(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(54) Title: OPHTHALMOLOGIC APPARATUS AND CONTROL METHOD THEREOF

FIG. 3A
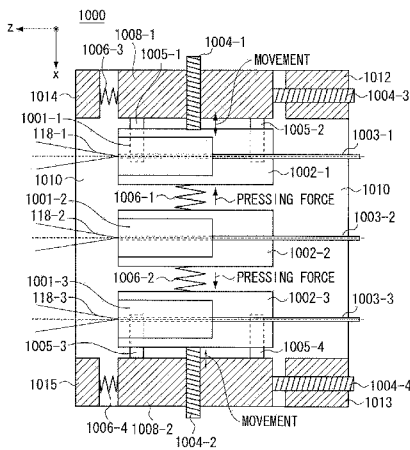
FIG. 3B
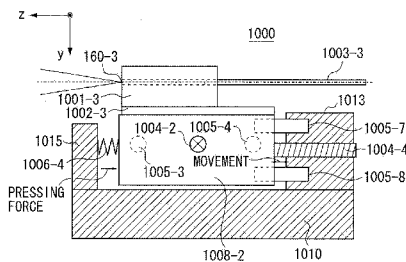
(57) Abstract: An ophthalmologic apparatus includes a scanning optical system configured to scan a plurality of different regions of a test eye with a plurality of different measurement light beams, an acquisition unit configured to acquire information about a shape of the test eye, and an adjustment unit configured to adjust a relative position between an output end of a measurement light beam that serves as a reference among the plurality of measurement light beams and an output end of other measurement light beams among the measurement light beams based on the acquired information about the shape of the test eye.
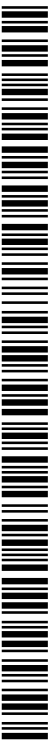
WO 2011/122684 A1

WO 2011/122684 A1

SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

DESCRIPTION

OPHTHALMOLOGIC APPARATUS AND CONTROL METHOD THEREOF

Technical Field

[0001]   The present invention relates to an ophthalmologic

apparatus and a control method thereof, and in particular, to

position adjustment of a plurality of measurement light beams.

Background Art

[0002]   Recently, an ophthalmologic apparatus using optical

coherence tomography (OCT) (hereinafter, sometimes referred to

as "OCT apparatus") that utilizes interference produced by low

coherence light are being developed for practical use.

[0003]   An OCT apparatus can obtain a high resolution

tomographic image by irradiating measurement light on a sample

and causing the backward scattering light from the sample

(returning light) to interfere with reference light. Since the

OCT apparatuses can acquire a tomographic image of a retina in

a fundus of a test eye and an anterior eye, the OCT apparatuses

are widely utilized to perform ophthalmologic diagnosis of the

retina, cornea, and the like.

[0004]   For example, for measurement performed by OCT in

ophthalmologic diagnosis of the retina, there is a risk of

positional deviation or missing in the tomographic image

occurring due to movement of the eyeball, as represented by

involuntary eye movement during visual-fixation. Especially,

when measurement is performed at a wide angle of view, since

it takes time to acquire the tomographic image, there is an
increased chance of this risk occurring.

[0005]   Accordingly, to shorten the measurement time,
Japanese Unexamined Patent Application Publication
(Translation of PCT Application) No. 2008-508068 discusses a
method that uses a plurality of measurement light beams
(hereinafter, sometimes simply referred to as "beams") to
narrow the measurement region per beam. According to Japanese
Unexamined Patent Application Publication No. 2008-508068, an
interferometer splits the plurality of beams respectively into
measurement light beams and reference light beams. The
interference light produced by each of the beams is dispersed,
and the dispersed interference light is detected by a
two-dimensional sensor array that is the same for all of the
plurality of beams.

[0006]   However, with the technique discussed in Japanese
Unexamined Patent Application Publication No. 2008-508068, the
position of the plurality of measurement light beams with
respect to the structure of the test eye cannot be adjusted.

[0007]   Further, when imaging of the test eye is performed
at an especially wide angle of view with a plurality of beams,
depending on the test eye, focal position deviation can occur
between the center and the periphery. For example, when an
image plane of the measurement light is determined so that
scanning is performed based on a test eye that has a normal
refractive power, focal position deviation can occur for a
myopic test eye.

Citation List

Patent Literature

[0008]   PTL 1 Japanese Unexamined Patent Application

Publication (Translation of PCT Application) No. 2008-508068

Summary of Invention

[0009]   The present invention is directed to improving

quality of an image acquired based on a plurality of measurement

light beams by adjusting a focal position of each measurement

light beam.

[0010]   According to an aspect of the present invention, an

ophthalmologic apparatus includes a scanning optical system

configured to scan a plurality of different regions of a test

eye with a plurality of different measurement light beams, an

acquisition unit configured to acquire information about a

shape of the test eye, and an adjustment unit configured to

adjust a relative position between an output end of a

measurement light beam that serves as a reference among the

plurality of measurement light beams and an output end of other

measurement light beams among the measurement light beams based

on the acquired information about the shape of the test eye.

[0011]   Further features and aspects of the present invention

will become apparent from the following detailed description

of exemplary embodiments with reference to the attached

drawings.

Brief Description of Drawings

[0012]   The accompanying drawings, which are incorporated in

and constitute a part of the specification, illustrate

exemplary embodiments, features, and aspects of the invention and, together with the description, serve to explain the principles of the invention.

[0013]   Fig. 1 is a schematic diagram illustrating a configuration of an ophthalmologic apparatus according to an exemplary embodiment of the present invention.

[0014]   Fig. 2A is a schematic diagram illustrating acquisition of a tomographic image by the ophthalmologic apparatus.

[0015]   Fig. 2B is a schematic diagram illustrating acquisition of a tomographic image by the ophthalmologic apparatus.

[0016]   Fig. 2C is a schematic diagram illustrating acquisition of a tomographic image by the ophthalmologic apparatus.

[0017]   Fig. 2D is a schematic diagram illustrating acquisition of a tomographic image by the ophthalmologic apparatus.

[0018]   Fig. 3A is a schematic diagram illustrating a configuration of a fiber end adjustment mechanism in the ophthalmologic apparatus.

[0019]   Fig. 3B is a schematic diagram illustrating a configuration of a fiber end adjustment mechanism in the ophthalmologic apparatus.

[0020]   Fig. 4A illustrates focal position deviation of a fundus in the ophthalmologic apparatus.

[0021]   Fig. 4B illustrates focal position deviation of a

fundus in the ophthalmologic apparatus.

[0022]   Fig. 4C illustrates focal position deviation of a fundus in the ophthalmologic apparatus.

[0023]   Fig. 5A is a flowchart illustrating focal position adjustment in the ophthalmologic apparatus.

[0024]   Fig. 5B is a flowchart illustrating focal position adjustment in the ophthalmologic apparatus.

[0025]   Fig. 6 illustrates a display screen displayed by the ophthalmologic apparatus.

Description of Embodiments

[0026]   Various exemplary embodiments, features, and aspects of the invention will be described in detail below with reference to the drawings.

[0027]   In a first exemplary embodiment, an ophthalmologic apparatus (OCT apparatus) in which the present invention is applied will be described with reference to Fig. 1.

[0028]   As illustrated in Fig. 1, an OCT apparatus 100 according to the present exemplary embodiment is formed overall as a Michelson interferometer. Each of the below-described constituent elements is operated under the control of a control unit (central processing unit (CPU)) 125. First, light output from a light source is split into measurement light and reference light. Then, a plurality of measurement light beams is irradiated via a respective measurement light path on an object to be inspected (inspection object). Using a plurality of multiplexed light beams in which returning light produced by the plurality of measurement light beams and a plurality of

reference light beams that passed along a reference light path are multiplexed to produce optical interference, a tomographic image of the inspection object is imaged.

[0029]   More specifically, in Fig. 1, output light 104, which is light output from a light source 101, is guided to a single mode fiber 110, and is incident on an optical coupler 156. The light is then split by the optical coupler 156 into output light beams 104-1 to 104-3, which pass along three light paths, a first light path, a second light path, and a third light path, respectively.

[0030]   Further, each of these three output light beams 104-1 to 104-3 passes through a polarized light controller 153-1, and is split into reference light beams 105-1 to 105-3 and measurement light beams 106-1 to 106-3 by optical couplers 131-1 to 131-3.

[0031]   The thus-split three measurement light beams 106-1 to 106-3 are reflected or scattered by a fundus 127 in a test eye 107, which is an observation target, and returned as returning light beams 108-1 to 108-3. Then, the light beams 108-1 to 108-3 are multiplexed with the reference light beams 105-1 to 105-3, which have passed along the reference light paths, by the optical couplers 131-1 to 131-3 to form synthesized light beams 142-1 to 142-3.

[0032]   The light source 101 vicinity will now be described. The light source 101 is a super luminescent diode (SLD) which is a representative low-coherence light source. The light source 101 has a center wavelength of 840 nm and a band width

of 50 nm. The band width is an important parameter, as it influences the resolution in an optical axis direction of the obtained tomographic image. Further, although a SLD is selected here, other types of light source may be employed as the light source 101. For example, as long as low-coherence light can be output, amplified spontaneous emission (ASE) may be used.

