



(51) International Patent Classification:

A61B 3/00 (2006.01) A61B 3/12 (2006.01)
A61B 3/117 (2006.01) A61B 3/14 (2006.01)

(21) International Application Number:

PCT/EP2023/065381

(22) International Filing Date:

08 June 2023 (08.06.2023)

(25) Filing Language:

English

(26) Publication Language:

English

(71) Applicant: **OD-OS MACUTHERM GMBH** [DE/DE];
Warthestraße 21, 14513 Teltow (DE).

(72) Inventors: **CUCU, Radu George**; Schöneberger Str. 8,
10963 Berlin (DE). **AMTHOR, Kay-Uwe**; Quebec Straße
5, 14513 Teltow (DE). **ROSE, Arnd**; Am Wiesengrund

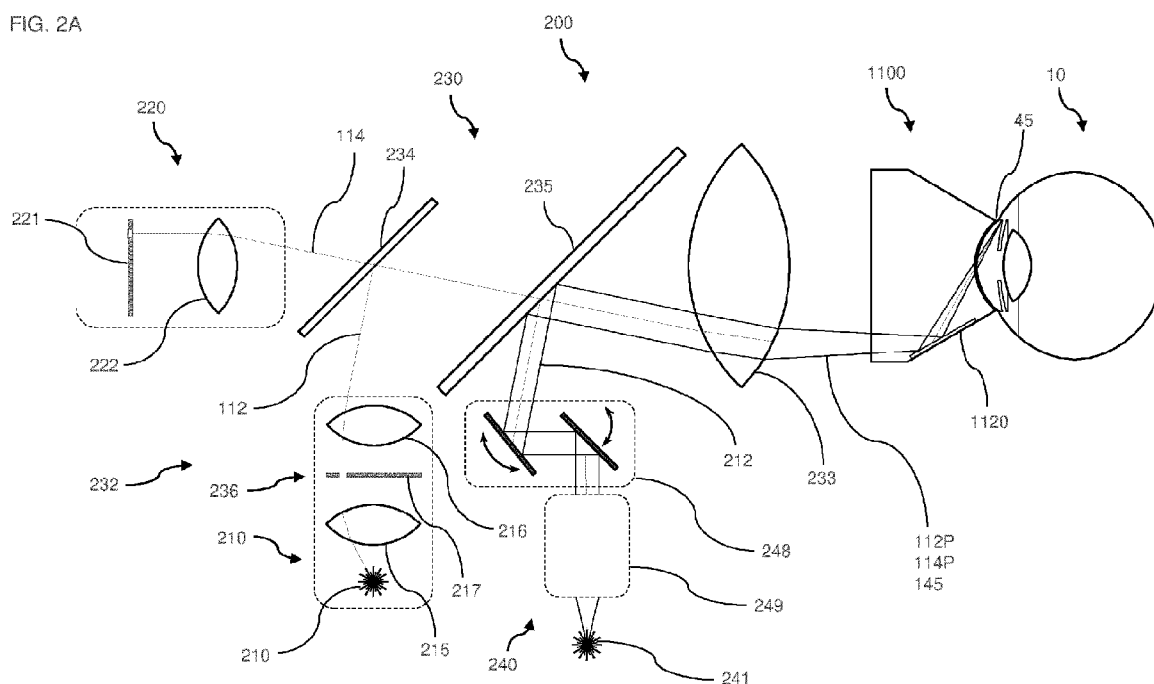
29a, 14532 Stahnsdorf (DE). **TEIWES, Winfried**; Eichen-
weg 26, 14532 Kleinmachnow (DE).

(74) Agent: **PFENNING, MEINIG & PARTNER MBB**;
Joachimsthaler Straße 10-12, 10719 Berlin (DE).

(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ,
CA, CH, CL, CN, CO, CR, CU, CV, CZ, DE, DJ, DK, DM,
DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,
HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG,
KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY,
MA, MD, MG, MK, MN, MU, MW, MX, MY, MZ, NA,
NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO,
RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH,
TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS,
ZA, ZM, ZW.

(54) Title: OPTHALMIC SYSTEMS, DEVICES AND RELATED METHODS

FIG. 2A



(57) Abstract: The present disclosure relates to ophthalmic systems, devices and related methods. An ophthalmic systems may comprise an illumination device for illuminating an eye through a gonioscopic lens, wherein the illumination device includes at least one light source to generate illumination beams that propagate through the gonioscopic lens and illuminate tissue of the eye, a camera for acquiring an image of the eye through the gonioscopic lens, the camera including an image sensor configured to receive observation beams propagating from tissue of the eye through the gonioscopic lens. An image processing module may be configured to receive the image acquired by the camera and identify at least one characteristic feature of an anterior chamber angle of the eye within at least one subregion of the image. A display device may be configured to at least partly display the at least one subregion of the image to a user.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

Ophthalmic Systems, Devices and Related Methods

Technical Field

5 The present disclosure generally relates to ophthalmic devices, systems and methods for observing a human eye and/or for treatment of a human eye by surgery. More specifically, some examples of the present disclosure relate to ophthalmic devices, systems and methods for diagnosis and/or laser treatment of certain conditions of the human eye such as types of glaucoma. In
10 one aspect, the present disclosure relates to an ophthalmic system that is usable with a gonioscopic lens, e.g., for examination and/or for treatment of an eye by laser surgery.

Background

15 Glaucoma is a common eye condition that can be characterized by an inability of the eye to maintain an appropriate balance between the amount of

internal fluid (aqueous humor) being produced within the eye and the amount of internal fluid being drained out of the eye. In a healthy eye, the internal fluid is being produced and drained at the same rate. In a glaucomatous eye, however, the drainage rate is typically lower than the production rate. As a consequence, an excess of internal fluid builds up causing a typical symptom of glaucoma, which is an elevated intraocular pressure (IOP).

One group of surgical treatments aims at decreasing the production rate, for instance by treating the ciliary body in which the internal fluid is produced. Another group of treatments aims at increasing the drainage rate, for instance by increasing the permeability of tissues through which the fluid is drained, such as the trabecular meshwork. Laser trabeculoplasty (LTP) belongs to the latter group of treatments. Examples of laser trabeculoplasty are Argon Laser Trabeculoplasty (ALT), Microsecond Pulses Laser Trabeculoplasty (MLT), and Selective Laser Trabeculoplasty (SLT) which differ, for instance, in one or more laser parameters, such as wavelength, laser power and/or pulse duration.

Laser trabeculoplasty generally includes application of laser energy to the trabecular meshwork. This is commonly done by using a gonioscopic lens to directing laser beams obliquely through the cornea into the anterior chamber angle, which is also termed the iridocorneal region. Gonioscopic lenses (more briefly gonioscopes or gonio lenses) are also commonly used to examine the anterior chamber angle, a procedure generally termed gonioscopy.

As shown in FIGs. 1A and 4A, a gonioscopic lens 1100 generally contain a contact member 1110 that is concentric to an optical or longitudinal axis 1114 of the gonioscopic lens and that is adapted to be placed onto the cornea 20, and further comprise at least one mirror surface 1120 that is oriented at an angle α_{GONIO} with respect to the longitudinal axis of the gonioscopic lens. As shown, for instance, in FIG. 4A, a light beam, such as an illumination beam or a laser beam 145, impinges on the mirror surface 1120 of the gonioscopic lens and is redirected such that it propagates through the contact member and through the cornea into the chamber angle and irradiates the trabecular meshwork. Observation beams of light backscattered by the chamber angle structures propagate along the same or a similar path into the opposite direction.

Many standard methods of trabeculoplasty that are performed via a gonioscopic lens include the use a laser applicator mounted on a slit lamp in combination with a gonioscopic lens. In these standard methods, the selection of the treatment spots on the trabecular meshwork and the aiming of the laser applicator at the treatment spots are performed by the physician carrying out the treatment. At the same time, the physician may also need to mitigate the effects of patient head and eye motions. Hence, the effectiveness and safety of these methods depend on the manual skills of the physician.

Moreover, since gonioscopic lenses provide only a limited field of view of the trabecular meshwork, they need to be rotated azimuthally around the patient eye if the whole circumference of the chamber angle is to be examined and/or treated. The need of manually rotating the gonioscopic lens further complicates the handling of the procedure and oftentimes causes discomfort to the patient and even carries a risk of corneal injury. Still further, in these standard procedures, the uniform placement of the laser spots along the trabecular meshwork by rotating the gonioscopic lens is entirely the task of the physician. The documentation of spot placement and laser parameters is often absent.

Hence, there is a general need for improved ophthalmic systems, devices and related methods which alleviate one or more of the aforementioned difficulties and address further problems in the prior art.

SUMMARY AND GENERAL DESCRIPTION

In one aspect, the present disclosure relates to an ophthalmic system that can be used in combination with a gonioscopic lens to examine an eye and/or to apply laser energy to the eye. A further aspects relate to method of examining and/or treating an eye by applying laser energy via a gonioscopic lens. Still further aspects relate to gonioscopic lenses, gonioscopic lens assemblies and patient interfaces. The aspects may be combined in any combination thereof. For instance, the gonioscopic system can be used with the gonioscopic lenses, gonioscopic lens assemblies and patient interfaces described herein and/or to perform any of the methods described herein. However, at least some examples of the ophthalmic system described herein may also be used with

conventional gonioscopic lenses. Some of the gonioscopic lenses, gonioscopic lens assemblies and patient interfaces described herein may also be used with known ophthalmic systems.

5 In one example, the ophthalmic system may comprise a gonioscopic lens. For instance, the gonioscopic lens may be part of the gonioscopic system and may be completely or at least partly integrated into the ophthalmic system, e.g., integrated into an optical system of the ophthalmic system. Alternatively, the gonioscopic lens may not form part of the ophthalmic system. For instance,
10 the gonioscopic lens may be an entity separate from the ophthalmic system and may be usable independently from the ophthalmic system. Moreover, in one example, the ophthalmic system may be usable with different types of gonioscopic lenses, as detailed below.

15 As mentioned above and as described in more detail below, a gonioscopic lens generally includes a contact member and at least one mirror surface (also referred to as gonio mirrors) angled relative to a longitudinal axis of the gonioscopic lens, which centrally traverses the contact member. The gonioscopic lens may include a cup-shaped member with a distal end carrying the contact member. The at least one mirror surface may be positioned on (e.g., attached to, or integrated into) an inner surface of a sidewall of the cup-shaped member. The contact member may be concentric relative to the longitudinal axis. An inclination angle α_{GONIO} (also referred as gonio angle) of the at least one mirror surface relative to the longitudinal axis of the gonioscopic lens is typically in a range between 10° and 60° . If the gonioscopic lens comprises more than one mirror surface, e.g., 2, 3, 4, 5, 6, or more mirror surfaces, the mirror surfaces may have the same or different inclination angles, the inclination angle of each mirror surface typically being within the aforementioned range. The at least one mirror surface may be flat. Alternatively, particularly in examples comprising only one single mirror surface, the mirror surface may have a conical shape. In addition to the inclination angle α_{GONIO} , the optical characteristics of a gonioscopic lens may further be specified by M_{GONIO} which specifies the image magnification of the gonioscopic lens in the peripheral gonio field(s) of view (seen via the mirror surface(s)),
30 and M_c which specifies the image magnification of the gonioscopic lens in the
35

central gonio field of view (seen centrally through the contact member without reflection on the mirror surfaces).

5 The gonioscopic lens may be a hand-held gonioscopic lens. Alternatively, the ophthalmic system may include a mount and the gonioscopic lens may be mounted onto the mount. The gonioscopic lens may be azimuthally rotatable relative to the mount. In some examples, the rotations may be performed manually. Alternatively, the mount may include a motor to rotate the gonioscopic lens. Examples of gonioscopic lenses, gonioscopic lens assemblies
10 and patient interfaces in accordance with the present disclosure are described further below, which may be hand-held or mounted to a mount of the ophthalmic system as described above, for instance, to allow rotation of the respective gonioscopic lens, gonioscopic lens assembly, patient interface, or parts thereof, as described further below and shown, for instance, in FIGs. 6A,
15 6B, and 22 to 28.

The ophthalmic system described herein comprises an illumination device for illuminating an eye of a patient. The illumination device includes at least one light source to generate illumination beams that propagate along beam paths
20 towards the eye. The illumination device is configured to illuminate the eye through the gonioscopic lens which may be placed between the illumination device and the eye. The illumination beams propagate through the gonioscopic lens and illuminate the eye, such as the trabecular meshwork, the iris and/or the retina.

25 The ophthalmic system further includes an imaging device or camera for acquiring an image of the eye through the gonioscopic lens. The camera includes at least one image sensor configured to receive observation beams which propagate from illuminated parts the eye, particularly from the
30 aforementioned tissues, through the gonioscopic lens towards the image sensor. The image sensor may be, for instance, a CCD sensor or a CMOS sensor. The camera may be a video camera and the image may thus be a video image (also termed live image) comprising a series of frames taken at a frame rate r_f . In one example, as described in more detail below, a field of
35 view of the camera is sufficiently large to simultaneously encompass one or

more of the at least one mirror surface and the contact member of the gonioscopic lens when imaging the eye through the gonioscopic lens.

5 The system may include an electronic processor or processing device which may be any arrangement of electronic circuits, electronic components, processors, program components and/or the like configured to store and/or execute programming instructions. The processor may further be configured to direct the operation of the other functional components of the system and may be implemented, for example, in the form of any combination of
10 hardware, software, and/or firmware.

The system may include an electronic image processing module. The image processing module may be implemented in any combination of hardware (e.g., circuitry), software, and/or firmware (the same applies to any other
15 electronic “module” described herein). In one example, the image processing module may be part of the aforementioned processor (the same applies to any other electronic “module” described herein). The image processing module may be configured to process the image, for instance, by performing an image segmentation algorithm. For example, the image processing module
20 may be configured to process the image by performing a region-growing algorithm, an edge detection algorithm, a pattern recognition algorithm, and/or other image processing algorithms.

The image processing module may be configured to receive the image
25 acquired by the camera and to detect and/or identify at least one characteristic feature of the eye within the image, for instance, within at least one subregion of the image. As explained in greater detail below, the at least one subregion may correspond to the at least one mirror surface of the gonioscopic lens, i.e., the at least one subregion may show portions of the eye as seen
30 by the camera via the at least one mirror surface of the gonioscopic lens. Hence, in the following, the subregion(s) of the image are also referred to as peripheral gonio field sub-image(s), each corresponding to one of the at least one mirror surfaces of the gonioscopic lens. The image processing module may be configured to detect the at least one subregion within the image. The
35 at least one characteristic feature of the eye may be a characteristic feature of the anterior chamber angle of the eye. The at least one characteristic feature

of the anterior chamber angle may be one or more of a Schwalbe's line, a trabecular meshwork, a scleral spur, a ciliary body, and an iris of the eye. For instance, the image processing module may be configured to detect one or more of these characteristic features, for instance, by means of a respective pattern recognition algorithm. In some examples, the image processing module may be configured to detect and/or identify the at least one characteristic feature of the eye by comparing the at least one subregion of the image with one or more reference images of the same eye. In some examples, the one or more reference images of the eye may have been acquired previously and/or be stored, for instance, in a memory of the ophthalmic system.

The image processing module may be configured to restrict the search to the at least one subregion of the image. For instance, the image processing module may be configured to first perform the search for the at least one subregion by means of a first search algorithm, and afterwards perform the search for the at least one characteristic feature of the anterior chamber angle only within the detected at least one subregion, e.g., by means of a second search algorithm different from the first search algorithm. In this manner, the search for the at least one characteristic feature may be performed more accurately and faster. For instance, some of the characteristic features of the interior chamber of the eye, such as the Schwalbe's line, the trabecular meshwork, and the scleral spur, may be represented in the (segmented) image as a curved line within one or more of the at least one subregion and spanning the respective subregions, as described in more detail below.

The image processing module may be configured to detect the at least one subregion of the image in the image, for instance after having segmented the image. For instance, the image processing module may be configured to search for the at least one subregion, e.g., by performing an edge-detection algorithm, as the borders of the one or more mirror surfaces of the gonioscopic lens may show up in the image as edges defining the respective subregions within the image (which may have been segmented). As mentioned before, the gonioscopic lens may have two or more mirror surfaces. The at least one subregion may therefore include a first subregion corre-

sponding to a first mirror surface of the two or more mirror surfaces of the gonioscopic lens, and a second subregion corresponding to a second mirror surface of the two or more mirror surfaces of the gonioscopic lens. The image processing module may be configured to identify the at least one characteristic feature of the anterior chamber angle of the eye in the first and also within the second subregion (and any further subregion) of the image.

The image processing module may be configured to detect and/or identify at least one further characteristic feature of the eye within a subarea of the image. As explained in greater detail below, the subarea is distinct from the at least one subregion of the image and typically corresponds to the contact member of the gonioscopic lens, i.e., it shows portions of the eye as seen by the camera centrally through the contact member of the gonioscopic lens. Hence, in the following, the subarea of the image is also referred to as central gonio field sub-image. The image processing module may be configured to detect the subarea. For instance, the image processing module may be configured to first search for the subarea in the image and, once the subarea is detected, search only within the detected subarea for the at least one further characteristic feature of the eye. The image processing module may be configured to search for the subarea by employing any of the image processing algorithms mentioned herein with regard to the detection of the subregion(s) of the image, for instance, by using an edge detection algorithm. For example, use can be made of the fact that the shape of the subarea typically corresponds to the shape of the contact member of the gonioscopic lens, which may be circular, for example.

In one example, the at least one further characteristic feature of the eye may comprise at least one characteristic feature of an iris of the eye. Additionally or alternatively, the at least one further characteristic feature of the eye may comprise at least one characteristic feature of a fundus of the eye. In some examples, the image processing module may be configured to detect and/or identify the at least one further characteristic feature of the eye by comparing the subarea of the image with one or more reference images of the same eye. As mentioned above, the one or more reference images of the eye may have been acquired previously and/or be stored, for instance, in a memory of the ophthalmic system.

The system may further include an electronic display device configured to display the image acquired by the camera or at least parts of the image to a user. For instance, the display device may be configured to display one or more of the at least one subregion of the image to a user, or at least a portion of any of these subregions. For instance, the display device may be configured to display simultaneously one or more or each one of the (detected) two or more subregions to a user, such as the aforementioned first and second subregions. The display device may be configured to show any of these subregions completely or only partially, i.e., only a portion of the respective subregion, such as the reduced subregion(s) described further below. The display device may be configured to also display the subarea of the image to a user, for instance simultaneously with displaying one or more of the at least one subregion.

For this purpose, the display device may include a screen, such as a touch screen which may also be used as an input device. The display device may be controlled, for instance, by the aforementioned processor of the system, by the image processing module and/or may comprise its own control module. As the image is typically a video image, the display device may be configured to display the subregion(s), i.e. the peripheral gonio field sub-image(s), and/or the subarea, i.e. the central gonio field sub-image, as video sub-images, i.e., showing streams the respective subregion(s) and/or of the subarea of the video image.

The illumination beams generated by the illumination device may comprise central illumination beams that are directed to propagate through the contact member without being reflected by the at least one mirror surface of the gonioscopic lens. The central illumination beams traverse the contact member and the cornea typically in a direction that may be approximately parallel to the pupillary axis of the eye or in a direction that defines an angle with the pupillary axis of less than 30°, of less than 15°, or of less than 5°. Typically, said angle is less than an inclination angle of the at least one mirror surface of the gonioscopic lens defined relative to the longitudinal axis of the gonioscopic lens. After having passed through the cornea, the central illumination beams impinge on the iris or traverse the pupil and irradiate the fundus of the eye.

The illumination beams generated by the illumination device may further include peripheral illumination beams that are reflected off one of the at least one mirror surface of the gonioscopic lens and propagate obliquely through the contact member of the gonioscopic lens and through the cornea. In one example, the peripheral illumination beams may be approximately parallel to the central illumination beams until they impinge on the mirror surface of the gonioscopic lens. In one example, a lateral distance between the central illumination beams from the pupillary axis of the eye is smaller than a lateral distance the peripheral illumination beams from the central axis of the eye. The peripheral illumination beams traverse the contact member and the cornea typically in a direction that defines an angle with the pupillary axis of more than 30° , more than 45° or more than 60° . Typically, said angle is greater than the inclination angle of the at least one mirror surface of the gonioscopic lens. Depending on said angle, the peripheral illumination beams may impinge on tissue of the anterior chamber angle of the eye, such as peripheral regions of the iris or the trabecular meshwork. At smaller angles, the peripheral illumination beams may pass through the pupil of the eye and impinge on tissue of the eye fundus, such as non-central or peripheral regions of the retina.

The illumination device may be configured to spatially and/or temporally modulate the illumination beams. The illumination device includes one or more light sources to generate illumination beams. The illumination device may further include an electronic illumination control module configured to control the light source(s), e.g., so as to modulate illumination beams. The illumination control module may be partly or completely be integrated into the processor of the ophthalmic system mentioned above. The light sources may be LEDs. The light sources may be integrated into an illumination array.

The temporal modulation is typically a periodical modulation with a modulation rate r_m . The illumination device may be configured to switch (e.g., by means of the illumination control module) between two or more illumination modes during one modulation cycle. The illumination modes may differ, for instance, in their respective illumination intensities and/or in their respective spatial intensity profile of the illumination beams. The illumination control

module may be configured to provide the processor, the image processing module and/or the camera with information about the current illumination mode. The image frames may be (electronically) labelled, e.g., by the image processing module or by the illumination control module, with a label
5 indicating which illumination mode that was present during the acquisition of the respective image frame.

The camera may be configured to have a sufficiently large dynamic range to function properly with the various illumination modes and intensity profiles.
10 For that purpose, the camera may be an HDR camera (the image sensor being an HDR image sensor), and the acquired images may be HDR images. The display devices may be configured accordingly to display the acquired HDR images.

15 In one example, the illumination device is configured to spatially modulate intensities of the illumination beams such that an intensity of the peripheral illumination beams is different (e.g., higher or lower) than an intensity of the central illumination beams. For example, when the intensity of the peripheral illumination beams is higher than the intensity of the central illumination
20 beams, it can be possible to avoid or reduce dazzling of the patient with the central illumination beams while at the same time illuminating the anterior chamber angle with sufficient brightness via the peripheral illumination beams.

25 Additionally or alternatively, the illumination device is configured to periodically modulate the illumination beams at a modulation rate r_m . The modulation rate r_m may be, for instance, smaller, equal or larger than a frame rate r_f of the camera. For instance, the modulation rate r_m may satisfy $r_m = r_f * N_i$ or $r_m = r_f / N_i$ with N_i being a positive integer (e.g. $N_i = 1, 2, 3, \dots$). As mentioned
30 above, the camera may be configured to capture a video or live image at a frame rate r_f such that the live image comprises a series of frames. The frame acquisition may be synchronized with the temporal modulation of the illumination beams. For instance, starts of the modulation cycles may be synchronized with starts of the frame acquisition cycles. For example, for a
35 periodical temporal modulation with $r_m = r_f$ ($N_i = 1$), each frame may be acquired during one entire modulation cycle. In an example, for a periodical

temporal modulation with $r_m = r_f$ ($N_l = 1$) with an additional synchronous spatial modulation, each frame may be acquired during illumination of the eye firstly with peripheral illumination beams at high intensity and then secondly with central illumination beams at low intensity.

5

In a further example, the illumination device is configured to periodically modulate the illumination beams at a modulation rate r_m that is smaller than the frame rate r_f of the camera, wherein the modulation rate r_m satisfies $r_m = r_f / N_l$ with $N_l > 1$ being a positive integer. For example, with $N_l = 2$, two consecutive frames may be acquired under two different stages of one modulation cycle. For example, without additional spatial modulation (same intensity for all illumination beams) and only temporal modulation of intensity between high intensity and low intensity, the frames may be acquired alternately at high intensity and low intensity. The first (low) intensity (in the first half of the modulation cycle) may be optimized for illumination of tissue at the iris or the fundus with central illumination beams (e.g., for achieving suitable exposure of the subarea of the image sensor corresponding to the subarea of the image). The second (high) illumination intensity may be optimized for illuminating tissue in the anterior chamber angle with peripheral illumination beams (e.g., for achieving suitable exposure of the subregion of the sensor corresponding to subregion of image). In a further example, with $N_l = 4$ and two intensity levels (same for all illumination beams), during one modulation cycle, two consecutive frames may be acquired at low illumination intensity and two consecutive frames may be acquired at high illumination intensity.

10

15

20

25

The image processing module may be configured to select two or more frames of the live image and combine the two or more frames to form a compound (live) image or compound frame which is also termed herein as combined (live) image or combined frame. The frames may, for instance, be acquired under different illumination modes, e.g. under a first (high intensity) illumination mode and a second (low intensity) illumination mode and/or under different focus modes as described in more detail below. For instance, the selected and combined frames may be acquired during the same modulation cycle. The selection may be based, for instance, on image data of each frame (such as brightness values of one or more pixels) or on the frame label

30

35

described herein, and/or on control signals received from the illumination device or the illumination control module. The labels of the frames may include information indicating, for instance, the respective illumination mode or a modulation cycle number.

5

In some examples, the image processing module may be configured to extract from each selected frame acquired during a first (e.g., high intensity) illumination mode a first frame portion including one or more subregions of the at least one subregion of the image but not including the subarea of the frame and to extract from each frame acquired during the second (e.g., low intensity) illumination mode a second frame portion including the subarea of the frame but not including the at least one subregion of the frame.

10

The light beams coming back from the illuminated eye, *i.e.*, the illumination beams being backscattered from the eye, are called herein observation beams. These beams may include central observation beams that emanate from eye tissues being illuminated by the central illumination beams (*i.e.*, being backscattered central illumination beams) and propagate through the contact member towards the camera without being reflected by any one of the at least one mirror surface of the gonioscopic lens. Similarly to the central illumination beams, the central observation beams traverse the cornea and the contact member typically in a direction that may be approximately parallel to the pupillary axis of the eye or in a direction that defines an angle with pupillary axis of less than 5°, of less than 15°, or of less than 30°. Typically, said angle is less than an inclination angle of the at least one mirror surface of the gonioscopic lens defined relative to the longitudinal axis of the gonioscopic lens.

15

20

25

The observation beams may further include peripheral observation beams that emanate from tissue of the eye illuminated by the peripheral illumination beams (*i.e.*, being backscattered peripheral illumination beams) and propagate obliquely through the contact member. The peripheral observation beams are reflected by one of the at least one mirror surface of the gonioscopic lens and propagate further to the camera and impinge onto the image sensor of the camera. Similarly to the peripheral illumination beams, the peripheral observation beams traverse the cornea and the contact member

30

35

typically in a direction that defines an angle with pupillary axis of more than 30°, more than 45° or more than 60°. Typically, said angle is greater than the inclination angle of the at least one mirror surface of the gonioscopic lens.

5 The field of view of the camera is defined in particular by the image sensor of the camera (and typically also by the optical system the ophthalmic system described further below). The gonioscopic lens typically has a proximal opening or window defining a cross-sectional area through which the eye is observed and through which the aforementioned illumination beams and
10 observation beams traverse. In some examples, the field of view of the camera is sufficiently large to contain the entire cross-sectional area of the proximal opening or window of the gonioscopic lens. In this case, the camera can “see” at the same time the contact member and each one of the at least one mirror surface of the gonioscopic lens. In other words, all of the afore-
15 mentioned central observation beams and all of the peripheral observation beams reflected from any one of the at least one mirror surface of the gonioscopic lens can simultaneously reach the image sensor. Alternatively, the size of the field of view of the camera may be such that it can contain only a part of said cross-sectional area. For instance, the field of view may be so
20 small that the camera can “see” at the same time only the contact member and one single mirror surface. In other words, the field of view can only contain the aforementioned central observation beams and the peripheral observation beams that are reflected from one single mirror surface of the gonioscopic lens whereas the peripheral beams reflected from other mirror
25 surfaces of the gonioscopic lens (if present) cannot be simultaneously contained in the field of view. Preferably, the field of view is however sufficiently large to accommodate at least the contact member and at least one mirror surface of the gonioscopic lens. Typically, the field of view of the camera has an outer border which may have a circular or rectangular shape.
30 Preferable, within the outer border, the field of view is continuous (i.e., does not have any voids or gaps, such as a central “blind” zone).

Within the field of view of the camera, the contact member defines a central gonio field (of view) and the at least one mirror surface of the gonioscopic
35 lens defines at least one peripheral gonio field (of view). In other words, within the central gonio field, the camera images portions of the eye as seen

straight through the contact member, e.g. the iris and/or the eye fundus.
Within the at least one peripheral gonio field, the camera images portions of
the eye as seen obliquely through the contact member via the at least one
mirror surface, e.g. portions of the chamber angle such as the trabecular
meshwork.

5

The central observation beams reaching the image sensor may be focused
onto a subarea of the image sensor and the aforementioned subarea of the
image acquired by the camera may thus correspond to the subarea of the
image sensor and contain the image formed by the central observation
beams. The subarea therefore typically corresponds to the contact member of
the gonioscopic lens. The shape of the subarea may corresponds to the shape
of the contact member, which may be circular, for instance. The subarea of
the image typically shows portions of the eye as seen by the camera centrally
through the contact member of the gonioscopic lens, for instance, portions of
the iris and/or of the fundus of the eye. The subarea of the image is therefore
also referred to as central gonio field sub-image.

10

15

The peripheral observation beams reaching the image sensor may be focused
onto one more subregions (each corresponding to one of the at least one
mirror surface) of the image sensor that is distinct from and non-overlapping
with the aforementioned subarea of the sensor. The aforementioned subre-
gion(s) of the image acquired by the camera thus correspond to the subre-
gions of the image sensor and contains the image formed by those peripheral
observation beams. Hence, the at least one subregion of the image typically
shows portions of the anterior chamber angle or peripheral portions of the
retina. The subregion(s) of the image is/are also referred to as peripheral
gonio field sub-image(s) or chamber angle sub-image(s). As the gonioscopic
lens may comprise one, two, or more distinct mirror surfaces, the image may
correspondingly include one, two or more distinct and non-overlapping
subregions, each of which corresponding to exactly one of the one, two or
more mirror surfaces of the gonioscopic lens.

20

25

30

The system may further include an optical system configured to direct the
light beams described herein, including the illumination beams, observation
beams and/or any laser beams, such that they follow their respective beam

35

paths as described herein. For that purpose, the optical system may include optical elements, such as an objective lens, one or more apertures, one or more further lenses, one or more mirrors, and/or one or more beam splitters, that may be fixed in the respective positions and orientations or be movable

5 rotatable or otherwise adjustable. Preferably the optical system is telecentric. For instance, the objective lens may be a telecentric lens. For instance, an entrance pupil of the objective lens or an exit pupil of the objective lens, or both, may be at infinity.

10 For instance, the optical system may include a focusing assembly. The focusing assembly may be configured to adjust a focus of the optical system. For that purpose, the focusing assembly may include any of the components of the optical system mentioned above. For instance, the focusing assembly

15 may include at least one adjustable and/or movable lens element, such as at least one motorized translatable lens element and/or at least one liquid lens element. For instance, the objective lens may be adjustable and/or movable to adjust the focus of the optical system.

20 The focusing assembly may be configured to focus the observation beams emanating from a portion of the eye onto the image sensor of the camera. In one example, adjusting a focus of the optical system includes shifting a conjugate focal plane of the image sensor of the camera. The conjugate focal plane of the image sensor includes those points that are imaged, by the

25 optical system, onto the image sensor, i.e., light beams emanating from the same point in the conjugated plane of the image sensor are focused (converge) in the same point on the image sensor. The conjugate focal plane of the image sensor may be defined as an object plane conjugate to an image plane of the image sensor, the image plane being defined by the surface of the image sensor of the camera.

30 For example, the central observation beams may be focused onto the aforementioned subarea of the image sensor to form, within that subarea, a focused image of that region of the eye which is illuminated by the central illumination beams and from which the central observation beams emerge,

35 e.g., from a portion of the iris and/or from a portion of the fundus of the eye. In this focus mode or focus configuration of the focusing assembly, the said

region of the eye (irradiated by the central illumination beams) is located within (or at least adjacent to) the conjugate focal plane of the image sensor.

5 Additionally or alternatively, the peripheral observation beams may be focused onto the aforementioned subregion of the image sensor, which is different from the aforementioned subarea, so as to form, within the subregion, a focused image of that region of the eye which is illuminated by the peripheral illumination beams and from which the peripheral observation beams emerge, e.g., from a portion of the chamber angle, such as from a portion of the trabecular meshwork, from a peripheral portion of the iris, or, if 10 the corresponding illumination beams and observation beams passed through the pupil of the eye, for instance from peripheral portions of the eye fundus. In this focus mode or focus configuration of the focusing assembly, the said region of the eye (irradiated by the peripheral illumination beams) is located within (or at least adjacent to) the conjugate focal plane of the image sensor. 15

As described in more detail below, the focusing assembly may be adjustable between two (or more) focus modes (or focus configurations) in order to focus the central observation beams (in a first focus mode) or the peripheral observation beams (in a second focus mode) onto the image sensor. Additionally or alternatively, the gonioscopic lens may include a lens element 20

25 Additionally or alternatively, adjusting a focus of the optical system may include shifting a conjugate focal plane of the illumination device, e.g., a conjugate focal plane of the light source or of an aperture of the illumination device. Light beams emanating from the same point at the light source or aperture are focused (converge) onto the same point of the respective conjugate focal plane. For instance, the conjugate focal plane of the light source or the aperture of the illumination device may be shifted such that a portion of the eye is near or adjacent the conjugate focal plane, so that the illumination beams are focused onto that portion of the eye, such as the trabecular meshwork or the retina. For instance, the peripheral illumination beams may be focused onto the trabecular meshwork or alternatively onto a peripheral portion of the retina, e.g., in the aforementioned first focus mode 30 of the focusing assembly. The central illumination beams may be focused onto 35

the iris or onto a (central) portion the retina, e.g., in the aforementioned second focus mode of the focusing assembly.

5 The ophthalmic system may include an electronic focus control module, which may be at least partly be integrated into the processor of the ophthalmic system mentioned above. The focus control module may be configured to adjust or change a focus mode of the focusing assembly. For instance, the focus control mode may be configured switch the focusing assembly between different focus modes, e.g., between a first focus mode in which the object
10 plane of the image sensor is in a first position and a second focus mode in which the object plane is in a second position different from the first position. In one example, the first and second focus modes are defined as described above. For instance, the focus control module may be configured to generate control signals to control one or more actuators of the focusing assembly,
15 such as electric motors, to move or otherwise adjust one or more lens elements of the focusing assembly, for instance, in accordance with the first or second focus mode. In one example, the focus control module may be configured to adjust or change the focus mode(s) in accordance with one or more parameter values defining the optical characteristics of the gonioscopic lens currently in use. For example, the one or more parameters values may include one or more of α_{GONIO} (inclination angle of mirror surface(s)), M_{GONIO} (image magnification of the peripheral gonio field(s)), and M_{C} (image magnification of central gonio field). For instance, the focus control module may be configured to receive the parameter values of the optical characteristics from
20 a memory device of the ophthalmic system storing the parameter values, to receive the parameter values via an interface, such as a user input device. Additionally or alternatively, as described in more detail below, in accordance with the present disclosure, the gonioscopic lens, the gonioscopic lens assembly and/or the patient interface disclosed herein may include a machine-readable identifier which may encode the aforementioned parameter values or any other identifying information that can be used to determine the parameter values (such as by querying a database storing the parameter values for various gonioscopic lenses, gonioscopic lens assemblies or patient interfaces). In one example, a reader device of the ophthalmic system may be
25 configured determine the parameters values from the identifier and to provide the focus control module with the parameter values.

The focus control module may be configured to switch the focusing assembly between the first focus mode and the second focus mode at a focus switching rate r_F . The focus switching rate r_F may be equal to, or smaller or greater than the aforementioned frame rate r_f of the camera. For instance, the switching rate r_F may be set to satisfy $r_F = r_f / N_F$ or $r_F = r_f * N_F$ with N_F being a positive integer (such as $N_F = 1, 2, 3, \dots$). For instance, the focus control module may be configured to generate control signals in accordance with the focus switching rate to control one or more actuators of the focusing assembly, such as electric motors, to move or otherwise adjust one or more lens elements of the focusing assembly in accordance with the first or second focus mode.

In examples, in which the image is a video image or live image, the image processing module may be configured to determine, for each frame of the live image, whether the frame was acquired during the first focus mode or during the second focus mode. The determination may be based, for instance, on image data of each frame (such as based on image sharpness within the subregion and/or within the subarea of the frame) or on the control signals received from focusing control unit. The image processing module may label the frames as belonging to the first focus mode or second focus mode. Additionally or alternatively, the image processing module may be configured to determine, for each frame of the live image, whether the frame was acquired during the first illumination mode or during the second illumination mode. The determination may be based, for instance, on image data of each frame (such as based on an image sharpness within the subregion and/or within the subarea of the frame) or on the control signals received from focusing control unit. The image processing module may label the frames as belonging to the first focus mode or the second focus mode.

In some examples, the image processing module may be configured to extract from one or more (or each) frame(s) acquired during the first focus mode a first frame portion including the subregion of the frame but not including the subarea of the frame. The image processing module may be configured to extract from one or more (or each) frame(s) acquired during the second focus mode a frame portion including the subregion of the frame but not including the subarea of the frame. Additionally or alternatively, as described above,

the image processing module may be configured to extract from each frame acquired during the first illumination mode a first frame portion including the subregion of the frame but not including the subarea of the frame and to extract from each frame acquired during the second illumination mode a frame portion including the first subregion of the frame but not including the subarea of the frame.

In one example, the image processing module is configured to combine two or more frames of the live image to form a combined (live) image or a combined frame which is also termed herein as compound (live) image or compound frame. For instance, a combined frame or image may be formed using a first portion extracted from a first frame and second frame portion extracted from a second frame of the live image. The image processing module may be configured to transmit the combined frames to the display device to display the combined frames to a user. The combined frames may be generated and displayed in a continuous manner, so that the user may continuously observe the eye in the displayed combined frames.

Additionally or alternatively, the image processing module may be configured to extract (image data from) the subregion of a frame depending on whether the frame has been acquired during the first focus mode and/or during the first illumination mode. The image processing module may be configured to extract (image data from) the subarea of a frame depending on whether the frame has been acquired in the second focus mode and/or in the second illumination mode. For instance, the image processing module may be configured to further process the thus extracted image data, e.g., for performing any of the feature detection functions described herein and/or for providing the thus extracted image data to the display device to display the thus extracted image data to a user. In this manner, it can be achieved that only such image data are further processed and/or displayed that have been acquired during the “right” focus and/or illumination mode. For instance, in this manner, the subregion of an image/frame showing the trabecular meshwork may be displayed only for those images/frames that are acquired when the trabecular meshwork is illuminated in the first illumination mode and/or the observation beams emanating from the trabecular meshwork are focused onto the corresponding subregions of the image sensor (e.g., in the

first focus mode). Similarly, the subarea of an image/frame showing the iris or a central portion of the retina may be displayed only for those images/frames that are acquired when the iris or central portion of the retina is illuminated in the second illumination mode and/or the observation beams emanating from the iris or central portion of the retina are focused onto the corresponding subarea of the image sensor (e.g., in the second focus mode).

The image processing module may be configured to define an eye coordinate system based on the at least one further characteristic feature of the eye within the subarea of the image, e.g., based on a characteristic feature of the iris or of the (central) retina. Additionally or alternatively, the image processing module may be configured to define an (additional or alternative) eye coordinate system based on the aforementioned characteristic feature within the at least one subregion of the image, e.g., based on a characteristic feature within the interior chamber angle, such as a peripheral portion of the iris. The eye coordinate system may be a two dimensional or a three dimensional coordinate system. The eye coordinate system may be, for instance, a (2D or 3D) Cartesian coordinate system, a (2D) polar coordinate system, or a (3D) spherical coordinate system. The eye coordinate system may be defined such that the pupillary axis of the eye runs through the origin of the eye coordinate system. The image processing module may be configured to use the eye coordinate system to define or determine positions of treatment regions within the eye and/or of image points or image regions of the image of the camera e.g., using one or more coordinates of the eye coordinate system.

Additionally or alternatively, the image processing module may be configured to use a camera coordinate system to define or determine positions of treatment regions within the eye and/or of image points or image regions of the image of the camera, e.g., using one or more coordinates of the camera coordinate system. For instance, the position of any point (pixel) of the image may be defined relative to the eye coordinate system and/or relative to the camera coordinate system. In particular, the position of each point or region of the eye (e.g., treatment region) that is contained in the image of the camera may be defined by coordinates of the eye coordinated system and/or the camera coordinate system. In some examples, an azimuthal orientation of any point or region may be defined or determined relative the eye coordinate

system, for instance, by an (eye) azimuth coordinate ϕ_{eye} , and/or relative to the camera coordinate system, e.g., by an (camera) azimuth coordinate ϕ_{camera} . Furthermore, as described in more detail below, an azimuthal orientation of any of the one or more subregions of the image (peripheral gonio field sub-image(s)) may be defined or determined relative the eye coordinate system, for instance, by an (eye) azimuth coordinate Φ_{eye} , and/or relative to the camera coordinate system, e.g., by an (camera) azimuth coordinate Φ_{camera} .

The image processing module may configured to define the aforementioned camera coordinate system. For instance, the camera coordinate system may be defined as a Cartesian coordinate system or as a polar coordinate system. Typically, the camera coordinate system is a two dimensional coordinate system. The origin of the camera coordinate system may be defined such that a central optical axis of the camera and/or a central optical axis of the objective lens run(s) through the origin of the coordinate system. The position of each point on the surface of the image sensor of the camera, and correspondingly the position of each image point (i.e., each pixel) in any image (or frame) acquired with the camera, can be uniquely defined by its coordinates relative to the camera coordinate system. Accordingly, each object point, which has a corresponding image point in the image acquired by the camera, may be also assigned a unique set of coordinates in the camera coordinate system, namely the coordinates of its image point.

The image processing module may be configured to determine a location and/or an orientation of the eye coordinate system relative to the camera coordinate system. In some examples, this may be achieved by determining, within the camera coordinate system, the location and/or orientation of the respective characteristic feature(s) used to define the eye coordinate system. The image processing module may be configured to perform coordinate transformations between the eye coordinate system and the camera coordinate system. In particular, the image processing module may be configured to transform the eye azimuth coordinate ϕ_{eye} (of any point or subregion of the image) into the corresponding camera azimuth coordinate ϕ_{camera} , and vice versa.

The system may further include an electronic eye tracking module, which may

be a part of the system's processor device and/or of the image processing module. The eye tracking module configured to track translational and/or rotational motions of the eye. For instance, the eye tracking module can be configured to use the image acquired by the camera and/or images of any further the imaging devices of the system to track the motions of the eye within the respective images. For instance, the eye tracking module of may be configured to track the translational and/or rotational motions of the eye using the identified at least one characteristic feature of the eye within the at least one subregion of the image. Additionally or alternatively, the eye tracking module may be configured to track the translational and/or rotational motions of the eye using the identified at least one further characteristic feature of the eye within the subarea of the image. For instance, the eye tracking module may be configured to determine positions of one or more of the aforementioned (further) characteristic features, such as the iris or the (central) retina, relative to the camera coordinate system in order to track their translational and/or rotational motions of the eye relative to the camera. As described in further detail below, the eye tracking module may be configured to provide a laser system of the ophthalmic system, for instance a laser control module of the laser system or a laser beam steering device of the laser system, with eye tracking data for laser beam positioning correction to compensate the tracked motions of the eye.

In some examples, the image processing module may be configured to determine an azimuthal orientation of one, of more than one or of each of the at least one subregion of the image. For instance, the image processing module may be configured to determine for each (detected) subregion a respective azimuthal orientation. The azimuthal orientation may, for instance, be determined relative to the camera coordinate system or relative to the eye coordinate system, i.e., as Φ_{camera} or as Φ_{eye} . As mentioned above, the image processing module may be configured to transform Φ_{eye} into Φ_{camera} , and vice versa.

The image processing module may be configured to control the display device to display, for one or more or for each subregion of the at least one subregion, the respective subregion of the image on the display device with an azimuthal orientation relative to a display coordinate system in accordance with the determined azimuthal orientation of the respective subregion of the

image, e.g., in accordance with the determined azimuthal orientation of the respective subregion of the image relative to the camera coordinate system or relative to the eye coordinate system (i.e., using Φ_{camera} or Φ_{eye}). In other words, the subregion may be displayed such that it has the same azimuthal orientation on the display device (optionally being rotated by a fixed azimuthal angle, such as 180° , in order to compensate for the inflection caused by the mirror surfaces) as it has relative to the camera or relative to the patient's eye. In this manner, the interpretation of the displayed information by the user and navigation within the anterior chamber angle is facilitated. Displaying the subregion in accordance with the determined azimuthal orientation of the respective subregion relative to the eye coordinate system (i.e., using Φ_{eye}) has the additional advantage that azimuthal rotational of the eye relative to the camera are compensated.

In the following, exemplary ways of determining the respective azimuthal orientations of the one or more subregions of the image are provided. For instance, the image processing module may be configured to detect an edge portion defining a boundary of one of the at least one subregion of the image and, optionally, to determine an orientation of the detected edge portion relative to the camera coordinate system or relative to the eye coordinate system. The image processing module may use the orientation of the edge portion to determine the azimuthal orientation of the respective subregion, e.g., relative to the camera coordinate system or (after a coordinate transformation, if needed) relative to the eye coordinate system.

In a further example, the image processing module may be configured to determine, for one or more or for each of the at least one subregion, an azimuthal orientation of the at least one characteristic feature within the respective subregion (relative to the camera coordinate system or relative to the eye coordinate system). For instance, the image processing module may be configured to use the azimuthal orientation of the at least one characteristic feature to determine the azimuthal orientation of the respective subregion of the image (relative to the camera coordinate system or relative to the eye coordinate system).

For instance, a characteristic feature of the iris or the (peripheral) eye fundus contained within the respective subregion are particularly useful for this

purpose as these tissues typically exhibit clear, rotationally non-symmetric characteristic features. As such features are typically unique for every given eye, the image processing module may be configured to use a reference image of the eye to identify any of the characteristic features in the image acquired with the camera.

It is also possible to use other characteristic features contained in the respective subregion for this and other purposes, for instance, the trabecular meshwork, the Schwalbe's line or the scleral spur, among others. These characteristic features are typically imaged as curved lines which span the respective subregion of the image (in an azimuthal direction, i.e., connecting opposite lateral edges of the respective subregion). The image processing module may be configured to determine a normal vector oriented orthogonally to the curved line, for instance, at a midpoint of the curved line within the respective subregion, and to determine the azimuthal orientation of the normal vector relative to the eye coordinate system or relative to the camera coordinate system. The image processing module may be configured to determine the azimuthal orientation of the respective subregion of the image based on the azimuthal orientation of the normal vector, e.g., as being equal to the orientation of the normal vector. The azimuthal orientation of the subregion may again be determined relative to the eye coordinate system or relative to the camera coordinate system.

