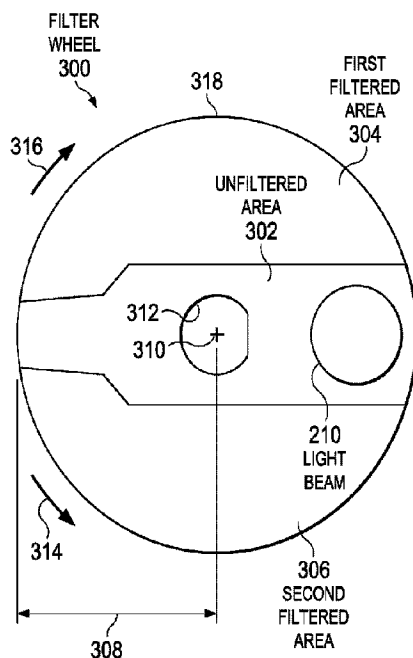




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(54) Title: OPHTHALMIC SURGICAL SYSTEM WITH BLUE LIGHT FILTERING



(57) **Abrégé/Abstract:**

An ophthalmic surgical system can include a light source configured to generate a light beam and a filter wheel disposed between the light source and an intraocular illumination device. The filter wheel can include an unfiltered area, a first filtered area, and a second filtered area. The first and second filtered areas can limit transmission of certain wavelengths of the light beam to the intraocular illumination device. The system can include an actuator configured to selectively move the filter wheel to cause the light beam to pass through the unfiltered area, the first filtered area, and/or the second filtered area. The system can include a computing device configured to provide a control signal to the actuator. The computing device can be configured to provide a control signal to the actuator based on a beam location, a beam composition, an exposure time, and/or a limited visibility condition.



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(54) Title: OPHTHALMIC SURGICAL SYSTEM WITH BLUE LIGHT FILTERING

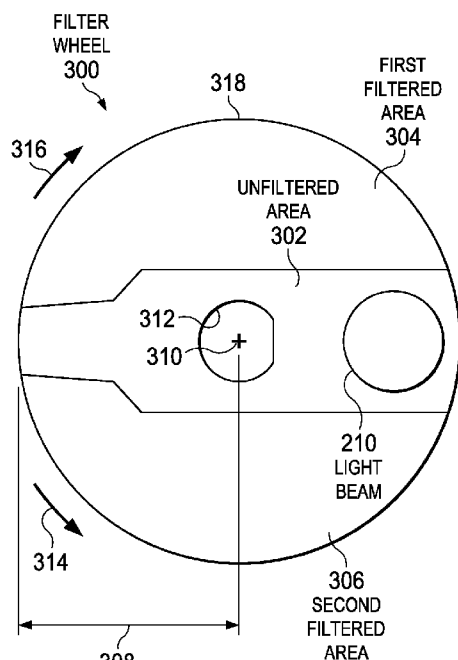


Fig. 3a

(57) Abstract: An ophthalmic surgical system can include a light source configured to generate a light beam and a filter wheel disposed between the light source and an intraocular illumination device. The filter wheel can include an unfiltered area, a first filtered area, and a second filtered area. The first and second filtered areas can limit transmission of certain wavelengths of the light beam to the intraocular illumination device. The system can include an actuator configured to selectively move the filter wheel to cause the light beam to pass through the unfiltered area, the first filtered area, and/or the second filtered area. The system can include a computing device configured to provide a control signal to the actuator. The computing device can be configured to provide a control signal to the actuator based on a beam location, a beam composition, an exposure time, and/or a limited visibility condition.

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Ophthalmic Surgical System with Blue Light Filtering

BACKGROUND

5 Technical Field

Embodiments disclosed herein are related to improved illumination for vitreo-retinal, macular, or other ophthalmic surgeries. More specifically, embodiments described herein relate to ophthalmic surgical systems including an illumination system with blue light filtering to reduce the risk of phototoxicity.

10 Related Art

Ophthalmic surgical procedures, such as vitreo-retinal surgeries, can involve illumination of relevant anatomy in a patient's eye. For example, light can be directed at the macula during a vitrectomy. Illumination can be provided by one or more illuminators, such as an endoillumination probe.

15 Providing illumination within the eye can be challenging for several reasons. For example, exposure to light associated with wavelengths in the blue region of the visible spectrum can be harmful to the eye. Shorter wavelength light has greater energy per photon and is therefore more likely to cause phototoxicity than longer wavelength light. The standardized metric for retinal phototoxicity is the Aphakic Hazard. The eye can
20 handle some amount of blue light without adverse effects, but if the duration of the surgery extends beyond a certain time, a surgeon must take steps to avoid harm to the eye. Conventionally, these steps include lowering the intensity of the light in the eye. This, however, can require the surgeon to work in a darker environment than desired for the duration of the surgical procedure—circumstances that can make successful completion
25 of the procedure more difficult.

More recently, illumination systems have been developed that allow a surgeon to eliminate wavelengths associated with blue light. In these systems, a surgeon has two choices: include blue light or exclude blue light. This too, however, can be problematic because the surgical field appears yellow with the removal of blue light. Such working
30 conditions are not ideal for a surgeon to successfully complete the surgical procedure.

Accordingly, there remains a need for improved devices, systems, and methods that facilitate intraocular illumination with improved blue light filtering by addressing one or more of the needs discussed above.

SUMMARY

5 The presented solution fills an unmet medical need with a unique solution to provide intraocular illumination during ophthalmic surgical procedures with selective filtering of one or more wavelength ranges associated with blue light.

Consistent with some embodiments, an ophthalmic surgical system can include: a light source configured to generate a light beam; a filter wheel disposed between the light
10 source and an intraocular illumination device, the filter wheel including an unfiltered area, a first filtered area configured to limit the transmission of a first range of wavelengths of the light beam to the intraocular illumination device, and a second filtered area configured to limit the transmission of a second range of wavelengths of the light beam to the intraocular illumination device; and an actuator configured to selectively
15 move the filter wheel to cause the light beam to pass through at least one of the unfiltered area, the first filtered area, and the second filtered area of the filter wheel.

Consistent with some embodiments, an ophthalmic filter wheel for filtering a light beam of an intraocular illumination device can include: an unfiltered area; a first filtered area configured to limit the transmission of a first range of wavelengths of the light beam
20 to the intraocular illumination device; and a second filtered area configured to permit the transmission of a second range of wavelengths of the light beam to the intraocular illumination device, wherein the unfiltered area is positioned adjacent to at least one of the first and second filtered areas.

Consistent with some embodiments, a method of performing an ophthalmic
25 surgical procedure can include: guiding a light beam through a filter wheel to an intraocular illumination device, wherein the filter wheel includes an unfiltered area, a first filtered area configured to limit the transmission of a first range of wavelengths of the light beam to the intraocular illumination device, and a second filtered area configured to limit the transmission of a second range of wavelengths of the light beam to the
30 intraocular illumination device; and selectively moving the filter wheel to cause the light beam to pass through at least one of the unfiltered area, the first filtered area, and the second filtered area of the filter wheel.

In accordance with some embodiments, there is provided an ophthalmic surgical system comprising:

a light source that generates a light beam;

5 a filter wheel disposed between the light source and an intraocular illumination device, the filter wheel including

an unfiltered area;

a first filtered area that limits the transmission of a first range of wavelengths of the light beam to the intraocular illumination device; and

10 a second filtered area that limits the transmission of a second range of wavelengths of the light beam to the intraocular illumination device; and

an actuator that selectively moves the filter wheel to cause the light beam to pass through one or more of the unfiltered area, the first filtered area, and the second filtered area of the filter wheel; and

15 a computing device in communication with the actuator, wherein said computing device

monitors transmission of blue light by the intraocular illumination device within an eye; and

20 outputs, in response to the monitoring the transmission of blue light by the intraocular illumination device, control signals to the actuator to limit the transmission of blue light within the eye to minimize retinal phototoxicity by causing the actuator to selectively move the filter wheel such that the light beam passes through the one or more of the unfiltered area, the first filtered area, and the second filtered area of the filter wheel.

