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Lens examination equipment and method

Technical Field of the Invention

The invention relates to equipment and methods for examining lenses and especially, but not exclusively, ophthalmic lenses in glasses.

5 Background to the Invention

It is often necessary to be able to determine the optical parameters of a lens such as those used in glasses. This may be required as part of the manufacturing process to ensure a lens conforms to the prescription and may be carried out either before the lens has been assembled into a glasses frame or after. It is also sometimes necessary to
10 determine the optical parameters of a lens in a pair of glasses which have been used, say as part of an ophthalmic examination where the person does not have their prescription to hand or to check that the lens is in conformity with their prescription. The present invention in its various aspects provides several new approaches to these operations, reducing substantially the reliance upon skilled personnel to carry out the
15 tasks. This is particularly important in areas where there is a shortage of such skills.

There is a need for a system for examining lenses which is easy to use and/or which provides more comprehensive data regarding the optical parameters of a lens.

There is a need in particular for a portable system for examining lenses in glasses.

20 There is also a need for a system for examining lenses which is substantially fully automated.

In addition, there is need for an alternative method of examining a lens which overcomes, or at least mitigates, some or all of the drawbacks of the known methods.

25 Further, there is a need for an alternative method of examining a lens which reduces processing time whilst providing data regarding the optical parameters of a lens which is sufficiently accurate.

There is a need in particular for an alternative method of examining a lens which can be used to determine an optical parameter of a lens at multiple locations simultaneously.

Summary of the Invention

According to a first aspect of the invention, there is provided a system for examining lenses in a pair of glasses, the system comprising a computing device having a built-in planar display screen, a camera mounted above the screen with the axis of the camera perpendicular to the plane of the screen, the camera being operatively connected to the computer for storing and processing image data captured by the camera; and a glasses mount for holding a pair of glasses with at least one lens located between the camera and the display screen in use.

The computing device may be a tablet computer.

The computing device may be configured in use to display a test pattern for examining a lens in a first section of the display screen below the camera and to display the results of the examination in another section of the display screen. The camera axis may be offset to one side of the display screen. In this case the test pattern may be displayed in one side of the display screen below the camera and the result in the other side. Alternatively, the axis of the camera may be aligned substantially in the centre of the display screen, in which case the test pattern may be displayed in a central section of the display screen below the camera and the results displayed to one side (or both sides) of the test pattern.

The system may comprise a frame mounted to the computing device, the camera being mounted to the frame.

The system may comprise a casing partially enclosing the computing device. The system may comprise a base to which the casing is attached, the camera being mounted to the base. In an embodiment, the base has a camera mount comprising an upright portion extending upwardly to the rear of the computing device and a horizontal portion extending forwardly over the display screen of the computing device from an upper end of the upright portion, the camera being mounted to a distal end of the horizontal portion above the screen. The casing may have an aperture in an upper wall through which at least the majority of the display screen is exposed.

In an embodiment, the glasses mount comprises a plinth slidably positionable on the display screen and means for securing a pair of glasses to the plinth. The

computing device may be arranged in use to display graphic symbols on the display screen to guide a user in correctly positioning the plinth.

Alternatively, the glasses mount may comprise a glasses clamp mounted to the frame above the display screen. The glasses clamp may be mounted to a runner
5 extending across the frame in a first direction above the display screen, the runner being movably mounted to the frame at either end for movement above the screen in a second direction perpendicular to the first. This enables movement of the glasses clamp above the screen parallel to the plane of the screen.

The computing device may be programmed to carry out image processing and
10 analysis steps as set out in any of the methods disclosed herein.

In accordance with a second aspect of the invention, there is provided a system for examining lenses in a pair of glasses, the system comprising a computing device in the form of a tablet computer having a planar display screen, a camera mounted above the screen with the axis of the camera perpendicular to the plane of the screen, the
15 camera being operatively connected to the computer for storing and processing image data captured by the camera; and a glasses mount for holding a pair of glasses with at least one lens located between the camera and the display screen in use, wherein the computer is partially enclosed in a casing attached to a base and wherein the camera is mounted to the base.

In an embodiment of the second aspect, the glasses mount comprises a plinth
20 slidably positionable on the display screen and means for securing a pair of glasses to the plinth. The computing device may be arranged in use to display graphic symbols on the display screen to guide a user in correctly positioning the plinth.

In accordance with a third aspect of the invention, there is provided a system
25 for examining lenses in a pair of glasses, the system comprising a planar display for displaying a test pattern and a glasses mount for holding a pair of glasses with at least one lens located above the display in use, wherein the glasses mount comprises a plinth slidably positionable on the display screen and means for securing a pair of glasses to the plinth.

The display may be the screen of an electronic visual display unit.
30

In a system according to any of the first to third aspects where the glasses mount is a plinth slidably positionable on the display screen/display and means for securing a pair of glasses to the plinth, the means for securing a pair of glasses to the plinth may be a glasses clamp mounted to the plinth. The plinth may define an aperture through which the display screen/display is visible from above when the plinth is positioned on the display screen/display in use and the glasses clamp may be mounted to the plinth such that it can be moved to selectively to position either one of the lenses in a pair of glasses mounted in the clamp above the aperture in use. The glasses clamp may be pivotally mounted to the plinth. The plinth may hold the lenses in a pair of glasses mounted to it at a distance from the display screen/display. The distance may be fixed or the plinth may have at least one separable spacer section which can be selectively removed to vary the distance. The distance may be set substantially at the focal length of a +20D lens.

According to a fourth aspect of the invention, there is provided a system to examine lenses in glasses comprises a frame, a visual display unit mounted on mounts on the frame, a glasses clamp mounted on the frame in front of the visual display unit, said clamp being mounted on the frame and movable in a plane parallel to the visual display unit, the clamp being arranged to hold the top and bottom of a pair of glasses substantially in said plane, and a camera in a camera mount on the frame, the camera directed perpendicularly to the visual display unit, through a lens of a pair of glasses when the pair of glasses is mounted in the glasses clamp.

Preferably the part of the visual display unit is arranged to display sequentially alternately a first pre-set regular pattern of lines, squares, or sine waves and a second pre-set pattern of circles. The visual display unit may be part of a computing device such as a tablet computer.

In one arrangement the clamp is calibrated to enable the separation of the centres of the lenses in a pair of glasses to be measured.

Ideally the camera mount is hinged enabling the camera to be stored in the frame when the system is not being used.

By use of a computer, it is possible for the characteristics identifying the lens to be displayed on a visual display unit. Ideally the visual display unit has a split screen, in which on in one half the patterns are displayed and on the other half the characteristics of the lens displayed.

5 Using a tablet style computing device, it is possible for the visual display and the computing facility to be combined in one unit.

In accordance with a fifth aspect of the invention, there is provided a method of examining lenses in a pair of glasses using a system according to any of the first, second, or fourth aspects of the invention set out above, the method comprising displaying a
10 test image on a first section of the display screen; mounting a pair of glasses in the glasses mount and positioning a lens of the glasses between the test pattern and the camera; capturing an image of the test pattern through the lens using the camera and saving the image data in the computing device; using the computing device to process the image data to determine the degree of distortion to the test pattern caused by the
15 lens and to determine from this at least one parameter of the lens; displaying the determined parameter in another section of display screen.

The computing device may be a tablet computer.

Where the glasses mount is a plinth, the step of positioning a lens of the glasses between the test pattern and the camera may comprise positioning the plinth with a pair
20 of glasses mounted to it on the display screen to correctly locate a lens of the glasses relative to the test pattern and the camera for examination. This may comprise sliding the plinth across the display screen as required to correctly locate the lens. The method may comprise using the computing device to display graphic symbols on the display screen to guide a user in correctly locating the plinth on the screen and the computing
25 device may be configured to display said graphic symbols in dependence on data received from the camera.

In the systems according to the any of the first, second or fourth aspects of the invention and the method according to the fifth aspect of the invention, the system may be configured to examine a lens in a pair of glasses to determine at least one optical
30 parameter of the lens using any of the methods disclosed herein.

By using the system and/or methods set out in this invention, it is possible readily and easily to identify the characteristics of glasses being used by a person and whether these are in conformity with the patient's prescription. It is also possible to use the system and methods as quality control in a manufacturing facility for glasses and ophthalmic lenses. In both cases the system and methods greatly reduce the need to use skilled personnel in what is a routine task, allowing the specialist's skills to be employed in identifying persons' needs.

Detailed Description of the Invention

In order that the invention in its various aspects may be more clearly understood one or more embodiments thereof will now be described, by way of example only, with reference to the accompanying drawings, of which:

Figure 1 is a perspective view of a first embodiment of a system for examining lenses in a pair of glasses in accordance with an aspect of the invention, showing the system in an open deployed position;

Figure 2 shows a part of the system of Figure 1 from above, with parameters calculated for the lens concerned displayed on a display screen of the system;

Figure 3 is a view similar to that of Figure 2 but illustrating how data relating to the type of lens under examination can be displayed in the form of a map of the lens;

Figure 4 is a perspective view of the system of Figure 1 in a folded configuration;

Figure 5 is a perspective view of a second embodiment of a system for examining lenses in a pair of glasses in accordance with an aspect of the invention;

Figure 6 is a view from one side of the system of Figure 5;

Figure 7 is a schematic representation of an alternative a system for examining a lens which can be used to carry out the various methods of examining a lens described herein;

Figure 8 is a schematic representation of an original test pattern for use in a first embodiment of a method of examining a lens in accordance with an aspect of the invention;

Figure 9 is a view similar to that of Figure 8 but illustrating how the test pattern may be distorted through a spherical lens;

Figure 10 is a view similar to that of Figure 8 but illustrating how the test pattern may be distorted through a cylindrical lens;

5 Figure 11 is a schematic repetition of an alternative original test pattern for use in the first embodiment of a method of examining a lens in accordance with an aspect of the invention; and

Figure 12 is a flow diagram showing the steps in measuring the power of a lens in a second embodiment of a method of examining a lens in accordance with an aspect
10 of the invention.

