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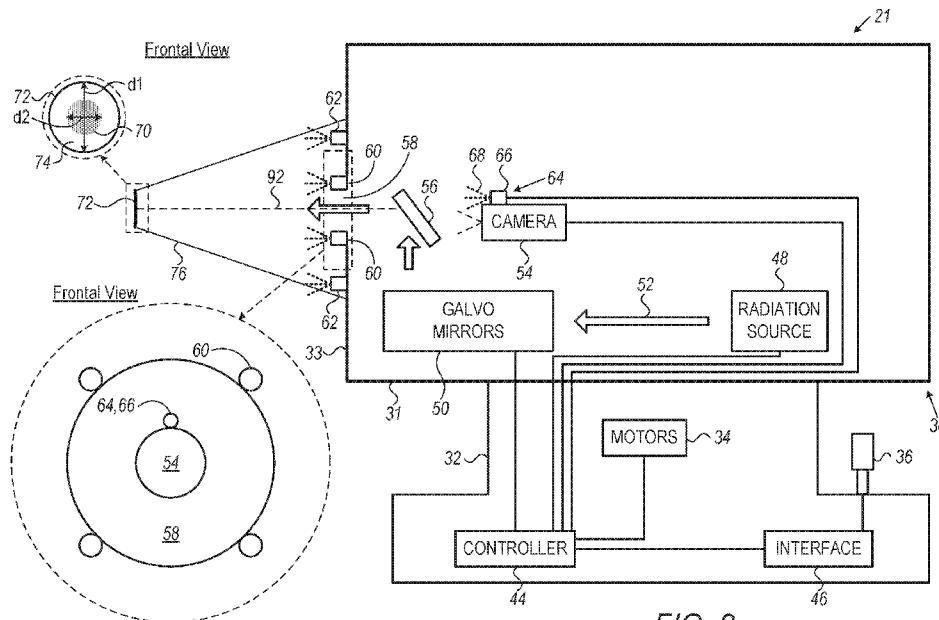


FIG. 2

(57) Abstract: An apparatus includes an optical unit (30), including a light source (66), one or more beam-directing elements (50, 56), and a radiation source (48). The radiation source is configured to irradiate an eye (25) of a patient (22) with one or more treatment beams (52) by emitting the treatment beams toward the beam-directing elements, while the eye fixates on the light source by virtue of the light source transmitting visible light (68). The apparatus further includes an optical filter (70) configured to inhibit passage of the treatment beams, but not the visible light, therethrough, while interposing between the beam-directing elements and a pupil (104) of the eye. Other embodiments are also described.

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PROTECTION FOR DIRECT SELECTIVE LASER TRABECULOPLASTY

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims the benefit of US Provisional Appl. No. 62/751,629, entitled “DSLTL Eye Protection,” filed October 28, 2018, whose disclosure is incorporated herein by
5 reference.

FIELD OF THE INVENTION

The present invention relates to ophthalmological devices and methods for the treatment of glaucoma, ocular hypertension (OHT), and other diseases.

BACKGROUND

10 In a trabeculoplasty procedure, a radiation source, typically a laser, irradiates the trabecular meshwork in an eye of a patient with one or more treatment beams, thus lowering the intraocular pressure in the eye.

US Patent 4,848,894 describes a contact lens made either with a laser-reflecting or absorbing layer embedded in a transparent optical lens material, or formed as a layer on the convex
15 side of such a material. The layer may be a Fabry-Perot reflector or a thin-film or holographically formed reflective or absorptive interference filter, or an absorbing layer.

US Patent 4,966,452 describes a contact lens for use in connection with transscleral cyclophotocoagulation. The lens has a planar entry surface and a frustoconically-shaped exit surface that contacts the sclera surrounding the cornea. The central portion of the lens is opaque
20 to prevent stray laser light from entering the optical portion of the eye during laser application.

US Patent 6,948,815 describes individually marked contact lenses for protection of one's eyes from harmful radiation. Contact lenses are coated or treated to be absorptive or reflective to a preselected wavelength or wavelengths. The lenses contain one or more identification areas on each lens to demonstrate that the lenses are being worn and to indicate the proper applications with
25 which the lenses should be used and/or the wavelengths for which the lens is protective. The identification area, which should be visible when worn to third parties and/or the person wearing the lenses, consists of markings such as colored bands or shaded areas in the region around the iris. Different colors or color patterns of the markings indicate which wavelengths the lens protects against. Other safety features may include fluorescent markers, added features and devices to

facilitate placement and retention in the eye, pick-up or release.

US Patent 8,004,764 describes a filter and method for filtering an optical beam. One embodiment of the filter is an optical filter for filtering an incident light beam, comprising an optically effective material characterized by: a light transmittance of less than 1% for wavelengths
5 below 420 nm; and a light transmittance for wavelengths complementary and near complementary to wavelengths below 420 nm that, combined with the transmittance for wavelengths below 420 nm, will yield a filtered light beam having a luminosity of about 90% and an excitation purity of 5% or less. The complementary wavelengths can be wavelengths above about 640 nm, wavelengths above about 660 nm, and/or wavelengths from about 540 nm to about 560 nm.

10 US Patent 9,480,599 describes an ophthalmic laser ablation system with various optional features, some especially suitable for non-penetrating filtration surgery on an eye. In one example, focusing of an ablation laser uses a movable lens coupled to a pair of converging light sources, which converge at the focal distance of the lens. In another example, laser ablation settings are selected for optimal ablation and minimal amount of thermal damage of a layer of percolating
15 scleral tissue.

International Patent Application Publication WO/1998/022016 describes a combination of a scanning laser ophthalmoscope and a photocoagulator. The device includes a therapeutic laser source, optic-mechanical Maxwellian view coupling, Maxwellian view control, and real-time electronic registration of the therapeutic beam location.

20 SUMMARY OF THE INVENTION

There is provided, in accordance with some embodiments of the present invention, an apparatus including an optical unit. The optical unit includes a light source, one or more beam-directing elements, and a radiation source. The radiation source is configured to irradiate an eye of a patient with one or more treatment beams by emitting the treatment beams toward the beam-
25 directing elements, while the eye fixates on the light source by virtue of the light source transmitting visible light. The apparatus further includes an optical filter configured to inhibit passage of the treatment beams, but not the visible light, therethrough, while interposing between the beam-directing elements and a pupil of the eye.

In some embodiments, the apparatus further includes an eye-stabilizing structure, the
30 radiation source is configured to irradiate the eye by emitting the treatment beams through the structure, and the optical filter is coupled to the structure.

In some embodiments, a proximal end of the structure is configured to couple to the optical

unit.

In some embodiments, the optical filter is coupled to a distal end of the structure.

In some embodiments, the apparatus further includes a contact optic including the optical filter, and the contact optic is coupled to the distal end of the structure and is configured to contact
5 the eye.

In some embodiments, a distal end of the structure is configured to contact the eye, and the optical filter is mounted to an inner wall of the structure.

In some embodiments, the optical filter is mounted between 0.5 and 20 mm from the distal end of the structure.

10 In some embodiments, the distal end of the structure includes a contact optic configured to contact the eye.

In some embodiments, the distal end of the structure includes a contact ring configured to contact the eye.

In some embodiments, the apparatus further includes one or more longitudinal elements
15 extending between the inner wall of the structure and the optical filter, the optical filter being mounted to the inner wall via the longitudinal elements.

In some embodiments, an inner wall of the structure is configured to absorb the treatment beams.

In some embodiments, a treatment-beam wavelength of the treatment beams is between
20 200 and 11000 nm, and a visible-light wavelength of the visible light is between 350 and 850 nm.

In some embodiments, the optical filter is configured to inhibit the passage of the treatment beams by absorbing the treatment beams.

In some embodiments, the optical filter is configured to inhibit the passage of the treatment beams by reflecting the treatment beams.

25 In some embodiments, the optical filter includes an anti-reflective surface configured to reduce reflection of the treatment beams.

In some embodiments, the apparatus further includes an optic including:
the optical filter; and

a transparent portion that surrounds the optical filter and is transparent to the treatment
30 beams.

In some embodiments,
the optical filter is a first optical filter, and
the optic further includes a second optical filter that surrounds the transparent portion and
is configured to inhibit the passage of the treatment beams.

5 In some embodiments, the apparatus further includes a contact optic including the optical
filter, and the contact optic is configured to contact the eye.

In some embodiments, a thickness of the contact optic is less than 2 mm.

In some embodiments, a diameter of the contact optic is less than 10 mm.

In some embodiments,
10 the optical unit includes a front face, and
the optical filter is coupled to the front face.

In some embodiments,
the front face includes an exit window,
the light source is configured to transmit the visible light, and the radiation source is
15 configured to emit the treatment beams, through the exit window, and
the optical filter overlays the exit window.

In some embodiments,
the front face includes an exit window,
the light source is configured to transmit the visible light, and the radiation source is
20 configured to emit the treatment beams, through the exit window, and
the optical filter is embedded within the exit window.

In some embodiments, the apparatus further includes a longitudinal element extending
between the front face and the optical filter, the optical filter being coupled to the front face via
the longitudinal element.

25 In some embodiments,
the front face includes an exit window,
the light source is configured to transmit the visible light, and the radiation source is
configured to emit the treatment beams, through the exit window, and
the longitudinal element extends between the exit window and the optical filter.

30 There is further provided, in accordance with some embodiments of the present invention,
a method including interposing an optical filter between one or more beam-directing elements and

a pupil of an eye of a patient. The method further includes, while the optical filter interposes between the beam-directing elements and the pupil, using a light source, transmitting visible light through the optical filter and, while the eye fixates on the light source by virtue of the light source transmitting the visible light, irradiating the eye with one or more treatment beams by emitting the treatment beams toward the beam-directing elements, the optical filter being configured to inhibit
5 passage of the treatment beams therethrough.

In some embodiments, the optical filter belongs to a contact optic, and interposing the optical filter includes interposing the optical filter by contacting the eye with the contact optic.

There is further provided, in accordance with some embodiments of the present invention,
10 a system including a camera, configured to acquire an image of an eye of a patient, a radiation source, and a controller. The controller is configured to identify a static region in a field of view of the camera that, in the image, is outside a limbus of the eye, and to treat one or more target regions of the eye, by, for each target region, ascertaining that the target region is not within the static region, and in response to the ascertaining, causing the radiation source to irradiate the target
15 region.

There is further provided, in accordance with some embodiments of the present invention, a method including, using a camera, acquiring an image of an eye of a patient. The method further includes identifying a static region in a field of view of the camera that, in the image, is outside a limbus of the eye. The method further includes treating one or more target regions of the eye, by,
20 for each target region, ascertaining that the target region is not within the static region, and in response to the ascertaining, irradiating the target region.

There is further provided, in accordance with some embodiments of the present invention, an apparatus including an optical unit. The optical unit includes a light source, configured to transmit visible light, one or more beam-directing elements, and a radiation source, configured to
25 irradiate a first eye of a patient with one or more treatment beams by emitting the treatment beams toward the beam-directing elements such that the beam-directing elements direct the treatment beams along an optical path to the first eye. The apparatus further includes an optical filter configured to inhibit the visible light and the treatment beams from reaching a pupil of the first eye. The light source is displaced from the optical path towards a second eye of the patient, and
30 the radiation source is configured to irradiate the first eye while the second eye fixates on the light source by virtue of the light source transmitting the visible light.

In some embodiments, the light source is displaced from the optical path by 18-44 mm.

There is further provided, in accordance with some embodiments of the present invention, a method, including interposing an optical filter, which is opaque to visible light transmitted by a light source and to treatment beams emitted by a radiation source, between (i) one or more beam-directing elements and (ii) a pupil of a first eye of a patient. The method further includes, while a second eye of the patient fixates on the light source by virtue of the light source transmitting the visible light, using the radiation source, irradiating the first eye with the treatment beams by emitting the treatment beams toward the beam-directing elements.

In some embodiments, the beam-directing elements direct the treatment beams along an optical path to the first eye, and the method further includes, prior to irradiating the first eye, displacing the light source from the optical path towards the second eye.

The present invention will be more fully understood from the following detailed description of embodiments thereof, taken together with the drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic illustration of a system for performing a trabeculoplasty procedure, in accordance with some embodiments of the present invention;

Fig. 2 is a schematic illustration of a trabeculoplasty device, in accordance with some embodiments of the present invention;

Figs. 3A-B are schematic illustrations of an eye-stabilizing structure as viewed from the side and from the front, respectively, in accordance with some embodiments of the present invention;

Figs. 4A-B are schematic illustrations of an eye-stabilizing structure as viewed from the side and from the front, respectively, in accordance with some embodiments of the present invention;

Figs. 5-6 are schematic illustrations of an optical filter coupled to an optical unit, in accordance with some embodiments of the present invention;

Fig. 7 is a schematic illustration of a technique for orienting an eye for treatment, in accordance with some embodiments of the present invention; and

Fig. 8 is a schematic illustration of an image of an eye treated in accordance with some embodiments of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

OVERVIEW

Embodiments of the present invention provide an automated trabeculoplasty device configured to perform a trabeculoplasty procedure on an eye safely and efficiently. The trabeculoplasty device comprises a controller and an optical unit, which comprises a radiation source (typically a laser), a camera and one or more illumination sources for imaging, one or more beam-directing elements, and a light source. By transmitting (i.e., emitting or reflecting) visible light, the light source functions as a fixation target for the eye. While the eye fixates on the light source, the controller, in response to feedback from the camera, causes the beam-directing elements to direct beams of radiation, which are emitted by the radiation source, toward targeted regions of the eye, which are typically located in the vicinity of the limbus of the eye.

