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(54) Apparatus and method for imaging optical coherence tomographic image

Vorrichtung und Verfahren zur Abbildung eines optischen Kohärenztomographiebildes

Appareil et procédé pour l'imagerie tomographique à cohérence optique

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EP 2 322 081 B1

Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to an apparatus and method for imaging an optical coherence tomographic image and, more particularly, to an imaging apparatus and method for use in an ophthalmic field.

Description of the Related Art

[0002] Currently, various ophthalmic apparatuses using optical devices are used. Such apparatuses are, e.g., an anterior eye camera, a fundus camera, and a confocal scanning laser ophthalmoscope (scanning laser ophthalmoscope (SLO)). Particularly, an optical coherence tomographic imaging apparatus (hereinafter referred to as an OCT apparatus) is configured to obtain a tomographic image of an inspection target at high resolution, and is becoming an indispensable apparatus in clinics dedicated to retinal outpatients. The above OCT apparatus uses a low-coherence light-source as a source of light. Light from the light-source is split into measurement light and reference light through a split optical path such as a beam splitter. With one of such split-light components, i.e., the measurement light, an inspection target such as an eye via a measurement optical path is irradiated. Return light thereof is guided to a detection position via a detection optical path. The return light is reflected light or scattered light, which contains information concerning an interface in a direction of light-irradiating of the inspection target. The other light component, i.e., the reference light is reflected by a reference mirror or the like via a reference optical path, and guided to the detection position. The return light and the reference light are caused to interfere with each other. Interference light generated therebetween is guided to a photoelectric conversion element such as a charge-coupled device (CCD) line sensor or a complementary metal-oxide semiconductor (CMOS) line sensor via an optical element such as a spectroscope. Then, wavelength spectra are collectively output therefrom as electric signals. The electric signals output in the above manner are converted by an analog-to-digital (A/D) converter into digital signals. In addition, the digital signals obtained by A/D conversion are subjected to a Fourier transform. Consequently, a tomographic image of the inspection target can be obtained. This method is referred to as a spectrum domain (hereinafter referred to as SD) method.

[0003] If a retina is employed as the inspection target in the OCT apparatus, a three-dimensional (3D) image of the retina can be acquired by scanning measurement light on the retina using a Galvano mirror or the like. However, if image information is acquired by setting, as the inspection target, a part of an eyeball such as a retina, it is difficult to accurately acquire image information concerning the eyeball, because of a subject's involuntary eye movement during visual-fixation. Thus, Japanese Patent Application Laid-Open No. 2008-104628 proposes an apparatus for imaging a conjunctiva and a sclera of a subject's eye by excluding effects of the subject's involuntary eye movement during visual-fixation.

[0004] The apparatus proposed in Japanese Patent Application Laid-Open No. 2008-104628 employs a system configured to exclude effects of the subject's involuntary eye movement during visual-fixation according to a method of adjusting a position of an imaging area corresponding to each taken image by following the subject's involuntary eye movement during visual-fixation, using a camera capable of imaging a target at a rate of 200 frames per second (fps) . However, in order to acquire a 3D-image of an ocular-fundus, according to the system discussed in Japanese Patent Application Laid-Open No. 2008-104628, hundreds milliseconds (ms) are taken to acquire a single 3D-image. That is, about only two 3D-images can be acquired per second, as will be described below. Thus, according to the system discussed in Japanese Patent Application Laid-Open No. 2008-104628, it is difficult to eliminate effects of the subject's involuntary eye movement upon an image during visual-fixation, particularly, effects of a flick thereupon causing a largest displacement of a retina among the motions of the subject's involuntary eye movement during visual-fixation. Document US 2005/270486 discloses an OCT imaging device that holds three-dimensional imaging during eye motion.

[0005] Hereinafter, these problems are described in detail. Figs. 2A through 2C illustrate aspects of a subject's involuntary eye movement during visual-fixation. In Fig. 2A, a solid curve 201 represents a trajectory of the center of the retina of the subject's eye. As illustrated in Fig. 2A, the retinal center initially positioned at point A moves to point B through paths that are represented by two-headed dashed arrows 202, 203, and 204 and generated by the subject's involuntary eye movement during visual-fixation. Usually, the involuntary eye movement includes a combination of the following three motions, i.e., a drift 202 in which the retinal center moves at low speed, a tremor 203 in which the retinal center repeats fine zigzag movements, and a flick 204 in which the retinal center instantaneously moves. In order to describe features of the subject's involuntary eye movement during visual-fixation, Fig. 2B illustrates the movement of the retinal center, which has been illustrated in Fig. 2A, by setting an abscissa axis and an ordinate axis to represent time, and acceleration in a direction of a y-axis (vertical direction) of a position of the retinal center, respectively. The retina operates in two-dimensional directions, i.e., a horizontal direction and a vertical direction, respectively, due to the involuntary eye movement during visual-fixation. For brevity of description, only an operation in the vertical direction is described. As illustrated in Fig. 2B, accelerations 212 are obtained where a drift is performed. Accelerations 213 are obtained where a tremor is performed. Accelerations 214 are obtained where a flick is performed. Fig. 2C illustrates the features of the three motions included in the involuntary eye movement during visual-fixation.

[0006] The drift is a small motion that substantially always occurs and that causes a retinal displacement of 7 μm through 17 μm in a time-period of 0.2 seconds (s) through 1 s. The tremor is a slight quiver that occurs periodically every period corresponding to a frequency of 30 Hertzes (Hz) through 100 Hz, i.e., every period of 10ms through 33ms and that causes a retinal displacement of 0.3 μm through 3.5 μm. The flick is an abrupt motion that occurs periodically every period corresponding to a frequency of 0.2 Hz through 2 Hz, i.e., every period of 500ms through 5 s and that causes a retinal displacement of 7 μm through 52 μm in a time-period of 10ms through 30ms.

[0007] Hereinafter, it is described a case of acquiring a 3D-image of an ocular-fundus by setting a scanning area of 6 millimeters (mm) $\times$ 6mm and a resolution corresponding to a size of 20μm $\times$ 20μm, using the apparatus discussed in Japanese Patent Application Laid-Open No. 2008-104628. It is assumed that interference light dispersed by a spectroscope is subjected to photoelectric conversion using a high-speed line camera at a line rate of 250 kilo-Hz (kHz), and that 20% of a time-period in which the ocular-fundus is two-dimensionally scanned using a Galvano mirror, is unavailable for reading a 3D-image of the ocular-fundus. In this case, time T required to read the 3D-image is given by:

$$T = (6/(20*10^{-3}))^2/(250*10^3)/0.8 = 450\text{ms}.$$

When a 3D-image of the ocular-fundus is acquired on the above conditions, among the motions of the involuntary eye movement during visual-fixation, the drift and the tremor are not so problematic in acquiring a 3D-image, in view of the resolution and the displacement per unit time. However, if a flick occurs in a time-period of 450ms, which is required to acquire a 3D-image, a position of an eye is extremely displaced in a short time. Accordingly, continuity of a read image cannot be assured. Consequently, an accurate 3D-image thereof cannot be acquired. According to the method using a camera capable of imaging at a rate of 200 fps, it is difficult to eliminate effects of the involuntary eye movement upon an image during visual-fixation, particularly, effects of a flick thereupon causing a largest displacement of a retina among the motions of the subject's involuntary eye movement during visual-fixation.