25 In accordance with some embodiments, there is provided an ophthalmic surgical system comprising:

a light source that generates a light beam;

a filter disposed between the light source and an intraocular illumination device, the filter including:

an unfiltered area;

a first filtered area that limits the transmission of a first range of wavelengths of the light beam to the intraocular illumination device; and

a second filtered area that limits the transmission of a second range of wavelengths of the light beam to the intraocular illumination device;

5 an actuator that selectively moves the filter to cause the light beam to pass through one or more of the unfiltered area, the first filtered area, and the second filtered area of the filter; and

a processor in communication with the actuator, wherein said processor:

10 detects a beam composition of the light beam transmitted by the intraocular illumination device within an eye; and

 based on the detected beam composition, outputs a first control signal to modify the detected beam composition by causing the actuator to selectively move the filter to a first position such that a first portion of the light beam passes through the unfiltered area and a second portion of the light beam passes through
15 the first filtered area or the second filtered area.

In accordance with some embodiments, there is provided an ophthalmic surgical system comprising:

an intraocular illumination device sized and shaped for positioning within an eye of a patient and for transmission of a light beam within the eye;

20 a filter positioned in a beam path of the light beam, the filter including:

an unfiltered area;

a first filtered area that limits the transmission of a first range of wavelengths of the light beam by the intraocular illumination device within the eye; and

25 a second filtered area that limits the transmission of a second range of wavelengths of the light beam by the intraocular illumination device within the eye;

30 an actuator that selectively moves the filter to cause the light beam to pass through one or more of the unfiltered area, the first filtered area, and the second filtered area of the filter; and

a processor in communication with the actuator, wherein said processor:

detects a beam composition of the light beam transmitted by the intraocular illumination device within the eye; and

5 based on the detected beam composition, outputs a first control signal to modify the detected beam composition by causing the actuator to selectively move the filter to a first position such that a first portion of the light beam passes through the unfiltered area and a second portion of the light beam passes through the first filtered area or the second filtered area.

10 Additional aspects, features, and advantages of the present disclosure will become apparent from the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 provides a diagram illustrating an ophthalmic surgical system.

FIG. 2a provides a diagrammatic perspective view of a portion of an ophthalmic surgical system.

15 **FIG. 2b** provides a diagrammatic perspective view of a portion of an ophthalmic surgical system.

FIG. 3a provides a diagram illustrating an ophthalmic filter wheel.

FIG. 3b provides a diagram illustrating an ophthalmic filter wheel.

FIG. 3c provides a diagram illustrating an ophthalmic filter wheel.

20 **FIG. 3d** provides a diagram illustrating an ophthalmic filter wheel.

FIG. 3e provides a diagram illustrating an ophthalmic filter wheel.

FIG. 3f provides a diagram illustrating an ophthalmic filter wheel.

In the drawings, elements having the same designation have the same or similar functions.

25 DETAILED DESCRIPTION

In the following description specific details are set forth describing certain embodiments. It will be apparent, however, to one skilled in the art that the disclosed embodiments may be practiced without some or all of these specific details. The specific embodiments presented are meant to be illustrative, but not limiting. One skilled in the

art may realize other material that, although not specifically described herein, is within the scope and spirit of this disclosure.

The ophthalmic surgical systems of the present disclosure can include a light filtering system using a filter wheel introduced into a beam path of a fiber-based illuminator. The filter wheel can have two sections that attenuate different wavelength ranges of light and a clear section that allows substantially all wavelengths to pass through unimpeded. The filter wheel can be moved into the beam path to provide filtering of one or more wavelength ranges associated with blue light. The filter wheel can also allow for light to pass through unimpeded and to pass through with concurrent filtering in multiple wavelength ranges.

The ophthalmic surgical systems including the filter wheel of the present disclosure can provide numerous advantages, including (1) improved patient safety by reducing the risk of phototoxicity and the Aphakic Hazard metric; (2) optimized control of blue light filtering based on the target area in the eye; (3) optimized control of the percentage of blue light allowed to pass through to the eye; (4) optimized control of blue light exposure time to the eye; (5) optimized control of illumination during the surgical procedure based on a patient's physiological conditions that limit a surgeon's ability to see relevant anatomy within the eye; (6) improved working conditions for a surgeon during the ophthalmic surgical procedure; (7) selective, incremented, and/or gradated blue light filtering; (8) attenuation and/or elimination of multiple wavelength ranges associated with blue light; and (9) relatively simple and cost-effective implementation.

FIG. 1 illustrates an ophthalmic surgical system 100. The ophthalmic surgical system 100 can include a light source 110 configured to generate a light beam 210 (**FIGS. 2a and 2b**). The ophthalmic surgical system 100 can include a filter wheel 300 disposed between the light source 110 and an intraocular illumination device 120. The filter wheel 300 can include an unfiltered area 302 (**FIGS. 3a-3f**) configured to permit transmission of the light beam 210 to the intraocular illumination device 120. The filter wheel 300 can include a first filtered area 304 and a second filtered area 306 (**FIGS. 3a-3f**) configured to limit the transmission of certain wavelengths of the light beam 210 to the intraocular illumination device 120. The ophthalmic surgical system 100 can include an actuator 220 (**FIGS. 2a and 2b**) configured to selectively move the filter wheel 300 to cause the unfiltered area 302, the first filtered area 304, and/or the second filtered area 306 to be

positioned in a path of the light beam 210 to limit the transmission of the certain wavelengths of the light beam 210.

As shown in **FIG. 1**, the ophthalmic surgical system 100 can include a light source 110 configured to generate the light beam 210 along a beam path 102. The light source 110 can be, for example, a laser source. The light beam 210 can be split into two, three, or more sub-beams along the beam path 102, between the light source 110 and the filter wheel 300. For example, two, three, or more intraocular illumination devices 120 can be optically or otherwise coupled to the light source 110. The system 100 can include a single filter wheel 300 or include a filter wheel 300 for each sub-beam of the light beam to facilitate filtering of the light going to the intraocular illumination device(s) 120. The light beam 210 along the beam path 102 can be relatively larger than the light beam transmitted to the surgical field by the intraocular illumination device 120. The diameter of the light beam 210 can be between about 10 μm to about 20 mm, between about 200 μm and about 20 mm, or between about 1 mm and about 20 mm, including values such as 1 mm, 2 mm, 3 mm, 4 mm, 5 mm, 6 mm, 7 mm, 8 mm, 9 mm, or other suitable value.

The filter wheel 300 can be disposed between the light source 110 and the intraocular illumination device 120. As described herein in the discussion of **FIGS. 3a-3f**, the filter wheel 300 can be configured to selectively limit the transmission of one or more wavelength ranges of the light beam 210 along the beam path 102 between the filter wheel 300 and the intraocular illumination device 120. The light beam can be mixed, focused, and/or otherwise processed along the beam path 102 and/or within the intraocular illumination device 120 such that a final output beam of the intraocular illumination device 120 can be homogenous. For example, the diameter of the light beam transmitted to the surgical field by the intraocular illumination device 120 can be between about 1 μm and 500 μm , between about 2 μm and 400 μm , or between about 10 μm and 200 μm , including values such as 5 μm , 10 μm , 15 μm , 20 μm , 100 μm , 200 μm , or other suitable value. Some portion of the beam path 102 and/or intraocular illumination device 120 can include an optical fiber through which the light beam travels.

The ophthalmic surgical system 100 can include an intraocular illumination device 120 configured to operate within a surgical field, such as a patient's eye. The intraocular illumination device 120 can be an optical probe, such as an endoillumination probe, or other device configured to provide light to the surgical field during ophthalmic surgical procedures. For example, the intraocular illumination device 120 can be a chandelier,

illuminated cannula entry port, illuminated vitreous cutter, illuminated laser probe, illuminated scissors, illuminated forceps, illuminated pic, or illuminated manipulator.

