A**



**FIG. 35D**



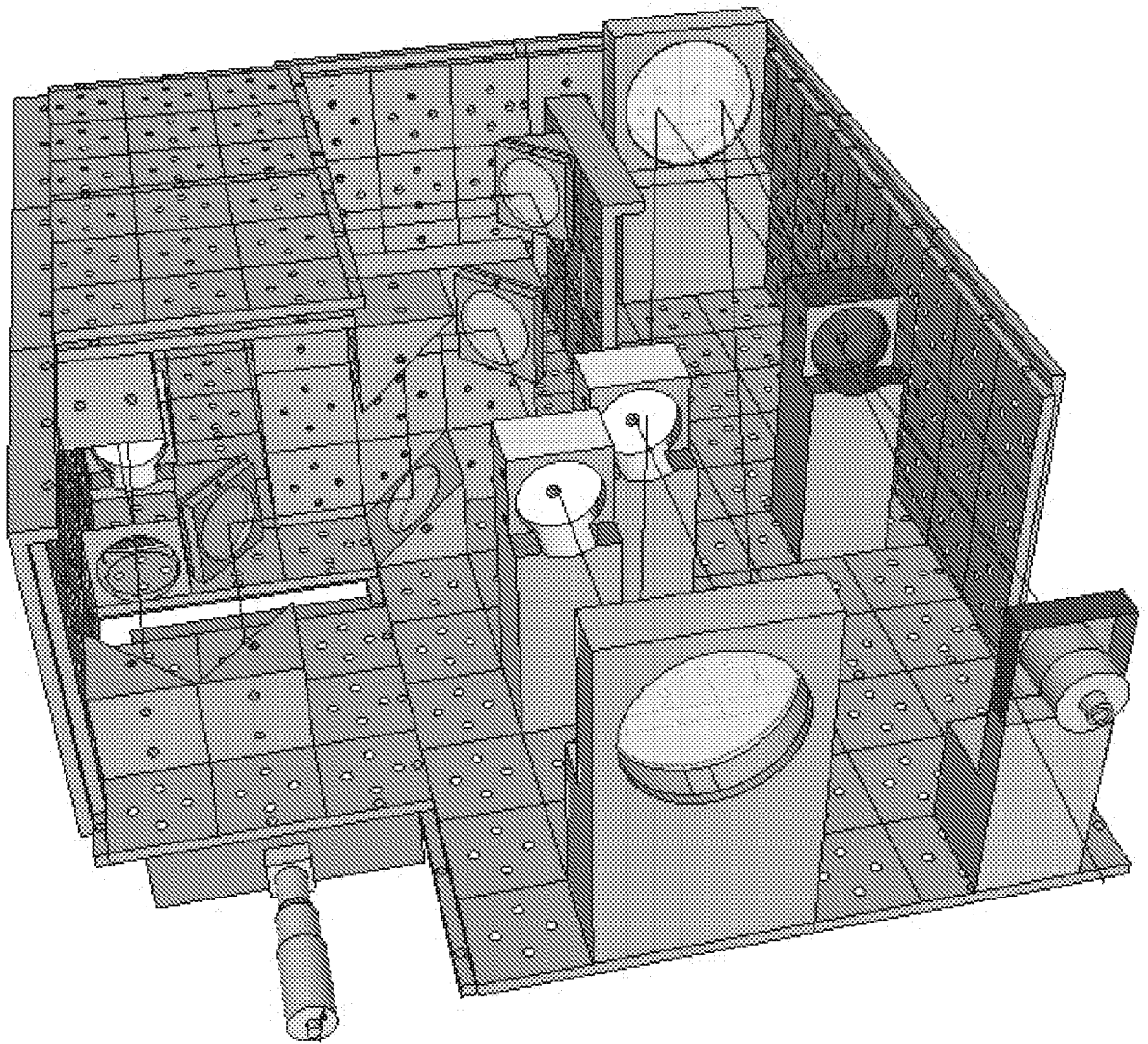
**FIG. 35B**



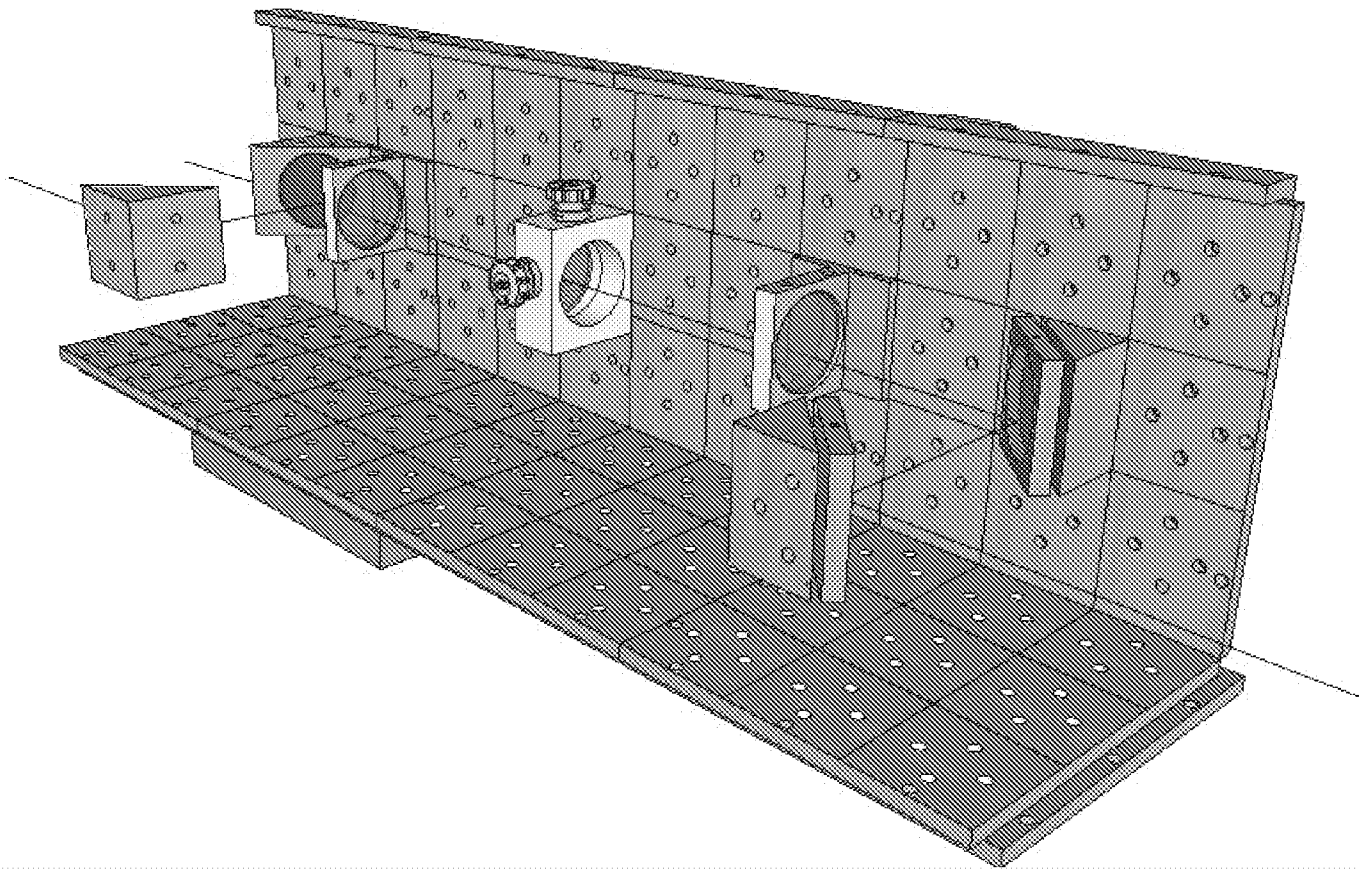