Embodiments of the present invention further provide an optical filter that is opaque to the treatment beams, but not to the visible light transmitted by the light source. By interposing between the optical unit and the pupil of the eye, the optical filter protects the retina of the eye from any stray radiation beams without inhibiting the eye from fixating on the fixation target.

In some embodiments, the optical filter belongs to a contact optic, which is worn in the eye without being held in place by any other element of the system. In other embodiments, the optical filter is mounted within or at the end of an eye-stabilizing structure, such as a hollow frustum-shaped structure, extending between the optical unit and the eye. In addition to supporting the optical filter, the eye-stabilizing structure may perform additional functions; for example, the eye-stabilizing structure may hold the eye open, stabilize the eye, and/or absorb any misaimed treatment beams. In yet other embodiments, the optical filter overlays the exit window of the optical unit, is embedded within the exit window, or is otherwise coupled to the optical unit.

In some embodiments, the peripheral portion of the eye lying outside the target regions is also protected. This protection may be provided by an additional (physical) optical filter. Alternatively or additionally, this protection may be provided by a virtual filter, in that the controller may identify a region in the camera's FOV in which the peripheral portion of the eye is located, and then inhibit the treatment beams from being fired at this region.

Although the present description focuses mainly on trabeculoplasty procedures, the techniques described herein may also be applied to automatic photocoagulation procedures, iridotomy procedures, corneal procedures, capsulectomy procedures, lens removals, or any other relevant ophthalmological procedures. The target of the radiation may include the trabecular meshwork and/or any other suitable portion of the eye. Embodiments of the present invention

may be used to treat glaucoma, ocular hypertension (OHT), and other diseases.

It is noted that in the context of the present application, including the claims, an optical element is said to be “opaque” to visible light transmitted therethrough if the element attenuates the light (by reflection and/or absorption) to an intensity that is less than the minimum intensity at which an average human eye is able to perceive the light. For other types of radiation, the optical element is said to be opaque to the radiation if the element attenuates the radiation (by reflection and/or absorption) to an intensity that is less than the maximum permissible exposure (MPE) value for the radiation as defined in any relevant standard, such as the International Electrotechnical Commission (IEC) 60825 standard.

Conversely, in the context of the present application, including the claims, an optical element is said to be “transparent” to radiation if the element is not opaque to the radiation.

SYSTEM DESCRIPTION

Reference is initially made to Fig. 1, which is a schematic illustration of a system 20, comprising a trabeculoplasty device 21, for performing a trabeculoplasty procedure, in accordance with some embodiments of the present invention. Reference is further made to Fig. 2, which is a schematic illustration of trabeculoplasty device 21, in accordance with some embodiments of the present invention.

Trabeculoplasty device 21 comprises an optical unit 30 and a controller 44. Optical unit 30 comprises one or more beam-directing elements, comprising, for example, one or more galvo mirrors 50, which may be referred to collectively as a “galvo scanner,” and/or a beam combiner 56. Optical unit 30 further comprises a radiation source 48, which is configured to irradiate an eye 25 of a patient 22 with one or more treatment beams 52 by emitting the treatment beams toward the beam-directing elements such that the beams are directed by the beam-directing elements toward the eye.

More specifically, before the emission of each treatment beam 52 from radiation source 48, or while the beam is being emitted, controller 44 aims the beam-directing elements at the desired target region on eye 25 such that the beam is directed, by the beam-directing elements, toward the target region. For example, the beam may be deflected by galvo mirrors 50 toward beam combiner 56, and then deflected by the beam combiner such that the beam impinges on the target region. (Since each treatment beam impinges on the eye with a non-infinitesimal spot size, the present application generally describes each beam as impinging on a “region” of the eye, whose area is a function of the spot size, rather than impinging at a “point” on the eye.) The beam thus

follows an optical path 92, which extends from the most downstream of the beam-directing elements – such as beam combiner 56 – to eye 25. (In practice, the respective paths of the beams vary slightly from each other due to the small distances between the target regions; however, given that this variation is very slight, the present description refers to a single optical path 92 followed by all the treatment beams.)

Typically, the radiation source comprises a laser, such as an EksplaTM NL204-0.5K-SH laser. The laser may be modified to include an attenuator, an energy meter, and/or a mechanical shutter. Alternatively or additionally to a laser, the radiation source may comprise any other suitable emitter.

In some embodiments, the treatment beams comprise visible light. Alternatively or additionally, the treatment beams may comprise non-visible radiation, such as microwave radiation, infrared radiation, X-ray radiation, gamma radiation, or ultraviolet radiation. Typically, the wavelength of the treatment beams is between 200 and 11000 nm, e.g., 500-850 nm, such as 520-540 nm, e.g., 532 nm. Each treatment beam 52 may have an elliptical (e.g., a circular) shape, a square shape, or any other suitable shape.

Optical unit 30 further comprises a camera 54. As shown in Fig. 2, camera 54 is typically aligned, at least approximately, with optical path 92; for example, the angle between optical path 92 and a hypothetical line extending from eye 25 to the camera may be less than 15 degrees. In some embodiments, the camera is positioned behind beam combiner 56, such that the camera receives light via the beam combiner.

Before the procedure, camera 54 acquires at least one image of eye 25. Based on the image, controller 44 and/or a user of the system, such as an ophthalmologist or another physician, may define and/or modify the target regions of the eye that are to be irradiated. Alternatively or additionally, based on the image, controller 44 may define one or more virtual filters, as further described below with reference to Fig. 8. Subsequently, during the procedure, camera 54 may acquire multiple images of the patient's eye at a relatively high frequency. Controller 44 may process these images and, in response thereto, control radiation source 48 and the beam-directing elements so as to irradiate the target regions of the eye.

Optical unit 30 further comprises a light source 66, which is aligned, at least approximately, with optical path 92. For example, the angle between optical path 92 and a hypothetical line extending from the end of path 92 on eye 25 to light source 66 may be less than 20 degrees, such as less than 10 degrees. Light source 66 is configured to function as a fixation target 64 by transmitting visible light 68. (It is noted that visible light 68 may also be described as a "fixation

beam” or as “fixation light.”)

In particular, prior to the procedure, patient 22 is instructed to fixate eye 25 on light source 66. Subsequently, during the procedure, by virtue of light source 66 transmitting visible light 68, eye 25 fixates on the light source, such that the eye’s line-of-sight is approximately coincident with optical path 92 (due to the light source being approximately aligned with the optical path) and the eye is relatively stable. While the eye fixates on the light source, the radiation source irradiates the eye with treatment beams 52. Light source 66 may also help orient the eye while an aiming beam is swept across the eye prior to the procedure, as further described below with reference to Fig. 8.

In some embodiments, light source 66 comprises a light emitter, such as a light emitting diode (LED). In other embodiments, the light source comprises a reflector configured to reflect light emitted from a light emitter.

Typically, the wavelength of visible light 68, which may be higher or lower than that of the treatment beams, is between 350 and 850 nm. For example, visible light 68 may be red, with a wavelength of 600-700 nm, while the treatment beams may be green, with a wavelength of 527-537 nm.

Typically, the optical unit comprises an optical bench, and at least some of the aforementioned optical components belonging to the optical unit, such as the radiation source, the galvo mirrors, and the beam combiner, are coupled to the optical bench. Typically, the optical unit further comprises a front face 33, through which the treatment beams and visible light 68 pass. For example, optical unit 30 may comprise an encasement 31, which at least partially encases the optical bench and comprises front face 33. (Encasement 31 may be made of a plastic, a metal, and/or any other suitable material.) Alternatively, front face 33 may be attached to, or may be an integral part of, the optical bench.

In some embodiments, front face 33 is shaped to define an opening 58, through which the treatment beams and visible light 68 pass. In other embodiments, as shown in Fig. 5 (described below), the front face comprises an exit window in lieu of opening 58, such that visible light 68 and treatment beams 52 pass through the exit window. The exit window may be made of a plastic, a glass, or any other suitable material.

Typically, optical unit 30 further comprises one or more illumination sources 60 comprising, for example, one or more LEDs, such as white-light or infrared LEDs. For example, the optical unit may comprise a ring of LEDs surrounding opening 58. In such embodiments, controller 44 may cause illumination sources 60 to intermittently flash light at the eye, as described

in International Patent Application PCT/IB2019/055564, whose disclosure is incorporated herein by reference. This flashing may facilitate the imaging performed by the camera, and may further help constrict the pupil of the eye. (For ease of illustration, the electrical connection between controller 44 and illumination sources 60 is not shown explicitly in Fig. 2.) In some embodiments, illumination sources 60 are coupled to front face 33, as shown in Fig. 2.

To facilitate positioning the optical unit, the optical unit may comprise a plurality of beam emitters 62 (comprising, for example, respective laser diodes), which are configured to shine a plurality of triangulating range-finding beams on the eye, e.g., as described in International Patent Application PCT/IB2019/055564. In some embodiments, beam emitters 62 are coupled to front face 33, as shown in Fig. 2. In other embodiments, beam emitters 62 are coupled directly to the optical bench.

Optical unit 30 is mounted onto an XYZ stage unit 32, which is controlled by a control mechanism 36, such as a joystick. Using control mechanism 36, the user of system 20 may position the optical unit (e.g., by adjusting the distance of the optical unit from the eye) prior to treating the eye. In some embodiments, XYZ stage unit 32 comprises locking elements configured to inhibit motion of the stage unit following the positioning of the stage unit.

In some embodiments, XYZ stage unit 32 comprises one or more motors 34, and control mechanism 36 is connected to interface circuitry 46. As the user manipulates the control mechanism, interface circuitry 46 translates this activity into appropriate electronic signals, and outputs these signals to controller 44. In response to the signals, the controller controls the motors of the XYZ stage unit.

In other embodiments, XYZ stage unit 32 is controlled manually by manipulating the control mechanism. In such embodiments, the XYZ stage unit may comprise a set of gears instead of motors 34.

System 20 further comprises a headrest 24, comprising a forehead rest 26 and a chinrest 28. During the trabeculoplasty procedure, patient 22 presses his forehead against forehead rest 26 while resting his chin on chinrest 28. In some embodiments, headrest 24 further comprises an immobilization strap 27, configured to secure the patient's head from behind and thus keep the patient's head pressed against the headrest.

In some embodiments, as shown in Fig. 1, headrest 24 and XYZ stage unit 32 are both mounted onto a surface 38, such as a tray or tabletop. (In some such embodiments, the headrest is L-shaped, and is attached to the side, rather than the top, of surface 38.) In other embodiments, the XYZ stage unit is mounted onto surface 38, and the headrest is attached to the XYZ stage unit.

Typically, as shown in Fig. 1, while irradiating the patient's eye, the optical unit is directed obliquely upward toward the eye while the eye gazes obliquely downward toward the optical unit, such that optical path 92 is oblique. For example, the optical path may be oriented at an angle θ of between five and twenty degrees with respect to the horizontal. Advantageously, this orientation reduces occlusion of the patient's eye by the patient's upper eyelid and associated anatomy.

In some embodiments, as shown in Fig. 1, the oblique orientation of the optical path is achieved by virtue of the optical unit being mounted on a wedge 40, which is mounted on the XYZ stage unit. In other words, the optical unit is mounted onto the XYZ stage unit via wedge 40. (Wedge 40 is omitted from Fig. 2.)

System 20 further comprises a monitor 42, configured to display the images of the eye acquired by the camera. Monitor 42 may be attached to optical unit 30 or disposed at any other suitable location, such as on surface 38 next to device 21. In some embodiments, monitor 42 comprises a touch screen, and the user inputs commands to the system via the touch screen. Alternatively or additionally, system 20 may comprise any other suitable input devices, such as a keyboard or a mouse, which may be used by the user.

In some embodiments, monitor 42 is connected directly to controller 44 over a wired or wireless communication interface. In other embodiments, monitor 42 is connected to controller 44 via an external processor, such as a processor belonging to a standard desktop computer.

In some embodiments, as shown in Fig. 2, controller 44 is disposed within XYZ stage unit 32. In other embodiments, controller 44 is disposed externally to the XYZ stage unit. Alternatively or additionally, the controller may cooperatively perform at least some of the functionality described herein with another, external processor.

In some embodiments, at least some of the functionality of controller 44, as described herein, is implemented in hardware, e.g., using one or more Application-Specific Integrated Circuits (ASICs) or Field-Programmable Gate Arrays (FPGAs). Alternatively or additionally, controller 44 may perform at least some of the functionality described herein by executing software and/or firmware code. For example, controller 44 may comprise a central processing unit (CPU) and random access memory (RAM). Program code, including software programs, and/or data may be loaded into the RAM for execution and processing by the CPU. The program code and/or data may be downloaded to the controller in electronic form, over a network, for example. Alternatively or additionally, the program code and/or data may be provided and/or stored on non-transitory tangible media, such as magnetic, optical, or electronic memory. Such

program code and/or data, when provided to the controller, produce a machine or special-purpose computer, configured to perform the tasks described herein. In some embodiments, the controller comprises a system on module (SOM), such as the VarisiteTM DART-MX8M.

