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- (71) Applicant: **TYB LLC** [US/US]; 353 W. 47th Street, 6A, Miami Beach, Florida 33140 (US).
- (72) Inventors: **BACH, Austin E.**; 353 W. 57th Street, 6A, Miami Beach, Florida 33140 (US). **MORRIS, Melissa**; 353 W. 47th Street, 6A, Miami Beach, Florida 33140 (US).
- (74) Agent: **ABID, Jack G.**; 255 S. Orange Avenue, Suite 1401, Orlando, Florida 32801 (US).
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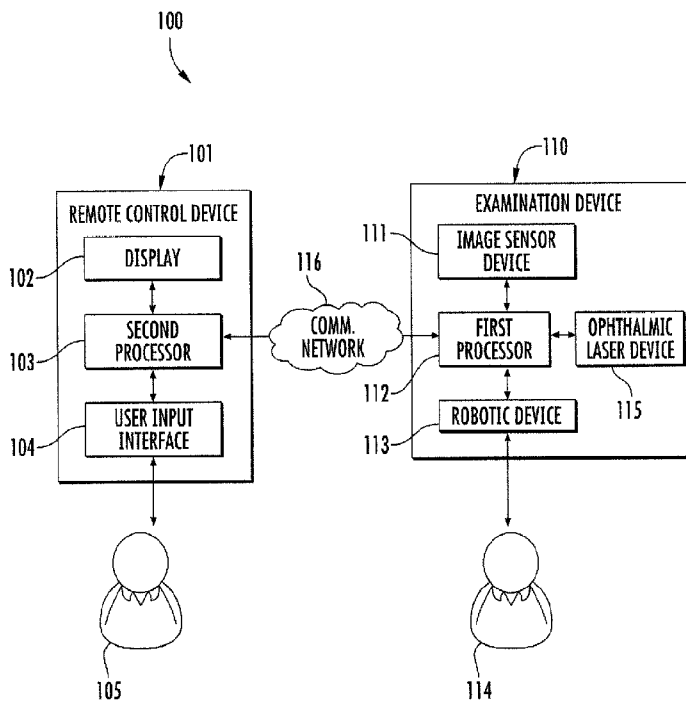


FIG. 1

(57) Abstract: A remote ophthalmic system may include an examination device having an ophthalmic laser device, and a first processor coupled to the ophthalmic laser device, a communication network, and a remote control device being associated with a user, being remote to the examination device, and being in communication with the examination device over the communication network. The first processor may be configured to receive target values for application of the ophthalmic laser device from the remote control device, the target values for application of the ophthalmic laser device being associated with an ophthalmic procedure on a patient, and perform the ophthalmic procedure on the patient by applying the ophthalmic laser device based upon the target values.

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## REMOTE OPHTHALMIC SYSTEM AND RELATED METHODS

### Technical Field

[0001] The present disclosure relates to the field of remote medical devices, and, more particularly, to a remote ophthalmic system and related methods.

### Background

[0002] Surgical procedures on the human eye are becoming more common as medical devices and associated technology improve. One common eye procedure is a trabeculectomy, which is a treatment for Glaucoma. The trabeculectomy is typically performed with a laser equipped slit lamp device. The laser is traditionally an Argon laser, but newer approaches are using lower powered solid state lasers. During the trabeculectomy, a gonioscope is positioned to abut the outer eye (i.e. the cornea) to provide optical access to the iridocorneal angle of the eye.

### Summary

[0003] Generally speaking, a remote ophthalmic system may comprise an examination device comprising an ophthalmic laser device, and a first processor coupled to the ophthalmic laser device. The remote ophthalmic system may comprise a communication network, and a remote control device being associated with a user, being remote to the examination device, and being in communication with the examination device over the communication network. The first processor may be configured to receive a plurality of target values for application of the ophthalmic laser device from the remote control device, the plurality of target values for application of the ophthalmic laser device being associated with at least one ophthalmic procedure on a patient, and perform the at least one ophthalmic procedure on the patient by applying the ophthalmic laser device based upon the plurality of target values. Advantageously, the user may perform a wide variety of ophthalmic procedures on the patient remotely.

[0004] More specifically, the examination device may comprise an image sensor device coupled to the first processor and configured to generate image data associated with an eye of the patient. The first processor may be configured to transmit the image data to the remote control device. The remote control device may comprise a display, and a second processor coupled to the display. The second processor may be configured to receive the image data, and display the image data on the display.

**[0005]** In some embodiments, the remote control device may include a user input interface coupled to the second processor. The second processor may be configured to generate the plurality of target values for application of the ophthalmic laser device based upon input from the user input interface. The user input interface may comprise a directional input, at least one video feed, and a plurality of control inputs.

**[0006]** Moreover, the examination device may include at least one robotic arm coupled to the first processor, and a lens coupled to a distal end of the at least one robotic arm. The first processor may be configured to position the lens via the at least one robotic arm. The first processor may be configured to position the lens based upon input from the remote control device. The first processor may be configured to receive at least one laser parameter for the plurality of target values for application of the ophthalmic laser device from the remote control device. The at least one laser parameter may comprise a pulse type and pulse duration.

**[0007]** Another aspect is directed to a method for making a remote ophthalmic system. The method may include providing an examination device comprising an ophthalmic laser device, and a first processor coupled to the ophthalmic laser device. The method may include providing a remote control device to be associated with a user, to be remote to the examination device, and to be in communication with the examination device over a communication network. The first processor may be configured to receive a plurality of target values for application of the ophthalmic laser device from the remote control device, the plurality of target values for application of the ophthalmic laser device being associated with at least one ophthalmic procedure on a patient, and perform the at least one ophthalmic procedure on the patient by applying the ophthalmic laser device based upon the plurality of target values.

#### **Brief Description of the Drawings**

**[0008]** FIG. 1 is a schematic diagram of a remote ophthalmic system, according to the present invention.

**[0009]** FIGS. 2A-2B are a flowchart illustrating operation of the remote ophthalmic system of FIG. 1.

**[0010]** FIG. 3 is a perspective view of an embodiment of the examination device.

**[0011]** FIG. 4 is a perspective view of an embodiment of the remote control device.

[0012] FIG. 5 is a perspective view of another embodiment of the remote control device.

[0013] FIGS. 6-7 are perspective views of another embodiment of the robotic device from the examination device, according to the present disclosure.

[0014] FIG. 8 is a perspective view of another embodiment of the robotic device from the examination device, according to the present disclosure.

[0015] FIGS. 9-10 are perspective views of another embodiment of the robotic device from the examination device, according to the present disclosure.

[0016] FIGS. 11-13 are flowcharts illustrating operation of the remote ophthalmic system of FIG. 1.

[0017] FIG. 14 is a schematic view of a user input interface from the remote control device, according to the present disclosure.

### Detailed Description

[0018] The present disclosure will now be described more fully hereinafter with reference to the accompanying drawings, in which several embodiments of the invention are shown. This present disclosure may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the present disclosure to those skilled in the art. Like numbers refer to like elements throughout, and base 100 reference numerals are used to indicate similar elements in alternative embodiments.

[0019] Referring initially to FIGS. 1-2B, a remote ophthalmic system **100** according to the present invention is now described. With reference to flowchart **200**, a method for operating the remote ophthalmic system **100** is also now described. The remote ophthalmic system **100** permits a user (i.e. doctor) **105** to remotely examine and perform ophthalmic procedures on a patient **114**.

[0020] The remote ophthalmic system **100** illustratively includes an examination device **110**, and a remote control device **101** physically separated from and remote to the examination device. The remote control device **101** is coupled to the examination device **110** over a communication path, such as a networked connection, e.g. Internet, cellular, closed wired or wireless local area network (LAN/WLAN). The remote control device **101** illustratively includes a display **102**, a processor **103** coupled to the display,

and a user input interface (e.g. control pad, mouse device) **104** coupled to the processor.

**[0021]** The remote control device **101** may comprise a computer programmed with software from the teachings herein. In some embodiments (FIG. 5), the user input interface **104** can comprise a full scale slit lamp device, i.e. operating as a clone device for the examination device version.

**[0022]** The examination device **110** illustratively includes a processor **112**, an image sensor device (e.g. high definition video sensor, 4k video sensor) **111** coupled to the processor, and a robotic device **113** coupled to the processor and adjacent the patient **114**. During typical use of the remote ophthalmic system **100**, the display **102** receives the output of the image sensor device **111**, and the user **105** manipulates the user input interface **104** for controlling the robotic device **113** to perform the procedure.

Advantageously, the user **105** is able to perform the procedure on the patient **114** from a remote location.

**[0023]** In some embodiments (FIG. 3), the robotic device **113** may comprise a slit lamp device **30**. The slit lamp device **30** illustratively includes a plurality of control mechanisms **24** (e.g. typical knobs for adjusting the slit lamp device), a support **32** for receiving the patient's chin, and an optical lens **31** (e.g. gonioscope, transequator lens) aligned with the patient's eyes. In the slit lamp device **30**, the image sensor device **111** is aligned with an output of the optical lens **31**. Also, the slit lamp device **30** also includes a plurality of motors actuating the corresponding plurality of control mechanisms, thereby providing the user **105** complete control.

**[0024]** In some embodiments, the slit lamp device **30** includes an optical source **26**, e.g. a surgical laser, such as an Argon or solid state laser, and the user input interface **104** permits control of the optical source (e.g. generating a plurality of laser pulses). Accordingly, the user **105** may remotely adjust the slit lamp device **30**, examine the eyes of the patient **114**, and perform the procedure. In some embodiments, the slit lamp device **30** may also include a plurality of robotic arms **22** with respective surgical tools (e.g. laser eye surgery tools, such as additional lens) thereon. In these embodiments, the user **105** may perform more complex procedures or surgeries from the remote location.

**[0025]** In the embodiment of FIG. 3, the slit lamp device **30** comprises a robotic arm **22** coupled to the slit lamp device and for positioning a lens **31** (e.g. gonio lens, transequator lens) that directs a laser beam into portions of the patient's eye (i.e. the retina, the iridocorneal angle and any place else in and around the eye). The remote control device **101** may control the robotic arm **22**. In addition, the remote control device **101** operates a software interface on the display **102** that enables the user **105** to select individual applications of the laser (i.e. individual pulse selection). In some embodiments, the user **105** selects the individual applications of the laser, and upon execution, the examination device **110** performs the individual applications without further input from the user. In other embodiments, the user **105** could manually select each position for near instantaneous laser application, i.e. a manual mode.

**[0026]** Indeed, in some embodiments, the user **105** is provided a detailed image of the patient's eye on the display **102**, and the user can individually select positions and parameters for application of the laser. The parameters can comprise laser pulse power, laser pulse duration, and laser pulse type. Once a plurality of individual applications has been selected, the remote control device **101** directs the laser to complete the plurality of individual applications.