Figures 1 to 4 illustrate a first embodiment of a system 1 for examining a lens in a pair of glasses 2 having a pair of lenses 4 and 5. The system comprises a square frame 10 mounted to a tablet style computer 12 having a built-in visual display unit with a display screen 13. The tablet style computer 12 can be any computing device
15 having a planar digital display screen 13 of a suitable size, such as an i-Pad (RTM). The frame is attached to the computer 12 by a number of mounts 14 extending rearwards from the frame 10 to engage with a rear surface of the computer and which clamp the frame to the computer. A glasses clamp 16 is mounted within the interior of the frame above the display screen 13.

20 The glasses clamp 16 has a pair of jaws 18, 20, the jaws having grooves 22 in opposing surfaces into which the top and bottom of the pair of glasses 2 are located and held in use. The jaws are mounted on a runner 24 which extends over the display screen from front to rear (as considered with the screen in landscape mode, the longer edges at the front and rear). The jaws 18, 20 are slidably mounted for movement along the
25 runner 24. A spring 25 (seen in figure 2) urges jaw 20 towards jaw 18 to grip the top and bottom of the pair of glasses. The jaws can be separated using a knob 20a on the movable jaw 20, which can be gripped by hand to pull jaws 18 and 20 apart. Runner 24 is slidably mounted on a pair of rails 26 which are attached on the inside of opposite sides of the frame 10 at the front and rear of the display screen. It can be seen that the
30 clamp 16 is movable in a plane parallel to the surface of the visual display unit 13 by

movement of the jaws along the runner 24 and movement of the runner along the rails 26.

5 A camera 28 is mounted on a camera mount 30 which locates the camera above part of the display screen with the axis X of the camera perpendicular to the display screen 13. The camera 28 may be a digital camera and is operatively connected to the computer 12 by a suitable cable or other means so that image data captured by the camera can be saved in the computer for processing and analysis and to allow control of the camera by the computer. The camera mount has a hinge 32 enabling the camera to be folded inside the frame 10 when the system is not in use (see figure 4).

10 In the first embodiment as shown in Figures 1 to 4, the frame 10 surrounds the left hand half 34 (figure 2) of the display screen 13, when considered in landscape mode. In this particular example, the computer 12 is 28 cm wide across, thus the inside dimensions of the frame 10 are 14 x 14 cm. The right hand half 36 of the display screen 13 (see figure 2) is clear for direct viewing.

15 For use in examining a lens 4, 5 in a pair of glasses, a test pattern is displayed in the left hand half 34 of the display screen below the camera. The pair of glasses 2 is mounted in the glasses clamp 16, the position of the jaws 18, 20 being adjusted to ensure a firm but not overtight grip of the glasses 2 in the grooves 18. The position of the clamp 16 is adjusted by moving the jaws along the runner and/or the runner 24 on the rails 26
20 to position one of the lenses between the test pattern and the camera. The test pattern is now seen by the camera 28 through the lens 4 and a digital image of the test pattern as viewed through the lens can be captured by the camera and image data saved in the computer memory for analysis. This image will be referred to as the "lens image". The test pattern as seen through the lens and captured in the lens image is usually distorted
25 by the lens and by comparing the degree and nature of the distortion of the test pattern from the lens image data with the original image it is possible to derive one or more optical parameters or characteristics of the lens. Several methods which can be used for this analysis in the system 1 will be described below. The results of the analysis are displayed on the right hand side 36 of the display screen 13 as illustrated in figures 2
30 and 3. Once the examination of one lens 4 is complete the process can be repeated for

the other lens 5. The camera mount and camera are omitted from figures 2 and 3 for clarity.

The frame 10 and camera 28 could be mounted centrally of the display screen 13. In this case, the test pattern would be displayed in a central region of the display screen below the camera and the results displayed on display screen to one or both sides of the frame.

In the arrangements set out in figures 1 to 4, the glasses clamp 16 may be calibrated to measure the separation of the centres of the two lenses.

A second embodiment of a system 101 for examining a lens in a pair of glasses will now be described with reference to figures 5 and 6. In the following description, features of the system 101 that are the same as those described above in relation to the first embodiment 1 or which fulfil the same function will be identified using the same reference numbers but increased by 100.

In the system 101 in accordance with the second embodiment, the frame 110 is in the form of a casing 150 in which the tablet style computer 112 is partially encased and a base 152 to which the casing 150 is mounted. The casing 150 has an aperture 154 in an upper wall so that substantially the whole of the display screen 113 of the computer is exposed. The casing 150 may have a number of parts that are releasably or permanently attached when assembled to the computer. The camera mount 130 is provided on the base 152 and has an upright section 130a extending upwardly to the rear of the computer 112 and a horizontal section 130b extending forwardly from the upper end of the upright section over the display screen 113. The camera 128 is mounted proximal the forward end of the horizontal section 130b so that the axis X of the camera is aligned perpendicular to the display screen 113. The camera mount 130 is off-set to the left side of the computer and is configured so that the axis X of the camera is located generally at the centre of the left-hand half of the display screen, with the camera a suitable distance above screen. The camera 128 is operatively connected to the computer 112 by a suitable cable or other means so that image data captured by the camera can be saved in the computer for image processing and analysis and to allow control of the camera by the computer.

A principal difference of the second embodiment of the system 101 over the first is that the glasses clamp 116 is not mounted to the frame but mounted to a separate plinth 156 which sits directly on the display screen 113. The plinth is placed directly on the screen and can be slid across the screen 113 for correct positioning of a lens relative to the camera and/or the test pattern.

The plinth 156 comprises a main body having a central aperture 158 through which the display screen 113 is visible from above when the plinth is located on the display screen. The glasses clamp 116 is mounted to the plinth body to one side of the aperture 158 and can be pivoted to selectively position either of the lenses in a pair of glasses mounted in the clamp 116 above the aperture.

The glasses clamp 116 in this embodiment has a pair of arms 160a, 160b pivotally coupled together at their centres in a scissor-like manner. The arms 160a, 160b are mounted to a pivot pin 162 so that the arms can pivot relative to each other and so that both arms can be pivoted together about the pin to selectively position one or other lens in a pair of glasses above the aperture 158. Each arm 160a, 160b is generally S shaped and carries an abutment 164 at either end. Each abutment 164 extends upwardly from the arm and is generally cylindrical with a groove 118 about its side for engaging with a pair of glasses. The arms 160a, 160b are configured so that one of the abutments 118 on each arm engages a top edge of the glasses and the other engages the bottom edge. The arms 160a, 160b are biased by a torsion spring to bring the opposed abutments at either end of the clamp together. Lugs 166 are provided on each arm 160a, 160b on one side of the clamp which can be used to move the arms to separate the abutments when mounting a pair of glasses. Once the glasses are in place, the lugs 166 are gently released and the bias force firmly clamps the top and bottom edges of the glasses between the abutments. The abutments 164 may engage with the glasses frame and/or edges of the lenses depending on the style.

The plinth 156 and glasses clamp 116 hold the top and bottom edges of the glasses substantially in a plane parallel to the display screen 113 with the lens being examined spaced from the display screen by a distance, which is usually less than the focal length of the lens. The plinth 156 as illustrated holds a lens to be tested at a fixed spacing from the display screen, which in this embodiment is set to the focal length of

+20D lenses, around 50mm. It has been found that this distance enables accurate results to be obtained in lenses ranging from -20D to +15D. This range covers the majority of lens used by the general public, which tend to fall in the range of -5D to +5D. However, it will be appreciated that the plinth could be configured to provide a different spacing
5 between the lens and screen to cope with lenses outside the normal range and the system could be provided with a set of two or more plinths which each provide a different spacing between the lens and the screen. In a further alternative, the plinth 156 could be provided with one or more removable spacer sections which can be selectively used to change the height of the plinth and hence the spacing between the lens and the display
10 screen. For example, to extend the range above +15D the distance between the lens and the screen would have to be decreased from that discussed above. This could be achieved by removing a spacer section to reduce the height of the plinth above the screen.

The system 101 in accordance with the second embodiment is used to examine
15 the lenses in a pair of glasses in a manner similar to that of the first embodiment. A pair of glasses is mounted in the clamp 116 on the plinth 156 and the clamp pivoted to position one of the lenses which is to be examined over the aperture 158. The plinth 156 is placed on the display screen to locate the lens being examined below the camera. The system 101 is configured to display information on the screen 113 to guide the user
20 in correctly positioning plinth and the lens. This could comprise graphic symbols displayed on the screen 113 which show the user where to position the plinth 156, for example, which may be generated by the computer in response to data from the camera 128. The plinth can be slid over the screen to correctly position the lens and to move the lens position during examination if required. With the lens in position, a test pattern
25 is displayed on the display screen 113 below the camera and the lens and the camera used to capture an image of the test pattern as seen through the lens – the lens image. The (usually distorted) test pattern in the lens image data is analysed the computer which determines the degree and nature of the distortion of the test pattern caused by the lens and from this is able to derive one or more optical parameters of the lens. The
30 results of the analysis are displayed on the right hand side of screen which is not obscured by the plinth.

