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(54) OPHTHALMIC APPARATUS AND CONTROL METHOD THEREFOR

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(57) **ABSTRACT**

An ophthalmic apparatus includes an illumination optical system which projects an illumination light beam from an illumination light source onto the fundus of the eye to be examined and an imaging optical system which guides reflected light from the fundus to imaging part. The ophthalmic apparatus calculates the contrast value of the fundus image formed by the imaging part, and focuses the imaging optical system on the fundus by moving a focus lens in the optical-axis direction of the imaging optical system based on the contrast value obtained by the calculation. The apparatus adjusts the contrast value obtained by the above calculation based on the position of the focus lens in the optical-axis direction.

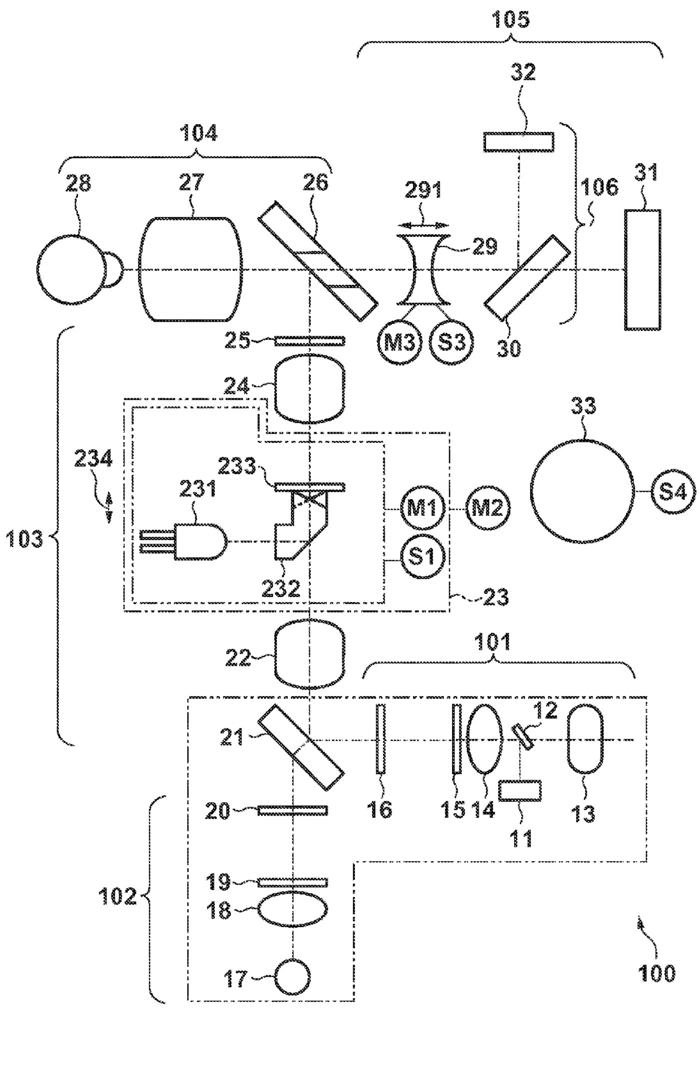


FIG. 1

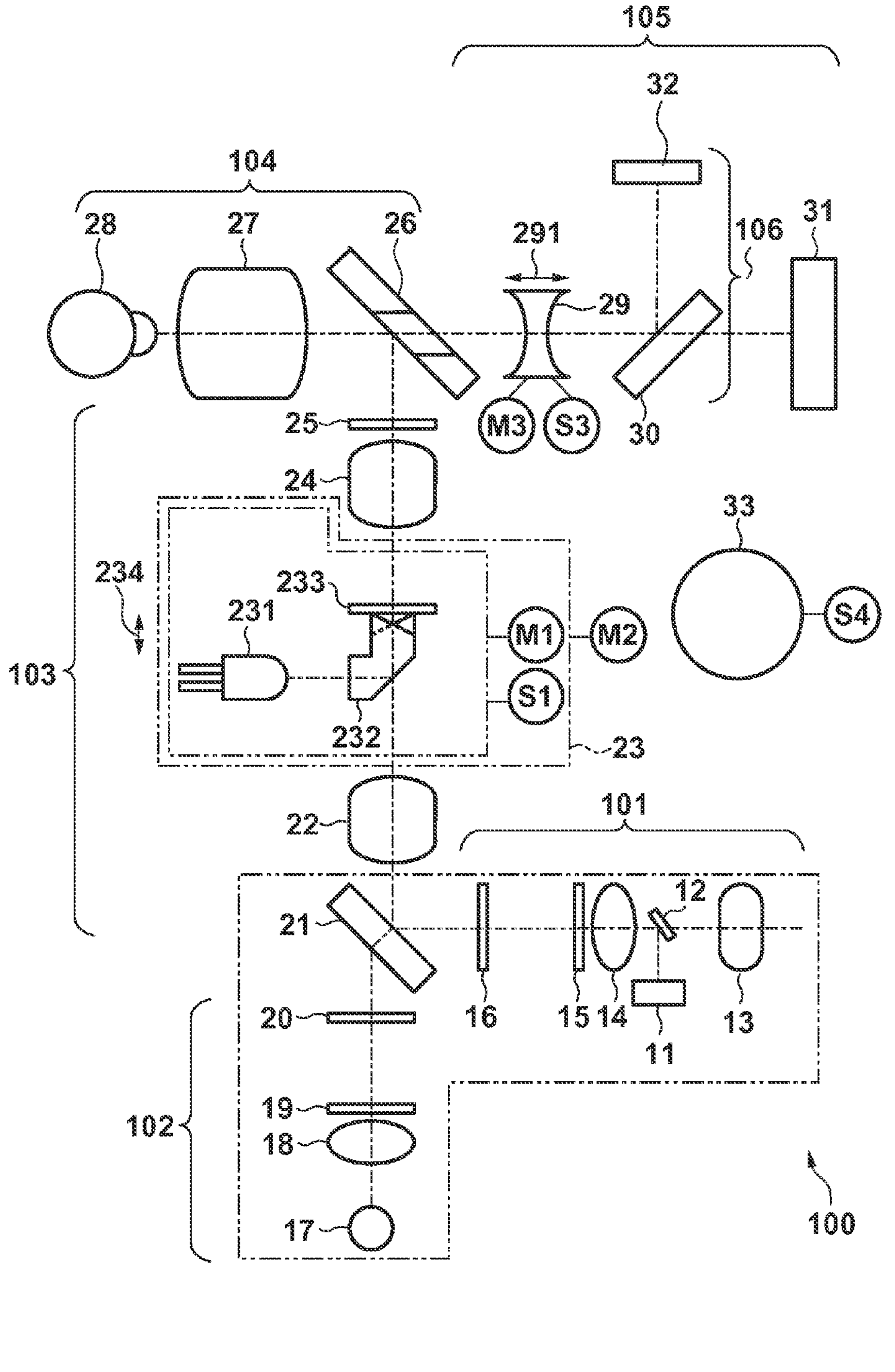

105
32
104
28
27
26
291
29
106
31
25
M3
S3
30
24
33
234
233
231
M1
M2
S4
103
S1
232
23
22
101
21
12
16
15
14
13
20
11
102
19
18
17
100