[0008] Furthermore, the document US 2005/270486 A1 discloses an eye tracking method for determining a position of an eye or a part of an eye in an image of an image sequence by performing a comparison between said image and a reference image. Thereby, the determined eye tracking path is used for position determination and tracking in combination with a diagnosis and/or surgical device, such as an optical coherence tomographic imaging apparatus. In case an abnormality during eye tracking is detected, which may be caused e.g. by a rapid eye movement, the retinal tracking system in operation delivers a HOLD signal to an OCT-scanning system. When the HOLD signal is active, the OCT scanning system stops the scanning pattern program. Further, in case it is determined that the abnormality is not present any more, the HOLD signal becomes inactive and the scan continues.

SUMMARY OF THE INVENTION

[0009] The present invention in its first aspect provides an ophthalmic imaging method as specified in claim 1.

[0010] Furthermore, the present invention in its second aspect provides an ophthalmic imaging apparatus as specified in claim 5.

[0011] Further features and advantageous modifications are shown in the dependent claims.

[0012] 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 THE DRAWINGS

[0013] 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. The invention is solely defined by the claims. All non-claimed embodiments, aspects and examples disclosed in the description and figures are for exemplary purpose only and do not form part of the invention.

Fig. 1 is a block diagram illustrating a configuration of an SD-OCT apparatus, which is an example of a configuration of an imaging apparatus for imaging an optical coherence tomographic image according to a first exemplary embodiment of the present invention.

Figs. 2A, 2B, and 2C illustrate a subject's involuntary eye movement during visual-fixation.

Fig. 3 illustrates a manner in which the SD-OCT apparatus according to the first exemplary embodiment of the present invention performs raster scan on a retina with measurement light.

Figs. 4A, 4B, and 4C illustrate two-dimensional images of an ocular-fundus read with a line camera of the SD-OCT apparatus according to the first exemplary embodiment of the present invention.

Fig. 5 is a flowchart illustrating a method of imaging an optical coherence tomographic image, which is performed by the SD-OCT apparatus according to the first exemplary embodiment of the present invention.

DESCRIPTION OF THE EMBODIMENTS

[0014] Various exemplary embodiments, features, and aspects of the invention will be described in detail below with reference to the drawings.

[0015] Modes for carrying out the present invention are described with reference to the following exemplary embodiments. However, the present invention is not limited to configurations of the following exemplary embodiments.

[0016] Hereinafter, an SD-OCT apparatus serving as an example of an ophthalmic OCT apparatus, to which an imaging apparatus for imaging an optical coherence tomographic image according to the present invention is applied, is described with reference to Fig. 1 as a first exemplary embodiment according to the present invention. Fig. 1 is a block diagram illustrating a configuration of an SD-OCT apparatus according to the present exemplary embodiment. As illustrated in Fig. 1, light output from a light source 101 is split by a beam splitter 102 into reference light 112 and measurement light 111.

[0017] The measurement light 111 is guided via a measurement optical-path to an eye 105 serving as an inspection target. Then, the measurement light 111 is reflected or scattered to be returned to the beam splitter 102 as return light 113. After that, the returned light 113 is combined with the reference light 112 via a reference optical-path by the beam splitter 102 into interference light 114.

[0018] The interference light 114 is dispersed by a diffraction grating 107. Then, an image is formed on a line sensor 109 by a lens 108.

[0019] In this apparatus, a CCD line sensor is used as the line sensor 109. However, a CMOS line sensor can be used as the line sensor 109 without problems. Image information (optical coherence tomographic information) photoelectrically converted at the line sensor 109 is subjected to A/D conversion at an image information processing unit 110. A tomographic image of the eye 105 can be obtained by a Fourier transform of digitalized image information.

[0020] Next, the light source 101 and related matters are described.

[0021] The light source 101 is a super luminescent diode (SLD) which is a typical low-coherence light source. The light source 101 outputs light which is 840 nanometers (nm) in wavelength and 50 nm in bandwidth. The bandwidth affects a resolution in a direction of an optical axis of an obtained tomographic image and is, therefore, an important parameter. In the present exemplary embodiment, the SLD is selected as the type of the light source. As long as the light source can output low coherence light, any other type of a light source, such as an amplified spontaneous emission (ASE) type light source can be used as the light source 101. In view of a fact that output light of the light source 101 is used for ocular measurement, near-infrared wavelengths are suitable for the wavelength of the light to be output from the light source 101. In addition, the wavelength of the output light affects a resolution in a lateral direction of the obtained tomographic image. Accordingly, it is preferable that the wavelength of the output light is as short as possible. In the present exemplary embodiment, the wavelength of the output light is set at 840 nm. Apparently, depending on a measurement region of an inspection target, other wavelengths can be selected as the wavelength of the output light of the light source 101.

[0022] Next, an optical path of the reference light 112 is described hereinafter.

[0023] The reference light obtained by splitting the output light of the light source 101 at the beam splitter 102 is reflected by a mirror 106 and returned to the beam splitter 102.

[0024] A length of this optical path is set to be the same as that of an optical path of the measurement light 111. Accordingly, the reference light 112 and the measurement light 111 can be caused to interfere with each other.

[0025] Next, the optical path of the measurement light 111 is described.

[0026] The measurement light 111 obtained by splitting the output light of the light source 101 at the beam splitter 102 is incident upon a mirror of an XY-scanner 103.

[0027] In Fig. 1, for simplicity of drawing, the XV-scanner 103 is illustrated as a single mirror.

[0028] However, actually, two mirrors, i.e., an X-scanning mirror and a Y-scanning mirror are arranged close to each other. The XY-scanner 103 performs raster scan on the retina of the eye 105 via a lens 104 in two-dimensional directions perpendicular to an optical axis thereof.

[0029] The XY-scanner 103 starts a scanning operation according to a start-up signal 117 output from a controller 116 which will be described below. The lens 104 focuses the measurement light 111 onto the retina.

[0030] Fig. 3 illustrates a manner in which the SD-OCT apparatus according to the present exemplary embodiment performs raster scan on the retina.

[0031] As indicated by each solid arrow 301 in Fig. 3, in order to read an image of a retina, the retina is scanned with a beam of the measurement light 111 while shifting in parallel at a predetermined speed.

[0032] Generally, a planar image acquired by performing such scanning on a retina so as to cut the retina by a plane is referred to as a B-scan image.

[0033] Then, as indicated by each dotted arrow 302 in Fig. 3, in order to read the next B-scan image, an irradiation position of the beam of the measurement light 111 is moved by driving the XY-scanner 103 at high speed.

[0034] In order to read a 3D-image of the retina, a scanning operation indicated by the arrows 301 and 302 is repeatedly performed.