**FIG. 35E**

**FIG. 35C**

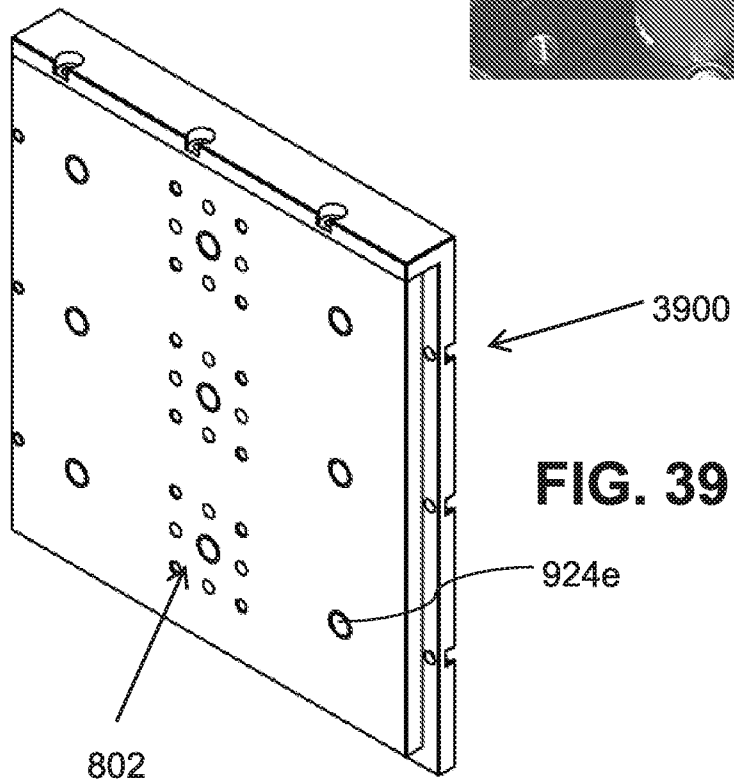
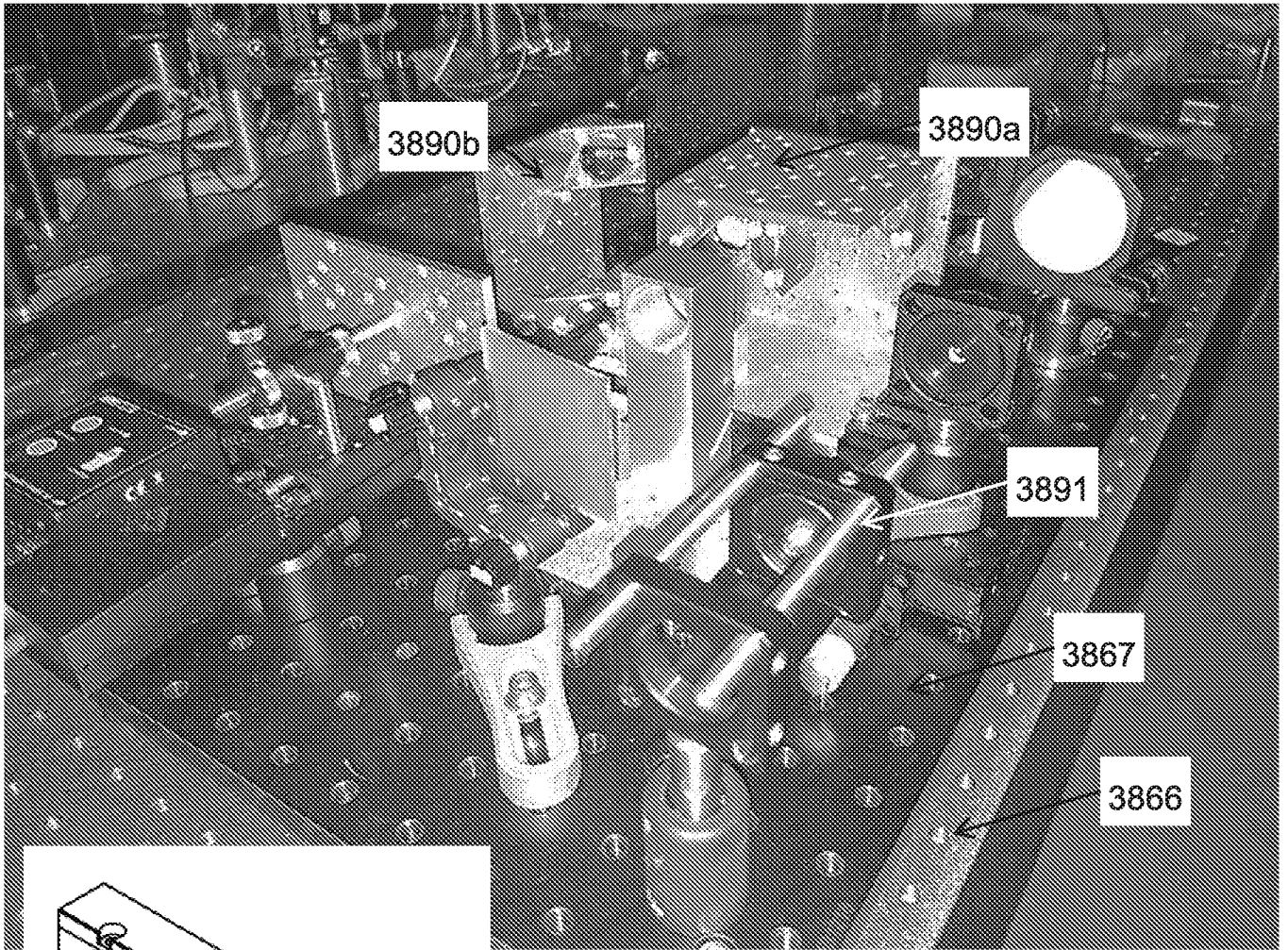
**FIG. 36**