FIG. 2

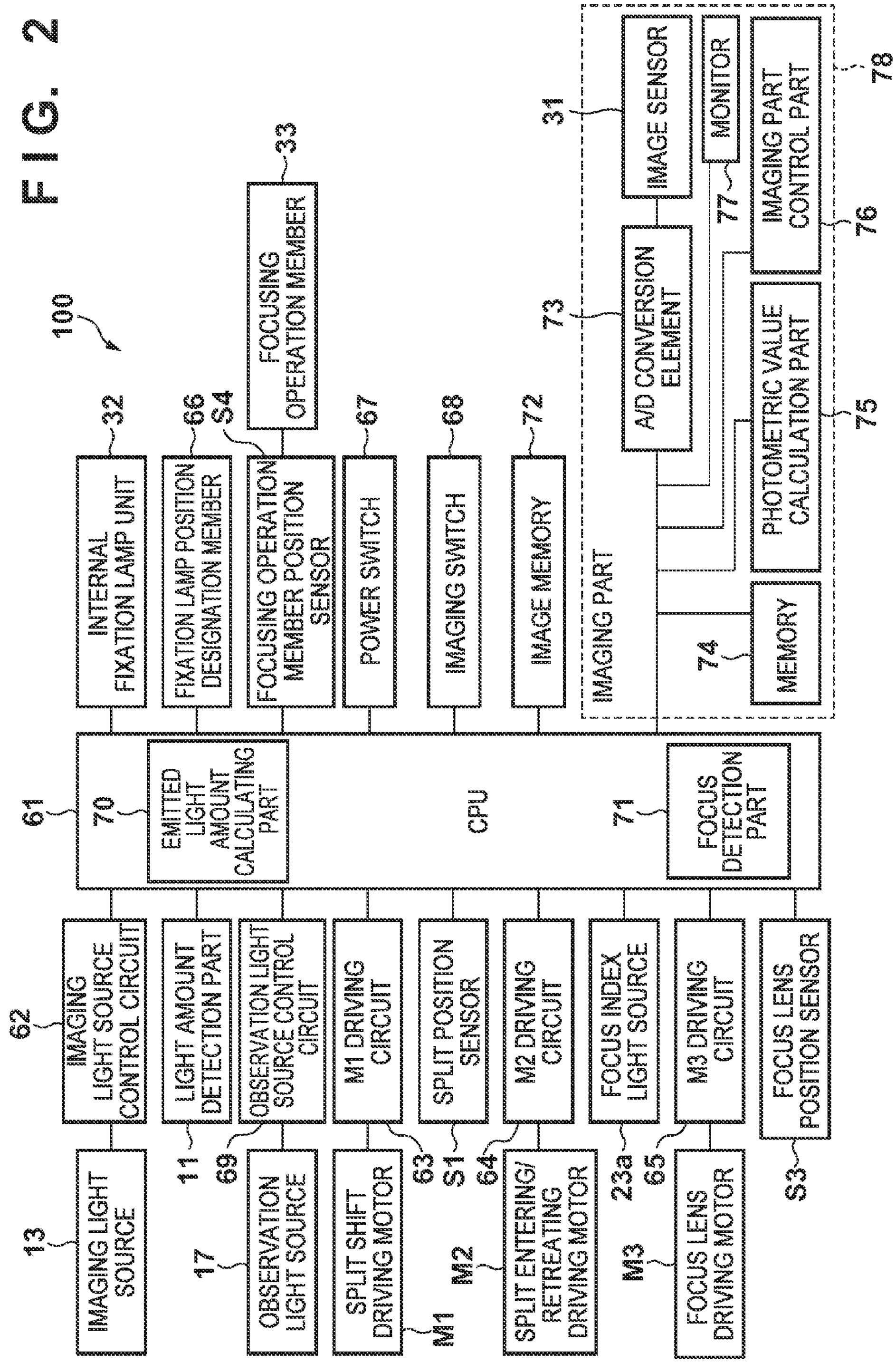

100
13
IMAGING LIGHT SOURCE
17
OBSERVATION LIGHT SOURCE
SPLIT SHIFT DRIVING MOTOR
M1
M2
SPLIT ENTERING/ RETREATING DRIVING MOTOR
M3
FOCUS LENS DRIVING MOTOR
62
IMAGING LIGHT SOURCE CONTROL CIRCUIT
11
LIGHT AMOUNT DETECTION PART
69
OBSERVATION LIGHT SOURCE CONTROL CIRCUIT
63
M1 DRIVING CIRCUIT
S1
SPLIT POSITION SENSOR
64
M2 DRIVING CIRCUIT
23a
FOCUS INDEX LIGHT SOURCE
65
M3 DRIVING CIRCUIT
S3
FOCUS LENS POSITION SENSOR
61
70
EMITTED LIGHT AMOUNT CALCULATING PART
CPU
71
FOCUS DETECTION PART