In some examples, particularly in examples involving laser trabeculoplasty, it can be useful to take into account the local curvature of the curved line within the subregion of the image, which corresponds to the apparent curvature of the trabecular meshwork as seen by the camera and as displayed by the display device. Typically, due to a perspective/ projection effect, which is explained in more detail below with reference to FIGs. 8-10, the local curvature of the curved line is not constant but varies within the subregions. Typically, the curvature is smallest at the midpoint of the curved line within the respective subregion and increases towards the ends of the curved line at the lateral edges of the subregion. The separation of the lateral edges define an azimuthal span Φ_{FOV} of the subregion.

For instance, it may be useful to restrict the view and/or the laser treatment to a central subsection of the curved line within the at least one subregion.

The central subsection may, for instance, be defined such that the apparent curvature of the curved line is approximately constant within the subsection e.g., a deviation of curvature is below a predefined threshold within the subsection. The image processing module may be thus configured to determine, for one, more than one or each subregion of the at least one subregion a central subsection of the curved line within the respective subregion including a midpoint of the curved line within the respective subregion. For instance, the imaging processing module may be configured to determine the central subsection such that, within the central subsection, a maximal deviation of a local curvature of the curved line from the local curvature of the curved line at the midpoint of the curved line is less than a predefined value. In one example, the image processing module is configured to determine the central subsection of the curved line within the respective subregion based on at least one of an iris diameter D_{Iris} of the eye, an angle α_{GONIO} defining the inclination of the mirror surface of the gonioscopic lens corresponding to the respective subregion of the image relative to the longitudinal axis of the gonioscopic lens, and/or an magnification parameter M_{GONIO} of the gonioscopic lens. See equations (5) to (7) provided further below. Additionally or alternatively, the image processing module is configured to determine the central subsection of the curved line based on at least one of a pre-defined spot size of a laser beam, a predefined number of laser spots to be applied to the trabecular threshold, and the iris diameter D_{Iris} . In this manner, as explained in more detail below with reference to equations (5) to (7) provided further below, a more even and regular application of laser spots onto the trabecular meshwork may be achieved and overlapping of adjacent laser pulses may be avoided. For instance, the imaging processing module may parametrize the curved line as an elliptic arc, as described in greater detail below with reference to FIGs. 8-10.

The image processing module may be configured to define a portion of the respective subregion of the image to be displayed by the display device such that the central subsection of the curved line spans over an entire width of the displayed portion of the respective subregion (e.g., in accordance with a limited or maximum allowable span Φ_M explained in more detail below with reference to FIGs. 8-10). The image processing module may be configured to control the display device to show the respective subregions only partly by

showing thereof merely said portion of the at least one subregion of the image including the respective central subsection of the curved line, and not showing other parts of the subregion. In this manner, the user is shown only a portion of the trabecular meshwork in which the apparent curvature of the trabecular meshwork is relatively constant which facilitates the application of evenly distributed laser spots onto the trabecular meshwork. In the following, the aforementioned portion of the subregion will also be referred to as “reduced subregions”, “allowable subregion”, “reduced peripheral gonio field” or “reduced peripheral gonio field sub-image”. Whenever in the following disclosure reference is made to the subregion(s) of the image (or peripheral gonio field, or peripheral gonio field sub-image), it is also possible to refer instead the corresponding reduced subregion(s) (or reduced peripheral gonio field(s) or reduced peripheral gonio field sub-image(s)).

As a further example, the image processing module may be configured to detect a marker that is attached to, or integrated into, the gonioscopic lens, a gonioscopic lens assembly, or a patient interface. Typically, a position of the marker relative to the at least one mirror surface of the respective gonioscopic lens, gonioscopic lens assembly, or patient interface is fixed. The image processing module may determine the azimuthal orientation of the at least one subregion based on (a) the position of the marker relative to the corresponding at least one mirror surface and (b) a position or azimuthal orientation of the detected marker within the image.

The ophthalmic system may include a laser system. The laser system may comprise one or more laser sources configured to generate one or more laser beams. For instance, the laser system may include treatment laser source configured to generate a treatment laser beam. Additionally, the laser system may include an aiming laser source configured to generate an aiming laser beam. Typically, the aiming laser beam is coaxially aligned with the treatment laser beam and has a power lower than the therapeutic laser beam, typically sufficiently low so as to avoid any irreversible effects on, or even damages of, the eye tissue irradiated therewith. The laser system may further include a laser beam steering device configured to steer the at least one laser beam. The laser steering device may be part of the aforementioned optical system and/or focusing assembly of the ophthalmic system and include any of the optical elements mentioned above to direct and/or focus the one or more

laser beams. The laser system may further include an electronic laser control module configured to control the at least one laser source and the laser steering device of the laser system.

As described above, the optical system, e.g., its focusing assembly, may be configured such that the illumination beams, the observation beams and, if present, the laser beams (treatment beams and aiming beams) are focused in, or emerge from, optical planes that are conjugate focal planes of each other, such as the aforementioned image plane the image sensor of the camera (defined by the surface of the image sensor) and the aforementioned object plane of the image sensor (located, e.g., within the eye) or any other conjugate focal plane of the image plane, such as, an aperture of the illumination device and/or an aperture of the laser system. In some examples, there is a (e.g., linear) one-to-one correspondence between the camera coordinates (x_c , y_c), herein also denoted as (x_{Camera} , y_{Camera}), and the coordinates (x_L , y_L) of the laser beam steering device used to position the laser beam(s) within the object plane of the image sensor:

$$(x_c, y_c) \rightarrow (x_L, y_L); \quad (x_L, y_L) \rightarrow (x_c, y_c) \quad (1)$$

The processing device and/or the image processing module may be configured to perform such coordinate transformations.

In one example, the laser control module may be configured to receive from the eye tracking module information about tracked eye motions of the eye and to control the laser steering device using this information to compensate for the eye motions, e.g., to correct the coordinates (x_L , y_L) so as to account for the detected eye motions and ensure that the intended treatment regions are irradiated by the laser beams.

The ophthalmic system may further include an electronic documentation module configured to store, for instance in a memory of the system, information which may, for instance, specify a laser treatment that has been performed with the laser system (or any other system) and/or which may specify a planned laser treatment to be performed in the future with the laser system (or any other system). For instance, the documentation module may be configured to store information on positions of treatment regions (herein also referred to as target regions, treatment regions, or target sites, or simply

as laser spots) of a planned or performed laser treatment within the eye, such as on the trabecular meshwork. The positions may be defined in the eye coordinate system and/or in the camera coordinate system. The position information may include two or more coordinates, such as an azimuth angle ϕ and a radial coordinate r . The azimuth angle ϕ may be defined, for instance, relative to an axis of the camera coordinate system or eye coordinate system, or relative to an azimuthal center of a subregion of the image containing the respective treatment region during the application of the laser pulse(s) to the treatment region. In this case, also the azimuthal orientation Φ of the corresponding subregion of the image may be stored (which again may be defined relative to the camera coordinate system or the eye coordinate system).

Moreover, for each treatment region, information on laser pulses that have been delivered to the respective treatment region or that are planned to be delivered to the respective treatment region, may be stored in the memory. The information may include, for instance, a number of laser pulses, a spot size (diameter), a pulse length, a time separation between consecutive laser pulses, the laser duty cycle, a laser energy per pulse or per time unit, a wavelength. The information may be stored in the memory as part of a treatment plan, as described further below.

The documentation module may be configured to receive the aforementioned information from the image processing module, from the laser control module, from the camera, from a user input device (such as display device, particularly if configured as a touchscreen), or from any other electronic component or electronic module of the ophthalmic system. Furthermore, the documentation module may be configured to receive from the image processing module, from the camera and/or from any other imaging device, such as an OCT imaging device, one or more images (or frames) or portions thereof that has been acquired before the treatment, such as a reference image of the eye, or during the treatment (such as the subregions, subareas and/or portions thereof), or any information associated with the images (or frames). For instance, the information associated with the image(s) may include the determined respective azimuthal orientation Φ of one or more or each subregion of the at least one subregion of the image, for instance, relative to the camera coordinate system and/or relative to the eye coordi-

nate system. Preferably, the (live) image or a frame of the live image is stored or the at least one subregion labelled with the respective azimuth orientation angle Φ . For instance, the reference image and/or the (live) image (or any portion thereof) of the camera, or a panoramic image described further below, may be shown to the user by the display device, allowing the user to define treatment regions within the respective image, e.g. using the display device as input device.

Examples of the ophthalmic system are configured to apply laser pulses to the patient's eye, for instance, to the trabecular meshwork. Some examples enable semi-automatic or automatic application of laser pulses. The image acquired by the camera typically is a "live" video image so that the eye can be observed on the display device in ("synchronous") real time. The operations described below may be performed or controlled, for instance, at least partly by the aforementioned processor. Additionally or alternatively, it is also possible to configure one or more of the electronic modules described herein to perform or control the operations, such as the image processing module, the laser control module and/or the laser control module. Hence, in the following description, any reference to the image processing module could as well be replaced by a reference to the processor or any other module.

In some examples, the image processing module is configured to provide instructions to the display device to show, in addition to the displayed at least one subregion of the live image, one or more shot markers indicating on the display device the positions of one or more planned laser treatment regions. The shot markers may be displayed on the display device in accordance with respective azimuthal angles ϕ_{plan}^i of the one or more planned laser treatment regions ($i > 0$ being an index for each treatment region). For instance, the azimuthal angles ϕ_{plan}^i may be defined relative to the camera coordinate system or relative to the eye coordinate system. The shot markers may be displayed on the display device with an azimuthal orientation relative to the display coordinate system in accordance with the respective azimuthal angles ϕ_{plan}^i of the one or more planned laser treatment regions. The image processing module may further be configured to use respective one or more azimuthal angles ϕ_{prev}^i of one or more previously treated laser treatment regions in the eye to determine the one or more azimuthal angles ϕ_{plan}^i of the one or more planned laser treatment regions, for instance, in accordance with

a predefined azimuthal step or increment value Φ_{Step} . For example, one more of the azimuthal angles ϕ_{plan}^i may be calculated using the formula $\phi_{\text{plan}}^i = \phi_{\text{prev}}^i + \Phi_{\text{Step}}$. The image processing module may be configured to retrieve the azimuthal angles ϕ_{prev}^i from a memory of the system or from the documenta-
5 tion module described herein. Additionally or alternatively, the image processing module may be configured to determine the azimuthal angles ϕ_{plan}^i of the one or more planned laser treatment regions such that the azimuthal angles ϕ_{plan}^i are within the aforementioned azimuthal span Φ_{FOV} (which defines the azimuthal field of view captured within one subregion of the at
10 least one subregion of the image), within the aforementioned limited or maximum allowable azimuthal span Φ_{M} (which is smaller than the azimuthal span Φ_{FOV}), and/or within the central subsection of the curved line described above. Examples of the azimuthal span Φ_{FOV} and the maximum allowable azimuthal span Φ_{M} are depicted in FIG. 10.

15 In some examples of the ophthalmic system, the image processing module is configured to use information about coordinates, e.g., azimuthal angles ϕ_{prev}^j (label j being a positive integer), of previously treated laser treatment regions in the eye and information about a current azimuthal orientation Φ of the at
20 least one subregion of the image to determine coordinates, e.g., azimuthal angles ϕ_{cur}^i (label i being a positive integer), of one or more current laser treatment regions to be irradiated within the at least one subregion at the current azimuthal orientation Φ . For instance, the previously treated laser treatment regions may have been irradiated using an azimuthal orientation of
25 the gonioscopic lens that is different from the current azimuthal orientation of the gonioscopic lens. Thus, some or all of the previously treated treatment regions may be positioned outside the peripheral gonio field of view provided by the mirror surfaces of the gonioscopic lens at its current azimuthal orientation, i.e., some or all of these treatment regions may not be included in the subregions of the live image as presently displayed on the display device.
30 However, in case of an overlap of the peripheral gonio field of view at the current azimuthal orientation of the gonioscopic lens with the peripheral gonio field of view at the previous azimuthal orientation of the gonioscopic lens, it is also possible that some treatment regions that have been treated under the previous azimuthal orientation of the gonioscopic lens are also
35 included in the gonio field of view of view at the current azimuthal orientation

of the gonioscopic lens. The image processing module may therefore be configured to ensure that the current laser treatment regions are all different from the previously treated laser treatment regions, e.g., by at least a predefined minimal (angular) distance value, to avoid multiple treatments of such treatment regions. The image processing module may be further configured to provide instructions to the display device to show, within the displayed at least one subregion of the live image, for each of the one or more laser treatment regions to be irradiated within the at least one subregion at the current azimuthal orientation Φ a shot marker indicating on the display device the position of the respective current laser treatment region in accordance with the coordinates (e.g., the azimuthal position ϕ_{cur}^i) of the respective current laser treatment region. The image processing module may further be configured to provide instructions to the display device to show, in addition to the displayed at least one subregion of the live image and the shot markers of the current treatment regions within the at least one subregion of the live image, treated regions markers indicating the positions of any previously treated treatment regions in accordance with the coordinates (e.g. azimuthal angles ϕ_{prev}^j) of the respective previously treated laser treatment regions.

In some examples, the image processing module is configured to determine the respective coordinates, e.g., azimuthal angles ϕ_{cur}^i , of the of the one or more current laser treatment regions such that the coordinates (e.g. azimuthal angles ϕ_{cur}^i) are one or more of: within the azimuthal span Φ_{FOV} defining the azimuthal field of view that is captured within one of the at least one subregion of the live image, within the azimuthal span Φ_M of one of the at least one subregion of the live image, within the central subsection of the curved line described above, and/or such that the treatment regions is spaced apart from the previously treated laser treatment regions by at least a predefined distance value, such as the distance value d in accordance with equation (8) defined below.

In some examples, the image processing module may be configured to select one or more frames of the live image and to extract, from the one or more selected frames, one or more subregions of the at least one subregion of the respective selected frame of the live image and to provide instructions to the display device to display, in addition to the at least one subregion of the live

image shown on the display device, the extracted one or more subregions of the one or more selected frames of the live image, e.g. as one or more still images. For instance, as described above, the selected frames may be acquired under the same azimuthal orientation of the gonioscopic lens under which laser pulses have been previously applied to the eye. The extracted subregions may each show treatment regions onto which laser pulses have been applied. The image processing module may further be configured to control the display device to additionally show shot markers at the respective treatment regions within the extracted subregions. The image processing module may be configured to provide instructions to the display device to display, for each of the one or more selected frames of the live image, the respective extracted one or more subregions, and optionally any of the aforementioned shot markers included therein, in accordance with an azimuthal orientation of the respective one or more subregions. The image processing module may be configured to determine whether the displayed at least one subregion of the live image overlaps with one or more of the displayed subregions extracted from the selected frames of the live image and, optionally, to use this information to determine treatment regions within the current at least one subregion of the live image. For example, as explained above, the image processing module may be configured to avoid defining any region as a new or intended treatment region if that region has already been treated under a different azimuthal orientation of the gonioscopic lens. The image processing module may be configured to instruct the display device to mark previously treated regions that are located within overlaps of the current at least one subregion of the live image with any additionally displayed extracted subregions (that have been acquired previously and under a different azimuthal orientation of the gonioscopic lens than the current azimuthal orientation of the gonioscopic lens) as being already treated, for instance, by means of a corresponding indication displayed on the display device at each of such previously treated region, such as by the aforementioned treated region markers.

An exemplary first method of using the ophthalmic system described herein may comprise one or more of the following steps. In the following, this exemplary method is also referred to as “auto-advance mode trabeculoplasty.” In a step 1, a user, such as a medical practitioner or physician, applies the

gonioscopic lens to the cornea of a patient's eye as described herein. The user may observe the at least one subregion of the live image that is captured by the system's camera and shown by the system's display device. Within the subregion, which corresponds to a respective mirror surface of the gonioscopic lens and to a respective peripheral gonio field of view having an azimuthal span Φ_{FOV} , the user may observe a sector of the anterior chamber angle of the eye including particularly a section of the trabecular meshwork.

In a step 2, using the image processing module, the (at least one) subregion of the image corresponding to the (at least one) mirror surface is identified, e.g., using a segmentation algorithm, and the current azimuth orientation of the subregion, and thus the azimuth angle Φ of the chamber angle sector shown in the subregion of the image, is determined, for instance, relative to the patient's eye coordinate system (e.g., using the iris or the fundus identified in the subarea of the image showing central gonio field of view) or relative to the camera coordinate system. The subregion may be shown on the display device in accordance with its current azimuthal orientation.

In a step 3, a segment of the trabecular meshwork (TM) within the (at least one) subregion is identified, e.g., using a segmentation algorithm. One or more shot markers, which indicate on the display device the positions of one or more planned laser treatment region, are applied to the identified segment of the TM in accordance with respective azimuthal angles ϕ_{plan}^i of the one or more planned laser treatment regions, for instance, manually using the display device as an input device (e.g., via a touch screen function) or automatically by means of the image processing module as described above. For instance, the shot markers may be applied in a non-overlapping manner and/or to a central segment of the TM with approximately constant curvature, as described herein.

In a step 4, the laser shots may be released, by the user or automatically, onto the treatment regions in accordance with the shot markers.

In a step 5, information about the treatment of the TM segment within the current chamber angle sector, such as the azimuthal angles ϕ_{plan}^i of the shot markers, may be stored in a memory of the system for documentation and/or for later use during the same session. Additionally, image data of the subre-

gion of the image acquired at the azimuthal orientation Φ during application of the laser shots may be stored in the memory.

5 In a step 6, optionally, said subregion may be shown on the display as a still image at the corresponding azimuthal orientation. The irradiated treatment regions therein may be marked with treated region markers that are distinct from the shot markers. In addition, the corresponding subregion of the live image is shown on the display device in accordance with its current azimuthal orientation Φ .

10 In a step 7, in order to treat further treatment regions, corresponding further shot markers are generated. For instance, in order to treat treatment regions within an adjacent chamber angle sector that is adjacent to the current chamber angle and that corresponds to an azimuth orientation $\Phi + \Phi_{\text{Step}}$ with a (predefined) increment Φ_{Step} , it is possible to automatically determine the azimuth angles of new treatment regions from the azimuth angles of the
15 previously treated treatment regions, e.g., using the formula $\phi_{\text{plan}}^i = \phi_{\text{prev}}^i + \Phi_{\text{Step}}$, wherein the previously stored azimuthal angles ϕ_{plan}^i may be retrieved from the memory and used as ϕ_{prev}^i in order to perform the calculation. The new shot markers may be shown on the display in accordance with the respective new azimuth angles ϕ_{plan}^i .

20 By manually automatically rotating the gonioscopic lens about its longitudinal axis, e.g., by the aforementioned azimuthal increment Φ_{Step} , the gonio field of view corresponding to the respective mirror surface may be rotated towards the adjacent sector of the chamber angle which thus becomes visible within the corresponding subregion of the image shown on the display device. In a
25 step 8, the gonioscopic lens is therefore rotated manually or automatically by Φ_{Step} until the TM segment within the rotated (i.e., the new current) subregion of the live image is aligned with the new shot markers at the new azimuth angles ϕ_{plan}^i .

30 In a step 9, when alignment is established, the laser shots may be released manually or automatically so that the segment of TM is irradiated with laser pulses at the planned treatment regions in accordance with the shot markers.

In a step 10, optionally, information about the treatment of the TM segment within the chamber angle sector $\Phi + \Phi_{\text{Step}}$ may be stored in the memory of

the system for documentation and/or for later use during the same session in the same way as described above in step 5.

5 In a step 11, the subregion including the new shot markers within the subregion may optionally be shown on the display as a standstill image at the azimuthal orientation $\Phi + \Phi_{\text{Step}}$. In addition, the corresponding subregion of the live image is shown on the display device in accordance with its new current azimuthal orientation, which may again be denoted as Φ .

10 In a step 12, by repeating the seventh to eleventh steps, laser shots may be applied in multiple sections of the TM in a step wise manner in accordance with the predefined increment Φ_{Step} .

15 In this exemplary method, a preliminary imaging of the anterior chamber is not required prior to the treatment procedure. Moreover, the method may in principle be performed without automatic patient or eye tracking, particularly when the physician manually brings the device in alignment with the targeted area in the patient's eye and manually rotates the gonio lens to bring the mirror surface in the right position, as indicated by automatically generated shot markers.

20 An exemplary second method of using the ophthalmic system described herein, which herein is also referred to as "automatic mode trabeculoplasty," may comprise steps 1 to 6 of the exemplary first method described above. Additionally, the exemplary second method may include one or more of the following steps.

25 In an step 7, in order to treat further treatment regions in a different or new section of the TM contained in a different or new chamber angle sector, the gonioscopic lens is rotated manually or automatically to a corresponding new azimuthal orientation $\Phi = \Phi_{\text{new}}$ until the new TM segment to be irradiated is shown within the rotated, i.e., new or current subregion of the live image.

30 In a step 8, step 2 is applied again after the rotation to identify the new (at least one) subregion and to determine the new azimuth angle Φ of the subregion and thus the azimuth angle Φ of the chamber angle sector shown in the subregion.

In a step 9, step 3 is applied again to identify within the new (at least one) subregion a corresponding new segment of the TM. Furthermore, any overlap with previously treated segments, if any, may be detected, e.g., using the image processing module. For instance, an overlap between treated segments may be determined using the stored coordinates of previously treated treatment regions, e.g., by determining whether these coordinates fall within onto the current (new) segment of the TM.

In a step 10, new shot markers are applied onto the new segment of the TM. Preferably, the shot markers are automatically generated by means of the image processing module as described above, particularly avoiding definition of any region that has already been treated under a previous azimuthal orientation of the gonioscopic lens as a new treatment region. For instance, the image processing module may generate the new such markers such that the new treatment regions are spaced apart from the previously treated laser treatment regions by at least a predefined distance value. The new shot markers may be shown on the display in accordance with respective new azimuth angles ϕ_{plan}^i . Treated region markers may be displayed accordingly.

In a step 11, step 4 is performed again to treat the new treatment regions.

In a step 12, step 5 is performed again to store information about the treatment of the TM segment at new treatment regions within the current chamber angle sector and to acquire a standstill image of the currently treated chamber section.

In a further step (12B), optionally, step 6 is performed to show the treated section of the TM on the display as a standstill image.

In a step 13, the steps 7 to 12 (and optionally step 12B) are repeated to apply laser shots in multiple sections of the TM in a step wise manner. Also in this exemplary second method, acquiring a preliminary imaging of the anterior chamber prior to the treatment procedure is not needed. Preferably, the method is performed while the patient and/or the patient's eye are tracked, e.g., in order to compensate motions of the eye relative to the system.

While with the ophthalmic system of the present disclosure, it may not be necessary to first acquire images of the anterior chamber before starting the

actual treatment session, there is also provided herein a mode of operation of the ophthalmic system in which a circumferential panoramic image, i.e., a snapshot of the entire chamber angle, may be acquired prior to performing the actual treatment procedure.

5 An exemplary third method of using the ophthalmic system described herein, may comprise one or more of the following steps. In the following, this exemplary method is also referred to as “planned mode trabeculoplasty.”

First, a treatment plan is defined, e.g., automatically or based on manual user input as described in more detail below. As an example, the user may define

10 the treatment plan by placing laser spots or treatment regions on the subregions of the (live) image or onto a circumferential snapshot or panoramic image which is described further below. Each laser spot can be characterized, for instance, by its coordinates (such as its position around the iris and its lateral or radial position, e.g., relative to the device or the center of the

15 pupil), and by laser parameters, such as laser pulse power/energy, and pulse duration (if applicable). Secondly, during the actual treatment, the TM is treated segment by segment in accordance with the peripheral gonio field of view at the current azimuthal orientation of the gonioscopic lens. Once an

azimuthal segment of the TM has been treated, the system may advance to the adjacent segment either by displaying on the display device the corre-

20 sponding shot markers in the adjacent segment in accordance with the treatment plan, thereby suggesting the physician where to (manually) rotate the gonioscopic lens accordingly, or by automatically rotating the gonioscopic lens (in its entirety or only partly, e.g., rotating a component thereof carrying the gonio mirror surface(s)). The laser pulses may be released either automa-

25 tically by the system device or the physician may be prompted by the system to release the shots.

As mentioned above, in some examples, the processing device or the image processing module may be configured to define a treatment plan including

30 one or more treatment regions within the eye to be irradiated with laser energy. For instance, the image processing module may be configured to define the one or more treatment regions within the at least one subregion of the image (which may be a live image or a still image acquired with the camera) or within the aforementioned panoramic image. In some examples, the image

35 processing module may be configured to define the one or more treatment

regions using information received, for instance, via a user interface of the ophthalmic system, i.e., based at least partially on user input. Additionally or alternatively, the image processing module may be configured to define the one of more treatment regions using information determined automatically by the image processing module based on image data, as described further below, and/or using stored information. The stored information may, for instance, be stored in and received from, a (local) memory of the ophthalmic system and/or a database internal or external of the ophthalmic system. Additionally or alternatively, the memory and/or the database may, for instance, be part of a computer network, such as a computer cloud, and/or be accessible via a wired or wireless computer network, such as via the internet. For instance, the memory and/or database may be accessible via an electronic data interface of the ophthalmic system, such as a wired or wireless network interface.

The information (whether stored, input by the user, automatically determined based on image data) may include information about the patient and/or the patient's eye (as described above and further below), information about locations of individual or single treatment regions. Moreover, the information may specify treatment plans or patterns and may, for instance, specify the locations (coordinates) of a plurality of individual treatment regions, a number of laser shots or pulses to be applied on each treatment region, a laser spot size and/or a spatial laser spot density. The information may further include laser parameters, such as laser wavelength, laser energy, laser energy per pulse, laser spot diameter, pulse duration time, pulse separation time, duty cycle, among others.

In some examples, the system is configured to generate a panoramic image of the anterior chamber. For instance, the image processing module may be configured to extract from images of a set of two or more images (e.g. from different frames of the image if it is a video image or live image), which have been acquired with the camera at different azimuthal orientations Φ_{gonio}^j of the gonioscopic lens ($j > 0$ being an index for indexing each one of the different azimuthal orientations of the gonioscopic lens), the at least one subregion of the respective image (e.g. frame) and to join together the extracted subregions (or at least portions thereof, such as the corresponding allowable spans Φ_M of the respective subregions) to create a (composite) panoramic image of

the anterior chamber angle of the eye. For instance, the extracted subregions and the panoramic image composed thereof may cover the entire chamber angle of the eye. The number of subregions required to cover the entire chamber angle of the eye depends on the azimuthal width Φ_{FOV} of the peripheral gonio field of view of each subregion or on the allowable span Φ_{M} . Moreover, the number of different azimuthal orientations Φ_{gonio}^j of the gonioscopic lens needed to cover the entire chamber angle also depends on the number of subregions that are included in each image, i.e., on the number of mirror surface of the gonioscopic lens used. In an example, the image processing module may be configured to determine which of the extracted subregions are adjacent to each other (e.g., based on the azimuthal orientation of each extracted subregion), and to join together each pair of adjacent subregions, for instance, by means of co-registering the adjacent subregions (e.g., within their mutual intersection or overlap region) and/or by stitching the adjacent subregions together. The subregions forming the panoramic image may be aligned in a linear array to form a linear panoramic image or alternatively in a circular array to form a circular panoramic image. Accordingly, the image processing module may be configured to control the display device to display the panoramic image as a linear panoramic image or as a circular panoramic image. In the circular panoramic image, the joined subregions are arranged and displayed in accordance with the azimuthal orientations of the respective subregions. In the linear panoramic image, the extracted and joined subregions are arranged along a straight axis.

In some examples, the processor and/or the image processing module of the ophthalmic system may be configured to automatically retrieve or produce information that may be used to define or alter the aforementioned treatment plan (e.g., prior to, at the beginning of, or even during a treatment session) and/or information that may be used to determine, set and/or adjust laser parameters (e.g. at the beginning or during a treatment session). The information may particularly comprise all or at least some pieces of the aforementioned information, particularly information about the patient's eye such as tissue characteristics and/or information on measured laser tissue interaction. The processor and/or the image processing module of the ophthalmic system may be configured to automatically determine said information based on the images, i.e. based on image data generated by the

camera, particularly based image data extracted from the at least one subregions of the image, and/or based on images or image data generated by other imaging devices, such as optical coherence tomography (OCT) imaging devices. The system may further be configured to determine, set and/or
5 adjust laser parameters based on said information, e.g., using a laser parameter adjustment module.

For instance, the ophthalmic system may comprise an (electronic) laser parameter adjustment module, which may be part of the processing device of the ophthalmic system. The laser parameter adjustment module may be
10 configured to determine, set and/or adjust, based on the information, such as tissue characteristics or laser tissue interaction, at least one laser parameter to be used by the laser system when applying laser energy at a treatment region to be irradiated (which may be identical to or different from a location at which the said information has been determined). For instance, the laser
15 parameter adjustment module may be configured to provide the laser control module with the newly set or adjusted laser parameters and the laser control module may be configured to control the laser system (e.g., the laser source(s), the laser steering device etc.) to irradiate treatment region(s) in accordance with the newly set or adjusted laser parameters. For instance, the
20 laser parameter adjustment module may be configured to newly set laser parameters, or adjust laser parameters that have been previously set, based on the measured at least one observable of laser tissue interaction and/or based on the tissue characteristics, e.g., in response to receiving such information from the image processing module. For instance, the laser
25 parameter adjustment module may be configured to set or adjust laser parameters for one or more treatment regions included in a treatment plan.

For example, the image processing module may be configured to determine, as tissue characteristics, a degree of pigmentation of the tissue of the eye, particularly a degree of pigmentation at the TM. For example, the image
30 processing module may be configured to determine, for one or more locations of the eye within the at least one subregion of the image, such as one or more test sites or one or more treatment regions, the tissue characteristics, such as the degree of pigmentation of the tissue of the eye at the respective location.

In some examples, the image processing module may be configured to

measure, based on image data, one or more observables of laser tissue interaction for one or more locations in the eye, such as one or more test sites or one or more treatment regions. The one or more observable may be indicative of, or correlated with, the aforementioned laser induced effect in the tissue. The image processing module may be configured to extract the image data, for instance, from one or more frames of the image of the camera, e.g., from the at least one subregion of the image, and/or from one or more OCT images acquired by an OCT imaging device. The image data may include reference image data obtained from frames or OCT images acquired prior to the application of one or more laser pulses to a test site or a treatment region in the eye and measurement image data obtained from frames or OCT images acquired after the application of the one or more laser pulses to the test site or the treatment region in the eye. The image processing module may be defined to measure the one or more observables of laser tissue interaction based on a comparison of the image data obtained before and after the application of one or more laser pulses of a set of one or more laser pulses.

For example, the predefined effect may be bubble formation at the site of laser tissue interaction (i.e., at a target site, such as a test site or a treatment region) and the at least one observable may be related to bubble formation at that site. The at least one observable may include a growth rate of bubbles, a number of bubbles generated at the site, a size of bubbles generated at the site (such as a mean size, a maximum size, a minimum size or a size distribution), a signal change due to micro-bubbles and/or due to macro bubbles at the site of laser tissue interaction.

Aspects of the present disclosure relate to gonioscopic lenses, gonioscopic lens assemblies, and patient interfaces. The ophthalmic system described herein may be operated with, and/or include, the gonioscopic lens, the gonioscopic lens assembly, or the patient interface, or any standard gonioscope lens. As described in greater detail below, the gonioscopic lens may be part of the gonioscopic lens assembly. Additionally or alternatively, the gonioscopic lens may be formed by the patient interface. In a further example, the gonioscopic lens may be formed by the combination of the patient interface and a coupling member of the ophthalmic system.

In some examples, a gonioscopic lens assembly in accordance with the present disclosure includes, in addition to the gonioscopic lens, a lens element. The additional lens element may be located at a proximal end of the gonioscopic lens assembly and may be concentric with the contact member of the gonioscopic lens of the gonioscopic lens assembly. A semi-diameter (SD_L) of the proximal lens element may be less than a (maximal) radial distance of the at least one mirror of the gonioscopic lens assembly from the longitudinal axis of gonioscopic lens. In some examples, the semi-diameter (SD_L) of the proximal lens element may be approximately the same as semi-diameter (SD_{CM}) of contact member. The proximal lens element may be attached to or integrated into a proximal window element of the gonioscopic lens assembly. For instance, as mentioned above, the gonioscopic lens may include a cup-shaped member with a distal end carrying the contact member and a proximal end carrying the proximal window element and/or the proximal lens element. The converging lens may be configured to converge the illumination beams, i.e., the central illumination beams, onto the iris. Alternatively, the proximal lens element may be a diverging lens. The diverging lens may be configured to diverge the illumination beams, i.e., the central illumination beams, such that they are focused onto the retina. For instance, the proximal lens element may be configured to focus the central illumination beams onto the iris or onto the central retina, when the peripheral illumination beams are focused onto eye tissue of the anterior chamber, e.g., onto the trabecular meshwork. For instance, when the focusing assembly is in the first focus mode, as described above, the proximal lens element may focus the central illumination beams onto the iris or onto the central retina. In this example, the proximal lens element may provide an alternative to switching between different illumination modes for the central and peripheral illumination beams.

In some examples, the gonioscopic lens assembly may include a filter element which may be located, for instance, at a proximal end of the lens assembly.

The filter element may be concentric with the contact member of the gonioscopic lens. For instance, the proximal filter element may be attached to the proximal end of the aforementioned cup-shaped element of the gonioscopic lens. A semi-diameter (SD_F) of the filter element may be less than a (maximal) radial distance of the at least one mirror surface of the gonioscopic lens from the longitudinal axis of gonioscopic lens. In some examples, the

semi-diameter (SD_F) of the filter element may be approximately the same as a semi-diameter (SD_{CM}) of contact member. The proximal filter element may be a neutral-density filter. The proximal filter element may be configured to reduce the intensity of the central illumination beams reaching the eye and to reduce the intensity of the central observation beams reaching the image sensor. In this manner, dazzling of the patient and/or an overexposure of the image sensor (particularly in the subarea of the image sensor onto which the central observation beams are focused) may be reduced or avoided, while the peripheral illumination and observation beams may have a sufficient intensity for illuminating and imaging the anterior chamber, for instance, when the illumination device is operated in the aforementioned first illumination mode. In this example, the filter element may provide an alternative to switching between different illumination modes for the central and peripheral illumination beams.

In accordance with the present disclosure, a patient interface is adapted for imaging an eye through the patient interface and/or for applying laser energy to the eye through the patient interface, as detailed below. The patient interface generally comprises a contact member which may share the same features as the contact member of the gonioscopic lens. The contact member includes a contact surface that is concentric relative to a longitudinal axis of the contact member and that is adapted to be placed adjacent to, or onto, a cornea of the eye. The contact member further includes an interface portion adapted to allow illumination beams and laser beams, e.g. from the ophthalmic system described herein, to propagate through the interface portion towards the contact surface of the contact member and to allow observation beams propagate from the contact surface through the interface portion, e.g. towards the camera of the ophthalmic system.

In some examples, the contact member may be, or include, a lens forming the contact surface, such as a plano-concave lens, a convex-concave lens or a meniscus lens. The contact member may include a body portion which may form the lens. Additionally or alternatively, the body portion may form the interface portion or at least parts thereof. The body portion may be formed completely or at least in regions of a material that is optically transparent for the illumination beams, laser beams and observation beams. The transparent material may be for instance, a glass or polymer, such as silica or PMMA.

In some examples, in which the patient interface forms the gonioscopic lens, the interface portion may include one or more of the mirror surfaces of the gonioscopic lens, the mirror surface(s) being inclined relative to the longitudinal axis of the contact member in accordance with respective gonio angles α_{GONIO} , in order to redirect peripheral illumination and observation beams, as described herein. The one or more mirror surfaces may be attached to at least one side surface of, or integrated into, the contact member, such as to the body portion, preferably to or into the transparent material mentioned above.

In one example, the interface portion may include at least one sidewall which laterally defines or surrounds a receiving space of the patient interface. The interface portion may further comprise a proximal opening which provides access to the receiving space from the proximal side of the patient interface. The receiving space and the opening may be concentric relative to the longitudinal axis of the contact member. In such an example, the contact member may be a cup-shaped member.

In some examples, the contact member is a sterile, single-use article. Preferably, the contact member is made of a low cost material and is discarded after use. In this way, the user avoids the costs and efforts involved in re-sterilization for multi-use. In some examples described in greater detail below, multi-use may be prevented by providing each the patient interface with a unique identifier.

The patient interface may further comprise a machine-readable identifier attached to, or integrated into, the contact member. The machine-readable identifier may include, for instance, an optically, magnetically or electronically readable code, e.g. a linear or a 2D barcode. Additionally or alternatively, the identifying may be or include a RFID tag. The machine-readable identifier may encode, in a machine-readable manner, information about the patient interface, such as information allowing to uniquely identify each entity of the patient interface. Additionally or alternatively, the information may specify optical characteristics of the patient interface, such as the imaging magnification value M_c of the central gonio field of the patient interface, as described above. Moreover, in examples in which the patient interface includes gonio mirrors and thus forms a gonioscopic lens, the information may include the number of mirror surfaces included in the patient interface, the inclination

angle α_{GONIO} of the one or more mirror surfaces, and/or at least one imaging magnification value M_{GONIO} associated with one more of the peripheral gonio fields of the respective mirror surfaces.

5 In some examples, the patient interface may further comprise a forceps or at least one lid opening element or a combination thereof. Typically, the forceps or the one or more lid opening element extending laterally from a side surface of the contact member.

10 In some examples, the patient interface may further comprise a pressure sensor configured to measure and/or indicate one or more pressures. For instance, the pressure sensor may be configured to measure and/or indicate a pressure with which the contact surface of the contact member is pressed against the cornea. Additionally or alternatively, the pressure sensor may be configured to measure and/or indicate an intraocular pressure (IOP) of an eye which the contact is in contact with.

15 In one example, the pressure sensor includes a flexible element which is configured to gradually deform depending on the magnitude of the pressure. The pressure sensor may, for instance, be configured to indicate a degree of the deformation of the flexible element in response to the pressure. The pressure sensor may include, for instance, a flexible membrane covering at
20 least a portion of the contact surface of the contact member and forming a chamber between the contact surface and the flexible membrane. The contact member may further include a channel extending within the contact member, one end of the channel being in fluid communication with the chamber via an opening formed in the contact surface of the contact member.
25 The chamber may be filled with a fluid. The fluid may enter the channel through the opening and flow through the channel in response to a pressure of the fluid within the chamber. The pressure in the chamber may depend, for instance, on the pressure with which the contact member is pressed against the cornea of the eye and/or on the IOP. The pressure sensor may include one
30 or more markings along the channel, which may form a (pressure) scale allowing to measure the pressure in accordance with a height of a liquid column formed by the liquid within the channel relative to the markings. In order to facilitate viewing the channel and the fluid therein from a proximal side of the contact member, the channel may extend in a direction (approximate)

mately) orthogonal to the longitudinal axis of the contact member of the patient interface.

In some examples, the ophthalmic system as described herein may include a coupling member configured to establish a connection state between the ophthalmic system and the patient interface. In the connection state, the coupling member may mechanically contact the interface portion of the contact member. In the connection state, a longitudinal axis of the coupling member may be, at least within a (predefined) tolerance range, aligned with the longitudinal axis of the contact member of the patient interface. Moreover, in the connection state, an axial distance between the coupling member and the interface portion typically is within a (predefined) tolerance range. Hence, the connection state allows for accurate illumination, observation and application of laser energy through the patient interface.

In some examples, the coupling member may include a resilient member configured to transition into a loaded or compressed state when the coupling member is pushed or pressed against the interface portion of contact member in the connection state. When the coupling member is separated from the interface portion of contact member (i.e. when the connection state is terminated), the resilient member may revert back to an unloaded or uncompressed state (or to a less loaded or less compressed state). The resilient member may include an elastic member, such as a spring member or a bellows member. The resilient member may be concentric with the longitudinal axis of the coupling member. The coupling member may be configured to contact the interface portion of the contact member of the patient interface (only) via the resilient member. For instance, the resilient member may extend from a main body of the coupling member in a distal direction. The interface portion may include a flange at a proximal end of the interface portion. The resilient member may be configured to abut against the interface portion, e.g., against the flange thereof, in the connection state. The resilient member may be configured to dampen and/or compensate axial motions between the coupling member and the interface portion of the contact member of the patient interface in the connection state, e.g. by reversibly or elastically changing its length along the longitudinal axis of the coupling member. In principle, the resilient member may also be part of interface portion, extending proximally from the interface portion of the contact

member and configured to abut against the coupling member, for instance against a flange thereof.

In some examples, the coupling member of the ophthalmic system includes a first marking and the contact member of the patient interface includes a second marking. The first and second markings may be positioned within a field of view of the camera of the ophthalmic system in the connection state. The image processing module may be configured to identify the first and the second marking within the image acquired by the camera and to determine a spatial relation between the first marking and the second marking within the image. For example, determining the spatial relation between the first marking and the second marking may include determining at least one of a distance between the first marking and the second marking within the image, an alignment of the first marking relative to the second marking, a displacement of the first marking relative to the second marking, and/or a size difference between the first marking and the second marking. The image processing module may be further configured to use the determined spatial relation between the first marking and the second marking to determine whether a positioning of the coupling member relative to the patient interface in the connection state is within a predefined range and/or whether a pressure with which the patient interface is pressed against the patient's eye is within a predefined range, as describe below.

For example, the predefined range may include at least one of a predefined range of an axial distance between the coupling member and the interface portion of the contact member of the patient interface, a predefined range of displacement orthogonally to the longitudinal axis of the interface portion of the contact member of the patient interface, and/or a predefined range of a rotation of the coupling member relative to the interface portion of the contact member about the longitudinal axis of the contact member of the patient interface. For example, the axial distance may be determined based on the size difference between the first marking and the second marking in the image, as the size difference increases with the axial distance between the first and second markings.

In some examples, the first marking may be a circular ring and the second marking may be a circular dot (or vice versa). The spatial relation between the

first marking and the second marking may be defined to be within the predefined range, for instance, if the dot is within the ring and completely fills the region defined by the ring.

5 For example, the imaging processing module may be configured to generate a confirmation signal indicating that the connection state has been successfully established if the determined spatial relation is within the predefined range and/or to generate a warning signal indicating that the connection state has not been successfully established if the determined spatial relation is not within the predefined range. In some examples, the laser system may be
10 configured to receive the signal(s) and to allow emission of laser beams only after receiving the confirmation signal and/or to prevent emission of laser beams after receiving the warning signal. Additionally or alternatively, the display device may be configured to receive the confirmation signal and/or the warning signal and to display to the user a corresponding warning or
15 confirmation signal.

In some examples, the image processing module is configured to determine at least one pressure using the determined spatial relation between the first marking and the second marking. The at least one pressure may be selected, for instance, from a pressure with which the coupling member of the patient
20 interface is pressed against the contact member of the patient interface and/or an intraocular pressure of the eye the contact member is in contact with. The image processing module may further be configured to determine whether the thus determined pressure is within a predefined range.

25 Additionally or alternatively, the aforementioned pressure sensor may be configured to be completely or least partly within a field of view of the camera, if the connection state between the ophthalmic system and the patient interface is established. The image processing module may be configured to determine the pressure as measured and/or indicated by the pressure sensor within the image of the camera. The image processing
30 module may further be configured to determine whether the pressure measured and/or indicated by the pressure sensor is within a predefined range.

The imaging processing module may be configured to generate a confirmation

signal indicating that the pressure, i.e., the pressure obtained using the pressure sensor or the pressure determined based on the spatial relation of the first and second markings, is within the predefined range and/or to generate a warning signal indicating that the pressure is above or below the predefined range. Additionally or alternatively, the display device may be configured to receive the confirmation signal and/or the warning signal and to display to the user a corresponding warning or confirmation signal. Additionally or alternatively, the display device may be configured to receive the determined pressure(s) and to display to the user the determined pressure(s), e.g., corresponding values thereof.

For example, to establish the connection state between the ophthalmic system and the patient interface, the coupling member may be configured to be inserted through the aforementioned proximal opening of the interface portion of the patient interface into the receiving space of the interface portion of the patient interface.

In the connection state between the ophthalmic system and the patient interface, the coupling member of the ophthalmic system and the contact member of the patient interface in combination may form the gonioscopic lens. In this example, the coupling member of the ophthalmic system includes the at least one mirror surface of the gonioscopic lens and the contact member forms the contact member of the gonioscopic lens. The at least one mirror surface may, for instance, be angled relative to the longitudinal axis of coupling member and configured to redirect the peripheral illumination beams from the illumination device towards the contact member and direct peripheral observation beams from the contact member towards the camera of the ophthalmic system. The ophthalmic system may include a drive member which may be configured to move, for instance, under the control of the processor or the image processing module of the ophthalmic system, the coupling member axially along the longitudinal axis of the coupling member and/or to rotate the coupling member about the longitudinal axis of the coupling member. For instance, the processor or image processing module may be configured to control the drive member to move the coupling member so as to establish the connection state, e.g., such that the aforementioned spatial relation between the first marking of the coupling member and the second marking of the contact member is moved into, or kept within, the

predefined range. Additionally or alternatively, the processor or image processing module may be configured to control the drive member to move the coupling member such that the aforementioned pressure (e.g., the pressure with which the contact member is pressed against the cornea of the eye, or the IOP) is moved into or kept within the predefined range.

In some examples, the ophthalmic system further includes a reader device configured to read out the information from the aforementioned machine-readable identifier of the patient interface. The reader device may be, or include, the aforementioned camera of the ophthalmic system and/or an additional camera of the ophthalmic system. Additionally or alternatively, the reader device may be, or include, an RFID reader. The machine-readable identifier may be positioned, for instance, on the contact member of the patient interface such that it is readable by the reader device at least during the connection state between the ophthalmic system and the patient interface. The ophthalmic system may further include an electronic identification module that is configured to identify the patient interface based on the information from the machine-readable identifier that has been readout by the reader device. For instance, the electronic identification module may be configured (e.g., via a suitable data interface or network interface) to assess a data base storing uniquely identifying information (e.g. IDs) of used patient interfaces. For instance, the electronic identification module may be configured to assess the data base, e.g., via the internet, and to perform queries on the database, for instance, whether the uniquely identifying information readout from an instant patient interface (e.g. that is momentarily connected to the coupling member of the ophthalmic system) is stored as belonging to a previously used patient interface. Hence, in some examples, the identification module may be configured to determine whether the patient interface has already been used in a previous session and, if so, to not support any use of the patient interface in a present or future session. For instance, the identification module may be configured to control the illumination device, the camera, the image processing module, and/or the laser system not to operate (or to operate only in a restricted mode) as long as the coupling member is connected to the patient interface, if the patient interface is determined as being previously used.