[0033]   Considering that a fundus is to be measured, infrared light is suitable as the wavelength. In addition, since the center wavelength influences the resolution in the horizontal direction of the obtained tomographic image, it is desired that the wavelength is as short as possible. In the present exemplary embodiment, the wavelength is 840 nm. Depending on a measurement site of the observation target, some other wavelength may be selected.

[0034]   Next, the light paths of the reference light 105 will be described. The reference light beams 105-1 to 105-3 pass through a polarized light controller 153-2, are converted into roughly parallel light by a lens 135-1, and output. Then, the reference light beams 105-1 to 105-3 pass through a dispersion compensating glass 115, and are concentrated on a mirror 114 by a lens 135-2. Next, the reference light beams 105-1 to 105-3 are reflected by the mirror 114, and again head toward the optical couplers 131-1 to 131-3.

[0035]   The dispersion compensating glass 115 compensates the reference light 105 for the dispersion that occurred when the measurement light 106 made a round trip to the test eye 107 and

a scanning optical system. In the present exemplary embodiment, as a representative value of an average eyeball diameter for a Japanese person, a value L = 23 mm will be used. An electric stage 117-1 can move in the direction indicated by the arrow in Fig. 1, so that a light path length of the reference light 105 can be adjusted and controlled.

[0036] The electric stage 117-1 can be controlled by the control unit (CPU) 125. In the present exemplary embodiment, although the same mirror 114, electric stage 117-1, and dispersion compensating glass 115 are used for all three lights paths, these units may be independently configured. In such a case, so that the respective light path lengths for the reference light beams 105-1 to 105-3 can be changed, the lens 135-2 and the mirror 114 include a different electric stage 117-1, and their position is controlled for each reference light beam.

[0037] Next, the light paths of the measurement light 106 will be described. The measurement light beams 106-1 to 106-3 pass through a polarized light controller 153-4, are output from respective fiber ends 118-1 to 118-3, which are output ends of the measurement light, are converted into roughly parallel light by a lens 120-3, and are then incident on a mirror of an XY scanner 119 that forms the scanning optical system. Although, for convenience, the XY scanner 119 is illustrated here as having one mirror, in actual fact the XY scanner 119 may be configured from two mirrors, an X scanning mirror and a Y scanning mirror that are arranged near to each other, for

performing raster scanning of the fundus 127 in a perpendicular direction to the optical axis.

[0038]   Lenses 120-1, 120-3, and 120-4 are adjusted so that the center of each of the measurement light beams 106-1 to 106-3 generally matches the rotational center of the XY scanner mirror. In addition, a beam expander which is configured from the lenses 120-1 and 120-4 enables the beam diameter of the measurement light beams 106-1 to 106-3 to be varied. The lenses 120-1, 120-2, and 120-4 form an optical system for scanning the fundus 127. The measurement light 106 has a role of scanning the fundus 127 using vicinity of an iris 126 as a fulcrum. A scan image can be obtained at each position on the fundus 127 by driving the XY scanner 119.

[0039]   An electric stage 117-2 can move in the direction indicated by the arrow in Fig. 1, so that a position of the accompanying lens 120-2 can be adjusted and controlled. By adjusting the position of the lens 120-2, a plurality of focal positions with respect to the fundus 127 of the measurement light beams 106-1 to 106-3 can be simultaneously adjusted. Although the apparatus also can perform individual adjustment, that will be described below. The electric stage 117-2 can be controlled by the control unit (CPU) 125.

[0040]   In the present exemplary embodiment, although the fiber ends 118-1 to 118-3 are arranged in roughly the same plane (XZ plane), the present invention is not limited to this arrangement. For example, the fiber ends 118-1 to 118-3 may be arranged in a perpendicular direction to the paper surface

(y direction), or have a component in both directions. By configuring in the above manner, the three beams can be used for scanning simultaneously.

[0041]   Next, the configuration of a spectroscope in the OCT apparatus of the present exemplary embodiment will be described. The above described synthesized light 142 is output from fiber ends 160-1 to 160-3, and converted into roughly parallel light by a lens 135. The roughly parallel light is incident to a transmissive diffraction lattice 141 that forms a detection unit, and is dispersed into light of different wavelengths. The dispersed light is concentrated by an imaging lens 143, and the intensity of the light is converted into a voltage for each position (wavelength) by a line sensor. Consequently, three interference fringes of spectral regions on the wavelength axis are observed on a line sensor 139.

[0042]   Acquisition of a tomographic image using the OCT apparatus will now be described. Here, acquisition of a tomographic image of the fundus 127 (parallel plane to the optical axis) will be described with reference to Figs. 2A to 2D.

[0043]   Fig. 2A illustrates the test eye 107 which is observed by the OCT apparatus 100. In Fig. 2A, the measurement light beam 106-1 is omitted. Units that are identical to or correspond to those illustrated in Fig. 1 are denoted with the same reference numerals, and a description of the overlapping units will be omitted.

[0044]   As illustrated in Fig. 2A, when the measurement light

beams 106-2 and 106-3 pass through the iris 126 and are incident
on the fundus 127, these measurement light beams 106-2 and 106-3
turn into the returning light beams 108-2 and 108-3 due to
reflection and scattering at various positions, and arrive at
the line sensor 139 with a time delay at each of those positions.
Although the returning light beams 108-2 and 108-3 are
illustrated in Fig. 2A without an axis for ease of understanding,
in actual fact the returning light beams 108-1 to 108-3 are
returning light that tracks back along the path of the
measurement light beams 106-1 to 106-3 in reverse.

[0045]   Fig. 2B illustrates which region on the fundus each
of the measurement light beams 106-1 to 106-3 observes. The
measurement light beams 106-1 to 106-3 are used to scan regions
180-1 to 180-3 respectively to observe each region. If
respective scan angles in an initial state are expressed as a
beam shift angle scanning near the iris 126, the scan angle
corresponding to a scanning width Ay is ±18° to the optical axis
center for each of the measurement light beams in the y direction,
and the scan angle of the scanning widths Ax1 to Ax3 is 12° for
each of the measurement light beams.

[0046]   The scanning width Ay can be changed by the shift width
of the mirror scanning the Y axis side of the XY scanner.
Further, an interval between the scanning widths Ax1 to Ax3 (12°
in the initial state) can be changed by movement of the fiber
end which is described below. The "initial value" is a wide
viewing angle mode for observing the fundus at a wide angle of
view.

[0047]   Since the band width of the light source 101 is wide
and a spatial coherence length is short, an interference fringe
can be detected by the line sensor 139 only when the light path
length of the reference light paths and the light path length
of the measurement light paths are roughly equal. As described
above, an interference fringe in the spectral region on the
wavelength axis is acquired by the line sensor 139.

[0048]   Next, the interference fringes which are information
about the wavelength axis are converted into an interference
fringes of an optical frequency axis for each of the multiplexed
light beams 142-1 to 142-3, taking into consideration the
properties of the line sensor 139 and the transmissive
diffraction lattice 141. In addition, information about the
depth direction can be obtained by subjecting the converted
optical frequency axis interference fringes to Fourier
transform.

[0049]   While driving the mirror on the Y axis side of the
XY scanner 119, if an interference fringe is detected, an
interference fringe can be obtained at each position on the Y
axis. More specifically, information about the depth
direction can be obtained for each position on the Y axis.

[0050]   Consequently, a two-dimensional distribution of the
intensity of the returning light beam 108-1 on the yz plane can
be obtained. The obtained two-dimensional distribution is,
specifically, a tomographic image 132 (Fig. 2C). The
tomographic image 132 is based on the intensity of the returning
light beam 108-1 in an array pattern. For example, the

tomographic image 132 is displayed by applying the intensity to a grey scale. Fig. 2C is illustrated with only boundaries of the obtained tomographic image highlighted.

[0051]   Further, as illustrated in Fig. 2D, if the measurement light beams 106-1 to 106-3 are each raster-scanned over the fundus by controlling the XY scanner 119, tomographic images of arbitrary locations on the fundus can be consecutively and simultaneously acquired. Fig. 2D illustrates scanning performed when a main scanning direction of the XY scanner is set as the Y axis direction and a sub-scanning direction is set as the X axis direction, which consequently allows a plurality of tomographic images in the yz plane to be obtained.

[0052]   A Mach-Zehnder interferometer may also be used as the interferometer. If using a Mach-Zehnder interferometer, although the configuration is more complex than a Michelson interferometer, there is an advantage that when the ratio between measurement light and reference light is smaller, the obtained tomographic images have a high contrast.

[0053]   A fiber end adjustment mechanism will now be described with reference to Figs. 3A and 3B. Fig. 3A is a view of a fiber unit as seen from the y direction, and Fig. 3B is a view as seen from the x direction.

[0054]   The fiber end adjustment mechanism illustrated in Figs. 3A and 3B includes a fiber unit 1000 and fiber portions 1003-1 to 1003-3 which are respectively connected to the measurement light side of the optical couplers 131-1 to 131-3. The fiber portions 1003-1 to 1003-3 are respectively fixed to

holding portions 1001-1 to 1001-3 which are formed by sandwiching the fibers with a material such as quartz, and polishing the fiber ends 118-1 to 118-3 side. Further, the holding portions 1001-1 to 1001-3 are bonded and fixed to fiber base portions 1002-1 to 1002-3, respectively.