THE OPTICAL FILTER

5 As shown in Fig. 2, trabeculoplasty device 21 further comprises an optical filter 70, which is opaque to the treatment beams but not to visible light 68. (In some embodiments, the optical filter is also transparent to the light emitted by illumination sources 60 and/or the light emitted by beam emitters 62.) Optical filter 70 is configured to inhibit passage of the treatment beams, but not visible light 68, therethrough, while interposing between the beam-directing elements and the
10 pupil of eye 25. (For ease of description, this act of interposing is referred to as “covering” the pupil.) Thus, the optical filter protects the retina of the eye while allowing the eye to fixate on fixation target 64. Typically, the optical filter is elliptical, e.g., circular. The optical filter may attenuate the treatment beams with an optical density (OD) that is between one and six, or even greater than six.

15 In some embodiments, optical filter 70 inhibits the passage of the treatment beams by absorbing the treatment beams. For example, optical filter 70 may comprise an absorptive plastic and/or an absorptive glass, such as a material used in the Thorlabs LG14 laser safety glasses or the Laser Safety Industries 35-235 laser safety glasses.

 In such embodiments, the optical filter may comprise an anti-reflective surface configured
20 to reduce reflection of the treatment beams. For example, the optical filter may comprise an absorptive material having a surface that is etched (e.g., subwavelength surface textured) or coated (e.g., with a dielectric coating) to reduce reflections therefrom. (The aforementioned coating may comprise a single layer or multiple layers.) In some embodiments, both surfaces of the optical filter are anti-reflective; the front anti-reflective surface, which faces the optical unit, protects the
25 user of the system from any primary reflections, while the back anti-reflective surface protects the eye from any secondary reflections. In other embodiments, only one the surfaces, such as the front surface, is anti-reflective.

 Alternatively or additionally to absorbing the treatment beams, the optical filter may inhibit
30 the passage of the treatment beams by reflecting the treatment beams. For example, the optical filter may comprise a piece of transparent material (such as plastic or glass, for example) coated with a thin-film or broadband reflective coating. Such a coating may be applied to the front surface of the piece of material, which faces the optical unit, and/or the back surface, which faces the eye.

In some embodiments, the trabeculoplasty device further comprises a contact optic 72, which comprises the optical filter and is configured to contact the eye. (Typically, contact optic 72 is elliptical, e.g., circular.) During the procedure, contact optic 72 contacts eye 25, with optical filter 70 covering the pupil of the eye. (It is noted that in the context of the present application, including the claims, the term “contact” may include contact via an optical coupling fluid or a gel.) Typically, the contact optic is curved, so as to conform to the shape of the eyeball of eye 25. In some embodiments, the thickness of the contact optic is less than 2 mm, such that the contact optic may be worn in the eye without being held in place.

In some embodiments, contact optic 72 comprises the optical filter along with a transparent portion 74, which surrounds the optical filter and is transparent to the treatment beams and to visible light 68. (Typically, transparent portion 74 is annular-elliptical, e.g., annular-circular.) In such embodiments, the diameter d1 of the contact optic is typically 12-17 mm, with the diameter d2 of the optical filter typically being less than 10 mm. During the procedure, optical filter 70 covers the pupil of the eye (and, typically, at least part of the cornea surrounding the pupil), while transparent portion 74 covers the targeted vicinity of the limbus. Hence, the vicinity of the limbus may be irradiated by the treatment beams and may also be imaged by camera 54.

For example, contact optic 72 may comprise a transparent optic having a central portion coated with a reflective coating, which constitutes the optical filter, along with an uncoated peripheral portion. Alternatively, for embodiments in which the optical filter comprises an absorptive material, the optical filter may be embedded in the center of a transparent optic. Such embedding may be performed using diffusion bonding, welding, soldering, or an adhesive.

In some embodiments, the contact optic further comprises another optical filter that surrounds the transparent portion and inhibits passage of the treatment beams therethrough, as described below with reference to Figs. 4A-B.

In other embodiments, the contact optic comprises the optical filter without comprising transparent portion 74. In such embodiments, diameter d1 (which is equal to diameter d2 due to the absence of transparent portion 74) is typically less than 10 mm, such that, during the procedure, the limbus and/or sclera of the eye are exposed. Although corrective contact lenses typically have a larger diameter so as not to discomfort the wearer, the inventors have realized that contact optic 72 is unlikely to discomfort the patient despite its small size, particularly if anesthetic eye drops are applied to the eye before the contact optic is placed in the eye.

In some embodiments, the trabeculoplasty device further comprises an eye-stabilizing structure 76, through which the various types of radiation described herein pass. Typically, the

length of structure 76 is between 10 and 70 mm.

In such embodiments, optical filter 70 is typically coupled to structure 76. For example, as shown in Fig. 2, contact optic 72 may be coupled to the distal end of the structure, such that optical filter 70 is coupled to the distal end of structure 76 by virtue of the contact optic comprising the optical filter. (In such embodiments, the thickness of the contact optic is typically greater than 2 mm; for example, the thickness may be between 3 and 20 mm.) For example, the edge of the contact optic may be coupled to the distal end of the structure using a mechanical attachment mechanism, such as a screw, and/or any suitable adhesive. Alternatively, optical filter 70 may be coupled to structure 76 in other ways, as further described below with reference to Figs. 3A-B and 4A-B.

Typically, structure 76 is hollow, such that the radiation described herein passes through air within the structure. For example, structure 76 may comprise a frustum-shaped or cylindrically-shaped tube, which may be made from metal, glass, or any other suitable material. In some such embodiments, the structure comprises a continuous wall. In other such embodiments, structure 76 is shaped to define one or more openings. For example, structure 76 may comprise a wire structure, such as a wire mesh. As further described below with reference to Fig. 8, an advantage of such embodiments is that the user may view the eye through the openings.

In other embodiments, structure 76 comprises a frustum-shaped or cylindrically-shaped transparent piece of material (e.g., glass), such that the radiation passes through the material.

Structure 76 typically provides several advantages, alternatively or additionally to holding optical filter 70. For example, as shown in Fig. 1, the distal end of structure 76 may retract the eyelids of eye 25. Additionally, the distal end of the structure may stabilize the eye, i.e., inhibit the eye from moving. Furthermore, structure 76 may facilitate placing the optical unit at the correct distance from the patient. Moreover, the inner and/or outer surface of structure 76 may be configured to absorb any misaimed treatment beams or scattered light, and/or to block any external light from interfering with the camera. For example, the inner and/or outer surface of the structure may comprise black flat paint, black flocked paper, or Vantablack.

In some embodiments, as shown in Figs. 1-2, the proximal end of the structure is configured to couple to the optical unit, e.g., via a spring. In such embodiments, the trabeculoplasty device may further comprise a pressure sensor coupled to structure 76 and configured to measure the pressure applied to the structure. Based on the pressure measurement, the user may position the optical unit such that the pressure applied to the structure, which is equivalent to the pressure applied to the eye, is within a predefined range suitable for stabilizing

the eye without hurting the patient. In other embodiments, the structure is not coupled to the optical unit, but rather, is held by the user of system 20 during the procedure.

In some embodiments, structure 76 is disposable, and a different respective structure is used for each patient.

5 As noted above, the optical unit may comprise an exit window in lieu of opening 58. In such embodiments, as further described below with reference to Fig. 5, the optical filter may overlay, or may be embedded within, the exit window.

10 As further described below with reference to Fig. 8, during the procedure, controller 44 may process images of the eye to calculate the position of each of the target regions. In some embodiments, the controller identifies contact optic 72 in each of the images, and verifies that the contact optic is in the correct location relative to the eye. Optionally, the controller may also calculate the position of the target region with reference to the position of the contact optic.

15 In some embodiments, to facilitate identifying the contact optic, the contact optic is opaque to wavelengths to which the camera is sensitive. For example, for embodiments in which the wavelength of the fixation light is between 600 and 700 nm, the camera may be sensitive only to wavelengths below 600 nm, and the contact optic may be opaque to wavelengths below 600 nm.

In other embodiments, the controller does not identify the contact optic in any of the images.

20 In some embodiments – particularly if structure 76 is not used - a finger, a speculum, or another tool may be used to retract one or both of the eyelids of eye 25.

It is emphasized that the configuration of device 21 shown in Fig. 2 is provided by way of example only. Moreover, alternatively or additionally to the components shown in Fig. 2, device 21 may comprise any suitable components.

25 Reference is now made to Figs. 3A-B, which are schematic illustrations of structure 76 as viewed from the side and from the front, respectively, in accordance with some embodiments of the present invention. Reference is further made to Figs. 4A-B, which are also schematic illustrations of structure 76 as viewed from the side and from the front, respectively, in accordance with some embodiments of the present invention.

30 In some embodiments, the optical filter is situated proximally to the distal end of eye-stabilizing structure 76, such that the distal end of the eye-stabilizing structure, but not the optical filter, contacts the eye. For example, as shown in Figs. 3A and 4A, the optical filter may be mounted to the inner wall 80 of structure 76, e.g., at a distance D0 of 0.5-20 mm from the distal

end of the structure. In such embodiments, diameter d_2 of the optical filter (Fig. 2) is matched to distance D_0 , such that the optical filter covers the pupil without covering the targeted regions of the eye. In other words, for a smaller D_0 , d_2 is made larger, and vice versa.

In some embodiments, as shown in Figs. 3A-B, the optical filter is mounted to inner wall
5 80 via one or more longitudinal elements 82, such as stiff wires or posts, extending between the inner wall and the optical filter.

In other embodiments, as shown in Figs. 4A-B, the trabeculoplasty device comprises an optic 84, which comprises optical filter 70 along with transparent portion 74. In such
10 embodiments, the edge of optic 84 may be coupled to inner wall 80 using a mechanical attachment mechanism, such as a screw, and/or any suitable adhesive. (Since optic 84 does not need to conform to the shape of the eye, optic 84 is typically not curved.)

In some embodiments, optic 84 further comprises another optical filter 86 that surrounds transparent portion 74 and is configured to inhibit the passage of the treatment beams. (Typically, optical filter 86 is annular-elliptical, e.g., annular-circular.) For example, optical filter 86 may
15 comprise an absorptive material and/or a thin-film reflective coating, such that optical filter 86 absorbs and/or reflects the treatment beams. Typically, optical filter 86 comprises the same materials as does optical filter 70, and/or is etched in the same way as is optical filter 70.

For embodiments in which the optical filter is situated proximally to the distal end of the eye-stabilizing structure, the distal end of the structure may comprise a contact optic 78 configured
20 to help stabilize the eye by contacting the eye. Typically, contact optic 78, or at least the portion of the contact optic that covers the treated vicinity of the limbus, is transparent to the treatment beams and to visible light. Typically, the diameter of contact optic 78 is between 12 and 17 mm. (It is noted that the view of the eye-stabilizing structure in each of Figs. 3B and 4B corresponds to the view seen through contact optic 78.)

25 In some embodiments, contact optic 78 is shaped to define an opening, and the trabeculoplasty device further comprises (i) a suction-applying device, such as a pump, and (ii) a tube having a proximal end connected to the suction-applying device and a distal end passing through the opening. In such embodiments, the suction-applying device may apply a suction force through the tube, thus helping the contact optic to stabilize the eye.

30 Alternatively or additionally to contact optic 78, the distal end of the structure may comprise a contact ring configured to help stabilize the eye by contacting the eye. Typically, the contact ring contacts the eye outside of, and sufficiently far from (e.g., at least 2 mm from), the limbus, such that the portion of the eye targeted by the treatment beams, which typically includes

the limbus and/or part of the sclera, is exposed to the treatment beams and to the camera. For example, the diameter of the contact ring may be between 14 and 18 mm. In some embodiments, the contact ring does not contact the eye continuously, but rather, only over several (e.g., between three and ten) points of contact.

5 In some embodiments, to facilitate stabilizing the eye, suction may be applied through the contact ring, as described above for contact optic 78. In addition to stabilizing the eye, the contact ring may retract the eyelids of the eye.

Reference is now made to Figs. 5-6, which are schematic illustrations of optical filter 70 coupled to optical unit 30, in accordance with some embodiments of the present invention.

10 In some embodiments, optical filter 70 is coupled to the optical unit.

For example, as shown in the frontal view of the optical unit in Fig. 5, the optical filter may overlay, or may be embedded within, an exit window 90 belonging to front face 33. For example, the optical filter may comprise a thin-film reflective coating that coats exit window 90. (To avoid any confusion, it is noted that the frontal view of the optical unit shown in Fig. 5 is not
15 the view typically seen by the patient during the procedure; in the latter view, optical filter 70 fills the patient's field of view, given that the optical filter typically covers the patient's entire pupil.)

As another example, as shown in Fig. 6, a longitudinal element 88, such as a stiff wire or a post, may extend between the front face and the optical filter, and the optical filter may be coupled to the front face via longitudinal element 88. In other words, the proximal end of
20 longitudinal element 88 may be coupled to front face 33 (e.g., to exit window 90), with the distal end of the longitudinal element coupled to the optical filter. (For embodiments in which eye-stabilizing structure 76 (Fig. 1) is used, longitudinal element 88 typically passes through the eye-stabilizing structure.) Typically, the longitudinal element is parallel to optical path 92.