**FIG. 37**

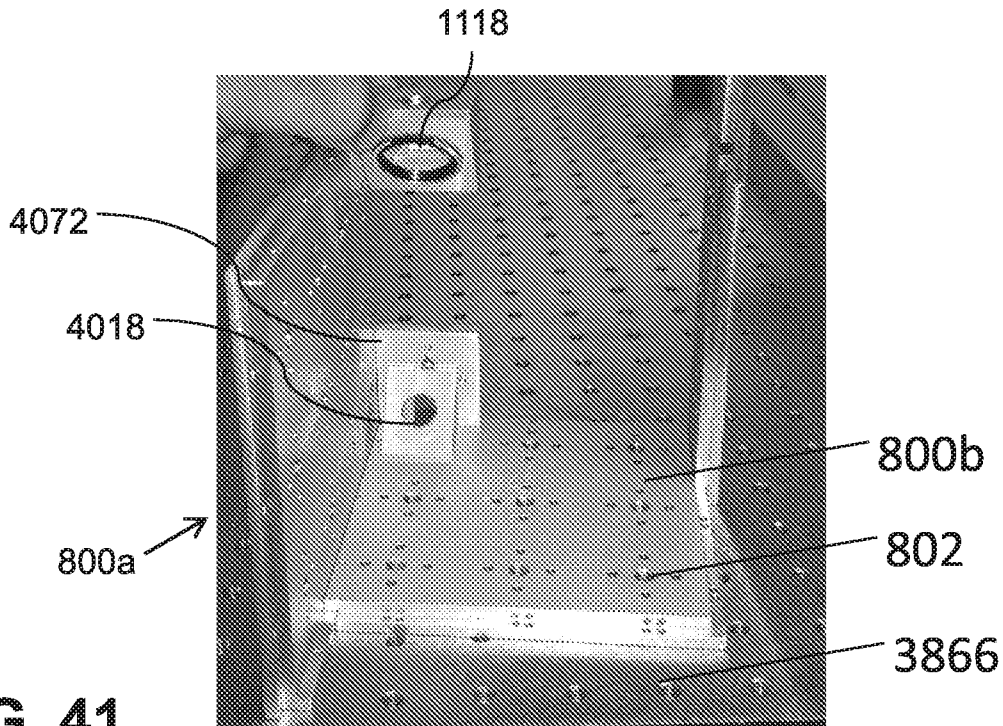


**FIG. 38**

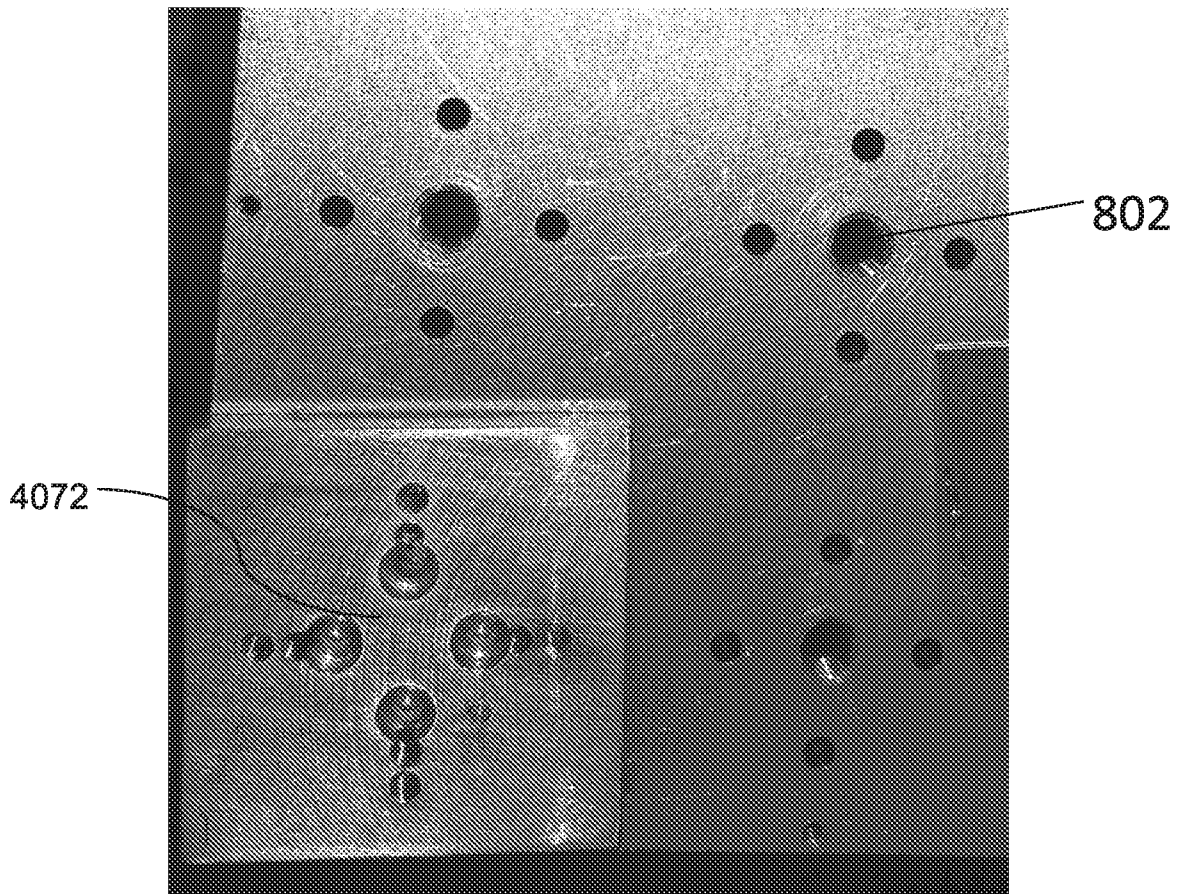