[0055]   The center fiber base portion 1002-2 is fixed to a base 1010 by a not-illustrated screw, for example. By adjusting the base 1010 in the optical axis position (x, y) and the optical axis direction (z) in Fig. 1, the center fiber end 118-2 can be aligned with the optical axis of the apparatus, and be optimally positioned at which the measurement light 160-2 can be the parallel light by the collimator lens 130-2.

[0056]   The upper and lower fiber base portions 1002-1 and 1002-3 in Fig. 3A can be relatively moved with respect to the center fiber base portion 1002-2 in a fiber interval direction (x direction). Taking the upper fiber base portion 1002-1 as an example, the fiber base portion 1002-1 includes guide portions into which pins 1005-1 and 1005-2 are inserted. The pins 1005-1 and 1005-2 are fixed to an X guide member 1008-1. The upper fiber base portion 1002-1 is held by these pins 1005-1 and 1005-2 so that it can move in the x direction.

[0057]   Further, a spring 1006-1 is provided between the fiber base portions 1002-1 and 1002-2. Consequently, the fiber base portion 1002-1 is pressed toward an arrow (pressing) direction in the y direction. A screw hole is provided in the X guide member 1008-1, into which an adjustment screw 1004-1 is inserted. The adjustment screw 1004-1 abuts on the fiber base portion

1002-1 to position the fiber base portion 1002-1 in the y

direction.

[0058]   By rotating the adjustment screw 1004-1, the interval

between the fiber base portions 1002-1 and 1002-2 can be varied

in the arrow (movement) direction. Accordingly, the interval

between the fiber ends 118-1 and 118-2 can be adjusted. A

similar configuration may be also provided on the fiber base

portion 1002-3 side, so that the interval between the fiber ends

118-2 and 118-3 can be adjusted. Consequently, the relative

interval among the measurement light beams 106-1 to 106-3 can

be adjusted, enabling the initial state to be adjusted to 12°

on the fundus.

[0059]   The upper and lower X guide members 1008-1 and 1008-2

in Fig. 3A can be relatively moved with respect to the center

fiber base portion 1002-2 in the optical axis direction (z

direction). The X guide member 1008-2 will now be described

as an example with reference to Figs. 3A and 3B.

[0060]   Pins 1005-7 and 1005-8 are fixed to a z guide portion

1013 which is integrated with the base 1010. The X guide member

1008-2 includes guide portions into which the pins 1005-7 and

1005-8 are inserted. These pins 1005-7 and 1005-8 hold the X

guide member 1008-2 so that it can move in the z direction.

Further, a spring 1006-1 is provided between the X guide member

1008-2 and a member 1015 which is integrated with the base 1010.

Consequently, the X guide member 1008-2 is pressed toward the

arrow (pressing) direction in the z direction.

[0061]   A screw hole is provided in the z guide portion 1013,

into which an adjustment screw 1004-4 is inserted. The adjustment screw 1004-4 abuts on the X guide member 1008-2 to position the X guide member 1008-2 in the z direction. By rotating the adjustment screw 1004-4, the X guide member 1008-2 can be moved in the arrow (movement) direction. Accordingly, the relative position in the z direction between the fiber ends 118-1 and 118-2 can be adjusted.

[0062]   A similar configuration is also provided on the fiber end 118-1 side.   The relative positions of the fiber ends 118-1 to 118-3 are adjusted based on their initial state so that the focal position matches a fundus shape of a standard test eye.

[0063]   The fundus of the standard test eye will now be schematically described with reference to Fig. 4A.   Fig. 4A is a schematic diagram illustrating a cornea 121-1, an iris 126-1, and a fundus 127-1 that is assumed to have a spherical shape. A distance (eye axial length) L1 between an apex on the optical axis of the cornea 121-1 and the fundus 127-1 is 23 mm. A distance L2 between the apex on the optical axis of the cornea 121-1 and the iris 126-1 is 3.5 mm.   A radius of curvature R1 of the fundus 127-1 is 12 mm.   A distance L3 from the iris 126-1 to the fundus 127-1 is 19.5 mm.

[0064]   The shape of the test eye when the eye axial length is long will now be schematically described with reference to Fig. 4B.   In this case, a cross-sectional shape of the fundus is approximate to an ellipse.   Fig. 4B is a schematic diagram illustrating a cornea 121-2, an iris 126-2, and a fundus 127-2. A distance (eye axial length) L1' between an apex on the optical

axis of the cornea 121-2 and the fundus 127-2 is 30 mm. A
distance L2' between the apex on the optical axis of the cornea
121-2 and the iris 126-2 is 3.5 mm. A long axis side radius
a of the fundus 127-2 is 16 mm.

[0065]   When a tomographic image of the fundus of the standard
test eye is captured, an image plane of each measurement light
beam on the fundus 127-1 is brought into focus by moving the
lens 120-2 with respect to the fundus 127-1 in the z axis
direction using the electric stage 172-2. Consequently, even
if a depth of focus of each measurement light beam is narrow,
the focal positions are in focus, so that the tomographic image
in good condition can be acquired. On the other hand, in the
case of the above described test eye with the long eye axial
length, the image plane can be adjusted to a position on the
optical axis of the fundus 127-2 by moving the lens 120-2 in
the z axis direction. However, at positions on the fundus where
the scan angle of the beam is large, a deviation occurs between
the image plane and the fundus.

[0066]   Such case will be illustrated in Fig. 4C. In Fig. 4C,
the horizontal axis represents the scan angle with the optical
axis being 0° , and the vertical axis represents a difference
(fundus positional deviation amount) in the fundus position
between the standard test eye and the test eye for each eye axial
length. In Fig. 4B, this corresponds to a distance at each angle
of view between the fundus 127-2 and the fundus of the standard
eye represented by the dotted line. This distance is a result
calculated by approximating the cross-sectional shape of each

test eye (other than the standard test eye) to an ellipse. For example, if the eye axial length in the above numerical example is 30 mm, the fundus positional deviation amount at the edge sides in the wide angle mode (18°) is more than 0.4 mm. A similar example will be shown for each eye axial length.

[0067]   On the other hand, depending on the depth of focus of the measurement light, the fundus positional deviation amount can exceed the depth of focus, which can cause the tomographic image resolution to deteriorate.

[0068]   The depth of focus (DOF) of an imaging system is represented by the following equation (1),

[Math. 1]

$$DOF = \pm k_2 * (\lambda / NA^2) \quad \ldots \quad (1)$$

in which k_2 is a constant of about 0.6.

[0069]   In the above equation (1), DOF is the depth of focus, NA represents numerical apertures of an eye forming an image from parallel measurement light, and λ represents the center wavelength of the measurement light. NA is determined based on the light beam diameter and the focal distance of the eye. When the focal distance of the eye is 22.5 mm, NA ~ d/(2 * f) (wherein d represents the light beam diameter on the iris 126, and f represents the focal distance of the eye during measurement).

[0070]   In the present exemplary embodiment, the light beam diameter is 2.2 mm. Thus, using $NA_{d-2.2\ mm} = 0.049$ into the above calculation, DOF can be calculated as ±0.2 mm.

[0071]   When the fundus in Fig. 4C having an eye axial length

of 30 mm is measured with this DOF value, although the center
beam (observation at a ±6° angle of view) is within the DOF range,
at the maximum angle of view 18° position for the beams on the
edge sides, the beams miss the DOF range.

[0072]   Accordingly, the DOF range of each measurement light
beam can be positioned on the fundus even for this eye axial
length by moving each of the fiber ends 118-1 and 118-3 on the
edge sides in the z direction. More specifically, it is most
desirable that the DOF center position is located in the middle
of the fundus difference. The measurement light beams on the
edge sides are used for scanning over a scan angle range of 6°
to 18° . Further, there is a difference in the fundus positional
deviation amount of 0.37 mm between these scan angles.
Therefore, the image plane of the beams on the edge sides is
moved about (0.6 + 0.37 / 2) = 0.25 mm (see an arrow in Fig.
4C). If the movement is converted into a fiber end movement
amount, based on a vertical magnification of the optical system
from the fiber ends 118-1 to 118-3 to the fundus 127 of 25, the
fiber ends are moved by 0.01 mm in the z direction which is an
arrow (minus) direction in Fig. 3A.

[0073]   Thus, the fundus positional deviation amount can be
estimated from the eye axial length. Based on the estimated
amount, a movement amount in the fiber optical axis direction
can be calculated. Further, by moving the fiber ends, which
are the output ends of the measurement light, based on the
movement amount, the fundus can be kept within the DOF, so that
a tomographic image can be obtained in which the resolution does

not change from the center beam.

[0074]   For the examples of other eye axial lengths
illustrated in Fig. 4C (28 mm and 20 mm), since both of these
cases have an angle of view that is up to 18° , which is within
the DOF, if the light beam diameter is 2.2 mm, the fiber ends
on the edges do not have to be moved.

[0075]   If the DOF changes from that described above, more
specifically, if the beam diameter on the iris 126 is changed
by the above-described beam expander, a determination is made
regarding whether to move the fiber ends on the edge sides by
comparing the DOF value and the fundus positional deviation
amount.