The ophthalmic surgery system 100 can include a computing device 130 communicatively coupled to the filter wheel 300 and the intraocular illumination device 120. In that regard, the computing device 130 can be electrically, optically, wirelessly, and/or otherwise communicatively coupled to the filter wheel 300 (or an actuator 220 associated therewith) and/or the intraocular illumination device 120. The computing device 130 can be configured to control and/or monitor the position (e.g., a degree of rotation) of the filter wheel 300. The computing device 130 can also be configured to monitor the position of the intraocular illumination device 120 within the surgical field. For example, the computing device 130 can be configured to track the amount of time, the wavelength ranges, the brightness, and/or other aspects of the light that has been transmitted to the surgical field, including particular areas of the surgical field, such as the macular area, by the intraocular illumination device 120. The computing device 130 can also be configured to provide a signal to move the filter wheel 300 to limit the transmission of certain wavelengths of the light beam 210 along the beam path 102. For example, the computing device 130 can be communicatively coupled to the actuator 220 (**FIGS. 2a and 2b**) that moves the filter wheel 300. The computing device 130 can provide a control signal to the actuator 220 to rotate the filter wheel 300 such that the light beam 210 along the beam path 102 crosses the unfiltered area 302, the first filtered area 304, and/or a second filtered area 306 (**FIGS. 3a-3f**).

FIGS. 2a and 2b illustrate various components of the ophthalmic surgical system 100. **FIGS. 2a and 2b** illustrate a portion of the ophthalmic surgical system 100 between the light source 110 and the intraocular illumination device 120. The filter wheel 300 and the actuator 220 can be disposed between the light source 110 and the intraocular illumination device 120. The actuator 220 can be coupled to and configured to move (e.g., rotate, translate, etc.) the filter wheel 300. The actuator 220 can be configured to selectively move the filter wheel 300 to cause the unfiltered area 302, the first filtered area 304, and/or the second filtered area 306 (**FIGS. 3a-3f**) to be positioned in the beam path 102 of the light beam 210 to limit the transmission of the filtered wavelengths associated with the first and second filtered areas 304, 306. The actuator 220 can be any mechanism suitable to move the filter wheel 300 such as a brushless DC motor, stepper motor, brushed DC motor, piezo actuator, hydraulic actuator, pneumatic actuator, electric

actuator, mechanical actuator, etc. For example, the actuator 220 can include a stepper motor configured to rotate the filter wheel 300. The actuator 220 can be coupled to the filter wheel 300 at an inner edge 312 (**FIGS. 3a-3f**). For example, a shaft of the actuator 220 can be coupled to the filter wheel 300 at the inner edge 312. Rotation of the shaft of the actuator 220 can cause rotation of the filter wheel 300. The actuator 220 can be coupled to an outer edge 318 of the filter wheel 300. The actuator 220 can be coupled to the filter wheel 300 at one or more locations (e.g., at the inner edge 312 and the outer edge 318, at multiple locations of the inner edge 312, at multiple locations of the outer edge 318, etc.).

The light beam 210 can pass through the filter wheel 300 as shown in **FIGS. 2a and 2b**. The transmission of one or more wavelength ranges of the light beam 210 can be limited based on whether the light beam 210 passes through the unfiltered area 302, the first filtered area 304, and/or the second filtered area 306 (**FIGS. 3a-3f**) of the filter wheel 300. The actuator 220 can move the filter wheel 300 (e.g., rotate clockwise or counterclockwise) to cause the light beam 210 to pass through different portions of the filter wheel 300, based on the desired wavelengths of light to be filtered during the ophthalmic surgical procedure.

FIGS. 3a-3f illustrate aspects of the filter wheel 300, including various filtering positions. The filter wheel 300 can include the unfiltered area 302 configured to permit full transmission of the light beam 210, the first filtered area 304 configured to limit the transmission of a first range of wavelengths, and the second filtered area 306 configured to limit a transmission of the second range of wavelengths. Wavelengths of the light beam 210 outside of the first and second filtered wavelength ranges can be allowed to pass through the first and second filtered areas 304, 306, respectively, without being impeded. The first and second ranges of filtered wavelengths can be selected at least partially based on the light source 110 (e.g., the beam composition) of the ophthalmic surgical system 100 and/or wavelengths known to cause damage to the eye, such as blue light wavelengths. Accordingly, the first and/or second range of wavelengths can include wavelengths between about 350 nm and about 520 nm, between about 350 nm and about 515 nm, between about 380 nm and about 480 nm, or other suitable range. For example, the first range of wavelengths can be between approximately 380 nm and approximately 475 nm, and the second range of wavelengths can be between approximately 380 nm and approximately 515 nm.

The first and second filtered areas 304, 306 can be bandpass filters. For example, the first filtered area 304 can be configured to permit wavelengths of the light beam 210 between approximately 475 nm and approximately 650 nm to pass through the filter wheel 300 without being impeded and to limit the transmission of wavelengths outside of that range. Similarly, the second filtered area 306 can be configured to permit wavelengths of the light beam 210 between approximately 515 nm and approximately 650 nm to pass through the filter wheel 300 without being impeded and to limit the transmission of wavelengths outside of that range.

The filter wheel 300 can have a circular or disc profile, as shown in **FIGS. 2a-3f**. The size of the filter wheel 300 (e.g., height, width, diameter, thickness, etc.), including the areas used to define the unfiltered area 302, the first filtered area 304, and the second filtered area 306, can be selected based on the expected diameter range(s) of the light beam 210. For example, the filter wheel 300 can have a radius 308 between about 10 mm and about 50 mm, between about 12 mm and 50 mm, or between about 12 mm and about 45 mm, including values such as 12 mm, 13 mm, 14 mm, 15 mm, 16 mm, 17 mm, 18 mm, 19 mm, 20 mm, or other suitable value. The filter wheel 300 can also have other configurations, including symmetric, non-symmetric, geometric, and/or non-geometric profiles of various sizes.

The unfiltered area 302 can be positioned adjacent to the first filtered area 304 and/or the second filtered area 306 to allow the light beam 210 to pass at least partially through one or more of the unfiltered area 302, the first filtered area 304, and the second filtered area 306, as discussed below. The unfiltered area 302, the first filtered area 304, and/or the second filtered area 306 can be variously sized and shaped such that a complete diameter of the light beam 210 or any portion thereof can pass therethrough. The unfiltered area 302, the first filtered area 304, and/or the second filtered area 306 can be positioned at any location on the filter wheel 300. Generally, the filter wheel 300 can include any number of filtered areas and any number of unfiltered areas arranged in a suitable manner to facilitate selective filtering of any number of wavelength ranges.

The filter wheel 300 can be made of or include glass, quartz glass, meteoritic glass, germanium, fluorite, plastic, high index plastic, Trivex, acrylic, polycarbonate, or other suitable material. The entirety of the filter wheel 300 can be made of the same material(s) or different portions of the filter wheel (e.g., the unfiltered area 302, the first filtered area 304, and the second filtered area 306) can be made of different material(s).

Each of the filtered areas of the filter wheel 300 can be an absorptive or dichroic filter. In that regard, the filter wheel 300 can include one or more optical coatings and/or embedded compounds to define the filtered areas. In that regard, the optical coating(s) and/or embedded compound(s) can be selected and/or applied in a manner to achieve
5 filtering of the desired wavelengths. The optical coating(s) and/or embedded compound(s) can include plastic, metal oxide, zinc sulfide, zinc selenide, sodium aluminum fluoride, natural and/or synthetic dye, organic and/or inorganic dye, colloidal dye, a rare earth transition element, or other suitable material(s). In addition to the optical coatings used for filtering, the filter wheel can include an anti-reflective coating and/or a
10 protective coating. For example, the unfiltered area 302 can include an anti-reflective coating. With the anti-reflective coating, the reflectance of the unfiltered area 302 can be less than or equal to approximately 1.0% of incident light.