[0035] The center of the beam of the measurement light 111 is adjusted to the center of rotation of the mirror.

[0036] When the measurement light 111 is incident upon the eye 105, the measurement light 111 is reflected or scattered by the retina of the eye 105 and turned into the return light 113.

[0037] A line camera (referred to also as a two-dimensional image acquisition means or as a fundus image acquisition means) 115 is configured by a lens, a line sensor, an A/D converter, and the like.

[0038] Reflection light from the retina irradiated with light rays from an infrared light source (not shown) is reflected by a scanner 118 and guided to the line camera 115. Thus, the reflection light corresponding to each line is read by the line camera 115. The scanner 118 is rotated around an axis parallel to a direction of each line from the line camera 115. Accordingly, an ocular-fundus image (referred to also as a two-dimensional image of the retina or as a retinal image) can be read by the camera 115. The controller 116 joins images respectively corresponding to lines so as to generate a single ocular-fundus image. Every time when an ocular-fundus image is generated, the scanner 118 repeats the action and continues to scan. Consequently, the controller 116 can consecutively acquire ocular-fundus images.

[0039] In addition, the controller 116 extracts feature points from the ocular-fundus images according to a known method. Then, the controller 116 detects, from a displacement of each feature point of the consecutively acquired ocular-fundus images, an amount of displacement of an eye due to the involuntary eye movement during visual-fixation. More specifically, a flick motion detection means for detecting a flick motion, among the motions of the involuntary eye movement during visual-fixation, is configured by causing the controller 116 to detect the amount of displacement of an eye due to the involuntary eye movement during visual-fixation.

[0040] Figs. 4A, 4B, and 4C illustrate images of an ocular-fundus read by the line camera 115.

[0041] Fig. 4A illustrates the entire image of the ocular-fundus. In Fig. 4A, an optic disc 402, retinal blood vessels 403 and a feature region 404 extracted by the controller 116 are shown in a retinal image 401.

[0042] Each of Figs. 4B, 4C and 4D illustrates the same retinal blood vessels in the retinal feature region 404 shown in an associated one of the consecutively acquired ocular-fundus images.

[0043] The controller 116 selects a branch point of the blood vessels encircled in each of Figs. 4B, 4C, and 4D as a feature point. Then, the controller 116 detects, from a change in coordinates of the branch point, an eye displacement due to the involuntary eye movement during visual-fixation.

[0044] As seen from Figs. 4B, 4C, and 4D, the position of the feature point moves from a leftwardly upper position to a rightwardly lower position.

[0045] This means that the eye moves leftwardly and upwardly. The ocular-fundus image is read with a view to detecting a displacement due to the involuntary eye movement during visual-fixation. Accordingly, it is unnecessary to read the entire retina. It is sufficient to determine a reading region in view of an update rate of the ocular-fundus image.

[0046] According to the present exemplary embodiment, it is assumed that a region of 1024×1024 pixels is read at a resolution of 10×10 μm every about 10 ms using a line camera having a line rate of 100 kHz. An operation of each of the above units and the like is controlled by a central processing unit (CPU (control means (not shown))) built in the controller 116.

[0047] More specifically, the apparatus is configured such that after an end of the flick motion is detected, the controller (flick motion detection means) 116 can start acquiring a tomographic image of an eye under the control of the CPU (control means).

[0048] Next, an imaging method according to the present exemplary embodiment by the SD-OCT apparatus according to the present exemplary embodiment is described with reference to Fig. 5.

[0049] First, in step S501, an ocular-fundus image is read using the scanner 118 and the line camera 115 according to an instruction from the controller 116.

[0050] Then, in step S502, the feature point of the retina is extracted by the controller 116 in a flick motion detection process. In addition, the controller 116 compares the extracted feature point with that in the immediately preceding ocular-fundus image and determines whether a displacement of the feature point is equal to or more or less than a predetermined value.

[0051] The predetermined value is a value to distinguish the flick from the other motions of the involuntary eye movement, i.e., from the drift and the tremor.

[0052] According to the present exemplary embodiment, the predetermined value is assumed to be 5μm, based on the update rate of the ocular-fundus image, which is 10ms, and the features of the involuntary eye movement during visual-fixation, which are described in Fig. 2C.

[0053] If a control-variable n=0, i.e., if the reading of a retinal image is started, there is no image of the immediately preceding frame. Thus, it is determined that the amount of the displacement of the feature point is less than the predetermined value.

[0054] Next, if it is determined that the amount of the displacement of the retina is less than the predetermined value, i.e., no flicks occur (NO in step S502), in step S503, the control-variable n is incremented by 1. Then, the process returns to step S501 in which the next ocular-fundus image is captured.

[0055] Then, the capturing of the ocular-fundus image is continued in steps S501 through S503 until it is determined that the amount of the displacement of the retina is equal to or more than the predetermined value, i.e., a flick occurs (YES in step S502) .

[0056] On the other hand, if it is determined that the amount of the displacement of the retina is equal to or more than the predetermined value, i.e., a flick occurs (YES in step S502), in step S504, the control-variable n is incremented by 1. Then, in step S505, the next ocular-fundus image is captured. Next, in step S506, it is determined whether the amount of the displacement of the feature point on the retina is equal to or more than the predetermined value.

[0057] Then, if it is determined that the amount of the displacement of the feature point on the retina is equal to or more than the predetermined value, i.e., a flick is being caused (YES in step S506), the process returns to step S504 in which the control-variable n is incremented by 1. Next, in step S505, the next ocular-fundus image is captured. Then, execution of a loop including steps S504 through S506 is continued until it is determined that the amount of the displacement of the retina is less than the predetermined value, i.e., the flick is terminated (NO in step S506).

[0058] Next, in the process of imaging a tomographic image, if it is determined that the amount of the displacement of the retina is less than the predetermined value, i.e., 5μm based on the features of the involuntary eye movement during visual-fixation, in other words, the flick is terminated (NO in step S506), a start-up signal 117 is output from the controller 116 to the XY-scanner 103.

[0059] Then, in step S507, imaging of a 3D-image of the ocular-fundus is started. Next, in step S508, an operation of the apparatus is terminated when the imaging of a 3D-image of the ocular-fundus is finished.

[0060] In the above exemplary embodiment, thresholds for determining whether a flick motion is started or ended are set in steps S502 and S506 at the same value. However, the thresholds are not necessarily set at the same value.

[0061] In the above exemplary embodiment, the line camera 115 and the scanner 118 are used as means for detecting the displacement of an eye. However, if the scanner 118 is set to two-dimensionally scan, a photoelectric conversion element can be used instead of the line camera 115, i.e., the line sensor. In addition, an area sensor configured to directly read an image of an oracular-fundus can be used.

[0062] An example of an apparatus configured to continue to measure an involuntary eye movement during visual-fixation even when a 3D-image of an oracular-fundus is being acquired differently from the first exemplary embodiment, is described as a second exemplary embodiment of the present invention.