[0076]   Further, in some cases the regions scanned by the
respective measurement light beams are changed. For example,
a case will be considered in which the scanning regions Ax1 to
Ax3 in Fig. 2B are reduced in size. Such case is performed when
scanning a region which a user wishes to pay particular
attention to at a high density. In such a case, the scanning
is performed by moving the fiber ends 118-1 and 118-3 in the
x direction. If the scanning regions Ax1 to Ax3 are
respectively scanned at a scan angle of 6° , the overall scan
angle in the x direction is 18° (the fiber ends 118-1 and 118-3
are closer to the fiber end 118-2 than in the wide angle mode).
In Fig. 4C, if the eye axial length is 30 mm at a scan angle
of 9° on one side, the fundus positional deviation amount is
0.124 mm. Consequently, when the light beam diameter is 2.2
mm, the fundus is sufficiently within the DOF, so that there

is no need to move the fiber ends. Obviously, it may be necessary to move the fiber ends if the DOF is narrowed due to changes in the light beam diameter.

[0077]   The flow of capturing a tomographic image in which the light beam diameters and the scanning regions can be changed will be described step by step with reference to Fig. 5A.

[0078]   In step S001, imaging starts under the control of the control unit (CPU) 125. Then, the processing proceeds to step S002.

[0079]   In step S002, an input regarding whether the test eye is an eye which an operator has imaged in the past is received from the operator. The processing in step S002 may also be performed by displaying on a display unit information about test eyes that were imaged in the past so that the operator can select a target test eye from among them. If it is determined that the test eye is a previously-imaged eye (YES in step S002), the processing proceeds to step S003. If it is determined that the test eye is not a previously-imaged eye (NO in step S002), the processing proceeds to step S009.

[0080]   In step S003, test eye information is called up from past imaging data under the control of the control unit (CPU) 125. In step S003, an acquisition unit 500 (not illustrated) acquires information relating to the shape of the test eye. For example, such information includes an eye axial length, right and left of the test eye, and refractive power. The information may further include a patient identification (ID), name, date of birth, and sex for acquiring the shape of the test eye. If

the test eye information is changed from the past imaging data,
the test eye information is edited and rewritten. Then, the
processing proceeds to step S004.

[0081]   In step S009, input of the test eye information is
received. Then, the processing proceeds to step S004.

[0082]   In step S004, the acquisition unit 500 receives an
imaging condition input. The imaging conditions may include
a region in which a tomographic image is captured (from which
the maximum angle of view in the x direction are guided), the
number of scanning locations included in one scanning in the
yz plane in Fig. 2D (corresponding to a tomographic image
density), and the light beam diameter on the iris. Then, the
processing proceeds to step S005.

[0083]   In step S005, a calculation unit 510 (not illustrated)
calculates the maximum fundus positional deviation amount based
on the input eye axial length and the maximum angle of view in
the x direction used in imaging, and the DOF in this imaging
based on the light beam diameter on the iris. Then, the
processing proceeds to step S006.

[0084]   In step S006, the calculation unit 510 compares the
maximum fundus positional deviation amount with the DOF value.
If the maximum fundus positional deviation amount is equal to
or less than the DOF (YES in step S007), the processing proceeds
to step S007. If the maximum fundus positional deviation amount
is greater than the DOF (NO in step S007), the processing
proceeds to step S010.

[0085]   In step S010, the calculation unit 510 calculates a

fiber end movement amount on the edge sides. According to the example described above, the fiber end movement amount is 0.01 mm. Then, the processing proceeds to step S011.

[0086]   In step S011, the fiber ends on the edge sides are moved under the control of the control unit (CPU) 125 by the fiber end movement amount only. Then, the processing proceeds to step S007.

[0087]   If the eye axial length is within a predetermined range of a standard eye axial length, only the electric stage 120-2 is moved with the position of the fiber ends as an initial value.

[0088]   In step S007, a tomographic image is acquired by scanning the fundus by each of the measurement light beams according to the imaging conditions under the control of the control unit (CPU) 125. The processing in step S007 also includes confirmation and display of the tomographic image. Then, the processing proceeds to step S008. If the eye axial length is within the predetermined range of the standard eye axial length (for example, between 28 mm to 20 mm), only the electric stage 120-2 is moved with the position of the fiber ends as an initial value. Then, in step S008, imaging is finished.

[0089]   The order of processing illustrated in the flowchart may be appropriately changed within a feasible range. For example, the input of the imaging conditions performed in step S004 may be performed immediately after imaging is started in step S001.

[0090]   As described above, in the present exemplary embodiment, the depth of each measurement light beam can be positioned on the fundus position by moving a relative position in the optical axis direction (z direction) of each fiber end based on the eye axial length, that is information about the test eye, and information about the imaging conditions (the light beam diameter on the iris and the scanning region). Consequently, a good tomographic image can be acquired.

[0091]   Although in the present exemplary embodiment, an OCT apparatus that acquires a tomographic image of a fundus is described, the same effects can be obtained even if a scanning laser ophthalmoscope (SLO) is employed.

[0092]   Further, the present invention is not limited to the fundus, and may be applied to an anterior eye. In this case, a surface image is acquired rather than a tomographic image. In addition, although in the above described exemplary embodiment, the x direction range of the scanning region is adjusted by the fiber ends, the present invention is not limited to this configuration. For example, a zoom function may be included in the optical system between the fiber ends 118-1 and 118-3 and the test eye 107.

[0093]   Like the first exemplary embodiment, an ophthalmologic apparatus according to a second exemplary embodiment is an OCT apparatus which acquires a tomographic image of a fundus. The difference from the first exemplary embodiment is how the movement amount of the fiber ends is

determined. Therefore, a description of the parts that are common in the first and second embodiments will be omitted. In the present exemplary embodiment, the fiber ends are moved based on a tomographic image.

[0094] One example is to cause an operator to move a depth position of each measurement light beam while the apparatus displays a tomographic image.

[0095] Fig. 6 illustrates a tomographic image adjustment screen. The adjustment screen displays an image output under the control of the control unit (CPU) 125 on a monitor (not illustrated in Fig. 1). In Fig. 6, tomographic images 2001-1 to 2001-3 are tomographic images in the yz direction of the fundus 127 produced by the measurement light beams 106-1 to 106-3, respectively, and tomographic images 2003-1 to 2003-3 are tomographic images in the xz direction. Further, the tomographic images 2001-1 to 2001-3 are tomographic images of near indicator lines 2004-1 to 2004-3 in the tomographic images 2003-1 to 2003-3, respectively. The tomographic images 2003-1 to 2003-3 are tomographic images of near indicator lines 2002-1 to 2002-3 in the tomographic images 2001-1 to 2001-3, respectively. The respective tomographic images in the adjustment screen have a lower scanning density than the images that are actually acquired and stored, so that display update can be performed quickly.

[0096] A gate adjustment slider 2006 enables the electric stage 117-1 illustrated in Fig. 1 to be moved based on an operation of the gate adjustment slider 2006. While looking

at the respective tomographic images, the operator performs

adjustment by operating the gate adjustment slider 2006 so that

the respective tomographic images are displayed within the

display screen without disruption.

[0097]   A focus adjustment slider 2005-2 enables the electric

stage 117-2 illustrated in Fig. 1 to be moved based on an

operation of the focus adjustment slider 2005-2. While looking

at a target layer in cross-sections in the tomographic images

2001-2 and 2003-2, the operator performs adjustment by

operating the focus adjustment slider 2005-2 so that the target

layer in the cross-sections has the highest luminance.

[0098]   Further, focus adjustment sliders 2005-1 and 2005-3

enable a motor (not illustrated) to rotate. The motor is

mechanically connected so that both of the adjustment screws

1004-3 and 1004-4 illustrated in Figs. 3A and 3B can rotate based

on an operation of the focus adjustment sliders 2005-1 and

2005-3. While looking at a target layer in the cross-sections

of the tomographic images 2001-1 and 2003-1, the operator

performs adjustment by operating the focus adjustment slider

2005-1 so that the target layer has the highest luminance.

Further, while looking at the target layer in the cross-sections

of the tomographic images 2001-3 and 2003-3, the operator

performs adjustment by operating the focus adjustment slider

2005-3 so that the target layer in the cross-sections has the

highest luminance.

[0099]   Consequently, unlike the first exemplary embodiment,

the fiber ends on the edges can be adjusted while directly

looking at the fundus state of the test eye without having to
assume that the fundus has a round or elliptical cross-section.
Therefore, the fundus can be imaged within the DOF even for
various types of test eyes whose fundus has a shape that is not
a round or elliptical cross-section. Although each of these
sliders is described as being operated by displaying on a screen,
the sliders may also be operated by a joystick or a mouse
connected to a control unit 200.

[0100]   As a modification of the above described exemplary
embodiment, the fiber ends may be automatically adjusted based
on the target layer in the tomographic images, or the luminance
of the overall fundus cross-section, or the contrast with the
background as an index. A processing flow for acquiring a
tomographic image by automatically performing gate position
adjustment, overall focus adjustment, and individual fiber
position adjustment will now be described with reference to Fig.
5B.

[0101]   In step S201, imaging starts under the control of the
control unit (CPU) 125. Then, the processing proceeds to step
S202.

[0102]   In step S202, gate position adjustment is performed.
The calculation unit 510 acquires a tomographic image to be used
for adjustment from the center measurement light beam 106-2,
extracts high luminance points from the whole fundus image, and
calculates a luminance ratio with a background portion for which
there is no tomographic image. Further, while moving the
electric stage 117-1 under the control of the control unit 200,

the electric stage 117-1 is stopped at a position where the luminance ratio is the highest. Then, the processing proceeds to step S203.