Additionally or alternatively, in examples in which the machine-readable

identifier encodes information specifying optical characteristics of the patient interface as described above, the identification module may be configured to provide one or more of the optical characteristics to the image processing module, to the illumination device or the illumination control module described above, and/or to the focusing assembly or the focus control module described above, each of which may be configured to operate in accordance with the received optical characteristics of the patient interface. For instance, the image processing module may be configured to perform a search of subregions of the image corresponding to the one or more mirror surface using the information, e.g., specifying the number of mirror surfaces included in the patient interface. As a further example, the focus control module may be configured to adjust the focus of the focusing assembly using the information, e.g., specifying the imaging magnification value M_c of the central gonio field of the patient interface and/or the at least one imaging magnification value M_{GONIO} associated with the one more peripheral gonio fields of the patient interface.

In one example of the patient interface, the contact member may comprise a marker configured to indicate an azimuthal orientation of the contact member about the longitudinal axis of the contact member. For instance, the marker may be configured to be visible from a proximal side of the contact member (the proximal side facing the ophthalmic system, e.g., facing the mount or coupling member thereof). In this example, the image processing module may be configured to identify the marker within the image of the camera and to use the identified marker to determine one or more of an azimuthal orientation of the patient interface (e.g. relative to the camera coordinate system and/or eye coordinate system), an azimuthal orientation of the at least one mirror surface (e.g. relative to the camera coordinate system and/or eye coordinate system), an azimuthal orientation of the at least one subregion of the image (e.g. relative to the camera coordinate system and/or eye coordinate system) and/or an azimuthal orientation of at least one characteristic feature of the eye within the image relative to the marker, relative to the camera coordinate system and/or relative to the eye coordinate system.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings illustrate aspects and various examples of the present disclosure that, together with the written descriptions herein, serve to explain this disclosure. Each drawing depicts one or more aspects of this disclosure as follows:

5

FIG. 1 depicts an exemplary ophthalmic system in accordance with the present disclosure, and a gonioscopic lens being placed onto an eye.

FIG. 1A depicts a gonioscopic lens placed onto the cornea of an eye.

10

FIGs. 2A-2D show exemplary variants of the ophthalmic system shown in FIG. 1 in accordance with the present disclosure.

FIGs. 3A-B shows the field of view as seen by a camera of an exemplary ophthalmic system in accordance with the present disclosure.

15

FIGs. 4A-4C depict exemplary illumination beams and observation beams generated using an exemplary ophthalmic system in accordance with the present disclosure and a gonioscopic lens placed on an eye.

FIG. 5 shows an exemplary image generated by an exemplary ophthalmic systems in accordance with the present disclosure, the image depicting characteristic features of different portions of the eye.

20

FIGs. 6A-B depict further exemplary illumination beams and observation beams generated using an exemplary ophthalmic systems in accordance with the present disclosure and exemplary of gonioscopic lens assemblies in accordance with the present disclosure with distributed optical power elements.

25

FIGs. 7A-B show exemplary images which are in accordance with the beam paths shown in FIGs. 6A-B, respectively.

FIG. 8 illustrates an exemplary chamber angle viewing geometry in accordance with the present disclosure.

FIG. 9 illustrates an exemplary parametrization of an ellipse approximating the observed trabecular meshwork using a gonioscopic lens in accordance with

the present disclosure.

FIG. 10 depicts an example of determining an azimuthal orientation of a peripheral gonio field in accordance with the present disclosure.

5 FIG. 11 shows an exemplary procedure workflow of using an exemplary ophthalmic system to perform laser trabeculoplasty via a gonioscopic lens in an “auto-advance mode” in accordance with the present disclosure.

FIG. 12 illustrates treatment regions of a trabecular meshwork of an eye being treated in accordance with the “auto-advance mode” illustrated in FIG. 11.

10 FIG. 13 shows an exemplary procedure workflow of using an exemplary ophthalmic system to perform laser trabeculoplasty via a gonioscopic lens in an “automatic mode” in accordance with the present disclosure.

FIG. 14 illustrates treatment regions of a trabecular meshwork of an eye being treated in accordance with the “automatic mode” illustrated in FIG. 13.

15 FIG. 15 illustrates treatment regions of a trabecular meshwork of an eye being treated using an exemplary ophthalmic system in a “planned mode” in accordance with the present disclosure.

FIGs. 16A-B depict exemplary camera images generated using an exemplary ophthalmic system in accordance with the present disclosure.

20 FIGs. 17A-B depict exemplary images generated using the camera images shown in FIGs. 16A-B.

FIGs. 18A-B depict exemplary camera images generated using an exemplary ophthalmic system in accordance with the present disclosure.

FIGs. 19A-B depict exemplary images generated using the camera images shown in FIGs. 18A-B.

25 FIG. 20 illustrates an exemplary method of imaging and displaying an eye’s chamber angle along its entire circumference using an exemplary ophthalmic system in accordance with the present disclosure.

FIG. 21 illustrates an exemplary method of applying laser pulses into an

anterior chamber angle along its full circumference using an exemplary ophthalmic system in accordance with the present disclosure.

FIGs. 22 to 27 show examples of patient interfaces in accordance with the present disclosure.

5 FIG. 28 depicts an example of an ophthalmic system in accordance with the present disclosure, the ophthalmic system including a coupling member to establish a connection with a patient interface of the present disclosure.

DETAILED DESCRIPTION

10 Aspects of the present disclosure are now described with reference to exemplary ophthalmic systems, gonioscopic lenses, gonioscopic lens assemblies, patient interfaces, and associated methods. Some aspects are described with reference to operations where a laser beam is directed to eye tissue, for instance, to the trabecular meshwork. Reference to such particular type of operation is provided for convenience and not intended to limit the present
15 disclosure unless claimed. Accordingly, the concepts described herein may be utilized for any analogous device or method - medical or otherwise, eye-specific or not.

As used herein, the terms "comprises," "comprising," or like variation, are intended to cover a non-exclusive inclusion, such that a device or method that
20 comprises a list of elements does not include only those elements, but may include other elements not expressly listed or inherent thereto. Unless stated otherwise, the term "exemplary" is used in the sense of "example" rather than "ideal." Conversely, the terms "consists of" and "consisting of" are intended to cover an exclusive inclusion, such that a device or method that
25 consists of a list of elements includes only those elements. As used herein, terms such as "about," "substantially," "approximately," or like variations, may indicate a range of values within +/- 5% of a stated value. Moreover, as used herein, the term "proximal" is intended to refer to a direction (or side) facing (or pointing) away from the patient's eye and towards the ophthalmic
30 system or a user of the system, whereas the term "distal" is intended to refer to a direction (or side) facing (or pointing) towards the patient's eye and away from the ophthalmic system or the user of the system.

Aspects of the present disclosure pertain to an exemplary ophthalmic system, examples of which are depicted in FIGs. 1 to 2D and 28. Further aspects of the present disclosure pertain to an exemplary gonioscopic lens assemblies, examples of which are depicted in FIGs. 1 to 2D and 28.

FIG. 1 shows a block diagram of an exemplary ophthalmic system 100 in accordance with the present disclosure. The ophthalmic system can be used in combination with a gonioscopic lens 1100 which may be an entity separate from the ophthalmic system 100. Alternatively, the ophthalmic system 100 may also comprise the gonioscopic lens 1100. For instance, a variant of the ophthalmic system 100 that is shown in FIG. 28 and has the reference numeral 600, comprises at least parts of a gonioscopic lens that are integrated, for instance, into a distal coupling member 690 of the ophthalmic system, the coupling member being configured to be connected with a patient interface 3600.

Accordingly, the ophthalmic system 100 may be used with different types of gonioscopic lenses 1100, gonioscopic lens assemblies 2100, 2200, and patient interfaces 3100, 3200, 3300, 3400, 3500, 3600, examples of which being described below, particularly with reference to FIGs. 1, 3A-3B, 6A-B, and 22-28. FIG. 1A schematically shows details of a patient's eye 10 and a gonioscopic lens 1100 being placed onto the cornea 20 of the eye 10.

The exemplary ophthalmic system 100 shown in FIG. 1 may be implemented in various ways, for instance, by using different optical components (such as lenses, mirrors, beam splitters, etc.) and/or arranging the optical components differently. For instance, as mentioned above, FIGs. 2A-2D and 28 show exemplary variants 200, 300, 400, 500, 600 of the ophthalmic system 100 shown FIG. 1. Unless indicated otherwise, the description of the ophthalmic system 100 shown in FIG. 1 may also be applied also to the ophthalmic systems 200, 300, 400, 500, 600 shown in FIGs. 2A-2D and 28, and vice versa.

The ophthalmic system 100 comprises an illumination device 110 with one or more light sources 111 configured to generate illumination beams 112 (shown, for instance, in FIGs. 2A-D), that propagate, via optical components specified further below, through the gonioscopic lens 1000 and illuminate the

eye 10. The light sources 111 may, for instance, be LEDs configured to emit light in the visible spectrum and in the infrared spectrum, an integrated into an illumination array (not shown). The illumination beams 112 may thus comprise, or consist of, light beams with wavelengths in the visible wavelength range, e.g. between 400 nm and 780 nm. Additionally or alternatively, the illumination beams 112 may comprise, or consist of, light beams with wavelengths in the infrared wavelength range, e.g. in a wavelength range between 780 nm and 2000 nm. For instance, the illumination device 110 may be configured to selectively emit visible (e.g., white) or infrared IR illumination beams. White visible illumination beams may be particularly useful for the physician to better discern certain anatomical features (such as the pigmented trabecular meshwork) but may be uncomfortable to the patient and cause dazzling. Once features of interest for treatment have been identified in a succession of images (frames) acquired under white visible illumination, the illumination device may be switched to only emit IR illumination beams. For instance, tracking of patient head and eye motion during the procedure may be performed using a live or video image acquired under IR illumination only.

For instance, as shown in FIGs. 2A-D, the illumination beams 112 may be directed to impinge on tissue in the anterior chamber angle 40 of the eye 10, such as the trabecular meshwork 45 and/or adjacent eye tissues, such as the iris 30. Additionally or alternatively, the illuminations beams may be directed to impinge on tissue of the peripheral or central eye fundus 50, such as the peripheral parts 57 or central parts 56 of the retina 55. See FIG. 1A. The illumination beams 112 are backscattered from the eye and return to the system as observation beams 114. Further details on different paths of illumination beams 112 and the corresponding observation beams 114 are described further below, particularly with reference to FIGs. 4A to 7B.

FIGs. 1A, 3A-B, and 4A-D show exemplary variants of the gonioscopic lens 1100 which generally includes a contact member 1110 and at least one mirror surface 1120 which is angled relative to a longitudinal axis 1114 of the gonioscopic lens 1100. As shown in FIG. 4A, the longitudinal axis 1114 centrally traverses the contact member 1110, i.e., the contact member 1100 is typically concentric relative to the longitudinal axis 1114. In the examples shown, an inclination angle α_{GONIO} of the at least one mirror surface 1100

relative to the longitudinal axis 1114 of the gonioscopic lens 1100 may be in a range between 10° and 60° , for instance, approximately 30° . If the gonioscopic lens 1110 comprises more than one mirror surface 1120, e.g., 4 or 6 mirror surfaces 1220, as shown for instance, in the examples depicted in FIGs. 3A-B, the mirror surfaces 1220 may have the same inclination angle α_{GONIO} . In alternative examples, the mirror surfaces 1120 may have different inclination angles α_{GONIO}^i , (i being an index labelling the mirror surfaces) the inclination angle α_{GONIO}^i of each mirror surface 1120 typically being within the aforementioned range.

During use, as shown for instance in FIGs. 1, 1A, 2A-D, and 4A-B, the contact member 1100 of the gonioscopic lens 1100 is placed onto, or adjacent to, the cornea 20 of the eye 10 such that a contact surface 1112 of the contact member 1110 facing the cornea 20 is adjacent to the outer surface of the cornea 20. An interspace defined between the contact surface 1112 of the contact member 1110 and the outer surface of the cornea 20 typically has a maximum width of less than 3 mm, less than 2 mm or less than 1 mm. The interspace may be filled with a liquid or a gel, such as tear liquid, saline, or a coupling gel, such as an index matching gel. During use, the gonioscopic lens 1110 is typically oriented relative to the eye 10 such that the longitudinal axis 1114 of the gonioscopic lens 1100 and a pupillary axis 36 of the eye 10, which may be defined as running through a midpoint of the cornea 20 and centrally through the pupil 35 of the eye 10, are parallel or define an angle in a range typically between 0° and 15° , between 0° and 10° , or between 0° and 5° . In the example shown in FIG. 1A, the longitudinal axis 1114 of the gonioscopic lens 1110 and the pupillary axis 36 of the eye coincide with each other and are both represented by the central dashed line depicted in FIG. 1A.

The ophthalmic system 100 further includes an imaging device or camera 120 for acquiring an image 125 of the eye 10 through the gonioscopic lens 1100. The camera 120 includes at least one image sensor 121, as shown in FIGs. 1 and 5A-B, configured to receive the aforementioned observation beams 114 propagating from the illuminated parts the eye 10, particularly from the aforementioned illuminated tissues of the trabecular meshwork 45, iris 30 and/or retina 55, through the gonioscopic lens 1100 towards the image sensor 121. The image sensor 121 can be a CMOS sensor or a CCD sensor, for

example. Examples of images 125 generated by the camera 120 are shown in FIGs. 3A-B, 7A-B, 12, 14, 15, 16A, and 18A. In the present examples, a field of view 126 of the camera 125 is sufficiently large so that the image 125 can encompass at least one or all of the mirror surfaces 1120 and the contact member 1110 of the gonioscopic lens 1100 simultaneously, when imaging the eye 10 through the gonioscopic lens 1100. In the present examples, the camera 120 may be a video camera and the generated image 125 may thus be a video image comprising a series of frames taken at a frame rate r_f of the camera 120. For instance, the frame rate r_f may be in a range of 50 to 100 Hz, for instance.

The illumination beams 112 generated by the illumination device 110 are shown, for instance in FIGs. 2A-D, 4A-C, and 6A-B. As specifically shown in FIGs. 4B-C and 6A-B, the illumination beams 112 may comprise central illumination beams 112C that are directed to propagate through the contact member 1110 without being reflected by any one of the at least one mirror surface 1120 of the gonioscopic lens 1100. The central illumination beams 112C traverse the contact member 1110 and the cornea 20 in a direction that is typically parallel to the pupillary axis 36 of the eye 10 or in a direction that defines an angle with the pupillary axis 36 of less than 30° , of less than 15° , or of less than 5° . Typically, said angle is less than the inclination angle of the at least one mirror surface 1120 of the gonioscopic lens 1100. After having passed through the cornea 20, the central illumination beams 112C may, for instance, impinge on the iris 30, as shown in FIGs. 4B and 6A, or traverse the pupil 35 and irradiate the retina 55 on the fundus 50 of the eye 10, as shown in FIGs. 4C and 6B.

As shown, for instance, in FIGs. 2A-D, 4A, 6A-B, the illumination beams 112 further include peripheral illumination beams 112P that are reflected by one of the at least one mirror surface 1120 of the gonioscopic lens and propagate obliquely through the contact member 1110 of the gonioscopic lens 1100 and through the cornea 20. The peripheral illumination beams 112P may be approximately parallel to the central illumination beams 112C until they impinge on the respective mirror surface 1120 of the gonioscopic lens. During use, a lateral distance of the central illumination beams 112C from the pupillary axis 36 of the eye 10 is typically smaller than a lateral distance the

peripheral illumination beams from the pupil axis 36 of the eye 10. The peripheral illumination beams 112P traverse the contact member 1110 and the cornea 20 in a direction that defines an angle with the pupillary axis 36 that is typically greater than 30°, greater than 45° or greater than 60°.

Typically, said angle is greater than the inclination angle of the respective reflecting mirror surface 1120 of the gonioscopic lens 1100. Depending on said angle, the peripheral illumination beams 112P may impinge on tissue of the anterior chamber angle 40 of the eye 10, such as peripheral regions of the iris 30 or the trabecular meshwork 45. At smaller angles, the peripheral illumination beams 112P may pass through the pupil 35 of the eye and impinge on tissue of the eye fundus 50, such as non-central or peripheral regions of the retina 55.

The observation beams 114 may include central observation beams 114C that emanate from eye tissues being illuminated by the central illumination beams 112C (*i.e.*, being backscattered central illumination beams 112C) and that propagate through the contact member 1110 towards the camera 120 without being reflected by any one of the at least one mirror surface 1120 of the gonioscopic lens 1100. As shown in FIGs. 2A-D, 4A and 6A-B, the central observation beams 114C are reflected by tissue of the iris 30 or the fundus 50 of the eye, particularly from the retina 55. Similarly to the central illumination beams 112C, the central observation beams 112C traverse the cornea 20 and the contact member 1110 typically in a direction that may be approximately parallel to the pupillary axis 65 of the eye or in a direction that defines an angle with pupillary axis of less than 5°, of less than 15°, or of less than 30°. Typically, said angle is less than an inclination angle of the at least one mirror surface 1120 of the gonioscopic lens 1100 defined relative to the longitudinal axis 1114 of the gonioscopic lens 1100.

The observation beams 1114 further includes peripheral observation beams 114P that emanate from tissue of the eye illuminated by the peripheral illumination beams 112P (*i.e.*, being backscattered peripheral illumination beams 112P) and propagate obliquely through the contact member 1110. The peripheral observation beams 114P are reflected by one of the at least one mirror surface 1120 of the gonioscopic lens 1110 and propagate further to the camera 120 and impinge onto the image sensor 121 of the camera 120. As

shown in FIGs. 2A-D, 4A and 6A-B, the peripheral observation beams 114P are reflected by tissue in the anterior chamber angle 40 of the eye, particularly from the trabecular meshwork 45. Similarly to the peripheral illumination beams 112P, the peripheral observation beams 114P traverse the cornea 20 and the contact member 1110 typically in a direction that defines an angle with pupillary axis 36 of more than 30°, more than 45° or more than 60°. Typically, said angle is greater than the inclination angle of the at least one mirror surface 1120 of the gonioscopic lens.

As further shown in FIG. 1, the ophthalmic system 100 may include an optical system 130 that is configured to direct and/or focus the aforementioned illumination beams 112 and observation beams 114 such that they follow their respective beam paths and are focused as described further below. If the system 10 further comprises a laser system 140, as in the present examples shown in the Figures, the optical system 130 may be further configured to also direct and/or focus one or more laser beams 145 of the laser system 140 as described further below. The optical system 130 may include an objective lens 133 and further optical elements 131, each of which may be fixed in their respective positions and orientations or be movable and/or rotatable for adjusting a focus of the optical system 130 and/or to change a direction the respective beam paths. Preferably, the objective lens 133 is a telecentric lens. For instance, the optical system 130 includes a focusing assembly 132 configured to adjust a focus of the optical system 130, for instance, by shifting an object plane that is conjugate to an image plane defined by the image sensor 121 of the camera 120, as described below. For instance, the aforementioned objective lens 133 and optical elements 131 of the optical system 130 may be integrated into the focusing assembly 132.

The laser system 140 comprises one or more laser sources 141 to generate one or more laser beams 145 (shown in FIGs. 2A-D), such as at least one treatment laser source configured to generate at least one treatment laser beam and at least one aiming laser source configured to generate at least one aiming laser beam. The aiming laser beam may be coaxially aligned with the treatment laser beam and have a power sufficiently low so as to avoid any irreversible effects on, or even damages of, the eye tissue irradiated therewith.

The light beams depicted in FIGs 4A-C and 6A-B may represent illumination beams 112 or observation beams 114, as these beams may share the same or similar beam paths at least within the eye 10 and within the gonioscopic lens 1100. For instance, observation beams 114 emanating from one object point 60 in the eye 10 may be focused and/or directed by the optical system 130 of the ophthalmic system 100 such that they converge in one image point 127 on the image sensor 121 of the camera 120, see FIGs. 5A-B, in order to image that object point 60 onto the image sensor 121. The image points 127 form the image 125 generated by the camera 120 (e.g., see FIGs. 6A-B, 7A-B).

Moreover, in order to illuminate a defined region within the eye 10, the illumination beams 112 may be focused by the optical system 130 of the ophthalmic system 100 so that they converge on that defined region within the eye 10. For example, the illuminated region may comprise the object points 60 of the eye 10 that are at the same focused onto the image sensor 121 of the camera 120 (i.e., the object points 60 are in or adjacent to the aforementioned object plane). As shown in the examples depicted in FIGs. 4A-C and 6A-B, the central illumination beams 112C may share the same or similar beam paths within the eye 10 and within the gonioscopic lens 1110 as the central observation beams 114C, and the peripheral illumination beams 112P may share the same or similar beam paths within the eye 10 and within the gonioscopic lens 1110 as the peripheral observation beams 114P. Further details regarding the beams paths of the illumination beams 112 and observation beams 114, and examples of separating these beams within the ophthalmic system 100, are provided below with reference to Figures 2A-D.

As mentioned above, FIGs. 2A-D and 28 show exemplary variants or embodiments of the exemplary ophthalmic system 100 shown in FIG. 1. In order to facilitate comparison between the embodiments 200, 300, 400, 500, 600 shown in FIGs. 2A-D, 28 respectively, their elements are denoted with the same reference numerals as the corresponding elements of the exemplary ophthalmic system 100, or with reference numerals that are increased, relative to the corresponding elements shown in FIG. 1, by 100, 200, 300, 400 or 500, respectively. Unless specified otherwise, ophthalmic systems 100, 200, 300, 400, 500, 600 and their corresponding elements, may be similar or even identical in structure and configuration. In particular, unless specified otherwise, the description of the various elements of the exemplary ophthalmic

mic system 100 may apply equally to the corresponding elements of the embodiments 200, 300, 400, 500, 600 and vice versa. The embodiments 100, 200, 300, 400, 500, 600 may thus have similar or even identical illumination devices 110, 210, 310, 410, 510, cameras 120, 220, 320, 420, 520, laser systems 140, 240, 340, 440, 540, optical systems 130, 230, 330, 430, 530, electronic processing devices 150, display devices 160 etc.. The components of the embodiments 200, 300, 400, 500, 600 may thus have the same functions and configurations as described with reference to the exemplary ophthalmic system 100. Particular differences between the optical systems 230, 330, 430, 530 of the ophthalmic system 200, 300, 400, 500, particularly between focusing assemblies 232, 332, 432, 532 and the beam paths of the respective illumination beams 212, 312, 412, 512, observation beams 114, 214, 314, 414, 514, and laser beams 145, 245, 345, 445, 545, are described below with reference to FIGs. 2A-D.

In the ophthalmic systems 200, 300, 400, 500 shown in FIGs. 2A-D, the respective optical system 230, 330, 430, 530 includes a focusing assembly 232, 332, 432, 532 to focus the illumination beams 212, 312, 412, 512, observation beams 114, 214, 314, 414, 514, and/or laser beams 145, 245, 345, 445, 545.

In the ophthalmic systems 100, 200, 300, 500 shown in FIG. 2A, 2B, and 2D, the respective focusing assembly 232, 332, 532 includes an objective lens 233, 333, 533. The beam paths of illumination beams 212, 312, 512, observation beams 114, 214, 314, 514, and laser beams 145, 245, 445, 545 run through the objective lens 233, 333, 533.

The focusing assemblies 232, 332, 432, 532 may comprise further optical elements, for instance, lenses and/or apertures that may for part of the respective illumination device 110, 210, 310, 410, 510, camera 120, 220, 320, 420, 520, and/or laser system 140, 240, 340, 440, 540. For instance, in each of the examples shown in FIGs. 2A-D, the illumination device 110, 210, 310, 410, 510 includes a first converging lens 215, 315, 415, 515, a second converging lens 216, 316, 416, 516, and an aperture 217, 317, 417, 517 between the first converging lens 215, 315, 415, 515 and the second converging lens 216, 316, 416, 516. The aperture 217, 317, 417, 517 may be fixed or may be configured as an oscillating slit shutter. In one example, the first converging lens 215,

315, 415, 515 is configured to collimate the illumination beams 212, 312, 412, 512 emitted from the light source 111, 211, 311, 411, 511. The second converging lens 216, 316, 416, 516 may be configured to focus the illumination beams 212, 312, 412, 512 exiting the aperture 217, 317, 417, 517. In the examples shown FIG. 2A, 2B, and 2D, focusing of the collimated illumination beams 212, 312, 512 is performed using both the second converging lens 216, 316, 416, 516 and the objective lens 233, 333, 533. In the example shown FIG. 2C, which is configured as Greenough type microscope, focusing of the collimated illumination beams 412 is performed using the second converging lens 416 without any objective lens. In each of these examples, however, the illumination beams 212, 312, 412, 512 may be focused into one or more regions of the eye 10, as described herein. By virtue of the oscillations of the oscillating slit 217, 317, 417, 517, the illumination beam 212, 312, 412, 512 may be scanned over different regions of the eye 10. Additionally or alternatively, scanning of the illumination beams 212, 312, 412, 512 may be also achieved by other known means, for instance, by means of one or more rotatable scanning mirrors. For instance, the optical systems 230, 530 of the ophthalmic systems 300 and 500 shown in FIGs. 2B and 2D include an illumination beam steering device 336, 536 separate from the (fixed) aperture 317, 517, such as a scanning mirror, e.g. a 2D-rotatable scanning mirror. Examples of oscillating slits and beam steering devices are described in US 2010/007849 A1, the entire content of which being incorporated herein by reference.

The focusing assembly 232, 332, 432, 532 may further comprise a lens forming part of the camera 120, 220, 320, 420, 520. For instance, in the examples shown in FIGs. 2A-D, the camera 120, 220, 320, 420, 520 may include a converging lens 222, 322, 422, 522 that is configured to focus the observation beams 114, 214, 314, 414, 514 emanating from the eye 10 onto the image sensor 121, 221, 321, 421, 521. In the examples shown FIG. 2A, 2B, and 2D, focusing of the observation beams 214, 314, 514 is achieved using both the converging lens 222, 322, 522 of the camera 222, 322, 522 and the objective lens 233, 333, 533. In the example shown FIG. 2C, focusing of the observation beam 412 is performed using the lens 422 without any objective lens. The camera 120, 220, 320, 420, 520 may be configured to be operable with an electronic rolling shutter that is synchronized with the scanning of the

illumination beams 112. Alternatively, the camera 120, 220, 320, 420, 520 may include an oscillating aperture, such as an oscillating slit, that is located between the converging lens 222, 322, 422, 522 and the image sensor 121, 221, 321, 421, 521 and configured to move synchronously with the scanning motions of the illumination beams, for instance, synchronously with the oscillating slit 217, 317, 417, 517 or scanning mirror, as described for instance in US 2010/007849 A1. As shown in FIG. 2C, the focusing assemblies 432 may also comprise a converging lens 446 of the laser system 440 to focus the laser beam 540 onto a target region of the eye 10.

The focusing assembly 132, 232, 332, 532 assembly may include one or more actuators (not shown) operable to move the objective lens 233, 333, 533, the lens 222, 322, 422, 522 of the camera 222, 322, 422, 522, and/or the lens 446 of the laser system 440 in order to focus the illumination beams 212, 312, 512, the observation beams 214, 314, 514, and/or the laser beams 245, 345, 545.

Each of the exemplary focusing assemblies 132, 232, 332, 532 may be configured to focus the observation beams 114 emanating from the eye 10 onto the image sensor 121, 221, 321, 421, 521 of the camera 120, 220, 320, 420, 520. For instance, the focusing assembly 132, 232, 332, 532 may configured to change between two different focus modes in which the object plane of the camera is shifted between two different positions, such as a first proximal position which may be adjacent to the anterior chamber angle of the eye 10, for instance at the TM 45, as shown in FIGs. 4A and 4B, and a second distal position which may be adjacent to the fundus 50 of the eye 10, such as at the (central) retina 55, as shown in FIG. 4C. The central observations beams 114C may thus be focused using a first focus mode and the peripheral observation beams 114P may be focused using a second focus mode different from the first focus mode. For example, any one of the objective lens 233, 333, 533, the lens 222, 322, 422, 522 of the camera 222, 322, 422, 522, and/or the lens 446 of the laser system 440 may be adjustable, such as translatable by means of an actuator or configured as liquid lens elements in order to focus the illumination beams 212, 312, 512, the observation beams 214, 314, 514, and/or the laser beams 245, 345, 545, and/or to change the focus mode, e.g., switch between the first and second focus modes.

For instance, the electronic focus control module 137, which may be integrated into the processor 151 or be a separate electronic processing device, may be configured to switch the focusing assembly 132, 232, 332, 532 between the first focus mode and the second focus mode at a focus switching rate r_F .

The focus switching rate r_F may be equal to, or smaller or greater than, a frame rate r_f of the camera 120. For instance, the switching rate r_F may be set to satisfy $r_F = r_f / N_F$ or $r_F = r_f * N_F$ with N_F being a positive integer (such as $N_F = 1, 2, 3, \dots$). For instance, the focus control module 137 may be configured to generate control signals in accordance with the focus switching rate to control one or more of the actuators of the focusing assembly 132, 232, 332, 532, such as electric motors, to move or otherwise adjust one or more lens elements of the focusing assembly 132, 232, 332, 532 in accordance with the first or second focus mode, respectively.

Additionally or alternatively, as shown in FIGs. 6A-B, and described in more detail below, the gonioscopic lens 1100 may be part of a gonioscopic lens assembly 2100, 2200 which additionally includes one or more lens elements 1130 configured to selectively converge or diverge the central observation beams 114C and central illumination beams 112C while not affecting the peripheral observation beams 114P.

The optical system 230 of the ophthalmic system 200 shown in FIG. 2A includes a beam splitter 234 to reflect the illumination beams 212 emitted from the illumination device 210 towards the objective lens 233 and to transmit the observation beams 214 coming from the objective lens 233 towards the camera 220. Between the beam splitter 234 and the patient's eye 10, the beam paths of the illumination beams 212 and observation beams 214 are coaxial.

The optical systems 230, 330 of the ophthalmic systems 200, 300 shown in FIGs. 2A and 2B each include a dichroic mirror 235, 335 configured to transmit the illumination beams 212, 312 emitted from the illumination device 210, 310 towards the objective lens 233, 333, and to reflect the laser beam 245, 345 emitted from the laser system 240, 340 towards the objective lens 233, 333. In the ophthalmic system 200 shown in FIG. 2A, the beam paths of the

illumination beams 212 and observation beams 214 are coaxial between the dichroic mirror 235 and the patient's eye 10. In the ophthalmic systems 300 and 500 shown in FIGs. 2B and 2D, the beam paths of the illumination beams 312, 512 and observation beams 314, 513 are shifted laterally relatively to each other.

In the ophthalmic systems 100, 200, 300, 500 shown in FIGs. 1, 2A, 2B, 2C, and 2D, the respective laser system 140, 240, 340, 540 includes a laser beam steering device 148, 248, 348, 448, 548 to steer the at least one laser beam 145, 245, 345, 445, 545, and a laser control module 142 (see FIG. 1) configured to control the at least one laser source 141, 241, 341, 441, 541 and the laser steering device 148, 248, 348, 448, 548. For instance, the laser beam steering device 148, 248, 348, 448, 548 may include one or two tiltable mirrors configured to steer the laser beam 245, 345, 445, 545. The laser control module 142 may be implemented, for instance, by the processor 150 or by a separate electronic processing device.

In the ophthalmic systems 400 and 500 shown in FIGs. 2C and 2D include a mirror 447, 547 configured to direct laser beams 445, 545 emitted from the laser system 440, 540 towards the eye 10. In the example shown in FIG. 2D, the mirror 547 is fixed, whereas in the example shown in FIG. 2C, the mirror 447 is a single 2D-rotatable mirror and forms part of the laser beam steering device 448 of the laser system 440 to steer the laser beam 455.

In the ophthalmic systems 100, 200, 300, 400, 500, 600, the laser systems 140, 240, 340, 440, 550 may further include a laser beam shaping device 149, 249, 349, 449, 549 configured to adjust a shape, beam profile and/or diameter of the laser beam 145, 245, 345, 445, 555 emitted from the laser source 141, 241, 341, 441, 541, including optical elements, such as lenses and/or apertures.

Each of FIGs. 3A-B, 5A-B, 7A-B can be interpreted as showing the field of view 126 as seen by the camera 120, 220, 320, 420, 520. Alternatively, each of FIGs. 3A-B, 5A-B, 7A-B may also be interpreted as depicting the image sensor 121, 221, 321, 421, 521 of the camera 120, 220, 320, 420, 520 with the observations beams 114 being focused onto its surface or, as yet another interpreta-

tion, as showing an image 125 generated by the camera 120, 220, 320, 420, 520 or the displayed image 162 as displayed by the system's display device 161 described further below. For the sake of consistency, FIGs. 3A-B are interpreted below as showing the field of view 126 seen by the camera, FIG. 5A is interpreted as showing the image sensor 121, 221, 321, 421, 521 of the camera 120, 220, 320, 420, 520 with the observations beams 114 being focused onto its surface. FIG. 5B is interpreted as showing the image 125 generated by the sensor 121, 221, 321, 421, 521 with the observations beams 114 being focused onto its surface as shown in FIG. 5A. FIGs. 7A-B are interpreted as showing images 125 generated by the sensor 121, 221, 321, 421, 521 with the observations beams 114 shown in FIGs. 6A-B being focused onto its surface.

FIGs. 3A-B show the field of view 126 of the camera 120, 220, 320, 420, 520 which is defined by the image sensor 121, 221, 321, 421, 521 and the optical system 130, 230, 330, 430, 530. In the example shown FIG. 3A, the gonioscopic lens 1110 includes 4 mirror surfaces 1120, 1121, 1122, 1123. In the example shown FIG. 3B, the gonioscopic lens 1110 includes 6 mirror surfaces 1120, 1121, 1123, 1124, 1125. The gonioscopic lens 1100 generally has a proximal opening or window 1140 defining a cross-sectional area through which the eye 10 is observed and through which all of the aforementioned illumination beams 112, 112C, 112P and observation beams traverse 114, 114C, 114P. In the examples shown, the field of view 126 of the camera is sufficiently large to contain the entire cross-sectional area of the proximal opening or window 1140 of the gonioscopic lens 1110 so that the camera 120, 220, 320, 420, 520 can see at the same time the contact member 1110 and each mirror surface 1120, 1121, 1123, 1124, 1125, 1126 of the gonioscopic lens 1110. In other words, all of the aforementioned central observation beams 114C and all of the peripheral observation beams 114P reflected from any one of the at least one mirror surface 1120, 1121, 1123, 1124, 1125, 1126 of the gonioscopic lens 1110 simultaneously reach the image sensor 121, 221, 321, 421, 521. In alternative examples, the size of the field of view 126 of the camera may be such that it can contain only a part of said cross-sectional area.

Within the field of view 126, the contact member 1110 defines a central gonio field (of view) 1150 and each of the mirror surfaces 1120, 1121, 1123, 1124, 1125, 1126 defines a respective peripheral gonio field (of view) 1160. In other

words, within the central gonio field 126, the camera 120, 220, 320, 420, 520 can image portions of the eye 10 as seen straightly through the contact member 1110, e.g. the iris 30 and/or a portion of the retina 55. Within one or more peripheral gonio fields 1160, the camera 120, 220, 320, 420, 520 can
5 image portions of the eye as seen obliquely through the contact member 1110 via the respective one or more mirror surfaces 1120, 1121, 1123, 1124, 1125, 1126, e.g., a respective portion of the chamber angle 40 such as the trabecular meshwork 45 and a respective peripheral portion of the iris 30.

As shown in FIGs. 5A-B, the central observation beams 114C reaching the
10 image sensor may be focused onto a subarea 123 of the image sensor 121 and a corresponding subarea 128 of the image acquired by the camera 120 may thus contain the image formed by the central observation beams 114C. The subarea 128 of the image 125 therefore corresponds to the contact member 1110 of the gonioscopic lens 1100 so that the shape of the subarea 128
15 corresponds to the shape of the contact member 1110. In the following, the subarea 128 of the image 125 is also referred to as the central gonio field sub-image 128. The peripheral observation beams 114P reaching the image sensor 121 can be focused onto one more subregions 124 (each corresponding to one of the at least one mirror surface) of the image sensor 121 that is distinct
20 from and non-overlapping with the aforementioned subarea 123 of the image sensor. A corresponding subregion 129 of the image 125 contains the image formed by those peripheral observation beams 114P. The subregion of the image 129 is also referred to as peripheral gonio field sub-image or chamber angle sub-image.

As illustrated in FIGs. 4A-C, 6A-B, 7A-B, the central observation beams 114C may be focused onto a subarea 124 of the image sensor 121 to form, within that subarea 124, a focused image of that region of the eye which is illuminated by the central illumination beams 112C and from which the central observation beams emerge 114C, e.g., from a portion of the iris as shown in
25 FIGs. 4B and 6A, or from a portion of the fundus 50 of the eye 10 as shown in FIGs. 4C and 6B. Correspondingly, depending on the (first or second) focus mode or configuration of the optical system, the subarea 128 of the image may, for instance, include a focused image of the iris 30, as shown in FIG. 7A, or a focused image of the retina 55, as shown in FIG. 7B.
30

For example, the images 125 shown in FIGs. 5B may be a compound image 125C formed by the image processing module 151 by combining frames acquired during two, three or more different focus modes, e.g. the focus modes described with reference to FIGs 4A-C. As shown, the subarea 128 of the compound image 125C may thus include both a focused image of the iris 30 and a focused image of the retina 55, as illustrated, for instance, in FIG. 5B. As illustrated in FIGs. 4A-C, 6A-B, 7A-B, the peripheral observation beams 114P are focused onto a subregion 124 of the image sensor 121, which is different from the subarea 123, so as to form, within the subregion 124, a focused image of that region of the eye which is illuminated by the peripheral illumination beams 112P and from which the peripheral observation beams 114P emerge, e.g., as shown, from a portion of the chamber angle 40, such as from a portion of the trabecular meshwork 45, from a peripheral portion of the iris 30. The subregion 129 of the compound image 125c shown in FIG. 5B may therefore include a focused image of the TM 45.

It is thus possible to form a compound (live) image 125C by combining images or frames acquired during different focus modes or focus configurations, so that the subarea 128 of the compound image 125C may include a focused image of the iris 30 and/or a focused image of the retina 55, whereas the one or more subregions may include a focused image of the trabecular meshwork 45, as illustrated, for instance, in FIGs. 5B, 7A-B.

The illumination device 110 may be configured to spatially and/or temporally modulate the illumination beams 112. The illumination device 110 may, for instance, include an electronic illumination control module 115 which may be partly or completely be integrated into the processor 151 or a separate electronic processing device. The illumination control module 115 may be configured to control the light sources 111 so as to temporally and/or spatially modulate the illumination beams 112.

An example of a temporal modulation is a periodical modulation of the illumination beams 112 with a modulation rate r_m . During one modulation cycle, the illumination device 110 may be configured to switch between two or more illumination modes. The illumination modes may differ, for instance, in their respective illumination intensities and/or in the spatial intensity profile of the illumination beams 112. The illumination control module may be

configured to provide the processor 150, the image processing module 151 and/or the camera 120 with information about the current illumination mode. The image frames may be labelled, e.g., by the image processing module 151, with a label indicating the illumination mode(s) under which the respective frame has been taken by the camera 120. The camera 120 may be configured to have a sufficiently large dynamic range to function properly with the various illumination modes and intensity profiles. For that purpose, the camera may be an HDR camera (the image sensor being an HDR image sensor), and the acquired images may be HDR images. The display device 161 may be configured accordingly to display the acquired HDR images.

In an example of spatial modulation of the illumination beams 112, an intensity of the peripheral illumination beams 112P is different (e.g., higher or lower) than an intensity of the central illumination beams 112C. For example, when the intensity of the peripheral illumination 112P beams is higher than the intensity of the central illumination beams 112C, dazzling of the patient may be reduced or avoided while still illuminating the anterior chamber angle 40 with sufficient brightness.

In one example, the illumination device 110 is configured to periodically modulate the illumination beams at the aforementioned modulation rate r_m . The modulation rate r_m may be, for instance, smaller, equal or larger than a frame rate r_f of the camera. For instance, the modulation rate r_m may satisfy $r_m = r_f * N_i$ or $r_m = r_f / N_i$ with N_i being a positive integer (e.g. $N_i = 1, 2, 3, \dots$) and with r_f being the frame rate of the camera 120. The frame acquisition may be synchronized with the temporal modulation of the illumination beams 112. For instance, the starts of the modulation cycles may be synchronized with the starts of the frame acquisition cycles. For example, for a periodical temporal modulation with $r_m = r_f$ ($N_i = 1$), each frame may be acquired during one entire modulation cycle. In a further example, for a periodical temporal modulation with $r_m = r_f$ ($N_i = 1$) with a synchronous spatial modulation (which may be as described above), each frame may be acquired during illumination of the eye firstly with peripheral illumination beams at high intensity and then secondly with central illumination beams at low intensity.

In a further example, the illumination device 110 is configured to periodically modulate the illumination beams 112 at a modulation rate r_m that is smaller than the frame rate r_f of the camera, wherein the modulation rate r_m satisfies $r_m = r_f / N_I$ with $N_I > 1$ being a positive integer. For example, with $N_I = 2$, two consecutive frames may be acquired under two different stages of one modulation cycle. For example, without additional spatial modulation (same intensity for all illumination beams 112P and 112C) and only temporal modulation of intensity between high intensity and low intensity, the frames may be acquired alternately at high intensity and low intensity. The first (low) intensity (in the first half of the modulation cycle) may be optimized for illumination of tissue at the iris 30 or the fundus 50 with central illumination beams 112C (e.g., for achieving suitable exposure of the subarea 123 of the image sensor 121 corresponding to the subarea 128 of the image or frame 125). The second (high) illumination intensity may be optimized for illuminating tissue in the anterior chamber angle 40 with the peripheral illumination beams 112P (e.g., for achieving suitable exposure of the subregion 124 of the image sensor 121 corresponding to the subregion 129 of the image). In a further example, with $N_I = 4$ and two intensity levels (same for all illumination beams 112C and 112P), during one modulation cycle, two consecutive frames 125 may be acquired at low illumination intensity and two consecutive frames may be acquired at high illumination intensity.

As described above, the image processing module 151 may be configured to select two or more frames 125 of the live image and combine the two or more frames 125 to form a compound image 125C. For example, the image 125 shown FIGs. 5A-B and 7A-B may be compound images. The frames of the compound image 125 may, for instance, be acquired as described above during different focus modes and/or during different illumination modes, e.g. under a first (high intensity) illumination mode and a second (low intensity) illumination mode. For instance, the selected and combined frames may be acquired during the same modulation cycle. The selection may be based, for instance, on image data of each frame (such as brightness values of one or more pixels) or on the frame label described above, and/or on control signals received from the illumination device 110, e.g. from the illumination control module 115. The labels of the frames may include information indicating, for

instance, the respective illumination mode and/or a modulation cycle number.

For instance, the image processing module 151 may be configured to extract from each selected frame acquired during the first (e.g., high intensity) illumination mode a first frame portion including one or more of the at least one subregion 129 of the respective frame but not including the subarea 128 of the respective frame and to extract from each frame acquired during the second (e.g., low intensity) illumination mode a second frame portion including the subarea 128 of the frame but not including the at least one subregion 129 of the frame. The compound image 125C may therefore include the extracted subregion(s) 129 and the extracted subarea 128, each of which have been acquired by the camera 120 under optimized illumination. The compound image 125 may be shown on the display device 161 to a user.

As shown in FIG. 1, the exemplary ophthalmic system 100 includes an electronic processing device or processor 100 including an image processing module 151 and an electronic user interface 160 including a display device 161, such as a touchscreen for also receiving user input via the touchscreen, and optionally further user input devices 165, such as a keyboard, a joystick, a trackpad, a computer mouse and/or similar user input devices. Although not shown in FIGs. 2A-D, also the embodiments 200, 300, 400, 500, 600 may include a processor device and a user interfaces having the same or a similar configuration as the processing device 100 and the user interface 160 of the embodiment 100. The image processing module 151 may be configured to receive and process the images or frames 125 acquired by the camera 120.

The image processing module 151 may be configured to identify at least one characteristic feature of the eye 70 within one or more (or each) of the at least one subregion 129 of the image 125. The at least one characteristic feature 70 of the eye 10 may be a characteristic feature of the anterior chamber angle 40 of the eye 10, such as a Schwalbe's line, the trabecular meshwork 45, a scleral spur, a ciliary body, and/or the iris 30 of the eye 10. For instance, the image processing module 151 may be configured to detect one or more of these characteristic features 70 by means of a respective pattern recognition algorithm. In some examples, the image processing module 125 is configured

to detect and/or identify the at least one characteristic feature 70 by comparing the at least one subregion 129 of the image 125 with one or more reference images of the same eye 10 which may have been acquired previously and/or be stored, for instance, in memory 170 of the ophthalmic system 100.

The image processing module 151 may be configured to restrict the search for the at least one characteristic feature 70 to the at least one subregion 129 of the image 125. For instance, the image processing module 151 may be configured to first perform a search for the at least one subregion 129 by means of a first search algorithm, and afterwards perform the search for the at least one characteristic feature 70 only within the detected at least one subregion 129 by means of a second search algorithm different from the first search algorithm. The image processing module 151 may be configured to detect the at least one subregion 129 after having segmented the image 125. For instance, the image processing module 151 may be configured to search for the at least one subregion 129 by performing an edge-detection algorithm, as the borders of the one or more mirror surfaces 1120 of the gonioscopic lens 1100 may show up in the image 125 as edges defining the respective subregions 129 within the image 125.

The image processing module 151 may be configured to detect or identify at least one further characteristic feature of the eye within the subarea 128 of the image 125. For instance, the image processing 151 module may be configured to first search for the subarea 128 in the image 125, e.g., using an edge detection algorithm, and, once the subarea 128 is detected, search only within the detected subarea 128 for the at least one further characteristic feature of the eye 10, e.g. using a pattern recognition algorithm and/or by comparing the subarea 128 of the image 125 with one or more of the aforementioned reference images of the eye 10. The at least one further characteristic feature of the eye 10 may comprise, for instance, a characteristic feature of the iris 30 and/or a characteristic feature of the fundus 50 of the eye 10.