**[0027]** In addition, the remote control device **101** operates eye tracking functions using the image sensor device **111**. The remote control device **101** automatically adjusts the plurality of individual applications based upon eye tracking feedback. The optical system can be used in a wide range of ophthalmic procedures, such as in Laser Trabeculoplasty or retinal surgery, for example.

**[0028]** With reference to flowchart **200**, the method for operating the remote ophthalmic system **100** begins at Block **201**, and includes obtaining an image of the patient's eye, which is sent to the remote control device **101** (Block **203**). The user **105** then selects laser application locations, and laser parameter settings (Blocks **205**, **207**, **209**, **211**). Once complete, the laser application locations and the parameter settings are transmitted to the examination device **110** (Block **213**). Once the patient's eye is properly positioned, the laser begins the laser firing process (Blocks **215**, **217**, **219**, **221**). In Block **221**, the examination device **110** is looking for proper positioning of the patient's eye via the image sensor device **111**. If the patient's eye is out of position, the

laser firing process is halted until the eye tracking software determines the position of the patient's eye. Once the laser firing process is complete, the user **105** is notified at Block **223**, and the user receives a final image of the patient's eye (Blocks **225**, **227**, **229**).

**[0029]** Referring now to FIGS. 3-6, an exemplary discussion of the remote ophthalmic system **100** now follows.

**[0030]** Introduction

The proposed device is a robotic slit-lamp (or slit-lamp-like device, not specifically shown here) under the direction of an ophthalmologist using a control console. The control console could be in the same room; however, it is expected that it will more typically be located at a remote location from the patient. The patient will be seated at the slit-lamp similarly as in-person slit-lamp procedures. At least one trained attendant will be assisting at the location with the robot and patient. The device will be capable of performing eye exams as well as certain laser surgeries.

**[0031]** Possible benefits include:

- (a) increased accuracy, increased speed, and increased precision of certain laser eye surgeries
- (b) increased access to eye care for patients in remote and impoverished areas
- (c) specialist access to and from nearly any location
- (d) increased ergonomics of laser surgery planning and execution
- (e) decreased travel for physicians covering large geographical areas
- (f) decreased travel for patients in rural areas
- (g) ability to monitor or record procedures for training or evaluation purposes

**[0032]** Device Features

Robotic Device (Patient-side)

The main components of the patient-side device are shown in FIG. 3. The patient will sit upright and place his/her head against the headrest shown on the left of FIG. 3. The patient's chin will rest on the chin bar and forehead on the upper brace. The chin bar height is adjusted via a screw mechanism **21**. This can be manually performed by the onsite assistant as done with non-robotic slit-lamps, or as an added option in another embodiment will allow the physician to control this via an electronic actuator. This will

align the eyes vertically for all procedures and eyes should be in-line with the lens holders.

**[0033]** The lens holder will be initially placed outward and out of the way. When needed, it can be swung into the position shown. The end of the lens holder will have a manual clip for the on-site assistant to insert the desired lens **31** for focusing on different parts of the eye. It will likely be tightened similarly as a band clamp or quick lock clamp (such as those used on pipes in the automotive industry), via a twist-lock (i.e. keyless chuck) mechanism (such as those used to secure bits inside drill chucks) or via set screws. In addition to being able to be pivoted, the lens holder will also have horizontal adjustments (likely via a screw mechanism) along the arm to fully align the lenses over the eye. Large adjustments can be manually performed by the assistant, but the physician will electronically actuate these functions for precise placement. There will be a lens holder on each side of the headrest so that procedures may be done on either eye.

**[0034]** All rotating parts of the slit-lamp will be fitted with accurate electronic actuators to allow the position of both the laser and the slit-illuminator to be independently adjusted. Their position can be directly controlled by the physician or computer-controlled pending the procedure being performed and the physician's preference. All necessary manual adjustment knobs **24** will be instead electronically actuated to allow for remote-control of key features of the slit-lamp. Only knobs that mechanically control features will be actuated, not necessarily all knobs shown in FIG. 3. They may not appear on the outside of the slit-lamp if on-site control is not desired, but are shown in the figure for representation. The full binocular microscope **25** is not necessary, though is shown in FIG. 3 so the appearance of a slit-lamp is maintained. The internal microscope portion is needed and a high-resolution digital video camera will be mounted to the slit-lamp. There are already several devices for connecting various types of cameras and phones to the slit-lamp. In some embodiments, the internal microscopic portion could be omitted if included in the camera apparatus.

**[0035]** The laser controller **26** will remain on-site with the foot pedal or trigger button **10** optionally connected. The physician will be able to determine whether any on-site control features remain active during the procedures. Typically, all physical on-site

laser triggers will be deactivated and removed to avoid inadvertent activation by untrained individuals. For added safety, an emergency stop button **27** will be placed to be easily accessible by the on-site assistant. This will immediately disconnect all power to the laser and actuated components. It is needed in the event of a robot malfunction or an on-site event requires that the procedure be immediately halted. Communication lines and video feed will remain active, however.

#### **[0036]**Communication

Not shown in FIGS. 3-5 are the communication connections between the robot and the physician console. Existing lines of communication will be used and can include direct wires, WiFi, Bluetooth, telephone lines, cable lines, cellular connections, satellite connection or any other forms of communication existing now or in the future. Any one or multiple methods of communication may be used pending the locations, desired use of a back-up and bandwidth requirements.

**[0037]** The communication lines will transmit bi-directional audio feed, video feed (minimally from the patient to the physician, bi-directional feed is optional), control instructions from the physician's console to the robot, and sensor information and feedback from the robot to the physician. The audio feed is necessary so that the physician can quickly communicate with the patient and assistant (though visual text-based communication could also be used). Appropriate hardware, such as microphones and speakers, is needed on both sides to facilitate this communication. None of these features will be novel, however.

#### **[0038]**Physician Console

There are two possible physician-side console options currently proposed. The first, shown in FIG. 4, is simpler and best when low-cost or portability are priorities. This design includes a monitor **28** that is of sufficient size and resolution for the physician to easily view the transmitted video feed sent from the robotic slit-lamp. The transmitted video may comprise one or more of 2D data and 3D data.

**[0039]** The control console **29** can comprise any combination of input mechanisms such as buttons, switches, joysticks, track pads, touch screens, etc. FIG. 4 shows a representation of various types of input mechanisms and not the actual final version of this console. The console could also be simply a computer mouse allowing the

physician to “point and click” on a computer screen to select laser target areas and menu options.

**[0040]** Another option is to use a tablet computer or a touch screen monitor **28** for implementing controls in this way. Software buttons and dials, “soft keys,” can appear on the monitor or tablet screen to allow for selecting various options during use. The use of a foot pedal or dedicated “hard” trigger button **29, 14** for the laser is optional and may provide a layer of comfort when activating the laser. It provides a different type of motion to ensure the laser is activated only when the physician is ready. Additional software checks will be in place to prevent most accidental laser triggers.

**[0041]** The second physician console option is shown in FIG. 5. This would be more familiar in use to physicians as it is similar to a slit-lamp. The physician would operate the master slit lamp on his/her end to control the slave slit-lamp at the patient's location. It is desirable that the master and slave slit-lamps be very similar, if not identical, in size and positioning of the key components such as the slit-illuminator. The master slit-lamp has position sensors **11** located on all moving joints. Information can be read from these sensors and transmitted to the slave slit-lamp to perform the same motion via electronic actuators or stored in memory to execute a task at a later time.

**[0042]** Control knobs also have position sensors **12** that transmit information to the slave device so that controls on the robotic device can be adjusted to the same setting. The physician may chose to use a regular monitor or binoculars **13**. The monitor is more ergonomic for performing remote procedures or surgeries, so the binoculars on the master device are not needed and are optional. However, by installing small displays into the binoculars, the device could potentially be used as a training tool or to provide 3D visual feedback without a specialized 3D monitor.

**[0043]** Software

The software will include necessary aspects for control of the robot device. It will be able to translate points selected on a picture of the eye to physical positions of the robotic slit-lamp to direct the laser to those points on the actual eye. It will also include all necessary components for providing communication between the robot and physician's console.

**[0044]** In some embodiments, due to the unavoidable delay in remote control, the software will monitor eye position. It should be noted that the patient's body/head will not be strapped down and will also be able to freely move his/her eyes. From the control console, the physician will select a point (or multiple points) on the eye as well as laser duration (for each point). Also, the duration, type, power, size, as well as any other parameters, are adjustable for the laser. When commanded, the robotic device will only fire the laser during times the eye is in the desired position(s) and otherwise wait. After all points have been hit for the desired duration, the physician will be notified that the task is complete and can inspect the progress. The software will allow for different modes of operation. The robot can move in real-time with the slave device (or control inputs pending the console style used). In addition, the robot can automatically move after a desired task has been fully "programmed." The software allows for recording of images or video. Split screens showing former and current images or video can be used for various evaluation needs. In another embodiment where the laser tracking speed is increased, the laser can fire in real time and compensate for movement of the eye without pausing.

**[0045]** Referring now again to FIG. 1, a remote ophthalmic system **100** illustratively includes an examination device **110** comprising an ophthalmic laser device (e.g. an argon laser) **115**, and a first processor **112** coupled to the ophthalmic laser device. The examination device **110** may have a slit lamp device form factor (i.e. Zeiss-Style, Haag-Streit Style, or portable/hand-held), for example. In some embodiments, the ophthalmic laser device **115** can be omitted in the examination device **110**.

**[0046]** The remote ophthalmic system **100** illustratively includes a communication network (e.g. the Internet, a cellular network, or a closed local area network) **116**, and a remote control device **101** being associated with a user **105**, being remote (e.g. another room in a same facility, or several miles away) to the examination device **110**, and being in communication with the examination device over the communication network. The first processor **112** is configured to receive a plurality of target values for application of the ophthalmic laser device **115** from the remote control device **101**, the plurality of target values (i.e. positional values within an eye of a patient **114**) for application of the ophthalmic laser device being associated with at least one ophthalmic procedure on the

patient, and perform the at least one ophthalmic procedure on the patient by applying the ophthalmic laser device based upon the plurality of target values.

**[0047]** More specifically, the examination device **110** illustratively includes an image sensor device **111** coupled to the first processor **112** and configured to generate image data (e.g. three-dimensional voxel image data or two-dimensional image data) associated with an eye of the patient **114**, and the first processor is configured to transmit the image data to the remote control device **101**. The remote control device **101** illustratively includes a display **102**, and a second processor **103** coupled to the display. The second processor **103** is configured to receive the image data, and display the image data on the display **102**. For example, the first and second processors **112**, **103** may comprise application specific integrated circuits, or field-programmable gate array (FPGA) integrated circuits configured with the teachings herein.