[0103]   In step S203, focus adjustment is performed with the center measurement light beam 106-2 as a reference under the control of the control unit (CPU) 125. The calculation unit 510 acquires a tomographic image to be used for adjustment from the center measurement light beam 106-2, and calculates an average luminance of a target layer in the cross-sections. Further, while moving the electric stage 117-2 under the control of the control unit 200, the electric stage 117-2 is stopped at a position where the luminance is the highest. Then, the processing proceeds to step S204.

[0104]   In step S204, the control unit 200 performs focus adjustment of the measurement light beams 106-1 and 106-3 on the edge sides. Taking the measurement light beam 106-1 as an example, the calculation unit 510 acquires a tomographic image to be used for adjustment from the measurement light beam 106-1, and calculates an average luminance of the target layer in the cross-sections. The control unit 200 rotates a motor (not illustrated) that is mechanically connected to the adjustment screw 1004-3, so that the electric stage 117-2 is stopped at a position where the luminance is the highest. Then, the processing proceeds to step S207.

[0105]   In step S207, a tomographic image is acquired. Then, the processing proceeds to step S208, and imaging is finished.

[0106]   The target layer is often different based on a lesion

which the operator wishes to observe. For glaucoma, the target

layer is usually a layer near the fundus surface. For macular

disease, the target layer is usually a pigment epithelial layer

positioned on the lower side of the cross-section. To calculate

the average luminance of the target layer, a known segmentation

method may be employed.

[0107]   Further, although the above processing flow uses the

average luminance of the target layer as an index for focus

adjustment, the total luminance of all the cross sections, or

a luminance ratio like that used as an index for gate adjustment

may also be used as the index. In addition, similar to the first

exemplary embodiment, the present exemplary embodiment may also

be applied in an SLO.

[0108]   Thus, in the ophthalmologic apparatus according to

the present exemplary embodiment, the quality of an image

acquired based on respective measurement light beams by

performing focus position adjustment on a plurality of beams

when the focal positions are different at the center and the

periphery can be improved for an even wider range of test eye

shapes than in the first exemplary embodiment.

[0109]   While the present invention has been described with

reference to exemplary embodiments, it is to be understood that

the invention is not limited to the disclosed exemplary

embodiments. The scope of the following claims is to be accorded

the broadest interpretation so as to encompass all such

modifications and equivalent structures and functions.

[0110]   This application claims the benefit of Japanese

Patent No. 2010-082805, filed March 31, 2010, which is hereby

incorporated by reference herein in its entirety.

CLAIMS

[1] An ophthalmologic apparatus, comprising:

a scanning optical system configured to scan a plurality of

different regions of a test eye with a plurality of different

measurement light beams;

an acquisition unit configured to acquire information about a

shape of the test eye; and

an adjustment unit configured to adjust a relative position

between an output end of a measurement light beam that serves

as a reference among the plurality of measurement light beams

and an output end of other measurement light beams among the

measurement light beams based on the acquired information about

the shape of the test eye.

[2] The ophthalmologic apparatus according to claim 1, further

comprising:

an electric stage configured to simultaneously change a

plurality of focal positions of measurement light beams output

from the adjustment unit,

wherein the information about the shape of the test eye is an

eye axial length, and

wherein, if the eye axial length is within a predetermined range

from a standard eye axial length, only the electric stage is

moved with a position of the adjustment unit as an initial value.

[3] The ophthalmologic apparatus according to claim 1 or 2,

wherein the adjustment unit changes an interval between the measurement light beams on the fundus by adjusting the relative position between the output end of the measurement light beam that serves as the reference and the output end of other measurement light beams.

[4]   The ophthalmologic apparatus according to any one of claims 1 to 3, further comprising a unit configured to change a diameter of a light beam that is incident on the test eye among the plurality of measurement light beams.

[5]   The ophthalmologic apparatus according to any one of claims 1 to 4, wherein the information about the test eye is an eye axial length.

[6]   The ophthalmologic apparatus according to any one of claims 1 to 4, further comprising a calculation unit configured to calculate a movement amount of the relative position based on an image obtained from the fundus of the test eye.

[7]   A method for controlling an ophthalmologic apparatus which includes a scanning optical system configured to scan different regions on a fundus of a test eye with a plurality of measurement light beams, the method comprising:
acquiring information about a shape of the test eye; and
adjusting a relative position between an output end of a measurement light beam that serves as a reference among the

plurality of measurement light beams and an output end of other

measurement light beams among the measurement light beams based

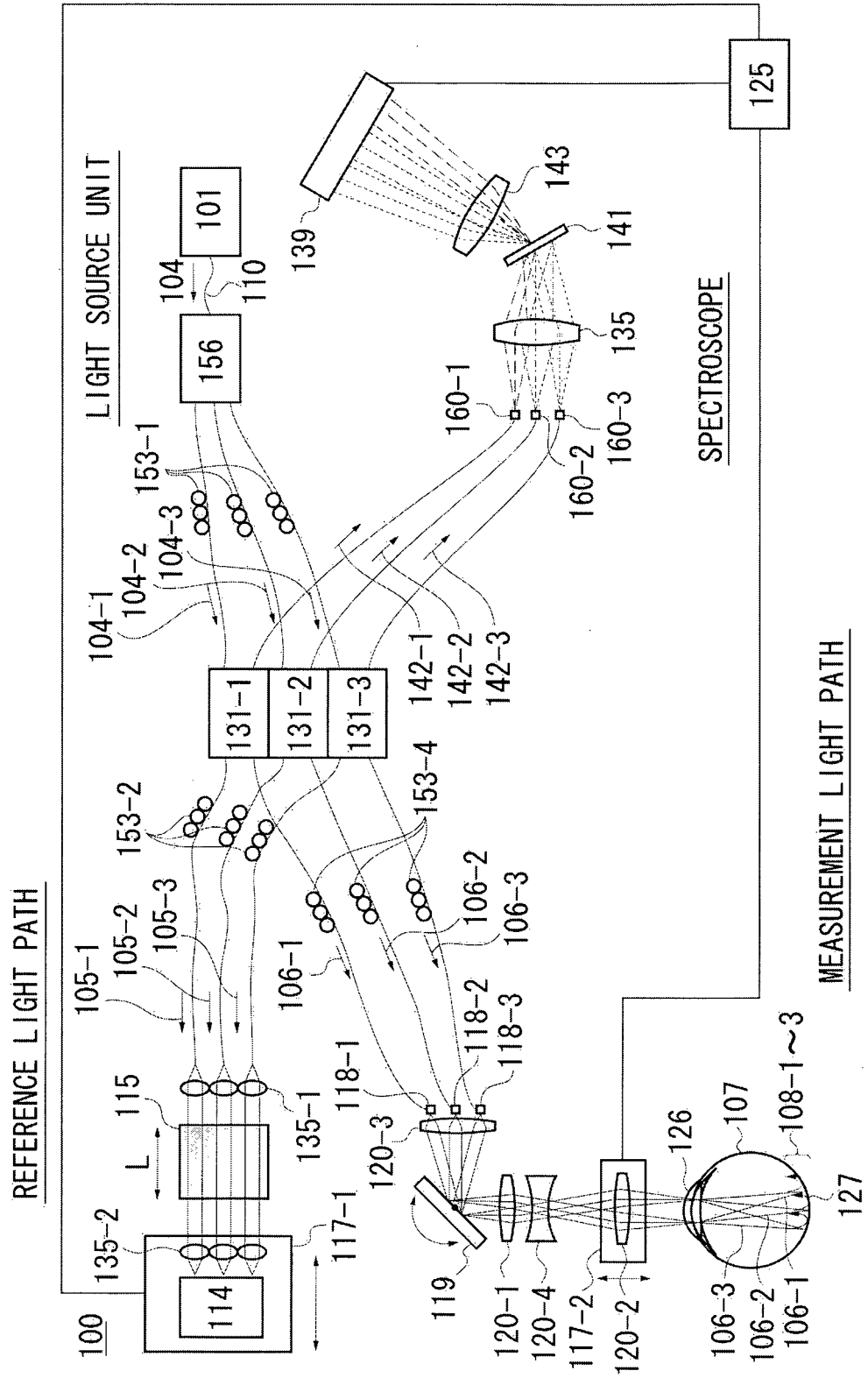on the acquired information about the shape of the test eye.
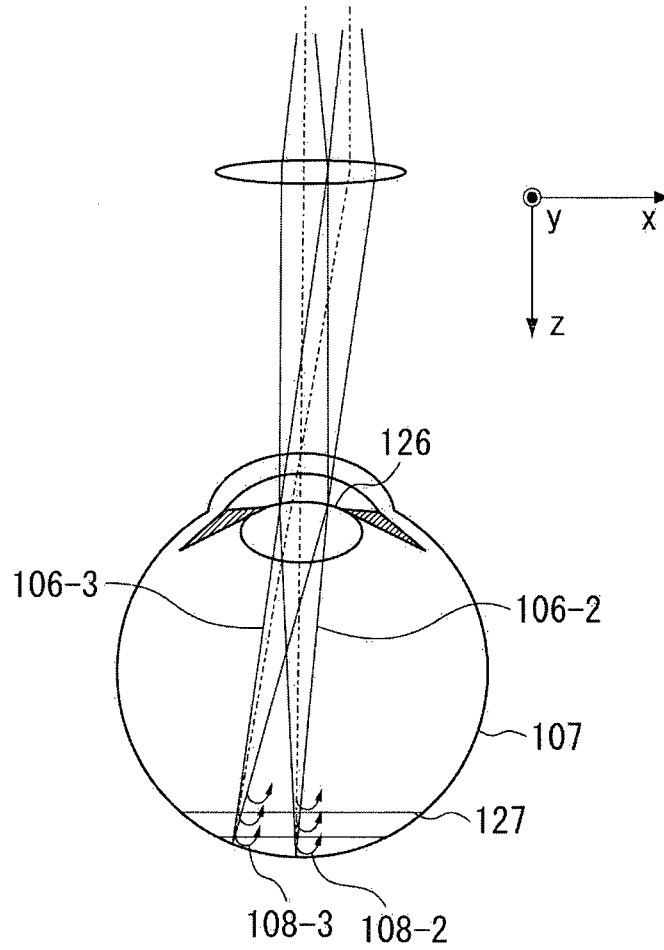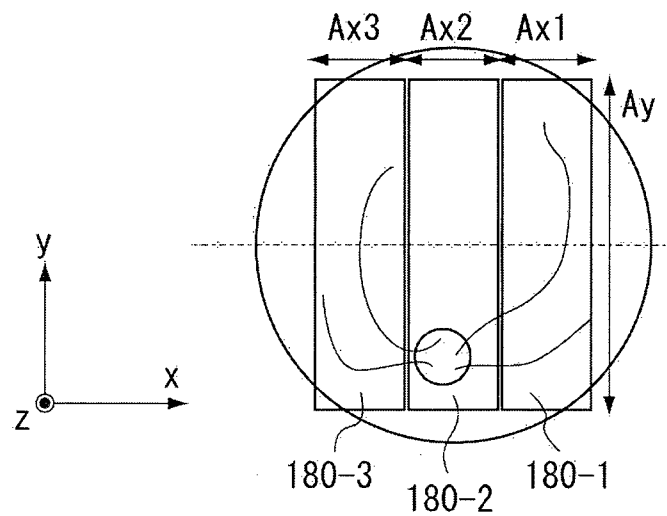
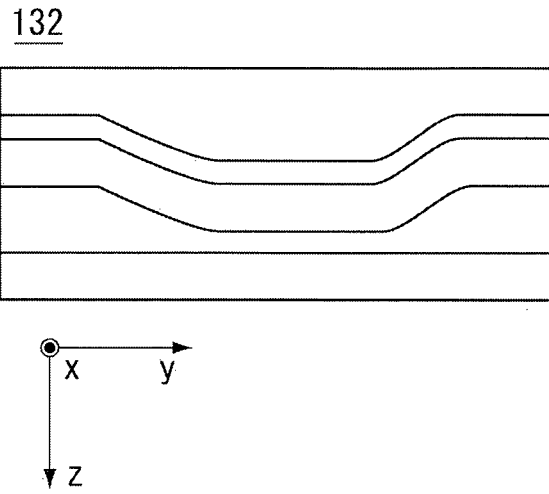FIG. 1