The camera 128 could be mounted centrally of the display screen 113. In this case, the test pattern would be displayed in a central region of the display screen below the camera and the results displayed to one or both sides of the display screen.

5 The system 1, 101 in accordance with either of the first and second embodiments is compact, highly portable and self-contained. Using a tablet computer to generate both the test image and display the results analysis and carry out the image processing and analysis eliminates the need to have multiple display units and a separate computing unit. The use of a tablet computer also saves on costs as it eliminates the need to design and manufacture dedicated computing and display hardware.

10 The system 1, 101 as described above can be adapted to carry out examination of a lens using a number of different test patterns and methods of analysis, several embodiments of which will now be described in relation to the examination of lens in a pair of glasses using the system 101 according to the second embodiment described above. However, the methods described can also be used in the system 1 according to
15 first embodiment. Indeed, the underlying principles of these methods can be adapted for use in any other suitable lens examining system. Figure 7 for example illustrates an alternative lens analysis system 201 that can be used to carry out the methods described below. The same reference numerals but increased by 100 will be used to identify features that are the same, or which fulfil the same function, as those of the previous
20 system 101.

The system 201 comprises a camera 228 looking perpendicularly at a display 213 on which a test pattern is displayed as described below. Between camera 228 and display 213 is a lens frame 267a. The camera is connected to a computer 212 which in turn is connected to a screen 268 for the user, and optionally to the display 213, to
25 enable dynamic adjustment of the test pattern. A lens 203 to be examined is inserted in the lens frame 267a so that the lens is orthogonal to the camera 228 and the midpoint of the lens is approximately on the line between the midpoint of the camera lens and the midpoint of the display. The camera is used to capture an image of the distorted test pattern seen through the lens (the lens image) and the distorted test pattern in the
30 lens image is analysed and compared to the original test pattern and the distortions

caused by the lens 203 are calculated in computer and used to determine the optical parameters of the lens which are displayed.

Where the distance between the lens 203 and the display 213 is fixed, to allow for examination of lenses having a greater focal length than the spacing, a supplementary compensating lens 269 is inserted in a second frame 267b.

A first embodiment of a method for examining a lens in accordance with an aspect of the invention will now be described with reference to figures 8 to 11.

In the following description and in the claims, the term “ellipse” should be understood as encompassing a circle, which is a special case of an ellipse in which the major and minor axes are equal.

With a pair of glasses mounted in the clamp 116 on the plinth 156 and the clamp pivoted to position one of the lenses which is to be examined over the aperture, the plinth 156 is placed on the display screen 113 to locate the lens being examined below the camera. With the lens in position, a test pattern is displayed on the screen 113 below the camera and the lens and the camera used to capture an image of the distorted test pattern as seen through the lens, the “lens image”. The lens image data is saved in the computer for image processing and analysis.

In the method according to this first embodiment, the test pattern 370 comprises at least one set 372 of dots 374 which can be joined by a first ellipse 376 of best fit, in which the major axis R_1 and minor axis R_2 are equal (in other words, a circle or circular ellipse) as illustrated in figure 7. Whilst the dots 374 may be circular, this is not essential and the term “dots” should be understood as encompassing any mark which can be used to indicate a point on the circumference (perimeter) of an ellipse regardless of shape unless otherwise stated.

Any number of dots 374 can be used in the set 372 to define the first ellipse. However, advantageously a minimum number of dots which defines an ellipse with sufficient accuracy is used in each set 372 as this reduces the number of data points that must be analysed and so reduces processing time. In tests, it has been found that an ellipse can be defined with sufficient accuracy using a set of six dots 374 arranged at the apexes of a notional regular hexagon.

As illustrated in figure 8, the test pattern can have an additional dot 374a at the centre of the set. The central dot 374a does not form part of the set but may be helpful in accurate positioning of the set relative to the lens and/or axis of the camera. However, the additional central dot 374a is not essential and could be omitted.

5 The lens will usually distort the test pattern 370 (unless it is a plain lens), so that in the test pattern in the lens image, the spacing between the dots may increase or decrease depending on the degree of magnification. For a magnification greater than 1, the spacing between the dots increases whilst for magnification less than 1 the spacing between the dots decreases. With a spherical lens, the spacing between the dots changes

10 by the same amount in all directions so that the major and minor axes of an ellipse of best fit joining the dots of the set in the distorted test pattern will be equal. However, a cylindrical lens will vary the spacing between the dots by different amounts in different directions. As a result, the major and minor axes of an ellipse of best fit joining the dots of the set in the distorted test pattern in the lens image will not be equal. Accordingly,

15 by comparing the major and minor axes of an ellipse of best fit defined by the set of dots in the distorted test pattern in the lens image with the major and minor axes of an ellipse defined by the set of dots in the original test pattern, it is possible to determine the magnification of the lens and, where present, astigmatic correction (cylindrical power) and the axis of the astigmatic correction. The power of the lens can be calculated

20 from the magnification using a function $f(M)=P$ in a known manner. This function can be determined from a set of standard lenses of known dioptric power.

Example 1

Figure 9 illustrates a distorted test pattern 370' in the lens image captured by the camera for a cylindrical lens. The dots 374' in the set 372' can be joined by a second ellipse of best fit 376', and the computer determines a major axis R_1' and a minor axis R_2' of the second ellipse 376' and compares these with the major axis R_1 and minor axis R_2 of a first ellipse 76 defined by the set of dots in the original test pattern 370 as illustrated below:

	$R_1 = 100$	$R_1' = 50$	Magnification = 0.5
30	$R_2 = 100$	$R_2' = 50$	Magnification = 0.5

In this example, since the lens is spherical, the set 372' of dots 374' in the distorted pattern 370' define an ellipse in which the major and minor axes R_1' and R_2' are equal.

5 Example 2

Figure 10 illustrates a distorted test pattern 370' in the lens image for a cylindrical lens. The dots 374' in the distorted set 372' can be joined by a second ellipse 376' of best fit and the computer determines a major axis R_1' and a minor axis R_2' of the second ellipse 376' and compares these with the major axis R_1 and minor axis R_2 of a first ellipse 376 defined by the set of dots in the original test pattern 370 as illustrated below:

$$\begin{array}{lll} R_1 = 100 & R_1' = 100 & \text{Magnification} = 1 \\ R_2 = 100 & R_2' = 50 & \text{Magnification} = 0.5 \end{array}$$

In this example where the lens is cylindrical, the dots 374' in the distorted pattern define an ellipse in which the major axis R_1' and the minor axis R_2' are not equal, indicating that the lens has distorted the test pattern by different amounts in different directions. The axis angle of the cylindrical lens can also be calculated by the computer from the direction of the major and minor axes.

The system 101 is configured to use the basic method as described above in a spot mode to determine the optical parameters at a single point in the lens or in a mapping mode to determine the optical parameters at a number of locations over the whole of the lens, or at least within an area of interest of the lens.

Mapping Mode

In the mapping mode, the original test pattern displayed on the screen 113 comprises a number of the sets 372 of dots 374, where the dots in each set 372 can be joined by a first ellipse of best fit having major and minor axes R_1 , R_2 that are equal. The sets are spread over the area of the display screen below the lens and some of the sets 372 may be partially overlapping to ensure that a sufficient number and density of sets are provided such that the optical parameters can be determined at the required

number of locations. In a particularly advantageous embodiment, the test pattern 370 comprises a plurality of dots 374 arranged in an array 378 as illustrated in Figure 11. In the array, the dots 374 are arranged in rows and columns, wherein the dots 374 in each row are equally spaced apart by a distance Y which is equal to the spacing Z between adjacent rows, and wherein alternate rows are off-set so that the dots 374 in any given row lie midway between the dots in an adjacent row or rows. In this test pattern array 378, each dot 374 (other than those at the edges of the array) is surrounded by six other dots 374 which are located at the apexes of a notional regular hexagon. The six surrounding dots form a set 372 that can be joined by a first ellipse 376 of best fit having major axis R_1 and a minor axis R_2 that are equal. This test pattern 370 can be used to determine the optical parameters of the lens over the whole of the lens, or an area of interest of the lens, by carrying out the above analysis for each hexagonal set 372 of dots 374 within the area of interest. Accordingly, the computer running suitable software determines a major axis R_1' and a minor axis R_2' for a second ellipse 376' of best fit through the dots in each hexagonal set 372 of dots in the distorted test pattern within the area of interest from the lens image data and compares these with the major axis R_1 and minor axis R_2 respectively of a first ellipse derivable from the corresponding set 372 of dots in the original test pattern. In the original test pattern, every hexagonal set 372 of dots defines a first ellipse 376 of the same size so that the major and minor axes R_1, R_2 are the same for every hexagonal set 372 of dots in the original test pattern. Accordingly, it is not necessary to actually generate an ellipse and determine the major and minor axes for every hexagonal set 372 of dots in the original test pattern. The computer may only determine the major axis R_1 and minor axis R_2 for one set or a sample number of the sets. Indeed data for the major axis R_1 and minor axis R_2 of the first ellipses in the original test pattern may be saved as data in the computer.