Performing an ophthalmic surgical procedure can include guiding the light beam 210 through the filter wheel 300 to the intraocular illumination device 120. The filter
15 wheel 300 can be selectively moved to cause the light beam 210 to pass entirely or partially through the unfiltered area 302, the first filtered area 304, and/or the second filtered area 306 during operation of the ophthalmic surgical system 100. For example, the light beam 210 can be directed at least partially through the unfiltered area 302 when phototoxicity and the Aphakic Hazard metric present less of a concern, such as during
20 surgery on the periphery of the retina. The light beam 210 can be directed at least partially through the first filtered area 304 when phototoxicity and the Aphakic Hazard metric present more of a concern, such as during surgery near the macula. When the second filtered area 306 blocks more wavelengths associated with blue light than the first filtered area 304, then the light beam 210 can be directed at least partially through the
25 second filtered area 306 when phototoxicity and the Aphakic Hazard metric present an even greater concern, such as during extended surgery near the macula.

The transmission of light within the first and/or second wavelength ranges can be limited or attenuated by the first and/or second filtered areas 304, 306 between 0% and 100%. 0% attenuation can occur when the complete diameter of the light beam 210
30 passes through unfiltered area 302. 100% attenuation within first and second wavelength range can occur when the complete diameter of the light beam 210 passes entirely through the first filtered area 304 or the second filtered area 306, respectively. Attenuation between 0% and 100% can occur when portions of the light beam

simultaneously pass through the unfiltered area 302 and at least one of the first and/or second filtered areas 304, 306. The filter wheel 300 can be moved such that the first and/or second ranges of wavelengths of the light beam 210 can be limited in increments of approximately 1%, 5%, 10%, 20%, 25%, 50%, or other suitable value.

5 In that regard, the filter wheel 300 can be positioned such that a certain percentage of the cross-sectional area of the light beam 210 passes through the filtered area(s) of the filter wheel to achieve a desired amount of filtering. The actuator 220 can be configured to move the filter wheel 300 incrementally to achieve the desired amount of filtering. For example, the actuator 220 can be configured to move the filter wheel 300 in increments
10 such that between about 0% and 100%, between about 0% and 75%, and/or between about 0% and 50% of the cross-sectional area of the light beam 210 can be introduced/removed from the beam path 102 upon each incrementally actuation.

FIGS. 3a-3f illustrate various positions of the filter wheel 300 associated with different amounts of desired filtering. The filter wheel 300 can be moved between the
15 various positions shown in **FIGS. 3a-3f** by rotating about an axis of rotation 310. The filter wheel 300 can be moved in a clockwise direction 316 and/or a counterclockwise direction 314 about the axis of rotation 310 between the various positions.

FIG. 3a illustrates a position of the filter wheel 300 where the entire diameter of the light beam 210 passes through the unfiltered area 302. **FIG. 3b** illustrates a position
20 of the filter wheel 300 where the light beam 210 passes partially through the unfiltered area 302 and partially through the first filtered area 304 such that the transmission of the first range of wavelengths can be partially limited. **FIG. 3c** illustrates a position of the filter wheel 300 where the entire diameter of the light beam 210 passes through the first filtered area 304 such that the transmission of the first range of wavelengths can be
25 completely limited by the first filtered area 304. **FIG. 3d** illustrates a position of the filter wheel 300 where the light beam 210 passes partially through the unfiltered area 302 and partially through the second filtered area 306 such that the transmission of the second range of wavelengths can be partially limited. **FIG. 3e** illustrates a position of the filter wheel 300 where the entire diameter of the light beam 210 passes through the second
30 filtered area 306 such that the transmission of the second range of wavelengths can be completely limited by the second filtered area 306. **FIG. 3f** illustrates a position of the filter wheel 300 where the light beam 210 passes partially through the unfiltered area 302, partially through the first filtered area 304, and partially through the second filtered area

306 such that the transmission of the first and second ranges of wavelengths can be partially limited.

5 The filter wheel 300 can be automatically rotated to position a desired amount of the unfiltered area 302, the first filtered area 304, and/or the second filtered area 306 in the path of the light beam 210 based on one or more conditions associated with the ophthalmic surgical system 100 and/or a surgical procedure. The filter wheel 300 can be moved (e.g., the computing device 130 can provide a control signal to the actuator 220) based on a beam location, a beam composition, an exposure time, and/or a limited visibility condition. The beam location can indicate the target location of the light in the surgical field (e.g., the macula, the periphery of the retina, etc.). For example, if the target location includes the macula, then the filter wheel 300 can be moved such that the light beam 210 passes at least partially through the first or second filtered area 304, 306. The beam composition can describe an amount of blue light included in the light being transmitted to the surgical field. If the light being transmitted includes a potentially harmful amount of blue light, the filter wheel 300 can be moved such that the light beam 210 passes at least partially through the first or second filtered area 304, 306. The exposure time can indicate how long the light has been transmitted to the surgical field. If the surgical procedure lasts for an extended duration such that continued transmission of blue light could be harmful, the filter wheel 300 can be moved such that the light beam 210 passes at least partially through the first or second filtered area 304, 306. A limited visibility condition can describe one or more physiological characteristics of a patient that limit a surgeon's ability to see relevant anatomy during the surgical procedure. For example, cataracts, vitreous hemorrhage, and/or high pigmentation can cause a limited visibility condition. In response, the filter wheel 300 can be moved such that the light beam 210 passes at least partially through the unfiltered area 302.

Embodiments as described herein can relate to devices, systems, and methods that facilitate blue light filtering during ophthalmic surgical procedures. The examples provided above are exemplary only and are not intended to be limiting. One skilled in the art may readily devise other systems consistent with the disclosed embodiments which are intended to be within the scope of this disclosure. As such, the application is limited only by the following claims.

CLAIMS

1. An ophthalmic surgical system, comprising:
- 5 a light source that generates a light beam;
- a filter wheel disposed between the light source and an intraocular illumination device, the filter wheel including
- an unfiltered area;
- a first filtered area that limits the transmission of a first range of
- 10 wavelengths of the light beam to the intraocular illumination device; and
- a second filtered area that limits the transmission of a second range of wavelengths of the light beam to the intraocular illumination device; and
- an actuator that selectively moves the filter wheel to cause the light beam to pass
- 15 through one or more of the unfiltered area, the first filtered area, and the second filtered area of the filter wheel; and
- a computing device in communication with the actuator, wherein said computing device
- monitors transmission of blue light by the intraocular illumination device within an eye; and
- 20 outputs, in response to the monitoring the transmission of blue light by the intraocular illumination device, control signals to the actuator to limit the transmission of blue light within the eye to minimize retinal phototoxicity by causing the actuator to selectively move the filter wheel such that the light beam passes through the one or more of the unfiltered area, the first filtered area, and
- 25 the second filtered area of the filter wheel.
2. The ophthalmic surgical system of claim 1, wherein:
- the first filtered area is positioned adjacent to the unfiltered area.

3. The ophthalmic surgical system of claim 2, wherein:
the second filtered area is positioned adjacent to the unfiltered area.
4. The ophthalmic surgical system of claim 3, wherein:
5 the unfiltered area extends between the first filtered area and the second filtered area.
5. The ophthalmic surgical system of any one of claims 1 to 4, wherein:
at least one of the first and second ranges of wavelengths is selected to limit the
10 transmission of blue light to the intraocular illumination device.
6. The ophthalmic surgical system of claim 5, wherein:
the first range of wavelengths includes wavelengths between approximately 380
nm and approximately 475 nm.
- 15 7. The ophthalmic surgical system of claim 6, wherein:
the second range of wavelengths includes wavelengths between approximately
380 nm and approximately 515 nm.
- 20 8. The ophthalmic surgical system of any one of claims 1 to 7, wherein:
the actuator incrementally moves the filter wheel.
9. The ophthalmic surgical system of any one of claims 1 to 8, wherein:
the computing device provides the control signal to the actuator based on at least
25 one of a beam location, a beam composition, an exposure time, and a limited
visibility condition.