FIG. 2A

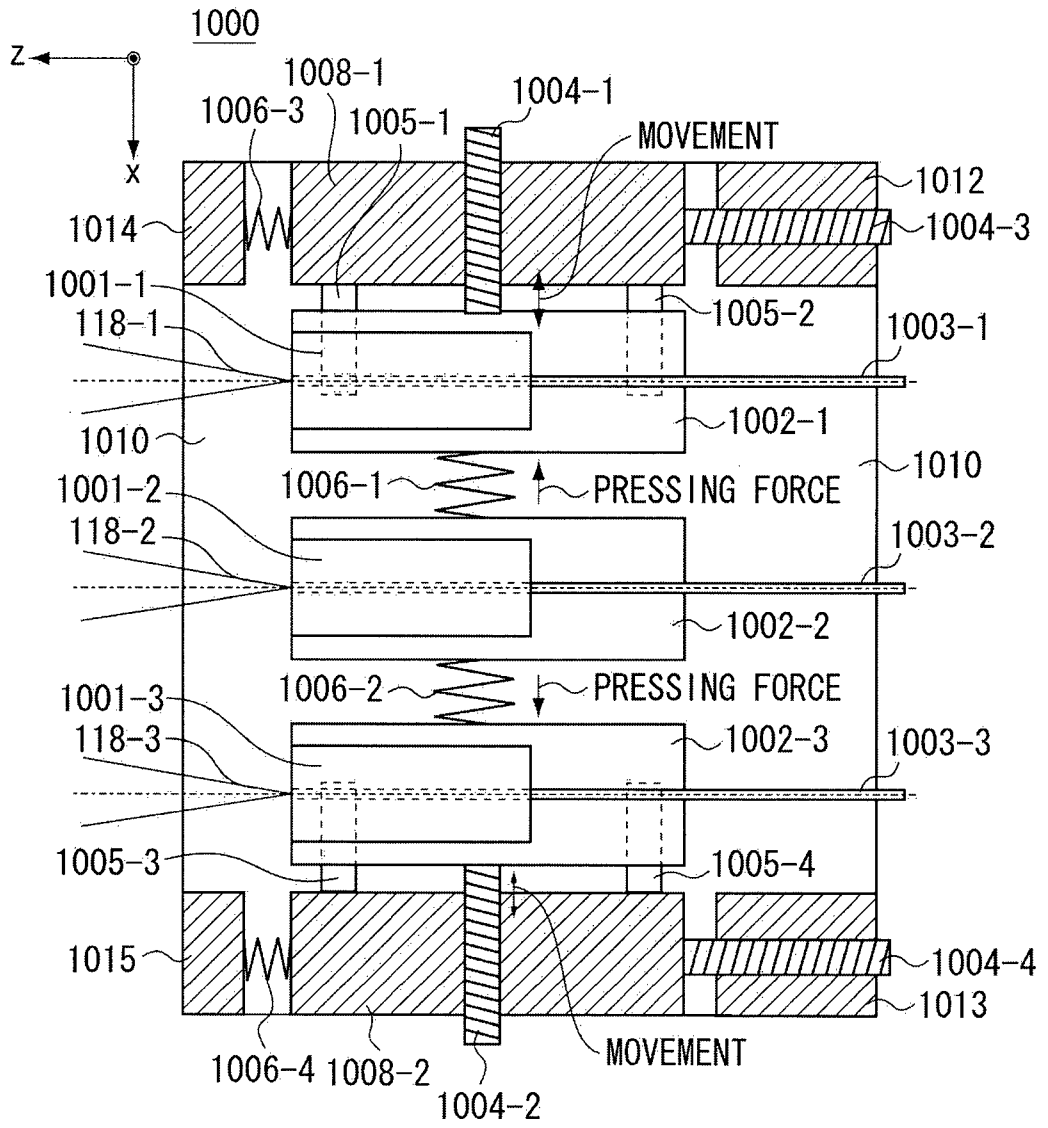FIG. 2B

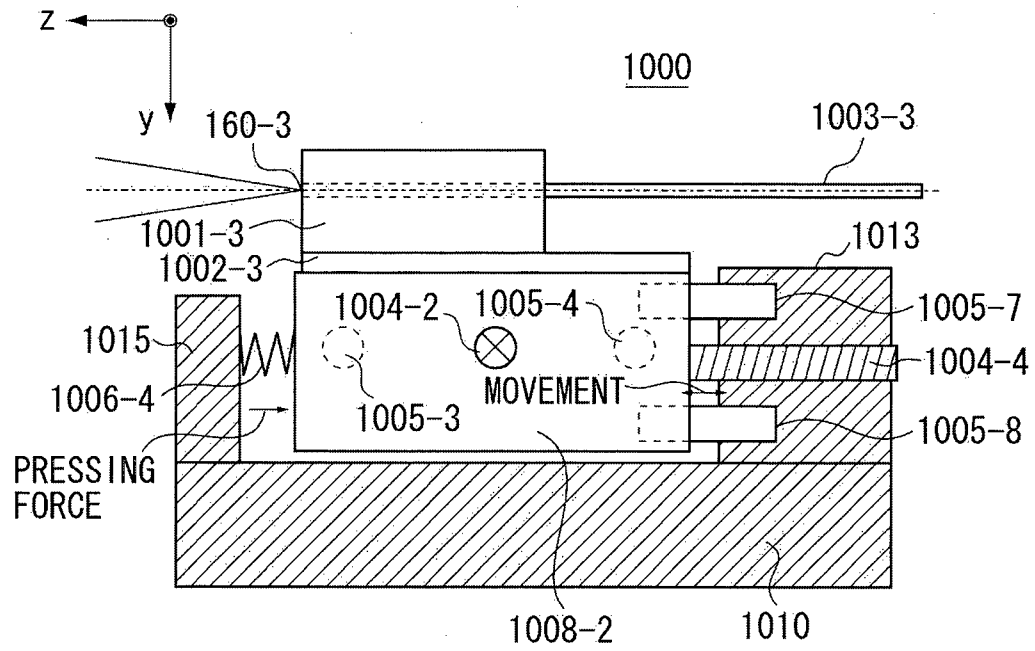FIG. 2C
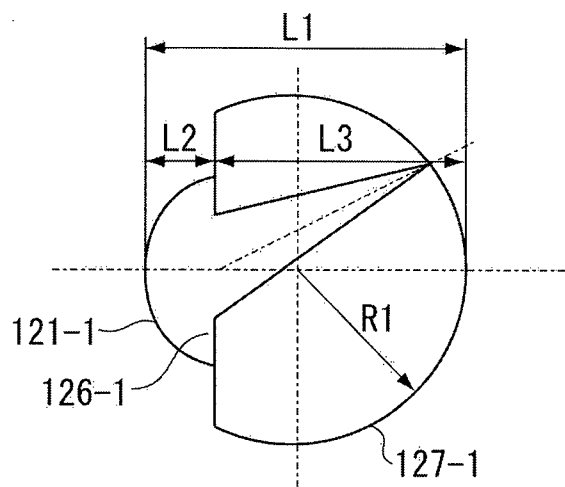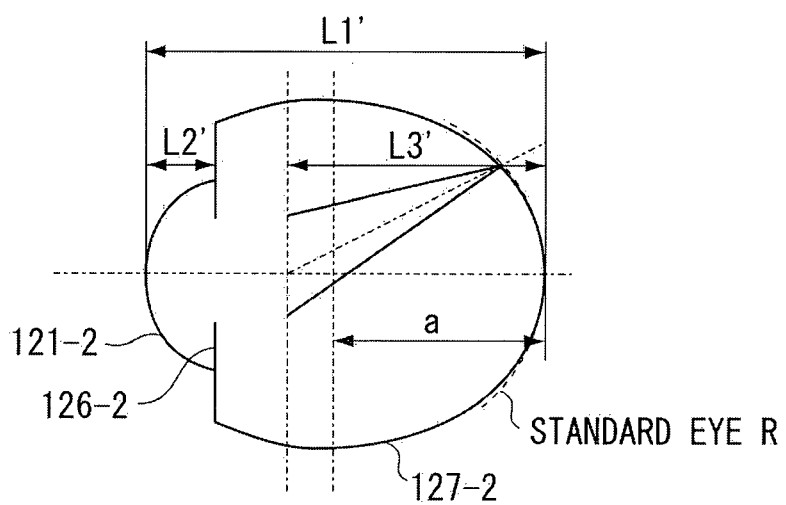
132

FIG. 2D
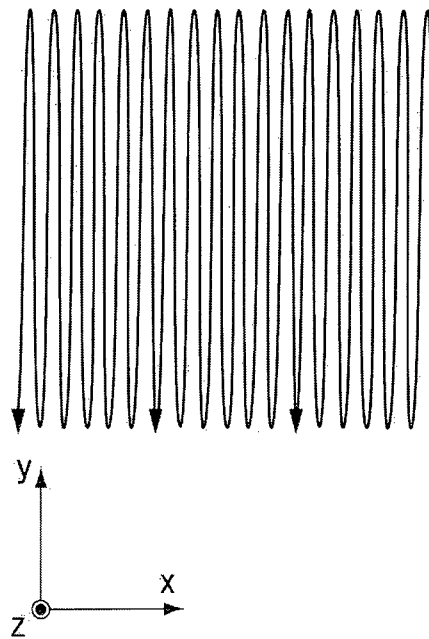
FIG. 3A

FIG. 3B

FIG. 4A

FIG. 4B

FIG. 4C