The display device 161 may be controlled, for instance, by the aforementioned processor 150 of the system, particularly by the image processing

module 151. The display device 161 is configured to display, as displayed image 162, the (video) image 125 acquired by the camera 120, or at least parts of the image 125, to a user, such as one or more of the at least one subregion 129 or at least a portion of any of these subregions 129. As shown, for instance, in FIGs. 3A-B, 5A-B, 7A-B, 12, 14, 15, 17A-B, 19A-B, the display device 161 may be configured to display simultaneously one or more or each one of the (detected) two or more subregions 126 to a user, such as the aforementioned first and second subregions. The display device 161 may be configured to show any of these subregions completely or only partially, i.e., only a portion of the respective subregion, such as the reduced subregion(s) described further below. As shown, for instance, in FIGs. 3A-B, 5A-B, 7A-B, 12, 14, 15, the display device 161 may be configured to also display the subarea 128 of the image 125, for instance, simultaneously with displaying the one or more of the at least one subregion 129. As the image is typically a video image, the display device may be configured to display the subregion(s) 129, i.e. the peripheral gonio field sub-image(s), and/or the subarea, i.e. the central gonio field sub-image 128, as video sub-images, i.e., showing streams of the respective subregion(s) 128 and/or of the subarea 129 of the video image. Furthermore, the image processing device 151 may be configured to instruct the device to display the aforementioned compound image 125C as a video image, and/or any extracted portion of any previously acquired frame, or any reference image, as a standstill image.

The image processing module 151 may be configured to define an eye coordinate system based on the at least one further characteristic feature 71 of the eye identified within the subarea 128 of the image 125, e.g., based on a characteristic feature of the iris 30 or of the (central) retina 55. Additionally or alternatively, the image processing module 151 may be configured to define an (additional or alternative) eye coordinate system based on the aforementioned characteristic feature 70 identified within the at least one subregion 129 of the image 125, e.g., based on a characteristic feature 71 within the interior chamber angle 40, such as a peripheral portion of iris 30. The eye coordinate system may be a two dimensional or a three dimensional coordinate system. The eye coordinate system may be, for instance, a (2D or 3D) Cartesian coordinate system, a (2D) polar coordinate system, or a (3D) spherical coordinate system. The eye coordinate system may be defined such

that the pupillary axis of the eye runs through the origin of the eye coordinate system. The image processing module 151 may be configured to use the eye coordinate system to define or determine positions of image points or image regions of the image of the camera e.g., using one or more coordinates of the eye coordinate system.

Additionally or alternatively, the image processing module 151 may be configured to use a camera coordinate system to define or determine positions of image points 127 or image regions of the image 125 of the camera 120. For instance, the position of any image point of pixel 127 of the image 125 may be defined relative to the eye coordinate system and/or relative to the camera coordinate system. In particular, the position of each (object) point of the eye 10 that is contained in the image 125 of the camera 120 may be defined by coordinates of the eye coordinated system and/or by coordinates of the camera coordinate system. In some examples, an azimuthal orientation of any (object) point of the eye 10 may be defined or determined relative the eye coordinate system, for instance, by an (eye) azimuth coordinate ϕ_{eye} , and/or relative to the camera coordinate system, e.g., by an (camera) azimuth coordinate ϕ_{camera} . Furthermore, as described in more detail below, an azimuthal orientation Φ of any of the one or more subregions 129 of the image 125, and of the respective gonio field of view and of the respective sector of the chamber angle 40, may be defined or determined relative the eye coordinate system, for instance, by a corresponding (eye) azimuth coordinate Φ_{eye} , and/or relative to the camera coordinate system, e.g., by a corresponding (camera) azimuth coordinate Φ_{camera} .

The image processing module 151 may configured to define the aforementioned camera coordinate system. For instance, the camera coordinate system may be defined as a Cartesian coordinate system or as a polar coordinate system. Typically, the camera coordinate system is a two dimensional coordinate system. The origin of the camera coordinate system may be defined, for instance, such that a central optical axis of the camera 125 and/or of the objective lens 233, 333, 533 of the ophthalmic system runs through the origin of the camera coordinate system. The position of each point on the surface of the image sensor 121 of the camera 125, and correspondingly the position of each image point 127 (i.e., each pixel) in any image (or frame) 125 acquired with the camera 120, can be uniquely defined by its coordinates

relative to the camera coordinate system. Accordingly, each object point 60, which has a corresponding image point 127 in the image acquired by the camera 125, may be also assigned a unique set of coordinates in the camera coordinate system, namely the coordinates of its image point.

5 The image processing module 151 may be configured to determine a location and/or an orientation of the eye coordinate system relative to the camera coordinate system. In some examples, this may be achieved by determining, within the camera coordinate system, the location and/or orientation of the respective characteristic feature(s) used to define the eye coordinate system.

10 The image processing module 151 may be configured to perform coordinate transformations between the eye coordinate system and the camera coordinate system. In particular, the image processing module 151 may be configured to transform the eye azimuth coordinate ϕ_{eye} or Φ_{eye} (of any point 127 or subregion 129 of the image 125) into the corresponding camera azimuth

15 coordinate ϕ_{camera} or Φ_{camera} , and vice versa.

The ophthalmic system 100 may further include an electronic eye tracking module 152, which may be implemented in any combination of hardware (circuitry), software, and/or firmware and may be part of the system's processor 150. The eye tracking module 152 may be configured to track

20 translational and/or rotational motions of the eye 10. For instance, the eye tracking module 152 can be configured to use the image 125 acquired by the camera 120 to track the motions of the eye 10 within the respective images 125. For instance, the eye tracking module 152 may be configured to track the translational and/or rotational motions of the eye 10 using the identified at

25 least one characteristic feature 70 of the eye 10 within the at least one subregion 129 of the image 125. Additionally or alternatively, the eye tracking module 152 may be configured to track the translational and/or rotational motions of the eye 10 using the identified at least one further characteristic feature 71 of the eye 10 within the subarea 128 of the image 125. For

30 instance, the eye tracking module 152 may be configured to determine positions of one or more of the aforementioned (further) characteristic features 71, such as the iris or the (central) retina, relative to the camera coordinate system in order to track their translational and/or rotational motions of the eye 10 relative to the camera 120. For example, the eye

35 tracking module 152 may be configured to provide the laser system 140 of the

ophthalmic system 100, for instance the laser control module 142 of the laser system 140, or directly the laser beam steering device 148 of the laser system 140, with eye tracking data for laser beam positioning correction to compensate motions of the eye. For instance, the laser control module 142 is configured to control the laser steering device 148 using information on the tracked motions of the eye received from the eye tracking module 152.

In some examples, the image processing module 151 may be configured to determine an azimuthal orientation of one, of more than one or of each of the at least one subregion 129 of the image 125. For instance, the image processing module 151 may be configured to determine for each (detected) subregion 129 a respective azimuthal orientation Φ^i . The azimuthal orientation Φ may, for instance, be determined relative to the camera coordinate system or relative to the eye coordinate system, i.e., as the aforementioned coordinate Φ_{camera} or Φ_{eye} . As mentioned above, the image processing module 151 may be configured to transform Φ_{eye} into Φ_{camera} , and vice versa.

The image processing module 151 may be configured to control the display device 161 to display, for one or more or for each of the at least one subregion 129, the respective subregion 129 of the image 125 on the display device 161 with an azimuthal orientation Φ_{display} relative to a display coordinate system 182 in accordance with the determined azimuthal orientation of the respective subregion 129 of the image 125, e.g., in accordance with the determined azimuthal orientation of the respective subregion 129 of the image relative to the camera coordinate system or relative to the eye coordinate system, e.g., setting $\Phi_{\text{display}} = \Phi_{\text{camera}}$ or $\Phi_{\text{display}} = \Phi_{\text{eye}}$. In other words, the subregion 129 may be displayed such that it has the same azimuthal orientation Φ_{display} on the screen as it has relative to the camera or relative to the patient's eye. In this manner, the interpretation of the displayed information by the user and navigation within the anterior chamber angle is facilitated. Displaying the subregion 129 in accordance with the determined azimuthal orientation of the respective subregion 129 relative to the eye coordinate system (e.g., setting $\Phi_{\text{display}} = \Phi_{\text{eye}}$) has the additional advantage that azimuthal rotational of the eye 10 relative to the camera 120 are compensated.

There are various ways of determining the respective azimuthal orientations

Φ of the one or more subregions 129. In a first example, the image processing module 151 may be configured to detect an edge portion 129' (see FIG. 10) defining a boundary of one of the at least one subregion 129 of the image 125 and to determine an orientation of the detected edge portion 129' (or, equivalently, the direction of an vector orthogonal to the edge portion 129') relative to the camera coordinate system or relative to the eye coordinate system. The image processing module 151 may use the orientation of the edge portion 129' to determine the azimuthal orientation Φ of the respective subregion 129, e.g., relative to the camera coordinate system, Φ_{camera} , or (after a coordinate transformation, if needed) relative to the eye coordinate system, Φ_{eye} .

In a second example, the image processing module 162 may be configured to determine, for one or more or for each of the at least one subregion 129, an azimuthal orientation of the at least one characteristic feature 70 identified within the respective subregion (relative to the camera coordinate system or relative to the eye coordinate system). For instance, the image processing module 151 may be configured to use the azimuthal orientation of the at least one characteristic feature 70 to determine the azimuthal orientation of the respective subregion of the image (relative to the camera coordinate system or relative to the eye coordinate system). For instance, characteristic features 70 of the iris 30 or the (peripheral) retina 55 contained within the respective subregion 129 are particularly useful for this purpose, as these tissues typically exhibit clear, rotationally non-symmetric characteristic features. As such features are typically unique for every given eye, the image processing module 151 may be configured to use a reference image of the eye 10 (which may have been acquired previously and/or be stored, for instance, in memory 170 of the ophthalmic system 100) to identify any of the characteristic features in the image acquired with the camera 161.

It is also possible to use one or more characteristic features 70 contained in the respective subregion 129 for this purposes, for instance, the trabecular meshwork 45, the Schwalbe's line or the scleral spur, among others. These characteristic features 70 are typically imaged as curved lines 72 which span the respective subregion 129 of the image 125 (in an azimuthal direction, i.e., connecting opposite lateral edges 129'' of the respective subregion 125, see

FIG. 10). The image processing module 151 may be configured to determine a normal vector v_n oriented orthogonally to the curved line 72, for instance, at a midpoint 73 of the curved line 72 within the respective subregion 151, and to determine the azimuthal orientation ϕ_n of the normal vector v_n relative to the eye coordinate system or relative to the camera coordinate system, i.e., $\phi_{n, \text{eye}}$ or $\phi_{n, \text{camera}}$. The image processing module 151 may be configured to determine the azimuthal orientation Φ of the respective subregion 129 of the image 124 based on the azimuthal orientation of the normal vector, e.g., as being equal to the orientation of the normal vector $\Phi = \phi_n$. The azimuthal orientation of the subregion may again be determined relative to the eye coordinate system or relative to the camera coordinate system, i.e., $\Phi = \phi_{n, \text{eye}}$ or $\Phi = \phi_{n, \text{camera}}$.

In a third example, the image processing module 151 may be configured to detect a marker that is attached to, or integrated into, the gonioscopic lens 1110, such as any one of the examples shown in FIGs. 1-4C, the gonioscopic lens assembly 2100, 2200 shown in FIGs. 6A-B, or a patient interface 3100, 3600 shown in FIGs. 22 to 27. For instance, each of the exemplary patient interfaces 3100, 3200 shown in FIGs. 22 and 23 includes a marker 3181, 3281. In the example shown in FIG. 22, the marker 3181 is further configured to be a machine-readable identifier 3180, as described in more detail below with reference to FIG. 23. The image processing module 151 may be further configured to determine the azimuthal orientation of the at least one subregion 129 based on a position or azimuthal orientation of the marker 3181, 3281 within the image 125 (e.g. relative to the camera coordinate system and/or eye coordinate system). As the position of the marker 3181, 3281 may be fixed relative to the at least one mirror surface 3120, 3220 of the respective patient interface 3100, 3200, the image processing module 151 may determine the azimuthal orientation of the at least one subregion 129 based on the relative position of the marker 3181, 3281.

In some examples, particularly in examples involving laser trabeculoplasty, it can be useful to take into account the local curvature R_{TM} of the curved line 72 within the subregion 129 of the image 125, in order to improve the accuracy of the application of laser pulses onto the trabecular meshwork 45 as the curved line 72 typically indicates the position of the TM 45 within the image

125. The curvature R_{TM} of the curved line 72 typically corresponds to the apparent curvature of the trabecular meshwork 45 as seen by the camera 120 and as displayed on the display device 161. Typically, due to a perspective/projection effect which is illustrated in FIGs. 8 and 9 and explained in greater detail below, the local curvature R_{TM} of the curved line 72 is not constant but varies within each subregion 129. The curvature of the curved line 72 is typically smallest at the midpoint 73 of the curved line 72 within the respective subregion 129 and increases towards the ends of the curved line 72 at the lateral edges 129'' of the subregion 129. The separation of the lateral edges 129'' may be used to define an azimuthal span Φ_{FOV} of the subregion 129. In some examples, it may be useful to restrict the view and/or the application of laser pulses to a central subsection 74 of the curved line 72 within the at least one subregion 129, e.g. to an allowable span Φ_M as shown in FIG. 10. The central subsection 74 may, for instance, be defined such that the apparent local curvature of the curved line 72 is approximately constant within the central subsection 74, e.g., such that a deviation p of the local curvature is below a predefined threshold within the central subsection 74.

The image processing module 151 may be thus configured to determine, for one, more than one or each of the at least one subregions 129, the central subsection 74 of the curved line 72 within the respective subregion 129, the central subsection 74 including the midpoint 73 of the curved line 72 within the respective subregion 129. For instance, the imaging processing module 151 may be configured to determine the central subsection 74 such that, within the central subsection 74, a maximum of the deviation p of the local curvature of the curved line 72 from a local curvature of the curved line at the midpoint 73 of the curved line 72 is less than a predefined value. In one example, the image processing module 151 is configured to determine the central subsection 74 of the curved line 72 within the respective subregion 129 based on at least one of an iris diameter D_{Iris} of the eye, the angle α_{GONIO} defining the inclination of the mirror surface 1120 of the gonioscopic lens 1100 corresponding to the respective subregion 129 of the image 125 relative to the longitudinal axis 1114 of the gonioscopic lens 1110, and/or an magnification parameter M_{GONIO} characterizing the Image magnification of peripheral gonio field of the gonioscopic lens 1110.

Additionally or alternatively, the image processing module 151 may be configured to determine the central subsection 74 of the curved line 72 based on at least one of a pre-defined spot size of the treatment laser beam 145, 245, 345, 445, 545, a predefined number of laser spots to be applied to the trabecular threshold 45, and the iris diameter D_{Iris} . In this manner, a more even and regular application of laser spots onto the trabecular meshwork 45 may be achieved and overlapping of adjacent laser pulses may be avoided.

For instance, the processing device 150 or the imaging processing module 151 may be configured to parametrize the curved line 72 as an elliptic arc, as described in greater detail below with reference to FIGs. 8-10.

The image processing module 151 may further be configured to define a portion of the respective subregion 129 of the image 125 to be displayed by the display device 161 such that the central subsection 74 of the curved line 72 spans over an entire width of the displayed portion of the respective subregion (e.g., in accordance with the limited or maximum allowable span Φ_M explained in more detail below) with reference to FIGs. 8-10. The image processing module 151 may be configured to control the display device 161 to show the respective subregions 129 only partly by showing thereof merely said portion of the at least one subregion 129 of the image 125 including the respective central subsection 74 of the curved line 72, and not showing parts of the subregion 129 that include other parts of the curved line 72. In this manner, the user is shown only a portion of the trabecular meshwork 45 in which the apparent curvature of the trabecular meshwork 45 is relatively constant which facilitates the application of evenly distributed laser spots onto the trabecular meshwork 45. In the following, the aforementioned portion of the subregion will also be referred to as the reduced or allowable subregion or as the reduced peripheral gonio field or as the reduced peripheral gonio field sub-image. Whenever in the following disclosure reference is made to the subregion(s) of the image (or peripheral gonio field, or peripheral gonio field sub-image), it is also possible to alternatively refer to the corresponding reduced subregion(s) (or reduced peripheral gonio field(s) or reduced peripheral gonio field sub-image(s)).

As mentioned above and as described in greater detail below with reference to FIGs. 8-10, the imaging processing module 151 may parametrize the curved

line 72 as an elliptic arc. In this parameterization, the camera coordinates of the curved line 72 representing the trabecular meshwork ($x_{C, TM}$, $y_{C, TM}$) may be a function of the azimuthal angle ϕ measured relative to the azimuthal center of the respective subregion of the image (i.e., $\phi = 0$ representing the azimuthal center within the subregion). See, for instance, equations (2) and (3) below.

5 The aforementioned subsection 74 of the curved line 72 may correspond to the reduced azimuthal span Φ_M which may be smaller than an azimuthal span Φ_{FOV} of the entire subregion 129 (i.e., the azimuthal span Φ_{FOV} defines an azimuthal field of view that is captured within the respective subregion of the image 125). In some examples, the local radius of curvature R_{TM} of the curved line 72 may be calculated using equation (6) below. The limited or maximum allowable span Φ_M may be calculated, for instance using equation (7) or equation (9) below.

15 The observation of the chamber angle 40 using a gonioscopic lens generally results in a deformation of the observed iridocorneal region due to a perspective/projection effect. Assuming the iris 30 (and therefore the iridocorneal angle region) is circular, observing it at an angle (as it is the case when using gonioscopic lenses) results in viewing it as an ellipse. The chamber view geometry is schematically illustrated in FIG. 8. The appearance of the trabecular meshwork 45 in one of the peripheral gonio images, i.e., within the subregions 129 of the image 125 acquired by the camera 120, is thus a curved line 72 which is typically shaped as an arc of an ellipse and thus may be approximated as an ellipse. The eccentricity of the ellipse is a function of the gonio angle α_{GONIO} (i.e., the inclination of the respective mirror surface 1120 of the gonioscopic lens 1100). Its semi-axes are given by:

$$a = R_{IRIS}; \quad b = |R_{IRIS} \cos(2\alpha_{GONIO})|, \quad (2)$$

wherein R_{IRIS} denotes the radius of the iris. The ellipse arc can thus be parametrized as a function of the azimuth angle ϕ referenced to the center of the observed part of the iridocorneal region 40, i.e., referenced to the center of the respective subregion 129 of the image, as follows:

$$x = a \sin \Phi; \quad y = b \cos \Phi. \quad (3)$$

Hence, the camera coordinates ($x_{C, TM}$, $y_{C, TM}$) corresponding to the apparent ellipsoidal arc of the trabecular meshwork TM 45 satisfy equation 3. The

parametrization may also be used to determine the camera coordinates of treatment regions on the trabecular meshwork 45. Making use of equation (1) above, the camera coordinates of the treatment regions or laser spots 80 may be transformed into corresponding coordinates used by the laser beam steering device 149, 249, 349, 449, 549 for steering the laser beams 145, and vice versa:

$$\begin{aligned} (x_{C, TM}, y_{C, TM}) &\rightarrow (x_{L, TM}, y_{L, TM}) ; \\ (x_{L, TM}, y_{L, TM}) &\rightarrow (x_{C, TM}, y_{C, TM}). \end{aligned} \quad (4)$$

As mentioned above, the apparent local radius of curvature R_{TM} of the trabecular meshwork 45, *i.e.*, the local radius of curvature of the curved line 72 representing or marking the trabecular meshwork within the image 125, typically is a function of the azimuth angle ϕ relative to the center of the respective subregion 129 of the image 125. The local radius of curvature has a maximum at a midpoint 73 of the curved line 72 within the respective subregion 129 of the image 125. Within the central subsection 74 of the curved line 72, the radius of curvature is approximately constant and decreases towards the ends of the curved line 72 at the lateral borders or lateral edges 129'' of the subregion 129, which thus define the azimuthal span Φ_{FOV} of the respective subregion 129 (*i.e.*, the azimuthal field of view as seen via of the respective mirror surface). Hence, the larger the azimuthal span Φ_{FOV} of a subregion 129 corresponding to a mirror surface 1120 of the gonioscopic lens 1100, the greater typically the variation in the apparent radius of curvature of the viewed portion of the curved line 72 that represents or marks the trabecular meshwork 45 in the image 125. The iris diameter $D_{IRIS} = 2R_{IRIS}$, the gonio mirror angle α_{GONIO} of a specific mirror surface 1120 of a specific gonioscopic lens 1100, and the magnification M_{GONIO} may be used to calculate an apparent radius of the local curvature R_{TM} of the central subsection 74 of the curved line 72:

$$R_{TM} = f(\alpha_{GONIO}, M_{GONIO}, D_{IRIS}). \quad (5)$$

For $M_{GONIO} = 1$, the apparent radius of curvature R_{TM} of the trabecular meshwork 45 as a function of the azimuth angle ϕ measured from the azimuthal center of the subregion 129 can be calculated (*e.g.*, by the image processing module 151) using the following equation:

$$R_{TM}(\Phi) = -\frac{D_{IRIS}}{2 \cos(2\alpha_{GONIO})} [\cos^2 \Phi + \cos^2(2\alpha_{GONIO}) \sin^2 \Phi]^{3/2} \quad (6)$$

As described above, the total available azimuthal span Φ_{FOV} may be truncated in order to cut off those parts of the curved line 72 in which the curvature of the curved line 72, i.e. the apparent curvature R_{TM} , deviates strongly, e.g. more than a threshold, from the curvature at the midpoint 73 of the curved line 72. For instance, the gonio field of view corresponding to a given subregion 129 may be limited to a region where the local apparent radius of curvature R_{TM} of the trabecular meshwork 45 does not change by more than a fraction p of the apparent radius of curvature R_{TM} at the center of the gonio field of view, i.e., at the midpoint 73 of the curved line 72. The thus defined maximum allowable azimuthal span Φ_M of the field of view for any given mirror surface 1120 of a gonioscopic lens 1110 used for trabeculoplasty may be determined using equation (7):

$$\Phi_M = 2 \cos^{-1} \left[1 - \frac{p}{\sin^2(2\alpha_{GONIO})} \right]^{1/2} \quad (7)$$

Using equation (7), the maximum allowable azimuthal span Φ_M is independent of the iris diameter D_{IRIS} and depends only on a gonio angle α_{GONIO} of the respective mirror surface 1120. For example, for $\alpha_{GONIO} = 62^\circ$ and $p = 5\%$, $\Phi_M \approx 31.3^\circ$, and for $\alpha_{GONIO} = 62^\circ$ and $p = 10\%$, $\Phi_M \approx 44.8^\circ$. Typically, for determining the maximum allowable azimuthal span Φ_M , the threshold p is set to a value above 3%, above 5% or above 8%. Moreover, typically, the value of threshold p is set to below 20%, below 15% or below 10%, for instance between 5% and 15%.

Depending on the mode of operation of the ophthalmic system 100, the display device 161 may, for instance, be configured show the iris 30 or the (central) retina 55, i.e., show the aforementioned subarea 128 of the image 125, and one or more of the subregions 129 of the image 125 (or only a portion of the subregion(s) 129 in accordance with the maximum allowable azimuthal span Φ_M) including section of the chamber angle 40, for instance in a representation concentric with the iris 30 or the (central) retina 55. If

needed, the peripheral gonio field sub-image(s), *i.e.*, the subregion(s), may be rescaled to allow their display on the display device 161.

5 The laser trabeculoplasty treatment may include, for instance, applying laser pulses or shots onto the trabecular meshwork 45 along the entire circumference of the chamber angle (360°), such as in the case of PSLT, MLT and SLT, or along a fraction of the circumference of the chamber angle, for instance half of the circumference (180°), such as in the case of ALT. The laser pulses or shots may, for instance, be applied in the following fashion:

- 10
- 1) uniformly spaced single shots along the pigmented trabecular meshwork;
 - 2) concentric patterns of shots centered on the pigmented trabecular meshwork following the arc of the trabecular meshwork.

15 In some examples, a uniform distribution of the laser spots is intended when applying shots to the trabecular meshwork. If, for instance, N spots are to be distributed uniformly around the circumference of the chamber angle, the distance d along the circumference between successive spots is given by:

$$d = \frac{\pi D_{IRIS}}{N} \quad (8)$$

20 However, due to observation using a gonioscopic lens 1100, the apparent spacing between successive spots typically becomes a function of the azimuth angle ϕ relative to the center of the gonio field of view 129 of the respective mirror surface 1120 of the gonioscopic lens 1100, and decreases with the azimuth angle ϕ in accordance with equation (9) (for $M_{GONIO} = 1$):

25

$$d(\Phi) = \frac{\pi D_{IRIS}}{N} \sqrt{\cos^2 \Phi + \cos^2(2\alpha_{GONIO}) \sin^2 \Phi} \quad (9)$$

For example, in the case of $\alpha_{GONIO} = 62^\circ$, $D_{IRIS} = 12$ mm, $N = 100$ shots and an azimuthal gonio field of view of 120° ($\Phi_{FOV} = 120^\circ$), the adjacent center to center apparent spot spacing changes from $377 \mu\text{m}$ in the center of the peripheral gonio field (which is equal to the real adjacent spot spacing) to 262

30

μm at the ends of the peripheral gonio field (i.e. at the lateral edges 129'' of the respective subregion 129 of the image 125). For a spot size of $400\ \mu\text{m}$ (which is a typical exemplary value SLT treatments), there may already be a real slight overlap between adjacent spots placed on the TM 45 for a patient of average iris size $D_{\text{IRIS}} = 12\ \text{mm}$ and $N = 100$ circumferential spots. In order to minimize the error in spot placement, the gonio peripheral field of view 129 may be limited to the maximal allowable azimuthal span Φ_M for which the center to center distance between adjacent spots does not fall below a predefined fraction of the spot size (limited degree of spot overlap). The maximum allowable azimuthal span Φ_M may be calculated using equation 9, for instance.

The peripheral gonio field of view 129 corresponding to at least one gonio mirror 1120 may thus be limited to the maximal allowable azimuthal span Φ_M for two reasons:

- 1) maintaining a constant apparent radius of curvature of the trabecular meshwork for spot placement and easy chamber angle sub-images display;
- 2) limiting the apparent degree of overlap between adjacent laser spots in the case of uniformly placed spots around the TM circumference due to the viewing geometry.

The laser shots may be applied one (or several in case the gonioscopic lens 1100 includes multiple gonio mirror surfaces 1120) at a time before moving to (a) new chamber angle region(s) around the circumference of the chamber angle by rotating the gonioscopic lens.

The ophthalmic system 100, 200, 300, 400, 500, 600 may further include an electronic documentation module 153 configured to store, for instance in memory 170, any information that may be useful to plan and/or perform a treatment on an eye 10 of a patient. The information may, for instance, specify a laser treatment that has been performed with the laser system 100, or any other system, and/or specify a planned laser treatment to be performed in the future with the laser system 100, or any other system. For instance, the documentation module 153 may be configured to store information on positions of treatment regions 80 of a planned or performed laser

treatment within the eye 10, such as on the trabecular meshwork 45. The positions may be defined in the eye coordinate system and/or in the camera coordinate system. The position information may include two or more coordinates, such as an azimuth angle ϕ and a radial coordinate r . The azimuth angle ϕ may be defined, for instance, relative to an axis of the eye coordinate system or relative to an azimuthal center (defined by Φ) of a subregion 129 of an image 125 containing the respective treatment region 80 during the application of the laser pulse(s) to the treatment region 80. Particularly in the latter case, also the azimuthal orientation Φ of the corresponding subregion 129 of the image 125 may be stored (which again may be defined relative to the camera coordinate system or the eye coordinate system).

Moreover, for each treatment region 80, information on laser pulses that have been delivered to the respective treatment region 80 or that are planned to be delivered to the respective treatment region, may be stored in the memory 170. The information may include, for instance, a number of laser pulses, a spot size (diameter), a pulse length, a time separation between consecutive laser pulses, the laser duty cycle, a laser energy per pulse or per time unit, and a wavelength. The information may be stored in the memory 170 as a treatment plan. Further details on treatment plans and examples of creating and using treatment plans are described below, particularly with reference to FIG. 15.

The documentation module 153 may be configured to receive the aforementioned information from the image processing module 151, from the laser control module 142, from the camera 120, from the user interface 160 (such as from display device 161, particularly if configured as a touchscreen, and/or from input device 165), or from any other electronic component or electronic module of the ophthalmic system 100. Furthermore, the documentation module 153 may be configured to receive from the image processing module 151, from the camera 120 and/or from any other imaging device of the ophthalmic system 100 or any other system, such as from an OCT imaging device. Preferably, the images or frames 125 acquired before, during and/or after the application of laser pulses are stored as well, or the at least one subregions 129 thereof labelled with the respective azimuth orientation angle Φ . For instance, in order to assist a user to define a treatment plan, the image processing module 151 may be configured to control the display device 161

simultaneously display the reference image as well as the (live) image 125 (or any portion thereof), e.g., these images being overlaid onto each other or arranged next to each other on the display device 161, allowing the user to define or select treatment regions 80 within the reference image or within live image 125, for instance, via the display device 161. For instance, in this manner, the user may be enabled to set shot markers 166 on the reference image and/or on the live image 125 via the display device 161 at intended treatment regions 80 in order to define a treatment plan. Additionally or alternatively, the processor 160 and/or the image processing module 151 may be configured to automatically or semi-automatically (e.g., at least partially depending on user input) define a treatment plan, for instance, during or prior to a treatment session. Additionally or alternatively, the processor 160 and/or the image processing module 151 may be configured to retrieve information, e.g., from memory 170, and (automatically or semi-automatically) define the treatment plan based on the retrieved information, such as any of the information mentioned above in connection with the documentation module 153. Particular examples of automatic and semi-automatic definitions of treatment plans during a treatment session are described further below with reference to FIGs. 10-21.

As shown in FIGs. 10, 12, 14, 15, the image processing module 151 may be configured to provide instructions to the display device 161 to show, in addition to the displayed at least one subregion 129 of the (live) image 125, one or more shot markers 166 indicating on the display device 161 the positions of one or more planned laser treatment regions 80. In the examples shown, the shot markers 166 are displayed on the display device 161 in accordance with respective azimuthal angles ϕ_{plan}^i of the planned laser treatment regions 80 ($i > 0$ being an index for each treatment region). The azimuthal angles ϕ_{plan}^i may be defined, for instance, relative to the camera coordinate system or relative to the eye coordinate system. The shot markers 166 may be displayed on the display device 161 with an azimuthal orientation relative to the display coordinate system 182 in accordance with the respective azimuthal angles ϕ_{plan}^i of the one or more planned laser treatment regions 80.

The image processing module 151 may further be configured to use respective one or more azimuthal angles ϕ_{prev}^i of one or more previously treated

laser treatment regions in the eye to determine the one or more azimuthal angles ϕ_{plan}^i of the one or more planned laser treatment regions, for instance, in accordance with a predefined azimuthal step or increment value ϕ_{Step} . For example, one more of the azimuthal angles ϕ_{plan}^i may be calculated using the formula $\phi_{\text{plan}}^i = \phi_{\text{prev}}^i + \Phi_{\text{Step}}$, see FIG. 12. The image processing module 151 may be configured to retrieve the azimuthal angles ϕ_{prev}^i from the memory 170 of the system 100 or from the documentation module 153, for instance. Additionally or alternatively, the image processing module 151 may be configured to determine the azimuthal angles ϕ_{plan}^i of the one or more planned laser treatment regions such that the azimuthal angles ϕ_{plan}^i are within the aforementioned azimuthal span Φ_{FOV} .

In some examples, the image processing module 151 is configured to use information about azimuthal angles ϕ_{prev}^j (label j being a positive integer) of previously treated laser treatment regions 80 in the eye 10 and information about a current azimuthal orientation Φ of the at least one subregion 129 of the image 125 to determine azimuthal angles ϕ_{cur}^i (label i being a positive integer) of one or more new or current laser treatment regions 80 to be irradiated within the at least one subregion 129 at the current azimuthal orientation $\Phi = \Phi_{\text{cur}}$. For instance, the previously treated laser treatment regions 80 may have been irradiated at a previous azimuthal orientation Φ_{prev} of the gonioscopic lens that is different from the current azimuthal orientation Φ of the gonioscopic lens 1100. Thus, some or all of the previously treated treatment regions 80 may be positioned outside the peripheral gonio field of view 129 provided by the mirror surfaces 1120 of the gonioscopic lens at its current azimuthal orientation Φ , i.e., some or all of these previous treatment regions may not be included in the subregions 129 of the live image 125 as presently displayed on the display device 161. However, in case of an overlap of the peripheral gonio field of view at the current azimuthal orientation Φ of the gonioscopic lens 1120 with the peripheral gonio field of view at the previous azimuthal orientation Φ_{prev} of the gonioscopic lens 1120, it is in principle possible that some treatment regions 80 that have been treated under the previous azimuthal orientation Φ_{prev} are also included in the gonio field of view of view at the current azimuthal orientation Φ . The image processing module 125 may therefore be configured to ensure that the current laser treatment regions 80 are all different from previously treated

laser treatment regions 80, e.g., by at least a predefined minimal (e.g. angular) distance value, to avoid multiple treatments of such treatment regions.

The image processing module 151 may be further configured to provide instructions to the display device 161 to show, within the displayed at least one subregion of the live image, for each of the one or more laser treatment regions to be irradiated within the at least one subregion at the current azimuthal orientation Φ a shot marker 166 indicating on the display device 161 the position of the respective current laser treatment region 80 in accordance with the azimuthal position ϕ_{cur}^i of the respective current laser treatment region 80. The image processing module 151 may further be configured to provide instructions to the display device 161 to show, in addition to the displayed at least one subregion 129 of the live image 124 and the shot markers 166 of the current treatment regions 80 within the at least one subregion of the live image 125, shot markers 166 of previously treated treatment regions 80 in accordance with azimuthal angles ϕ_{prev}^j of the respective previously treated laser treatment regions 80.

In some examples, the image processing module 151 is configured to determine the respective azimuthal angles ϕ_{cur}^i of the of the one or more current laser treatment regions 80 such that the azimuthal angles ϕ_{cur}^i are one or more of: within the azimuthal span Φ_{FOV} defining the azimuthal field of view captured within a respective one of the at least one subregion 129 of the live image 125, within the allowable azimuthal span Φ_M ($< \Phi_{FOV}$), within the central subsection 74 of the curved line 72 of the TM 45, and/or such that the treatment regions is spaced apart from the previously treated laser treatment regions by at least a predefined distance value, such as the distance value d in accordance with equation (8) defined above.

In some examples, the image processing module 151 may be configured to select one or more frames of the live image 125 and to extract, from the one or more selected frames, one or more subregions 129 of the at least one subregion 129 of the respective selected frame 125 and to provide instructions to the display device 161 to display, in addition to the at least one (current) subregion 125 of the currently acquired live image 125 shown on the display device 161, the extracted one or more subregions 129 of the one or

more previously selected frames of the live image 125, e.g., as still images. The previously selected frames may be acquired under the same (previous) azimuthal orientation Φ of the gonioscopic lens 1120 under which laser pulses have (previously) been applied to the eye. The extracted subregions 129 may each show treatment regions 80 onto which laser pulses have previously been applied. The image processing module 151 may further be configured to control the display device 161 to additionally show shot markers 166 at the respective treatment regions 80 within the extracted subregions 129. The image processing module 151 may be configured to provide instructions to the display device 161 to display, for each of the one or more selected frames of the live image 125, the respective extracted one or more subregions 129, and optionally any of the aforementioned shot markers 166 included therein, in accordance with an azimuthal orientation of the respective one or more subregions 129. The image processing module 151 may be configured to determine whether the displayed at least one subregion 129 of the live image 125 overlaps with one or more of the displayed subregions 129 extracted from the previously selected frames of the live image 125 and, optionally, to use this information to determine new (still to be treated) treatment regions 80 within the current at least one subregion 129 of the live image 125. For example, the image processing module 151 may be configured to avoid defining any region as a treatment region 80 if that region has already been treated under a different (i.e., previous) azimuthal orientation Φ of the gonioscopic lens. The image processing module may be configured to instruct the display device 161 to mark previously treated regions that are located within overlaps of the current at least one subregion 129 of the live image 125 with any additionally displayed extracted subregions 129 of the previously selected frames (that have been acquired previously and under a different azimuthal orientation of the gonioscopic lens than the current azimuthal orientation Φ of the gonioscopic lens) as being already treated, for instance, by means of a corresponding indication or treated region marker 167 displayed on the display device 161 at each of such previously treated region, the treated region markers 167 preferably having a design or appearance different and clearly discernable from that of the shot markers 166, e.g., empty circle versus full circles, as shown in FIGs 12, 14, and 15.

FIGs. 11 to 15 relate to exemplary method of performing trabeculoplasty

treatment using an ophthalmic system in accordance with the present disclosure, such as one of the exemplary ophthalmic system 100, 200, 300, 400, 500, 600.

5 In particular, FIGs. 11 and 12 respectively show an exemplary flow chart and corresponding displayed images 162 displayed on the display device 161 for an exemplary first method which is in accordance with an “auto-advance mode” of the ophthalmic system. The exemplary first method may include one or more of the following steps:

10 In step 1, a user, such as a medical practitioner or physician, applies the gonioscopic lens 1100 (or, alternatively, any other gonioscopic lens described herein, or the gonioscopic lens assembly or the patient interface described herein) to the cornea 20 of the patient's eye 10 and thus may observe the at least one subregion 129 of the live image 125 that is captured by the camera 125 and shown on the display device 161. Within the subregion 129, which
15 corresponds to a respective mirror surface 1120 of the gonioscopic lens 1100 and to a respective peripheral gonio field of view 129 having an azimuthal span Φ_{FOV} , the user may observe a particular sector of the anterior chamber angle 40 of the eye 10 including a section of the trabecular meshwork 45. By (manually or automatically) rotating the gonioscopic lens 1100 about its
20 longitudinal axis 1114 by an azimuthal angle, as in step 7, the gonio field of view 129 corresponding to the respective mirror surface 1120 may be rotated accordingly towards a different (e.g., adjacent) sector of the chamber angle 40 which thus becomes visible within the corresponding subregion 129 of the image 125 shown on the display device 161.

25 In step 2, using the image processing module 151, the subregion 129 of the image 125 may be identified, e.g., using a segmentation algorithm, and the current azimuth orientation of the subregion 129, and thus the azimuth angle Φ of the chamber angle sector shown in the subregion 129 of the image 125 may be determined, for instance, relative to the patient's eye coordinate
30 system (e.g., defined using the iris 30 or the fundus 50 identified in the subarea 128 of the image 125 showing central gonio field of view) or relative to the camera coordinate system. The subregion 129 may be shown on the display device 161 in accordance with its current azimuthal orientation, as shown in FIGs. 10, 12, and 14, respectively.

In step 3, the image processing module 151 may also identify, e.g., using a segmentation algorithm, the segment of the trabecular meshwork (TM) within the subregion 129. Shot markers 166 indicating on the display device 161 the positions of one or more planned laser treatment regions 80 (in accordance with respective azimuthal angles ϕ_{plan}^i of the one or more planned laser treatment regions 80) may be applied to the segment of the TM 45 shown on the display device 161, for instance, manually by using the display device 161 as an input device (e.g., via a touch screen function), or automatically by means of the image processing module 151 as described herein. For instance, the shot markers 166 may be applied in a non-overlapping manner and/or to the central segment of the TM with approximately constant curvature, e.g., to the central subsection 74 of the curved line 72, as described above with reference to FIG. 10.

In step 4, laser shots of the laser system 140 may be released (by the user or automatically) and directed onto the treatment regions 80 in accordance with the shot markers 166.

In step 5, information about the treatment of the TM segment within the current chamber angle sector, such as the azimuthal angles ϕ_{plan}^i as well as the used laser parameters characterizing the applied laser pulses, may be stored in the memory 170, e.g., by means of documentation module 153, for documentation and/or for later use during the same session. As a further example, image data of the subregion 129 of the image 125 acquired at the azimuthal orientation Φ during application of the laser shots may be stored in the memory 170, e.g., as a standstill image of the subregion 129.

Optionally, in step 6, said subregion 129 including the shot markers 166 may be shown on the display as a standstill image at the corresponding azimuthal orientation Φ . In addition, the current subregion 129 of the live image 125 is shown on the display device 161 in accordance with its current azimuthal orientation Φ .

In step 7, in order to treat further treatment regions 80, corresponding further shot markers 166 may be generated. For instance, in order to treat treatment regions 80 within an adjacent chamber angle sector that is adjacent to the current chamber angle and that corresponds to an azimuth orientation

$\Phi + \Phi_{\text{Step}}$, wherein Φ_{Step} is a predefined angular incremental value, the processor 150 or the image processing module 151 may automatically determine the azimuth angles of new (planned) treatment regions from the azimuth angles of the previously treated treatment regions, e.g., using the formula $\phi_{\text{plan}}^i = \phi_{\text{prev}}^i + \Phi_{\text{Step}}$. The previously stored azimuthal angles ϕ_{plan}^i may be retrieved from the memory 170 and used as ϕ_{prev}^i in order to determine the new azimuthal angles ϕ_{plan}^i of the next treatment regions 80 to be treated. The new shot markers 166 may be shown on the display device 161 in accordance with the respective new azimuth angles ϕ_{plan}^i . The predefined increment Φ_{Step} may be, for instance, greater than 10°, 15°, or 20°, and less than 90°, 75°, or 60°, for example. For instance, the incremental value Φ_{Step} may be 30° or 45°.

In step 8, the gonioscopic lens 1120 may be rotated manually or automatically by Φ_{Step} and positioned relatively to the eye 10 such that the TM segment within the rotated (i.e., new or current) subregion 129 of the live image 125 is aligned with the new shot markers 166 at the new or current azimuth angles ϕ_{plan}^i .

In step 9, as soon as the alignment is determined (by the user or, alternatively, by the image processing module 151), the laser shots are released manually or automatically so that the current segment of the TM 45 at $\Phi = \Phi_{\text{Prev}} + \Phi_{\text{Step}}$ is irradiated with laser pulses at the planned treatment regions 80 in accordance with the shot markers 166 at the current azimuthal angles ϕ_{plan}^i .

In step 10, optionally, information about the treatment of the TM segment within the current chamber angle sector Φ may be stored in the memory 170 for documentation and/or for later use during the same session as described above.

In step 11, optionally, the subregion 129 may be shown on the display 161 as a standstill image at the corresponding azimuthal orientation used during the application of the laser pulses, as well as treated region markers 167 indicating the treated regions. In addition, the current subregion 129 of the live image 125 is shown on the display device 161 in accordance with its current azimuthal orientation, which is again denoted as Φ .

In step 12, previous steps 7-11 may be repeated in order to apply laser shots

onto further sections of the TM 45, for instance, along half of, or the entire of, the TM 45 in a step wise manner.

FIGs. 13 and 14 respectively show an exemplary flow chart and corresponding displayed images 162 displayed on the display device 161 for an exemplary second method in accordance with an “automatic mode trabeculoplasty.” As shown in FIG. 13, the second exemplary method may comprise steps 1 to 6 of the exemplary first method described above. Additionally, the exemplary second method may include one or more of the following steps:

In step 7, in order to treat further treatment regions 80 in a different or new section of the TM 45 contained in a different or new chamber angle sector, the gonioscopic lens 1100 is rotated manually or automatically to a corresponding new azimuthal orientation $\Phi = \Phi_{\text{new}}$ until the new TM segment to be irradiated is shown within the rotated (new or current) subregion 129 of the live image 125.

In step 8, step 2 is applied again after the rotation to identify the subregion 129 of the live image 125 and to determine the current new azimuth angle Φ of the subregion 129 after the rotation and thus the azimuth orientation of the chamber angle sector shown in the subregion 129.

In step 9, step 3 is applied again to identify within the current (rotated) subregion 129 of the live image 125 a corresponding new segment of the TM 45. Furthermore, any overlap with previously treated segments, if any, may be detected, e.g., using the image processing module 129. For instance, an overlap between treated segments may be determined using the stored coordinates of previously treated treatment regions, e.g., by determining whether these coordinates fall within onto the current (new) segment of the TM 45 shown in the subregions 129 of the live image 125.

In step 10, new shot markers on the new segment of the TM. Preferably, the shot markers are automatically generated by means of the image processing module as described above, particularly avoiding definition of any region that has already been treated under a previous azimuthal orientation of the gonioscopic lens as a new treatment region. For instance, the image processing module may generate the new such markers such that the new treatment regions are spaced apart from the previously treated laser treat-

ment regions by at least a predefined distance value. The new shot markers may be shown on the display in accordance with respective new azimuth angles ϕ_{plan}^i . Treated region markers may displayed accordingly.

In step 11, step 4 is performed again to treat the new treatment regions.

5 In step 12, step 5 is performed again to store information about the treatment of the TM segment at new treatment regions within the current chamber angle sector and to acquire a standstill image of the currently treated chamber section.

10 In a further step (12B), optionally, step 6 is performed to show the treated section of the TM on the display 161 as a standstill image, optionally including corresponding treated region markers 167.

15 In a step 13, the steps 7 to 12 (and optionally step 12B) are repeated to apply laser shots in multiple sections of the TM in a step wise manner. Also in this exemplary second method, acquiring a preliminary imaging of the anterior chamber prior to the treatment procedure is not needed.

20 Preferably, the exemplary second method is performed while the patient and/or the patient's eye are tracked. For instance, lateral and rotational motion of the patient eye 10 may be detected and correction signals are applied to the beam steering device 148 to maintain the aiming laser beam 145 on the intended spot positions. The tracking of the iris 30 or the central retina 55 relative to the camera coordinate system provides the camera co-ordinates of the iris ($x_{\text{IRIS}}, y_{\text{IRIS}}$). These coordinates, together with the camera coordinates corresponding to the trabecular meshwork 45 (e.g., the curved line 72) viewed via the gonioscopic lens 1100 with its central cup centered within the intermediate image plane IIP of the device ($x_{\text{C, TM}}, y_{\text{C, TM}}$) may be used, for instance, by the eye tracking module 152, to calculate the motion corrected coordinates of the beam steering devices ($x_{\text{L}}, y_{\text{L}}$) that position the aiming and treatment laser 125 beams on the trabecular meshwork 45:

$$(x_{\text{IRIS}} + x_{\text{C, TM}}, y_{\text{IRIS}} + y_{\text{C, TM}}) \rightarrow (x_{\text{L}}, y_{\text{L}}); (x_{\text{L}}, y_{\text{L}}) \rightarrow (x_{\text{IRIS}} + x_{\text{C, TM}}, y_{\text{IRIS}} + y_{\text{C, TM}}) \quad (10)$$

30 FIG. 15 shows the workflow of an exemplary third method of using the ophthalmic system 100, which is referred to as "planned mode trabeculoplas-

ty.” During a planning phase, a treatment plan is defined. As shown, the treatment plan may be defined by setting shot markers 166 at the intended treatment regions 80 on the TM 45 within the current subregions 129 of the (live) image 129 shown on the display device 161. As shown, during the planning phase, the gonioscopic lens 1100 may be rotated in a step wise manner, successively shot markers 166 may be placed along multiple sections of the chamber angle 40. In the present case shown, the gonioscopic lens 1100 may be rotated at each step about an angle which allows applying shot markers 166 at adjacent sections of the chamber angle 40. During the entire planning phase, the gonioscopic lens 1100 may be rotated around 360° about its longitudinal axis 1114 so that shot markers 166 are applied along the entire circumference of the TM 45. The shot markers 166 are shown on the display device 161 in accordance with their respective coordinates. As described herein, the coordinates of the shot markers 166 may be defined relative to the eye coordinate system (e.g., by azimuthal orientations ϕ_{eye}^i and radial coordinates r_{eye}^i) so that the shot markers 166 follow the movements of the eye 10 on the display device 161. The shot markers 166 may be set, for instance, manually by the user via the user interface 160, or automatically by the system, e.g., by the image processing module 151. In the treatment plan, each laser spot 80 can be characterized, for instance, by its coordinates (such as its position around the iris and its lateral or radial position, e.g., relative to the device or the center of the pupil), and laser parameters, such as laser pulse power/energy, and pulse duration (if applicable).