Typically, the distance between the front face of the optical unit and the optical filter, which
25 is generally equal to the length of longitudinal element 88, is between 10 and 50 mm, and/or the distance between the optical filter and the eye is between 0.1 and 20 mm.

As yet another alternative, the optical filter may be coupled to the optical bench belonging to the optical unit. For example, the optical filter may be coupled to the optical bench downstream from the most downstream of the beam-directing elements, such as between beam combiner 56
30 and opening 58 (Fig. 2), such that the optical filter interposes between the most downstream of the beam-directing elements and the pupil of the eye.

ALTERNATIVE EMBODIMENTS

In alternative embodiments, optical filter 70 is opaque both to the treatment beams and to the fixation light, i.e., the visible light transmitted by light source 66 (Fig. 2). For example, the optical filter may comprise a metal or ceramic disk. Although, in such embodiments, the optical filter inhibits both the visible light and the treatment beams from reaching the pupil of eye 25, eye 25 may nonetheless be oriented for treatment, as described immediately below. Hence, the optical filter may be manufactured more cheaply and easily, without compromising the safety and efficacy of the procedure.

For example, to allow eye 25 to fixate on the light source, the light source may be coupled to the optical bench parallel to or downstream from the optical filter. For example, the optical filter and the light source may each be coupled to the optical bench between the most downstream of the beam-directing elements and opening 58, such that (i) the optical filter interposes between the most downstream of the beam-directing elements and the pupil of the eye, and (ii) light source 66 is disposed next to optical path 92, parallel to or downstream from the optical filter. Alternatively, the light source may be disposed behind the optical filter, as in Fig. 2; however, one or more reflectors coupled to the optical bench may reflect the fixation light through opening 58, such that the fixation light may reach eye 25 without needing to pass through the optical filter.

Alternatively, for embodiments in which eye 25 cannot see the fixation light through the optical filter, eye 25 may be oriented by causing the untreated eye of the patient to fixate on light source 66. In such embodiments, prior to the procedure, the patient is instructed to fixate the untreated eye on the light source. Subsequently, by virtue of the light source transmitting visible light, the untreated eye fixates on the light source, such that eye 25, by virtue of moving in tandem with the untreated eye, gazes approximately along optical path 92. Thus, while the untreated eye fixates on the fixation target, the treated eye may be irradiated with the treatment beams.

In this regard, reference is now made to Fig. 7, which is a schematic illustration of an alternative technique for orienting eye 25 for treatment, in accordance with some embodiments of the present invention. (Fig. 7 shows a schematic overhead view of optical unit 30 and patient 22.)

In some embodiments, the position of the light source is adjustable. For example, the light source may be mounted on a slider, such that the distance of the light source from optical path 92 is variable. In such embodiments, to facilitate orienting eye 25 via the fixation of the untreated eye 23 of the patient on the light source, the position of the light source is varied responsively to the degree to which the patient's eyes can converge onto the light source.

For example, for those patients, such as younger patients, whose eyes can converge onto

light source, the light source may be aligned, at least approximately, with optical path 92, as described above with reference to Fig. 2. As untreated eye 23 fixates on the light source along a first line-of-sight 93, eye 25 gazes toward the light source along a second line-of-sight 95, which is approximately coincident with optical path 92.

5 For other patients, particularly older patients, whose eyes cannot converge onto the light source due to the relatively small distance between the patient and the light source, the light source may be displaced from the optical path towards the untreated eye, typically along an axis parallel to the interpupillary axis of the patient. For example, the light source may be placed at a distance D1 from the optical path that is approximately equal to the interpupillary distance of the patient;
10 thus, for example, D1 may be between 45 and 80 mm. During the procedure, the untreated eye fixates on the light source along an alternate first line-of-sight 93', such that second line-of-sight 95 is approximately coincident with optical path 92.

In other embodiments, a single position of the light source is used for all patients. For example, the light source may be displaced from the optical path towards the untreated eye,
15 typically along an axis parallel to the interpupillary axis of the patient, by a distance that is less than, such as 30%-70% of, an average or median interpupillary distance for a suitable population of patients. For example, assuming an average interpupillary distance of 62 mm, the light source may be displaced from the optical path by between 18 and 44 mm. Advantageously, this position may help second line-of-sight 95 to be sufficiently coincident with optical path 92, regardless of
20 the degree to which the patient's eyes converge onto the light source.

PROTECTING THE EYE DURING TREATMENT

Reference is now made to Fig. 8, which is a schematic illustration of an image 94 of eye 25 treated in accordance with some embodiments of the present invention.

Prior to the procedure, the camera acquires image 94. Based on the image, the user defines
25 one or more target regions 110 of the eye that are to be irradiated. Typically, as described in International Patent Application PCT/IB2019/055564, target regions 110 are defined semi-automatically, based on input from the user via a graphical user interface (GUI) 96 displayed on monitor 42. Typically, at least part of each target region is located near (e.g., within 2 mm of) the limbus 98 of the eye; for example, each target region may overlap limbus 98.

30 Typically, following the definition of the target regions, the controller executes a mock trabeculoplasty by causing radiation source 48 (Fig. 2) to sweep an aiming beam across the target regions. Alternatively, the aiming beam may be emitted by an additional radiation source, such

as a lower-power laser, that is collinear with radiation source 48. (Typically, the aiming beam differs from the treatment beams at least in that the energy of the aiming beam is subtherapeutic.) While this sweep is performed, camera 54 (Fig. 2) acquires images of the eye at a relatively high frequency and the images are displayed on monitor 42, such that the user may validate the target regions. Alternatively or additionally, for embodiments in which structure 76 (Fig. 1) does not have a continuous wall, the user may view the aiming beam, as it impinges on the eye, through an opening in the structure.

Following the validation of the target regions, the user starts the procedure, typically by entering an appropriate input via GUI 96. Subsequently, as described above with reference to Fig. 1, the target regions of the eye are irradiated by radiation source 48, i.e., the radiation source fires respective treatment beams at the target regions.

In some embodiments, during the procedure, the camera acquires images of the eye at a relatively high frequency (e.g., at a frequency greater than 40 Hz or 50 Hz). Based on the images, controller 44, by executing image-processing software, tracks motion of the eye, e.g., by identifying the center of the limbus in each image. Based on the motion tracking, the controller, prior to the irradiation of each target region, locates the target region in the FOV of the camera, and then controls the beam-directing elements such that a treatment beam impinges on the target region. In other embodiments, the eye-stabilizing structure may sufficiently stabilize the eye such as to obviate the need for high-frequency motion tracking. In such embodiments, during the procedure, the camera may acquire images of the eye, and the controller may check for movement of the eye, at a lower frequency; alternatively, the image acquisition and motion tracking may be omitted entirely. Similarly, high-frequency motion tracking may be omitted if only a small number of treatment beams are fired. For example, the radiation source may emit a single treatment beam – shaped, for example, as an ellipse or an arc – that simultaneously irradiates all the target regions.

In any case, regardless of whether high-frequency motion tracking is performed, embodiments of the present invention, as an extra precaution, protect the eye from any (unlikely) misaimed treatment beams that deviate too far from the limbus. Such protection may be effected using optical filter 70, which was described at length above. In particular, optical filter 70 may protect the retina of the eye by covering the pupil 104 of the eye. As described above with reference to Fig. 2, optical filter 70 may also cover at least part of the cornea 108 surrounding the pupil, thus protecting cornea 108. Alternatively or additionally, a peripheral optical filter, such as optical filter 86 belonging to optic 84 (described above with reference to Figs. 4A-B), may protect the sclera 106 of the eye by covering sclera 106.

In some embodiments, the optical filter is opaque to the camera (i.e., to the frequencies to which the camera is sensitive). In such embodiments, the controller may identify the optical filter in the images acquired by the camera, and may further verify that the optical filter is covering the pupil, e.g., as described above with reference to Fig. 2. In other embodiments, the optical filter is transparent to the camera. (Fig. 8 assumes that the optical filter is transparent to the camera; nevertheless, for clarity, the edge of the optical filter is shown in Fig. 8.)

In some embodiments, alternatively or additionally to using an optical filter, the eye is protected using a virtual filter, implemented in the software and/or firmware run by the controller. In particular, prior to the firing of any treatment beams, controller 44 (Fig. 1) causes camera 54 to acquire image 94. Subsequently to the acquisition of image 94, the controller, based on the image, identifies one or more static regions in the FOV of the camera that include non-targeted portions of the eye. Subsequently, prior to the irradiation of each target region of the eye (i.e., prior to the firing of a treatment beam at the target region), the controller ascertains that the target region is not within any of the static regions. In response to ascertaining that the target region is not within any of the static regions, the controller causes the radiation source to irradiate the target region; otherwise, the treatment beam is not fired. Furthermore, in some embodiments, the controller inhibits the beam-directing elements from being aimed at any of the static regions even while the radiation source is inactive.

For example, as described in International Patent Application PCT/IB2019/055564, based on image 94, the controller may identify a central static region encompassing pupil 104 in the image. Subsequently, the controller may inhibit the radiation source from firing any treatment beams at the central static region. The central static region may thus protect the retina of the eye in the event that optical filter 70 is not used, or provide extra protection to that provided by the optical filter.

Alternatively or additionally, the controller may identify a peripheral static region 102 that, in the image, is outside limbus 98 of the eye. Static region 102 may protect sclera 106 in the event that a peripheral optical filter is not used, or provide extra protection to that provided by a peripheral optical filter. As shown in Fig. 8, the peripheral static region may further protect the eyelids of the eye, along with other nearby tissue.

Typically, the peripheral static region includes the portion of the camera's FOV lying outside an elliptical (e.g., circular) boundary 100, which, in image 94, may be located outside limbus 98 at a distance of between 1 and 5 mm from the limbus.

It is emphasized that each of the static regions is "static" by virtue of being defined in terms

of the FOV of the camera, such that the position of the region is not adjusted by the controller even in response to detected motion of the eye. Thus, the eye is protected even in the event of an (unlikely) error in the motion tracking performed by the controller.

5 It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described hereinabove. Rather, the scope of the present invention includes both combinations and subcombinations of the various features described hereinabove, as well as variations and modifications thereof that are not in the prior art, which would occur to persons skilled in the art upon reading the foregoing description.

CLAIMS

1. Apparatus, comprising:
an optical unit, comprising:
a light source;
5 one or more beam-directing elements; and
a radiation source, configured to irradiate an eye of a patient with one or more treatment beams by emitting the treatment beams toward the beam-directing elements, while the eye fixates on the light source by virtue of the light source transmitting visible light; and
10 an optical filter configured to inhibit passage of the treatment beams, but not the visible light, therethrough, while interposing between the beam-directing elements and a pupil of the eye.
2. The apparatus according to claim 1, further comprising an eye-stabilizing structure, wherein the radiation source is configured to irradiate the eye by emitting the treatment beams through the structure, and wherein the optical filter is coupled to the structure.
- 15 3. The apparatus according to claim 2, wherein a proximal end of the structure is configured to couple to the optical unit.
4. The apparatus according to claim 2, wherein the optical filter is coupled to a distal end of the structure.
5. The apparatus according to claim 4, further comprising a contact optic comprising the
20 optical filter, wherein the contact optic is coupled to the distal end of the structure and is configured to contact the eye.
6. The apparatus according to claim 2, wherein a distal end of the structure is configured to contact the eye, and wherein the optical filter is mounted to an inner wall of the structure.
7. The apparatus according to claim 6, wherein the optical filter is mounted between 0.5 and
25 20 mm from the distal end of the structure.
8. The apparatus according to claim 6, wherein the distal end of the structure comprises a contact optic configured to contact the eye.
9. The apparatus according to claim 6, wherein the distal end of the structure comprises a contact ring configured to contact the eye.
- 30 10. The apparatus according to claim 6, further comprising one or more longitudinal elements extending between the inner wall of the structure and the optical filter, the optical filter being

mounted to the inner wall via the longitudinal elements.

11. The apparatus according to claim 2, wherein an inner wall of the structure is configured to absorb the treatment beams.
12. The apparatus according to any one of claims 1-11, wherein a treatment-beam wavelength of the treatment beams is between 200 and 11000 nm, and wherein a visible-light wavelength of the visible light is between 350 and 850 nm.
13. The apparatus according to any one of claims 1-11, wherein the optical filter is configured to inhibit the passage of the treatment beams by absorbing the treatment beams.
14. The apparatus according to any one of claims 1-11, wherein the optical filter is configured to inhibit the passage of the treatment beams by reflecting the treatment beams.
15. The apparatus according to any one of claims 1-11, wherein the optical filter comprises an anti-reflective surface configured to reduce reflection of the treatment beams.
16. The apparatus according to any one of claims 1-11, further comprising an optic comprising:
the optical filter; and
a transparent portion that surrounds the optical filter and is transparent to the treatment beams.
17. The apparatus according to claim 16,
wherein the optical filter is a first optical filter, and
wherein the optic further comprises a second optical filter that surrounds the transparent portion and is configured to inhibit the passage of the treatment beams.
18. The apparatus according to claim 1, further comprising a contact optic comprising the optical filter, wherein the contact optic is configured to contact the eye.
19. The apparatus according to claim 18, wherein a thickness of the contact optic is less than 2 mm.
20. The apparatus according to any one of claims 18-19, wherein a diameter of the contact optic is less than 10 mm.
21. The apparatus according to claim 1,
wherein the optical unit comprises a front face, and
wherein the optical filter is coupled to the front face.
22. The apparatus according to claim 21,
wherein the front face comprises an exit window,

wherein the light source is configured to transmit the visible light, and the radiation source is configured to emit the treatment beams, through the exit window, and
wherein the optical filter overlays the exit window.