32
INTERNAL FIXATION LAMP UNIT
66
FIXATION LAMP POSITION DESIGNATION MEMBER
S4
FOCUSING OPERATION MEMBER POSITION SENSOR
33
FOCUSING OPERATION MEMBER
67
POWER SWITCH
68
IMAGING SWITCH
72
IMAGE MEMORY
IMAGING PART
73
A/D CONVERSION ELEMENT
31
IMAGE SENSOR
77
MONITOR
74
MEMORY
75
PHOTOMETRIC VALUE CALCULATION PART
76
IMAGING PART CONTROL PART
78

FIG. 3

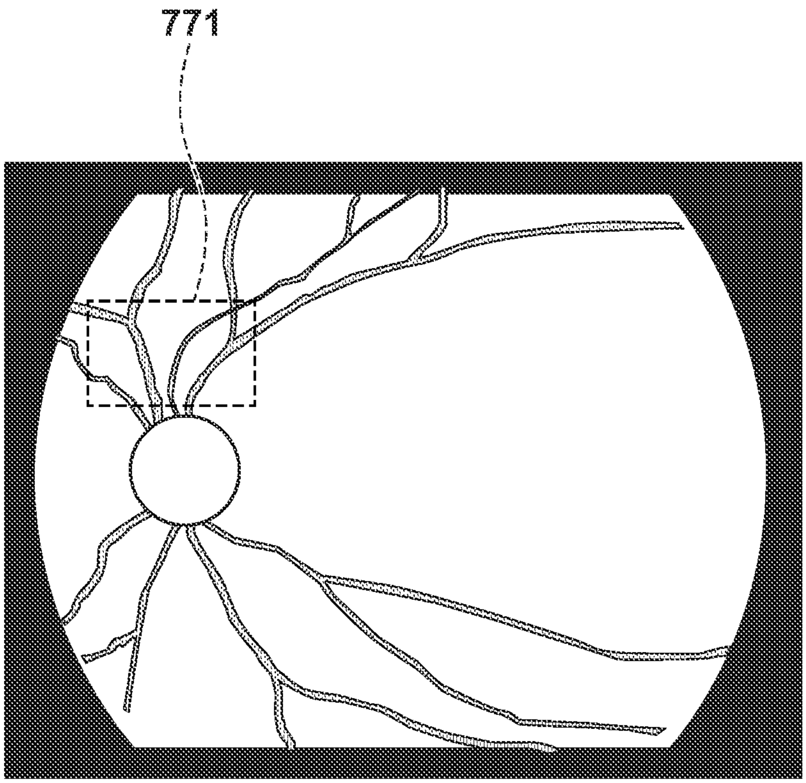


FIG. 4A

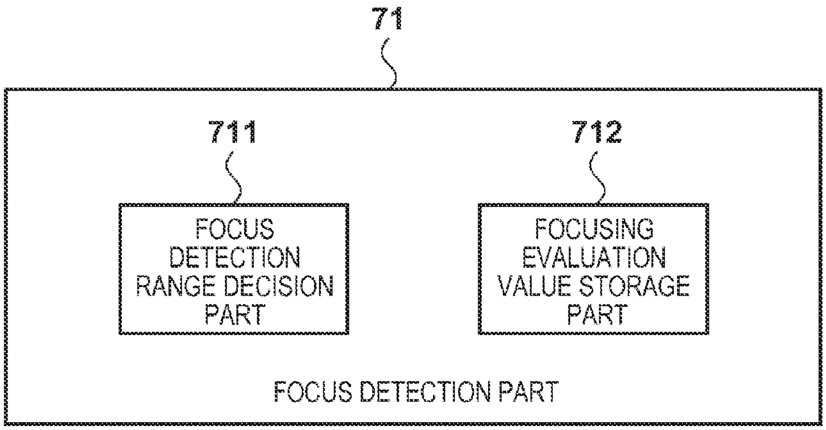
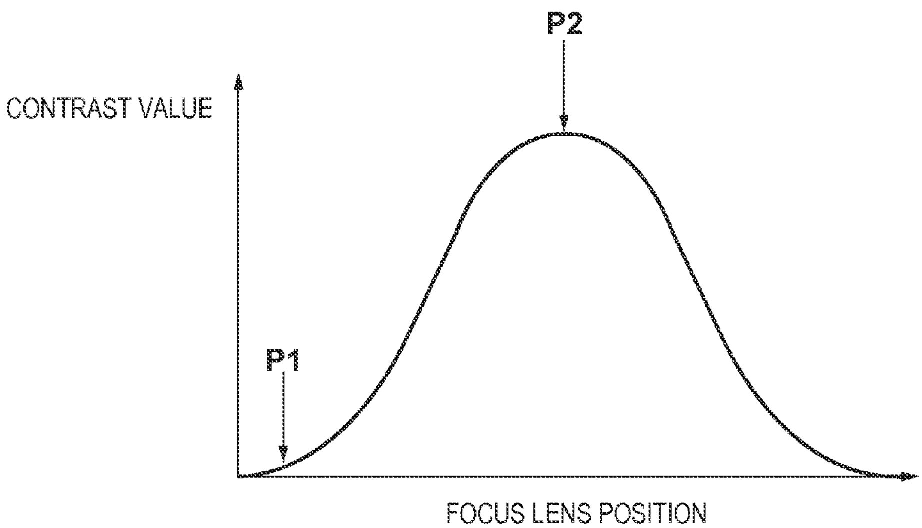
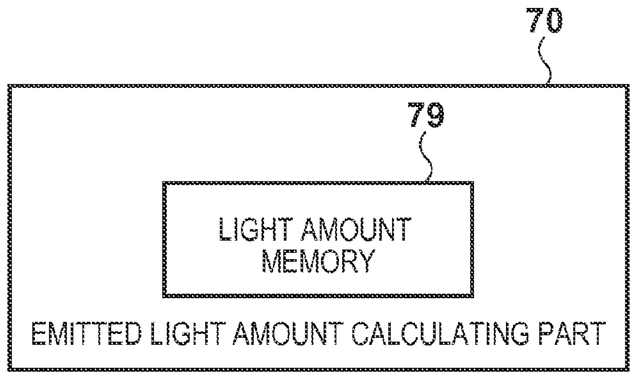