During the treatment phase, the TM 45 may be treated segment by segment, irradiating the treatment regions 80 that visible in the current peripheral gonio field of view at the current azimuthal orientation Φ of the gonioscopic lens 1100. Once an azimuthal segment of the TM 45 has been treated, the system 100 may prompt the user to advance to the adjacent segment of the chamber angle 40, for instance, by displaying on the display device 161 the shot markers 166 of the next (adjacent) segment in accordance with the treatment plan, thereby suggesting the physician to (manually) rotate the gonioscopic lens 1100 accordingly. Alternatively, the system may automatically rotate the gonioscopic lens (in its entirety or of a component thereof carrying the internal gonio mirror(s)) to the next segment. The laser pulses may be released either automatically by the system device or the physician

may be prompted by the system 100 to release the shots. Once, a treatment region 80 has been irradiated, the corresponding shot marker 166 may be replaced by a treated region marker 167, as described above.

5 In some examples, as in the example illustrated in FIG. 15 and described above, the image processing module 151 may be configured to define a treatment plan including one or more treatment regions 80 within the eye 10 to be irradiated with laser energy. For instance, the image processing module 151 may be configured to define the one or more treatment regions 80 within the at least one subregion 129 of the image 125 (which may be a live image or a snapshot/still image acquired with the camera 120 of the system 100) or within a panoramic image described further below. In some examples, the image processing module 151 may be configured to define the one or more treatment regions 80 using information received, for instance, via the user interface 160, i.e., based at least partially on user input. Additionally or 15 alternatively, the image processing module 151 may be configured to define the one or more treatment regions 80 using information determined automatically by the image processing module 151 based on image data, as described further below, and/or using stored information. The stored information may, for instance, be stored in and received from, the (local) memory 170 and/or a database internal or external of the ophthalmic system 100. The database may, for instance, be part of a computer network, such as a computer cloud, and/or be accessible via a wired or wireless computer network, such as via the internet, accessible via a data interface of the ophthalmic system (not shown). 20

25 The information (whether stored, input by the user, automatically determined based on image data) may include information about the patient and/or the patient's eye 10, information about locations (coordinates) of individual or single treatment regions 80 (also termed treatment spots), a number of laser pulses to be applied on each treatment region, a laser spot size and/or a spatial laser spot density. The information may further include laser parameters, such as laser wavelength, laser energy, laser energy per pulse, laser spot diameter, pulse duration time, pulse separation time, duty cycle, among 30 others. The information may be input and stored prior to the actual treatment or collected during the treatment, e.g., by performing measurements of properties of the eye tissue based on image data included in the images 125 acquired by the camera 120. The laser parameters may be adjusted based on 35

the measurements before the application of future next laser pulses during the same (or future) treatment session, as described in more detail below.

FIGs. 16A-19B illustrate two exemplary workflows of creating a panoramic image of the anterior chamber angle 40 of the eye 10 using any of the ophthalmic systems 100, 200, 300, 400, 500, 600 described herein. For example, the image processing module 151 may be configured to extract from images 125 of a set of two or more images 125 (e.g. from different frames of the image if the camera 120 acquires it is a video image or live image), which have been acquired with the camera 120 at different azimuthal orientations Φ_{gonio}^j of the gonioscopic lens 1100 ($j > 0$ being an index for indexing each one of the different azimuthal orientations of the gonioscopic lens), the at least one subregion 129 of the respective image 125 (e.g. frame) and to join together the extracted subregions 129 (or at least portions thereof, such as the corresponding allowable spans Φ_M of the respective subregions) to create a panoramic image 125P of the anterior chamber angle 40 of the eye 10. For instance, the extracted subregions 129 and the panoramic image 125P composed thereof may cover the entire chamber angle 40 of the eye 10, as shown in FIGs. 17B and 19B. The number of subregions 129 required to cover the entire chamber angle 40 of the eye 10 depends on the azimuthal width Φ_{FOV} of the peripheral gonio field of view of each subregion or on the allowable span Φ_M if the latter is used to compose the panoramic image 125P. Moreover, the number of different azimuthal orientations Φ_{gonio}^j of the gonioscopic lens 1100 needed to cover the entire chamber angle 40 also depends on the number of subregions 129 that are included in each image 125, i.e., on the number of mirror surface 1120 of the gonioscopic lens 1100 used. In the example shown in FIGs. 16A-19B, the gonioscopic lens 1100 includes four mirror surface 1140 so that each image 125 includes four corresponding subregions 129 which are labeled by numbers 1 to 4 for a first image 125 taken at a first azimuthal orientation of the gonioscopic lens 1100, and by 1' to 4' for a second image 125' taken at a second azimuthal orientation of the gonioscopic lens 1100. Moreover, in the examples shown in FIGs. 16A-19B, the two image 125 and 125' are sufficient to cover the entire chamber angle 40.

The image processing module 151 may be configured to determine which of the extracted subregions 129 are adjacent to each other (e.g., based on the

azimuthal orientation of each extracted subregion 129), and to join together each pair of adjacent subregions 129, for instance, by means of co-registering the adjacent subregions (e.g., within their mutual intersection or overlap region) and/or by means of stitching the adjacent subregions 129 together. As shown in FIG. 17B, the subregions 129 forming the panoramic image can be arranged in a circular array to form a circular panoramic image 125P. Alternatively, as shown in FIG. 19B, the subregions 129 may be aligned in a linear array to form a linear panoramic image 125B. Accordingly, the image processing module 151 may be configured to control the display device 16 to display the panoramic image 125 as a linear panoramic image 152P or as a circular panoramic image 125P.

FIG. 20 shows an exemplary algorithm or workflow for imaging and displaying the full chamber angle 40, e.g., by generating the panoramic images 125P shown in FIGS. 17B and 19B, using the ophthalmic system 100 described herein. As shown in FIGS. 16A, 18A, mirror surface with labels 1 and 3 show inferior and superior sections of the chamber angle 40. The corresponding subregions 1 and 3 are shown on the bottom and top of the display device 161, respectively, to give the physician a representation of the sections the correct orientation. The same applies for mirror surfaces 2 and 4 which show the nasal or temporal part of chamber angle, respectively. The corresponding subregions 129 are shown on the left or right side of the display device 161, depending on the laterality of the eye under examination, OD or OS. The device also detects laterality and displays the nasal and temporal part of the chamber angle. As discussed above, depending gonioscopic lens 1100, only little rotation may be needed to fully cover the full chamber angle 40. The “static” gonio field of view for the exemplary gonioscopic lens 1100 is shown in FIGS. 16A-19B is 120° . Accordingly, each mirror surface 1120 provides a field of view or azimuthal span Φ_{FOV} of 30° , so that for full chamber angle imaging the lens may be rotated two times by 30° each or continuously by 60° in total. For each rotation of the gonioscopic lens 1100 the newly appearing chamber angle images, i.e. subregions 129, are stitched to the previously acquired chamber angle images so that the resulting panoramic image 125P shows the chamber angle sections in the correct orientation. The iris 30 (or a portion of the central retina 55) is visible in the subarea 128 of the image 125. The iris can be detected and tracked to always have the eye’s coordinate

system as a reference for displaying the chamber angle in the correct orientation (for instance, azimuth angle relative to an arbitrary reference locked to the patient's iris or central retina). In some examples, pupil 35 may also be detected in the subarea 128 (i.e. the central gonio field sub-image) of the image 125 and possibly also in subregions 129 (i.e. the peripheral gonio sub-images). In some examples, a central line connecting the pupil 35 imaged in the subarea 128 and pupil 35 imaged in any one of the subregions 129 may be used to determine the azimuthal orientation Φ of the respective subregions 129. Additionally or alternatively, as described above, a vector v_n normal to an edge portion 129' (see FIG. 10) of the subregions 129 may be used to determine the azimuthal orientation Φ of the respective subregion 129. Before detecting the edge 129', the subregions 129 may be segmented.

In further examples, it is also possible to use (indirect) gonioscopic lenses 1100 with a (relatively larger) number of identical mirror surfaces that have the following characteristics: (a) an overlap between gonio fields of view of adjacent mirror surfaces of the gonioscopic lens so that chamber angle structures imaged via adjacent mirror surfaces overlap correspondingly; (b) preferably minimal apparent distortion of the chamber angle structures within the sub-images corresponding to the respective mirror surfaces. Furthermore, it is preferably also provided that (a) the alignment of the patient's eye is robust; and (b) the field of view of the camera is sufficiently large to accommodate all mirror surfaces and preferably without or with only low vignetting). Using such a gonioscopic lens 1100, it is possible to generate a complete circumferential panoramic image 125P of the chamber angle 40 based on one single image or frame 125 of the camera 120. In this case, the sub-images or subregions 129 corresponding to adjacent chamber angle segments of all mirror surfaces 1120 of the gonioscopic lens 1100 can be co-registered and stitched together to provide a complete circumferential image or panoramic image 125P of the chamber angle 40, for instance, of the type shown in FIGs. 17B and 19B. The panoramic image 125P of the chamber angle 40 may be uniquely referenced to the iris 30 or the central retina 57 shown in the subarea central gonio sub-image 128 of the image 125 that is imaged centrally through the gonioscopic lens 1100.

FIG. 21 shows a workflow or algorithm for treating the full chamber angle using any one of the exemplary ophthalmic systems 100, 200, 300, 400, 500,

600. In this method, all mirror surfaces 1120 of the gonioscopic lens 1100 are imaged in a single image or frame 125 acquired by the camera 120. The mirrors surfaces 1120 may be segmented within the frame 125 and the subregions 129 of the image 125 corresponding to the mirror surfaces 1120 may be created (identified). Moreover, the sections of the chamber angle 40 contained in the subregions 129 may be identified by means of image segmentation, and the azimuthal orientation thereof may be determined. The sections of the chamber angle 40 corresponding to the mirror surfaces 1120 may be displayed on the display device 161 in accordance with the respective azimuthal orientations thereof. Treatment patterns, i.e. sets of shot markers 166 with predefined positions relative to each other, are placed (manually or automatically as described herein) onto portions of the displayed sections chamber angle 40, such as onto the displayed TM 45, in order to define intended treatment regions 80. Laser pulses are released (manually or automatically) onto the treatment regions 80 in the chamber angle 40 in accordance with the shot markers 166. The shot markers 166 may be replaced by treated regions markers 167 after irradiation of the corresponding treatment regions 80. The gonioscopic lens 1120 may be rotated (manually or automatically) in order to image new (e.g. adjacent) sections of the angle chamber 40. The subregions 129 of the image may be tracked during the rotation and/or be (newly) identified by means of image segmentation. Similarly, also the sections of the chamber angle 40 currently imaged within the subregions 129 may be tracked during the rotation and/or be (newly) identified by means of image segmentation. Again, treatment patterns with shot markers 166 may be placed on portions of the newly displayed sections chamber angle 40 in order to define new treatment regions 80 that have not yet been treated within the respective subregions 129 of the image 125. Laser pulses are applied onto the new treatment regions 80 in accordance with the newly set shot markers 166. After laser irradiation, the shot markers 166 may be replaced by treated regions markers 167. The procedure of rotating the lens 1120, applying shot markers 166 and releasing laser pulses in accordance with the shot markers 166 may be repeated until the entire circumference (or only a part thereof, as needed) has been treated.

In some examples, the processor 150 or the image processing module 151 may be configured to automatically determine all or at least some pieces of

information used to define or adjust the aforementioned treatment plan and/or used to set or adjust laser parameters characterizing the laser pulses emitted by the laser system 140 to irradiate the treatment regions 80 (of the treatment plan). The information may particularly comprise information about the patient's eye and be based on image data generated by the camera 120 and/or generated by other imaging devices, such as an OCT imaging device of the ophthalmic system (not shown). For example, the image processing module 151 may be configured to determine a tissue characteristics, such as a degree of pigmentation, of the tissue of the eye 10 at the treatment regions 80 or at test sites that are distinct from the treatment regions 80, for instance at the TM 45 or at other parts of the angular chamber 40.

Additionally or alternatively, the image processing module 151 may be configured to measure one or more observables of laser tissue interaction based on image data. The one or more observable may be indicative of, or correlated with, the aforementioned laser induced effects in the tissue. The image processing module 151 may be configured to extract the image data, for instance, from one or more frames of the image 125 of the camera 120, such as from the subregions 129, and/or from one or more optical coherence tomography (OCT) images acquired by an OCT imaging device (not shown). The image data may include reference image data obtained from frames or OCT images acquired prior to the application of one or more laser pulses to a test site or a treatment region 80 in the eye, and further comprise treatment image data obtained from frames or OCT images acquired after the application of one or more pulses of the one or more laser pulses. The image processing module 151 may be configured to measure the one or more observables of laser tissue interaction based on a comparison of the image data obtained before and after the application of the one or more laser pulses. For instance, the image processing module 151 may be configured to determine differences of pixel values at image points 127 corresponding to the test sites or treatment regions 80 before and after pulse application (for instance, the image data before and after pulse application may be registered to from a difference image).

For instance, the image processing module 151 device may be configured to provide the laser system 140, for instance an electronic laser parameter

adjustment module 143 of the ophthalmic system 100 with the determined information, e.g., with the determined tissue characteristics and/or with the measured observables of laser tissue interaction. The laser parameter adjustment module 143 of the laser system 140 may be configured to
5 determine, set, and/or adjust laser parameters based on the aforementioned measured at least one observable of laser tissue interaction, and/or on the aforementioned degree of pigmentation of the tissue of the eye. The laser control module 142 may be configured to control the at least one laser source 141 and the beam steering device 148 to irradiate the respective treatment
10 region 80 with the laser energy in accordance with the newly set or adjusted at least one laser parameter. For example, the measurements of the tissue characteristics and/or laser tissue interaction may be performed during a treatment session and the laser parameter adjustments may be performed after each application of one or more laser pulses and/or before application of
15 further laser pulses on treatment regions 80 included in a treatment plan and are yet to be treated. In an example, the imaging processing module 151 may be configured to detect for each treatment region 80 or target point the degree of pigmentation. The degree of pigmentation may be determined based on image data at image points corresponding to the respective
20 treatment region or target point in the image. The image data may be based on, for instance, image color contrast, reflectometry of the illumination beams 112 and/or reflectometry of the laser aiming beam 145.

In one example, the pulse energy may be set to a value on a range between 0.6 to 1.4 mJ and may be varied in 0.1 mJ steps, such that small bubbles can
25 be observed to appear at the position of the laser shot. The bubbles may serve as a detectable endpoint for a titration or dosing process. Bubbles are typically created because the laser energy absorbed by the chromophores in the tissue, e.g., the TM 45, leads to a temperature rise in the chromophores. The chromophores may vaporize and bubbles may form. The heating of the
30 chromophores to sufficient energy depends on the energy absorbed by the chromophore. The laser spot of a given energy may be distributed over a spot diameter. Herein, typical spot diameters may be, for instance, in a range between 30 – 500 μm . Such spot diameters are however much larger than single chromophores. Therefore, the heat absorbed per laser shot depends on
35 the density of chromophores within the irradiated area. The degree of

pigmentation of the TM 45 is directly correlated to the density of chromophores. As described above, the degree of pigmentation may be automatically detected or measured and the amount of laser energy may be set to a value that will lead to an endpoint which, for instance, is defined by the aforementioned creation of bubbles or by bleaching of the tissue, or at an endpoint slightly below bubble formation or tissue bleaching.

As used herein, the term endpoint refers to a predefined state of the tissue due to laser irradiation. The endpoint may be characterized by a predefined effect occurring due to the laser tissue interaction, such as the aforementioned bubble creation or tissue bleaching, or by a predefined intensity of the effect. Further examples of endpoints are, for instance, a predefined growth rate of bubbles, a predefined number of bubbles, a predefined (e.g. average or maximum) size of bubbles, a change of an OCT signal (e.g. above a predefined threshold value) which may be due to micro-bubbles and/or macro bubbles, or bleaching of the tissue at the target site.

In some examples, upon reaching the endpoint at a given treatment region, or just before reaching the endpoint, the irradiation is stopped (manually or automatically). In some examples, the laser parameters, such as the laser energy, are determined such that the irradiation of the tissue with the laser in accordance with the laser parameters may likely result in reaching the endpoint, or a state just before the endpoint, at the respective target site.

The laser parameters, particularly the laser energy, may be set or adjusted using a correlation between the degree of pigmentation and a laser energy that is likely to result in a desired endpoint. The correlation may be determined, for instance, from an initial manual titration of laser energy by the operator. Alternatively, the correlation may be retrieved from a database containing the laser parameters for a given degree of pigmentation.

The laser parameters may be determined, set and/or adjusted such that irradiation of the respective eye tissue is likely to result in reaching the predefined endpoint. The laser parameters may be determined, set and/or adjusted during and/or after each application laser energy at a target site. The image processing module may be configured to detect, based on image data, whether or not the predefined endpoint has been reached in the tissue at the

target site. For example, when the predefined endpoint is bubble formation at the target site, the at least one observable measured by the image processing module 151 may include, for instance, a growth rate of bubbles generated at the target site, a number of bubbles generated at the target site, a size of bubbles generated at the target site (such as a mean size, a maximum size, a minimum size or a size distribution), or a (OCT) signal change due to micro-bubbles and/or due to macro bubbles.

In a database (which may be stored in the system, e.g. in memory 170, or on an external data storage system, such as in a computer cloud) any data relevant for the treatment may be saved, such as laser parameters (pulse energy, pulse duration, spot diameter, duty cycle, number of shots, etc.) that are likely to achieve a predefined endpoint, a degree of pigmentation at the irradiation site or treatment region, and a definition or a degree of the (intended) endpoint (such as listed above).

In some examples, a machine learning algorithm may be implemented in the processing device 150 of the ophthalmic system 100. For instance, based on a grading by the operator or other experts of a treatment success, of achieved endpoints, and of the degree of pigmentation, the data from the database may be used for machine learning to improve the algorithms used for detection of the degree of pigmentation and/or to improve the automatic or manual setting and/or adjusting of laser parameters for the treatment.

Examples of methods of detecting an endpoint and/or of measuring a signal, whose magnitude changes in response to laser tissue interaction and which may indicate whether or not the endpoint in tissue has been reached, include ophthalmoscopic measurements, opto-acoustic measurements, modulation of back-scattered light, and OCT measurements, among others, as described below.

An exemplary method for detecting the creation of bubbles in the tissue, which may be implemented, for instance, with the image processing module 151, may comprise: saving an image of the camera acquired prior to laser shot (application of one or more laser pulses), acquiring an image or a sequence of images of the camera during and/or after (each) laser shot, registering the images, subtracting (pairs of) the images to create difference images, detect-

ing bubbles in the difference images (binary image by thresholding, blob detection, adapted cell counting etc.), measuring the number of bubbles, measuring the sizes of the bubbles, measure a growth rate of the bubbles, e.g., by comparing bubble size between images of image sequence.

5 Additionally or alternatively, the ophthalmic system may comprise an OCT
imaging device (not shown). The OCT imaging device may include a light
source configured to generate and emit an (optical) OCT beam. The OCT beam
may be combined with (e.g., superimposed onto) the laser beam 145, e.g., by
means of the optical system 130 of the ophthalmic system 100, so that the
10 OCT beam and the treatment laser beam 145 (and optionally the aiming laser
beam) are directed onto the same target region in the eye. In this manner,
OCT images of the tissue at the target regions may be generated, for instance
(shortly) before, simultaneously with, and/or (shortly) after the application of
(treatment) laser pulses. The image processing module 151 may be configured
15 to use the OCT images as described above, e.g., for detecting (changes of)
signals in the tissue due to laser tissue interaction at the target site and/or to
determine whether a (predetermined) endpoint has been reached or not.
Based on this information, the laser parameters may be determined, set or
adjusted as described above, e.g., by means of the parameter adjustment
20 module 143, such as for dosing the treatment laser beam. Additionally or
alternatively, the OCT imaging device may be configured to acquire B-scans
perpendicular to the limbal circumference to visualize and/or measure the
chamber angle. A method to detect and measure laser tissue interaction
based on the OCT image data generated by the OCT imaging device may be
25 implemented as described above for detecting bubbles based on the images
of the camera, e.g., based on OCT signal change due to fringe washout at the
target sites. Typically, such method requires multiple shots per target site.
With the database mentioned above the number of shots may however be
reduced. For instance, the image processing module may be configured to
30 measuring the thermal expansion of the chromophores at the target site
based on the image data of the OCT images.

Referring again to FIGs. 6A-B, an exemplary gonioscopic lens assembly 2100 or
2200 includes, in addition to a gonioscopic lens 1100, one or more additional
lens elements 1130 configured to selectively converge or diverge the central
35 observation beams 114C and central illumination beams 112C. In the exam-

ples shown, the additional lens element 1130 is located at a proximal end or proximal portion 1170 of the gonioscopic lens assembly 2100, 2200 and is concentric with the contact member 1110 of the gonioscopic lens 1100. A semi-diameter SD_L of the proximal lens element 1130 (measured relative to the longitudinal axis 1114) may be less than a (maximal) radial distance RD_{MS} of the at least one mirror surface 1120 of the gonioscopic lens 1100 from the longitudinal axis of gonioscopic lens. The semi-diameter SD_L of the proximal lens element 1130 may be approximately the same as semi-diameter SD_{CM} of contact member 1110. The proximal lens element 1130 may be attached to or integrated into a proximal window element 1140 of the gonioscopic lens 2100, 2200. For instance, as mentioned above, the gonioscopic lens may include a conical or cup-shaped member 1113 with a distal end carrying the contact member 1110 and a proximal end carrying the proximal window element 1140 and/or the proximal lens element 1130.

As shown in FIG. 6A, the proximal lens element 1130 may be a converging lens configured to converge the central illumination beams 112C onto the iris. Alternatively, as shown in FIG. 6B, the proximal lens element 1130 may be a diverging lens configured to diverge the central illumination beams 112C such that they are focused onto the retina 55. For instance, the proximal lens element 1130 may be configured to focus the central illumination beams 112C onto the iris 30 or onto the central retina 55, when the peripheral illumination beams 112P are focused onto eye tissue of the anterior chamber 40, e.g., onto the trabecular meshwork 45. For instance, when the focusing assembly is in the first focus mode, as described above, the proximal lens element 1130 may focus the central illumination beams 112C onto the iris 30 or onto the central retina 55. In this example, the proximal lens element may provide an alternative to switching between different illumination modes for the central and peripheral illumination beams 112C and 112P.

Additionally or alternatively, the gonioscopic lens assembly 2100, 2200 may include a filter element (not shown) located at the proximal end of the gonioscopic lens 1100. The filter element may be concentric with the contact member 1110 of the gonioscopic lens 1100. For instance, the proximal filter element may be attached to the proximal end 1170 of the aforementioned cup-shaped element 1113 of the gonioscopic lens 1100. A semi-diameter SD_F of the filter element may be less than a (maximal) radial distance of the at

least one mirror surface of the gonioscopic lens 1100 from the longitudinal axis 1114 of gonioscopic lens 1100. In some examples, the semi-diameter SD_F of the filter element may be approximately the same as the semi-diameter SD_{CM} of contact member 1110. The proximal filter element may be a neutral-density filter. The proximal filter element may be configured to reduce the intensity of the central illumination beams 112C reaching the eye and to reduce the intensity of the central observation beams 114C reaching the image sensor 121 while the intensities of the peripheral illumination and observation beams 112P, 114P remain unaffected by the proximal filter element. The filter element may therefore provide an alternative to switching between different illumination modes in order to achieve different intensities of the central and peripheral illumination beams 1112C and 112P as described above.

FIGs. 22 to 28 show examples of patient interfaces 3100, 3200, 3300, 3400, 3500, 3600 in accordance with the present disclosure. The patient interfaces 3100, 3200, 3300, 3400, 3500, 3600 may in principle be held by the user, such as by the physician, during use. Alternatively, any one of the patient interface 3100, 3200, 3300, 3400, 3500, 3600 may be mechanically connected to the respective ophthalmic system in use, particularly to any one of the exemplary ophthalmic systems described above. For instance, the exemplary ophthalmic system 600 shown in FIG. 29, which may be configured as and include any of the features of the ophthalmic systems 100, 200, 300, 400, 500, 600, describe above, may include a coupling member 690 configured to establish a connection state between the ophthalmic system 600 and any one of the patient interface 3100, 3200, 3300, 3400, 3500, 3600. Each of the patient interface 3100, 3200, 3300, 3400, 3500, 3600 is adapted for imaging an eye through the patient interface and for applying laser energy to the eye through the patient interface.

As shown in FIGs. 22 to 28, each one of the patient interfaces 3100, 3200, 3300, 3400, 3500, 3600 comprises a contact member 3110, 3210, 3310, 3410, 3510, 3610 with a contact surface 3112, 3212, 3312, 3412, 3512, 3612 that is concentric relative to a longitudinal axis 3314 (see FIG. 24) of the contact member and that is adapted to be placed adjacent to, or onto, the cornea 20 of an eye 10. The contact member 3110, 3210, 3310, 3410, 3510, 3610 further includes an interface portion 3115, 3215, 3315, 3415, 3515, 3615 adapted to

allow illumination beams 112 and laser beams 145, e.g. from the ophthalmic system 100, to propagate through the interface portion 3115, 3215, 3315, 3415, 3515, 3615 towards the contact surface 3112, 3212, 3312, 3412, 3512, 3612 of the contact member 3110, 3210, 3310, 3410, 3510, 3610 and to allow observation beams 114 propagate from the contact surface 3112, 3212, 3312, 3412, 3512, 3612 through the interface portion, e.g. towards the camera 120 of the ophthalmic system 100.

In the examples shown, the contact member includes a lens 3117, 3217, 3317, 3417, 3517, 3617 that forms the contact surface 3112, 3212, 3312, 3412, 3512, 3612, such as a plano-concave lens (as shown), or alternatively a convex-concave lens or a meniscus lens. The lens 3117, 3217, 3317, 3417, 3517, 3617 is formed of a transparent material, such as a glass or polymer, such as silica or PMMA.

The contact member 3110, 3210, 3310, 3410, 3510, 3610 may include a body portion 3116, 3216, 3316, 3416, 3516, 3616. The body portion may form the lens 3117, 3217, 3317, 3417, 3517, 3617 and/or the interface portion 3115, 3215, 3315, 3415, 3515, 3615 of the contact member 110, 3210, 3310, 3410, 3510, 3610. The body portion may be formed completely or at least in regions of a transparent material for the illumination beams 112, laser beams 145 and observation beams 114. The transparent material may be for instance, a glass or polymer, such as silica or PMMA.

For instance, as shown for the exemplary patient interface 3300 in FIG. 24, the body portion 3316 may form the interface portion 3315 and be separate and rotatable relative to the lens 3317. For instance, the interface portion may be coupled to a motorized mount (not shown) of the ophthalmic system 100 that may be configured to rotate the interface portion 3315 when connected to the mount. As shown in FIG. 24, the body portion 3316 is rotatable relative to the lens 3317 about the longitudinal axis 3314 of the contact member 3310. Each of the body portion 3316 and the lens 3317 may include a planar surface, the planar surfaces facing each other. An interspace or gap defined between the planar faces may be filled with a gel, such as with an index matching gel. Alternatively, the body portion 3316 may integrally form both the lens 3317 and the interface portion 3315 of the contact member 3310 of the patient interface 3300.

In some examples, as shown for instance, in FIG. 22, 23, 24, the patient interface 3100, 3200, 3300 forms a gonioscopic lens and includes, in addition to the contact member, one or more mirror surfaces 3120, 3220, 3320 that are inclined relative to the longitudinal axis of the contact member in accordance with respective gonio angles α_{GONIO} , in order to redirect peripheral illumination 112P and observation beams 114P, as described above. As shown, for example, in FIG. 24, the one or more mirror surfaces 3320 are attached to at least one side surface of, or integrated into, the transparent material of the body portion 3316. By rotating the body portion 3316 relative to the lens 3317, it is possible to view and/or treat different peripheral sections of the anterior chamber angle of the eye 10.

In some examples, as in the patient interfaces 3400, 3500, 3600 shown in FIGS. 25 to 27, the interface portion 3415, 3515, 3615 of the contact member 3410, 3510, 3610 includes at least one sidewall 3440, 3540, 3640 which laterally defines or surrounds a receiving space 3441, 3541, 3641 of the patient interface 3400, 3500, 3600. The interface portion 3415, 3515, 3615 comprises a proximal opening 3442, 3542, 3642 which provides access to the receiving space 3441, 3541, 3641 from the proximal side of the patient interface 3400, 3500, 3600. The receiving space 3441, 3541, 3641 and the opening 3442, 3542, 3642 are concentric relative to the longitudinal axis 3414, 3514, 3614 of the contact member 3410, 3510, 3610. As shown, the contact member 3410, 3510, 3610 may be conical or cup-shaped. The receiving space may be shaped and dimensioned to receive therein the coupling member 690 of the ophthalmic system 600, as described in greater detail below with reference to FIGs. 25, 27, and 28. As shown in FIGs. 25, 27, and 28 the mirror surfaces may be attached to or integrated into the coupling member 690, as described below.

In some examples, as in the exemplary patient interface 3400, 3500, 3600 shown in FIGs. 25 to 27, the patient interface 3400, 3500, 3600 comprises a forceps 3443, 3543, 3643 or at least one lid opening element 3444, 3544, 3644 or a combination thereof. Typically, the forceps and/or the one or more lid opening elements extend away from an external side surface of the contact member 3443, 3543, 3643 so as to contact and spread apart upper and lower lids of the eye 10, thereby preventing the lids from covering the cornea 20. In the example shown, the forceps 3443, 3543, 3643 and/or lid

opening elements 3444, 3544, 3644 may be formed by the sidewalls 3440, 3540, 3640 defining the receiving space 3441, 3541, 3641.

5 In the examples shown, the patient interfaces 3100, 3200, 3300, 3400, 3500, 3600, or at least the contact members 3110, 3210, 3310, 3410, 3510, 3610 thereof, are sterile, single-use articles made of low cost materials. Each one of the patient interface 3100, 3200, 3300, 3400, 3500, 3600 may include a machine-readable identifier. For instance, as in the example shown in FIG. 22, the patient interface 3100 may comprise a machine-readable identifier 3180
10 attached to, or integrated into, the contact member 3110. The machine-readable identifier 3180 may include, for instance, an optically, magnetically, or electronically readable code, e.g. a linear or a 2D barcode. Additionally or alternatively, the identifying may be or include a RFID tag. The machine-readable identifier 3180 may encode, in a machine-readable manner,
15 information about the patient interface, such as information allowing to uniquely identify each entity of the patient interface 3100 which may be used, for example, to prevent reusing the patient interface 3100. Additionally or alternatively, the information may specify optical characteristics of the patient interface 3100, such as the imaging magnification value M_C of the central gonio field of the patient interface 3100, as described above. Moreover, in
20 examples in which the patient interface 3100 includes gonio mirrors and thus forms a gonioscopic lens, such as in the examples shown in FIGS. 22, 23, and 24, the information may include the number of mirror surfaces included in the patient interface 3100, the inclination angle α_{GONIO} of the one or more mirror surfaces, and/or at least one imaging magnification value M_{GONIO} associated
25 with one more of the peripheral gonio fields of the respective mirror surfaces.

In some examples, as shown in FIG. 27, the patient interface 3500 may further comprise a pressure sensor 3530 configured to measure and indicate a
30 pressure, such as the pressure with which the contact surface 3512 of the contact member 3510 is pressed against the cornea 20 of the eye 10. Additionally or alternatively, the pressure sensor 3530 may be configured to measure and indicate an intraocular pressure (IOP) of an eye 10 which the contact member 3500 is in contact with. In the example shown, the pressure
35 sensor 3530 includes a flexible element 3531 which is configured to gradually deform depending on the magnitude of the pressure. The pressure sensor

3530 may, for instance, be configured to indicate a degree of the deformation of the flexible element 3531 in response to the pressure. The pressure sensor 3530 may include, for instance, a flexible membrane 3532 covering at least a portion of the contact surface of the contact member 3510 and forming a chamber 3533 between the contact surface 3512 and the flexible membrane 3532. The contact member 3510 may further include a channel 3534 extending within the contact member 3510, one end of the channel 3534 being in fluid communication with the chamber 3533 via an opening formed in the contact surface of the contact member 3510. The chamber 3533 may be filled with a fluid. The fluid may enter the channel 3534 through the opening and flow through the channel 3534 in response to a pressure of the fluid within the chamber 3534 depending on the pressure with which the contact member 3510 is pressed against the cornea of the eye and/or on the IOP. The pressure sensor 3530 may include one or more markings 3535 along the channel, which may form a (pressure) scale allowing to measure the pressure by reading off a height of a liquid column formed by the liquid within the channel 3534 relative to the markings 3535. In order to facilitate viewing the channel 3534 and the fluid therein from a proximal side of the contact member 3510, the channel 3534 may extend in a direction approximately orthogonal to the longitudinal axis of the contact member 3510 of the patient interface 3500.

FIG. 28 shows an exemplary ophthalmic system 600 which may be configured as, and include any of the features of the exemplary ophthalmic systems 100, 200, 300, 400, 500, 600 described above. The ophthalmic system 600 further includes a coupling member 690 configured to establish a connection state between the ophthalmic system 600 and a patient interface as disclosed herein, such as any of the exemplary patient interfaces described above, such as the patient interfaces 3400, 3500, 3600 shown in FIGs. 22 to 27. In the connection state, the coupling member 690 mechanically contacts the interface portion 3415, 3515, 3615 of the contact member 3410, 3510, 3610, and the longitudinal axis 691 of the coupling member 690 is, e.g. within a (predefined) tolerance range, aligned with the longitudinal axis 3414, 3514, 3614 of the contact member 3410, 3510, 3610 of the patient interface 3400, 3500, 3600. Moreover, in the connection state, an axial distance between the coupling member 690 and the interface portion typically is within a (predefined) tolerance range. Hence, the connection state allows for accurate

illumination, observation and application of laser energy through the patient interface 3400, 3500, 3600.

In the examples shown in FIGS. 25-27, to establish the connection state, the coupling member 690 is inserted through the proximal opening 3442, 3542, 3642 of the interface portion 3415, 3515, 3615 of the patient interface 3400, 3500, 3600 into the receiving space 3441, 3541, 3641. In the connection state, the coupling member 690 and the contact member 3410, 3510, 3610 in combination form a gonioscopic lens having, for instance, the features described above in connection the gonioscopic lens 1100. In particular, the coupling member 690 includes the at least one mirror surface 691 of the gonioscopic lens and the contact member 691 forms the contact member of the gonioscopic lens. The at least one mirror surface 692 may be angled relative to the longitudinal axis 691 of the coupling member 690 and configured to redirect the peripheral illumination beams 112P from the illumination device 110 towards the contact member 3410, 3510, 3610 and direct peripheral observation beams 114P from the contact member 3410, 3510, 3610 towards the camera 120 of the ophthalmic system 600, as described above in connection the gonioscopic lens 1100 and ophthalmic system 100.

The ophthalmic system 600 may include a motorized drive member 693 configured to move, for instance, under the control of the processor 150 or the image processing module 151 of the ophthalmic system 600, the coupling member 690 axially along the longitudinal axis 691 of the coupling member 690 and/or to rotate the coupling member 690 about the longitudinal axis 691 of the coupling member 690. For instance, the processor 150 or image processing module 151 may be configured to control the drive member 693 to move the coupling member 690 so as to establish the connection state, e.g., such that a spatial relation between a first marking 695 of the coupling member 690 and a second marking 3645 of the contact member 3600 (FIG. 27) is moved into or kept within a predefined range, as described in more detail below. Additionally or alternatively, the processor 150 or image processing module 151 may be configured to control the drive member 693 to move the coupling member 690 such that the aforementioned pressure (e.g., the pressure with which the contact member is pressed against the cornea of the eye, or the IOP) is moved into or kept within the predefined range.

In the example shown in FIG. 27, the coupling member 690 includes a resilient member 694 configured to transition into a loaded or (axially) compressed state when the coupling member 690 is pressed (axially along the longitudinal axis 691) against the interface portion 3615 of the contact member 3610 in the connection state. When the coupling member 690 is separated from the interface portion 3615 of the contact member 3610 (i.e. when the connection state is terminated), the resilient member 694 may revert back to an (axially) unloaded or uncompressed state (or to a less loaded or less compressed state). The resilient member 694 may include a spring member or, as shown in FIG. 27, a bellows member. The resilient member may be concentric with the longitudinal axis of the coupling member 690. The coupling member 690 may be configured to contact the interface portion 3615 of the contact member 3610 of the patient interface 3600 via the resilient member 694. For instance, the resilient member 694 may extend from a main body 696 of the coupling member 690 in a distal direction. The interface portion 3615 of the patient interface 3600 may include a flange portion 3646 at a proximal end of the interface portion 3615, such as at the proximal opening 3642. The resilient member 694 may be configured to abut against the interface portion 3415, such as against the flange portion 3646 thereof, in the connection state. The resilient member 694 may be configured to dampen and/or compensate axial motions between the coupling member 690 and the interface portion 3615 of the contact member 3610 of the patient interface 3600 in the connection state, e.g. by reversibly or elastically changing its length along the longitudinal axis 691 of the coupling member 690. In principle, the resilient member 694 may also be part of interface portion 3415, 3515, 3615, extending proximally from the interface portion 3415, 3515, 3615 of the contact member 3410, 3510, 3610 and configured to abut against the coupling member 690, for instance against a flange thereof.

As mentioned above, the coupling member 690 includes a first marking 695 and the contact member 3610 includes a second marking 3645. The first marking 695 and the second marking 3645 may be positioned within a field of view 126 of the camera 120 of the ophthalmic system 600 in the connection state between the ophthalmic system 600 and the patient interface 3600. The image processing module 151 may be configured to identify the first marking 695 and the second marking 3645 within the image 125 acquired by the

camera 120 and to determine the aforementioned spatial relation between first marking 695 and the second marking 3645 within the image 125. For example, determining the spatial relation between first marking 695 and the second marking 3645 may include determining at least one of a distance between the first marking 695 and the second marking 3645 within the image 125, an alignment of the first marking relative 695 to the second marking 3645, a displacement of the first marking 695 relative to the second marking 3645, and/or a size difference between the first marking 695 and the second marking 3645. The image processing module 151 may be further configured to use the determined spatial relation between the first marking 695 and the second marking 3645 to determine whether the positioning of the coupling member 690 relative to the patient interface 3600 in the connection state is within the predefined range.

For example, the predefined range may include at least one of a predefined range of an axial distance between the coupling member 690 and the interface portion 3615 of the contact member 3610 of the patient interface 3600, a predefined range of displacement orthogonally to the longitudinal axis 3614 of the interface portion 3615 of the contact member 3610 of the patient interface 3600, and/or a predefined range of a rotation of the coupling member 690 relative to the interface portion 3615 of the contact member 3610 about the longitudinal axis 3614 of the contact member 3410 3610 of the patient interface 3600. For example, the axial distance may be determined based on the size difference between the first marking 695 and the second marking 3645 in the image 125, as the size difference increases with the axial distance between the first and second markings.

In the particular example shown in FIG. 27, the first marking 695 is a circular ring and the second marking 3645 is a circular dot. The spatial relation between the first marking 695 and the second marking 3645 may be defined to be within the predefined range, for instance, if the dot is within the ring and completely fills the region defined by the ring but is not larger than the ring.

The imaging processing module 151 may be configured to generate a confirmation signal indicating that the connection state has been successfully established if the determined spatial relation is within the predefined range

and/or to generate a warning signal indicating that the connection state has not been successfully established if the determined spatial relation is not within the predefined range. The laser system 149, e.g. the control module 142, may be configured to receive the signal(s) and to allow emission of laser beams 145 only after receiving the confirmation signal and/or to prevent emission of laser beams after receiving the warning signal. Additionally or alternatively, the display device may be configured to receive the confirmation signal and/or the warning signal and to display to the user a corresponding warning or confirmation signal.

In some examples, the image processing module 151 is configured to determine at least one pressure using the determined spatial relation between the first marking 695 and the second marking 3645. The at least one pressure may be selected, for instance, from a pressure with which the coupling member 690 is pressed against the contact member 3610 of the patient interface 3600 and/or an intraocular pressure of the eye 10 the contact member 3410 3610 is in contact with.

In some examples, as in the example shown in FIG. 26, the pressure sensor 3530 may be configured to be completely or least partly within the field of view 126 of the camera 125, if the connection state between the ophthalmic system 600 and the patient interface 3500 is established. The image processing module 151 may be configured to determine the pressure as measured and/or indicated by the pressure sensor 3530 within the image 125 of the camera 120. The image processing 151 module may further be configured to determine whether the pressure measured and/or indicated by the pressure sensor 3530 is within a predefined range. For example, the imaging processing module 151 may be configured to generate a confirmation signal indicating that the determined pressure is within the predefined range and/or to generate a warning signal indicating that the pressure is above or below the predefined range. Additionally or alternatively, the display device 161 may be configured to receive the confirmation signal and/or the warning signal and to display to the user a corresponding warning or confirmation signal. Additionally or alternatively, the display device 161 may be configured to receive the determined pressure(s) and to display to the user the determined pressure(s), e.g., corresponding values thereof.

In some examples, the ophthalmic system 100, 600 further includes a reader device 190 (as schematically shown in FIG. 1) configured to read out the information from the aforementioned machine-readable identifier 3180 of the patient interface 3100, as shown in FIG. 22. The reader device 190 may be, or include, the camera 120 of the ophthalmic system 100, 600 and/or an additional camera (not shown) of the ophthalmic system 100, 600. Additionally or alternatively, the reader device 190 may be, or include, an RFID reader. The machine-readable identifier 3180 may be positioned, as shown in FIG. 22, on the contact member 3110 of the patient interface 3100 such that it is readable by the reader device 190, e.g. when the patient interface 3100 is within the field of view 126 of the camera 120 and/or during the connection state between the ophthalmic system 600 and the patient interface 3600. The ophthalmic system 100, 600 may further include an electronic identification module 191 (as schematically shown in FIG. 1) that may be part of the processor device 150 or be a separate processing device, and that is configured to identify the patient interface 3100 based on the information from the machine-readable identifier 3180 as readout with the reader device 190. For instance, the electronic identification module 191 may be configured (e.g., via a suitable data interface or network interface) to assess an external a data base (not shown) storing uniquely identifying information (e.g. IDs) of used patient interfaces. For instance, the electronic identification module 191 may be configured to assess the data base, e.g., via the internet, and to perform any queries on the database, for instance, on whether the uniquely identifying information readout from an instant patient interface (e.g. which is momentarily connected to the coupling member 690 of the ophthalmic system 600) is stored in the data base as belonging to a previously used patient interface. In this manner, the identification module 191 may determine whether the patient interface 3100 has already been used in a previous session and, if so, to not support any further use of the patient interface 3100. For instance, the identification module 191 may be configured to control the illumination device 110, the camera 120, the processing device 150, the image processing module 151, and/or the laser system 140 not to operate (or to operate only in a restricted mode) as long as the coupling member 690 is, e.g., detectable within the field of view 126 of the camera 120 and/or connected to the patient interface 3100, if the patient interface 3100 is determined as being previously used.

Additionally or alternatively, in examples in which the machine-readable identifier 3180 encodes information specifying optical characteristics of the patient interface 3100, the identification module 191 may be configured to provide one or more of the optical characteristics to the image processing module 151, to the illumination device 110 or the illumination control module 115, and/or to the focusing assembly 132 or the focus control module 137, which may be configured to operate in accordance with the received optical characteristics of the patient interface 310. For instance, the image processing module 151 may be configured to perform a search of the subregions 129 of the image 125 corresponding to the one or more mirror surface 3120 using the information on the number of mirror surfaces 3120 included in the patient interface 3100. The focus control module 137 may be configured to adjust the focus of the focusing assembly 132 using the information of the imaging magnification value M_c of the central gonio field of the patient interface 3100 and/or on the at least one imaging magnification value M_{GONIO} associated with the one more peripheral gonio fields of the patient interface 3100.

As shown in FIGs. 22 23 and described above, the contact member 3100, 3200 may comprise a marker 3181, 3281 to indicate the azimuthal orientation of the contact member 3110, 3210 about the longitudinal axis of the contact member 3310, 3410. As shown, the marker 3181, 3281 is visible from the proximal side of the contact member 3110, 3210 facing the ophthalmic system 100, 600, e.g., the coupling member 690 thereof. In this example, the image processing module is configured to identify the marker 3181, 3281 within the image 125 of the camera 120. For instance, the image processing module 151 may be configured to use the identified marker 3181, 3281 to determine the azimuthal orientation Φ of the patient interface 3100, 3200 relative to the camera coordinate system and/or eye coordinate system, an azimuthal orientation Φ of the at least one mirror surface 3120, 3220 relative to the camera coordinate system and/or eye coordinate system, and/or an azimuthal orientation Φ of the at least one subregion 129 of the image 125 relative to the camera coordinate system and/or eye coordinate system. Additionally or alternatively, the image processing module 151 may be configured to use the identified marker 3181, 3281 to determine the azimuthal orientation ϕ of at least one characteristic feature 70 within the subregion 129 relative to the identified marker 3181, 3281, relative to the camera

coordinate system and/or relative to the eye coordinate system. Additionally or alternatively, the image processing module 151 may be configured to use the identified marker 3181, 3281 to determine the azimuthal orientation ϕ of at least one characteristic feature 70 within the subregion 129 relative to the identified marker 3181, 3281, relative to the camera coordinate system and/or relative to the eye coordinate system. The azimuthal orientations may be used as described above, e.g., for controlling the laser system 140 and/or to define or select treatment regions 80 in the eye 10.