**[0048]** Referring now additionally to FIG. 14, the remote control device **101** includes a user input interface **104** coupled to the second processor **103** (i.e. the second processor operatively renders the user input interface on the display **102**). The second processor **103** is configured to generate the plurality of target values for application of the ophthalmic laser device **115** based upon input from the user input interface **104**. In the illustrated embodiment, the user input interface **104** comprises a software user interface **790** comprising a directional input **791**, a plurality of video feeds **792a-792b**, a plurality of control inputs **793a-793g**, and a stop command button **794**.

**[0049]** Moreover, the examination device **110** illustratively includes a robotic device defining a robotic arm **113** coupled to the first processor **112** (i.e. operatively coupled so that the first processor controls circuitry driving the robotic arm), and a lens coupled to a distal end of the robotic arm. The first processor **112** is configured to position the lens via the robotic arm **113**. The first processor **112** is configured to position the lens based upon input from the remote control device **101**. The first processor **112** is configured to receive at least one laser parameter for the plurality of target values for application of the ophthalmic laser device **115** from the remote control device **101**. The at least one laser parameter may comprise a pulse type pulse duration, a laser source power, and a size of collimated beam, for example.

**[0050]** Another aspect is directed to a method for making a remote ophthalmic system **100**. The method may include providing an examination device **110** comprising an ophthalmic laser device **115**, and a first processor **112** coupled to the ophthalmic laser device, and providing a remote control device **101** to be associated with a user **105**, to be remote to the examination device, and to be in communication with the examination device **110** over a communication network **116**. The first processor **112** is configured to receive a plurality of target values for application of the ophthalmic laser device **115** from the remote control device **101**, the plurality of target values for application of the ophthalmic laser device being associated with at least one ophthalmic procedure on a patient **114**, and perform the at least one ophthalmic procedure on the patient by applying the ophthalmic laser device based upon the plurality of target values.

**[0051]** Referring now additionally to FIGS. 6-7, another embodiment of the robotic device **313** is now described. In this embodiment of the robotic device **313**, those elements already discussed above with respect to FIG. 1 are incremented by 200 and most require no further discussion herein. This embodiment differs from the previous embodiment in that this robotic device **313** comprises a motorized slit lamp device component. In particular, the robotic device **313** illustratively includes a housing **350**, and a geared interface **351** carried by the housing.

**[0052]** As will be appreciated by the skilled person, the typical slit lamp comprises a plurality of manual adjustment mechanisms, the local operator engaging the plurality of manual adjustment mechanisms (e.g. knobs) to fit the patient. The geared interface **351** is part of one of the plurality of manual adjustment mechanisms. Rather than the typical manual driver (e.g. knob), which is removed, the robotic device **313** illustratively includes a frame **353** carried by the housing **350**, and an electric motor **354** carried by the frame, and a gear **352** operatively coupled to the electric motor and driving the geared interface **351**. In this embodiment, the motorized slit lamp device component is used for retrofit applications, i.e. converting typical slit lamp devices into motorized slit lamp devices used in the remote ophthalmic system **100**. The first processor (not shown) is configured to actuate the electric motor **354** via commands received from the remote control device (not shown).

**[0053]** In this embodiment, the base of the slit lamp device may also be motorized. So, the user of the remote control device can position the examination device (i.e. slit lamp device). The examination device may include a plurality of omni-wheels (e.g. four) mounted on two transverse shafts for allowing respectively for left-right and back-forth movement of the slit lamp device base on the table. This raises the base of the slit lamp device off of the table by up to a couple of inches. As a result, the tracks on either side should be raised appropriately so that the slit lamp device is not able to be moved off of the table, either by manual force or use of the motors. A double-shafted motor or servo moves each axle with an omni-wheel mounted on each end of the axles. Omni-wheels have rollers so that the wheels can be passively moved in a perpendicular angle from normal active-motion by the alternate drive shaft. In other embodiments, mecanum wheels could be used, though with different angular placement, or passive rollers could be used allowing the use of only two omni-wheels underneath to save on cost, though this isn't the preferred method of installation.

**[0054]** In this embodiment, motors, wires, sensors, etc. are nearly all mounted on the outside of the slit lamp device in order to facilitate fit and ease of adjustments, alterations and repairs. It is not intended that this embodiment be used for production models, except in the possible cases where a retrofit of specific models are desired (e.g. for a group of doctors fond of a particular model of slit lamp device that cannot be specially manufactured with the robot components integrated from the start). This embodiment may advantageously lower costs for organizations that already have slit-lamps and could also be used to create lower cost robotic slit-lamps for poorer populations since donated used equipment could be used. This embodiment may require that covers (not shown) be produced out of plastic, metal, fabric, or silicone, for example, in order to hide/shield the motors and wires and keep them from easy patient access. These covers are to be custom-built in each instance to fit as close to the slit-lamp as possible without hindering movement.

**[0055]** Referring now additionally to FIG. 8, another embodiment of the robotic device **513** is now described. In this embodiment of the robotic device **513**, those elements already discussed above with respect to FIG. 1 are incremented by 400 and most require no further discussion herein. This embodiment of the robotic device **513**

comprises a motorized slit lamp device component. In particular, the robotic device **513** illustratively includes a housing **550**, a frame **553** carried internally by the housing, and a geared interface **551** carried internally by the housing. In this embodiment, the motorized slit lamp device component is installed during manufacture of the slit lamp device.

**[0056]** In this embodiment, the motors, wires, sensors, etc. are nearly all mounted on the inside of the slit lamp device. A slit lamp device would be produced (and dimensions altered, if necessary) so that small geared motors fit inside the interior compartments with geared inserts at the joints to allow movement.

**[0057]** Referring now additionally to FIGS. 9-10, another embodiment of the robotic device **613** is now described. In this embodiment of the robotic device **613**, those elements already discussed above with respect to FIG. 1 are incremented by 500 and most require no further discussion herein. This embodiment differs from the previous embodiment in that this robotic device **613** comprises a robotic arm. The robotic device **613** illustratively includes a housing (e.g. the illustrated post) **650**, an electric motor **654** coupled to the housing, an arm **655** having a plurality of arm segments, a plurality of spring members **656a-656c** coupled between the plurality of arm segments, and a lens **631** carried by a distal portion of the arm. The robotic device **613** illustratively includes a plurality of retaining screws **658a-658b** fixing the lens **631** to the distal portion of the arm **655**. The arm **655** illustratively includes a plurality of retractable cables **657a-675c** configured to extend and retract the plurality of arm segments.

**[0058]** The lens holder allows for robotic adjustment of the position so that appropriate areas of the retina can be brought into focus for examination and surgery. The appropriate lens must be manually clamped (via the plurality of retaining screws **658a-658b**) into the end holder by the on-site medical assistant. Lubricant between the lens and eye is also applied manually as the lens is manually moved into the appropriate general position. At that point, robotic control is used to make minute adjustments in the position of the lens.

**[0059]** In order to keep the lens holder light and minimize obstruction in front of the patient's eye and face, indirect drives are recommended for actuation. In other embodiments, the arm **655** could alternatively include a plurality of small electric motors

respectively driving each arm segment. In these embodiments, the arm **655** could comprise a robotic arm, as available from the Fanuc America Corporation of Rochester Hills, Michigan. A lens holder is needed on both sides to be mounted to the chin-rest bars. One side is the mirror-image of the other (only one side is shown in the drawings below).

**[0060]** In the indirectly-driven model, a tendon **657a-657c** attaches to each joint. These tendons **657a-657c** are usually strong strings or lubricated metal cables. The cables are routed through the arm **655** with more tendons **657a-657c** being present as one nears the base of the robotic arm. Each tendon **657a-657c** is mounted to a motor shaft where the rotation of the shaft winds or unwinds the tendon. This changes the tendon length and also the tension it exerts at joint, causing the joint to move. This only works in one direction, so springs **656a-656c** are used as counter tension. In the illustrated embodiment, the arm **655** comprises springs **656a-656c** in as a functional model, but other embodiments have flexible joints made from pretension material to act as the spring). The springs **656a-656c** also help to passively keep the lens **631** on the eye as the patient moves slightly during the procedure. This type of drive mechanism is known as cable-driven, tendon-driven, and sometimes a type of Bowden driven mechanism.

**[0061]** Referring now additionally to FIGS. 11-13, a flowchart **700** begins with Block **701** and illustrates control of the software for the remote control device **101**. In particular, Blocks **702-707** relate to system boot-up; Blocks **708-712** relate to patient diagnosis; Blocks **708, 713-716** relate to patient treatment. In flowchart **730**, the process for patient treatment in the remote ophthalmic system **100** is described. Blocks **731-733** relate to retrieving an image of the eye of the patient. Blocks **734-736** relate to selection of the plurality of target values for application of the ophthalmic laser device **115**. Blocks **737-743** relate to the transmission of the selection of the plurality of target values to the examination device **110** and the execution of the at least one ophthalmic procedure on the patient **114**. Blocks **744-747** relate transmission of an update final image of the eye of the patient **114**, and ending of the at least one ophthalmic procedure.

**[0062]** In flowchart **760**, the process for operation of a treatment program in the examination device **110** is now described. Blocks **761-766** to selection of the plurality of

target values for application of the ophthalmic laser device **115**. Blocks **767-770** relate to the transmission of the selection of the plurality of target values to the examination device **110** and the execution of the at least one ophthalmic procedure on the patient **114**. Blocks **771-774** relate transmission of an update final image of the eye of the patient **114**, and ending of the at least one ophthalmic procedure.

**[0063]** Many modifications and other embodiments of the present disclosure will come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is understood that the present disclosure is not to be limited to the specific embodiments disclosed, and that modifications and embodiments are intended to be included within the scope of the present disclosure.

**THAT WHICH IS CLAIMED IS:**

1. A remote ophthalmic system comprising:  
an examination device comprising an ophthalmic laser device, and a first processor coupled to said ophthalmic laser device;  
a communication network; and  
a remote control device being associated with a user, being remote to said examination device, and being in communication with said examination device over said communication network;  
said first processor configured to  
receive a plurality of target values for application of said ophthalmic laser device from said remote control device, the plurality of target values for application of said ophthalmic laser device being associated with at least one ophthalmic procedure on a patient, and  
perform the at least one ophthalmic procedure on the patient by applying said ophthalmic laser device based upon the plurality of target values.
2. The remote ophthalmic system of claim 1 wherein said examination device comprises an image sensor device coupled to said first processor and configured to generate image data associated with an eye of the patient; and wherein said first processor is configured to transmit the image data to said remote control device.
3. The remote ophthalmic system of claim 2 wherein said remote control device comprises a display, and a second processor coupled to said display; and wherein said second processor is configured to receive the image data, and display the image data on said display.
4. The remote ophthalmic system of claim 3 wherein said remote control device comprises a user input interface coupled to said second processor; and wherein said second processor is configured to generate the plurality of target values for application of said ophthalmic laser device based upon input from said user input interface.