10. An ophthalmic surgical system, comprising:

a light source that generates a light beam;

a filter disposed between the light source and an intraocular illumination device,
the filter including:

5 an unfiltered area;

a first filtered area that limits the transmission of a first range of
wavelengths of the light beam to the intraocular illumination device; and

a second filtered area that limits the transmission of a second range of
wavelengths of the light beam to the intraocular illumination device;

10 an actuator that selectively moves the filter to cause the light beam to pass
through one or more of the unfiltered area, the first filtered area, and the second
filtered area of the filter; and

a processor in communication with the actuator, wherein said processor:

15 detects a beam composition of the light beam transmitted by the
intraocular illumination device within an eye; and

based on the detected beam composition, outputs a first control signal to
modify the detected beam composition by causing the actuator to selectively move
the filter to a first position such that a first portion of the light beam passes
through the unfiltered area and a second portion of the light beam passes through
20 the first filtered area or the second filtered area.

11. The ophthalmic surgical system of claim 10, wherein the processor further
outputs a second control signal to further modify the detected beam composition
by causing the actuator to move the filter to a second position such that the first
25 portion of the light beam passing through the unfiltered area decreases and the
second portion of the light beam passing through the first filtered area or the
second filtered area increases.

12. The ophthalmic surgical system of claim 10 or 11, wherein the beam composition corresponds to a color of the light beam transmitted by the intraocular illumination device.

5 13. The ophthalmic surgical system of claim 12, wherein:

 the first range of wavelengths limits the transmission of a first color to the intraocular illumination device; and

 the second range of wavelengths limits the transmission of a second color to the intraocular illumination device.

10 14. The ophthalmic surgical system of claim 12, wherein at least one of the first or second ranges of wavelengths includes a subset of wavelengths greater than 350 nm.

15 15. The ophthalmic surgical system of claim 12, wherein at least one of the first or second ranges of wavelengths includes a subset of wavelengths less than 520 nm.

 16. The ophthalmic surgical system of claim 12, wherein:

20 the first range of wavelengths includes a subset of wavelengths less than 480 nm; and

 the second range of wavelengths includes a subset of wavelengths greater than 480 nm.

25 17. The ophthalmic surgical system of claim 12, wherein:

 the first range of wavelengths includes a subset of wavelengths less than 520 nm; and

 the second range of wavelengths includes a subset of wavelengths greater than 350 nm.

18. The ophthalmic surgical system of any one of claims 10 to 17, wherein:
the first filtered area and the second filtered area are each adjacent to the
unfiltered area; and
5 the unfiltered area extends between the first filtered area and the second filtered
area.

19. The ophthalmic surgical system of any one of claims 10 to 17, wherein:
the unfiltered area and the first filtered area intersect at a first boundary that is
10 non-perpendicular to a direction of motion of the filter; and
the unfiltered area and the second filtered area intersect at a second boundary
that is non-perpendicular to the direction of motion of the filter.

20. The ophthalmic surgical system of any one of claims 10 to 19, wherein the
15 filter comprises a filter wheel.

21. The ophthalmic surgical system of any one of claims 10 to 20, wherein the
filter comprises a dichroic filter.

22. An ophthalmic surgical system, comprising:
an intraocular illumination device sized and shaped for positioning within an
eye of a patient and for transmission of a light beam within the eye;
a filter positioned in a beam path of the light beam, the filter including:
an unfiltered area;
20 a first filtered area that limits the transmission of a first range of
wavelengths of the light beam by the intraocular illumination device within the
eye; and

a second filtered area that limits the transmission of a second range of wavelengths of the light beam by the intraocular illumination device within the eye;

5 an actuator that selectively moves the filter to cause the light beam to pass through one or more of the unfiltered area, the first filtered area, and the second filtered area of the filter; and

a processor in communication with the actuator, wherein said processor:

detects a beam composition of the light beam transmitted by the intraocular illumination device within the eye; and

10 based on the detected beam composition, outputs a first control signal to modify the detected beam composition by causing the actuator to selectively move the filter to a first position such that a first portion of the light beam passes through the unfiltered area and a second portion of the light beam passes through the first filtered area or the second filtered area.

15

23. The ophthalmic surgical system of claim 22, further comprising:
a light source that generates the light beam.

20 24. The ophthalmic surgical system of claim 23, wherein the filter is positioned in the beam path of the light beam between the light source and the intraocular illumination device.

25 25. The ophthalmic surgical system of any one of claims 22 to 24, wherein the intraocular illumination device comprises at least one of an endoillumination probe, ophthalmic chandelier, illuminated cannula entry port, illuminated vitreous cutter, illuminated laser probe, illuminated scissors, illuminated forceps, illuminated pic, and illuminated manipulator.

26. The ophthalmic surgical system of any one of claims 22 to 25, wherein the processor further outputs a second control signal to further modify the detected beam composition by causing the actuator to move the filter to a second position such that the first portion of the light beam passing through the unfiltered area decreases and the second portion of the light beam passing through the first filtered area or the second filtered area increases.

27. The ophthalmic surgical system of any one of claims 22 to 26, wherein the beam composition corresponds to a color of the light beam transmitted by the intraocular illumination device.

28. The ophthalmic surgical system of claim 27, wherein:
the first range of wavelengths limits the transmission of a first color by the intraocular illumination device within the eye; and
the second range of wavelengths limits the transmission of a second color by the intraocular illumination device within the eye.

29. Use of the ophthalmic surgical system of any one of claims 1 to 28 to perform an ophthalmic surgical procedure.

30. The use according to claim 29, wherein the actuator selectively moves the filter wheel by at least:

positioning the filter wheel such that the light beam passes through the unfiltered area when the light beam is directed to a periphery of the retina of the eye;

positioning the filter wheel such that the light beam passes through the first filtered area when the light beam is directed to a macula of the eye; and

positioning the filter wheel such that the light beam passes through the second filtered area when the light beam is directed to the macula for an extended duration.

31. The use according to claim 29, wherein the actuator selectively moves the filter wheel by at least:

5 positioning the filter wheel such that the light beam passes through the first filtered area when the light beam is transmitted to the eye for a first duration; and
 positioning the filter wheel such that the light beam passes through the second filtered area when the light beam is transmitted to the eye for a second duration exceeding the first duration.

10 32. Use of the ophthalmic surgical system of any one of claims 1 to 9 to perform an ophthalmic surgical procedure, wherein the computing device monitors the transmission of blue light by at least:

 tracking at least one of a beam location or an exposure time.

15 33. The use according to claim 32, wherein the computing device monitors the transmission of blue light by additionally:

 determining the light beam is directed to a macula of the eye; or

 determining the light beam is transmitted for an extended duration.