**FIG. 39**

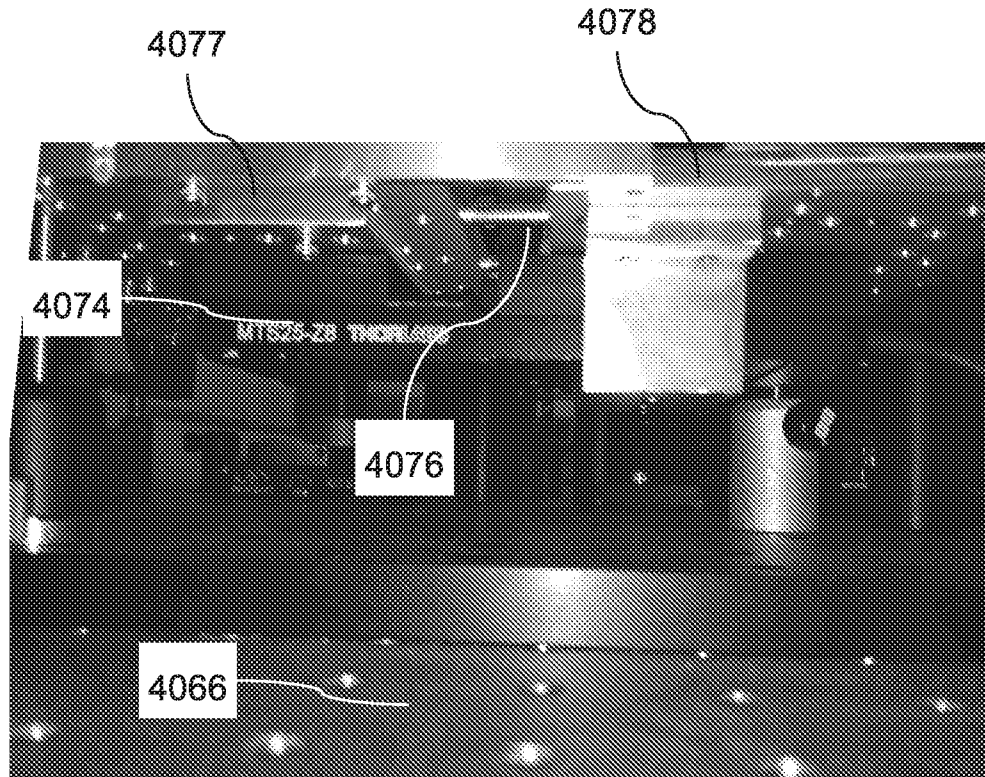
**FIG. 40**



**FIG. 41**



**FIG. 42A**



**FIG. 42B**