5. The remote ophthalmic system of claim 4 wherein the user input interface comprises a directional input, at least one video feed, and a plurality of control inputs.

6. The remote ophthalmic system of claim 1 wherein said examination device comprises at least one robotic arm coupled to said first processor, and a lens coupled to a distal end of said at least one robotic arm; and wherein said first processor is configured to position said lens via said at least one robotic arm.

7. The remote ophthalmic system of claim 6 wherein said first processor is configured to position said lens based upon input from said remote control device.

8. The remote ophthalmic system of claim 1 wherein said first processor is configured to receive at least one laser parameter for the plurality of target values for application of said ophthalmic laser device from said remote control device.

9. The remote ophthalmic system of claim 8 wherein the at least one laser parameter comprises, a pulse type, a pulse duration, a laser source power, and a size of collimated beam.

10. A remote ophthalmic system comprising:  
an examination device comprising  
    an ophthalmic laser device,  
    a first processor coupled to said ophthalmic laser device,  
    an image sensor device coupled to said first processor and  
configured to generate image data associated with an eye of a patient,  
    at least one robotic arm coupled to said first processor, and  
    a lens coupled to a distal end of said at least one robotic arm;  
a communication network; and  
a remote control device being associated with a user, being remote to said examination device, and being in communication with said examination device over said communication network;  
said first processor configured to  
    transmit the image data to said remote control device,

receive a plurality of target values for application of said ophthalmic laser device from said remote control device, the plurality of target values for application of said ophthalmic laser device being associated with at least one ophthalmic procedure on the patient, and

perform the at least one ophthalmic procedure on the patient by applying said ophthalmic laser device based upon the plurality of target values, and by positioning said lens via said at least one robotic arm.

11. The remote ophthalmic system of claim 10 wherein said remote control device comprises a display, and a second processor coupled to said display; and wherein said second processor is configured to receive the image data, and display the image data on said display.

12. The remote ophthalmic system of claim 11 wherein said remote control device comprises a user input interface coupled to said second processor; and wherein said second processor is configured to generate the plurality of target values for application of said ophthalmic laser device based upon input from said user input interface.

13. The remote ophthalmic system of claim 12 wherein the user input interface comprises a directional input, at least one video feed, and a plurality of control inputs.

14. The remote ophthalmic system of claim 11 wherein said first processor is configured to position said lens based upon input from said remote control device.

15. The remote ophthalmic system of claim 11 wherein said first processor is configured to receive at least one laser parameter for the plurality of target values for application of said ophthalmic laser device from said remote control device.

16. A method for making a remote ophthalmic system comprising:  
providing an examination device comprising an ophthalmic laser device, and a first processor coupled to the ophthalmic laser device; and

providing a remote control device to be associated with a user, to be remote to the examination device, and to be in communication with the examination device over a communication network;

the first processor configured to

receive a plurality of target values for application of the ophthalmic laser device from the remote control device, the plurality of target values for application of the ophthalmic laser device being associated with at least one ophthalmic procedure on a patient, and

perform the at least one ophthalmic procedure on the patient by applying the ophthalmic laser device based upon the plurality of target values.

17. The method of claim 16 wherein the examination device comprises an image sensor device coupled to the first processor and configured to generate image data associated with an eye of the patient; and wherein the first processor is configured to transmit the image data to the remote control device.

18. The method of claim 17 wherein the remote control device comprises a display, and a second processor coupled to the display; and wherein the second processor is configured to receive the image data, and display the image data on the display.

19. The method of claim 18 wherein the remote control device comprises a user input interface coupled to the second processor; and wherein the second processor is configured to generate the plurality of target values for application of the ophthalmic laser device based upon input from the user input interface.

20. The method of claim 19 wherein the user input interface comprises a directional input, at least one video feed, and a plurality of control inputs.