IMAGE PLANE POSITIONAL DEVIATION BETWEEN STANDARD
EYE AND TEST EYE HAVING DIFFERENT AXIAL LENGTH

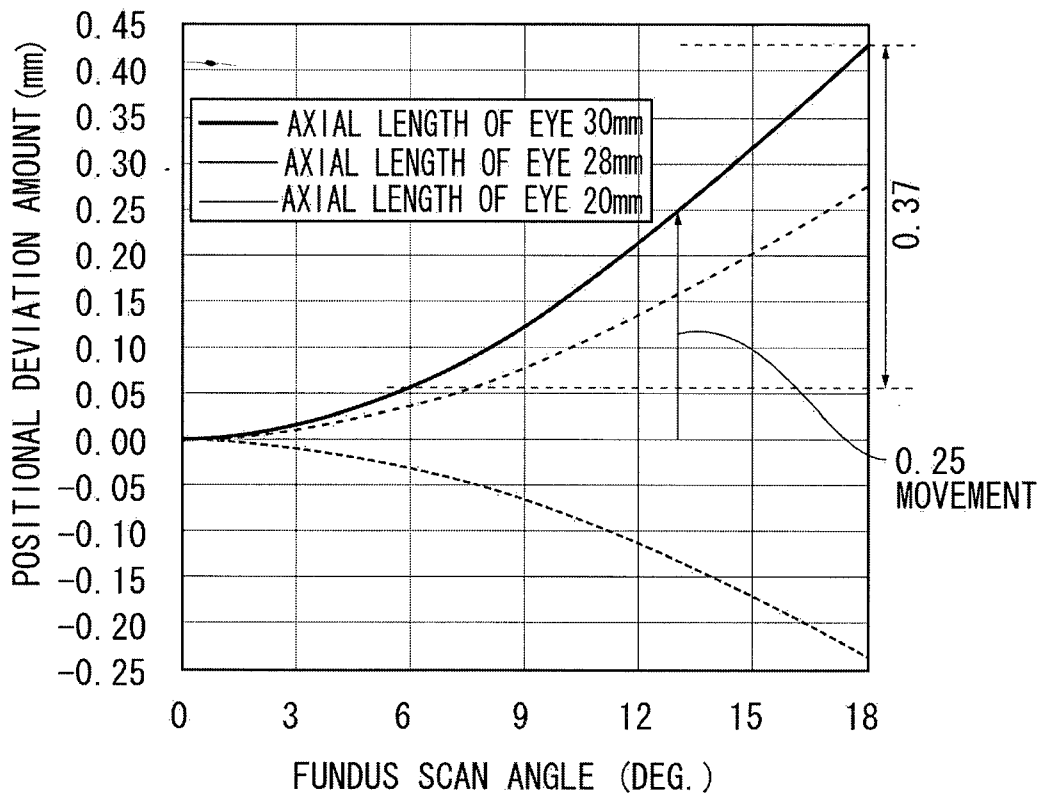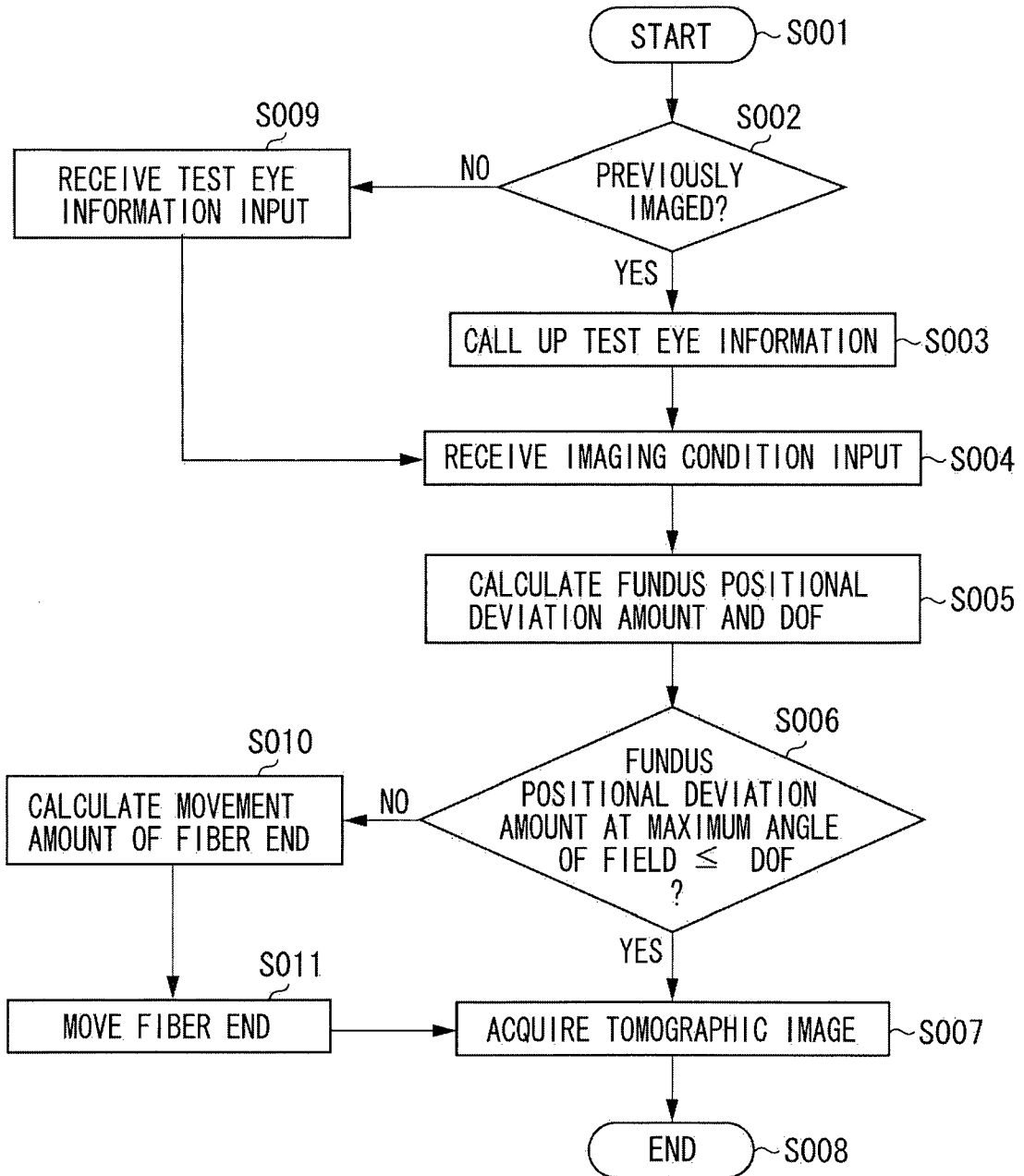— AXIAL LENGTH OF EYE 30mm
— AXIAL LENGTH OF EYE 28mm
— AXIAL LENGTH OF EYE 20mm

0.25
MOVEMENT

POSITIONAL DEVIATION AMOUNT (mm)

FUNDUS SCAN ANGLE (DEG.)