71
711
712
FOCUS DETECTION RANGE DECISION PART
FOCUSING EVALUATION VALUE STORAGE PART
FOCUS DETECTION PART

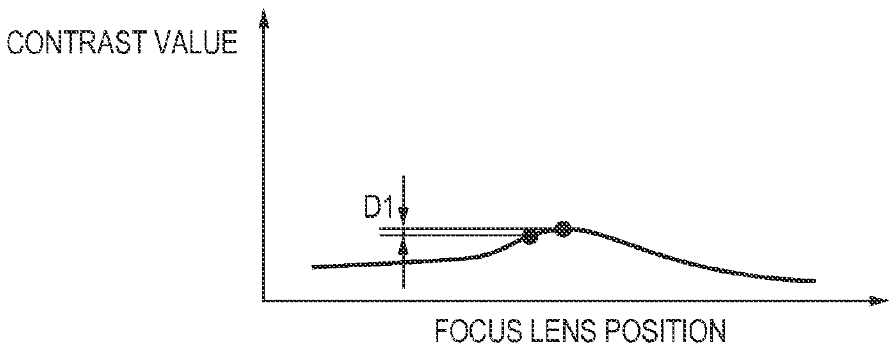
FIG. 4B


P2
CONTRAST VALUE
P1
FOCUS LENS POSITION

F I G. 5A




F I G. 5B




F I G. 5C

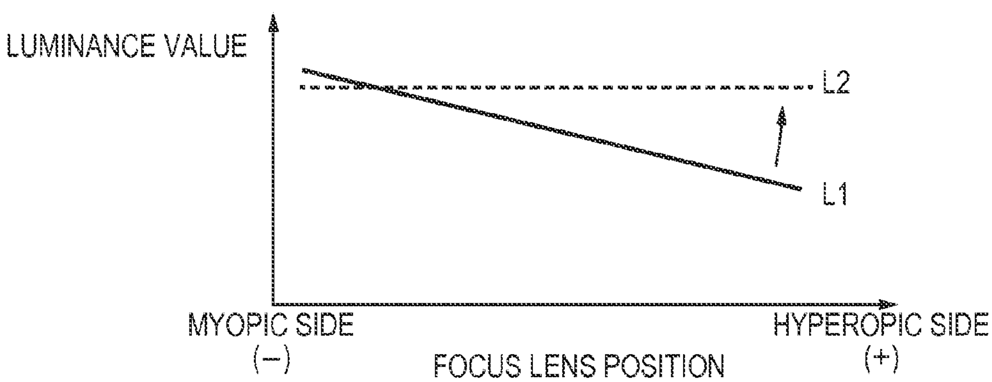


FIG. 6

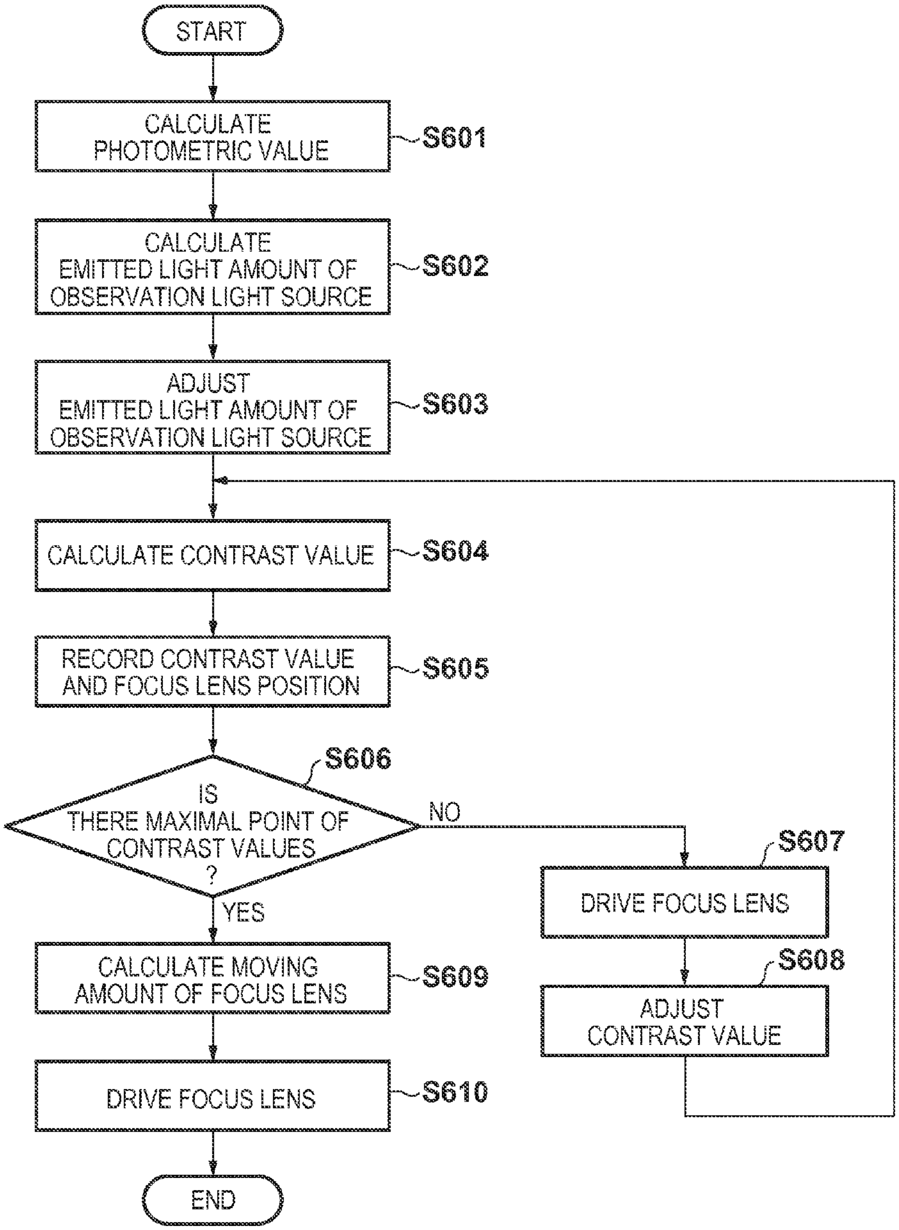

START
CALCULATE PHOTOMETRIC VALUE
S601
CALCULATE EMITTED LIGHT AMOUNT OF OBSERVATION LIGHT SOURCE
S602
ADJUST EMITTED LIGHT AMOUNT OF OBSERVATION LIGHT SOURCE
S603
CALCULATE CONTRAST VALUE
S604
RECORD CONTRAST VALUE AND FOCUS LENS POSITION
S605
IS THERE MAXIMAL POINT OF CONTRAST VALUES ?
S606
NO
YES
DRIVE FOCUS LENS
S607
ADJUST CONTRAST VALUE
S608
CALCULATE MOVING AMOUNT OF FOCUS LENS
S609
DRIVE FOCUS LENS
S610
END