[0063] In the foregoing description of the first exemplary embodiment, it has been described a method for imaging, when the imaging of a 3-D image of an oracular-fundus is started after a flick is finished, the entire predetermined region of an image of an oracular-fundus as it is, without measuring an involuntary eye movement during visual-fixation. However, the 3D-imaging of an oracular-fundus, and the measurement of an involuntary eye movement during visual-fixation, can be performed independent of each other. Thus, a method for continuing, even while the 3D-imaging of an oracular-fundus is performed, the measurement of an involuntary eye movement during visual-fixation, is effective.

[0064] More specifically, even in a time-period since the start of the 3D-imaging of an oracular-fundus in step S507 until the end of the 3D-imaging in step S508, the controller 116 continues to cause the line camera 115 and the scanner 118 to operate, and also continues to detect whether a flick occurs.

[0065] In this case, it is enough to determine whether an eye movement extremely affecting an image of an oracular-fundus is caused. Accordingly, it is sufficient to repeatedly perform, during an operation in steps S507 and S508 illustrated in Fig. 5, an operation in steps S501 through S503.

[0066] If an eye movement extremely affecting an image of an oracular-fundus is caused during the 3D-imaging, it is advisable to issue a measurer a warning indicating that the 3D-imaging is stopped, and to, e.g., start the 3D-imaging over again.

[0067] A value differing from 5μm employed as a pre-imaging threshold can be used as a threshold for detecting a displacement of a retina during 3D-imaging.

[0068] 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 modifications, equivalent structures, and functions.

[0069] An ophthalmic imaging apparatus for imaging a subject's eye (105) includes a detection means configured to detect facts that the subject's eye (105) moves by an amount of movement thereof, which is equal to or more than a predetermined value, and that the movement thereof is finished, and an imaging start means configured to start imaging of the subject's eye (105) according to a result of detection by the detection means.

Claims

1. An ophthalmic imaging method for three-dimensional imaging a tomographic image of a subject's eye (**105**) based on interference light generated by interference between return light (**113**) from the subject's eye (**105**) irradiated with measurement light (**111**) and reference light (**112**) corresponding to the measurement light (**111**), **characterized by:**

   prior to acquiring a three-dimensional tomographic image of an entire predetermined region of the subject's eye (**105**),

   acquiring (S501) consecutive images of an ocular-fundus of the subject's eye **(105),** and using the acquired images of the ocular-fundus to thereby detect (S502) an amount of displacement of the subject's eye (**105**) due to a subject's involuntary eye movement during visual-fixation; and
   detecting (S506) a flick motion among motions of the subject's involuntary eye movement during visual-fixation, based on the detected amount of displacement of the subject's eye (**105**); and

   starting acquisition (S507) of the three-dimensional tomographic image of the entire predetermined region of the subject's eye (**105**) after an end of the flick motion is detected in detecting the flick motion.

2. The ophthalmic imaging method according to claim 1, wherein the detecting of the flick motion is performed by determining whether the amount of the displacement, which is detected by comparison between the acquired consecutive images of the ocular-fundus, is equal to or more than a predetermined value.

3. The ophthalmic imaging method according to claim 1, wherein the detecting of the flick motion is continued even during acquisition of the three-dimensional tomographic image.

4. A program stored in a non-transitory tangible computer-readable storage medium comprising instructions to cause the ophthalmic imaging apparatus according to any of claims 5 to 8 to execute the steps of the ophthalmic imaging method according to any of claims 1 to 3.

5. An ophthalmic imaging apparatus for three-dimensional imaging a subject's eye (**105**), comprising:

   means configured to image a tomographic image of a subject's eye (105) based on interference light generated by interference between return light (113) from the subject's eye irradiated with measurement light (111) and reference light (112) corresponding to the measurement light (111), an acquisition means (**115**) configured to, prior to acquiring a three-dimensional tomographic image of an entire predetermined region of the subject's eye (**105**), consecutively acquire images of an ocular-fundus of the subject's eye (**105**);
   a detection means (116) configured to, prior to acquiring the three-dimensional tomographic image of the subject's eye (**105**), detect facts that the subject's eye moves by an amount of movement, which is equal to or more than a predetermined value, and that the movement thereof is finished, wherein the detection means (**116**) performs the detection using the images of the ocular-fundus acquired by the acquisition means (**115**); and
   an imaging start means (**116**) configured to start, after the detection means (**116**) detected the facts that the motion of the subject's eye is finished, three-dimensional imaging of the entire predetermined region of the subject's eye (**105**) for acquiring the three-dimensional tomographic image of the subject's eye (**105**) according to a result of detection by the detection means.

6. The ophthalmic imaging apparatus according to claim 5, wherein the amount of movement, which is equal to or more than the predetermined value, is generated due to a flick motion among motions of the subject's involuntary eye movement during visual-fixation.

7. The ophthalmic imaging apparatus according to claim 5, wherein the imaging start means (**116**) starts acquisition of the three-dimensional tomographic image of the subject's eye (**105**) based on interference light generated by interference between return light (**113**) from the subject's eye (**105**) irradiated with measurement light (**111**), and reference light (**112**) corresponding to the measurement light (**111**).

8. The ophthalmic imaging apparatus according to claim 5, further comprising:

   an imaging termination means (**116**) configured to finish imaging of the subject's eye (**105**) according to a result of the detection by the detection means when the amount of movement, which is equal to or more than the predetermined value, is detected by the detection means while consecutively acquiring a plurality of tomographic images of the subject's eye (**105**).

Patentansprüche

1. Ophthalmisches Abbildungsverfahren zum dreidimensionalen Abbilden eines tomographischen Bildes eines Auges einer Testperson (**105**) basierend auf Interferenzlicht, das durch eine Interferenz zwischen einem zurückkehrenden Licht (**113**) von dem Auge der Testperson (**105**), das mit Messlicht (**111**) bestrahlt wird, und einem Referenzlicht (**112**) entsprechend des Messlichts (**111**) erzeugt wird,
gekennzeichnet durch:

    vor dem Beziehen eines dreidimensionalen tomographischen Bildes einer gesamten vorbestimmten Region des Auges der Testperson (**105**),

        Beziehen (**S501**) von aufeinanderfolgenden Bildern eines Augenhintergrunds des Auges der Testperson (**105**), und Verwenden der bezogenen Bilder des Augenhintergrunds, um dadurch ein Ausmaß einer Verschiebung des Auges der Testperson (**105**) aufgrund einer unbeabsichtigten Augenbewegung der Testperson während einer visuellen Fixierung zu erfassen (**S502**); und
        Erfassen (**S506**) einer Ruckbewegung aus Bewegungen der unbeabsichtigten Augenbewegung der Testperson während einer visuellen Fixierung, basierend auf dem erfassten Ausmaß einer Verschiebung des Auges der Testperson (**105**); und

    Starten des Beziehens (**S507**) des dreidimensionalen tomographischen Bildes der gesamten vorbestimmten Region des Auges der Testperson (**105**), nachdem ein Ende der Ruckbewegung bei der Erfassung der Ruckbewegung erfasst wird.