10 List of reference numerals

	10	Eye
	20	Cornea
	25	Sclera
15	30	Iris
	35	Pupil
	36	Central/pupillary axis of the eye
	38	Lens
20	40	Anterior chamber angle / iridocorneal region
	45	Trabecular meshwork (TM)
	50	Fundus
	55	Retina
	56	Central retina
25	57	Peripheral retina
	60	Object point
	70	Characteristic feature
	71	Further characteristic feature
	72	Curved line
30	73	Midpoint of curved line
	74	Central subsection of curved line
	80	Treatment region / target site / laser spot
	100; 200; 300; 400; 500; 600	Ophthalmic system

	110, 210, 310, 410, 510	Illumination device
	111, 211, 311, 411, 511	Light source
	112	Illumination beam
	112C	Central illumination beam
5	112P	Peripheral illumination beam
	114	Observation beam
	114C	Central observation beam
	114P	Peripheral observation beam
	115	Illumination control module
10	215, 315, 415, 515	Lens
	216, 316, 416, 516	Lens
	217, 317, 417, 517	Aperture
	120, 220, 320, 420, 520	Camera
	121, 221, 321, 421, 521	Image sensor
15	222, 322, 422, 522	Lens
	123	Subarea of image sensor
	124	Subregion of image sensor
	125	Image, frame
	125C	Compound image / combined
20		image
	125P	Panoramic image
	126	Field of view
	127	Image point / pixel
	128	Subarea of image / central gonio
25		field sub-image
	129	Subregion of image / peripheral
		gonio field sub-image
	129'	Edge portion
	129''	Lateral edge
30	130, 230, 330, 430, 530	Optical system
	131	Optical element
	132, 232, 332, 532	Focusing assembly
	133, 233, 333, 533	Objective lens
	234	Beam splitter
35	235, 335	Dichroic mirror
	336, 536	Illumination beam steering device

	137	Focus control module
	140, 240, 340, 440, 540	Laser system
	141, 241, 341, 441, 541	Laser source
	142	Laser control module
5	143	Laser parameter adjustment module
	145	Laser beam (treatment or aiming)
	446	Lens
	447, 547	Mirror
10	148, 248, 348, 448, 548	Laser beam steering device
	149, 249, 349, 449, 549	Laser beam shaping device
	150	Processor/processing device
	151	Image processing module
	152	Eye tracking module
15	153	Documentation module
	160	User interface
	161	Display device
	162	Displayed image
	165	Input device
20	166	Shot marker
	167	Treated region marker
	170	Memory
	190	Reader device
	191	Identification module
25	690	Coupling member
	691	Longitudinal axis
	692	Mirror surface
	693	Drive member
	694	Resilient member
30	695	First marking
	696	Main body
	1100	Gonioscope or Gonioscopic lens
	1110	Contact member
	1112	Contact surface
35	1113	cup-shaped member
	1114	Longitudinal axis

	1120, 1121, 1123, 1124, 1125, 1126	Mirror surface
	1130	Lens element
	1140	Proximal opening or window
	1150	central gonio field (of view)
5	1160	peripheral gonio field (of view)
	1170	Proximal portion or end
	2100; 2200	Gonioscopic lens assembly
	3100, 3200, 3300, 3400, 3500, 3600	Patient interface
	3110, 3210, 3310, 3410, 3510, 3610	Contact member
10	3112, 3212, 3312, 3412, 3512, 3612	Contact surface
	3314, 3414, 3514, 3614	Longitudinal axis
	3115, 3215, 3315, 3415, 3515, 3615	Interface portion
	3116, 3216, 3316, 3416, 3516, 3616	Body portion
	3117, 3217, 3317, 3417, 3517, 3617	Lens
15	3120, 3220	Mirror surface
	3440, 3540, 3640	Sidewall
	3441, 3541, 3641	Receiving space
	3442, 3542, 3642	Proximal opening
	3443, 3543, 3643	Forceps
20	3444, 3544, 3644	Lid opening element
	3645	Second marking
	3646	Flange portion
	3180	Machine-readable identifier
	3181, 3281	Marker
25	3530	Pressure sensor
	3531	Flexible element
	3532	Flexible membrane
	3533	Chamber
	3534	Channel
30	3535	Marking

List of terms and abbreviations

35	r_f	Frame rate
	r_m	Modulation rate

	r_F	Focus switching rate
	N_I	Positive integer
	N_F	Positive integer
5	Φ	Azimuth coordinate of subregion/gonio field of view/chamber angle sector
	ϕ	Azimuth coordinate of treatment region or characteristic features
10	ϕ_{eye} or Φ_{eye}	Azimuth coordinate in eye coordinate system
	ϕ_{camera} or Φ_{camera}	Azimuth coordinate in camera coordinate system
	r	Radial coordinate
15	r_{eye}	Coordinate r in eye coordinate system
	r_{camera}	Coordinate r in camera coordinate system
20	Φ_{FOV}	Azimuthal span of subregion/gonio field of view/chamber angle sector
	Φ_M	Allowable azimuthal span
	α_{GONIO}	Gonio mirror angle
	M_{GONIO}	Image magnification of peripheral gonio field
25	M_C	Image magnification of central gonio field
	D_{Iris}	Iris diameter
	R_{Iris}	Iris radius
	R_{TM}	Apparent radius of the TM
30	p	Allowable change of R_{TM} within Φ_M
	d	distance between laser spots
	v_n	Normal vector
	SD_L	semi-diameter or radius of proximal lens element
35	SD_{CM}	Semi-diameter or radius of contact member

SD_F	Semi-diameter of the filter element
RD_{MS}	Radial distance of mirror surface from longitudinal axis

Claims

5

1. Ophthalmic system, the system comprising:
 - an illumination device for illuminating an eye through a gonioscopic lens, wherein the illumination device includes at least one light source to generate illumination beams that propagate through the gonioscopic lens and illuminate tissue of the eye, wherein the gonioscopic lens includes a contact member to be placed adjacent to a cornea of the eye and at least one mirror surface angled relative to a longitudinal axis of the gonioscopic lens,
 - a camera for acquiring an image of the eye through the gonioscopic lens, the camera including an image sensor configured to receive observation beams propagating from tissue of the eye through the gonioscopic lens;
 - an image processing module configured to receive the image acquired by the camera and configured to identify at least one characteristic feature of an anterior chamber angle of the eye within at least one subregion of the image,
 - a display device configured to at least partly display the at least one subregion of the image to a user.
2. Ophthalmic system of claim 1, wherein the at least one subregion of the image corresponds to one of the at least one mirror surface of the gonioscopic lens.
3. Ophthalmic system of any one of claims 1 or 2, wherein the image processing module is configured to detect the at least one subregion of the image in the image.
4. Ophthalmic system of any one of the preceding claims, wherein the at least one subregion includes a first subregion corresponding to a first mirror surface of two or more mirror surfaces of the gonioscopic lens and a second subregion corresponding to a second mirror surface of

10

15

20

25

30

the two or more mirror surfaces of the gonioscopic lens, wherein the image processing module is configured to identify the at least one characteristic feature of the anterior chamber angle of the eye also within the second subregion of the image and to control the display device to display simultaneously at least a portion of the first subregion of the image and at least a portion of the second subregion to a user.

5. Ophthalmic system of any one of the preceding claims, wherein the at least one characteristic feature of the anterior chamber angle is selected from a Schwalbe's line, a trabecular meshwork (TM), a scleral spur, a ciliary body, and an iris.

6. Ophthalmic system of any one of the preceding claims, wherein the image processing module is configured to identify at least one further characteristic feature of the eye within a subarea of the image, wherein the subarea is distinct from the at least one subregion of the image and correspond to the contact member of the gonioscopic lens.

7. Ophthalmic system of claim 6, wherein the image processing module is configured to detect the subarea of the image in the image.

8. Ophthalmic system of any one of claims 6 or 7, wherein the at least one further characteristic feature of the eye comprises at least one characteristic feature of an iris of the eye.

9. Ophthalmic system of any one of claims 6 to 8, wherein the at least one further characteristic feature of the eye comprises at least one characteristic feature of a fundus of the eye.

10. Ophthalmic system of any one of claims 6 to 9, wherein the image processing module is configured to define an eye coordinate system based on the identified at least one further characteristic feature of the eye.

11. Ophthalmic system of claim 10, wherein the image processing module is configured to determine a location and/or an orientation of the eye coordinate system relative to a camera coordinate system and/or to

perform a transformation of coordinates between the eye coordinate system and the camera coordinate system.

- 5 12. Ophthalmic system of any one of the preceding claims, further including an eye tracking module configured to track translational and/or rotational motions of the eye relative to the camera using the image of the camera.
13. Ophthalmic system of claim 12, wherein the eye tracking module is configured to track the translational and/or rotational motions of the eye using the identified at least one characteristic feature of the eye.
- 10 14. Ophthalmic system of claim 12 or 13, as far as this claim further depends on any one of claim 6 to 11, wherein the eye tracking module is configured to track the translational and/or rotational motions of the eye using the identified at least one further characteristic feature of the eye.
- 15 15. Ophthalmic system of any one of the preceding claims, wherein the image processing module is configured to determine an azimuthal orientation of one or more of the at least one subregion of the image.
- 20 16. Ophthalmic system of claim 15, wherein the image processing module is configured to control the display device to display one or more of the at least one subregions of the image on the display device with an azimuthal orientation relative to a display coordinate system in accordance with the determined azimuthal orientation of the respective subregion of the image.
- 25 17. Ophthalmic system of one of claims 15 or 16, wherein the image processing module is configured to detect an edge portion defining a boundary of one of the at least one subregion of the image and to determine the azimuthal orientation of the respective subregion of the image using the at least one detected edge portion of the respective subregion of the image.
- 30 18. Ophthalmic system of any one of claims 15 to 17, wherein the image

processing module is configured to determine, for at least one or for each of the at least one subregion, an azimuthal orientation of the at least one characteristic feature of the respective subregion and to determine the azimuthal orientation of the respective subregion of the image using the determined azimuthal orientation of the at least one characteristic feature.

19. Ophthalmic system of any one of the preceding claims, wherein the at least one characteristic feature includes a curved line, the curved line spanning the respective subregion of the image, and, as far as this claim depends on claim 15, wherein the image processing module is preferably configured to determine a normal vector oriented orthogonally to the curved line and to determine the azimuthal orientation of the respective subregion of the image based on an azimuthal orientation of the normal vector.

20. Ophthalmic system of claim 19, wherein the image processing module is configured to determine, for one or more of the at least one subregion of the image, a central subsection of the curved line within the respective subregion.

21. Ophthalmic system of claim 20, wherein the image processing module is configured to determine the central subsection such that, within the central subsection, a maximal deviation of a local curvature of the curved line from a local curvature of the curved line at a midpoint of the curved line within the respective subregion is less than a predefined value.

22. Ophthalmic system of any one of claims 20 or 21, wherein the image processing module is configured to determine the central subsection of the curved line within the respective subregion based on at least one of an iris diameter D_{Iris} of the eye, an angle α_{GONIO} defining the inclination of the mirror surface of the gonioscopic lens corresponding to the respective subregion of the image, and/or an magnification parameter of the gonioscopic lens.

- 5 23. Ophthalmic system of any one of claims 20 to 22, wherein the image processing module is configured to determine the central subsection of the curved line based on at least one of a predefined spot size of a laser beam and a predefined number of treatment regions on the trabecular meshwork.
- 10 24. Ophthalmic system of any one of claims 20 to 23, wherein the image processing module is configured to define a portion of the respective subregion of the image to be displayed by the display device such that the central subsection of the curved line spans over an entire width of the portion of the respective subregion, wherein the image processing module is configured to control the display device to only partly show the respective subregion by showing the defined portion of the at least one subregion.
- 15 25. Ophthalmic system of any one of the preceding claims, further comprising a laser system including at least one laser source configured to generate at least one laser beam, a laser beam steering device configured to steer the at least one laser beam, and a laser control module configured to control the at least one laser source and/or the laser steering device.
- 20 26. Ophthalmic system of claim 25 combined with any one of claims 12 to 14, wherein the laser control module of the laser system is configured to control the laser steering device using information on the tracked motions of the eye received from the eye tracking module.
- 25 27. Ophthalmic system of any one of the preceding claims, further including a documentation module configured to store information associated with the image and/or information associated with a laser treatment.
- 30 28. Ophthalmic system of claim 27, as far as it depends on one of claims 15 to 19, wherein the information includes the determined azimuthal orientation of the at least one subregion of the image.

29. Ophthalmic system of one of claim 27 or 28, wherein the documentation module is configured to store information about laser pulses applied to respective treatment regions within the eye, the information including positions of the treatment regions and one or more laser parameters characterizing the laser pulses, including a number of laser pulses, a pulse duration, a time separation between the laser pulses, a laser energy per pulse or per time unit, a laser spot size, and/or a laser wavelength.
30. Ophthalmic system of claim 29, wherein the position information of each treatment region includes an azimuthal angle ϕ defined relative to an azimuthal orientation Φ of the subregion of the image containing the respective treatment region during the application of the laser pulse to the treatment region.
31. Ophthalmic system of any one of the preceding claims, wherein the illumination device is configured to generate illumination beams to illuminate the eye, wherein the illumination beams comprise central illumination beams directed to propagate centrally through the contact member of the gonioscopic lens without being reflected by the at least one mirror surface of the gonioscopic lens and to impinge on tissue of the iris or the fundus of the eye and peripheral illumination beams directed to be reflected by one of the at least one mirror surface of the gonioscopic lens and propagate obliquely through the contact member of the gonioscopic lens and to impinge on tissue of the anterior chamber angle of the eye and/or on tissue of a peripheral portion of the eye fundus.
32. Ophthalmic system of claim 31, wherein the illumination device is configured to spatially and/or temporally modulate the illumination beams.
33. Ophthalmic system of claim 32, wherein the illumination device is configured to spatially modulate intensities of the illumination beams such that an intensity of the peripheral illumination beams is higher than an intensity of the central illumination beams.

34. Ophthalmic system of claim any one of claims 32 or 33, wherein the illumination device is configured to periodically modulate the illumination beams at a modulation rate r_m that is equal or larger than a frame rate r_f of the camera.
- 5 35. Ophthalmic system of claim any one of claims 32 or 33, wherein the illumination device is configured to periodically modulate the illumination beams at a modulation rate r_m that is equal to, or smaller than, a frame rate r_f of the camera.
- 10 36. Ophthalmic system of claim 35, wherein the image processing module is configured to select, for each cycle of the periodical modulation of the illumination beams, two or more frames and combine the respective two or more frames to form a compound image.
- 15 37. Ophthalmic system of claim 36, wherein the image processing module is configured to extract from each selected frame acquired during a first illumination mode a first frame portion including one or more of the at least one subregion of the image but not including the subarea of the image and to extract from each frame acquired during the second illumination mode a second frame portion including the subarea of the frame but not including the at least one subregion of the frame.
- 20 38. Ophthalmic system of any one of the preceding claims, wherein the system comprises a focusing assembly configured to shift an object plane conjugate to an image plane defined by the image sensor of the camera.
- 25 39. Ophthalmic system of claim 38, wherein the focusing assembly includes at least one motorized translatable lens element or at least one liquid lens element.
- 30 40. Ophthalmic system of any one of claims 38 or 39, further comprising a focus control module configured switch the focusing assembly between a first focus mode in which the object plane is in a first position and a second focus mode in which the object plane is in a second posi-

tion, wherein the focus control module is configured to switch the focusing assembly between the first focus mode and the second focus mode at a focus switching rate r_F , wherein the focus switching rate r_F is equal to or smaller or greater than a frame rate r_f of the camera.

- 5 41. Ophthalmic system of claim 40, wherein the image processing module is configured to determine, for each frame of the live image, whether the frame was acquired during the first focus mode or during the second focus mode.
- 10 42. Ophthalmic system of claim 41, wherein the image processing module is configured to extract from frames acquired during the first focus mode a first frame portion including the subregion of the frame but not including the subarea of the frame and to extract from frames acquired during the second focus mode a second frame portion including the subregion of the frame but not including the subarea of the frame.
- 15 43. Ophthalmic system of claim 42, wherein the image processing module is configured to combine frames of the live image to form a combined image, wherein each combined image is formed using the extracted first and second frame portions.
- 20 44. Ophthalmic system of any one of the preceding claims, wherein the system comprises the gonioscopic lens.
45. Ophthalmic system of any one of the preceding claims, wherein the system comprises a gonioscopic lens assembly including the gonioscopic lens.
- 25 46. Ophthalmic system of claim 45, wherein the gonioscopic lens assembly includes a proximal lens element located at a proximal end of the lens assembly and concentric with the contact member, wherein a semi-diameter (SD_L) of the proximal lens element is less than a radial distance (RD_{MS}) of the at least one mirror surface of the gonioscopic lens from the longitudinal axis of gonioscopic lens.
- 30 47. Ophthalmic system of claim 46, wherein the proximal lens element is a

converging lens.

48. Ophthalmic system of claim 47, wherein the proximal lens element is a diverging lens.

49. Ophthalmic system of any one of claims 45 to 48, wherein the gonioscopic lens assembly includes a proximal filter element located at a proximal end of the gonioscopic lens and concentric with the contact member, wherein a semi-diameter (SD_F) of the proximal filter element is less than a maximum radial distance of the at least one mirror surface of the gonioscopic lens from the longitudinal axis of gonioscopic lens.

50. Ophthalmic system of any one of the preceding claims, wherein the image is a live image and wherein the image processing module is configured to:

provide instructions to the display device to show, in addition to the displayed at least one subregion of the live image, one or more shot markers indicating on the display device the positions of one or more planned laser treatment regions in accordance with respective azimuthal angles ϕ_{plan}^i of the one or more planned laser treatment regions.

51. Ophthalmic system of claim 50, wherein the image processing module is configured to:

determine the azimuthal angles ϕ_{plan}^i of the one or more planned laser treatment regions using azimuthal angles ϕ_{prev}^i of one or more previously treated laser treatment regions in the eye and a pre-defined azimuthal step value Φ_{Step} .

52. Ophthalmic system of any one of claims 50 or 51, wherein the image processing module is configured to:

determine the azimuthal angles ϕ_{plan}^i of the planned one or more planned laser treatment regions such that the azimuthal angles ϕ_{plan}^i are within one of:

an azimuthal span Φ_{FOV} defining a peripheral gonio field of view

that is captured within one subregion of the at least one subregion of the image,

a limited azimuthal span Φ_M which is smaller than the azimuthal span Φ_{FOV} , and/or,

5 inasmuch this claim is combined with any one of claim 20 to 24, the central subsection of the curved line.

53. Ophthalmic system of any one of the previous claims, wherein the image is a live image and wherein the image processing module is configured to:

10 use information about coordinates of previously treated laser treatment regions in the eye and information about a current azimuthal orientation Φ of the at least one subregion of the image to determine coordinates of one or more current laser treatment regions to be irradiated within the at least one subregion at the current azimuthal orientation Φ ,

15 provide instructions to the display device to show, within the displayed at least one subregion of the live image, for each of the one or more laser treatment regions to be irradiated within the at least one subregion at the current azimuthal orientation Φ a shot marker indicating on the display device the position of the respective current laser treatment region in accordance with the coordinates of the respective current laser treatment region.

20 54. Ophthalmic system of claim 53, wherein the image processing module is configured to provide instructions to the display device to show, in addition to the displayed at least one subregion of the live image and the shot markers of the current treatment regions, treated region markers indicating positions of previously treated treatment regions in accordance with azimuthal angles ϕ_{prev}^i of the respective previously treated treatment regions.

30 55. Ophthalmic system of one of claims 53 or 54, wherein the image processing module is configured to determine the azimuthal angles ϕ_{cur}^i of the current laser treatment regions such that the current laser treatment regions are one or more of:

within an azimuthal span Φ_{FOV} defining an peripheral gonio field of view that is captured within one of the at least one subregion of the image,

within an limited azimuthal span Φ_{M} which is smaller than the azimuthal span Φ_{FOV} ,

inasmuch this claim is combined with any one of claim 20 to 24, within the central subsection of the curved line, and/or

spaced apart from the previously treated laser treatment regions by at least a predefined distance value.

56. Ophthalmic system of any one of the preceding claims, wherein the image is a live image and wherein the image processing module is configured to select one or more frames of the live image and to extract, from the one or more frames, one or more subregions of the at least one subregion of the respective selected frame of live image and to provide instructions to the display device to display, in addition to the at least one subregion of the live image shown by the display device, the extracted one or more subregions of the one or more selected frames of the live image.
57. Ophthalmic system of claim 56, the image processing module is configured to provide instructions to the display device to display, for each of the one or more selected frames of the live image, the extracted one or more subregions in accordance with an azimuthal orientation of the respective one or more subregions.
58. Ophthalmic system of one of claims 56 to 57, wherein the image processing module is configured to determine whether the displayed at least one subregion of the live image overlaps with one or more of the displayed subregions extracted from the selected frames of the live image.
59. Ophthalmic system of one of the preceding claims, wherein the image processing module is configured to extract from images of a set of two or more images, which have been acquired by the camera at different azimuthal orientations Φ_{gonio}^i of the gonioscopic lens, the at least one

subregion of the respective image and to join together at least portions of the extracted subregions to create a panoramic image of the anterior chamber angle of the eye.

- 5 60. Ophthalmic system of claim 59, wherein the image processing module is configured to control to display device to display the joined subregions in accordance with their respective azimuthal orientations to create a circular panoramic image of the anterior chamber angle of the eye.
- 10 61. Ophthalmic system of claim 59, wherein the image processing module is configured to control to display device to display the extracted subregions along a straight axis to create a linear panoramic image of the anterior chamber angle of the eye.
- 15 62. Ophthalmic system of any one of claims 59 to 61, wherein the image processing module is configured to define a treatment plan including one or more treatment regions defined within the panoramic image.
- 20 63. Ophthalmic system of any one of the preceding claims, wherein the image processing module is configured to define the one or more treatment regions within the at least one subregion of the image or, inasmuch this claim depends on any one of claims 59 to 61, within the panoramic image.
64. Ophthalmic system of claim 63, further including a user interface configured to receive input from a user, and wherein the image processing module is configured to define the one of more treatment regions based on the user input.
- 25 65. Ophthalmic system of any one of the preceding claims, wherein the image processing module is configured to determine within the at least one subregion of the image a degree of pigmentation of the tissue of the eye at a test site or at a treatment region.
66. Ophthalmic system of any one of the preceding claims, wherein the

image processing module is configured to measure one or more observables of laser tissue interaction at a test site or at a treatment region in the eye based on image data.

- 5 67. Ophthalmic system of claim 66, wherein the image processing module is configured to extract the image data from one or more frames of the image acquired by the camera and/or from one or more OCT images acquired by an OCT imaging device.
- 10 68. Ophthalmic system of claim 67, wherein the image data include reference image data obtained from frames or OCT images acquired prior to the application of one or more laser pulses to the test site or the treatment region in the eye and measurement image data obtained from frames or OCT images acquired after the application of the one or more laser pulses to the test site or treatment region in the eye.
- 15 69. Ophthalmic system of any one of claims 66 to 68, wherein the at least one observable is related to bubble formation at sites of laser tissue interaction, wherein the at least one observables are one or more selected from:
- 20 a growth rate of bubbles,
 a number of bubbles,
 a size of bubbles,
 a signal change due to micro-bubbles,
 and/or macro bubbles.
- 25 70. Ophthalmic system of any one of the preceding claims, further comprising a laser parameter adjustment module, wherein the laser parameter adjustment module is configured to determine, set and/or adjust one or more laser parameters based on, as far as this claim refers to one of claims 66 to 69, the measured at least one observable of laser tissue interaction measurement, and/or, as far as this claim refers to claim 65, on the determined degree of pigmentation of the tissue of
- 30 the eye.
71. Patient interface for imaging an eye through the patient interface

and/or for applying laser energy to the eye through the patient interface, the patient interface comprising:

a contact member including a contact surface concentric relative to a longitudinal axis of the contact member and adapted to be placed onto a cornea of the eye, the contact member further including an interface portion adapted to allow illumination beams and laser beams propagate through the interface portion towards the contact surface and allow observation beams propagate from the contact surface through the interface portion.

- 5
- 10
- 15
- 20
- 25
- 30
72. Patient interface of claim 71, wherein contact member includes a plano-concave lens, a convex-concave lens or a meniscus lens.
73. Patient interface of any one of claims 71 or 72, wherein the interface portion includes one or more mirror surfaces that are inclined relative to the longitudinal axis of the contact member.
74. Patient interface of any one of claim 71 to 73, wherein the contact member includes a body portion formed of a transparent material, the body portion defining the contact surface.
75. Patient interface of claims 73 and 74, wherein the interface portion is completely or at least partly formed of the transparent material of the body portion, and wherein the one or more mirror surfaces are attached to at least one side surface of, or integrated into, the transparent material of the body portion.
76. Patient interface of any one of claims 71 to 75, wherein the interface portion includes at least one sidewall laterally defining a receiving space, the interface further comprising a proximal opening providing access to the receiving space, wherein the receiving space and the opening are concentric relative to the longitudinal axis of the contact member.
77. Patient interface of any one of claims 71 to 76, wherein the contact member is a sterile, single-use article.

78. Patient interface of any one of claims 71 to 77, further comprising a machine-readable identifier attached to or integrated into the contact member, the machine-readable identifier encoding, in a machine-readable manner, information about the patient interface.
- 5 79. Patient interface of claims 78, wherein the machine-readable identifier includes an optically, magnetically and/or electronically readable code.
80. Patient interface of any one of claims 78 to 79, wherein the machine-readable identifier includes information for uniquely identifying each entity of the patient interface.
- 10 81. Patient interface of any one of claims 78 to 80, wherein the machine-readable identifier encodes information specifying optical characteristics of the patient interface, including one or more of:
- an imaging magnification value M_C of a central gonio field of the patient interface,
- 15 a number of mirror surfaces included in the patient interface,
- an inclination angle α_{GONIO} of one or more mirror surfaces of the patient interface, if present, and/or
- at least one imaging magnification values M_{GONIO} associated with one more peripheral gonio fields of one or more mirror surfaces
- 20 the patient interface, if present.
82. Patient interface of any one of claims 71 to 81, further comprising a forceps and/or at least one lid opening element extending laterally from a side surface of the contact member.
83. Patient interface of any one of claims 71 to 82, further comprising a pressure sensor configured to measure and/or indicate one or more pressures selected from
- 25 a pressure with which the contact surface of the contact member is pressed against the cornea, and/or
- an intraocular pressure of an eye which the contact is in contact with.
- 30 84. Patient interface of claim 83, wherein the pressure sensor includes a

flexible element configured to gradually deform depending on the magnitude of the pressure.

- 5 85. Patient interface of claim 84, wherein the flexible element includes a flexible membrane, the flexible membrane covering at least a portion of the contact surface and forming a chamber between the contact surface and the flexible membrane, wherein the contact member includes a channel extending within the contact member, one end of the channel being in fluid communication with the chamber via an opening in the contact surface of the contact member, wherein the chamber is
- 10 filled with a fluid, wherein the fluid is configured to enter the channel through the opening and flow through the channel in response to a pressure of the fluid within the chamber.
86. Patient interface of claim 85, wherein the pressure sensor includes one or more markings along the channel.
- 15 87. Patient interface of any one of claims 85 and 86, wherein channel extends in a direction orthogonal to the longitudinal axis of the contact member of the patient interface.
- 20 88. Patient interface of any one of claims 71 to 87, wherein the contact member comprises a marker configured to indicate an azimuthal orientation of the contact member about the longitudinal axis of the contact member, the marker configured to be visible from a proximal side of the contact member.
- 25 89. Ophthalmic system of any one claims 1 to 70, the ophthalmic system further including a coupling member configured to establish a connection state between the ophthalmic system and the patient interface of any one of claims 71 to 88, in which the coupling member mechanically contacts the interface portion of the contact member and in which a longitudinal axis of the coupling member is aligned with the longitudinal axis of the contact member of the patient interface.
- 30 90. Ophthalmic system of claim 89, wherein the coupling member includes a resilient element configured to transition into a compressed state

when the coupling member is pushed against the interface portion of contact member.

- 5 91. Ophthalmic system of any one of claims 89 to 90, wherein the coupling member of the ophthalmic system includes a first marking and the contact member of the patient interface includes a second marking, wherein the first and second markings are positioned within a field of view of the camera of the ophthalmic system in the connection state between the ophthalmic system and the patient interface.
- 10 92. Ophthalmic system of claim 91, wherein the image processing module is configured to identify the first and second markings within the image and to determine a spatial relation between the first marking and the second marking within the image.
- 15 93. Ophthalmic system of claim 92, wherein determining the spatial relation between the first marking and the second marking includes determining at least one of:
- a distance between the first marking and the second marking within the image,
 - an alignment of the first marking relative to the second marking,
 - 20 a displacement of the first marking relative to the second marking, and/or
 - a size difference between the first marking and the second marking.
- 25 94. Ophthalmic system of one of claims 90 and 93, wherein the image processing module is configured to determine whether a positioning of the coupling member relative to the patient interface is within a predefined range.
- 30 95. Ophthalmic system of claim 94, wherein the predefined range includes at least one of:
- a predefined range of an axial distance between the coupling

member and the interface portion of the contact member of the patient interface,

a predefined range of displacement orthogonally to the longitudinal axis of the interface portion of the contact member of the patient interface, and/or

a predefined range of a rotation of the coupling member relative to the interface portion of the contact member about the longitudinal axis of the contact member of the patient interface.

96. Ophthalmic system of one of claims 92 to 93 in combination with one of claims 95 to 96, wherein the image processing module is configured to determine whether the positioning of the coupling member relative the patient interface is within the predefined range using the determined spatial relation between the first marking and the second marking.

97. Ophthalmic system of one of claims 92 to 96, wherein the image processing module is configured to determine at least one pressure using the determined spatial relation between the first marking and the second marking, wherein the at least one pressure is selected from:

a pressure with which the coupling member is pressed against the contact member of the patient interface and/or

an intraocular pressure of the eye the contact member is in contact with.

98. Ophthalmic system of one of claims 89 to 97, as far as this claim is combined with one or more of claims 83 to 88, wherein, in the connection state between the ophthalmic system and the patient interface, the pressure sensor is least partly within a field of view of the camera, and wherein the image processing module is configured to determine the pressure indicated by the pressure sensor within the image of the camera.

99. Ophthalmic system of 98, wherein the image processing module is configured to determine whether the pressure indicated by the pressure sensor is within a predefined range.

- 5 100. Ophthalmic system of any one of claims 89 to 99, in combination with claim 76, wherein the coupling member is configured to be inserted through the proximal opening into the receiving space of the interface portion of the patient interface to establish the connection state between the ophthalmic system and the patient interface.
- 10 101. Ophthalmic system of any one of claims 89 to 100, wherein, in the connection state between the ophthalmic system and the patient interface, the coupling member of the ophthalmic system and the contact member of the patient interface in combination are the gonioscopic lens, wherein the coupling member of the ophthalmic system includes the at least one mirror surface of the gonioscopic lens and the contact member forms the contact member of the gonioscopic lens.
- 15 102. Ophthalmic system of any one of claims 89 to 101, further including a drive member configured to move the coupling member axially along the longitudinal axis of the coupling member and/or to rotate the coupling member about the longitudinal axis of the coupling member.
- 20 103. Ophthalmic system of any one of claims 89 to 102, as far as this claim refers to one of claims 78 to 81, further including a reader device configured to read out the information from the machine-readable identifier of the patient interface.
- 25 104. Ophthalmic system of any one of claim 103, wherein the machine-readable identifier is positioned on the patient interface such that it is readable by the reader device at least during the connection state between the ophthalmic system and the patient interface.
- 30 105. Ophthalmic system of any one of claims 103 or 104, as far as this claim relates to claim 80, wherein the ophthalmic system includes an identification module configured to identify the patient interface based on the information read out from the machine-readable identifier.
106. Ophthalmic system of claim 105, wherein the identification module is configured to determine whether the patient interface has already been used in a previous session and, if so, to not support further use of

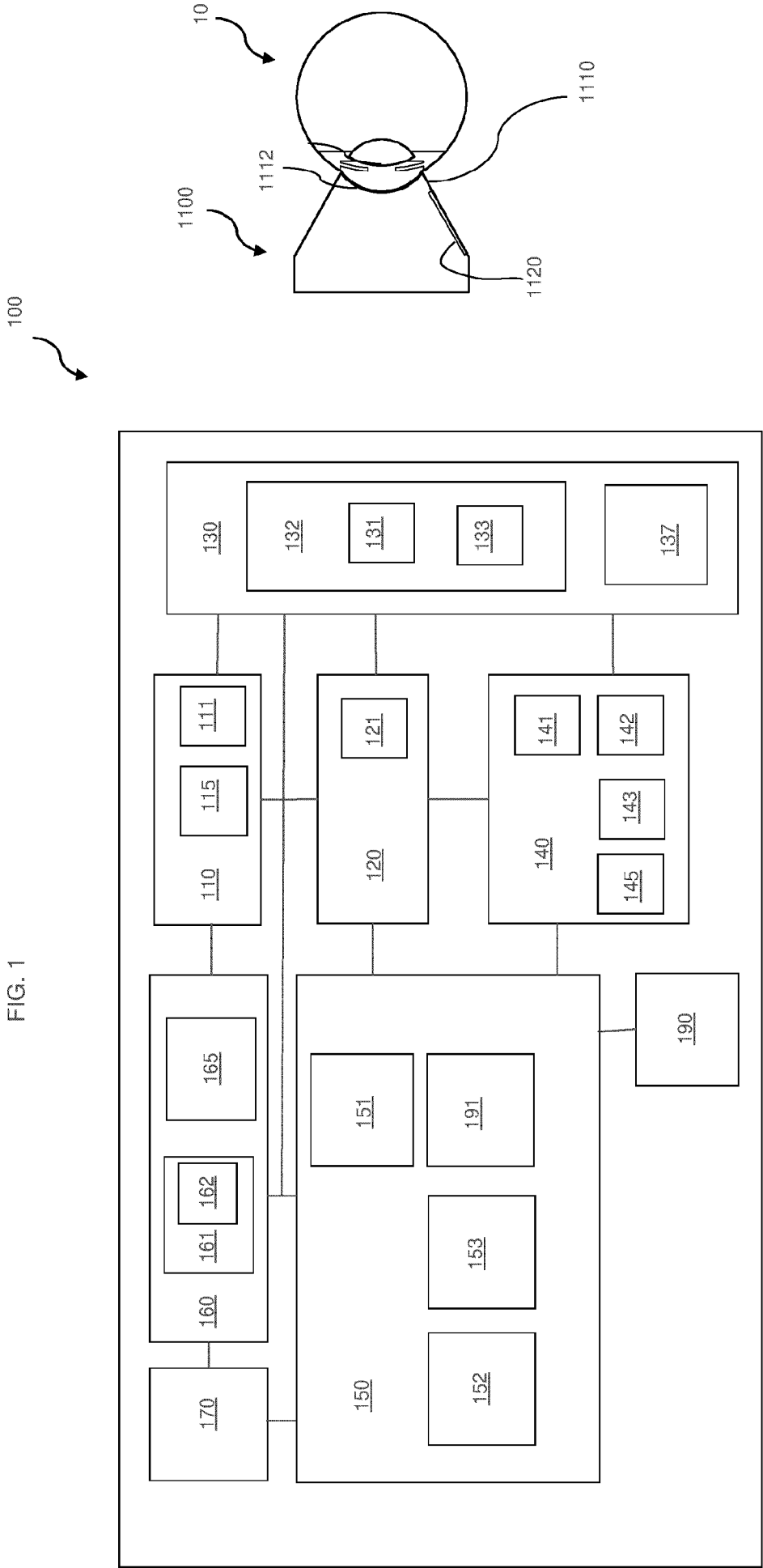
the patient interface.

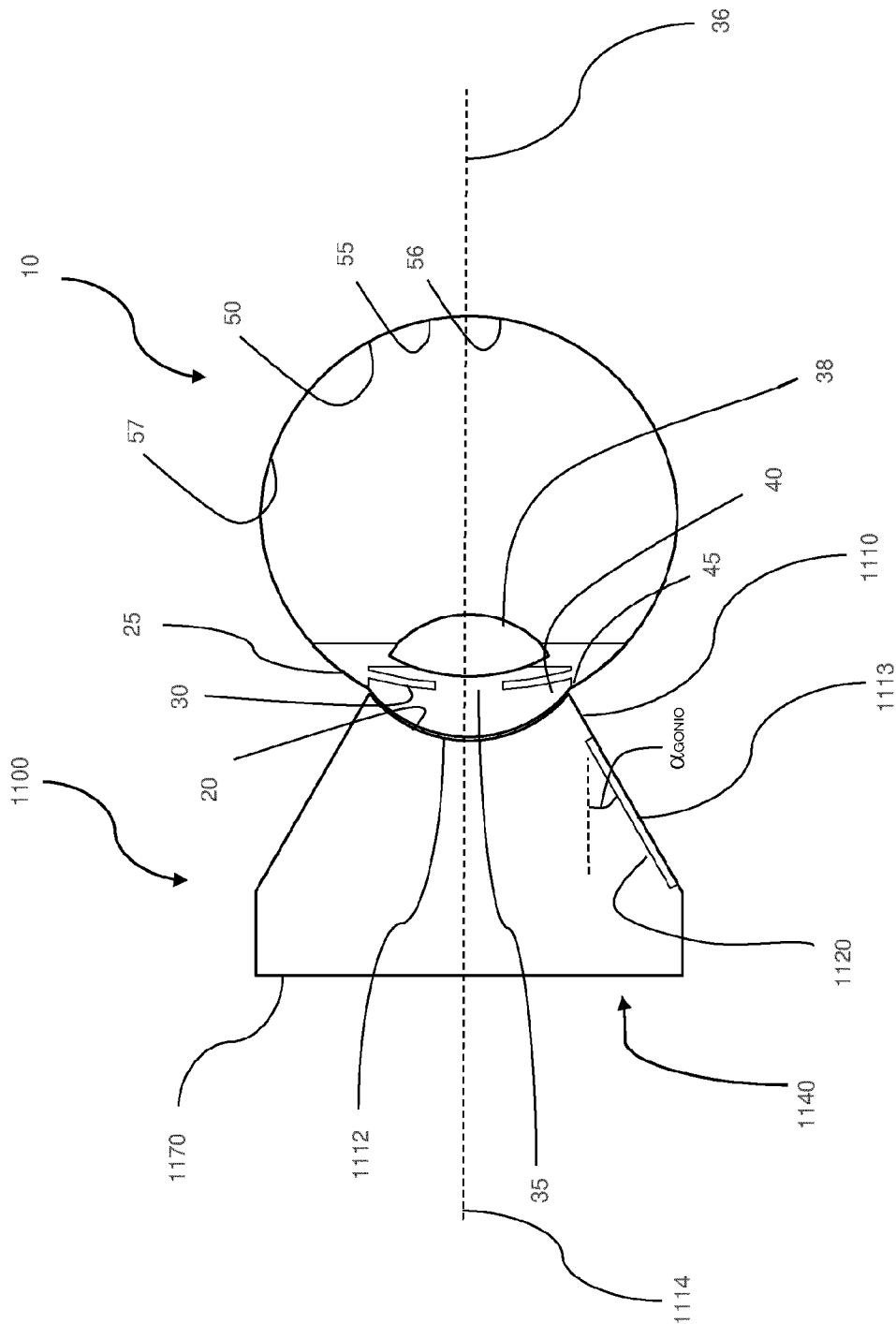
107. Ophthalmic system of any one of claims 103 to 106, as far as this claim relates to claims 81, wherein the identification module is configured to provide one or more of the optical characteristics to:

- 5 the image processing device,
 the illumination device or an illumination control unit thereof,
and/or
 the focus focusing assembly or a focus control module thereof,
as far as this claim refers to any one of claims 38 to 43.

10 108. Ophthalmic system of any one of claims 103 to 107, as far this claim refers to claim 88, wherein the image processing module is configured to identify the marker within the image of the camera and to use the identified marker to determine one or more of:

- 15 an azimuthal orientation of the patient interface,
 an azimuthal orientation of the at least one mirror surface,
and/or
 an azimuthal orientation of at least one characteristic feature
of the eye within the image relative to the marker.