23. The apparatus according to claim 21,
5 wherein the front face comprises an exit window,
wherein the light source is configured to transmit the visible light, and the radiation source is configured to emit the treatment beams, through the exit window, and
wherein the optical filter is embedded within the exit window.

24. The apparatus according to claim 21, further comprising a longitudinal element extending
10 between the front face and the optical filter, the optical filter being coupled to the front face via the longitudinal element.

25. The apparatus according to claim 24,
wherein the front face comprises an exit window,
wherein the light source is configured to transmit the visible light, and the radiation source
15 is configured to emit the treatment beams, through the exit window, and
wherein the longitudinal element extends between the exit window and the optical filter.

26. A method, comprising:
interposing an optical filter between one or more beam-directing elements and a pupil of
an eye of a patient; and
20 while the optical filter interposes between the beam-directing elements and the pupil:
using a light source, transmitting visible light through the optical filter; and
while the eye fixates on the light source by virtue of the light source transmitting
the visible light, irradiating the eye with one or more treatment beams by emitting the
treatment beams toward the beam-directing elements,
25 the optical filter being configured to inhibit passage of the treatment beams
therethrough.

27. The method according to claim 26, wherein the optical filter is coupled to an eye-stabilizing structure, and wherein irradiating the eye comprises irradiating the eye by emitting the treatment beams through the structure.

30 28. The method according to claim 27, wherein the light source and the beam-directing elements belong to an optical unit, and wherein emitting the treatment beams through the structure comprises emitting the treatment beams through the structure while a proximal end of the structure

is coupled to the optical unit.

29. The method according to claim 27, wherein the optical filter is coupled to a distal end of the structure.

30. The method according to claim 29, wherein the optical filter belongs to a contact optic coupled to the distal end of the structure, and wherein interposing the optical filter comprises interposing the optical filter by contacting the eye with the contact optic.

31. The method according to claim 27, wherein the optical filter is mounted to an inner wall of the structure, and wherein emitting the treatment beams through the structure comprises emitting the treatment beams through the structure while a distal end of the structure contacts the eye.

32. The method according to claim 31, wherein the optical filter is mounted between 0.5 and 20 mm from the distal end of the structure.

33. The method according to claim 31, wherein the optical filter is mounted to the inner wall via one or more longitudinal elements extending between the inner wall and the optical filter.

34. The method according to any one of claims 26-33, wherein a treatment-beam wavelength of the treatment beams is between 200 and 11000 nm, and wherein a visible-light wavelength of the visible light is between 350 and 850 nm.

35. The method according to any one of claims 26-33, wherein the optical filter belongs to an optic that includes a transparent portion that surrounds the optical filter and is transparent to the treatment beams.

36. The method according to claim 35,
wherein the optical filter is a first optical filter, and
wherein the optic further includes a second optical filter that surrounds the transparent portion and is configured to inhibit the passage of the treatment beams.

37. The method according to claim 26, wherein the optical filter belongs to a contact optic, and wherein interposing the optical filter comprises interposing the optical filter by contacting the eye with the contact optic.

38. The method according to claim 37, wherein a thickness of the contact optic is less than 2 mm.

39. The method according to any one of claims 37-38, wherein a diameter of the contact optic is less than 10 mm.

40. The method according to claim 26,
wherein the light source and the beam-directing elements belong to an optical unit that includes a front face, and
wherein the optical filter is coupled to the front face.
- 5 41. The method according to claim 40,
wherein the front face includes an exit window,
wherein transmitting the visible light comprises transmitting the visible light through the exit window,
wherein emitting the treatment beams comprises emitting the treatment beams through the
10 exit window, and
wherein the optical filter overlays the exit window.
42. The method according to claim 40,
wherein the front face includes an exit window,
wherein transmitting the visible light comprises transmitting the visible light through the
15 exit window,
wherein emitting the treatment beams comprises emitting the treatment beams through the exit window, and
wherein the optical filter is embedded within the exit window.
43. The method according to claim 40, wherein the optical filter is coupled to the front face
20 via a longitudinal element extending between the front face and the optical filter.
44. The method according to claim 43,
wherein the front face includes an exit window,
wherein transmitting the visible light comprises transmitting the visible light through the exit window,
25 wherein emitting the treatment beams comprises emitting the treatment beams through the exit window, and
wherein the longitudinal element extends between the exit window and the optical filter.
45. A system, comprising:
a camera, configured to acquire an image of an eye of a patient;
30 a radiation source; and
a controller, configured to:
identify a static region in a field of view of the camera that, in the image, is outside a limbus of the eye, and

treat one or more target regions of the eye, by, for each target region:
ascertaining that the target region is not within the static region, and
in response to the ascertaining, causing the radiation source to irradiate the
target region.

- 5 46. A method, comprising:
using a camera, acquiring an image of an eye of a patient;
identifying a static region in a field of view of the camera that, in the image, is outside a
limbus of the eye; and
treating one or more target regions of the eye, by, for each target region:
10 ascertaining that the target region is not within the static region, and
in response to the ascertaining, irradiating the target region.

47. Apparatus, comprising:
an optical unit, comprising:
a light source, configured to transmit visible light;
15 one or more beam-directing elements; and
a radiation source, configured to irradiate a first eye of a patient with one or more
treatment beams by emitting the treatment beams toward the beam-directing elements such
that the beam-directing elements direct the treatment beams along an optical path to the
first eye; and
20 an optical filter configured to inhibit the visible light and the treatment beams from
reaching a pupil of the first eye,
the light source being displaced from the optical path towards a second eye of the
patient, and
the radiation source being configured to irradiate the first eye while the second eye
25 fixates on the light source by virtue of the light source transmitting the visible light.

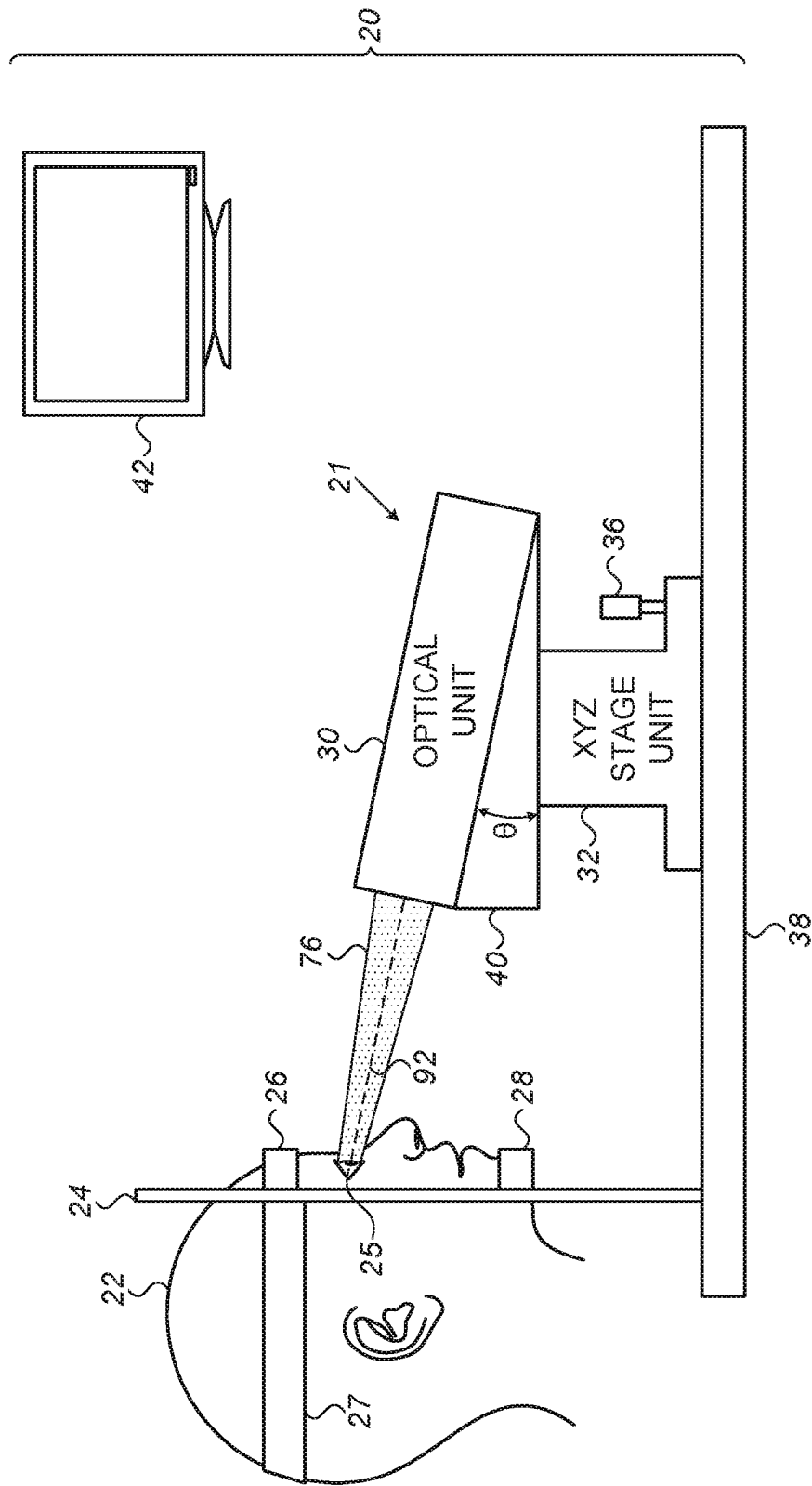
48. The apparatus according to claim 47, wherein the light source is displaced from the optical
path by 18-44 mm.

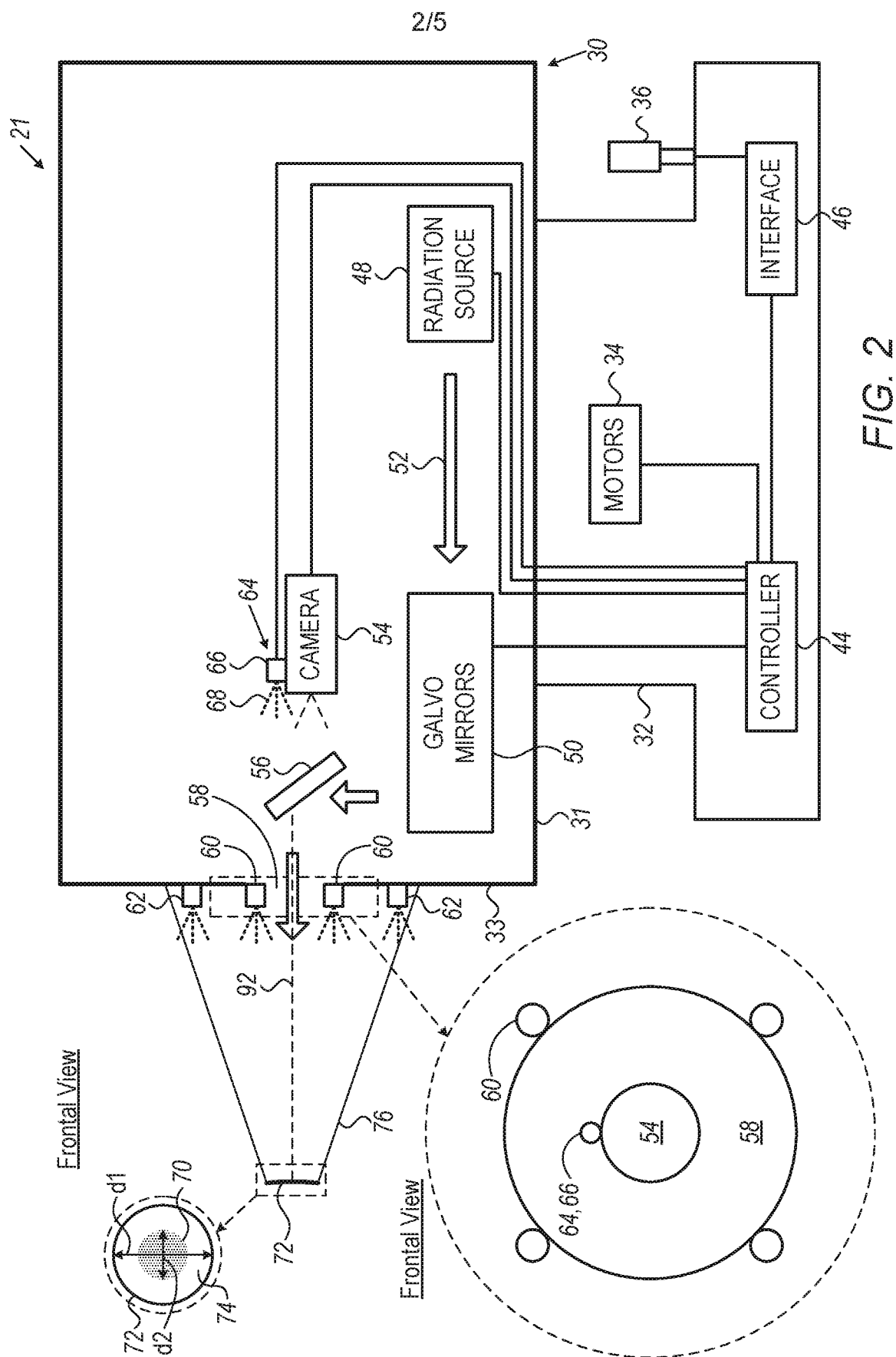
49. A method, comprising:
interposing an optical filter, which is opaque to visible light transmitted by a light source
30 and to treatment beams emitted by a radiation source, between (i) one or more beam-directing
elements and (ii) a pupil of a first eye of a patient; and
while a second eye of the patient fixates on the light source by virtue of the light source

transmitting the visible light, using the radiation source, irradiating the first eye with the treatment beams by emitting the treatment beams toward the beam-directing elements.