2. Ophthalmisches Abbildungsverfahren gemäß Anspruch 1, wobei das Erfassen der Ruckbewegung durch bestimmen, ob das Ausmaß der Verschiebung, das durch einen Vergleich zwischen den bezogenen aufeinanderfolgenden Bildern des Augenhintergrunds erfasst wird, größer oder gleich einem vorbestimmten Wert ist, durchgeführt wird.

3. Ophthalmisches Abbildungsverfahren gemäß Anspruch 1, wobei das Erfassen der Ruckbewegung fortgesetzt wird, auch während des Beziehens des dreidimensionalen tomographischen Bildes.

4. Programm, das in einem nicht-transitorischen materiellen computerlesbaren Speichermedium gespeichert ist, welches Anweisungen zum Bewirken der ophthalmischen Abbildungsvorrichtung gemäß einem der Ansprüche 5 bis 8, um die Schritte des ophthalmischen Abbildungsverfahren gemäß einem der Ansprüche 1 bis 3 auszuführen, aufweist.

5. Ophthalmische Abbildungsvorrichtung zum dreidimensionalen Abbilden eines Auges einer Testperson (**105**), mit:

    einer Einrichtung, die konfiguriert ist, um ein tomographisches Bild eines Auges einer Testperson (**105**) basierend auf Interferenzlicht, das durch eine Interferenz zwischen einem zurückkehrenden Licht (**113**) von dem Auge der Testperson, das mit Messlicht (**111**) bestrahlt wird, und einem Referenzlicht (**112**) entsprechend des Messlichts (**111**) erzeugt wird, abzubilden,
    einer Bezugseinrichtung (**115**), die konfiguriert ist, um vor Beziehen eines dreidimensionalen tomographischen Bildes einer gesamten vorbestimmten Region des Auges der Testperson (**105**) aufeinanderfolgende Bilder eines Augenhintergrunds des Auges der Testperson (**105**) zu beziehen;
    einer Erfassungseinrichtung (**116**), die konfiguriert ist, um vor Beziehen des dreidimensionalen tomographischen Bildes des Auges der Testperson (**105**), Gegebenheiten zu erfassen, dass sich das Auge der Testperson um ein Ausmaß einer Bewegung bewegt, das größer oder gleich einem vorbestimmten Wert ist, und dass die Bewegung davon beendet ist, wobei die Erfassungseinrichtung (**116**) die Erfassung unter Verwendung der durch die Bezugseinrichtung (**115**) bezogenen Bilder des Augenhintergrunds durchführt; und
    einer Abbildungsstarteinrichtung (**116**), die konfiguriert ist, um, nachdem die Erfassungseinrichtung (**116**) die Gegebenheit erfasst hat, dass die Bewegung des Auges der Testperson beendet ist, ein dreidimensionales Abbilden der gesamten vorbestimmten Region des Auges der Testperson (**105**) zum Beziehen des dreidimensionalen tomographischen Bildes des Auges der Testperson (**105**) gemäß einem Ergebnis einer Erfassung

durch die Erfassungseinrichtung zu starten.

6. Ophthalmische Abbildungsvorrichtung gemäß Anspruch 5, wobei das Ausmaß einer Bewegung, das größer oder gleich dem vorbestimmten Wert ist, aufgrund einer Ruckbewegung aus Bewegungen der unbeabsichtigten Augenbewegung der Testperson während einer visuellen Fixierung erzeugt wird.

7. Ophthalmische Abbildungsvorrichtung gemäß Anspruch 5, wobei die Abbildungsstarteinrichtung (**116**) ein Beziehen des tomographischen Bildes des Auges der Testperson (**105**) basierend auf Interferenzlicht, das durch eine Interferenz zwischen einem zurückkehrenden Licht (**113**) von dem Auge der Testperson (**105**), das mit Messlicht (**111**) bestrahlt wird, und einem Referenzlicht (**112**) entsprechend des Messlichts (**111**) erzeugt wird, startet.

8. Ophthalmische Abbildungsvorrichtung gemäß Anspruch 5, weiterhin mit:

einer Abbildungsbeendigungseinrichtung (**116**), die konfiguriert ist, um ein Abbilden des Auges der Testperson (**105**) gemäß einem Ergebnis durch die Erfassungseinrichtung, wenn das Ausmaß einer Bewegung, das größer oder gleich dem vorbestimmten Wert ist, durch die Erfassungseinrichtung erfasst wird, während aufeinanderfolgend eine Vielzahl von tomographischen Bildern des Auges der Testperson (**105**) bezogen wird.

Revendications

1. Procédé de formation d'image ophtalmique destiné à la formation d'image tridimensionnelle d'une image tomographique de l'oeil (105) d'un sujet sur la base d'une lumière d'interférence générée par interférence entre une lumière renvoyée (113) à partir de l'oeil (105) du sujet exposé à une lumière de mesure (111) et une lumière de référence (112) correspondant à la lumière de mesure (111),
caractérisé par :

avant l'acquisition d'une image tomographique tridimensionnelle de la totalité d'une région prédéterminée de l'oeil (105) du sujet,
l'acquisition (S501) d'images consécutives d'un fond d'oeil de l'oeil (105) du sujet, et l'utilisation des images acquises du fond d'oeil afin de détecter (S502) ainsi un niveau de déplacement de l'oeil (105) du sujet dû à un mouvement d'oeil involontaire du sujet pendant la fixation visuelle ; et
la détection (S506) d'un mouvement de clignement parmi des déplacements du mouvement d'oeil involontaire du sujet pendant la fixation visuelle, sur la base du degré détecté de déplacement de l'oeil (105) du sujet ; et
le début de l'acquisition (S507) de l'image tomographique tridimensionnelle de la totalité de la région prédéterminée de l'oeil (105) du sujet après qu'une fin du mouvement de clignement a été détectée lors de la détection du mouvement de clignement.

2. Procédé de formation d'image ophtalmique selon la revendication 1, dans lequel la détection du mouvement de clignement est effectuée en déterminant si le niveau de déplacement, détecté par comparaison entre les images consécutives acquises du fond d'oeil, est égal ou supérieur à une valeur prédéterminée.

3. Procédé de formation d'image ophtalmique selon la revendication 1, dans lequel la détection du mouvement de clignement est poursuivie même pendant l'acquisition de l'image tomographique tridimensionnelle.

4. Programme stocké sur un support de stockage lisible par ordinateur tangible non volatil comprenant des instructions destinées à amener l'appareil de formation d'image ophtalmique selon l'une quelconque des revendications 5 à 8 à exécuter les étapes du procédé de formation d'image ophtalmique selon l'une quelconque des revendications 1 à 3.