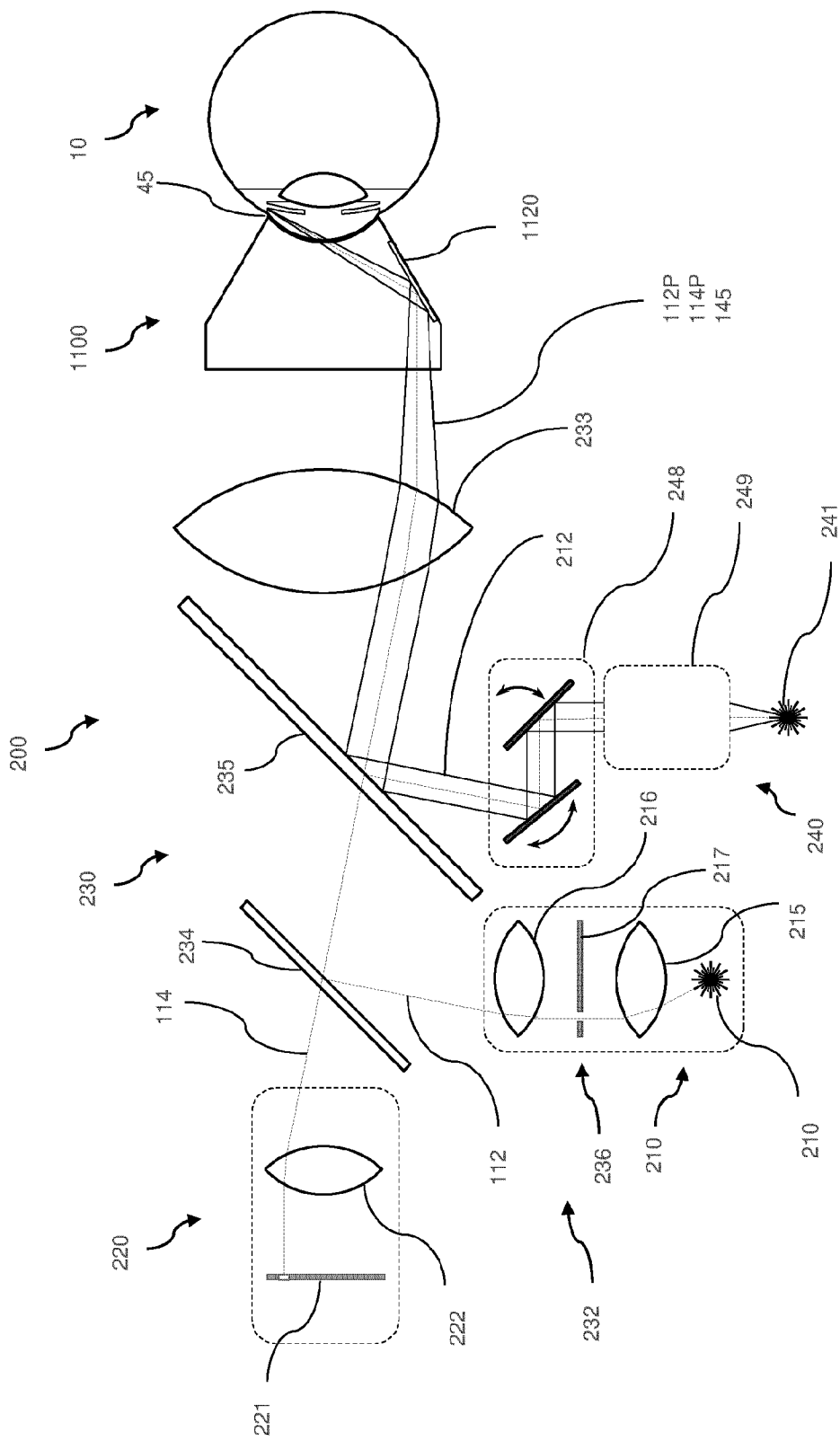


FIG. 2A

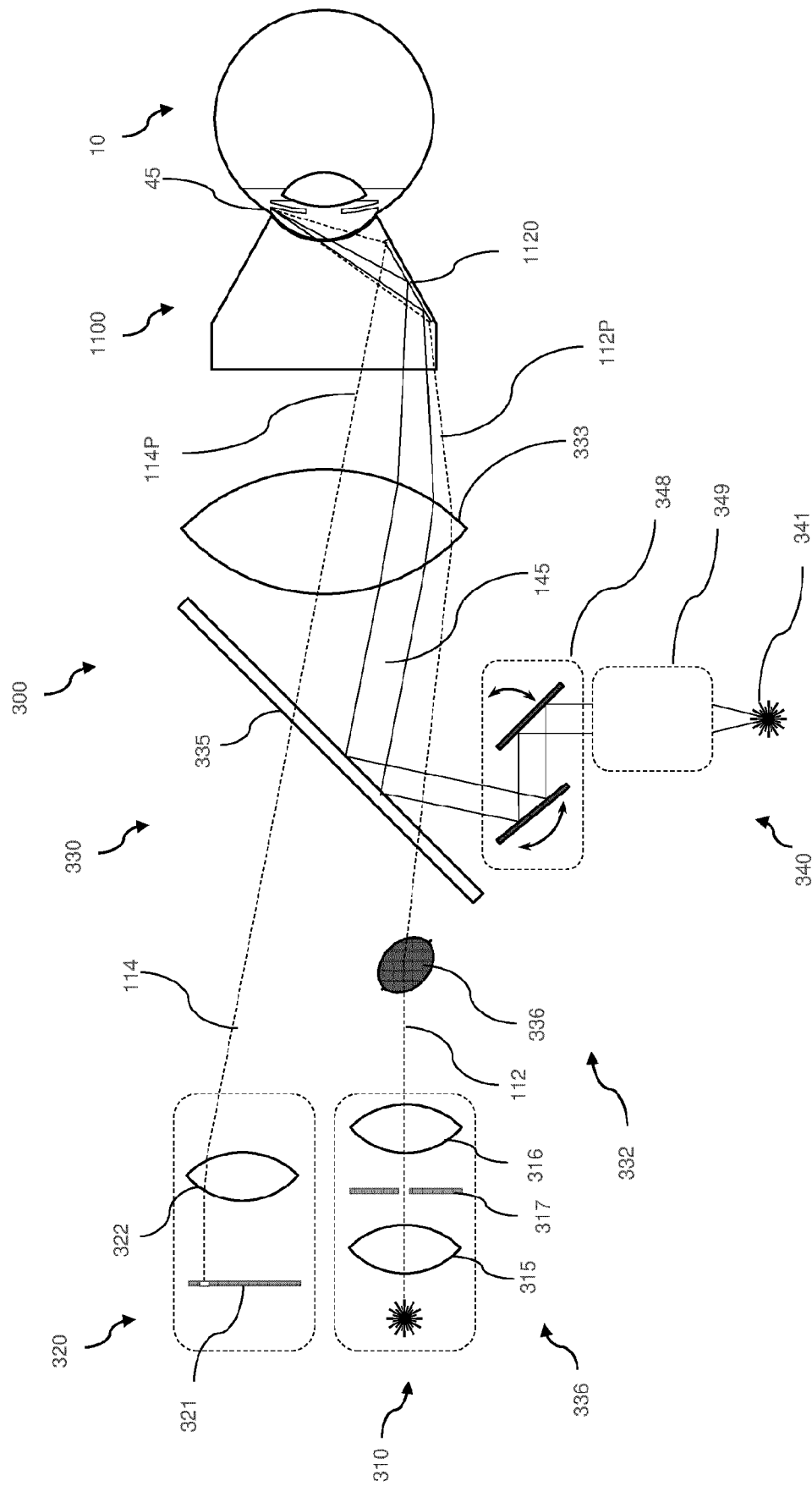


FIG. 2B

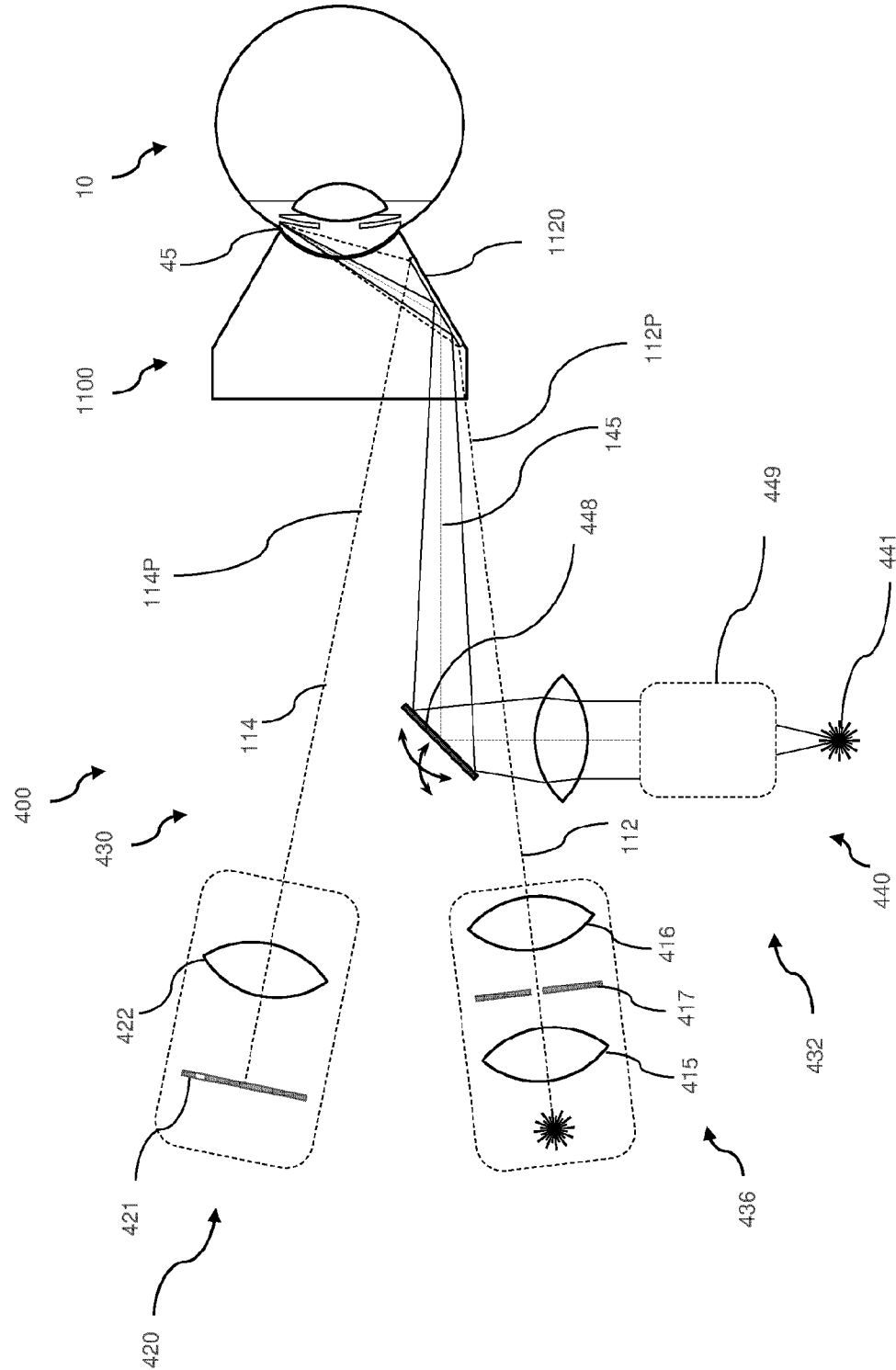


FIG. 2C

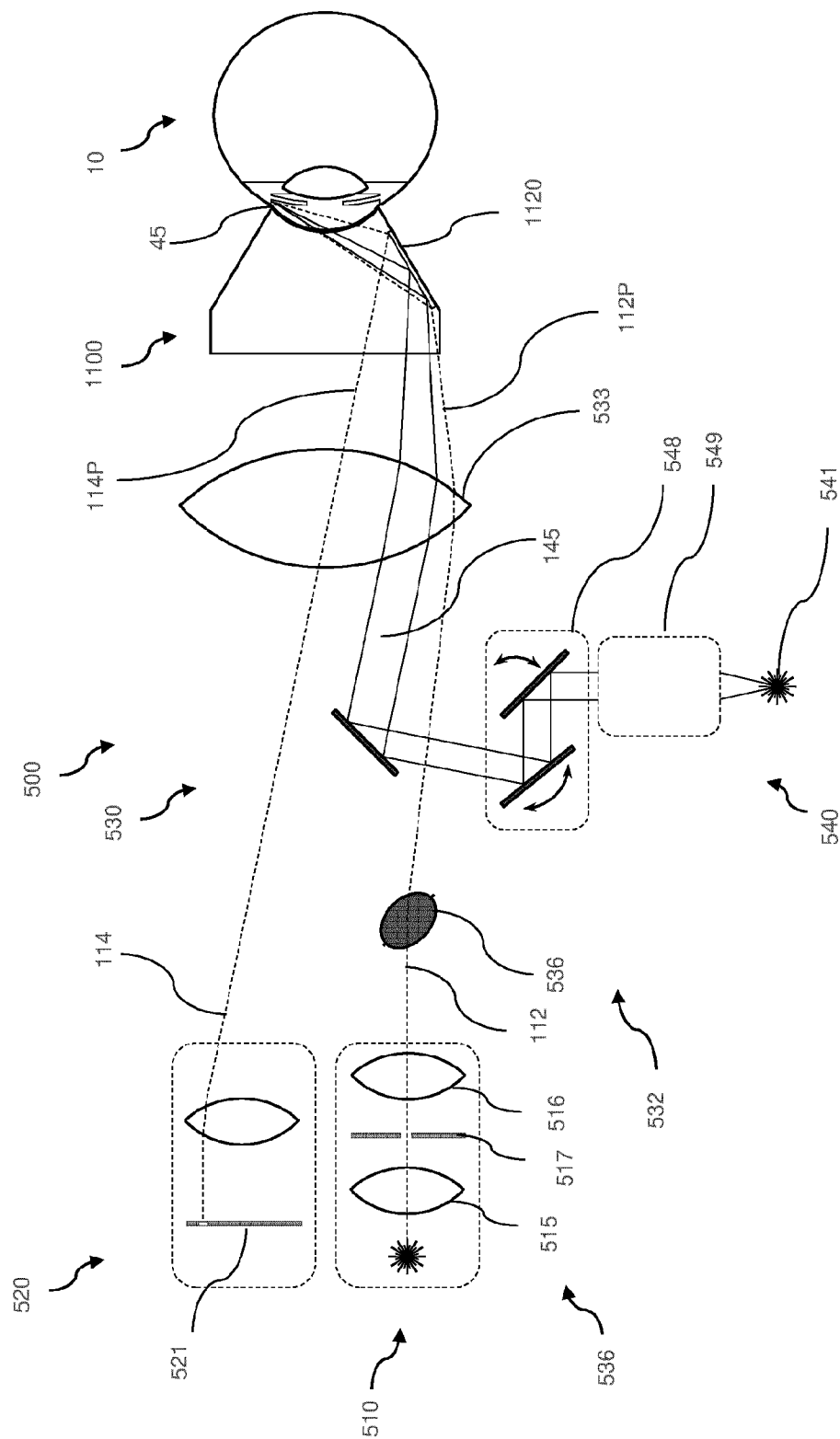


FIG. 2D

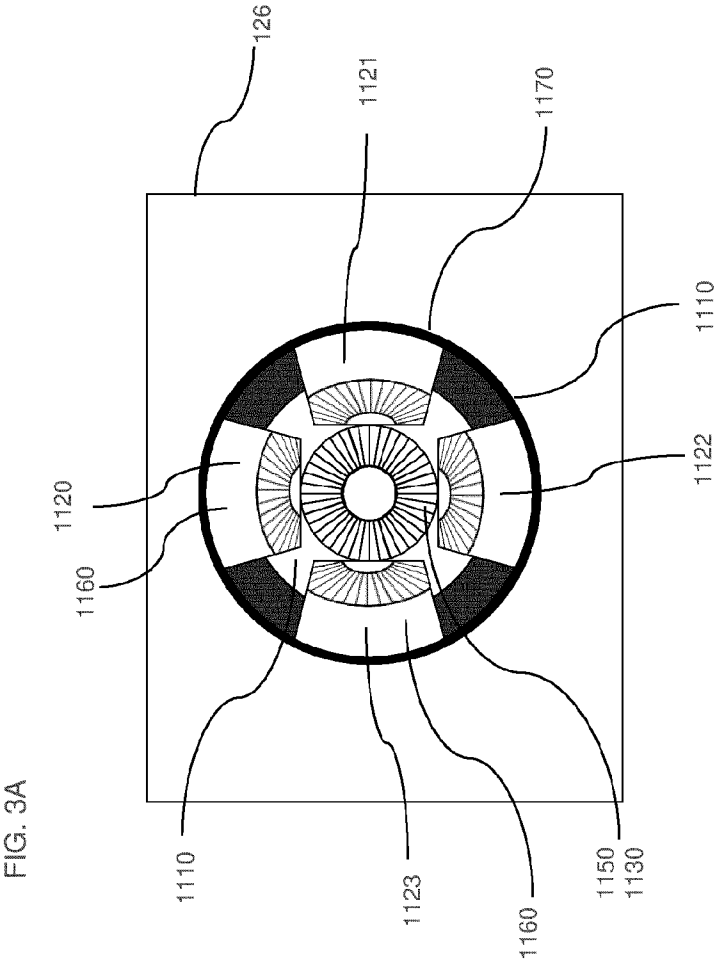
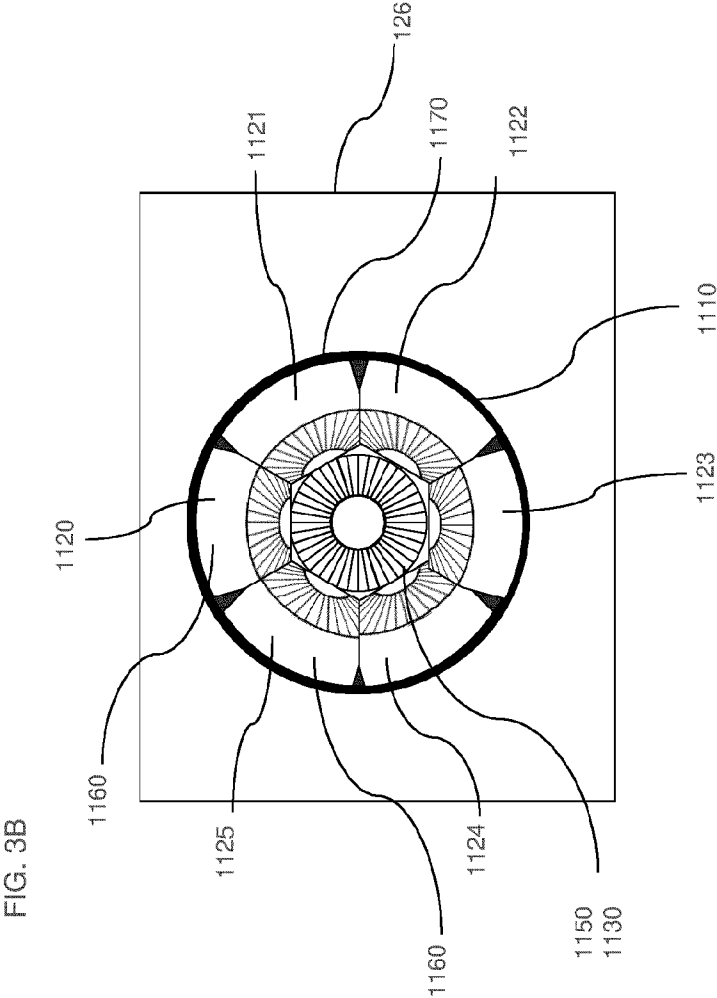


FIG. 4C

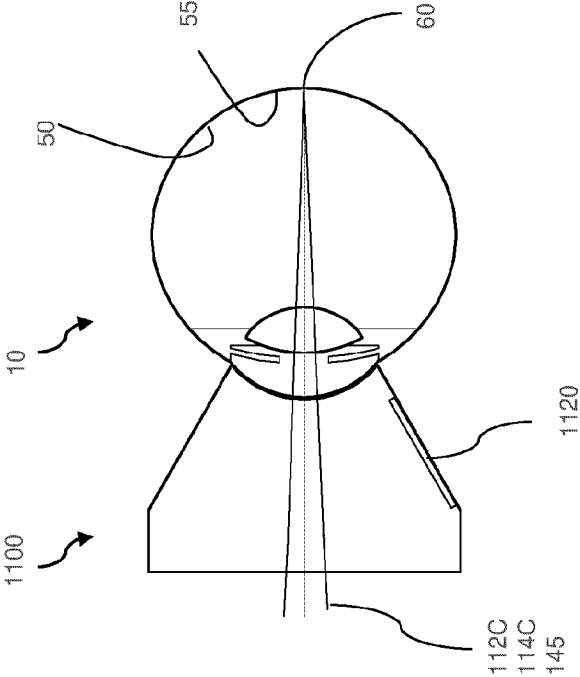


FIG. 4B

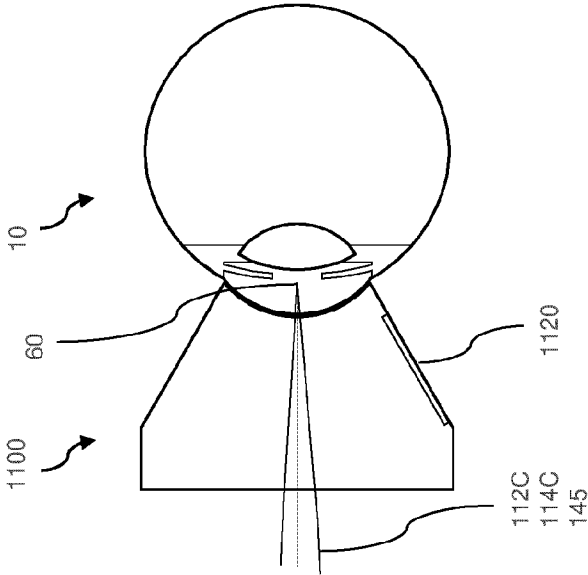


FIG. 4A

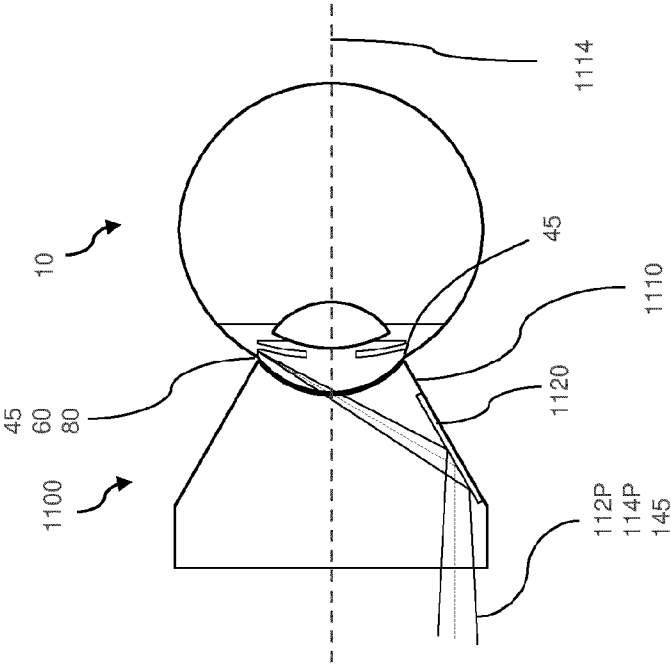


FIG. 5A

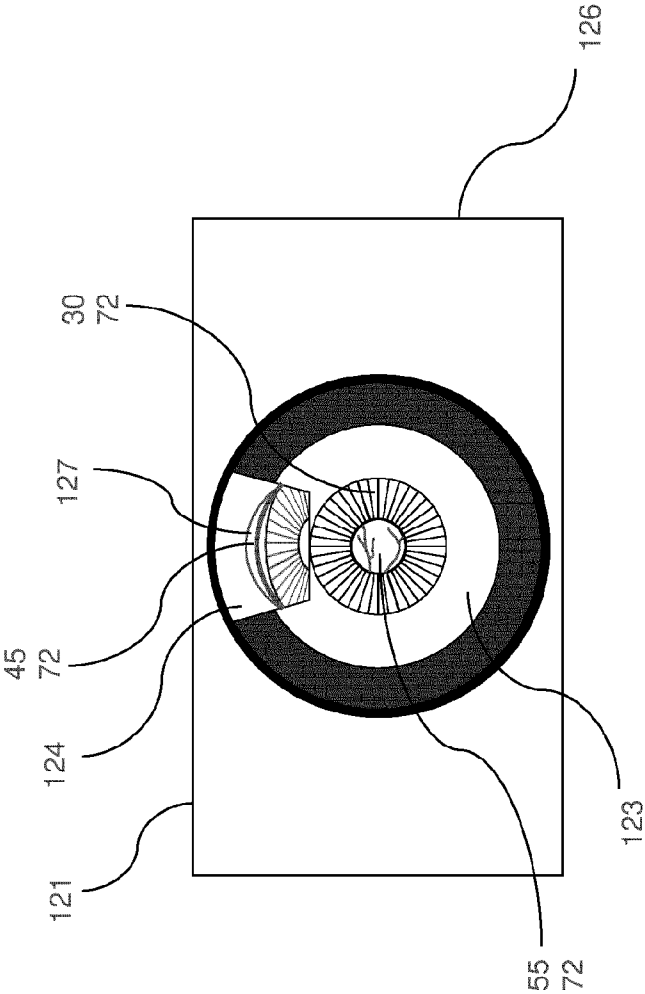


FIG. 5B

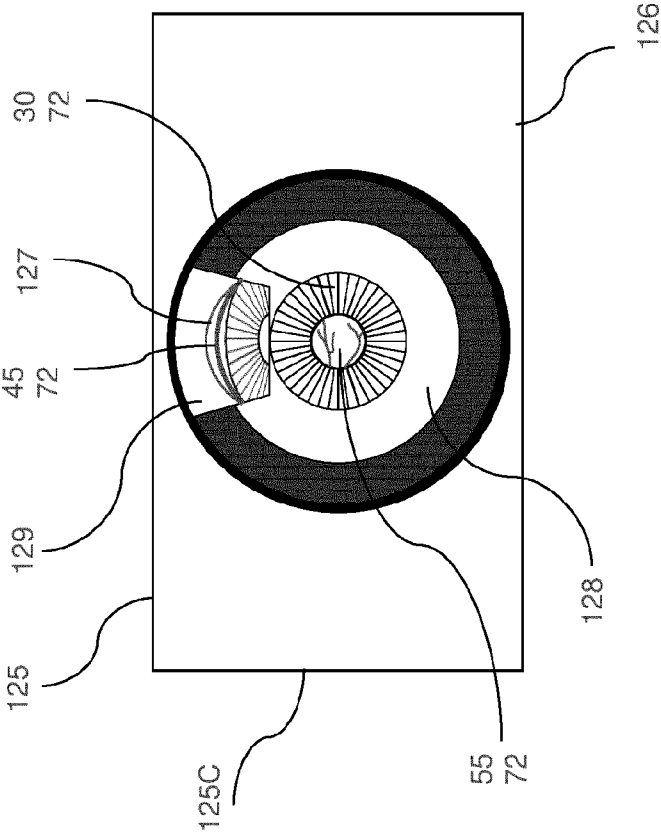


FIG. 6A

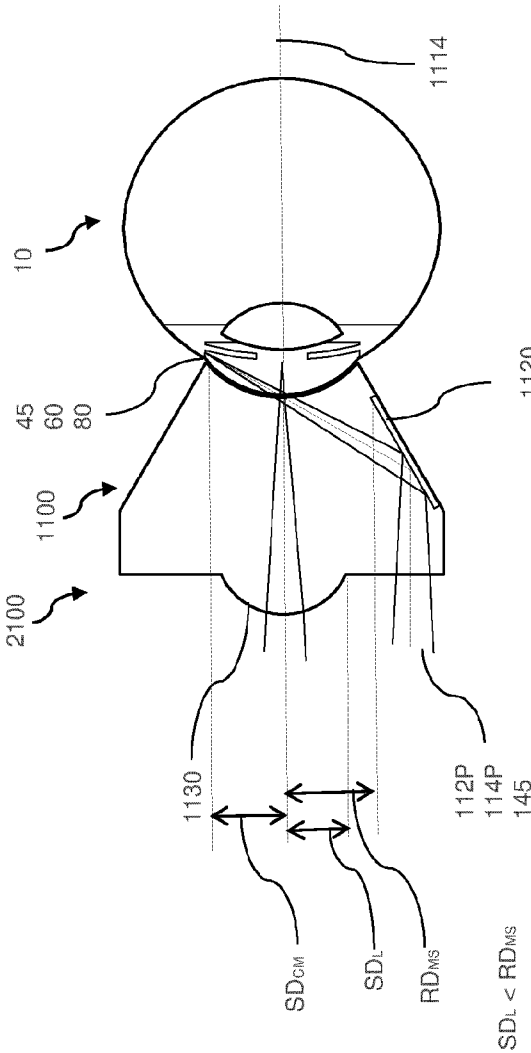


FIG. 6B

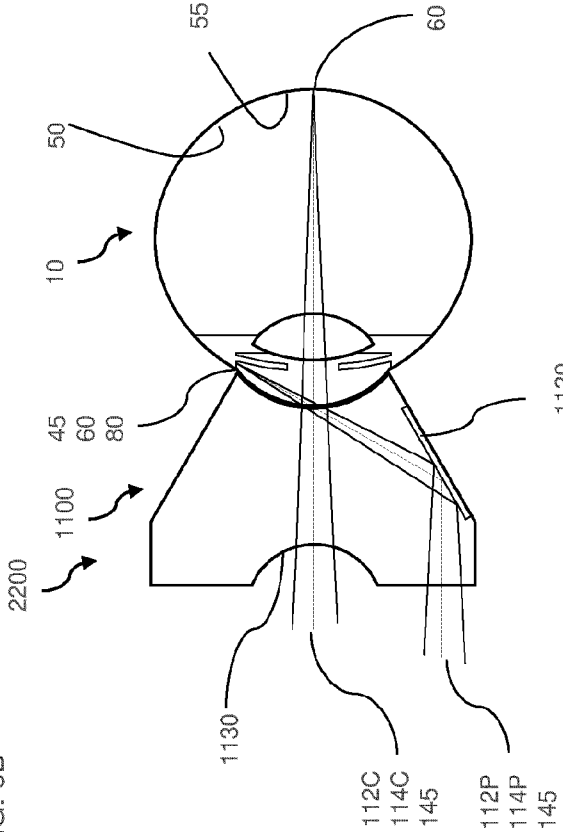


FIG. 7A

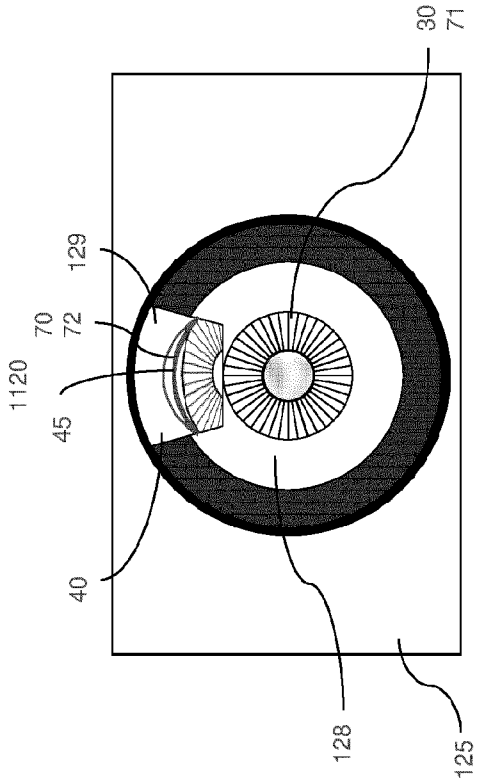
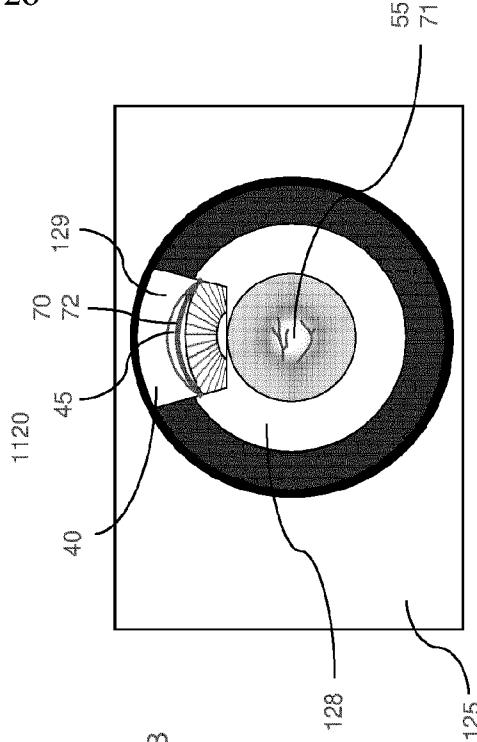
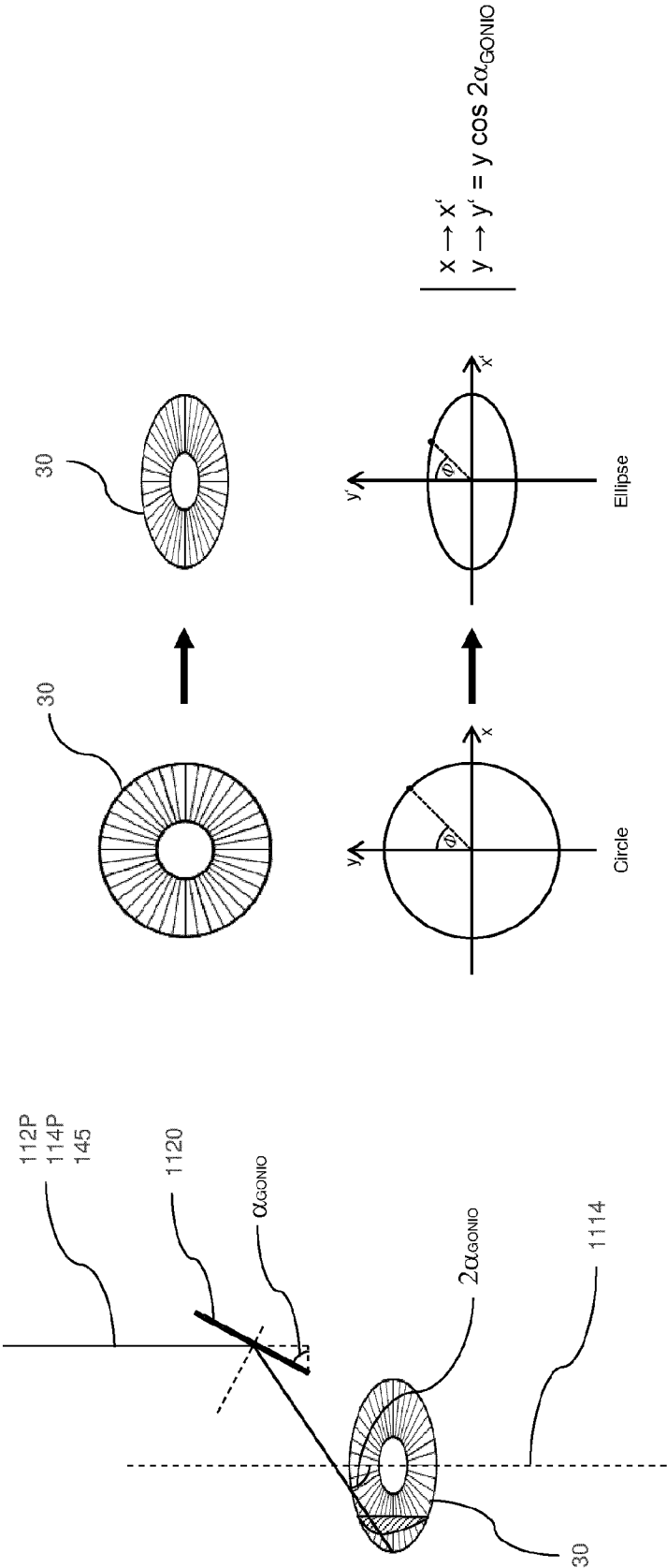


FIG. 7B





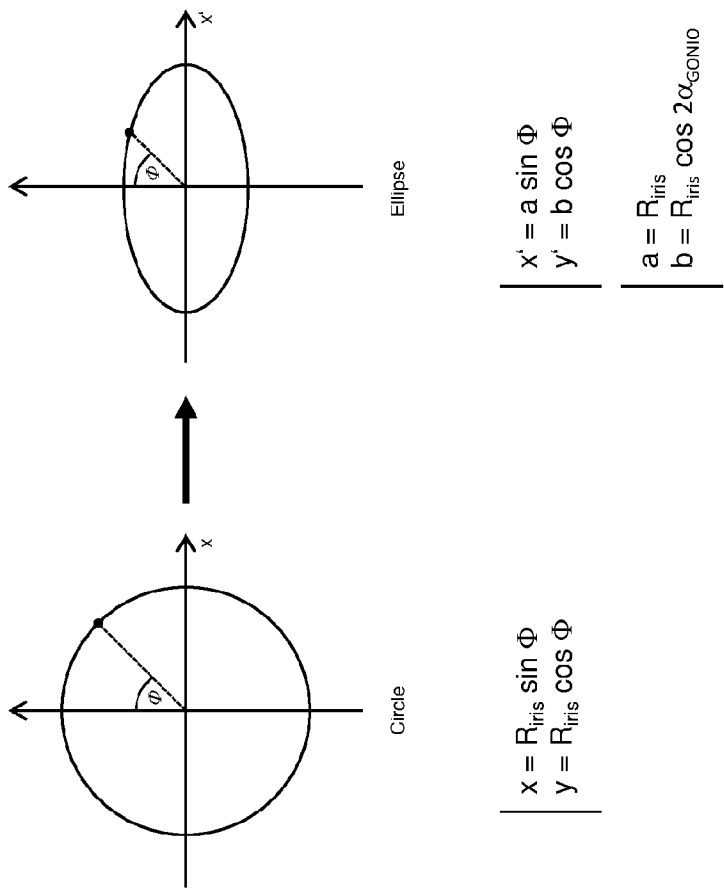


FIG. 9

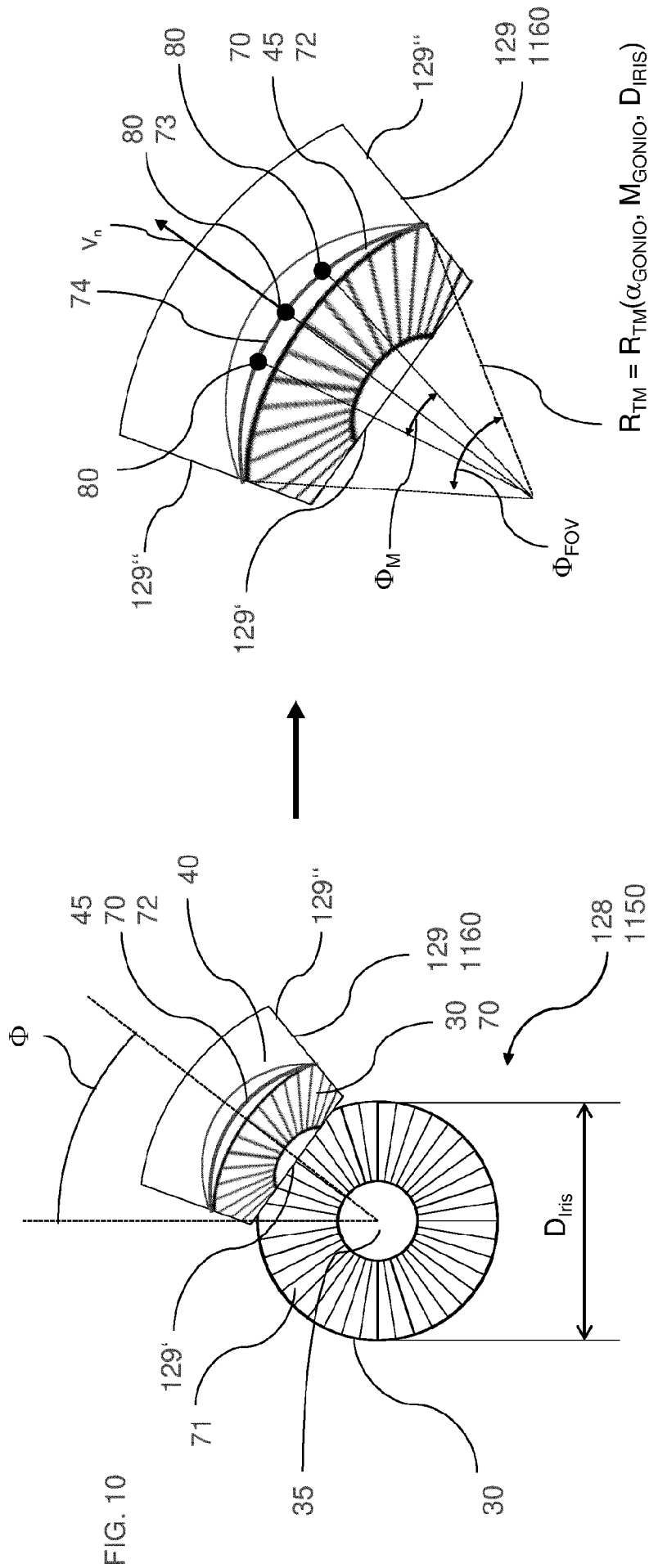


FIG. 11

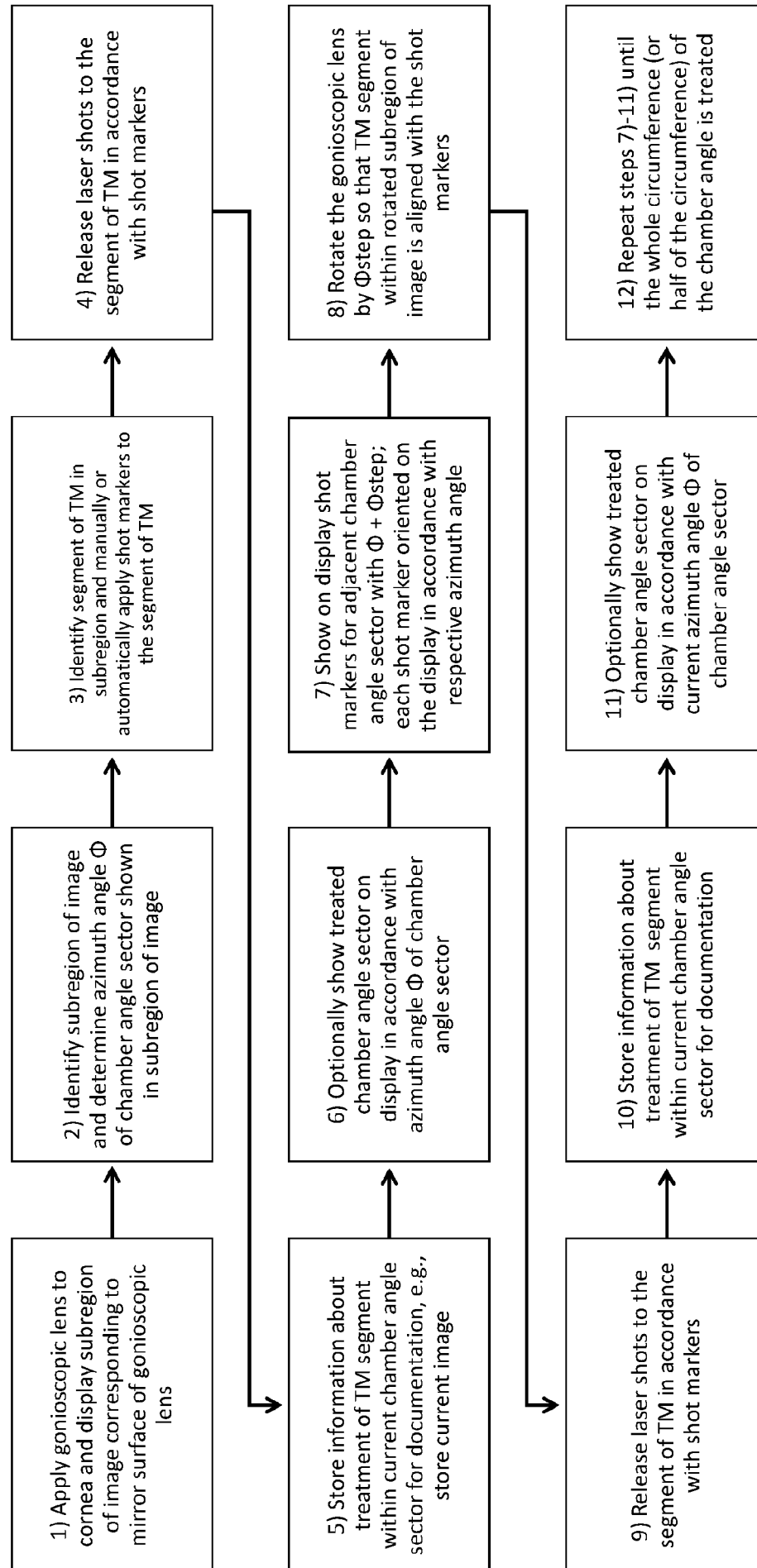


FIG. 12

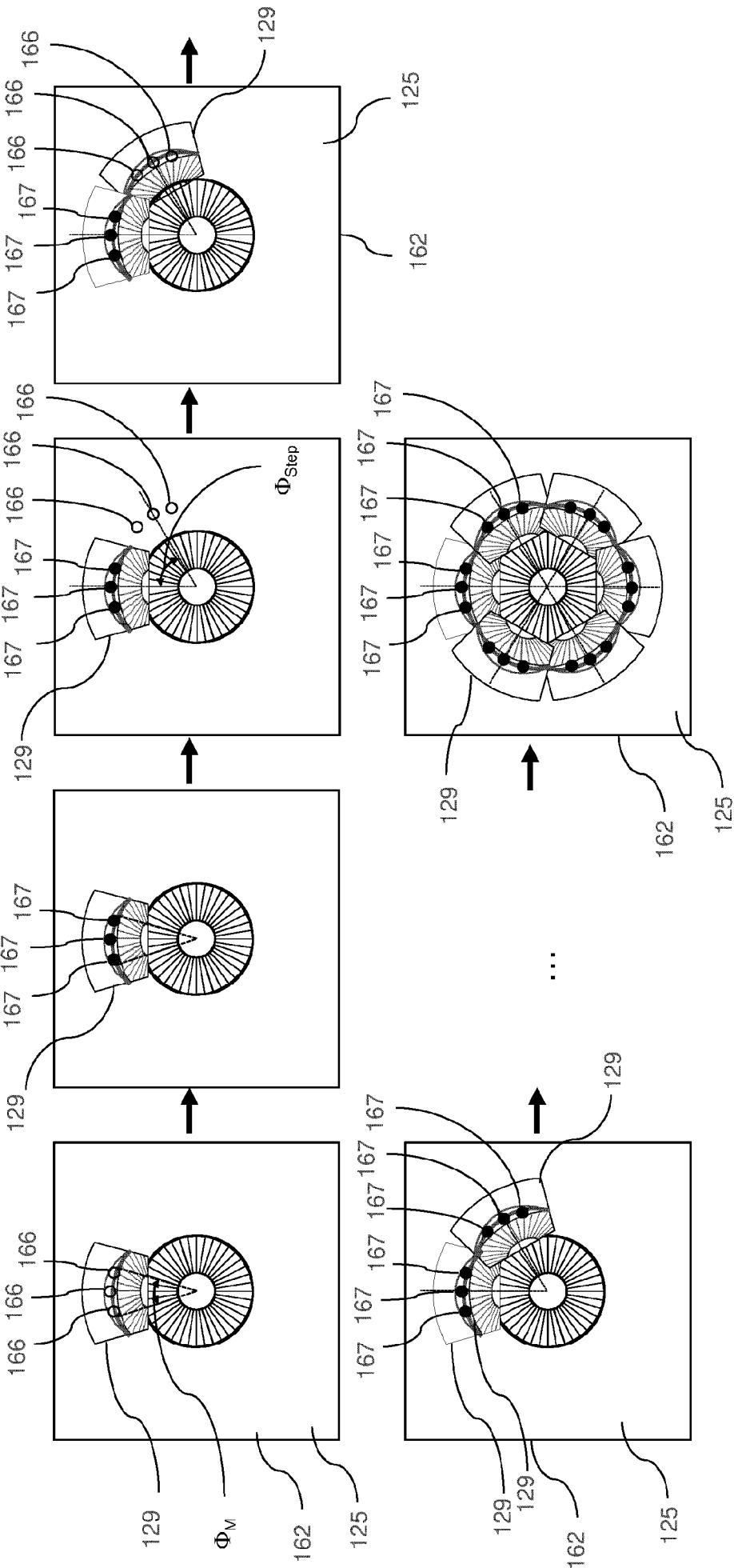
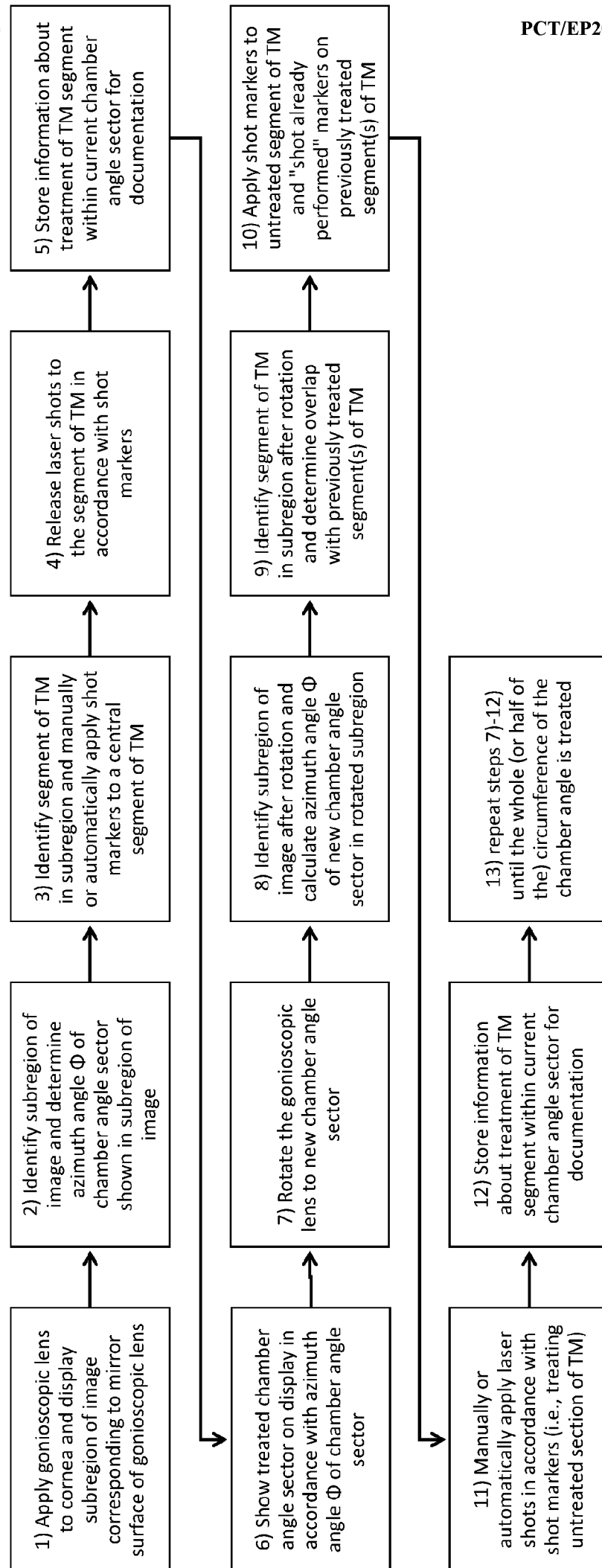
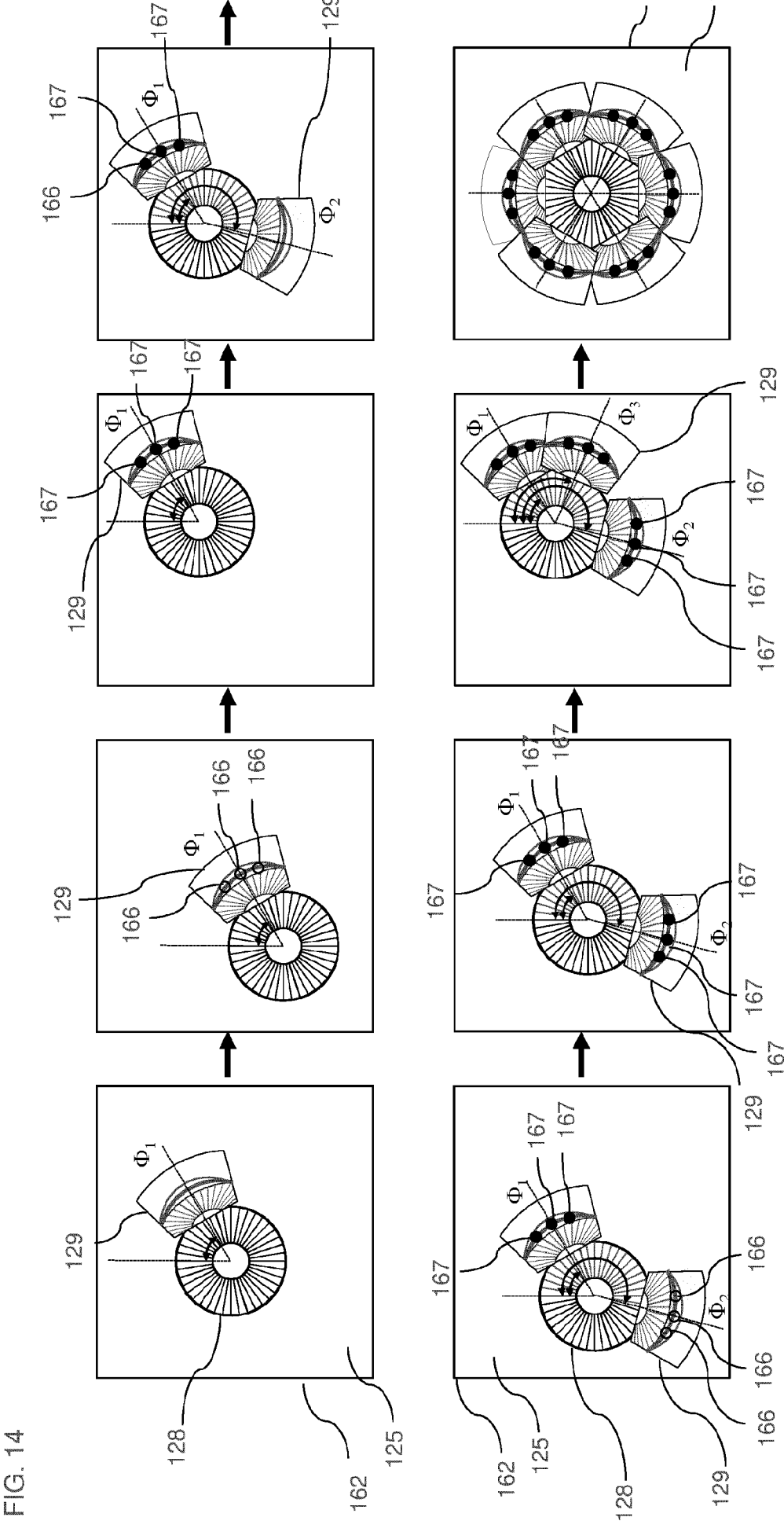
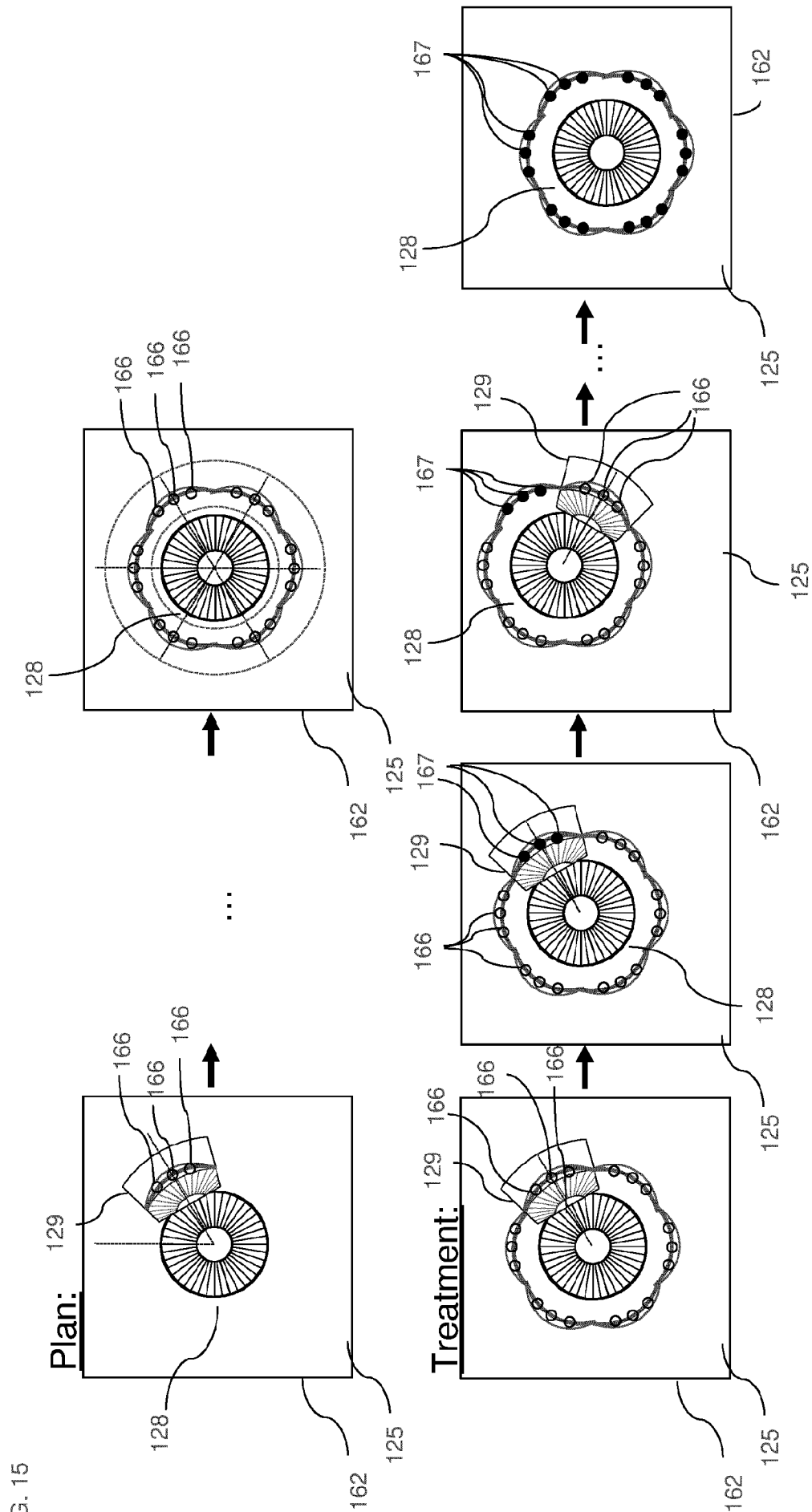