FIG. 7

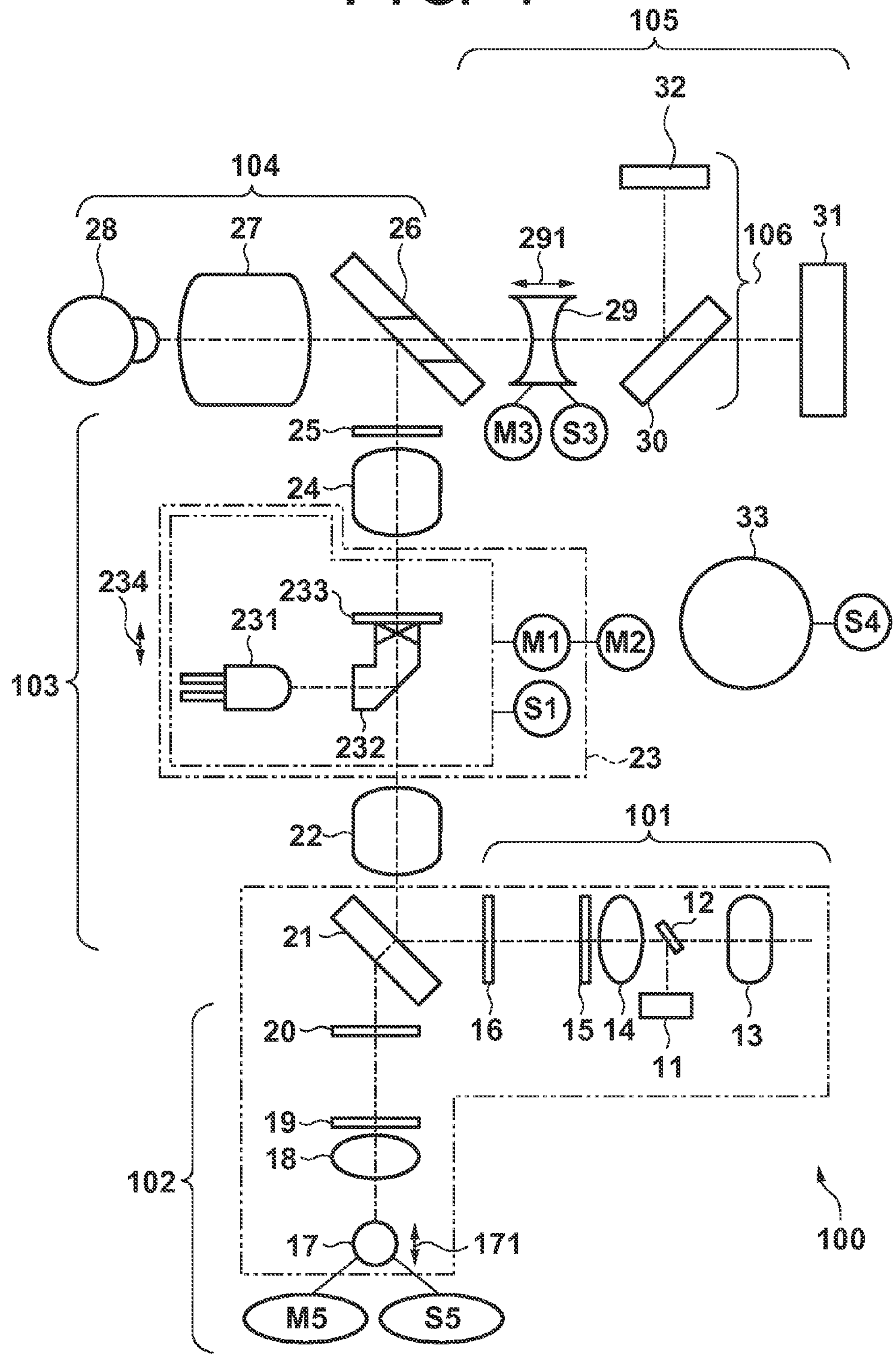

105
32
104
28
27
26
291
29
106
31
M3
S3
30
25
24
33
234
233
231
M1
M2
S4
103
S1
232
23
22
101