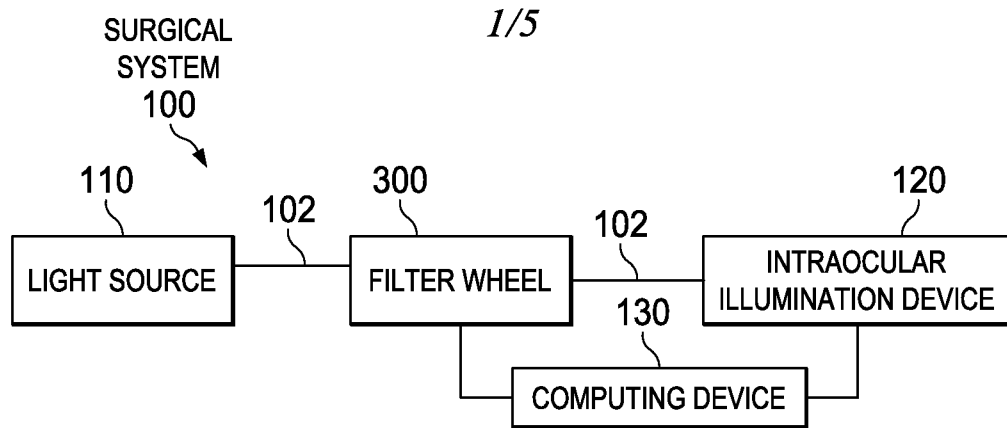


Fig. 1

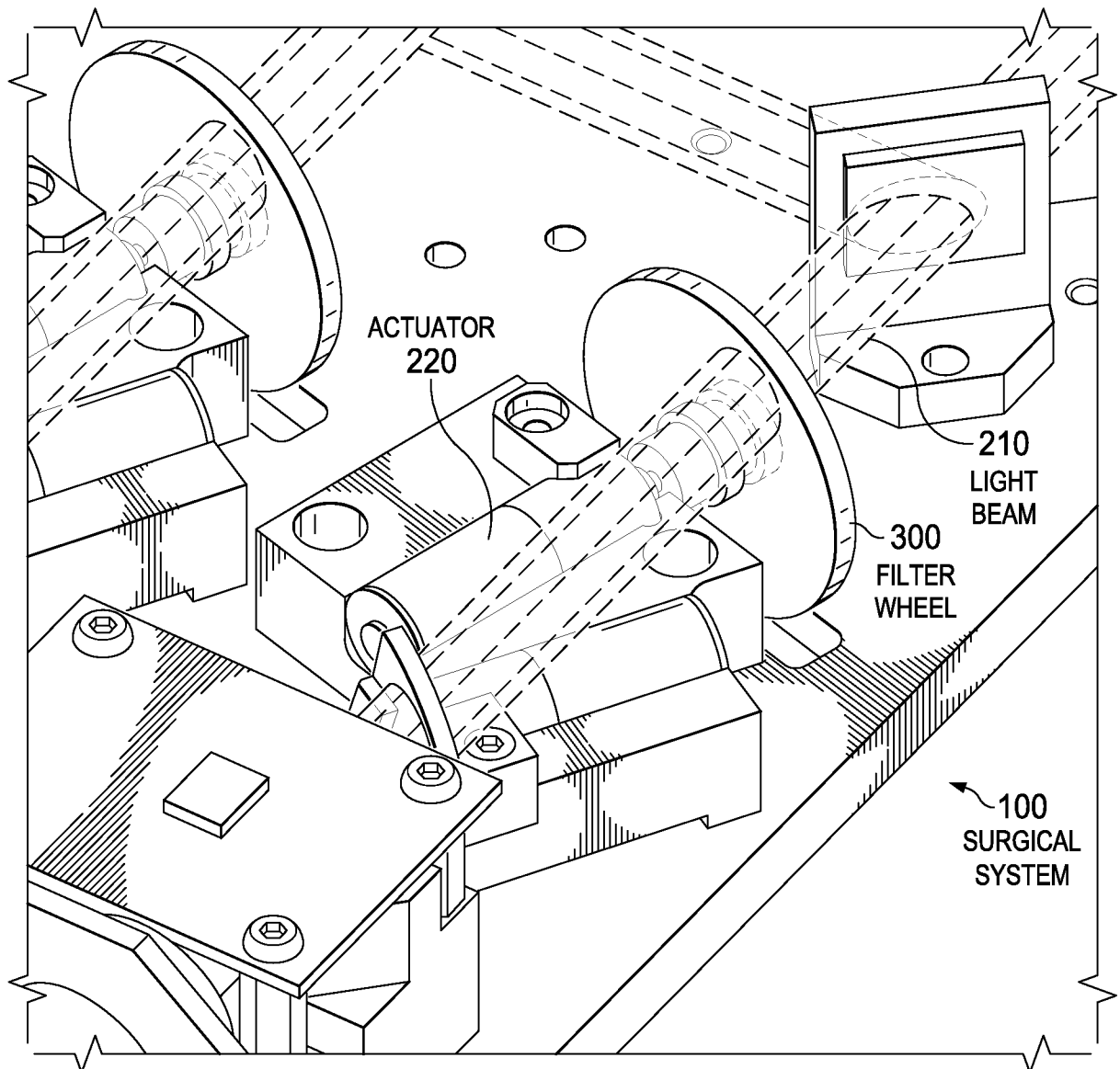


Fig. 2a

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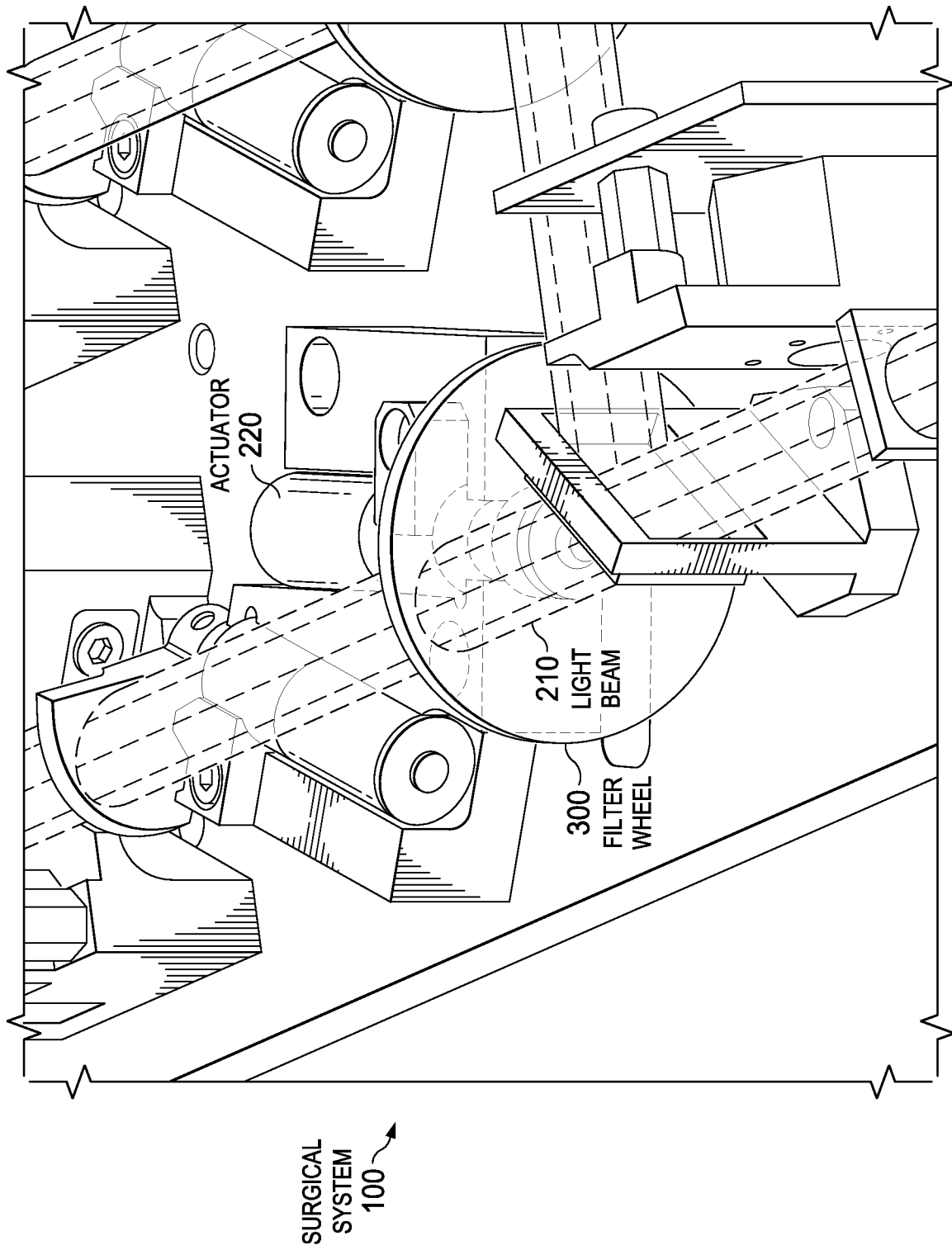