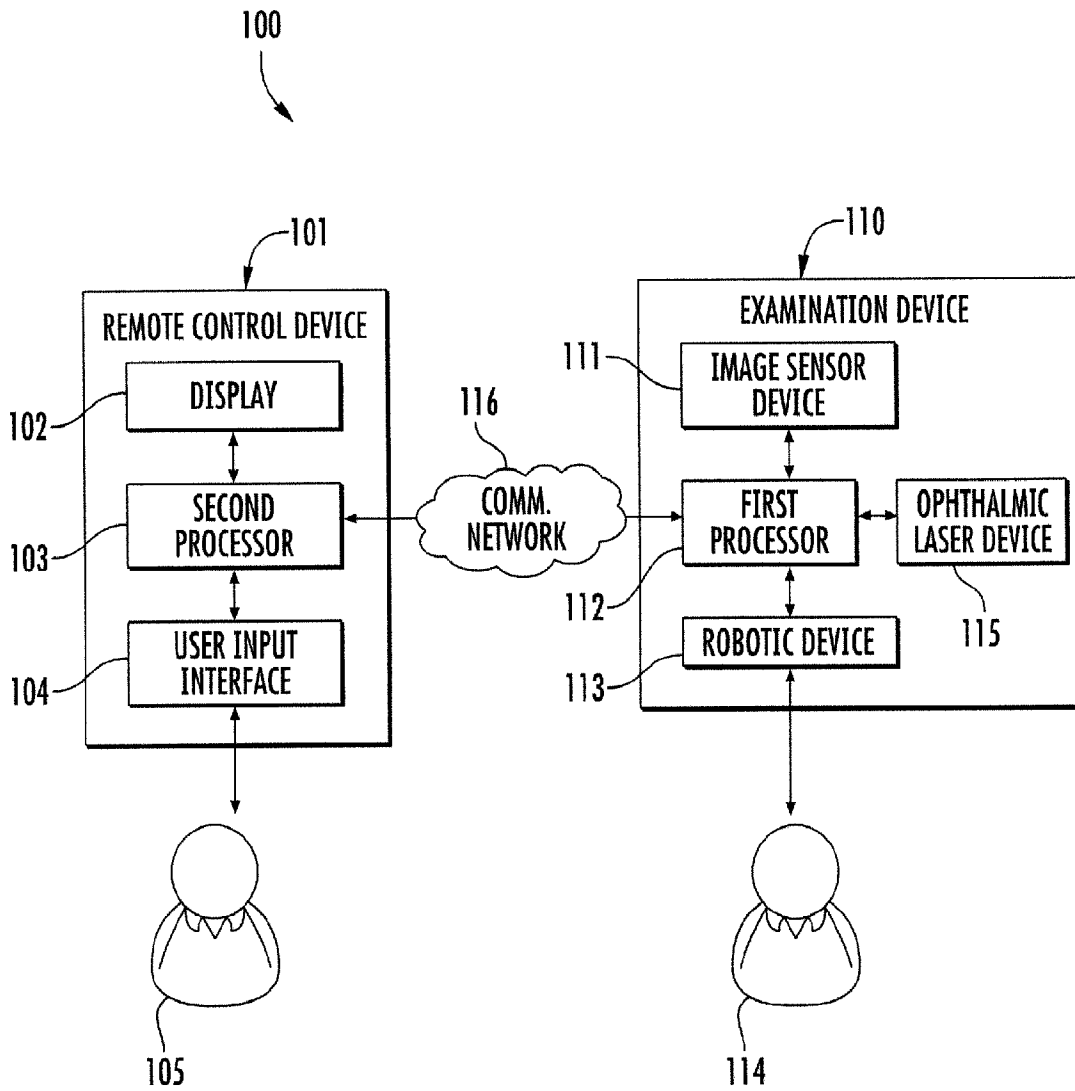


FIG. 1

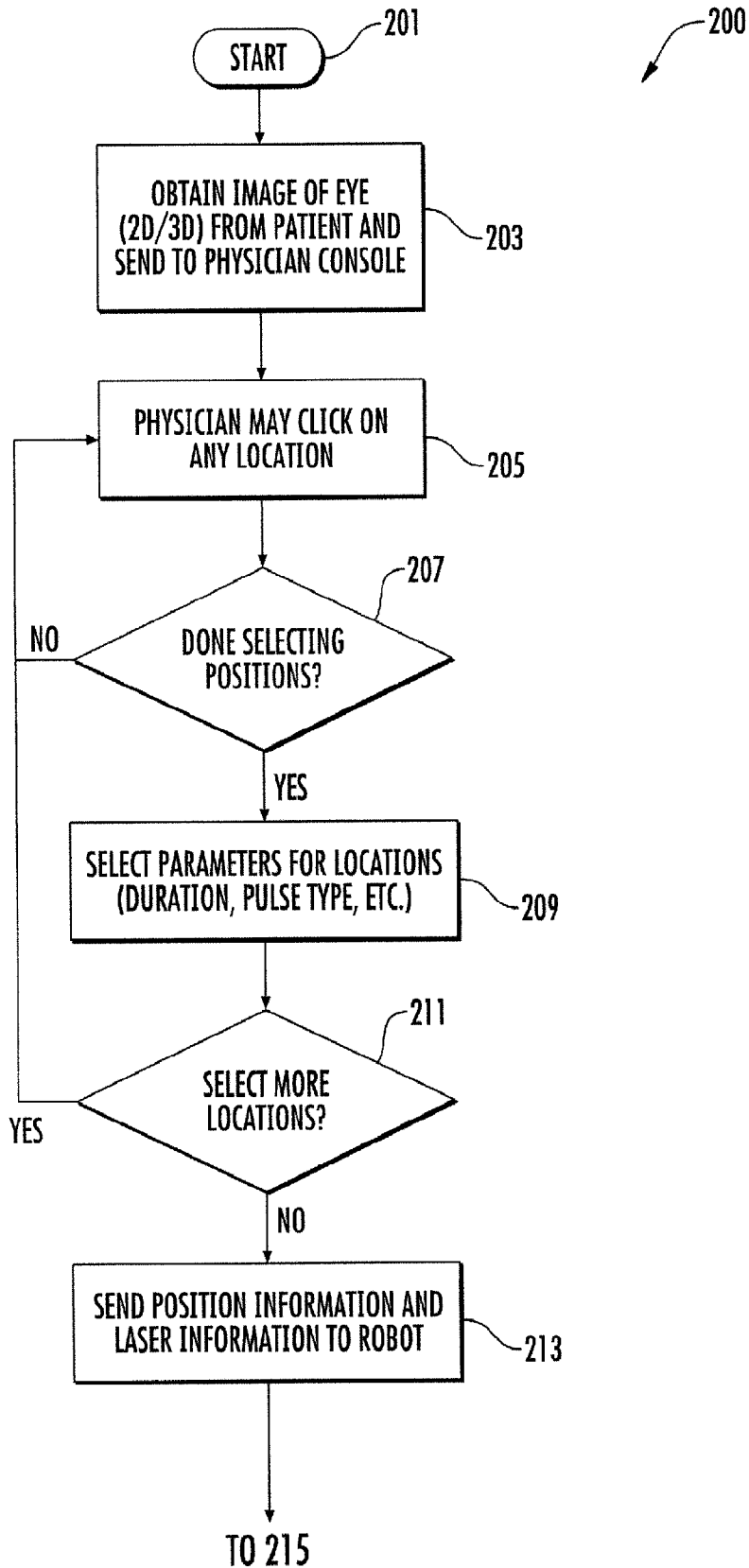


FIG. 2A

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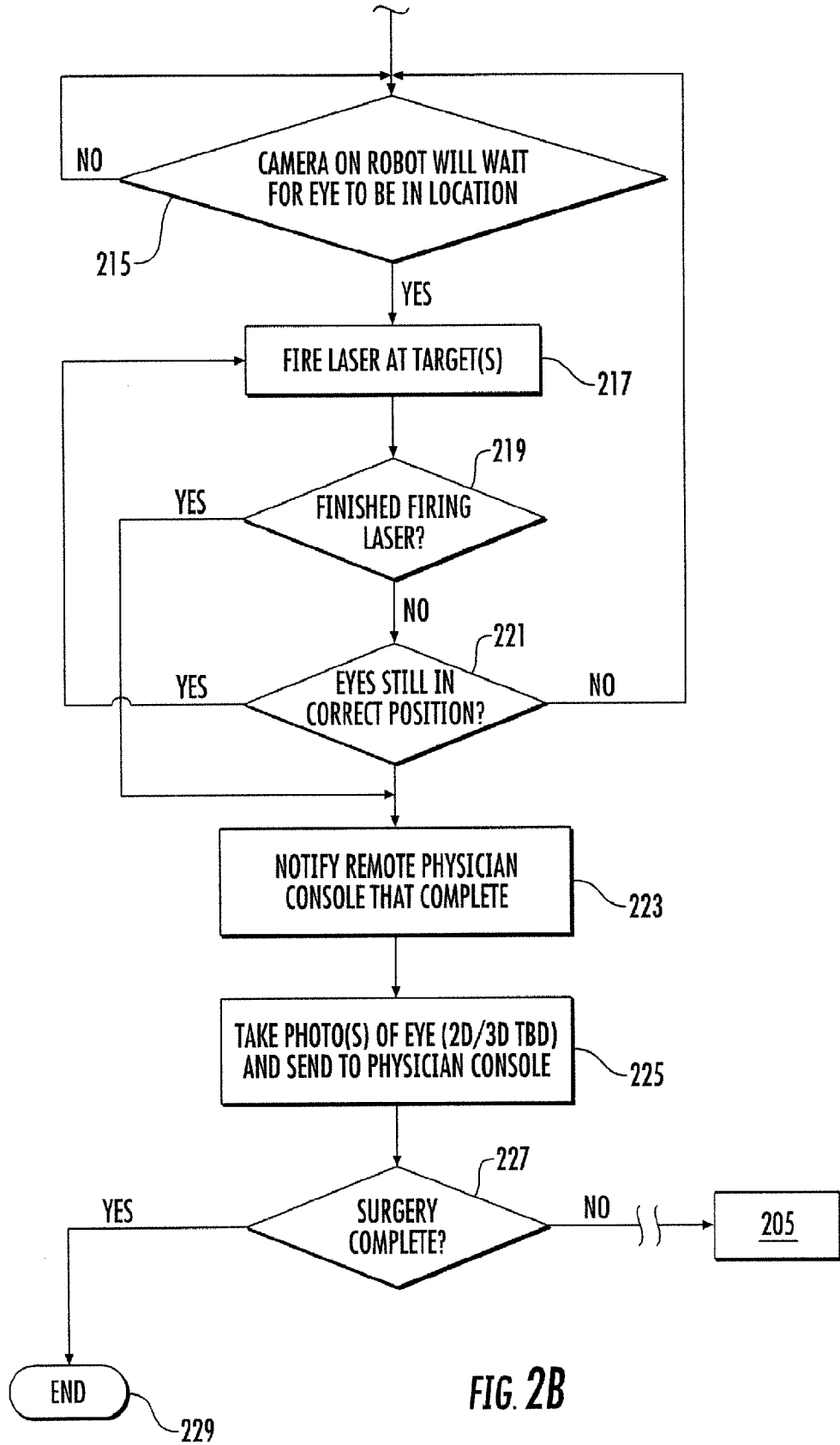
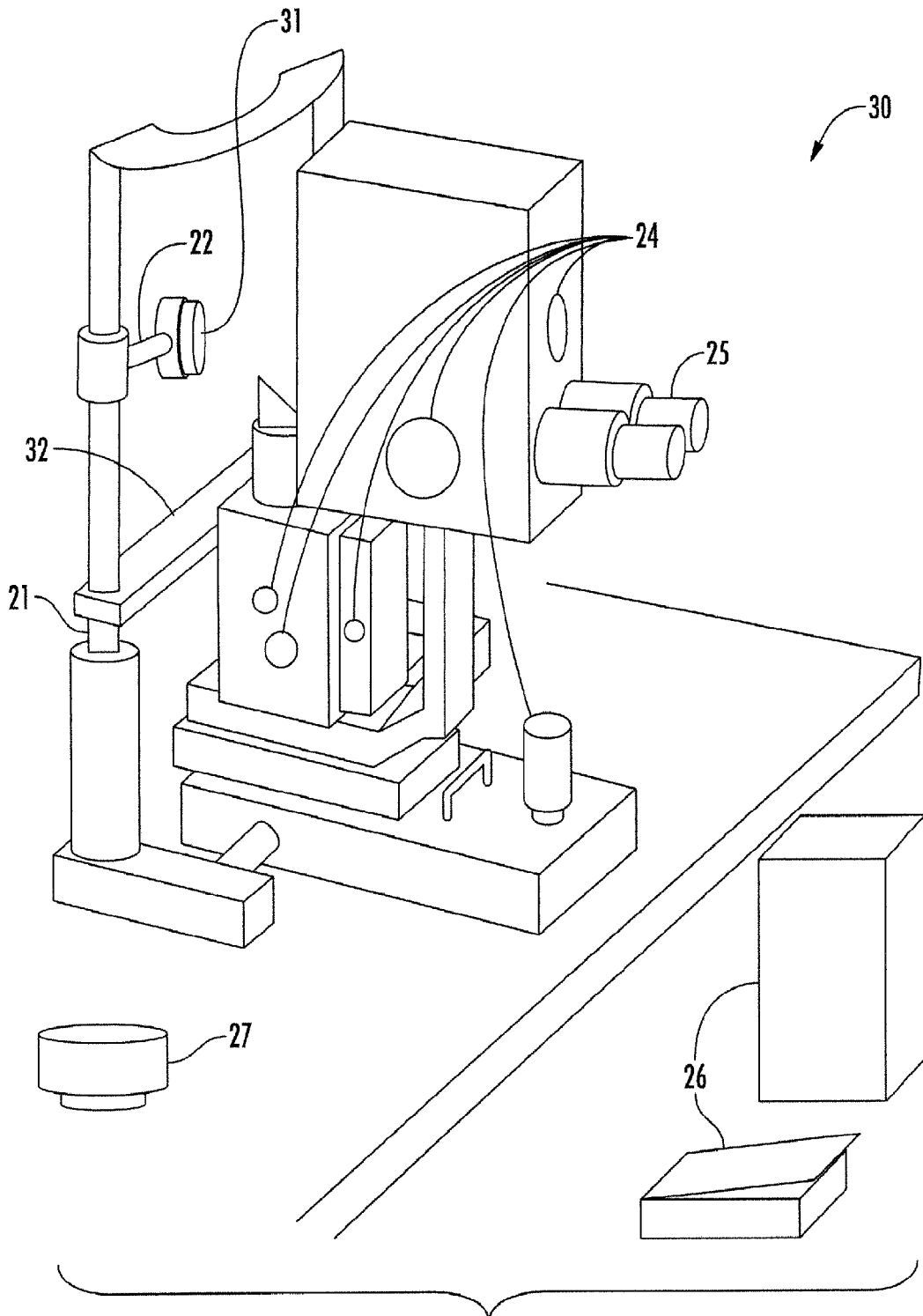