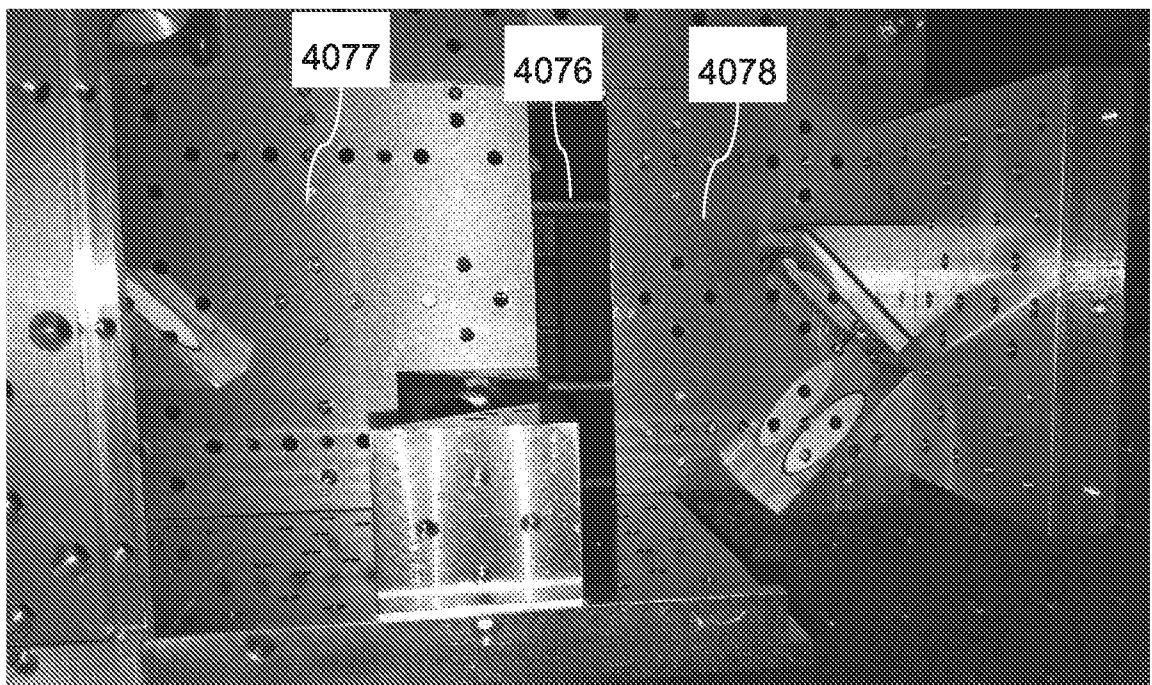
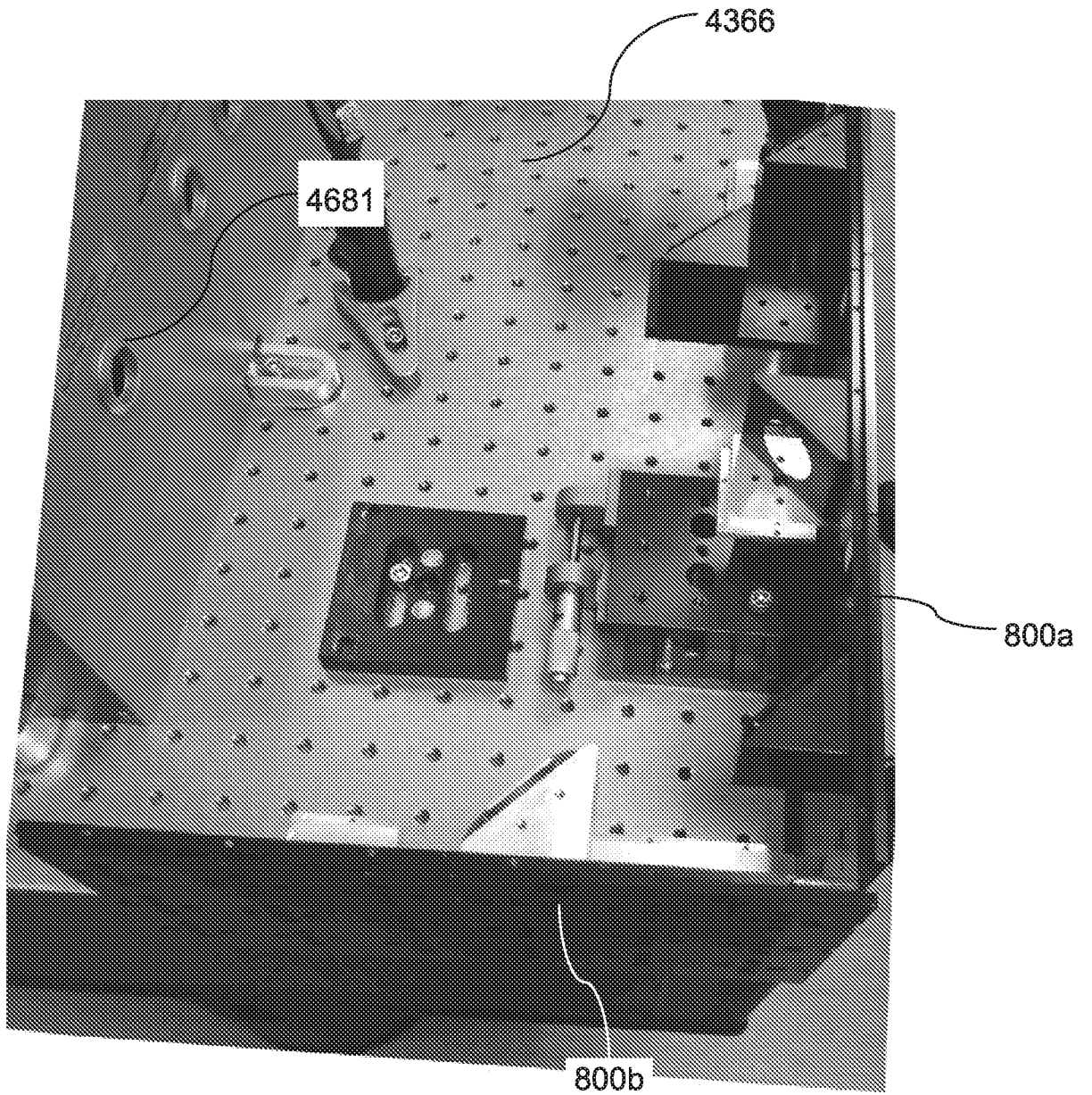
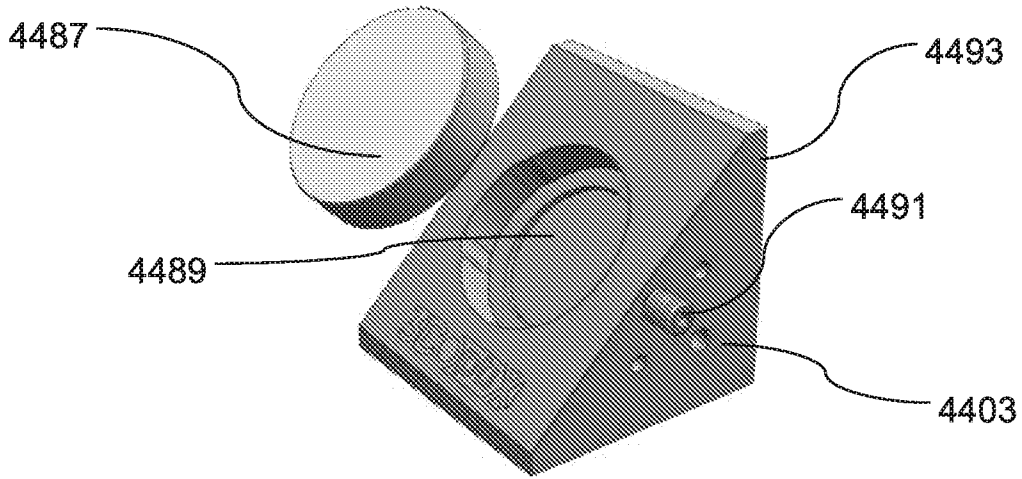