5. Appareil de formation d'image ophtalmique destiné à la formation d'image tridimensionnelle de l'oeil (105) d'un sujet, comprenant :

un moyen configuré pour former une image tomographique de l'oeil (105) d'un sujet sur la base d'une lumière d'interférence générée par interférence entre une lumière renvoyée (113) à partir de l'oeil du sujet exposé à une lumière de mesure (111) et une lumière de référence (112) correspondant à la lumière de mesure (111),
un moyen d'acquisition (115) configuré pour, avant l'acquisition d'une image tomographique tridimensionnelle de la totalité d'une région prédéterminée de l'oeil (105) du sujet, acquérir consécutivement des images d'un fond d'oeil de l'oeil (105) du sujet ;

un moyen de détection (116) configuré pour, avant l'acquisition de l'image tomographique tridimensionnelle de l'oeil (105) du sujet, détecter des faits selon lesquels l'oeil du sujet se déplace d'une quantité de mouvement qui est égale ou supérieure à une valeur prédéterminée, et selon lesquels ledit mouvement est terminé, le moyen de détection (116) effectuant la détection en utilisant les images du fond d'oeil acquises par le moyen d'acquisition (115) ; et

un moyen de début de formation d'image (116) configuré pour commencer, après que le moyen de détection (116) a détecté les faits selon lesquels le mouvement de l'oeil du sujet est terminé, la formation d'image tridimensionnelle de la totalité de la région prédéterminée de l'oeil (105) du sujet afin d'acquérir l'image tomographique tridimensionnelle de l'oeil (105) du sujet conformément à un résultat de détection fourni par le moyen de détection

6. Appareil de formation d'image ophtalmique selon la revendication 5, dans lequel la quantité de mouvement, qui est égale ou supérieure à la valeur prédéterminée, est générée du fait d'un mouvement de clignement parmi des déplacements du mouvement involontaire de l'oeil du sujet pendant la fixation visuelle.

7. Appareil de formation d'image ophtalmique selon la revendication 5, dans lequel le moyen de début de formation d'image (116) commence l'acquisition de l'image tomographique tridimensionnelle de l'oeil (105) du sujet sur la base d'une lumière d'interférence générée par interférence entre une lumière renvoyée (113) à partir de l'oeil (105) du sujet exposé à une lumière de mesure (111), et une lumière de référence (112) correspondant à la lumière de mesure (111).

8. Appareil de formation d'image ophtalmique selon la revendication 5, comprenant en outre :

un moyen de fin de formation d'image (116) configuré pour terminer la formation d'image de l'oeil (105) du sujet conformément à un résultat de détection obtenu par le moyen de détection lorsque la quantité de mouvement, qui est égale ou supérieure à la valeur prédéterminée, est détectée par le moyen de détection tout en acquérant consécutivement une pluralité d'images tomographiques de l'oeil (105) du sujet.