FIG. 5A

FIG. 5B

```
                    ( START )~S201
                         │
                         ▼
        ┌──────────────────────────────────┐
        │      ADJUST GATE POSITION        │~S202
        └──────────────────────────────────┘
                         │
                         ▼
        ┌──────────────────────────────────┐
        │  ADJUST CENTER BEAM STANDARD FOCUS │~S203
        └──────────────────────────────────┘
                         │
                         ▼
        ┌──────────────────────────────────┐
        │       ADJUST END BEAM FOCUS       │~S204
        └──────────────────────────────────┘
                         │
                         ▼
        ┌──────────────────────────────────┐
        │     ACQUIRE TOMOGRAPHIC IMAGE     │~S207
        └──────────────────────────────────┘
                         │
                         ▼
                    ( END )~S208
```
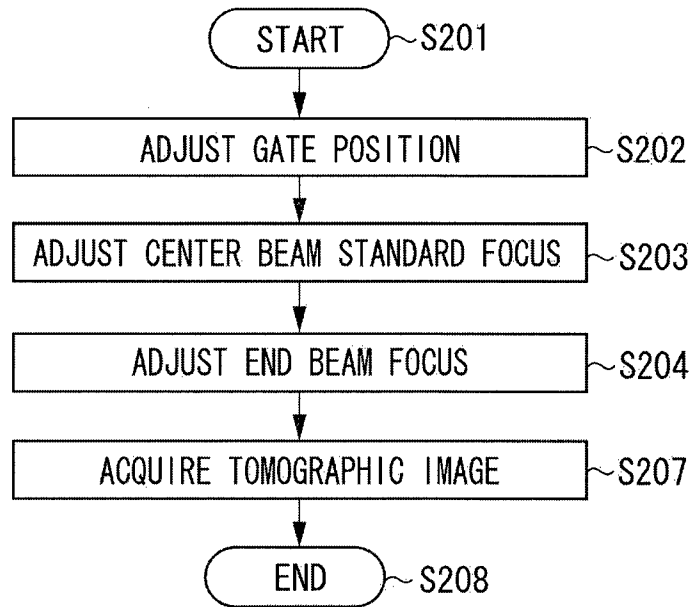
FIG. 6
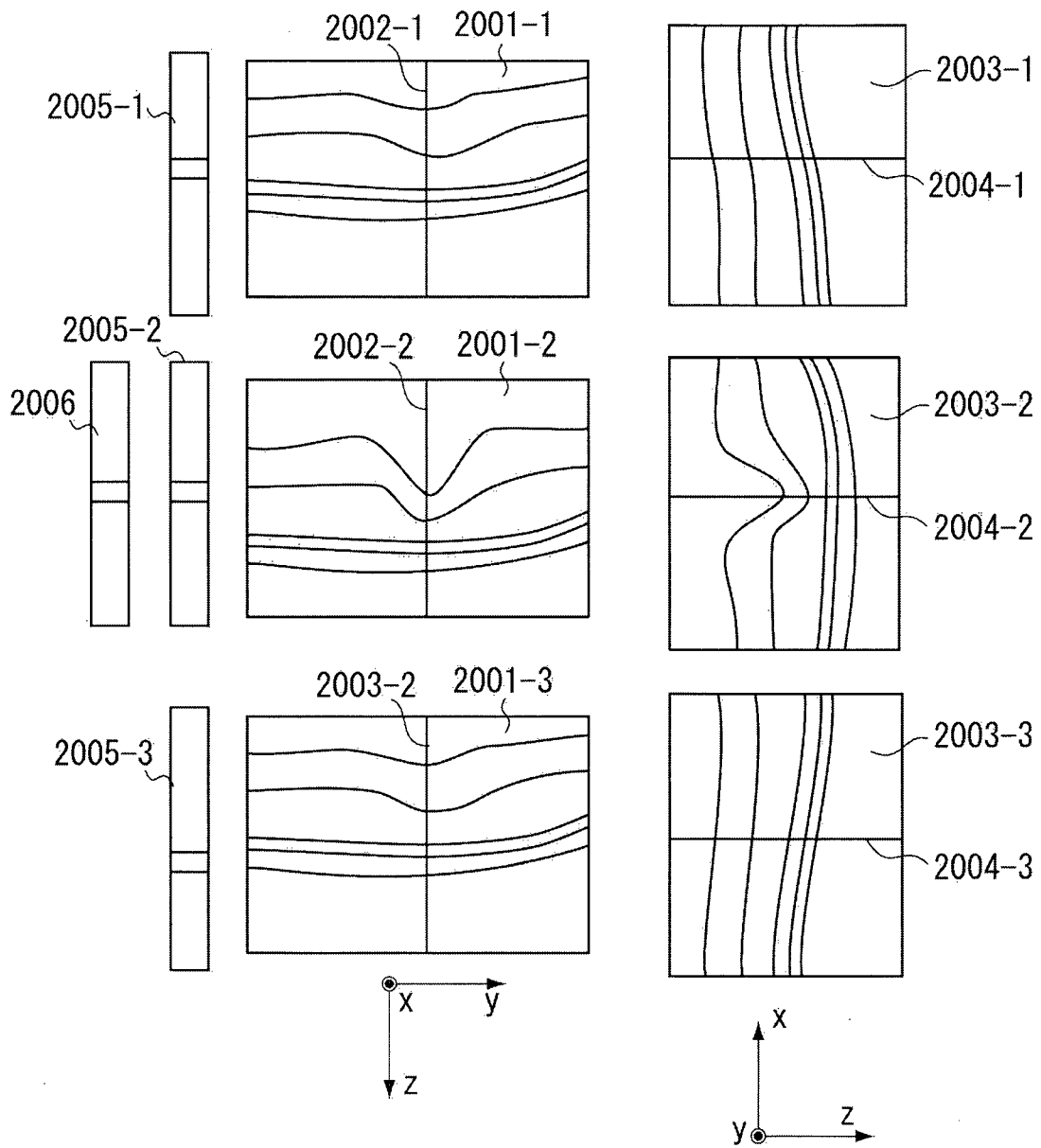
	International application No.
	PCT/JP2011/058160

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. A61B3/12(2006.01)i, A61B3/10(2006.01)i

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)

Int.Cl. A61B3/12, A61B3/10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
        Published examined utility model applications of Japan 1922-1996
        Published unexamined utility model applications of Japan 1971-2011
        Registered utility model specifications of Japan 1996-2011
        Published registered utility model applications of Japan 1994-2011

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2010-12166 A (CANON KABUSHIKI KAISHA) 2010.01.22, whole document & US 2010/0002241 A1	1-7
A	WO 2008/116270 A1 (THE INSTITUTE FOR EYE RESEARCH LIMITED) 2008.10.02, whole document & JP 2010-522049 A & US 2010/0225883 A & EP 2139381 A & MX 2009010406 A & CA 2682172 A & CN 101668475 A & KR 10-2010-0015980 A	1-7
A	JP 2005-511233 A (TECHNOVISION GMBH GESELLSCHAFT FUER DIEENTWICKLUNG TECHNOLOGIEN) 2005.04.28, whole document & US 2005/0163455 A1 & EP 1455638 A & WO 2003/051187 A2 & CA 2469780 A & BR 215101 A & CN 1604753 A & AU 2002358138 B	1-7

☑ Further documents are listed in the continuation of Box C.　　☐ See patent family annex.

* Special categories of cited documents:	"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
"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	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11.05.2011	24.05.2011

Name and mailing address of the ISA/JP	Authorized officer	
Japan Patent Office	Takanobu Miyagawa	2Q 9208
3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No. +81-3-3581-1101 Ext. 3292	

Form PCT/ISA/210 (second sheet) (July 2009)

C (Continuation).	DOCUMENTS CONSIDERED TO BE RELEVANT	
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2008-203246 A (KABUSIKIKAISHA TOPCON) 2008.09.04, whole document & US 2009/0027685 A1 & EP 1950526 A1 & DE 602008000765 D & AT 460641 T & CN 101229053 A	1-7
P,A	JP 2010-220774 A (KABUSHIKI KAISHA NIDEK) 2010.10.07, whole document (No Family)	1-7