12
21
16
15
14
13
11
20
19
18
102
17
171
100
M5
S5

FIG. 8

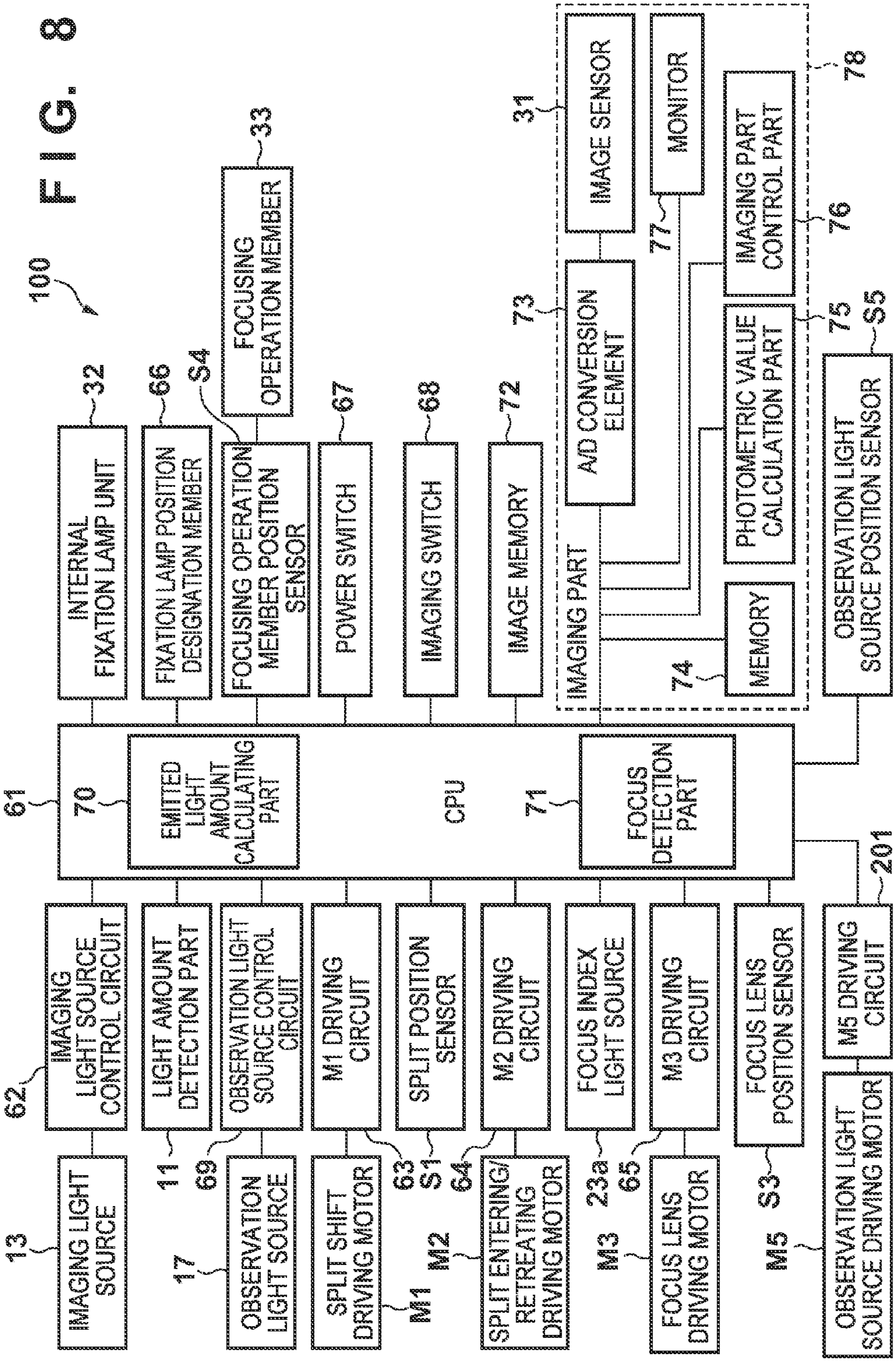
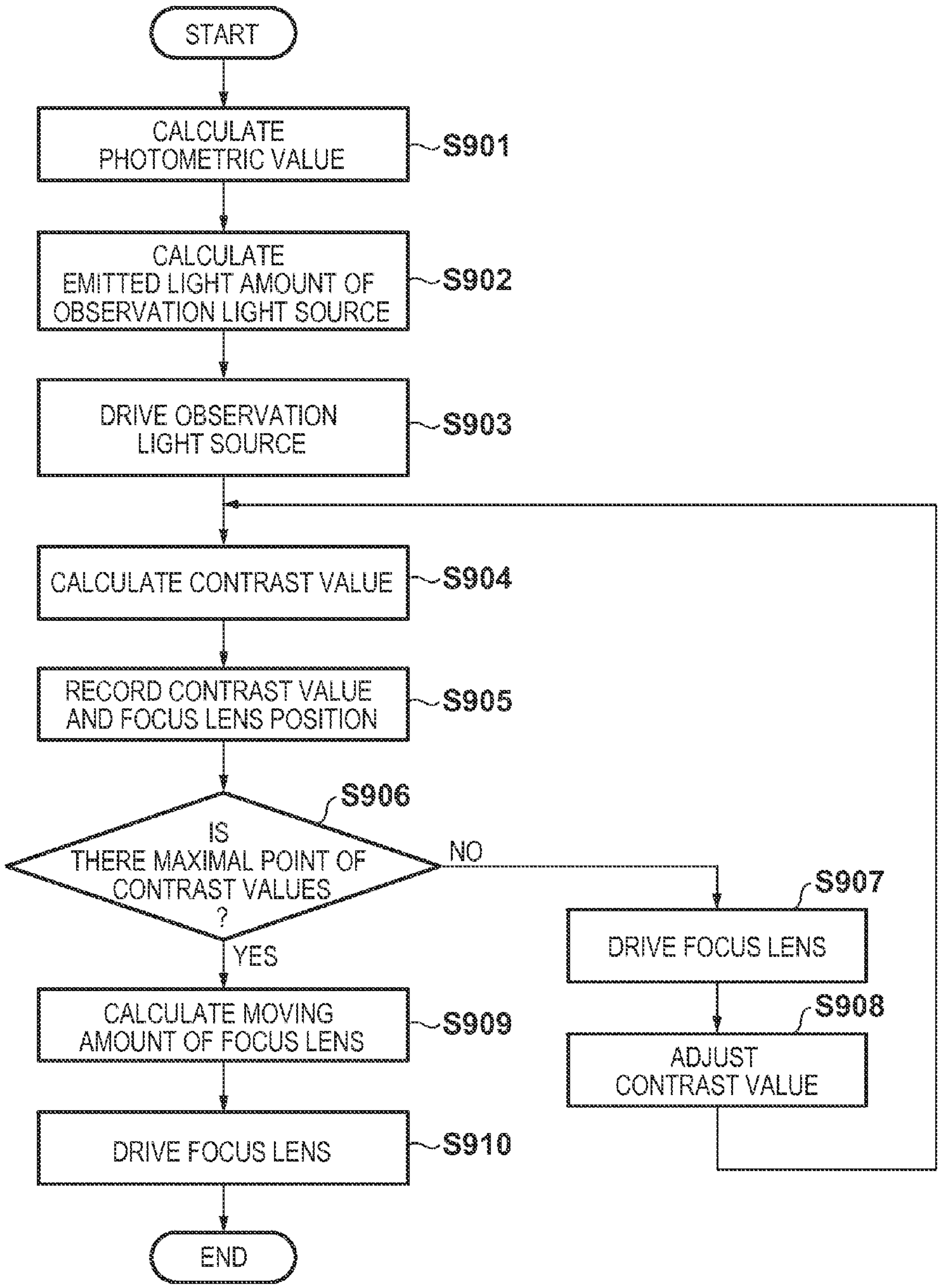