The test pattern 370 as illustrated in Figure 11 provides a convenient way of presenting a large number of sets of dots evenly distributed across the area of interest. Because they are interlinked and partially overlapping, the sets defined in the array are highly concentrated allowing for a detailed analysis of the characteristics of the lens within the area of interest. Each set of dots 372 is used to define the optical parameters of the lens at the position occupied by that set.

The results of the analysis are conveniently displayed on the right hand side of the display screen 113 by means of a graphical representation of the lens in which the optical parameters are displayed in the form of a colour contour map.

5 Use of the mapping mode provides for a fully automated system of examining a lens which does not require the user to select a number of locations for examination and reposition the lens for each measurement.

Spot Mode

The spot mode of is used to find the optical parameters of the lens at one position only, usually at the optical centre of the lens.

10 In this mode, only one set of dots 372 defining an ellipse in which the minor and major axes are equal is used as a test pattern as illustrated in figure 8. In carrying out the spot mode method, the centre of the test pattern 372 is aligned with the optical centre of the lens and the optical axis X of the camera and the camera used to capture an image of the distorted test pattern 370' through the lens – the lens image. The
15 analysis as described above is then carried out for the single set of dots only to determine the optical characteristics of the lens at that point. This method could though be used to determine the optical parameters of a lens at a single position other than the optical centre.

The displayed test pattern used in the spot mode may be a sub-set of the array
20 378 used in the mapping mode including one central dot surrounded by six dots at the apexes of the notional hexagon. This is advantageous in enabling the system 101 to use the same grid pattern or part thereof in both modes. However, the central dot is not essential and could be omitted in the spot mode.

The method according to the first embodiment can also be carried out using the
25 first embodiment of the system 1 or indeed any other suitable lens examination system having a means to display the test pattern, a digital camera or other means for capturing an image of the test pattern through the lens, computing means to carry out the required image processing and computational analysis on the image data, and means such as a display screen to display the results. Further, it is not essential that the test pattern be
30 displayed on a digital screen and it could be displayed in other ways such as on printed

media. However, the use of a digital display screen, such as the screen 13, 113 of the systems 1, 101 described above, is advantageous as the test pattern can be changed dynamically. This is advantageous, for example, where the lens is held at a fixed distance above the screen as the size and/or spacing of the dots 374 in the test pattern 5 370 displayed can be varied to accommodate lenses having differing focal length. For example, in the system 101 where the plinth 156 is configured to hold the lens at a distance from the display screen 113 which is set to the focal length of a +20D lens, the system can handle lenses designed for myopia by adjusting the size and/or spacing of the dots in the test pattern without the need to adopt any particular physical measure or 10 the use of additional lenses.

A second embodiment of a method for examining a lens in accordance with an aspect of the invention will now be described with reference to figure 12.

The method according to the second embodiment is similar to the first method described above, except that the test pattern is different.

15 In the second embodiment, a first test pattern comprising a regular pattern of lines, which may be vertical lines, squares, or sine waves is displayed on the display screen 13, 113. A pair of glasses is mounted to the system 1, 101 as previously described with one of the lenses of the glasses positioned between the test pattern and the camera, with the optical centre of the lens aligned with the optical axis of the camera. An image 20 of the first test pattern as distorted by the lens is recorded (the lens image) and image data sent to the computing unit of the tablet computer 12, 112. The computer determines the degree of distortion of the test pattern caused by the lens by comparing the test pattern in the recorded lens image data with the original test pattern and from this calculates the magnification of the lens. The computer 12, 112 is then able to 25 generate the power and curvature and astigmatic correction of the lens and displays this (item 38) on the right hand half 36 of visual display unit 13 (see figure 2). No distortion would, of course indicate a plain glass lens. The power can be determined using a function $f(M)=P$ which may be determined from a set of standard lenses of known power as described above.

30 The first test pattern is replaced by a second test pattern of concentric circles on the display screen 13, 113. The centre of the lens, the axis X of the camera and the

centre of the circles are aligned and an image of the distorted second test pattern as seen through the lens (the lens image) is captured by the camera and again sent to the computer 12, 112. On the basis of the previous power calculations, the computer will identify specific points on the lens from which an image should be obtained. This can
5 be done by moving the lens relatively with respect to the axis X of the camera, moving the glasses clamp 16 on the rails 26 in the first system 1 or by moving the plinth 156 in the second system 101. By comparing the lens images obtained with known images the computer is able to derive and display a results image representative of the optical parameters of the in the right hand part of the screen. The results image shown will be
10 characteristic of the lens. In this system a uniform image would be characteristic of a plain lens, an image changing darkening colour from bottom to top, would be a progressive lens pattern, an image bright at the bottom but changing suddenly to dark would be a bifocal, colour brightness changing from right to left would be characteristic of a prismatic. In Figure 3 the image generated by a plain lens is shown at 40.

15 The method used is to set out block diagram form in figure 12.

Regardless of which of the methods of analysis described above are used, it may be necessary to calibrate the system used to carry out the method in order to remove distortions to the test pattern in the lens image captured by the camera produced by the system itself rather than by the lens. Such system distortions may arise, for example, in
20 displaying the test pattern on the screen 13, 113 and in capturing an image of the test pattern using the camera 128.

Accordingly, the methods described above may include a calibration step in which an image of the original test pattern displayed on the screen 13, 113, 213 is captured by the camera 28, 128, 228 without a lens in place. This can be called a
25 "system image". The test pattern in the system image is compared to the original test pattern by the computer to determine what distortions have been introduced by the system. The computer 12, 112, 212 using appropriate algorithms, calculates error coefficients and generates a transform algorithm which can be applied to the distorted test pattern in the system image data to transform it back to the original, perfect test
30 pattern. The transform algorithm is stored in the computer.

When a lens is subsequently tested, the test pattern in the lens image captured by the camera includes distortions introduced by the system and distortions introduced by the lens. The transform algorithm is applied to the test pattern in the lens image data to remove the system distortions. The resulting test pattern can be called a “transformed test pattern”. Any remaining distortions in the transformed test pattern are the result of the lens only and the transformed test pattern can be compared with the original test pattern to determine the optical parameters of the lens in accordance with the methods described above.

Calibration may not be required where the system is of sufficient quality such that any system distortions are negligible and is less important for the spot mode in the first method. Where calibration is required, it may only be necessary to derive a suitable transform algorithm once when the system is first commissioned and then to use the stored transform algorithm each time a lens is examined. However, for other systems it may be necessary to check the calibration and derive a transform algorithm periodically to ensure that further system errors have not been introduced over time. For portable systems such as the systems 1, 101 described above, it may be necessary to check the calibration and derive a transform algorithm each time the system is set up and/or transported. In some cases it may be necessary to check the calibration and derive a transform algorithm each time a lens is tested or at least each time a new pair of glasses is to be tested.

The above embodiments are described by way of example only. Many variations are possible without departing from the scope of the invention as defined in the appended claims and statements of invention.

CLAIMS

1. A system for examining lenses in a pair of glasses, the system comprising a computing device having a planar display screen, a camera mounted above the screen with the axis of the camera perpendicular to the plane of the screen, the camera being operatively connected to the computing device for storing and processing image data captured by the camera; and a glasses mount for holding a pair of glasses with at least one lens located between the camera and the display screen in use.
5
2. A system as claimed in claim 1, wherein the computing device is a tablet computer.
10
3. A system as claimed in claim 1 or claim 2, wherein the camera axis is offset to one side of the display screen.
4. A system as claimed in any one of claims 1 to 3, wherein the computing device is configured in use to display a test pattern for examining a lens in a first section of the display screen below the camera and to display the results of the examination in another section of the display screen.
15
5. A system as claimed in any one of claims 1 to 4, the system comprising a frame mounted to the computing device, the camera being mounted to the frame.
6. A system as claimed in any one of claims 1 to 5, the system comprising a casing partially enclosing the computing device.
20
7. A system as claimed in claim 6, wherein the system comprises a base to which the casing is attached, the camera being mounted to the base.
8. A system as claimed in any one of the preceding claims, wherein the glasses mount comprises a plinth slidably positionable on the display screen and means for securing a pair of glasses to the plinth.
25
9. A system as claimed in claim 8, wherein the computing device is arranged in use to display graphic symbols on the display screen to guide a user in correctly positioning the plinth.

10. A system for examining lenses in a pair of glasses, the system comprising a computing device in the form of a tablet computer having a planar display screen, a camera mounted above the screen with the axis of the camera perpendicular to the plane of the screen, the camera being operatively connected to the computer for storing and processing image data captured by the camera; and a glasses mount for holding a pair of glasses with at least one lens located between the camera and the display screen in use, wherein the computer is partially enclosed in a casing attached to a base and wherein the camera is mounted to the base.
11. A system for examining lenses in a pair of glasses, the system comprising a planar display for displaying a test pattern and a glasses mount for holding a pair of glasses with at least one lens located above the display screen in use, wherein the glasses mount comprises a plinth slidably positionable on the display and means for securing a pair of glasses to the plinth.
12. A method of examining lenses in a pair of glasses using a system as claimed in any one of claims 1 to 10, the method comprising displaying a test image on a first section of the display screen; mounting a pair of glasses in the glasses mount and positioning a lens of the glasses between the test pattern and the camera; capturing an image of the test pattern through the lens using the camera and saving the image data in the computing device; using the computing device to process the image data to determine the degree of distortion to the test pattern caused by the lens and to determine from this at least one parameter of the lens; displaying the determined parameter in another section of display screen.
13. A method as claimed in claim 12, wherein the glasses mount is a plinth slidably positionable on the display screen and means for securing a pair of glasses to the plinth, wherein the step of positioning a lens of the glasses between the test pattern and the camera comprises positioning the plinth with a pair of glasses mounted to it on the display screen to correctly locate a lens of the glasses relative to the test pattern and the camera for examination.