50. The method according to claim 49, wherein the beam-directing elements direct the treatment beams along an optical path to the first eye, and wherein the method further comprises,
5 prior to irradiating the first eye, displacing the light source from the optical path towards the second eye.

FIG. 1





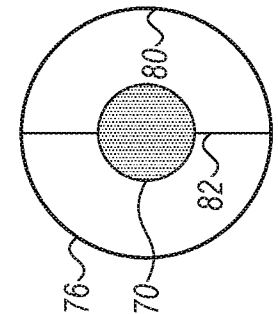


FIG. 3B

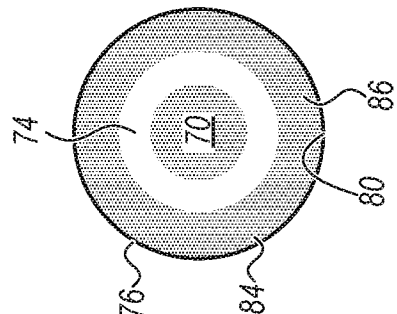


FIG. 4B

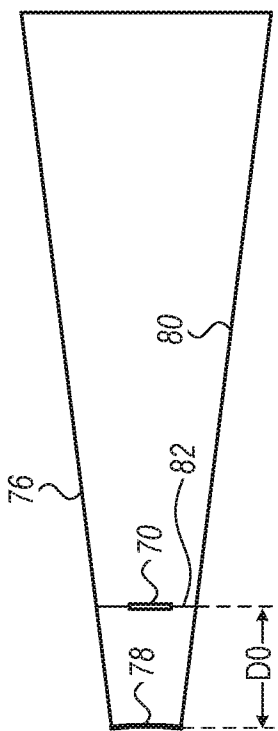


FIG. 3A

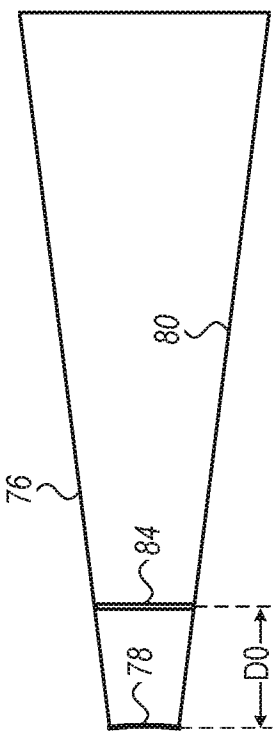


FIG. 4A

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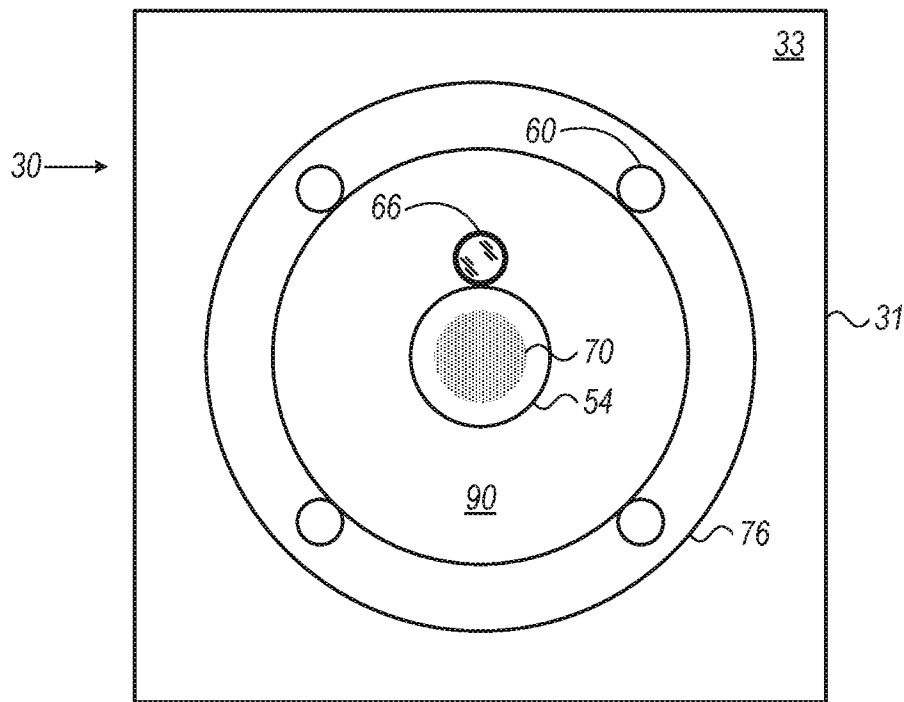


FIG. 5

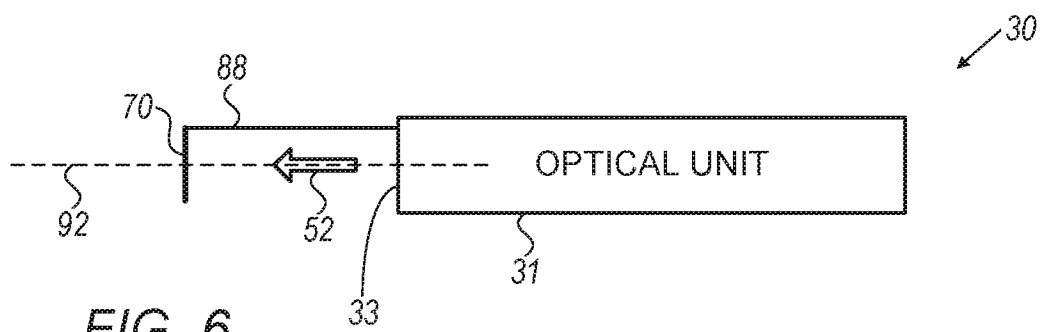


FIG. 6

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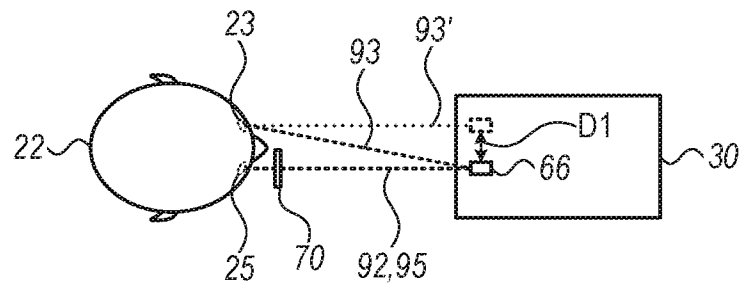


FIG. 7

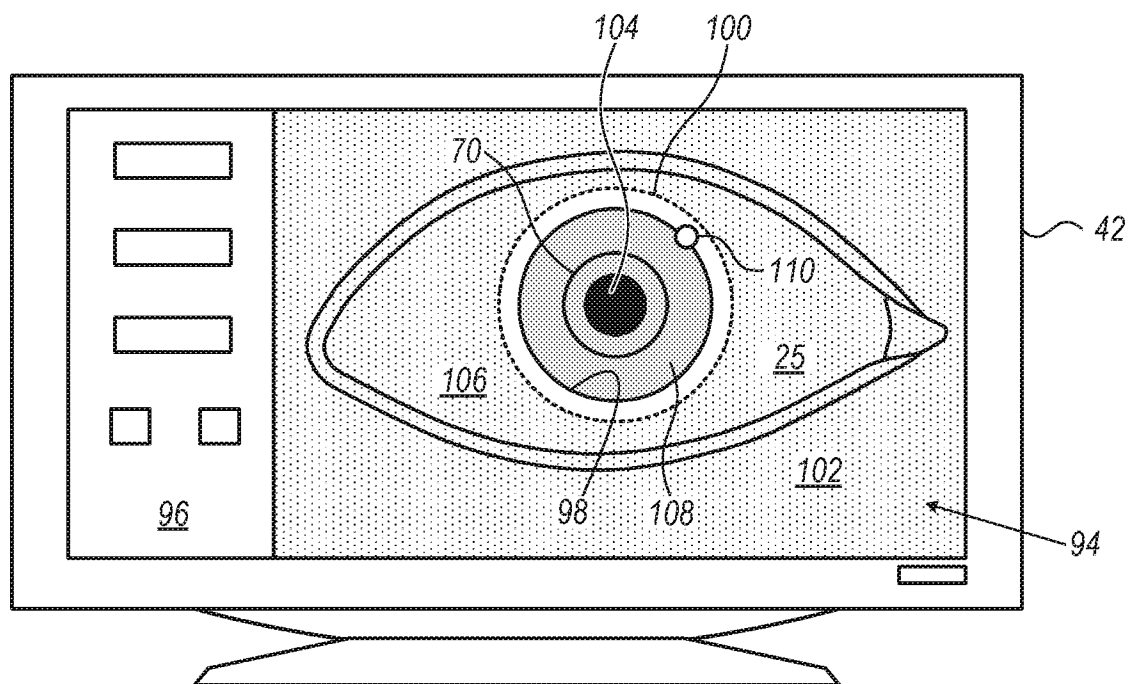


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB2019/059058

A. CLASSIFICATION OF SUBJECT MATTER IPC (20200101) A61F 9/008 CPC (20130101) A61F 9/00802, A61F 2009/00861, A61F 2009/00868, A61F 2009/00891 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC (20200101) A61F 9/008 CPC (20130101) A61F 9/00802, A61F 2009/00861, A61F 2009/00868, A61F 2009/00891 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) Databases consulted: Google Patents, Orbit		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010002837 A1 ORAYA THERAPEUTICS INC 07 Jan 2010 (2010/01/07) The whole document	1-50
X	US 2016346126 A1 OJAI RETINAL 10 Dec 2016 (2016/12/10) The whole document	1-50
A	EP 2602005 A1 ORAYA THERAPEUTICS INC 12 Jun 2013 (2013/06/12) The whole document	1-50
A	ES 2380076 T3 OPTIMEDICA CORP 08 May 2012 (2012/05/08) The whole document	1-50
A	CN 101431975 A OPTIMEDICA CORP 13 May 2009 (2009/05/13) The whole document	1-50
☐ Further documents are listed in the continuation of Box C. ☒ 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 "D" document cited by the applicant in the international application "E" earlier application or patent but published on or after the international filing date "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) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "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 "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 "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 "&" document member of the same patent family		
Date of the actual completion of the international search 16 Feb 2020		Date of mailing of the international search report 16 Feb 2020
Name and mailing address of the ISA: Israel Patent Office Technology Park, Bldg.5, Malcha, Jerusalem, 9695101, Israel Email address: pctoffice@justice.gov.il		Authorized officer Zreiqi Asia Telephone No. 972-73-3927231

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2019/059058

Patent document cited search report			Publication date	Patent family member(s)			Publication Date
US	2010002837	A1	07 Jan 2010	US	2010002837	A1	07 Jan 2010
				US	7961845	B2	14 Jun 2011
				AU	2007349806	A1	02 Oct 2008
				AU	2007349806	B2	06 Sep 2012
				AU	2008260682	A1	11 Dec 2008
				AU	2008260682	B2	19 Dec 2013
				BR	PI0717529	A2	22 Oct 2013
				CA	2666366	A1	02 Oct 2008
				CA	2666366	C	07 Jun 2016
				CA	2709233	A1	18 Jun 2009
				CA	2709233	C	29 Nov 2016
				CA	2925590	A1	02 Oct 2008
				CN	101588842	A	25 Nov 2009
				CN	101588842	B	25 Sep 2013
				CN	101945685	A	12 Jan 2011
				CN	101945685	B	21 May 2014
				CN	101951990	A	19 Jan 2011
				CN	103446676	A	18 Dec 2013
				EP	2077901	A2	15 Jul 2009
				EP	2077901	A4	29 Jun 2011
				EP	2077901	B1	23 Sep 2015
				EP	2152142	A1	17 Feb 2010
				EP	2152142	A4	29 Jun 2011
				EP	2152142	B1	17 Jul 2013
				EP	2152145	A1	17 Feb 2010
				EP	2152145	A4	13 Jul 2011
				EP	2152145	B1	07 Aug 2013
				EP	2231276	A1	29 Sep 2010
				EP	2231276	A4	06 Apr 2011
				EP	2231277	A2	29 Sep 2010