Fig. 2b

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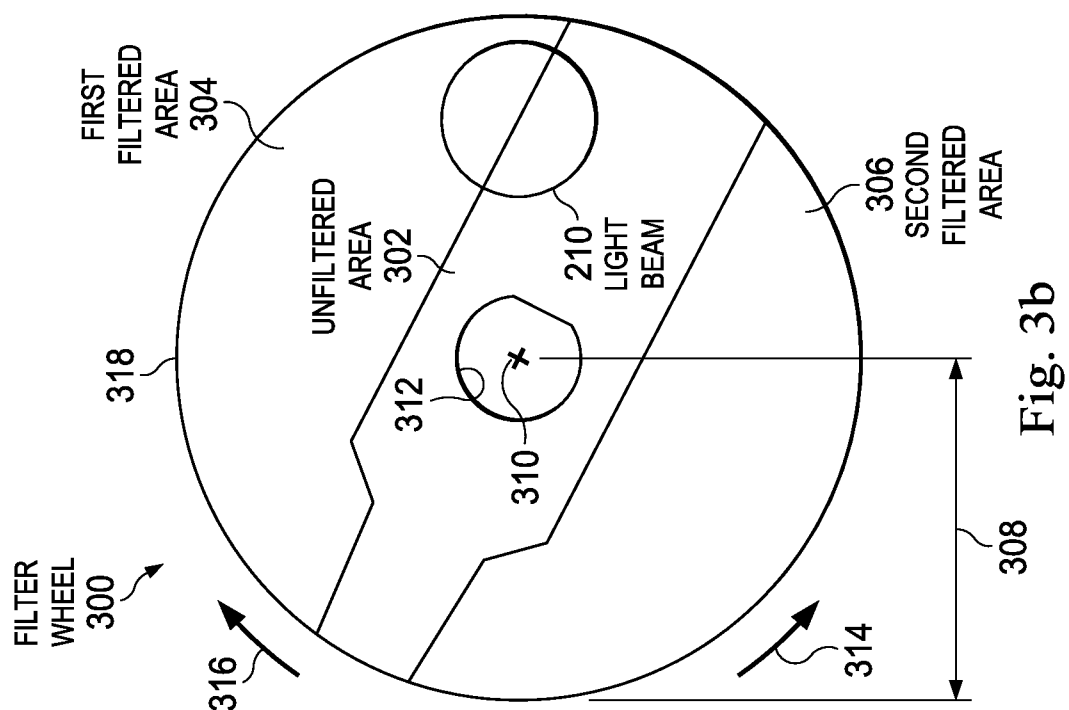


Fig. 3b

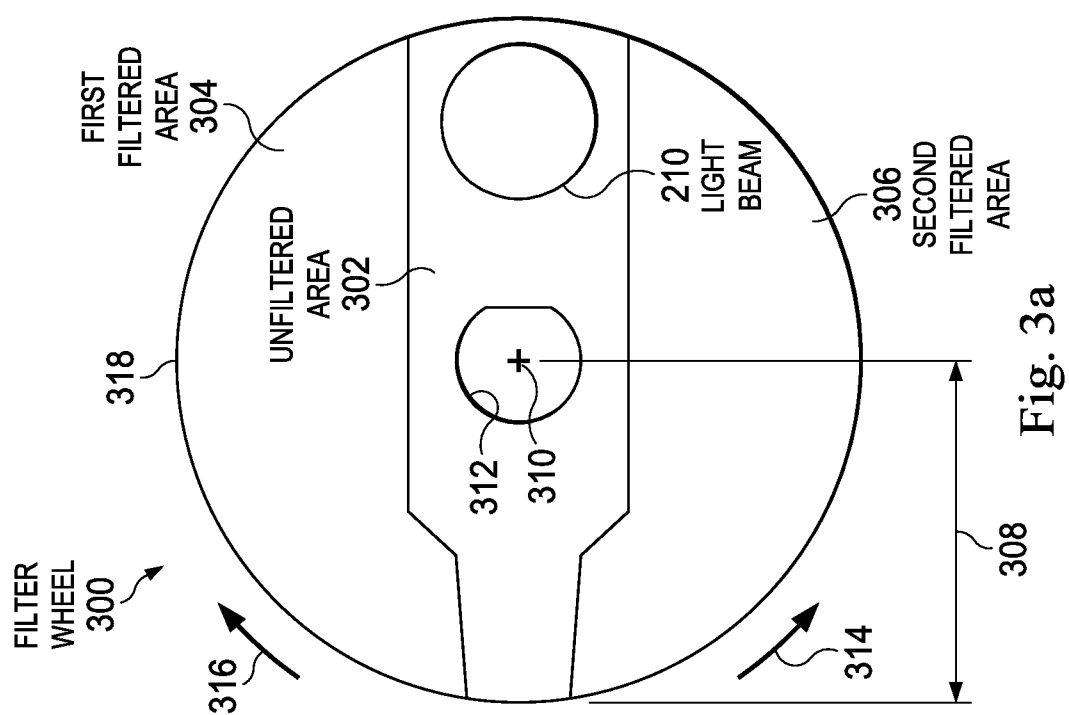


Fig. 3a

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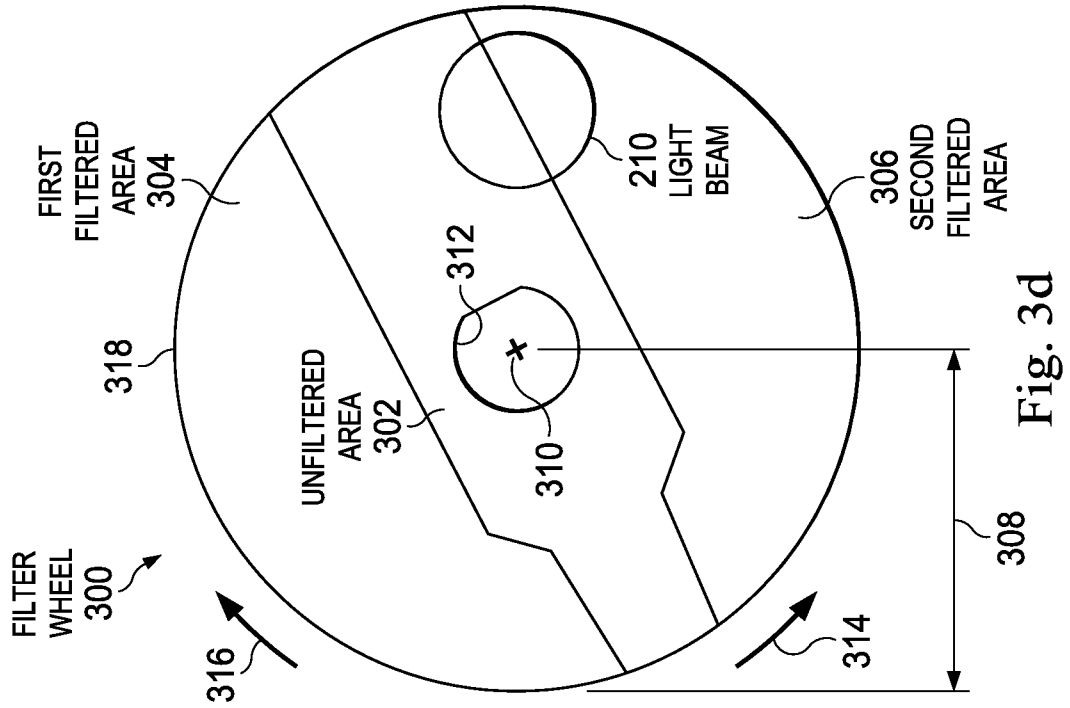