FIG. 2B



**FIG. 3**

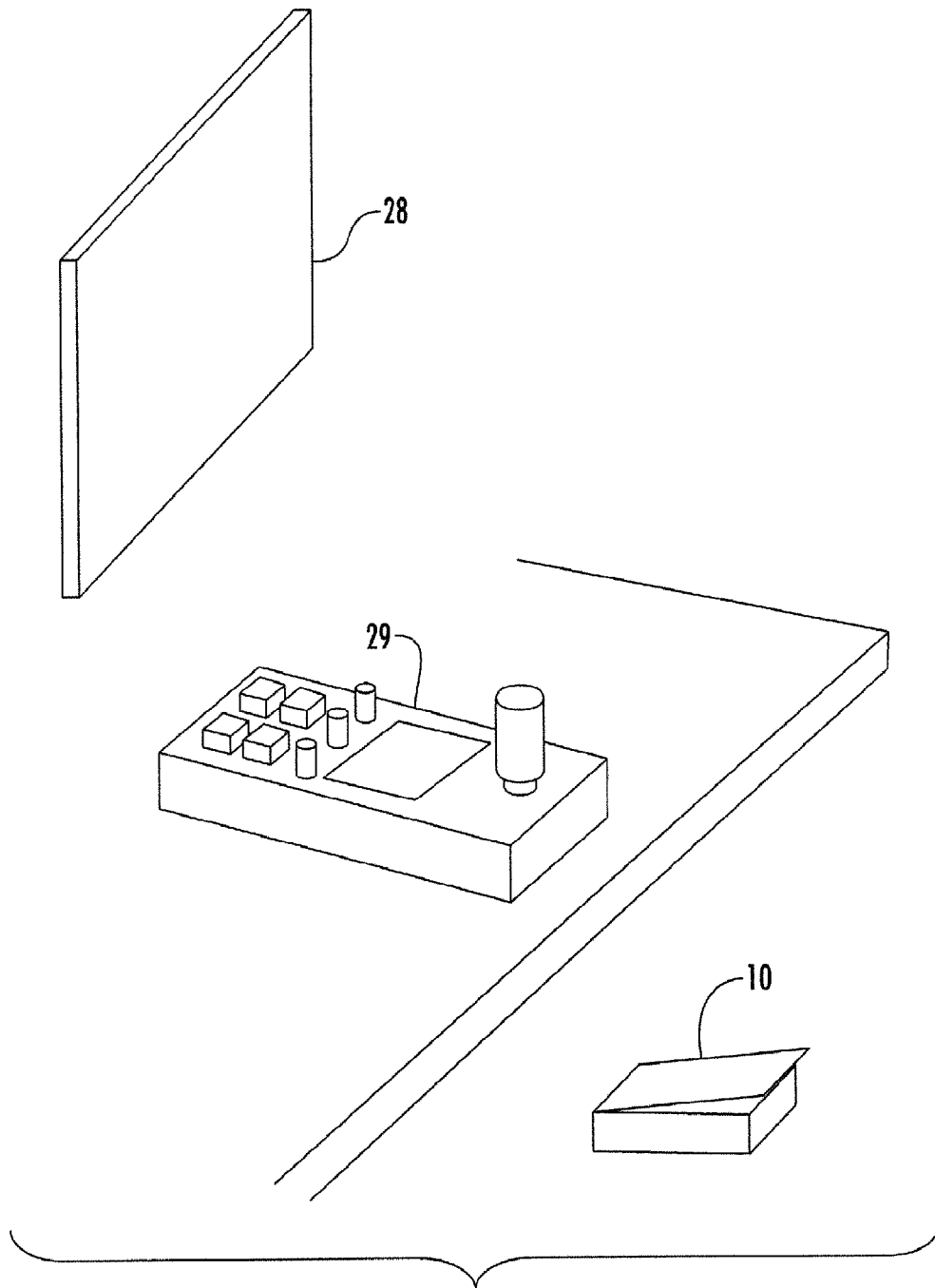


FIG. 4

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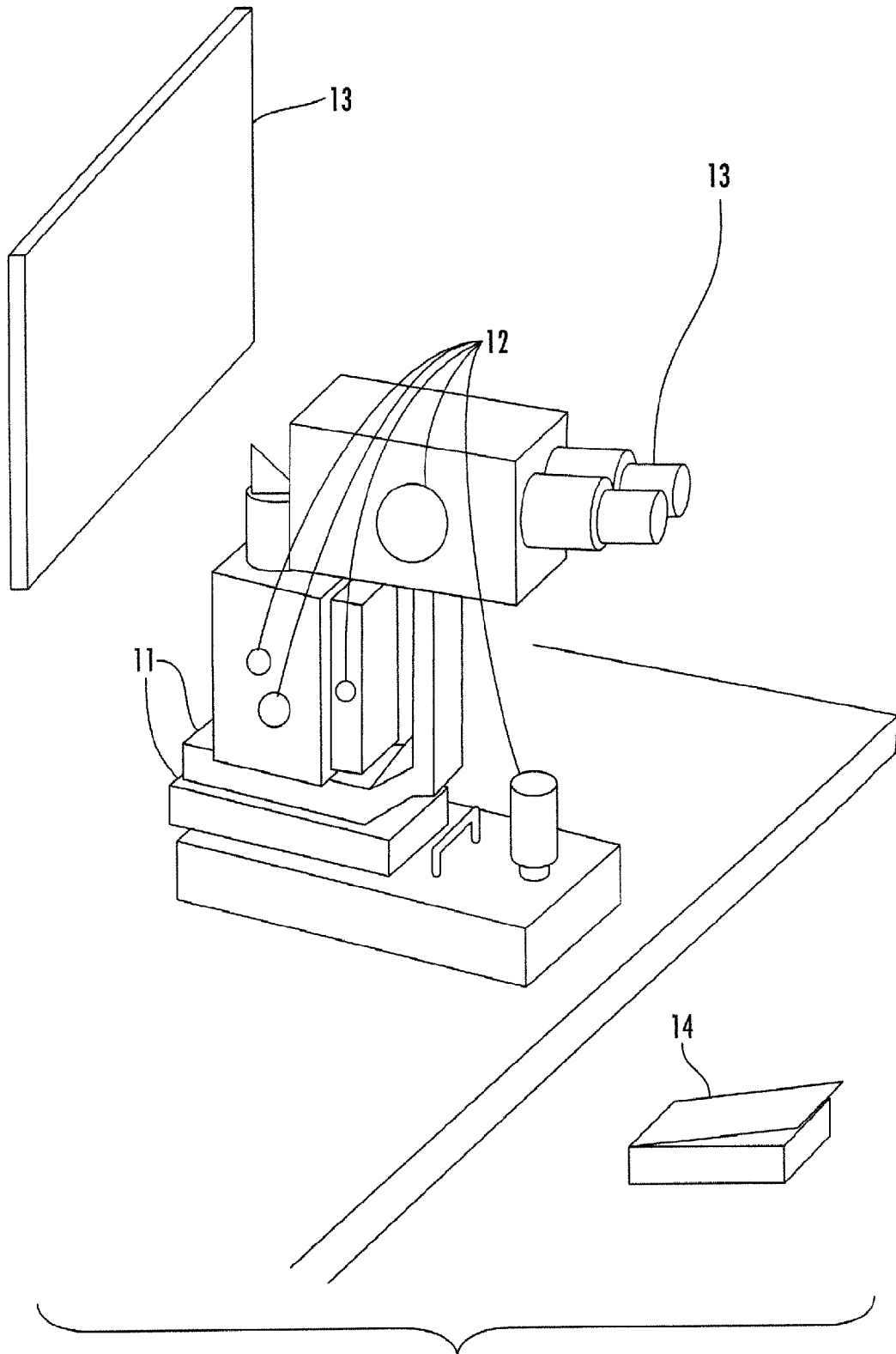


FIG. 5

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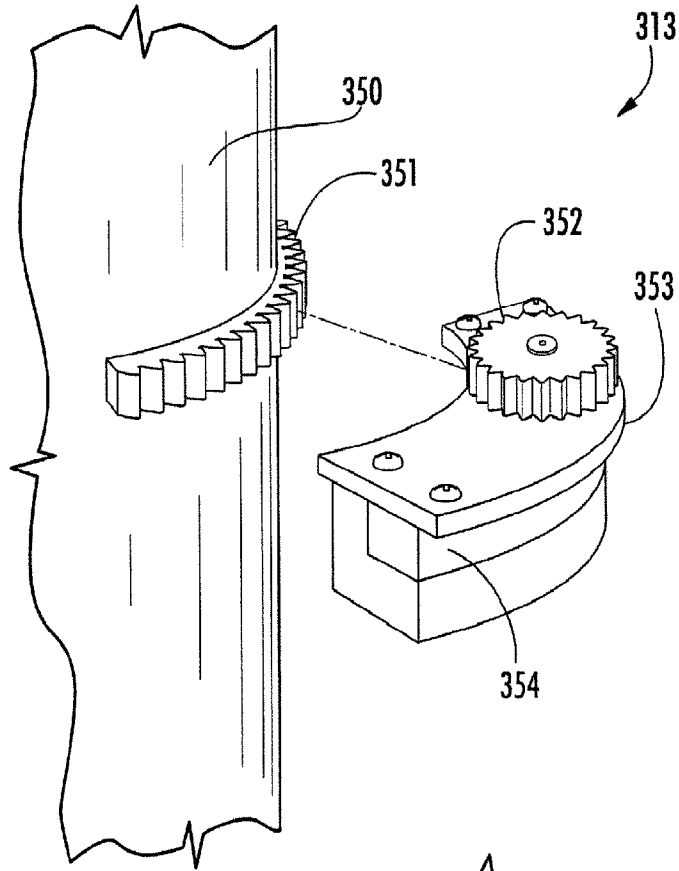


FIG. 6

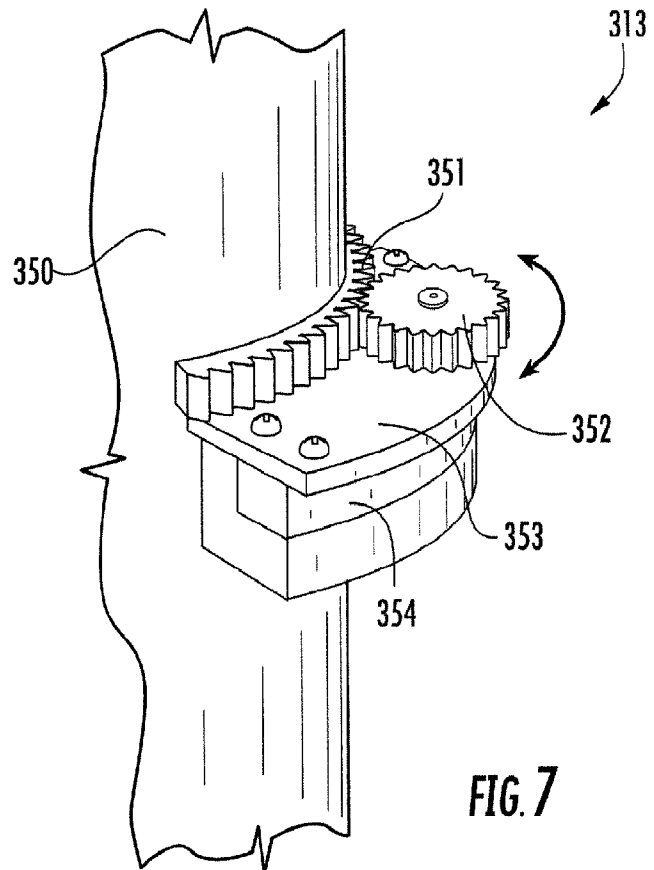


FIG. 7

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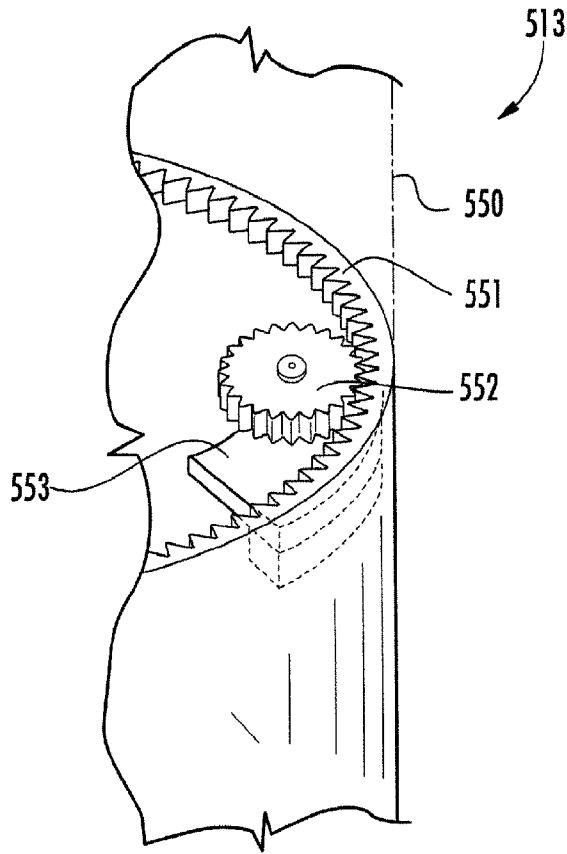