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2019/059058

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
	EP 2231277	A4	30 Mar 2011
	EP 2231277	B1	30 Aug 2017
	EP 2602005	A1	12 Jun 2013
	EP 2602005	B1	23 Sep 2015
	EP 2606864	A1	26 Jun 2013
	EP 2606864	B1	14 Sep 2016
	EP 2992863	A1	09 Mar 2016
	EP 2992863	B1	12 Dec 2018
	EP 2992931	A1	09 Mar 2016
	EP 2992931	B1	09 Aug 2017
	EP 2992932	A1	09 Mar 2016
	EP 2992932	B1	12 Dec 2018
	EP 2995349	A1	16 Mar 2016
	EP 2995349	B1	11 Apr 2018
	EP 3272395	A1	24 Jan 2018
	EP 3272395	B1	17 Jul 2019
	ES 2553187	T3	04 Dec 2015
	ES 2556615	T3	19 Jan 2016
	ES 2600146	T3	07 Feb 2017
	ES 2638928	T3	24 Oct 2017
	ES 2645686	T3	07 Dec 2017
	ES 2671023	T3	04 Jun 2018
	HK 1141961	A1	18 Oct 2013
	HK 1141977	A1	15 Nov 2013
	HK 1179911	A1	15 Sep 2016
	HK 1180205	A1	30 Jun 2017
	HK 1219863	A1	21 Apr 2017
	HK 1219911	A1	21 Apr 2017
	HK 1219912	A1	21 Apr 2017
	HK 1219913	A1	21 Apr 2017
	IL 198179	D0	24 Dec 2009

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2019/059058

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
	JP 2010528758	A	26 Aug 2010
	JP 5400040	B2	29 Jan 2014
	JP 2014039867	A	06 Mar 2014
	JP 5838192	B2	06 Jan 2016
	JP 2014113502	A	26 Jun 2014
	JP 6210892	B2	11 Oct 2017
	JP 2016127973	A	14 Jul 2016
	JP 6464335	B2	06 Feb 2019
	JP 2010506689	A	04 Mar 2010
	KR 20140084360	A	04 Jul 2014
	KR 101461403	B1	13 Nov 2014
	KR 20090080976	A	27 Jul 2009
	KR 101472342	B1	12 Dec 2014
	MX 2009003961	A	03 Jul 2009
	US 2008089481	A1	17 Apr 2008
	US 7496174	B2	24 Feb 2009
	US 2008089480	A1	17 Apr 2008
	US 7535991	B2	19 May 2009
	US 2008187100	A1	07 Aug 2008
	US 7564946	B2	21 Jul 2009
	US 2008212738	A1	04 Sep 2008
	US 7620147	B2	17 Nov 2009
	US 2008187098	A1	07 Aug 2008
	US 7680244	B2	16 Mar 2010
	US 2008181362	A1	31 Jul 2008
	US 7680245	B2	16 Mar 2010
	US 2008187099	A1	07 Aug 2008
	US 7693258	B2	06 Apr 2010
	US 2008192893	A1	14 Aug 2008
	US 7693259	B2	06 Apr 2010
	US 2008247510	A1	09 Oct 2008

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2019/059058

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
	US 7693260	B2	06 Apr 2010
	US 2008187101	A1	07 Aug 2008
	US 7697663	B2	13 Apr 2010
	US 2009161827	A1	25 Jun 2009
	US 7792249	B2	07 Sep 2010
	US 2009161826	A1	25 Jun 2009
	US 7801271	B2	21 Sep 2010
	US 2008144771	A1	19 Jun 2008
	US 7822175	B2	26 Oct 2010
	US 2008187102	A1	07 Aug 2008
	US 7912178	B2	22 Mar 2011
	US 2009022274	A1	22 Jan 2009
	US 7912179	B2	22 Mar 2011
	US 2009003525	A1	01 Jan 2009
	US 7953203	B2	31 May 2011
	US 2010166148	A1	01 Jul 2010
	US 7978818	B2	12 Jul 2011
	US 2010067656	A1	18 Mar 2010
	US 7978819	B2	12 Jul 2011
	US 2011038456	A1	17 Feb 2011
	US 8059784	B2	15 Nov 2011
	US 2010172473	A1	08 Jul 2010
	US 8073105	B2	06 Dec 2011
	US 2010195794	A1	05 Aug 2010
	US 8094779	B2	10 Jan 2012
	US 2010260320	A1	14 Oct 2010
	US 8180021	B2	15 May 2012
	US 2011228908	A1	22 Sep 2011
	US 8184772	B2	22 May 2012
	US 2011170665	A1	14 Jul 2011
	US 8189739	B2	29 May 2012

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2019/059058

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
	US 2010067658	A1	18 Mar 2010
	US 8229069	B2	24 Jul 2012
	US 2011274248	A1	10 Nov 2011
	US 8229073	B2	24 Jul 2012
	US 2010067657	A1	18 Mar 2010
	US 8238517	B2	07 Aug 2012
	US 2011268250	A1	03 Nov 2011
	US 8295437	B2	23 Oct 2012
	US 2011243304	A1	06 Oct 2011
	US 8306186	B2	06 Nov 2012
	US 2010254513	A1	07 Oct 2010
	US 8320524	B2	27 Nov 2012
	US 2009163898	A1	25 Jun 2009
	US 8363783	B2	29 Jan 2013
	US 2011170664	A1	14 Jul 2011
	US 8442185	B2	14 May 2013
	US 2010239067	A1	23 Sep 2010
	US 8457277	B2	04 Jun 2013
	US 2011081001	A1	07 Apr 2011
	US 8494116	B2	23 Jul 2013
	US 2011081000	A1	07 Apr 2011
	US 8503609	B2	06 Aug 2013
	US 2009182310	A1	16 Jul 2009
	US 8506558	B2	13 Aug 2013
	US 2009182311	A1	16 Jul 2009
	US 8512236	B2	20 Aug 2013
	US 2012057675	A1	08 Mar 2012
	US 8611497	B2	17 Dec 2013
	US 2013141696	A1	06 Jun 2013
	US 8630388	B2	14 Jan 2014
	US 2012177179	A1	12 Jul 2012

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2019/059058

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
		US 8761336 B2	24 Jun 2014
		US 2013301800 A1	14 Nov 2013
		US 8787524 B2	22 Jul 2014
		US 2012076272 A1	29 Mar 2012
		US 8837675 B2	16 Sep 2014
		US 2013315374 A1	28 Nov 2013
		US 8848869 B2	30 Sep 2014
		US 2013243158 A1	19 Sep 2013
		US 8855267 B2	07 Oct 2014
		US 2009182312 A1	16 Jul 2009
		US 8920406 B2	30 Dec 2014
		US 2014126700 A1	08 May 2014
		US 8923479 B2	30 Dec 2014
		US 2014105362 A1	17 Apr 2014
		US 8995618 B2	31 Mar 2015
		US 2014037063 A1	06 Feb 2014
		US 9025727 B2	05 May 2015
		US 2014328461 A1	06 Nov 2014
		US 9272161 B2	01 Mar 2016
		US 2010078470 A1	01 Apr 2010
		WO 2008118198 A2	02 Oct 2008
		WO 2008118198 A3	19 Feb 2009
		WO 2008124801 A2	16 Oct 2008
		WO 2008124801 A3	31 Dec 2008
		WO 2008150330 A1	11 Dec 2008
		WO 2008150331 A1	11 Dec 2008
		WO 2009075714 A1	18 Jun 2009
		WO 2009085204 A2	09 Jul 2009
		WO 2009085204 A3	30 Dec 2009
		WO 2010037123 A1	01 Apr 2010
US 2016346126 A1	10 Dec 2016	US 2016346126 A1	01 Dec 2016

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2019/059058

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
		US 9962291 B2	08 May 2018
		AU 2013266816 A1	27 Nov 2014
		AU 2013266816 B2	02 Mar 2017
		AU 2015290225 A1	08 Dec 2016
		AU 2015380376 A1	20 Jul 2017
		AU 2015380376 B2	11 Apr 2019
		AU 2015380409 A1	20 Jul 2017
		AU 2015380409 B2	18 Oct 2018
		AU 2015380411 A1	20 Jul 2017
		AU 2015380411 B2	14 Mar 2019
		AU 2016342091 A1	26 Apr 2018
		AU 2016346526 A1	15 Mar 2018
		AU 2016405579 A1	04 Oct 2018
		AU 2017200606 A1	23 Feb 2017
		AU 2017308587 A1	17 Jan 2019
		AU 2017412681 A1	31 Oct 2019
		AU 2017412681 B2	14 Nov 2019
		AU 2018236202 A1	29 Aug 2019
		AU 2019201564 A1	28 Mar 2019
		BR 112014029326 A2	27 Jun 2017
		BR 112017000365 A2	23 Jan 2018
		BR 112017016255 A2	27 Mar 2018
		BR 112017016267 A2	27 Mar 2018
		BR 112017016288 A2	27 Mar 2018
		BR 112018005267 A2	09 Oct 2018
		BR 112018008359 A2	23 Oct 2018
		BR 112018072711 A2	19 Feb 2019
		BR 112019001348 A2	30 Apr 2019
		CA 2949956 A1	21 Jan 2016
		CA 2972416 A1	04 Aug 2016

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2019/059058

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
	CA 2972416	C	14 Jan 2020
	CA 2972420	A1	04 Aug 2016
	CA 2972438	A1	04 Aug 2016
	CA 2994110	A1	27 Apr 2017
	CA 2996981	A1	04 May 2017
	CA 3018167	A1	09 Nov 2017
	CA 3022624	A1	04 Aug 2016
	CA 3030483	A1	15 Feb 2018
	CA 3051444	A1	20 Sep 2018
	CA 3058891	A1	08 Nov 2018
	CA 3063889	A1	04 Aug 2016
	CN 104487031	A	01 Apr 2015
	CN 104487031	B	27 Oct 2017
	CN 106456369	A	22 Feb 2017
	CN 107205768	A	26 Sep 2017
	CN 107205846	A	26 Sep 2017
	CN 107205848	A	26 Sep 2017
	CN 108024870	A	11 May 2018
	CN 108136195	A	08 Jun 2018
	CN 109069294	A	21 Dec 2018
	CN 109562272	A	02 Apr 2019
	CN 110520194	A	29 Nov 2019
	CN 110582238	A	17 Dec 2019
	EP 2854729	A1	08 Apr 2015
	EP 2854729	A4	18 May 2016
	EP 3171838	A1	31 May 2017
	EP 3171838	A4	23 May 2018
	EP 3250139	A1	06 Dec 2017
	EP 3250139	A4	27 Jun 2018
	EP 3250166	A1	06 Dec 2017
	EP 3250166	A4	12 Sep 2018

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2019/059058

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
	EP	3250167 A1	06 Dec 2017
	EP	3250167 A4	01 Aug 2018
	EP	3364925 A1	29 Aug 2018
	EP	3364925 A4	18 Sep 2019
	EP	3368153 A1	05 Sep 2018
	EP	3368153 A4	27 Feb 2019
	EP	3451983 A1	13 Mar 2019
	EP	3451983 A4	23 Oct 2019
	EP	3496810 A1	19 Jun 2019
	EP	3496810 A4	16 Oct 2019
	EP	3593771 A1	15 Jan 2020
	EP	3595775 A1	22 Jan 2020
	HK	1252431 A1	24 May 2019
	HK	1252432 A1	24 May 2019
	IN	2588KON2014 A	08 May 2015
	JP	2018503434 A	08 Feb 2018
	JP	6480588 B2	13 Mar 2019
	JP	2018503433 A	08 Feb 2018
	JP	6527946 B2	12 Jun 2019
	JP	2015520653 A	23 Jul 2015
	JP	2017527320 A	21 Sep 2017
	JP	2018202256 A	27 Dec 2018
	JP	2018503432 A	08 Feb 2018
	JP	2018531051 A	25 Oct 2018
	JP	2018533992 A	22 Nov 2018
	JP	2019108334 A	04 Jul 2019
	JP	2019514454 A	06 Jun 2019
	JP	2019524179 A	05 Sep 2019
	SG	10201609812S A	27 Jan 2017
	SG	11201407205W A	30 Dec 2014
	SG	11201609858U A	29 Dec 2016