100
13
IMAGING LIGHT SOURCE
62
IMAGING LIGHT SOURCE CONTROL CIRCUIT
11
LIGHT AMOUNT DETECTION PART
17
OBSERVATION LIGHT SOURCE
69
OBSERVATION LIGHT SOURCE CONTROL CIRCUIT
M1
SPLIT SHIFT DRIVING MOTOR
63
M1 DRIVING CIRCUIT
S1
SPLIT POSITION SENSOR
M2
SPLIT ENTERING/ RETREATING DRIVING MOTOR
64
M2 DRIVING CIRCUIT
23a
FOCUS INDEX LIGHT SOURCE
M3
FOCUS LENS DRIVING MOTOR
65
M3 DRIVING CIRCUIT
S3
FOCUS LENS POSITION SENSOR
M5
OBSERVATION LIGHT SOURCE DRIVING MOTOR
201
M5 DRIVING CIRCUIT
61
CPU
70
EMITTED LIGHT AMOUNT CALCULATING PART
71
FOCUS DETECTION PART
32
INTERNAL FIXATION LAMP UNIT
66
FIXATION LAMP POSITION DESIGNATION MEMBER
S4
FOCUSING OPERATON MEMBER POSITION SENSOR
33
FOCUSING OPERATION MEMBER
67
POWER SWITCH
68
IMAGING SWITCH
72
IMAGE MEMORY
IMAGING PART
73
A/D CONVERSION ELEMENT
31
IMAGE SENSOR
77
MONITOR
74
MEMORY
75
PHOTOMETRIC VALUE CALCULATION PART
76
IMAGING PART CONTROL PART
78
S5
OBSERVATION LIGHT SOURCE POSITION SENSOR

FIG. 9


START
CALCULATE PHOTOMETRIC VALUE
S901
CALCULATE EMITTED LIGHT AMOUNT OF OBSERVATION LIGHT SOURCE
S902
DRIVE OBSERVATION LIGHT SOURCE
S903
CALCULATE CONTRAST VALUE
S904
RECORD CONTRAST VALUE AND FOCUS LENS POSITION
S905
IS THERE MAXIMAL POINT OF CONTRAST VALUES ?
S906
NO
DRIVE FOCUS LENS
S907
ADJUST CONTRAST VALUE
S908
YES
CALCULATE MOVING AMOUNT OF FOCUS LENS
S909
DRIVE FOCUS LENS
S910
END

# OPHTHALMIC APPARATUS AND CONTROL METHOD THEREFOR

## BACKGROUND OF THE INVENTION

**[0001]** 1. Field of the Invention

**[0002]** The present invention relates to an ophthalmic apparatus and a control method therefor.

**[0003]** 2. Description of the Related Art

**[0004]** In general, a fundus camera projects split focus indices on the pupil of an eye to be examined to facilitate detecting a focal position on the fundus of the eye at the time of focusing operation. The operator performs focusing while observing a positional relationship between the reflected focus index images through a focus lens disposed in an imaging optical system. It is also known to image the focus index images projected and reflected by the eye and perform autofocus operation from the positional relationship between the focus index images.