FIG. 8

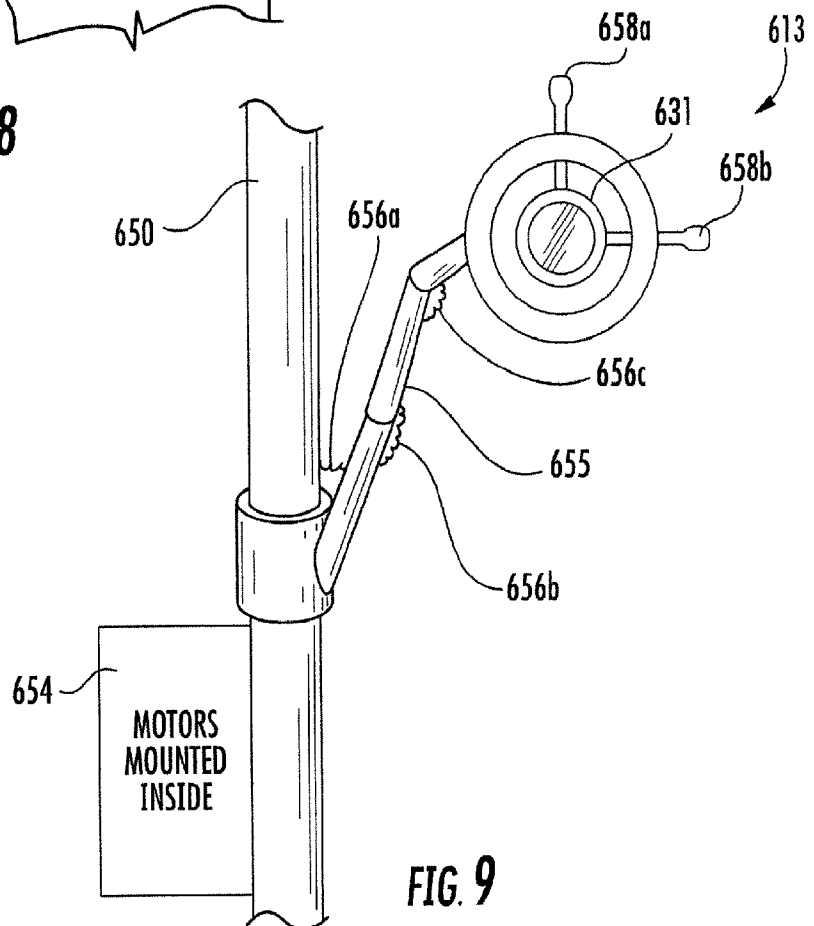


FIG. 9

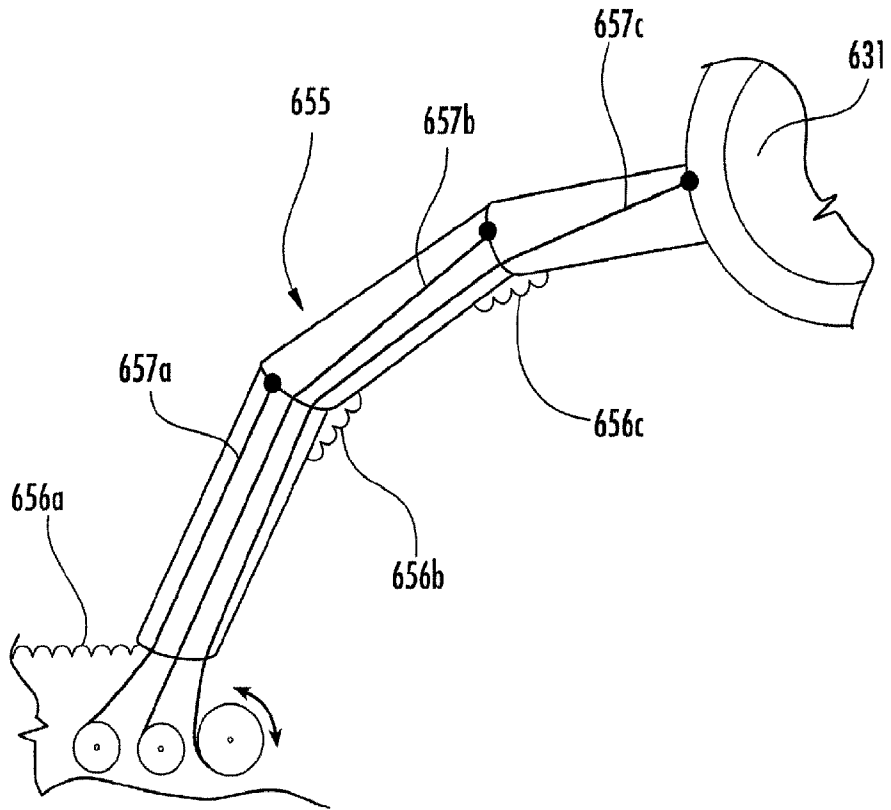


FIG. 10

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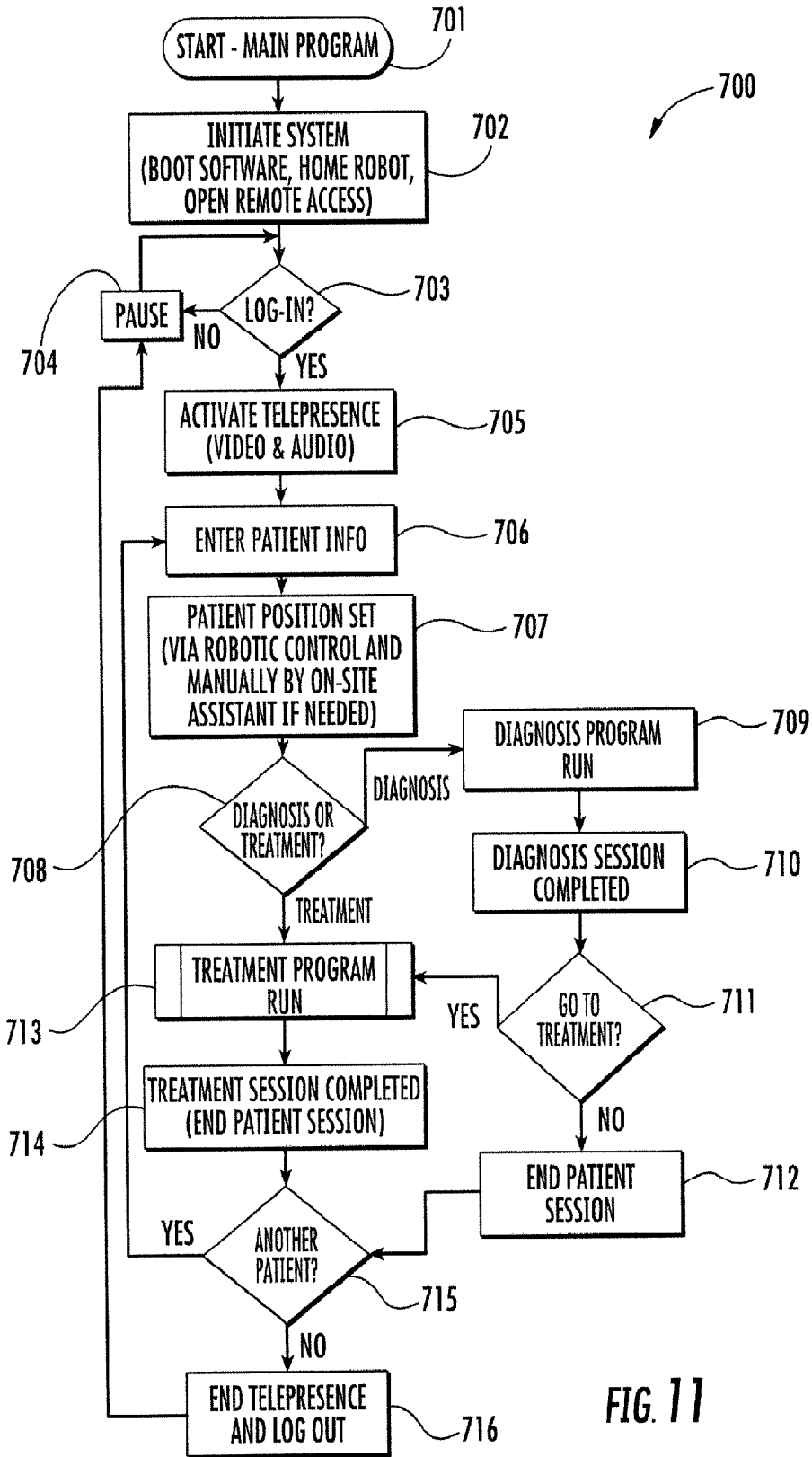


FIG. 11

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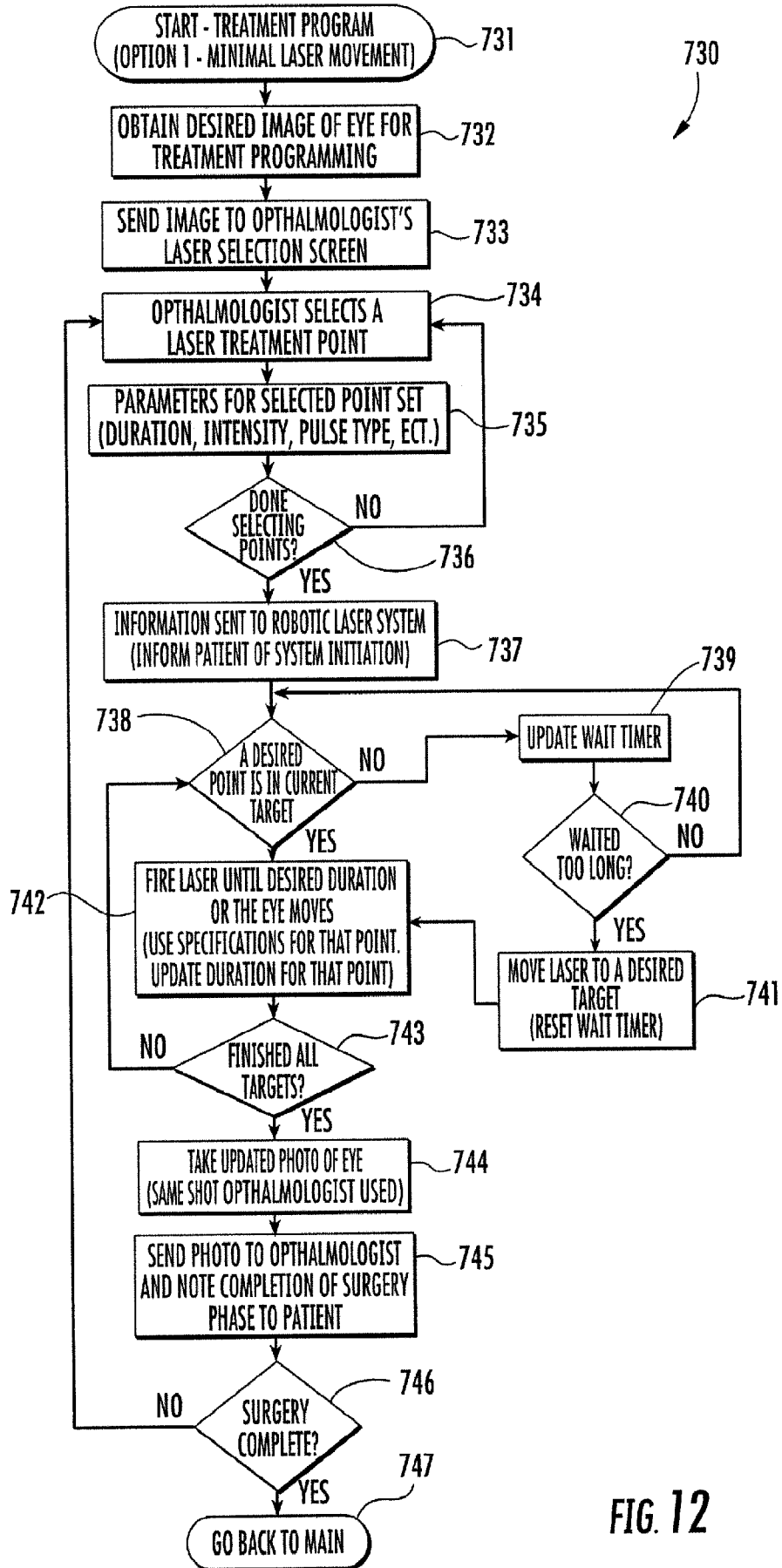