Fig. 3d

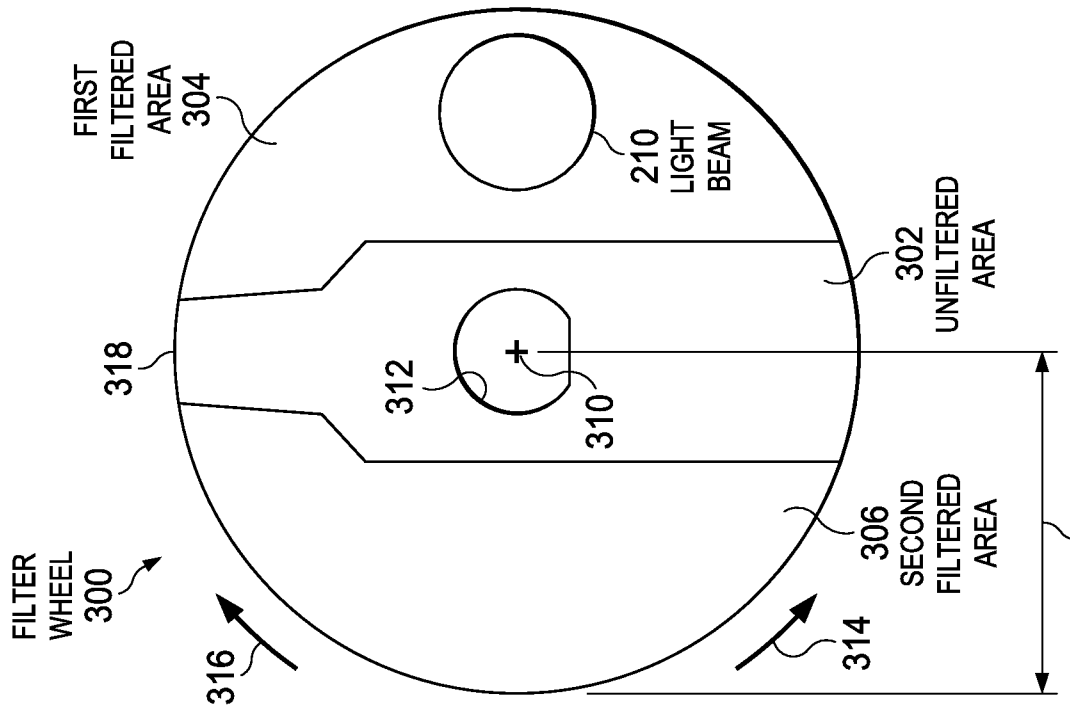


Fig. 3c

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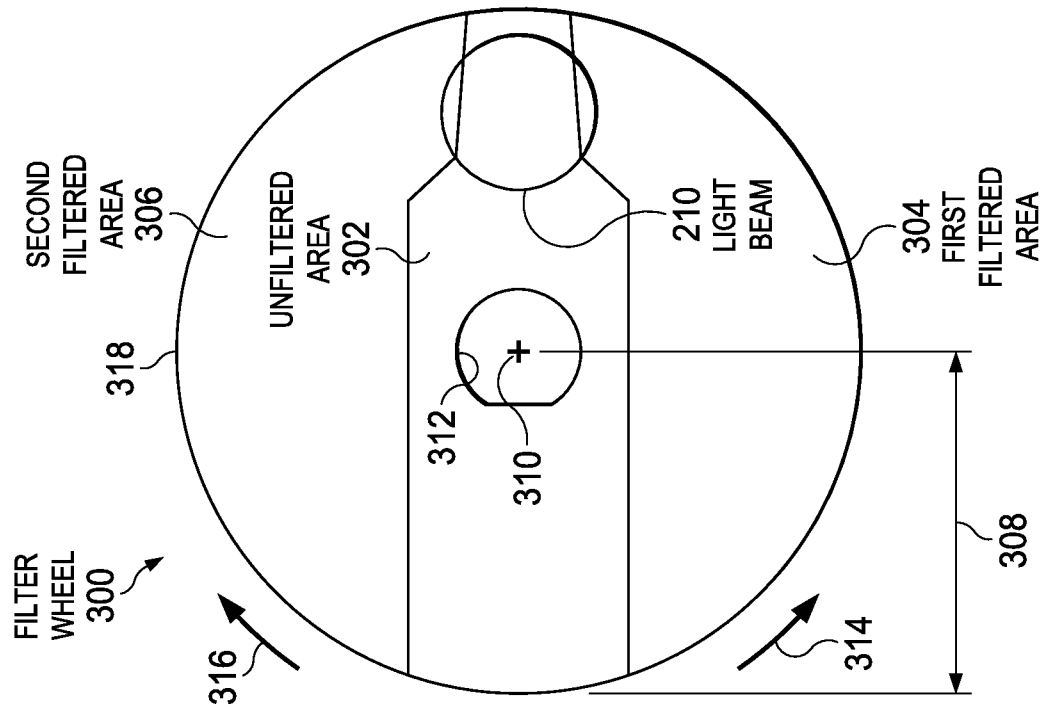


Fig. 3f

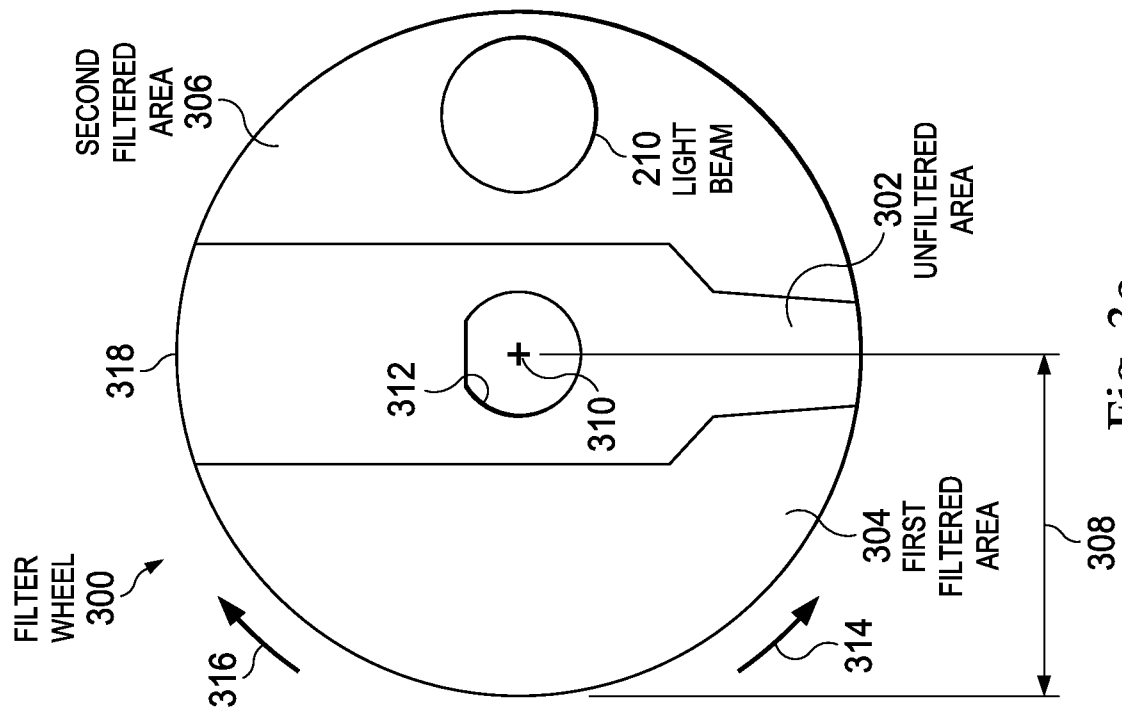


Fig. 3e