14. A method as claimed in claim 13, wherein the method comprises using the computing device to display graphic symbols on the display screen to guide a user in correctly locating the plinth on the screen.
 15. A method as claimed in claim 14, wherein the computing device is configured to display said graphic symbols in dependence on data received from the camera.
- 5

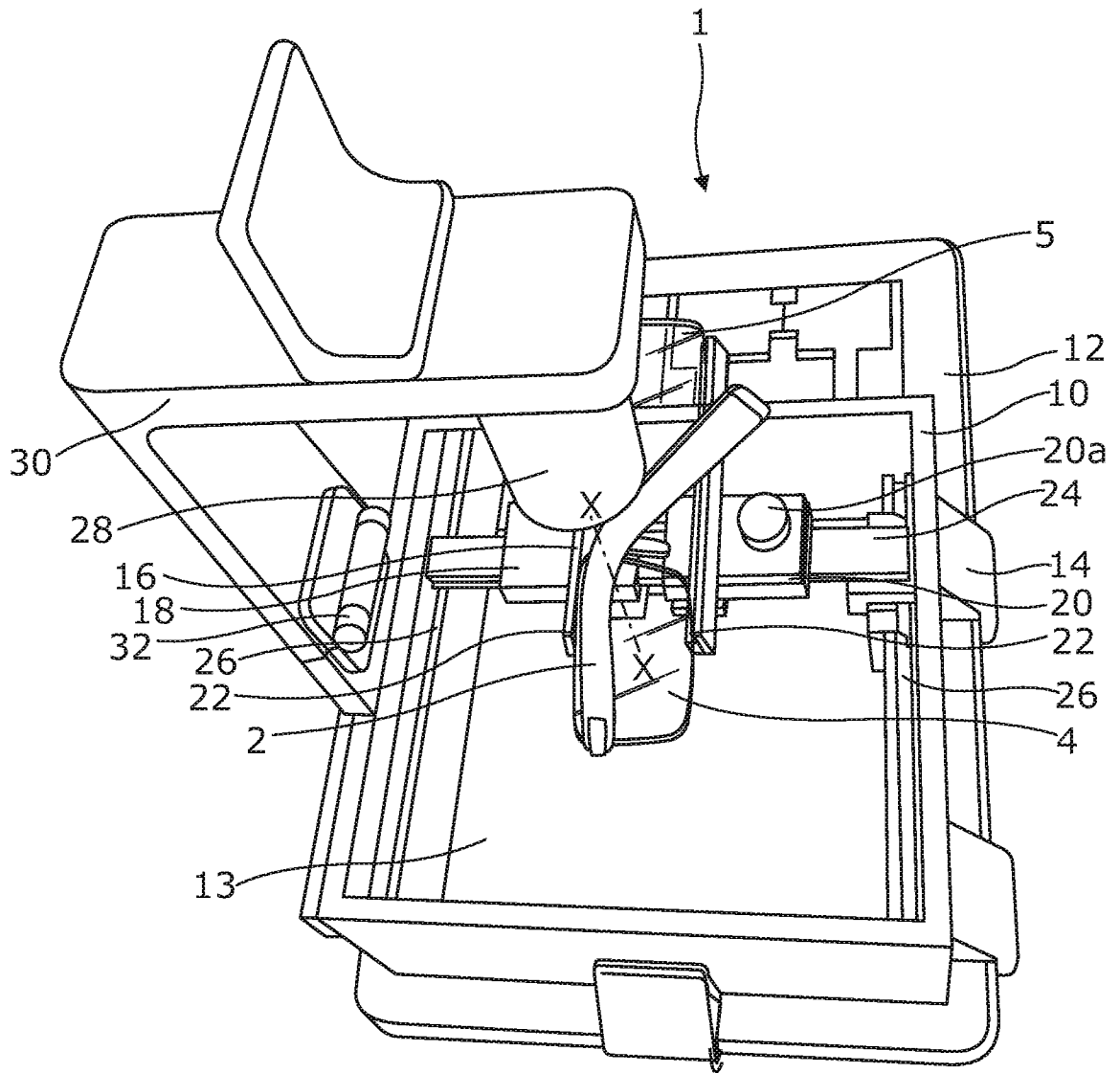


Figure 1

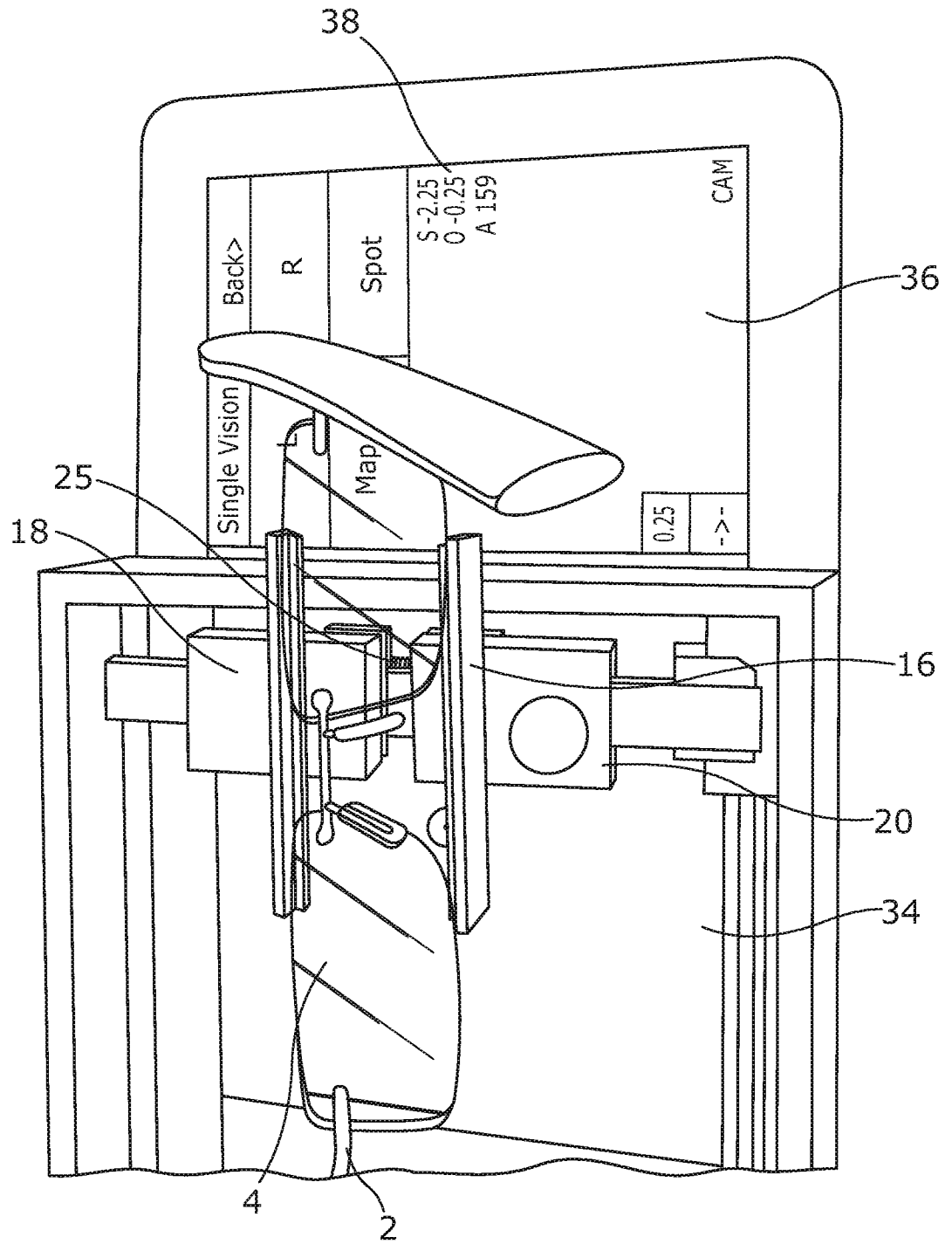


Figure 2

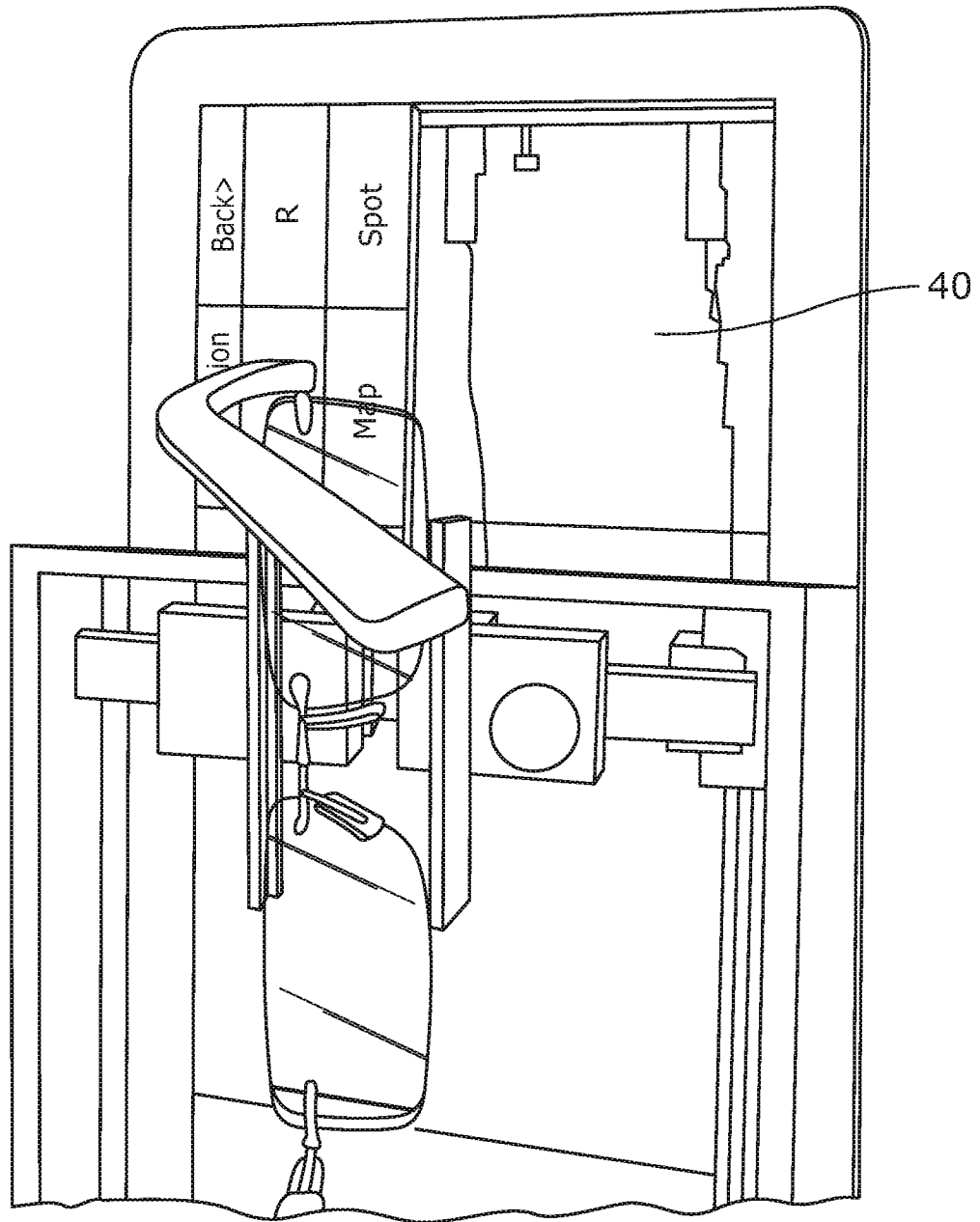


Figure 3

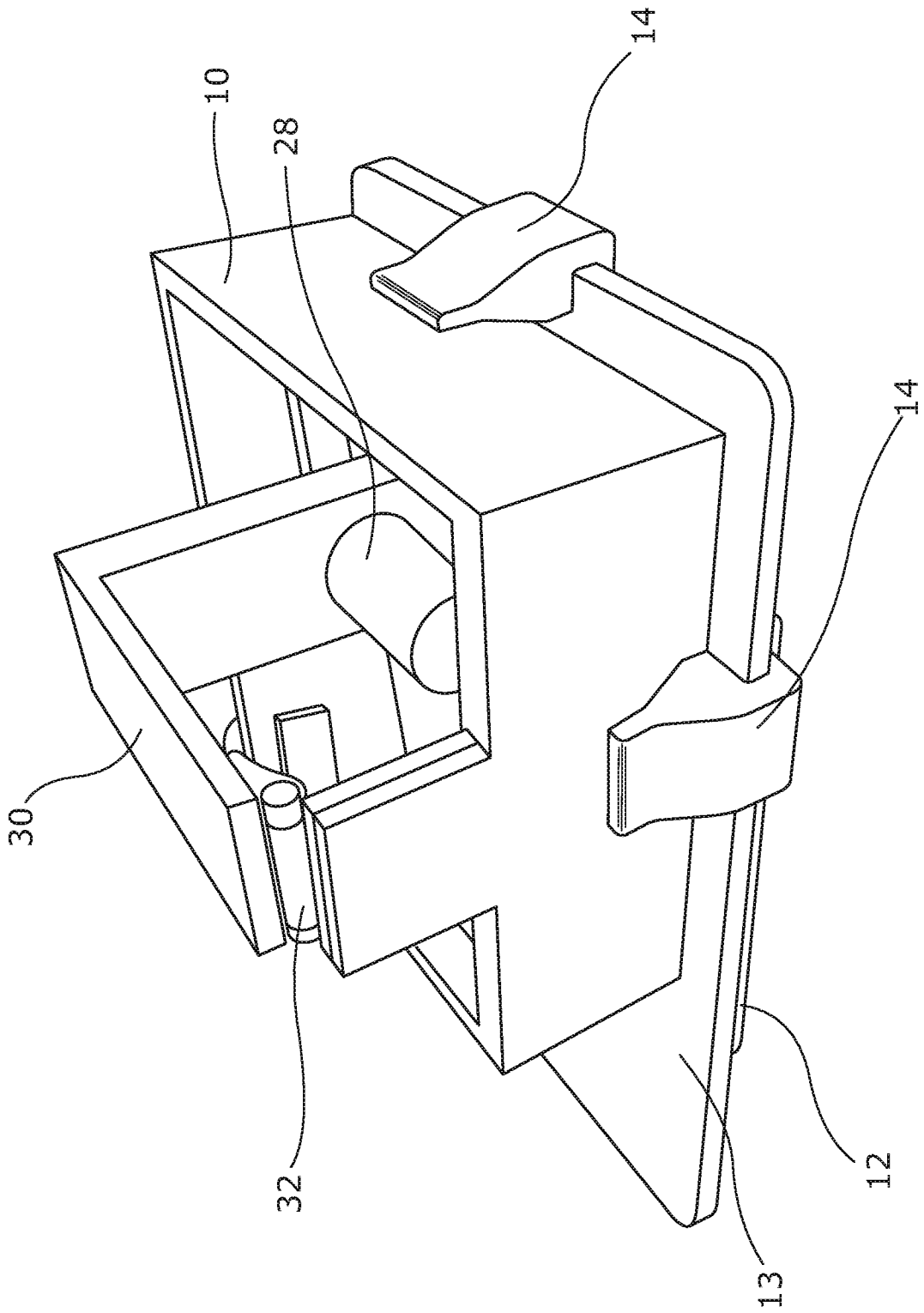