FIG. 1

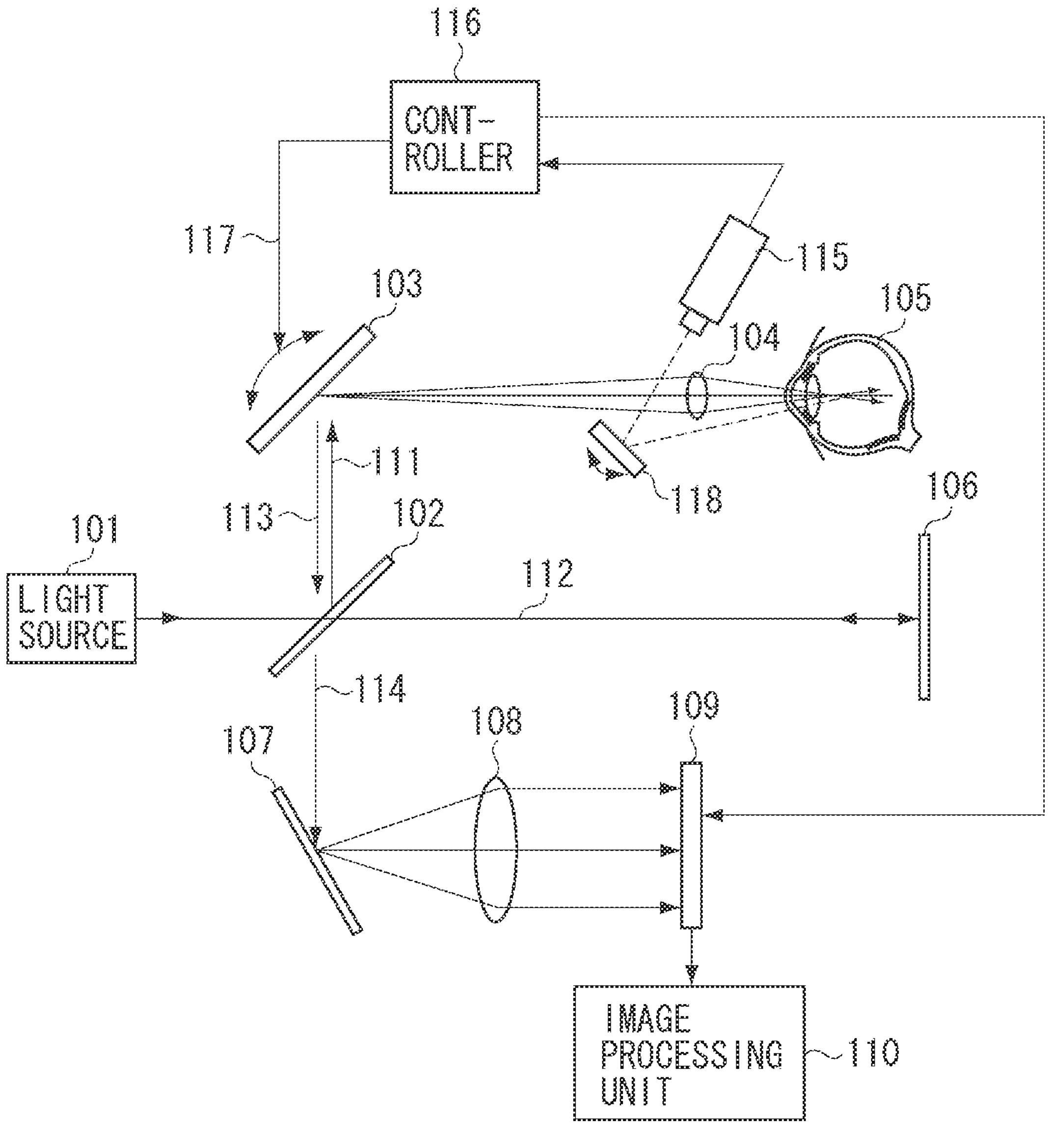

116
CONT-
ROLLER
117
115
103
105
104
118
111
113
102
106
101
LIGHT
SOURCE
112
114
107
108
109
IMAGE
PROCESSING
UNIT
110

FIG. 2A

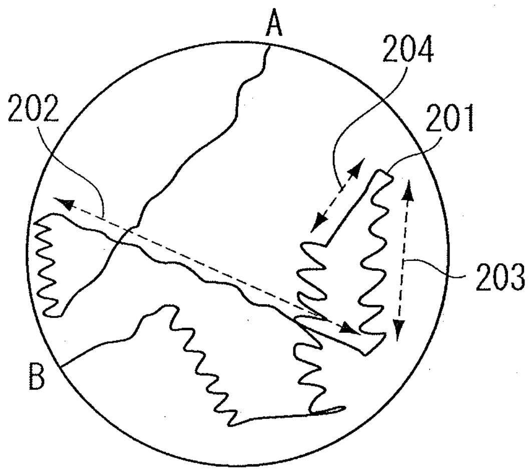


FIG. 2B

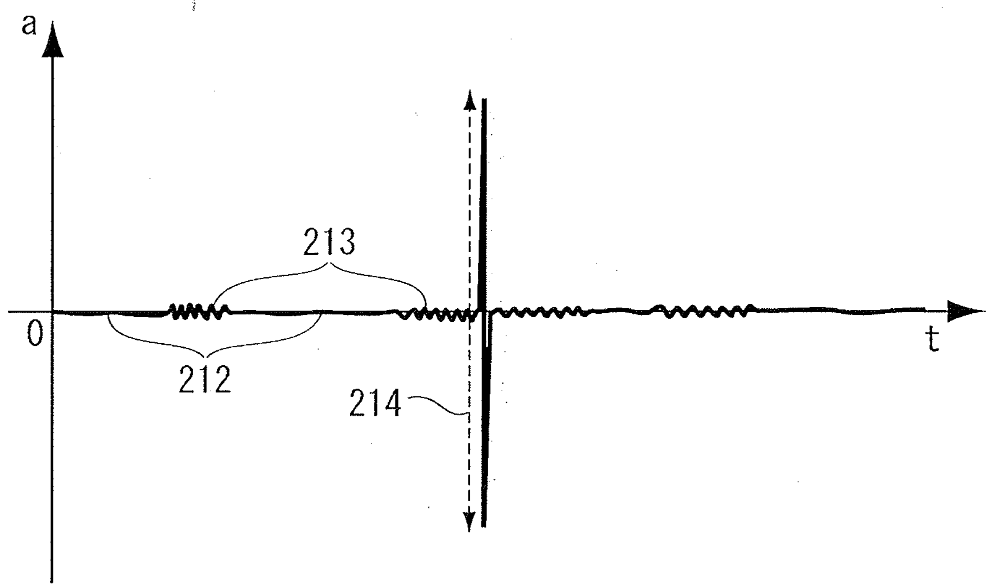


FIG. 2C

	TIME-PERIOD	CYCLE	DISPLACEMENT
DRIFT	0.2～1s		7～17μm
TREMOR		30～100Hz	0.3～3.5μm
FLICK	10～30ms	0.2～2Hz	7～52 μm

FIG. 3

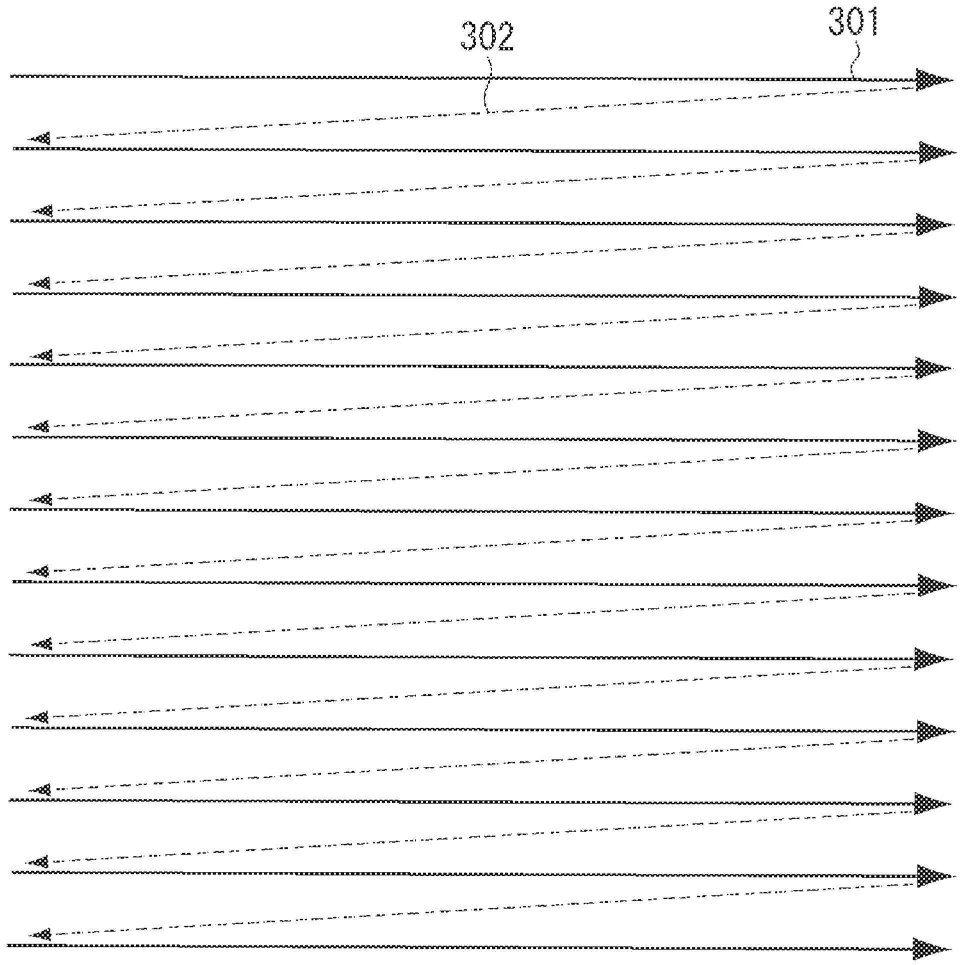


FIG. 4A

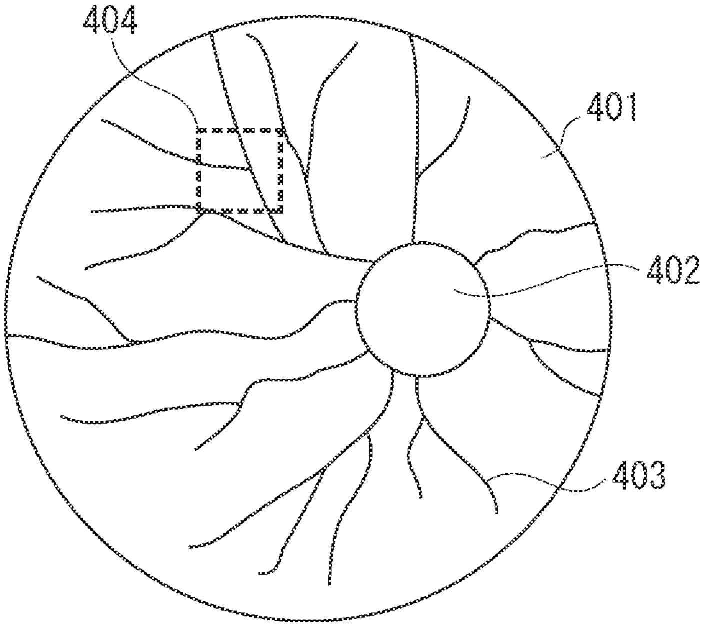


FIG. 4B

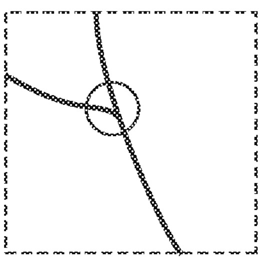


FIG. 4C

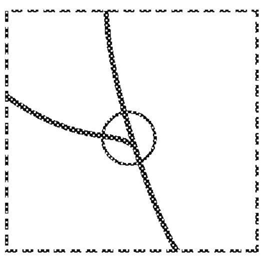


FIG. 4D

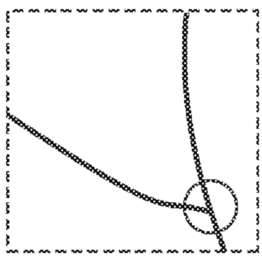
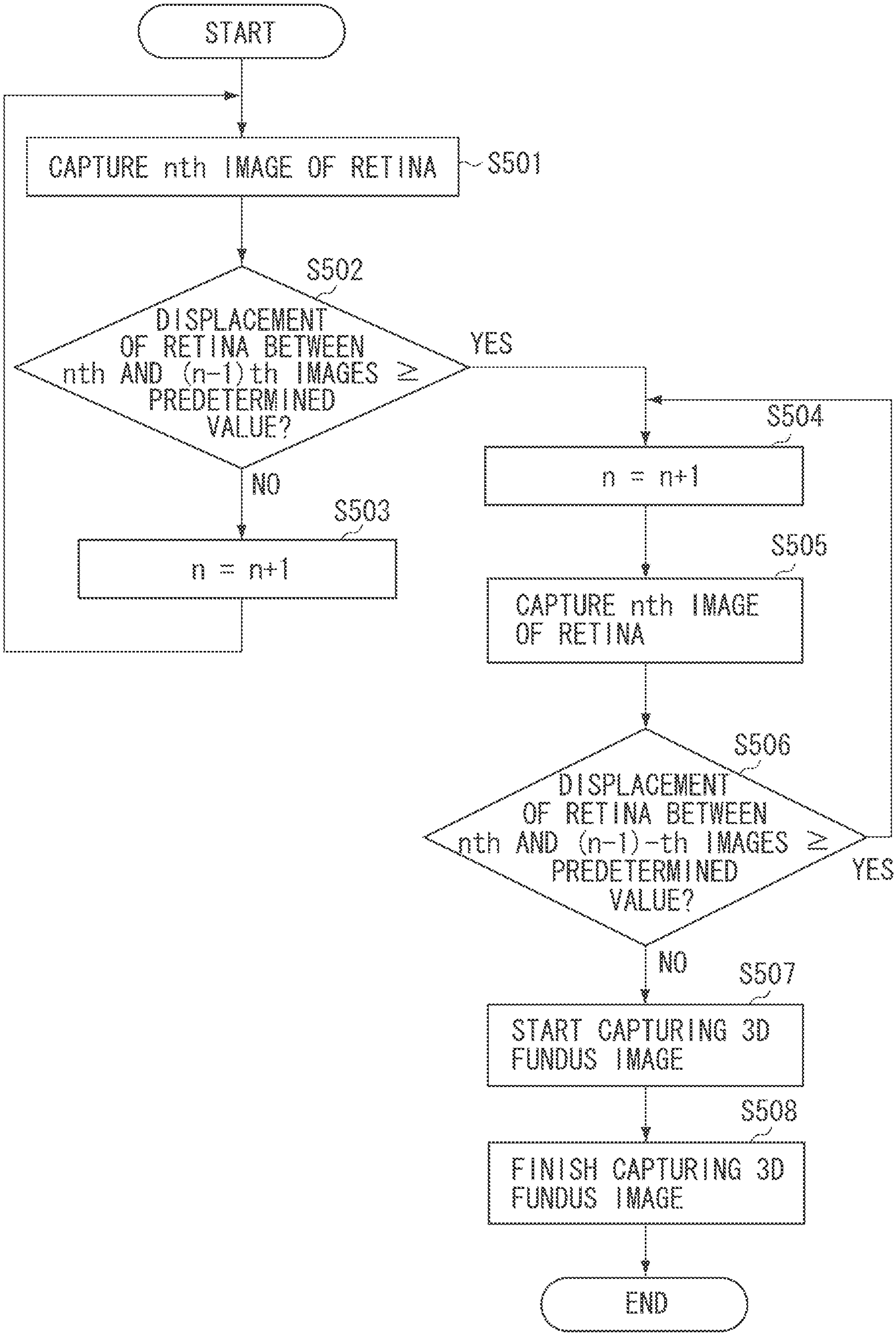


FIG. 5


START
CAPTURE nth IMAGE OF RETINA
S501
S502
DISPLACEMENT OF RETINA BETWEEN nth AND (n-1)th IMAGES ≥ PREDETERMINED VALUE?
YES
NO
S503
n = n+1
S504
n = n+1
S505
CAPTURE nth IMAGE OF RETINA
S506