FIG. 12

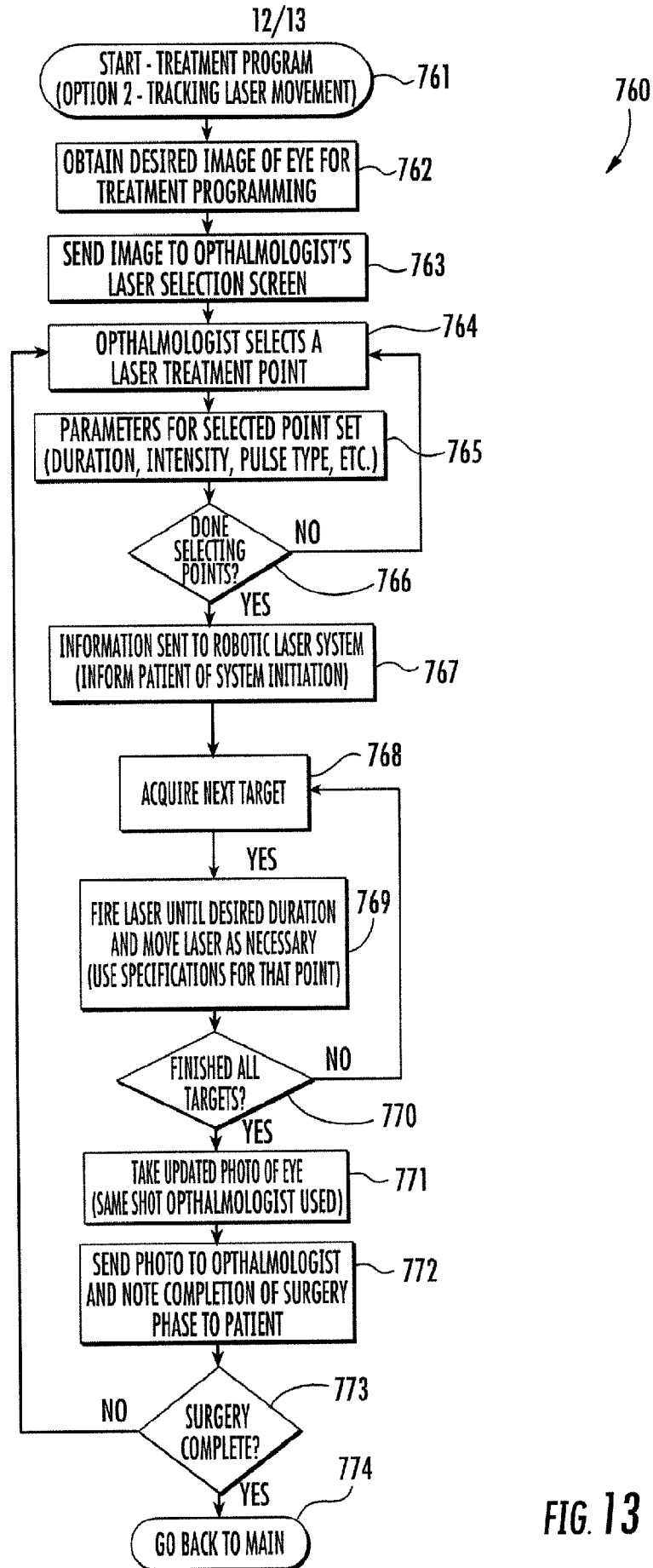


FIG. 13

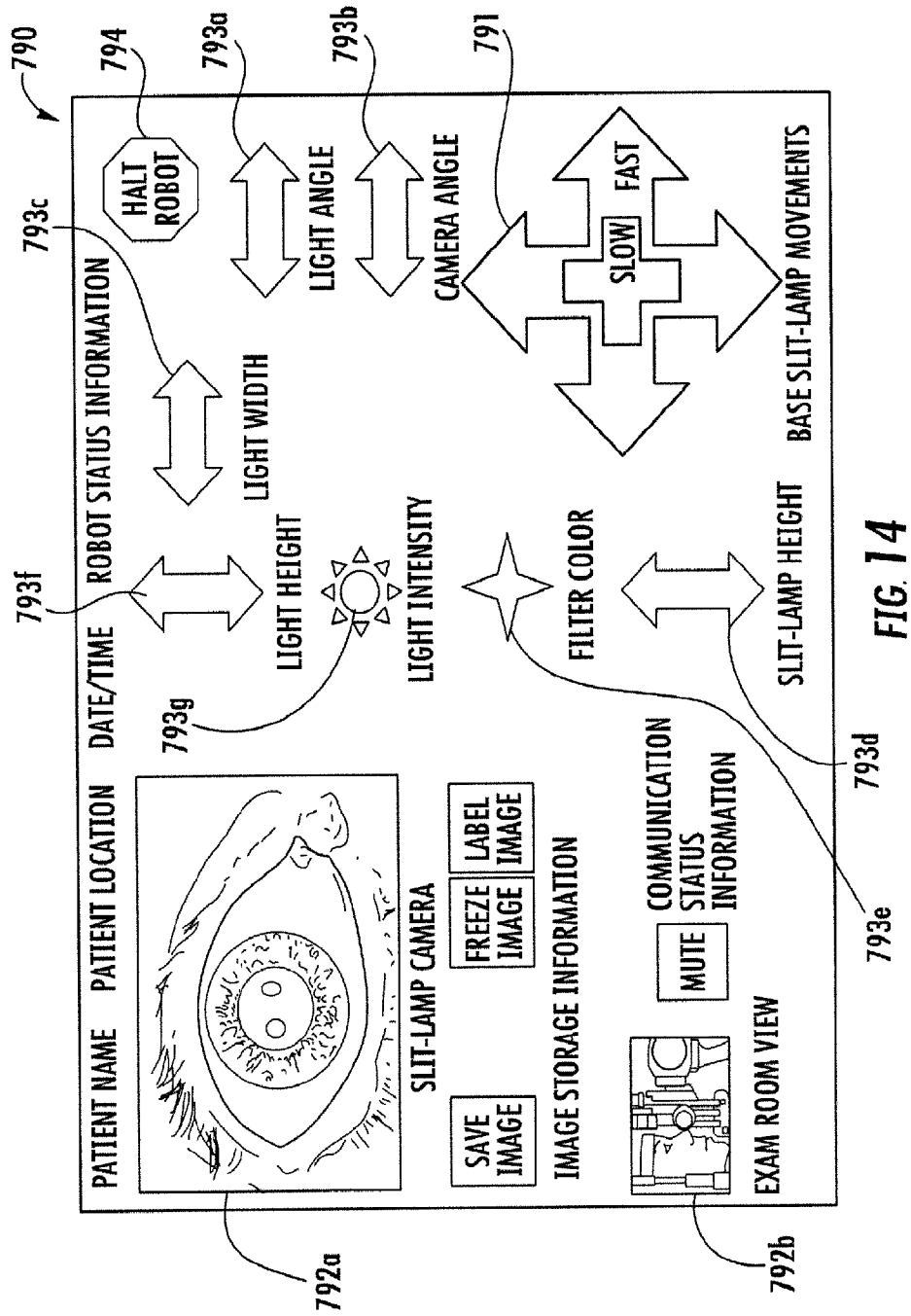


FIG. 14

**INTERNATIONAL SEARCH REPORT**

International application No  
PCT/US2016/030910

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> INV. A61F9/008 ADD. A61B34/35		
According to International Patent Classification (IPC) or to both national classification and IPC		
<b>B. FIELDS SEARCHED</b> Minimum documentation searched (classification system followed by classification symbols) A61F A61B		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/054358 A1 (COX IAN G [US] ET AL) 18 March 2004 (2004-03-18)	1-5,8,9
Y	paragraphs [0010] - [0013], [0059], [0060], [0121] - [0124] figures 1-4, 12	6,7, 10-15
	-----	
X	US 2003/208189 A1 (PAYMAN GHOLAM A [US]) 6 November 2003 (2003-11-06)	1-15
Y	paragraphs [0014] - [0020], [0050] - [0052], [0077] - [0082]	6,7, 10-15
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X	WO 97/46183 A1 (CHIRON TECHNOLOGAS GMBH [DE]; HOHLA KRISTIAN [DE]) 11 December 1997 (1997-12-11) page 2, line 4 - page 7, line 13 figures 1-4	1-5,8,9
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<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	
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family	
"P" document published prior to the international filing date but later than the priority date claimed		
Date of the actual completion of the international search	Date of mailing of the international search report	
27 July 2016	05/08/2016	
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer  Lohmann, Stefan	

# INTERNATIONAL SEARCH REPORT

International application No  
PCT/US2016/030910

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 368 015 A (WILK PETER J [US]) 29 November 1994 (1994-11-29) column 5, line 13 - column 10, line 19 -----	1-5,8,9

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US2016/030910

## Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.  Claims Nos.: 16-20  
because they relate to subject matter not required to be searched by this Authority, namely:  
Rule 39.1(iv) PCT - Method for treatment of the human or animal body by surgery
2.  Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3.  Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1.  As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2.  As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3.  As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4.  No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

### Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2016/030910

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