Figure 4

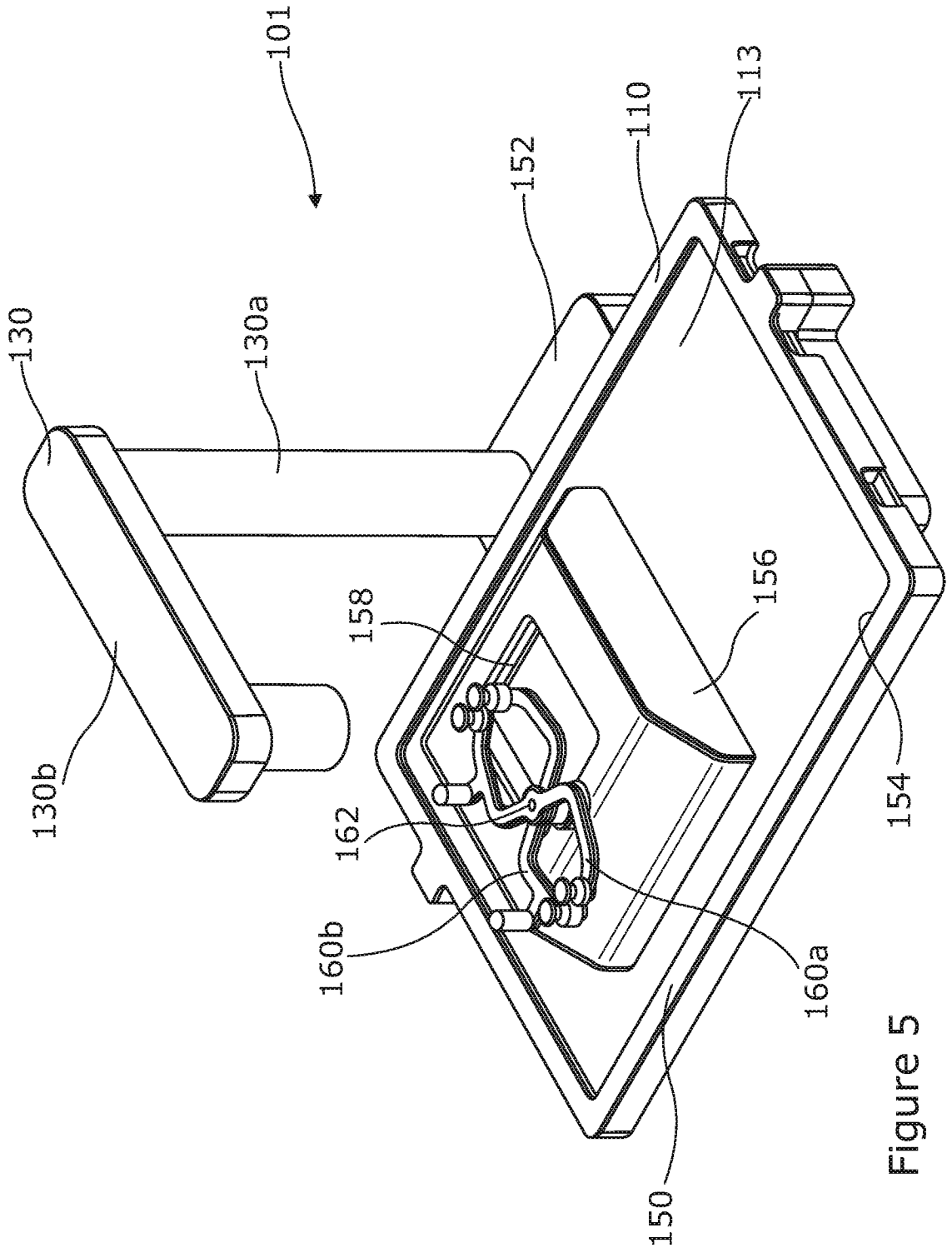


Figure 5

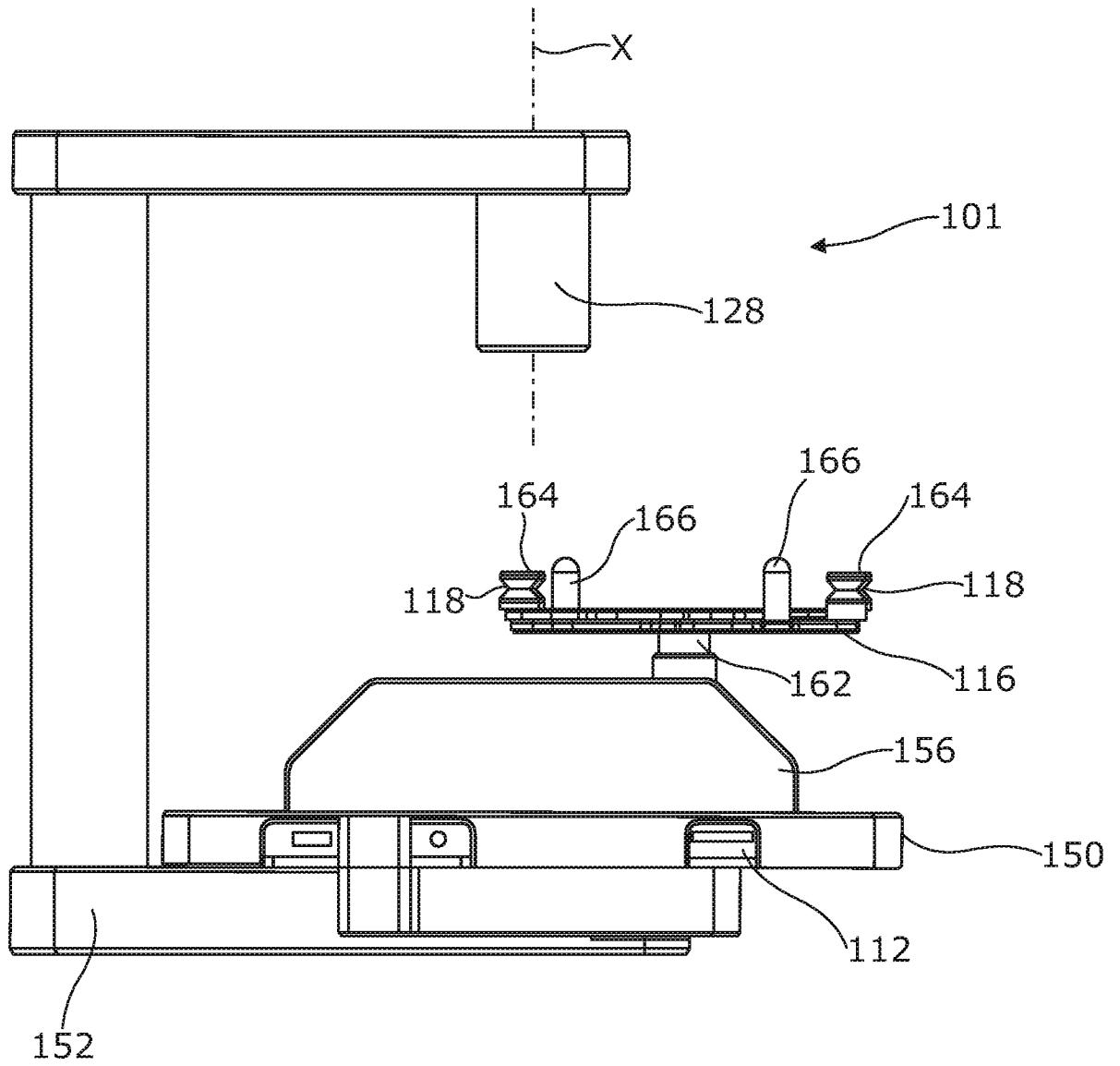


Figure 6

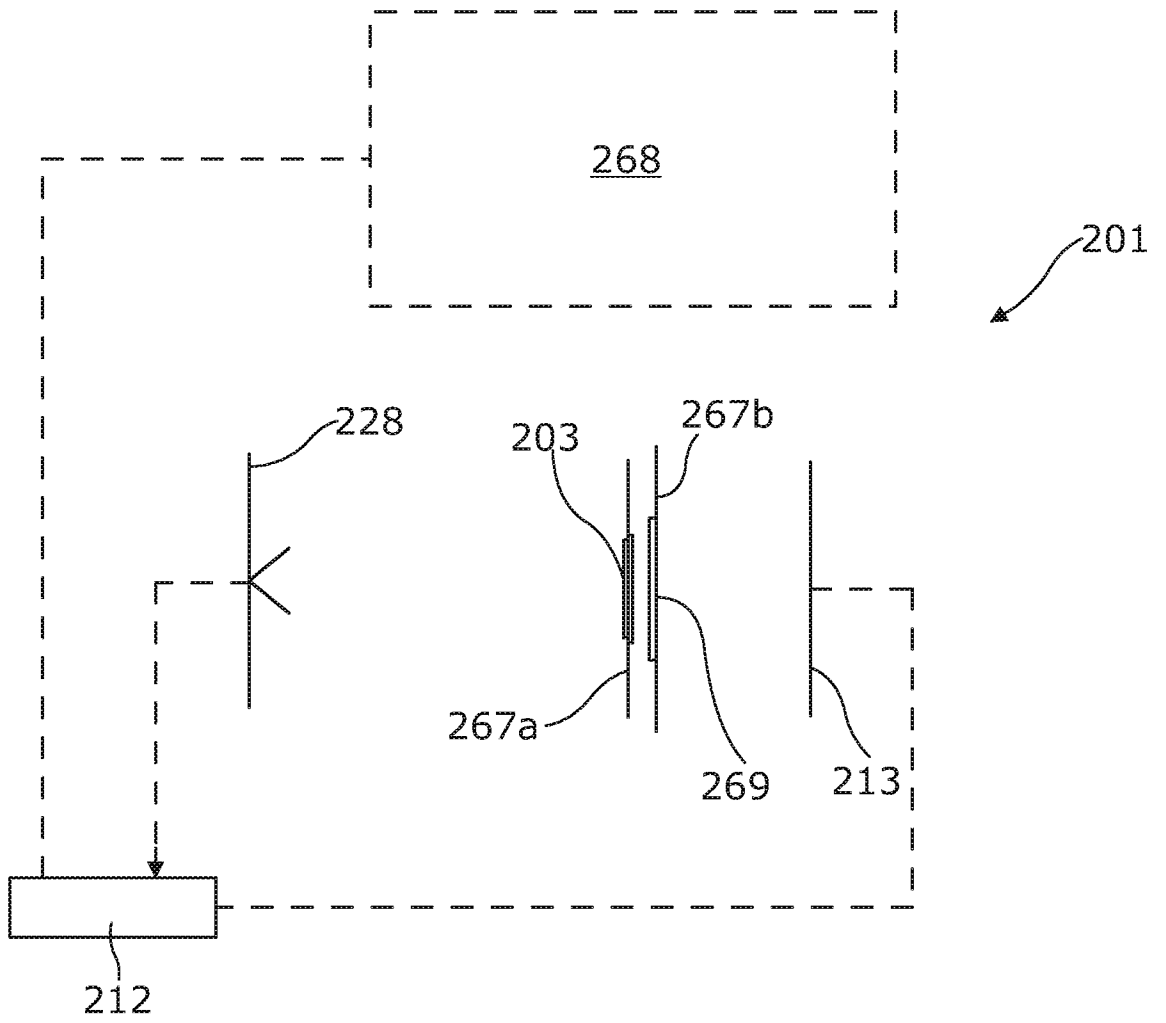


Figure 7

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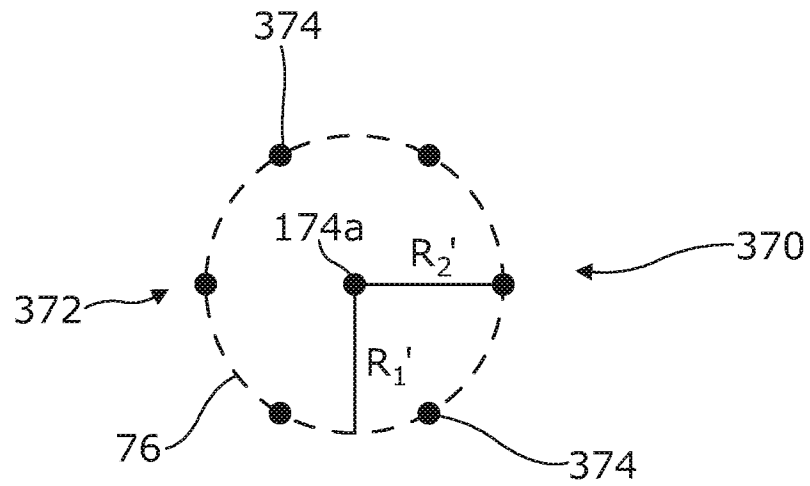