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2019/059058

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
	SG	11201705655T A	30 Aug 2017
	SG	11201705677W A	30 Aug 2017
	SG	11201800734Q A	30 May 2018
	SG	11201801331U A	30 May 2018
	SG	11201808069V A	29 Nov 2018
	SG	11201907081T A	27 Sep 2019
	SG	11201909214Y A	28 Nov 2019
	US	2015157498 A1	11 Jun 2015
	US	9168174 B2	27 Oct 2015
	US	2013317570 A1	28 Nov 2013
	US	9381115 B2	05 Jul 2016
	US	2016058617 A1	03 Mar 2016
	US	9381116 B2	05 Jul 2016
	US	2016082294 A1	24 Mar 2016
	US	9427602 B2	30 Aug 2016
	US	2016364491 A1	15 Dec 2016
	US	9626445 B2	18 Apr 2017
	US	2016339264 A1	24 Nov 2016
	US	10076671 B2	18 Sep 2018
	US	2017035612 A1	09 Feb 2017
	US	10117777 B2	06 Nov 2018
	US	2013317487 A1	28 Nov 2013
	US	10219947 B2	05 Mar 2019
	US	2016296374 A1	13 Oct 2016
	US	10238542 B2	26 Mar 2019
	US	2017319383 A1	09 Nov 2017
	US	10278863 B2	07 May 2019
	US	2018271707 A1	27 Sep 2018
	US	10278865 B2	07 May 2019
	US	2017027755 A1	02 Feb 2017
	US	10285859 B2	14 May 2019

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2019/059058

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
	US	2018280196 A1	04 Oct 2018
	US	10299961 B2	28 May 2019
	US	2018221206 A1	09 Aug 2018
	US	10307294 B2	04 Jun 2019
	US	2017193065 A1	06 Jul 2017
	US	10331800 B2	25 Jun 2019
	US	2018078412 A1	22 Mar 2018
	US	10357398 B2	23 Jul 2019
	US	2016287443 A1	06 Oct 2016
	US	10363171 B2	30 Jul 2019
	US	2016338757 A1	24 Nov 2016
	US	10531908 B2	14 Jan 2020
	US	2014330352 A1	06 Nov 2014
	US	2016199227 A1	14 Jul 2016
	US	2017203132 A1	20 Jul 2017
	US	2017232269 A1	17 Aug 2017
	US	2018200532 A1	19 Jul 2018
	US	2018339167 A1	29 Nov 2018
	US	2018339170 A1	29 Nov 2018
	US	2019159932 A1	30 May 2019
	US	2019269552 A1	05 Sep 2019
	US	2019310976 A1	10 Oct 2019
	US	2019328577 A1	31 Oct 2019
	WO	2013176810 A1	28 Nov 2013
	WO	2016010627 A1	21 Jan 2016
	WO	2016122717 A1	04 Aug 2016
	WO	2016122750 A1	04 Aug 2016
	WO	2016122752 A1	04 Aug 2016
	WO	2017069819 A1	27 Apr 2017
	WO	2017074532 A1	04 May 2017
	WO	2017192168 A1	09 Nov 2017

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2019/059058

Patent document cited search report			Publication date		Patent family member(s)		Publication Date
					WO	2018031255 A1	15 Feb 2018
					WO	2018169560 A1	20 Sep 2018
					WO	2018169969 A1	20 Sep 2018
					WO	2018203930 A1	08 Nov 2018
					WO	2019099068 A1	23 May 2019
					WO	2019177654 A1	19 Sep 2019
					WO	2019177654 A1	19 Sep 2019
EP	2602005	A1	12 Jun 2013		EP	2602005 A1	12 Jun 2013
					EP	2602005 B1	23 Sep 2015
					AU	2007349806 A1	02 Oct 2008
					AU	2007349806 B2	06 Sep 2012
					AU	2008260682 A1	11 Dec 2008
					AU	2008260682 B2	19 Dec 2013
					BR	PI0717529 A2	22 Oct 2013
					CA	2666366 A1	02 Oct 2008
					CA	2666366 C	07 Jun 2016
					CA	2709233 A1	18 Jun 2009
					CA	2709233 C	29 Nov 2016
					CA	2925590 A1	02 Oct 2008
					CN	101588842 A	25 Nov 2009
					CN	101588842 B	25 Sep 2013
					CN	101945685 A	12 Jan 2011
					CN	101945685 B	21 May 2014
					CN	101951990 A	19 Jan 2011
					CN	103446676 A	18 Dec 2013
					EP	2077901 A2	15 Jul 2009
					EP	2077901 A4	29 Jun 2011
					EP	2077901 B1	23 Sep 2015
					EP	2152142 A1	17 Feb 2010
					EP	2152142 A4	29 Jun 2011
					EP	2152142 B1	17 Jul 2013

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2019/059058

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
	EP 2152145	A1	17 Feb 2010
	EP 2152145	A4	13 Jul 2011
	EP 2152145	B1	07 Aug 2013
	EP 2231276	A1	29 Sep 2010
	EP 2231276	A4	06 Apr 2011
	EP 2231277	A2	29 Sep 2010
	EP 2231277	A4	30 Mar 2011
	EP 2231277	B1	30 Aug 2017
	EP 2606864	A1	26 Jun 2013
	EP 2606864	B1	14 Sep 2016
	EP 2992863	A1	09 Mar 2016
	EP 2992863	B1	12 Dec 2018
	EP 2992931	A1	09 Mar 2016
	EP 2992931	B1	09 Aug 2017
	EP 2992932	A1	09 Mar 2016
	EP 2992932	B1	12 Dec 2018
	EP 2995349	A1	16 Mar 2016
	EP 2995349	B1	11 Apr 2018
	EP 3272395	A1	24 Jan 2018
	EP 3272395	B1	17 Jul 2019
	ES 2553187	T3	04 Dec 2015
	ES 2556615	T3	19 Jan 2016
	ES 2600146	T3	07 Feb 2017
	ES 2638928	T3	24 Oct 2017
	ES 2645686	T3	07 Dec 2017
	ES 2671023	T3	04 Jun 2018
	HK 1141961	A1	18 Oct 2013
	HK 1141977	A1	15 Nov 2013
	HK 1179911	A1	15 Sep 2016
	HK 1180205	A1	30 Jun 2017
	HK 1219863	A1	21 Apr 2017

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2019/059058

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
	HK	1219911 A1	21 Apr 2017
	HK	1219912 A1	21 Apr 2017
	HK	1219913 A1	21 Apr 2017
	IL	198179 D0	24 Dec 2009
	JP	2010528758 A	26 Aug 2010
	JP	5400040 B2	29 Jan 2014
	JP	2014039867 A	06 Mar 2014
	JP	5838192 B2	06 Jan 2016
	JP	2014113502 A	26 Jun 2014
	JP	6210892 B2	11 Oct 2017
	JP	2016127973 A	14 Jul 2016
	JP	6464335 B2	06 Feb 2019
	JP	2010506689 A	04 Mar 2010
	KR	20140084360 A	04 Jul 2014
	KR	101461403 B1	13 Nov 2014
	KR	20090080976 A	27 Jul 2009
	KR	101472342 B1	12 Dec 2014
	MX	2009003961 A	03 Jul 2009
	US	2008089481 A1	17 Apr 2008
	US	7496174 B2	24 Feb 2009
	US	2008089480 A1	17 Apr 2008
	US	7535991 B2	19 May 2009
	US	2008187100 A1	07 Aug 2008
	US	7564946 B2	21 Jul 2009
	US	2008212738 A1	04 Sep 2008
	US	7620147 B2	17 Nov 2009
	US	2008187098 A1	07 Aug 2008
	US	7680244 B2	16 Mar 2010
	US	2008181362 A1	31 Jul 2008
	US	7680245 B2	16 Mar 2010
	US	2008187099 A1	07 Aug 2008

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2019/059058

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
	US 7693258	B2	06 Apr 2010
	US 2008192893	A1	14 Aug 2008
	US 7693259	B2	06 Apr 2010
	US 2008247510	A1	09 Oct 2008
	US 7693260	B2	06 Apr 2010
	US 2008187101	A1	07 Aug 2008
	US 7697663	B2	13 Apr 2010
	US 2009161827	A1	25 Jun 2009
	US 7792249	B2	07 Sep 2010
	US 2009161826	A1	25 Jun 2009
	US 7801271	B2	21 Sep 2010
	US 2008144771	A1	19 Jun 2008
	US 7822175	B2	26 Oct 2010
	US 2008187102	A1	07 Aug 2008
	US 7912178	B2	22 Mar 2011
	US 2009022274	A1	22 Jan 2009
	US 7912179	B2	22 Mar 2011
	US 2009003525	A1	01 Jan 2009
	US 7953203	B2	31 May 2011
	US 2010002837	A1	07 Jan 2010
	US 7961845	B2	14 Jun 2011
	US 2010166148	A1	01 Jul 2010
	US 7978818	B2	12 Jul 2011
	US 2010067656	A1	18 Mar 2010
	US 7978819	B2	12 Jul 2011
	US 2011038456	A1	17 Feb 2011
	US 8059784	B2	15 Nov 2011
	US 2010172473	A1	08 Jul 2010
	US 8073105	B2	06 Dec 2011
	US 2010195794	A1	05 Aug 2010
	US 8094779	B2	10 Jan 2012

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2019/059058

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
	US	2010260320 A1	14 Oct 2010
	US	8180021 B2	15 May 2012
	US	2011228908 A1	22 Sep 2011
	US	8184772 B2	22 May 2012
	US	2011170665 A1	14 Jul 2011
	US	8189739 B2	29 May 2012
	US	2010067658 A1	18 Mar 2010
	US	8229069 B2	24 Jul 2012
	US	2011274248 A1	10 Nov 2011
	US	8229073 B2	24 Jul 2012
	US	2010067657 A1	18 Mar 2010
	US	8238517 B2	07 Aug 2012
	US	2011268250 A1	03 Nov 2011
	US	8295437 B2	23 Oct 2012
	US	2011243304 A1	06 Oct 2011
	US	8306186 B2	06 Nov 2012
	US	2010254513 A1	07 Oct 2010
	US	8320524 B2	27 Nov 2012
	US	2009163898 A1	25 Jun 2009
	US	8363783 B2	29 Jan 2013
	US	2011170664 A1	14 Jul 2011
	US	8442185 B2	14 May 2013
	US	2010239067 A1	23 Sep 2010
	US	8457277 B2	04 Jun 2013
	US	2011081001 A1	07 Apr 2011
	US	8494116 B2	23 Jul 2013
	US	2011081000 A1	07 Apr 2011
	US	8503609 B2	06 Aug 2013
	US	2009182310 A1	16 Jul 2009
	US	8506558 B2	13 Aug 2013
	US	2009182311 A1	16 Jul 2009

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2019/059058

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
	US	8512236 B2	20 Aug 2013
	US	2012057675 A1	08 Mar 2012
	US	8611497 B2	17 Dec 2013
	US	2013141696 A1	06 Jun 2013
	US	8630388 B2	14 Jan 2014
	US	2012177179 A1	12 Jul 2012
	US	8761336 B2	24 Jun 2014
	US	2013301800 A1	14 Nov 2013
	US	8787524 B2	22 Jul 2014
	US	2012076272 A1	29 Mar 2012
	US	8837675 B2	16 Sep 2014
	US	2013315374 A1	28 Nov 2013
	US	8848869 B2	30 Sep 2014
	US	2013243158 A1	19 Sep 2013
	US	8855267 B2	07 Oct 2014
	US	2009182312 A1	16 Jul 2009
	US	8920406 B2	30 Dec 2014
	US	2014126700 A1	08 May 2014
	US	8923479 B2	30 Dec 2014
	US	2014105362 A1	17 Apr 2014
	US	8995618 B2	31 Mar 2015
	US	2014037063 A1	06 Feb 2014
	US	9025727 B2	05 May 2015
	US	2014328461 A1	06 Nov 2014
	US	9272161 B2	01 Mar 2016
	US	2010078470 A1	01 Apr 2010
	WO	2008118198 A2	02 Oct 2008
	WO	2008118198 A3	19 Feb 2009
	WO	2008124801 A2	16 Oct 2008
	WO	2008124801 A3	31 Dec 2008
	WO	2008150330 A1	11 Dec 2008

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2019/059058

Patent document cited search report			Publication date	Patent family member(s)			Publication Date
				WO	2008150331	A1	11 Dec 2008
				WO	2009075714	A1	18 Jun 2009
				WO	2009085204	A2	09 Jul 2009
				WO	2009085204	A3	30 Dec 2009
				WO	2010037123	A1	01 Apr 2010
				ES	2380076	T3	08 May 2012
				AT	535205	T	15 Dec 2011
				AU	2008226863	A1	18 Sep 2008
				AU	2008226863	B2	02 Jun 2011
				CN	101657165	A	24 Feb 2010
				EP	2129315	A1	09 Dec 2009
				EP	2129315	A4	07 Apr 2010
				EP	2129315	B1	30 Nov 2011
				JP	2010521224	A	24 Jun 2010
				JP	5166454	B2	21 Mar 2013
				US	2008319427	A1	25 Dec 2008
				US	8568393	B2	29 Oct 2013
				WO	2008112236	A1	18 Sep 2008
				CN	101431975	A	13 May 2009
				CN	101431975	B	26 Jan 2011
				AU	2005260743	A1	12 Jan 2006
				AU	2005260743	B2	29 Jan 2009
				EP	1771140	A2	11 Apr 2007
				EP	1771140	A4	16 Sep 2009
				EP	1771140	B1	30 Jan 2013
				ES	2405274	T3	30 May 2013
				JP	2008504075	A	14 Feb 2008
				JP	5060949	B2	31 Oct 2012
				US	2005288745	A1	29 Dec 2005

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2019/059058

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
		WO 2006005038 A2	12 Jan 2006
		WO 2006005038 A9	06 Apr 2006
		WO 2006005038 A3	02 Apr 2009