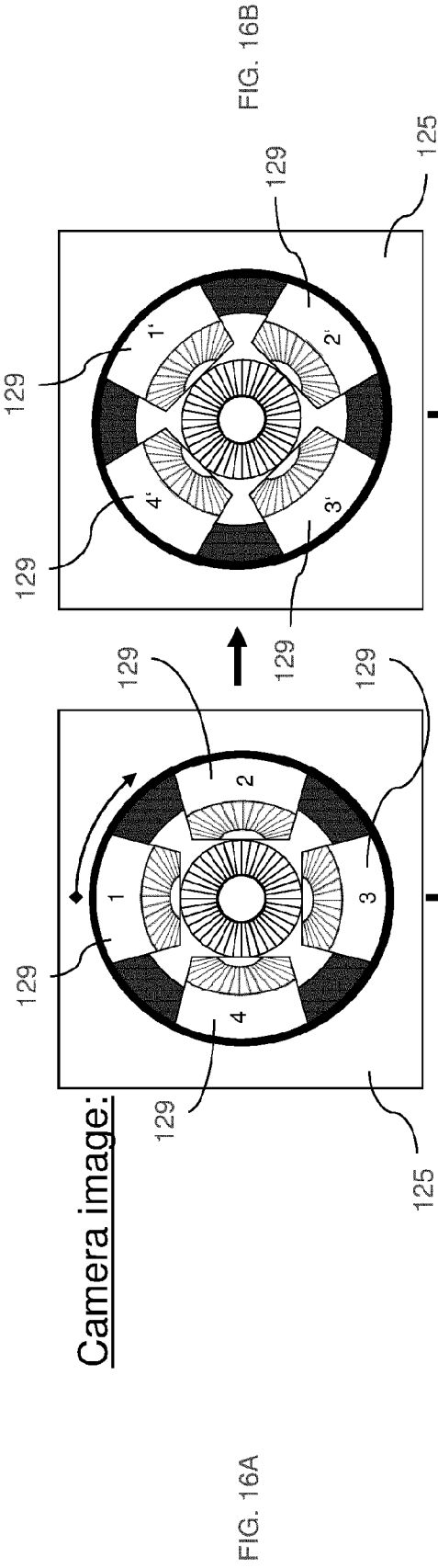
FIG. 13



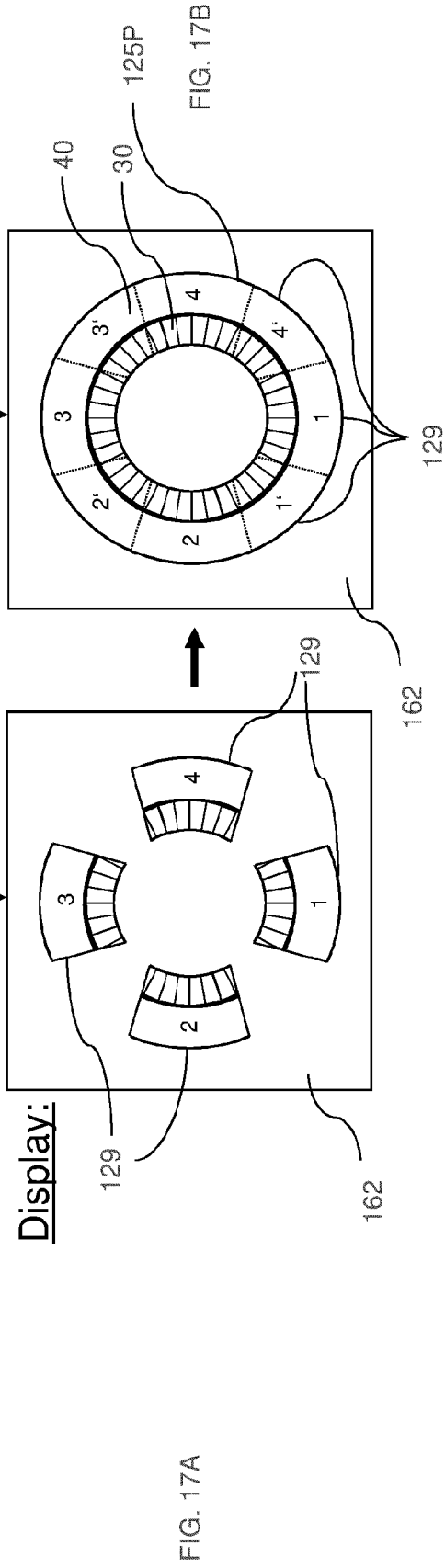




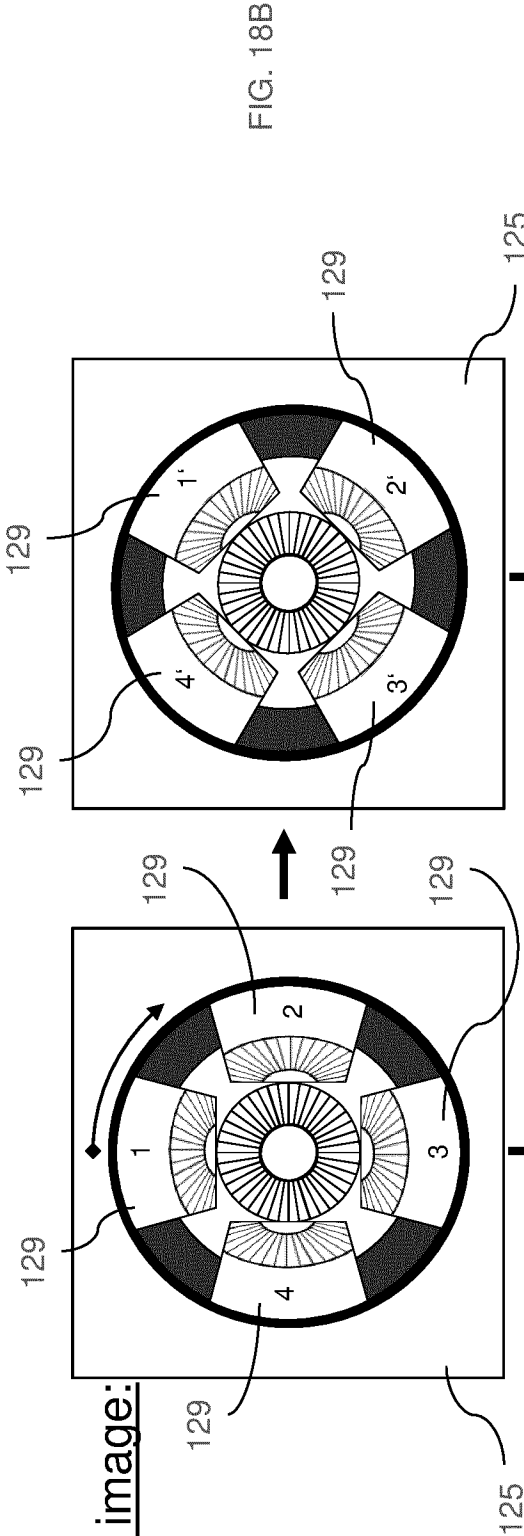
Camera image:



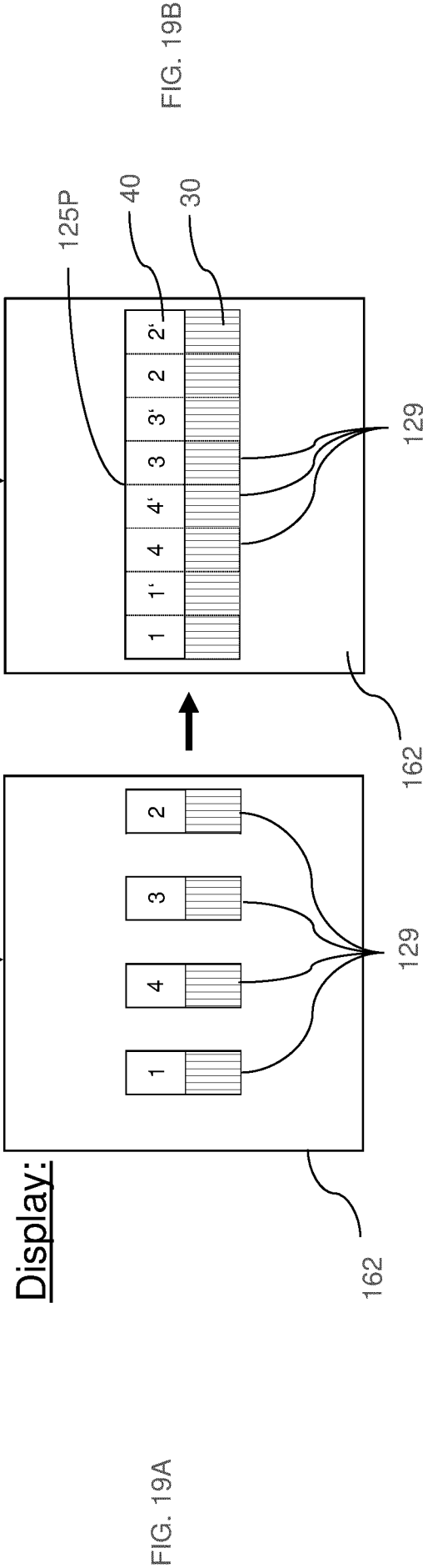
Display:



Camera image:



Display:



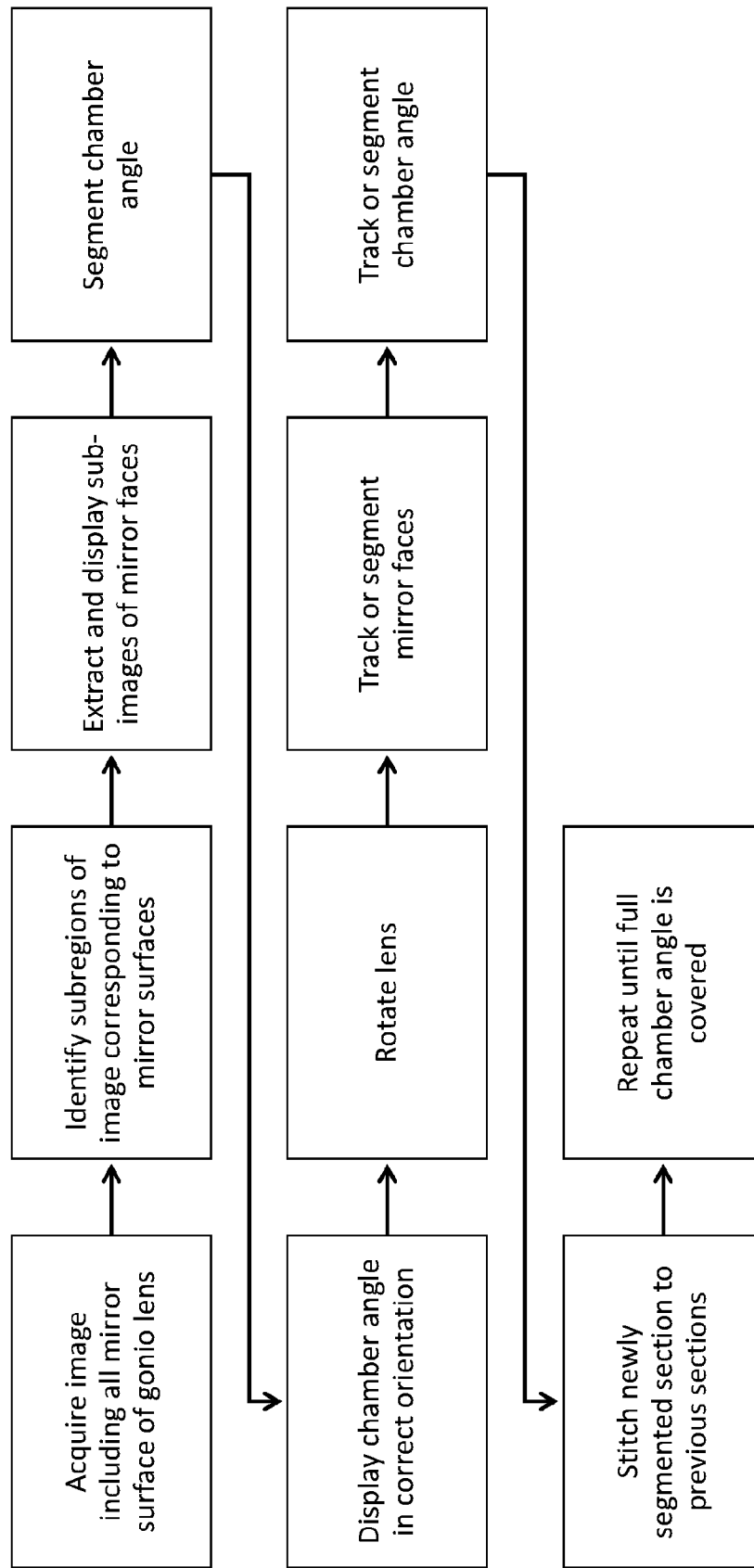


FIG. 20

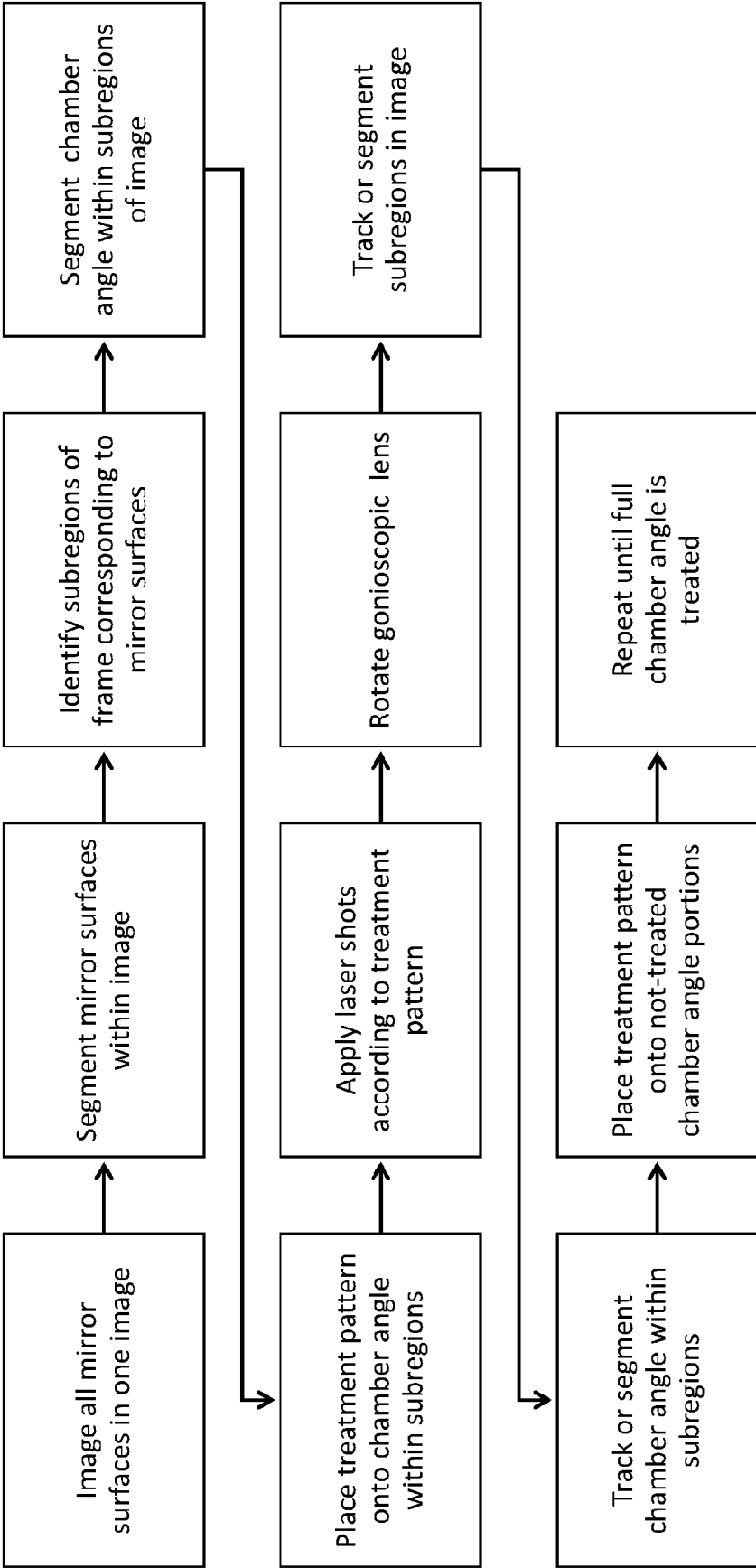
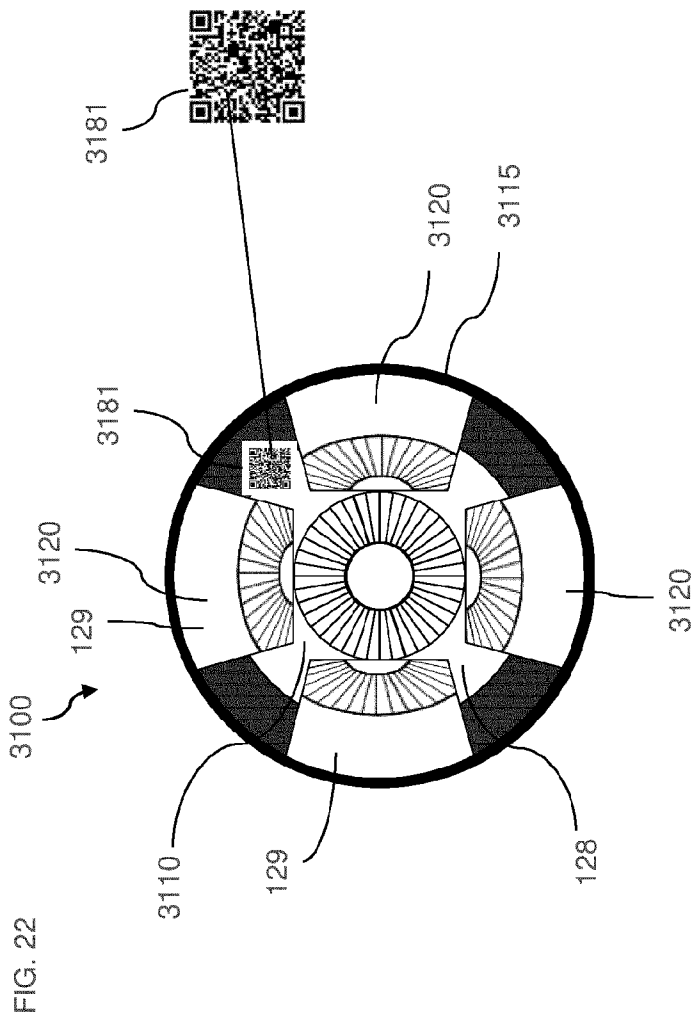
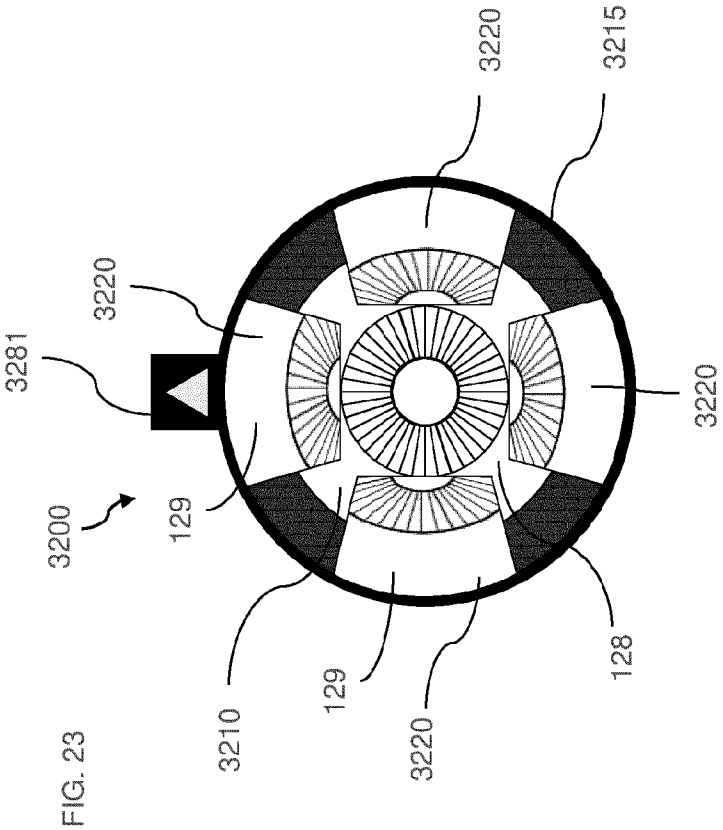


FIG. 21



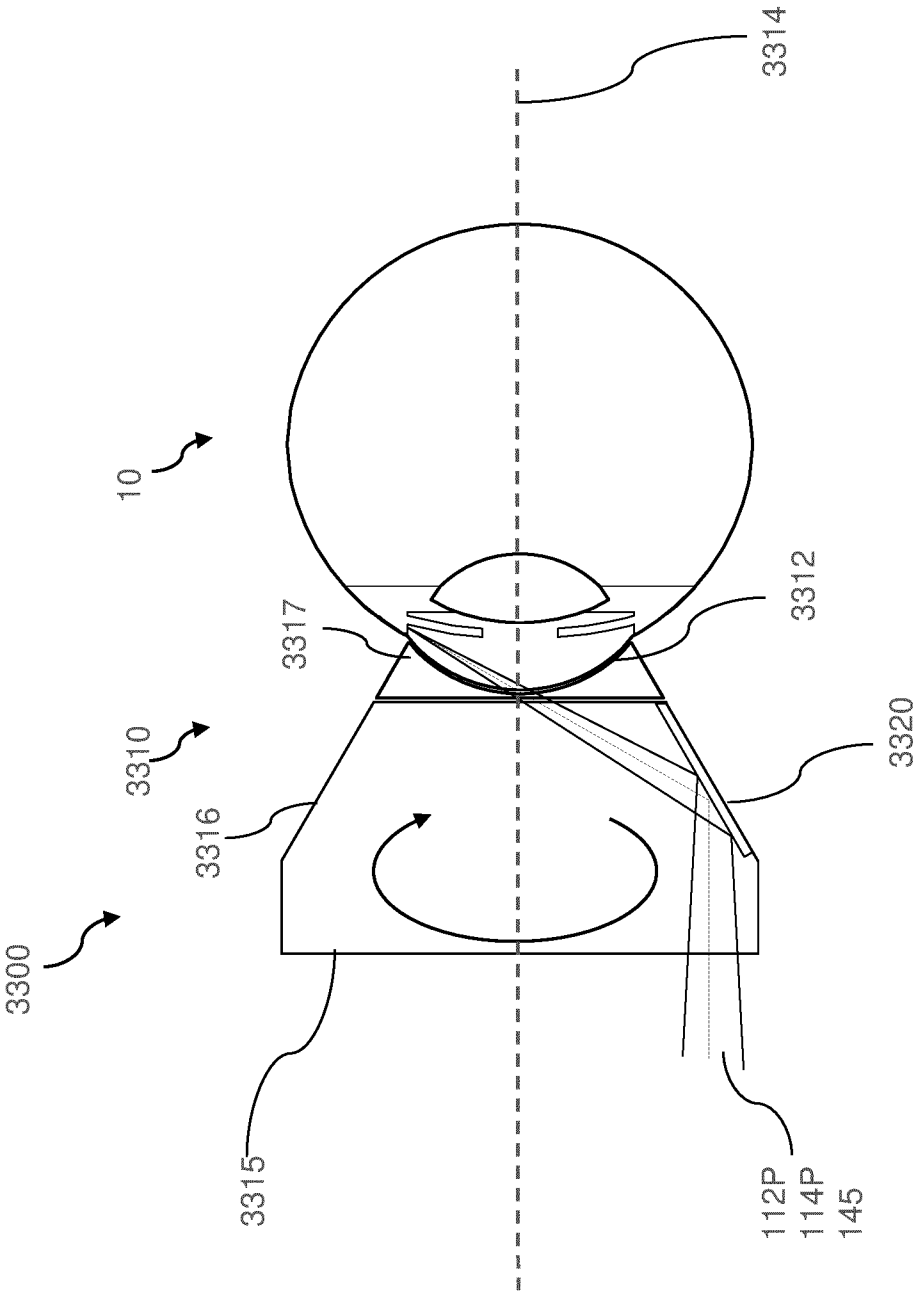


FIG. 24

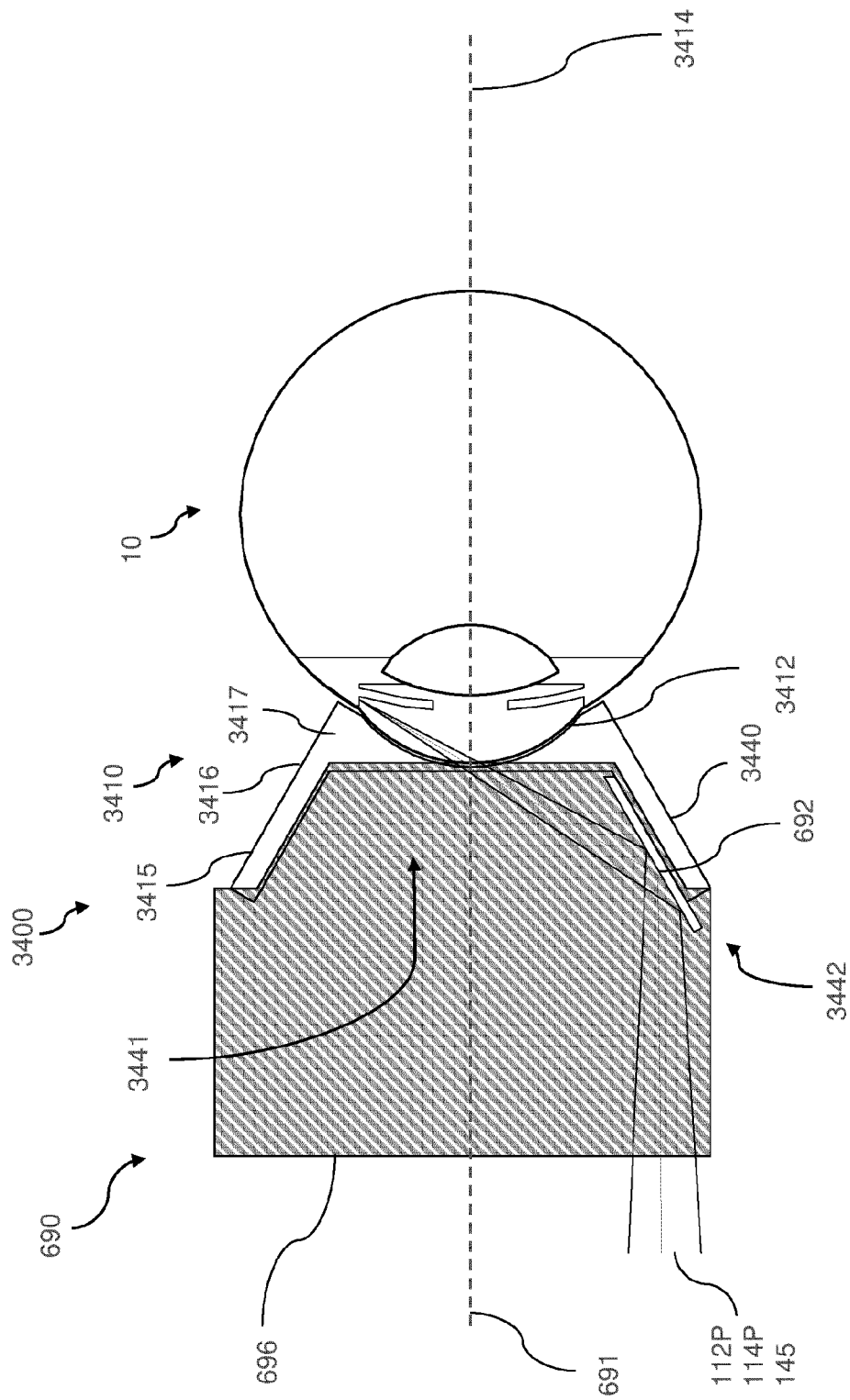
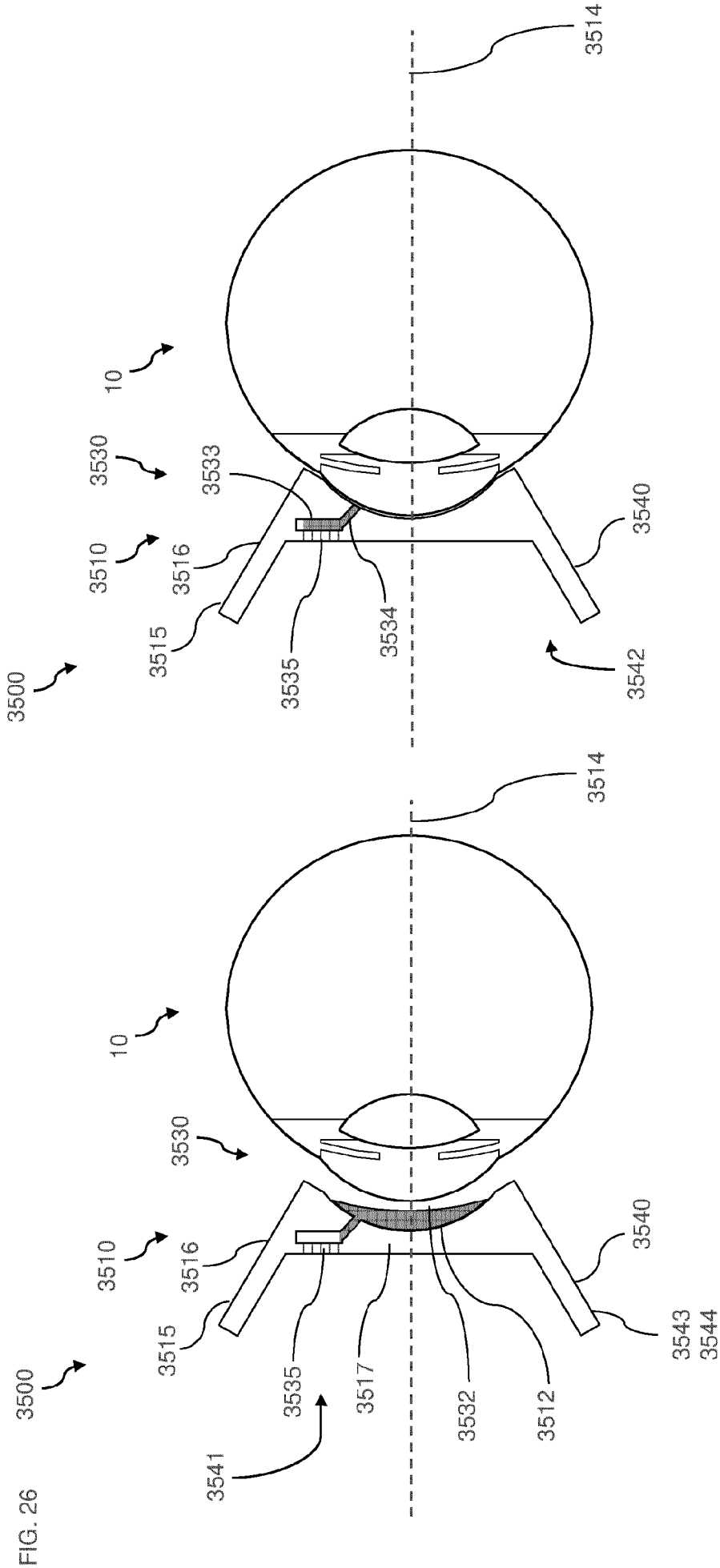


FIG. 25



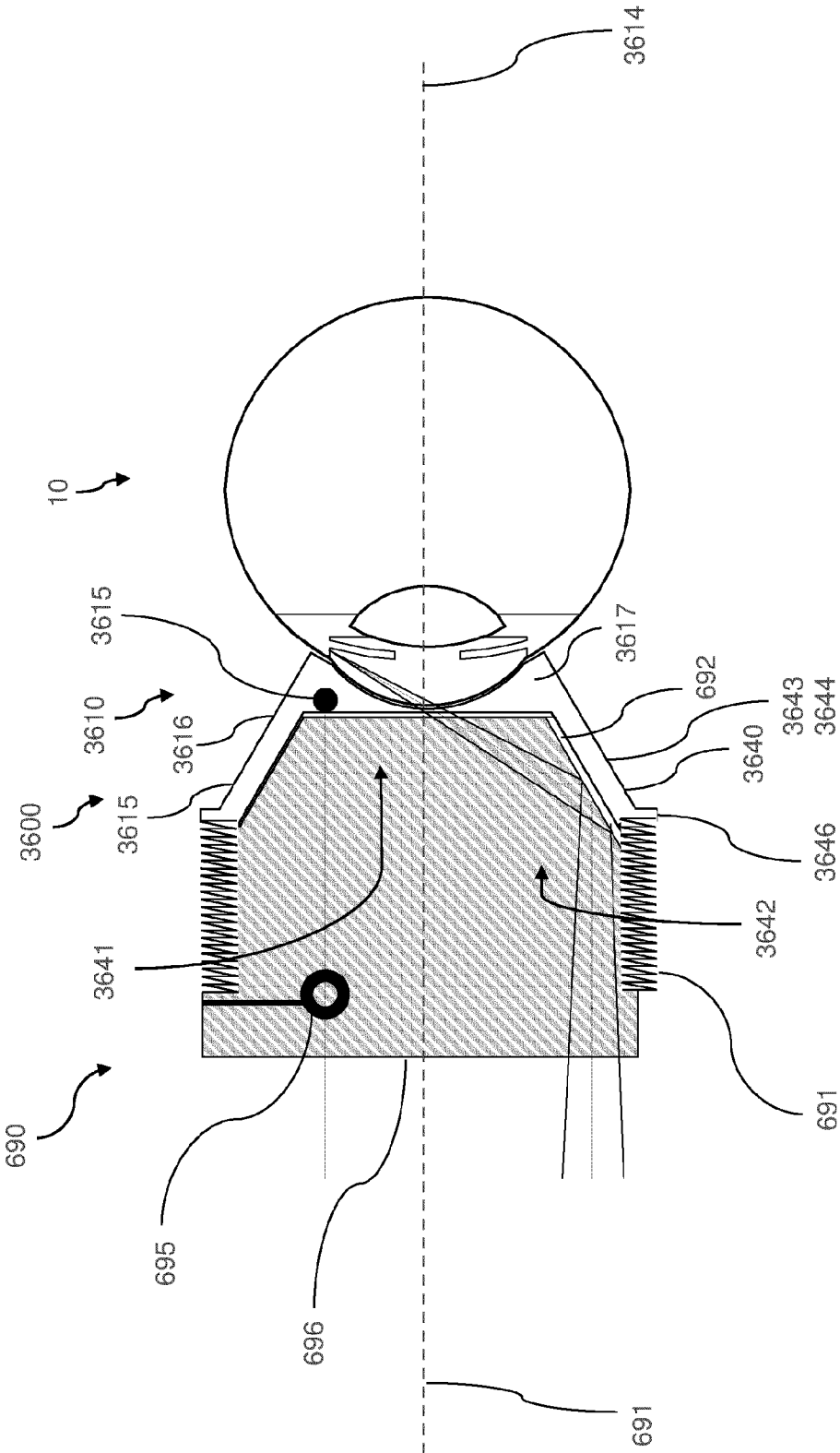


FIG. 27

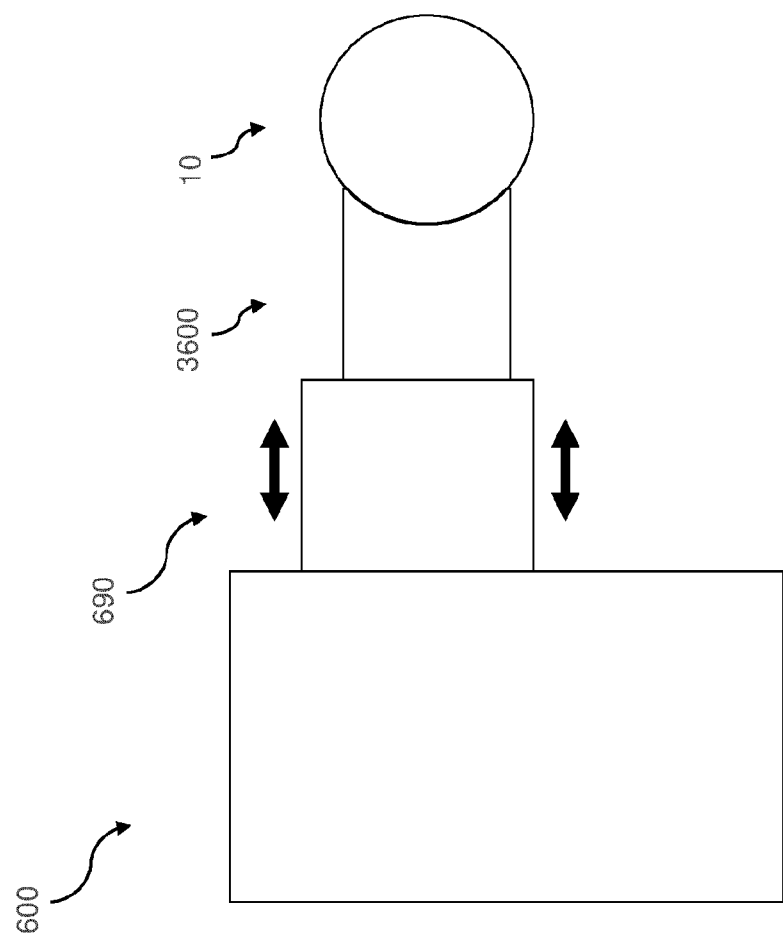


FIG. 28

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2023/065381

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

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

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

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

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

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims;; it is covered by claims Nos.:
2-18 (completely) ; 1 (partially)

Remark on Protest

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

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2023/065381

A. CLASSIFICATION OF SUBJECT MATTER INV. A61B3/00 A61B3/117 A61B3/12 A61B3/14 ADD.		
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) A61B		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2019/012551 A1 (SRINIVAS HIREKATUR VENKATARAM [IN]) 17 January 2019 (2019-01-17)	1-9
Y	the whole document -----	10-18
Y	US 2020/306080 A1 (HEREKAR RAJEEV [US] ET AL) 1 October 2020 (2020-10-01) paragraph [0205] - paragraph [0223] -----	10-14
Y	WO 2013/094588 A1 (DAINIPPON PRINTING CO LTD [JP]) 27 June 2013 (2013-06-27) page 13, line 8 - line 13 -----	15-18
X	WO 2019/103631 A1 (REMO JOCELYN THERESE M [PH]; TAN JAESSER T [PH]) 31 May 2019 (2019-05-31)	1
A	page 4, line 21 - page 7, line 23 ----- -/-	2-18
☒ 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 "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		Date of mailing of the international search report
8 December 2023		08/02/2024
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Alvazzi Delfrate, S

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2023/065381

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2014/354951 A1 (IZATT JOSEPH A [US] ET AL) 4 December 2014 (2014-12-04) paragraph [0032] - paragraph [0041] -----	1-18

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2023/065381

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2019012551 A1	17-01-2019	NONE	
US 2020306080 A1	01-10-2020	EP 3684310 A1	29-07-2020
		US 2020306080 A1	01-10-2020
		WO 2019060756 A1	28-03-2019
WO 2013094588 A1	27-06-2013	CN 104011767 A	27-08-2014
		JP 5966341 B2	10-08-2016
		JP 2013127739 A	27-06-2013
		KR 20140102174 A	21-08-2014
		TW 201342306 A	16-10-2013
		US 2014314336 A1	23-10-2014
		WO 2013094588 A1	27-06-2013
WO 2019103631 A1	31-05-2019	PH 12017050116 A1	10-06-2019
		WO 2019103631 A1	31-05-2019
US 2014354951 A1	04-12-2014	US 2014354951 A1	04-12-2014
		US 2017127938 A1	11-05-2017
		WO 2013112700 A1	01-08-2013

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 2-18 (completely); 1 (partially)

Ophthalmic system configured to identify one subregion of the image corresponding to one mirror surface of a gonioscopic lens

2. claims: 19-24 (completely); 1 (partially)

Ophthalmic system wherein an image processing module is configured to identify a curved line spanning the respective subregion of the image

3. claims: 25-30 (completely); 1 (partially)

Ophthalmic system comprising a laser system including at least one laser source, a laser beam steering device and a laser control module

4. claims: 31-37 (completely); 1 (partially)

Ophthalmic system wherein the illumination beams comprise central illumination beams

5. claims: 38-43 (completely); 1 (partially)

Ophthalmic system comprising a focusing assembly

6. claims: 44-49 (completely); 1 (partially)

Ophthalmic system comprising a gonioscopic lens assembly

7. claims: 50-69 (completely); 1 (partially)

Ophthalmic system wherein the image processing module is configured to provide instructions to the display device

8. claims: 70 (completely); 1 (partially)

Ophthalmic system comprising a laser parameter adjustment module

9. claims: 71-88

Patient interface

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

10. claims: 89-108 (completely); 1 (partially)

Ophthalmic system including a coupling member