DISPLACEMENT OF RETINA BETWEEN nth AND (n-1)-th IMAGES ≥ PREDETERMINED VALUE?
YES
NO
S507
START CAPTURING 3D FUNDUS IMAGE
S508
FINISH CAPTURING 3D FUNDUS IMAGE
END

REFERENCES CITED IN THE DESCRIPTION

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- JP 2008104628 A **[0003] [0004] [0007]**
- US 2005270486 A **[0004]**
- US 2005270486 A1 **[0008]**

patsnap

专利名称(译)	用于成像光学相干断层图像的设备和方法		
公开(公告)号	EP2322081B1	公开(公告)日	2018-01-03
申请号	EP2010188818	申请日	2010-10-26
[标]申请(专利权)人(译)	佳能株式会社		
申请(专利权)人(译)	佳能株式会社		
当前申请(专利权)人(译)	佳能株式会社		
[标]发明人	UTAGAWA TSUTOMU		
发明人	UTAGAWA, TSUTOMU		
IPC分类号	A61B3/12 A61B3/113 A61B5/00 A61B5/11 A61B3/10		
CPC分类号	A61B3/102		
代理机构(译)	TBK		
优先权	2009262394 2009-11-17 JP		
其他公开文献	EP2322081A1		
外部链接	Espacenet		

摘要(译)

一种用于对对象的眼睛进行成像的眼科成像装置（105）包括检测装置（116），其被配置为检测对象的眼睛（105）移动其移动量的事实，其等于或大于预定值，以及其运动结束，并且成像开始装置（116）被配置为根据检测装置（116）的检测结果开始对象眼睛（105）的成像。

$$T = (6/(20\times10^{-3}))^{2}/(250\times10^{-3})/0.8 = 45ms.$$