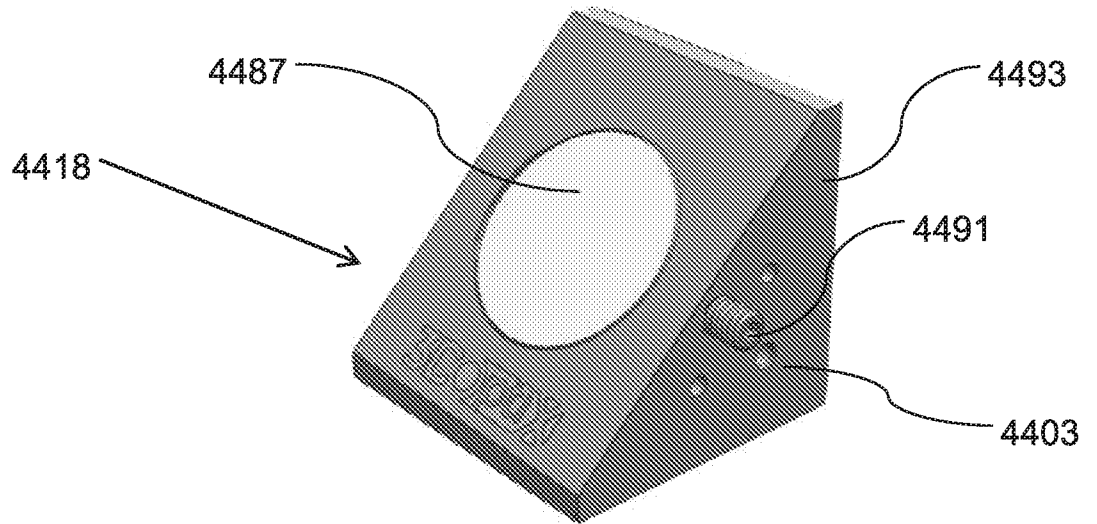
FIG. 43



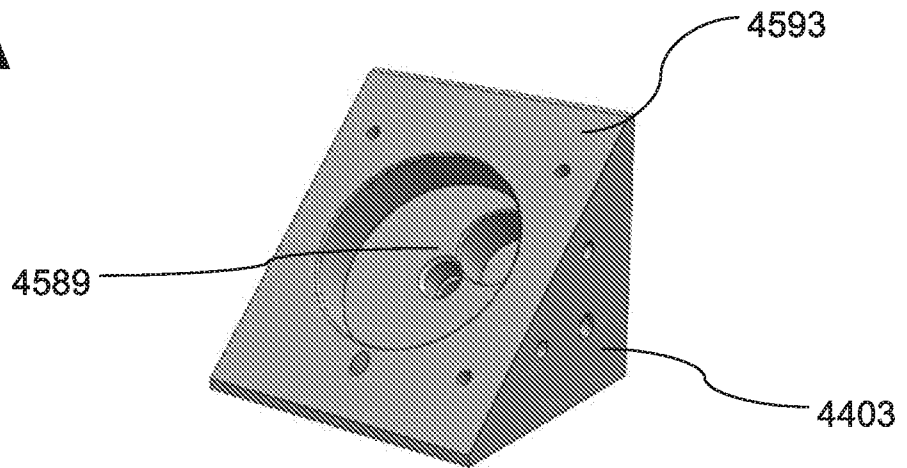
**FIG. 44A**



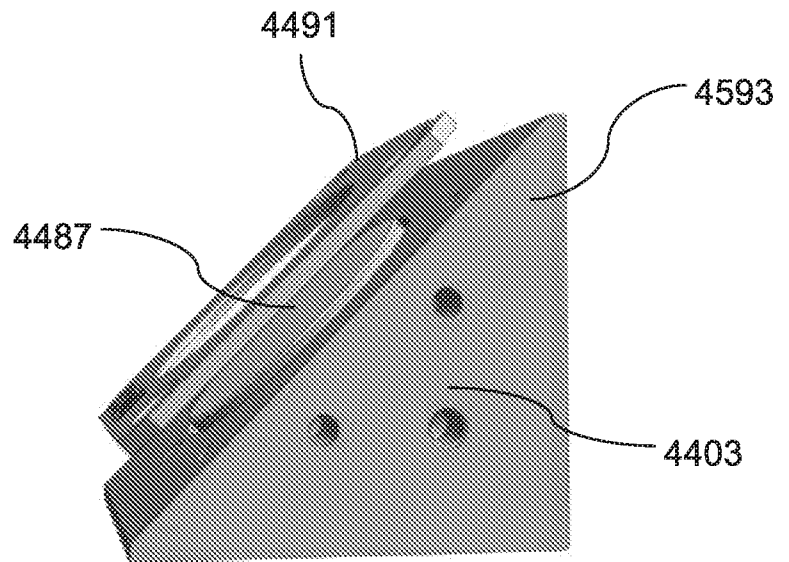
**FIG. 44B**



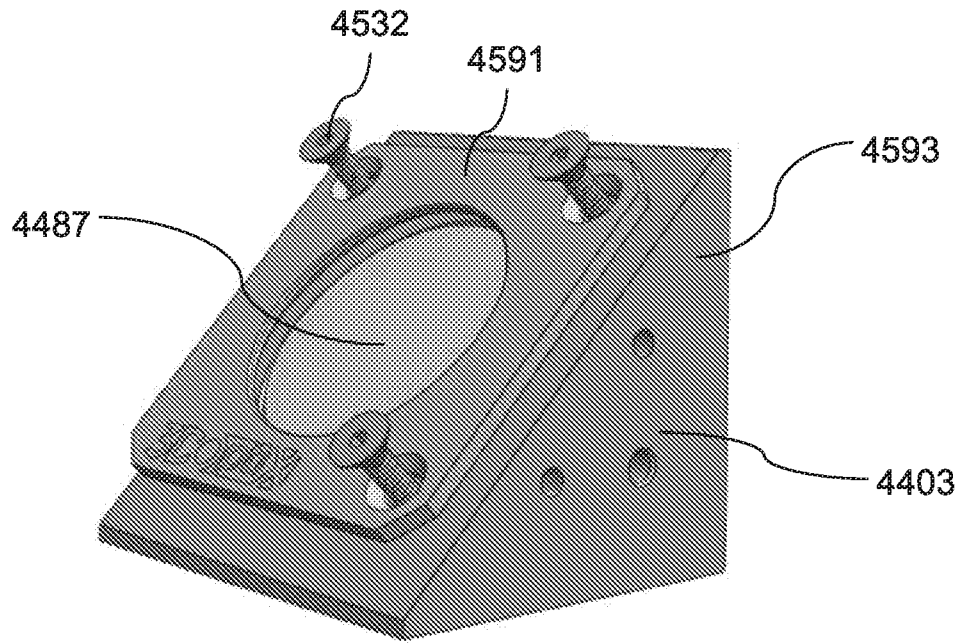
**FIG. 45A**



**FIG. 45B**



**FIG. 45C**



**FIG. 45D**

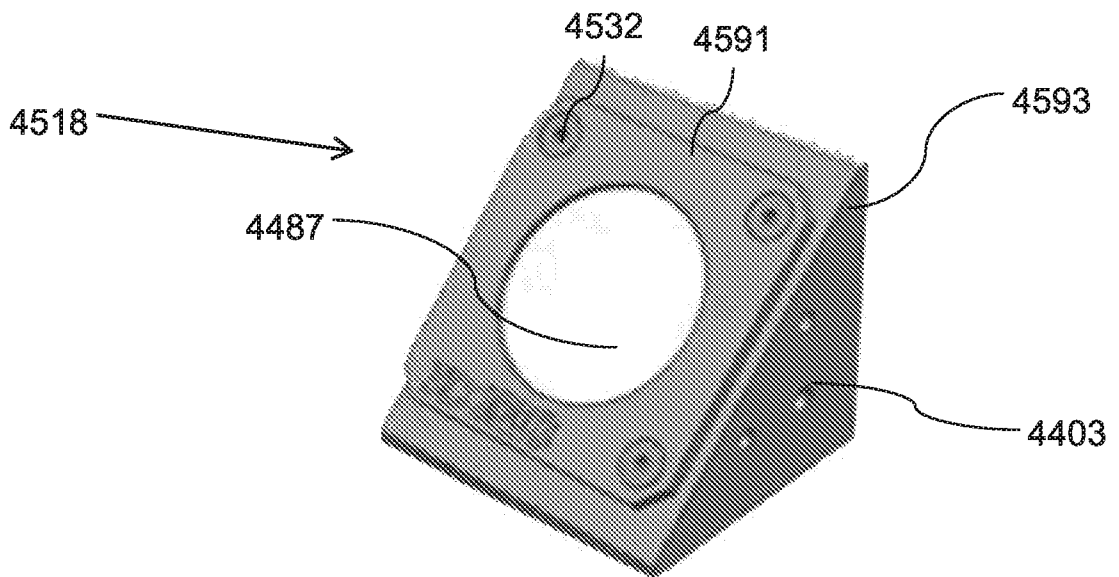
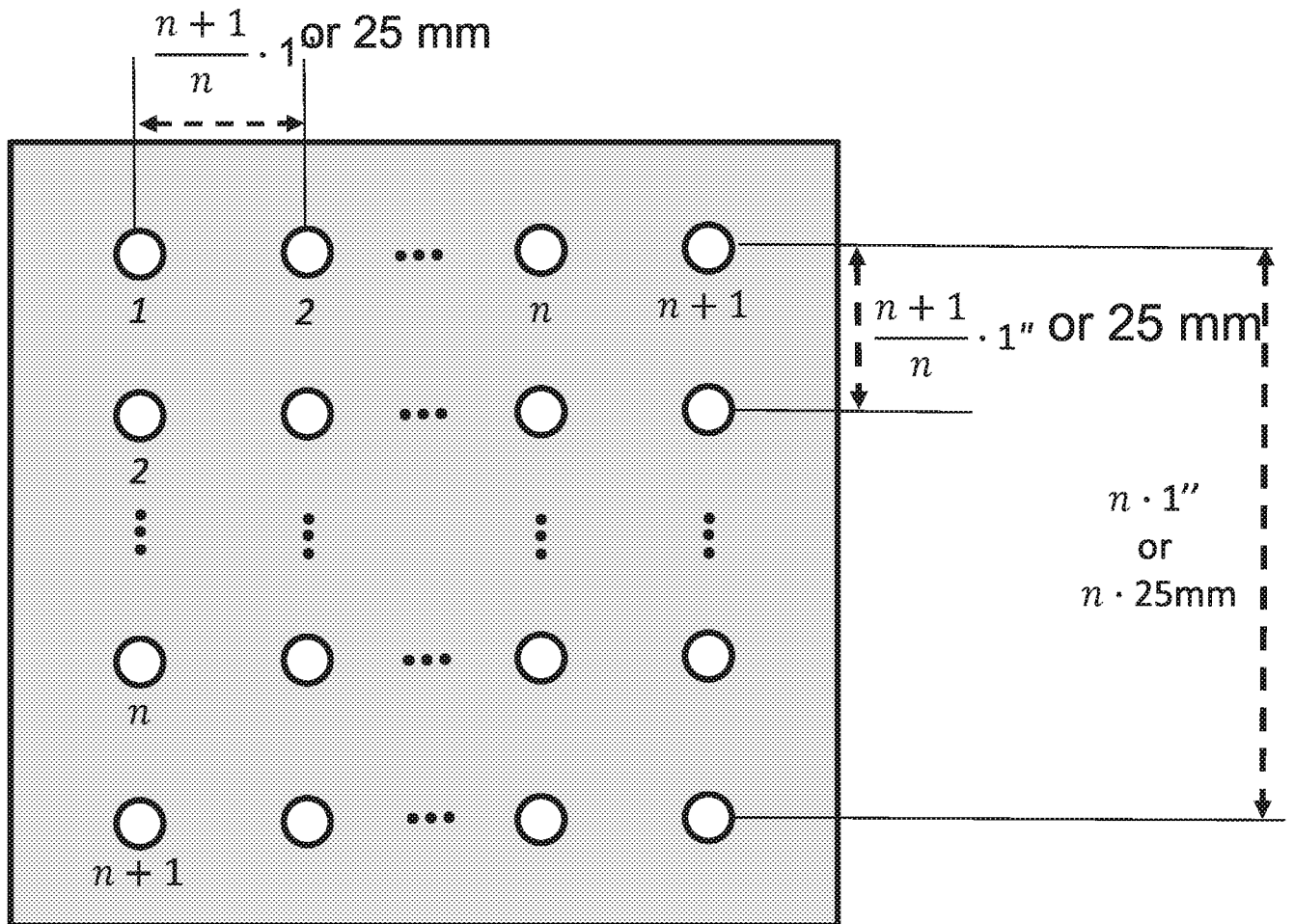


FIG. 46



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB2017/057498

A. CLASSIFICATION OF SUBJECT MATTER IPC (2018.01) G01M 11/04, G02B 7/00		
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) IPC (2018.01) G01M 11/04, G02B 7/00		
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) Databases consulted: Orbit		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004165285 A1 GALPIN JOHN 26 Aug 2004 (2004/08/26) The whole document	1-4,6,8,13-15,18-21, 23-30,34,43,45,48,49
Y	The whole document	5,7,9-12,16,17,22, 31-33,35-42,44,46,47,50