Figure 8

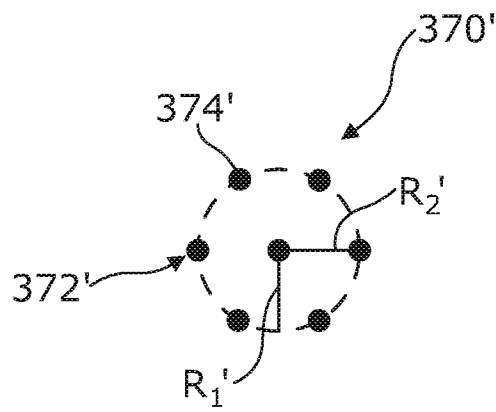


Figure 9

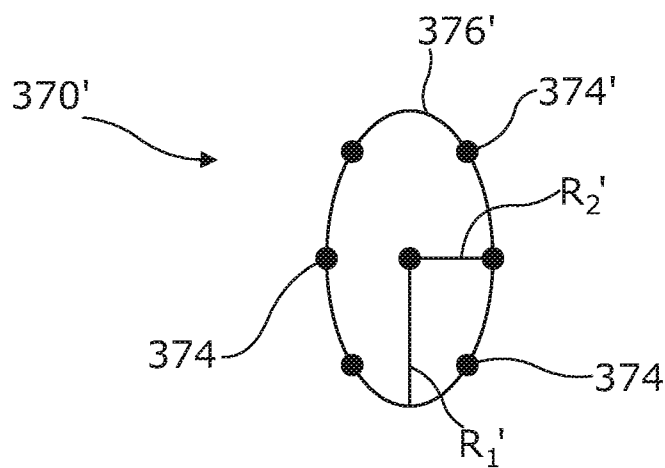


Figure 10

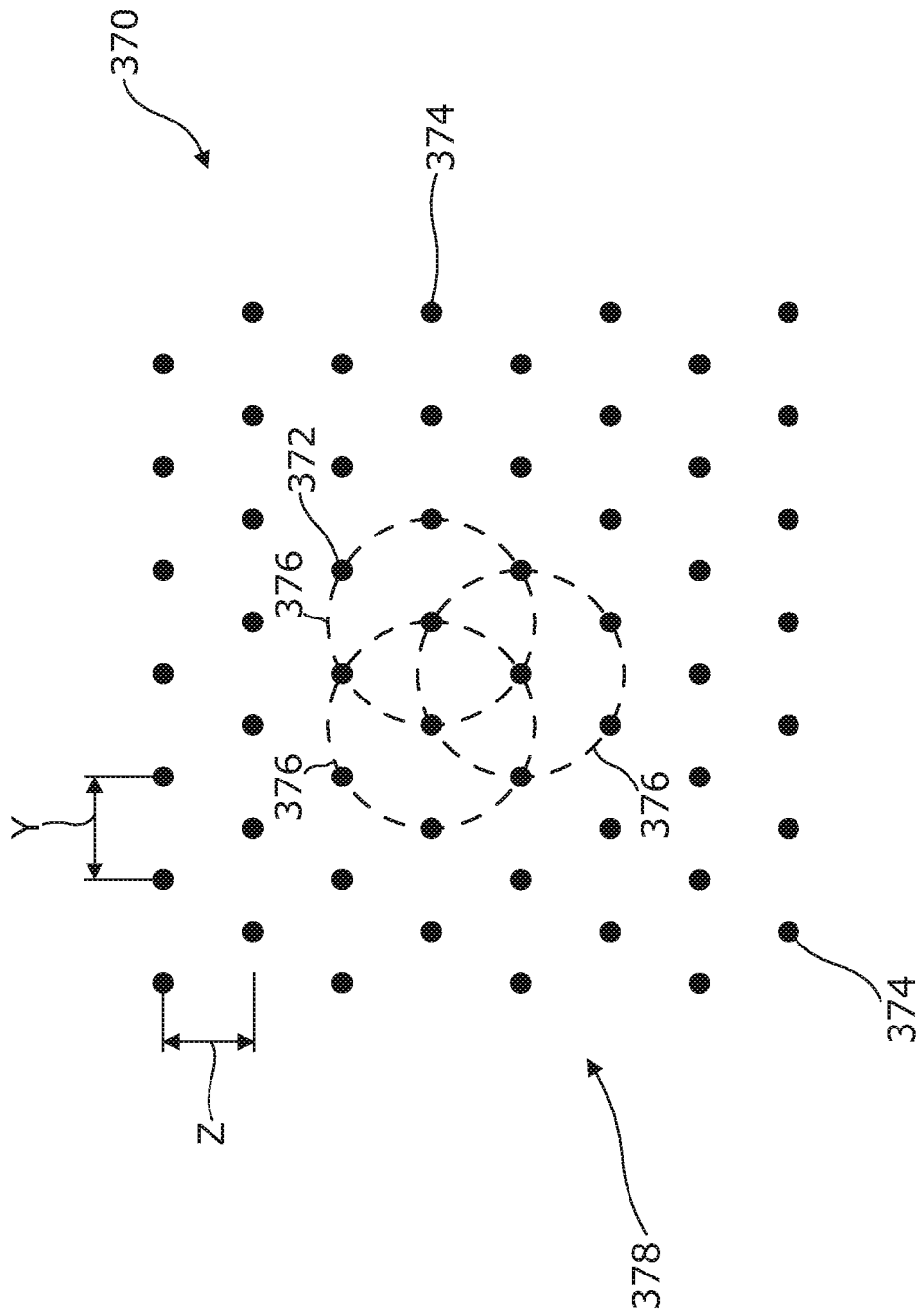
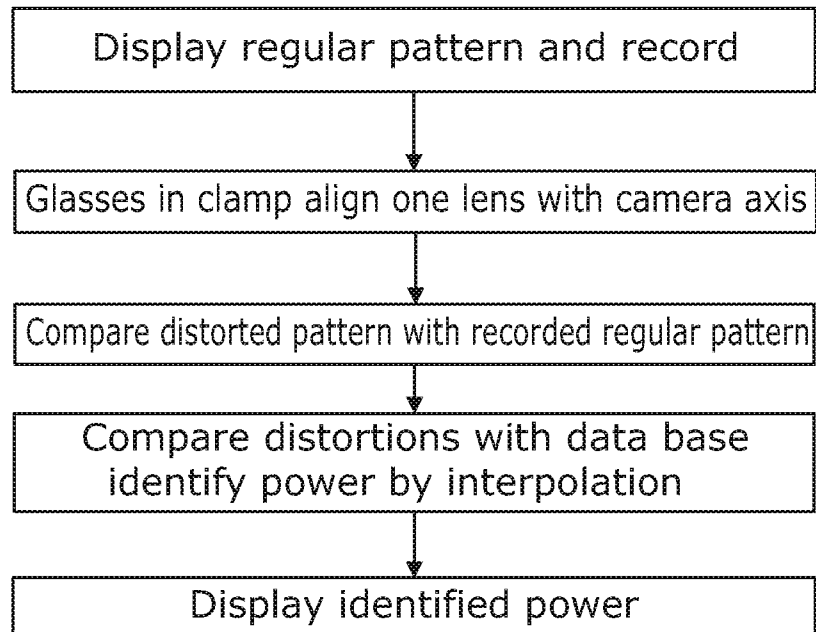


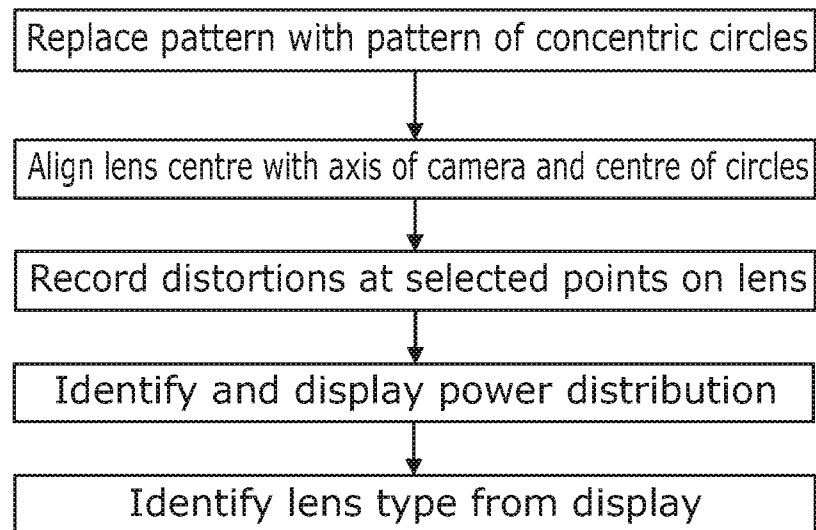
Figure 11

10/10

Stage 1



Stage 2



Stage 3 - repeat Stages 1 and 2 for other lens of pair

Figure 12