X	US 2004204909 A1 ABITAN HAIM; BUCHHAVE PREBEN; PRYDS NINI 14 Oct 2004 (2004/10/14) The whole document	1,14,15,18,24,34,45, 48,49
X	US 5825558 A ANVIK CORP 20 Oct 1998 (1998/10/20) The whole document	1,14,15,18,24,34,45, 48,49
Y	US 5148235 A DEUTSCHE FORSCH LUFT RAUMFAHRT 15 Sep 1992 (1992/09/15) The whole document	5,7,9-12,16,17,22, 31-33,35-42,44,46,47,50
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.		
* Special categories of cited documents:		
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	
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"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family	
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Date of the actual completion of the international search 25 Mar 2018	Date of mailing of the international search report 26 Mar 2018	
Name and mailing address of the ISA: Israel Patent Office Technology Park, Bldg.5, Malcha, Jerusalem, 9695101, Israel Facsimile No. 972-2-5651616	Authorized officer BITTON Oren  Telephone No. 972-2-5657812	

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB2017/057498

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2002021446 A1 CIT ALCATEL 21 Feb 2002 (2002/02/21) The whole document	5,7,9-12,16,17,22, 31-33,35-42,44,46,47,50
A	US 2007035856 A1 GALPIN JOHN; GURNER PHILIP; CHAPMAN GORDON; COATES JIM; HERBERT TERENCE 15 Feb 2007 (2007/02/15) The whole document	1-50

**INTERNATIONAL SEARCH REPORT**  
Information on patent family members

International application No.  
PCT/IB2017/057498

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
US 2004165285 A1	26 Aug 2004	NONE	
US 2004204909 A1	14 Oct 2004	NONE	
US 5825558 A	20 Oct 1998	NONE	
US 5148235 A	15 Sep 1992	NONE	
US 2002021446 A1	21 Feb 2002	NONE	
US 2007035856 A1	15 Feb 2007	NONE	