**[0005]** However, only setting the focus index images in a predetermined positional relationship (aligning them in a line) will cause an error in a detected focal position on the fundus of the eye to be examined due to the influence of aberration in the optical system inside the eye due to astigmatism or the like. This makes it difficult to perform imaging at an accurate focal position.

**[0006]** In order to solve the above problem, Japanese Patent Laid-Open No. 2011-50531 (to be referred to as literature 1 hereinafter) discloses a fundus camera which performs focusing by directly using a specific region of the fundus of the eye to be examined for focal position detection without using any focus index images for focal position detection with respect to the fundus of the eye. The fundus camera proposed in literature 1 performs autofocus operation by detecting the contrast of a specific region on the fundus of the eye to be examined by a focusing state detection part, calculating a contrast value based on the detection result, and determining a position where the contrast value is maximal as a focal position. In addition, the fundus camera disclosed in literature 1 includes an illumination light amount control part which adjusts the amount of illumination light emitted by an observation light source as a technique for implementing accurate autofocus operation. When, for example, detecting a contrast at a papillary portion where highlight detail loss tends to occur, this illumination light amount control part detects the contrast first by using a focusing state detection part and then controls the illumination light amount based on the detection result, thereby performing autofocus operation.

**[0007]** However, when using a non-mydriatic fundus camera designed to perform observation by using infrared light, since the contrast at a specific region of the fundus of the eye to be examined is low relative to infrared light, it is difficult to detect a maximal point of contrast values which corresponds to the position of a focus lens. A camera disclosed in Japanese Patent Laid-Open No. 5-199998 (to be referred to as literature 2 hereinafter) is provided with a reflected light amount detection part which detects the amount of light reflected by the fundus of the eye to be examined to sharpen a reflection image of infrared light from the fundus of the eye. The fundus camera disclosed in literature 2 operates a contrast enhancement and edge enhancement means in accordance with the amount of light detected by this reflection light amount detection part.

**[0008]** The luminance value of a fundus image of the eye to be examined which is captured by an image sensor changes depending on the position of a focus lens disposed in an imaging optical system. This is because as the position of the focus lens changes, the imaging magnification (field angle) of the fundus image captured by the image sensor changes to result in a change in illuminance on the image sensor. Compare, for example, a case in which the focus lens is located on the myopic side with a case in which the focus lens is located on the hyperopic side. The imaging magnification on the hyperopic side is larger, and hence the illuminance on the image sensor is lower, resulting in smaller luminance values. In general, the luminance value of a fundus image of the eye to be examined has an influence on a contrast value. For this reason, when determining, as a focal position, a position where the contrast value of a specific region of the fundus of the eye to be examined becomes maximal, if the luminance value of a fundus image of the eye is low or varies depending on the position of the focus lens, it is difficult to detect an accurate focal position.

**[0009]** The fundus camera disclosed in literature 1 calculates a contrast value at a specific region of the fundus of the eye to be examined with a constant illumination light amount under control, and hence still has the above problem. In addition, with regard to the fundus camera disclosed in literature 2, there are no descriptions about an arrangement for coping with a luminance value which changes depending on the position of the focus lens and an autofocus process using a contrast value.

## SUMMARY OF THE INVENTION

**[0010]** An embodiment of the present specification provides an ophthalmic apparatus which implements accurate autofocus in autofocus operation performed by using the contrast value of a fundus image which is obtained by illuminating the fundus of the eye to be examined and a control method for the apparatus.

**[0011]** According to one aspect of the present invention, there is provided an ophthalmic apparatus comprising: an illumination optical system which projects an illumination light beam from an illumination light source onto a fundus of an eye to be examined; an imaging optical system which guides reflected light from the fundus to imaging unit; a calculation unit configured to calculate a contrast value of a fundus image formed by the imaging unit; a focusing unit configured to focus the imaging optical system on the fundus by moving a focus lens in an optical-axis direction of the imaging optical system based on a contrast value obtained by the calculating unit; and an adjusting unit configured to adjust the contrast value obtained by the calculating unit based on a position of the focus lens in the optical-axis direction.

**[0012]** Also, according to another aspect of the present invention, there is provided a control method for an ophthalmic apparatus including an illumination optical system which projects an illumination light beam from an illumination light source onto a fundus of an eye to be examined and an imaging optical system which guides reflected light from the fundus to imaging unit, the method comprising: a calculation step of calculating a contrast value of a fundus image formed by the imaging unit; a focusing step of focusing the imaging optical system on the fundus by moving a focus lens in an optical-axis direction of the imaging optical system based on a contrast value obtained in the calculation step; and an adjusting step of adjusting the contrast value obtained in the calculation step based on a position of the focus lens in the optical-axis direction.

[0013] Further features of the present invention will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. **1** is a view showing an example of the schematic arrangement of a fundus camera according to the first embodiment;
[0015] FIG. **2** is a block diagram showing an example of the control arrangement of the fundus camera according to the first embodiment;
[0016] FIG. **3** is a view showing an example of the fundus image of the eye to be examined which is displayed on a monitor and a focus detection range;
[0017] FIG. **4**A is a view showing the schematic arrangement of a focus detection part;
[0018] FIG. **4**B is a graph for explaining an example of the principle of contrast detection;
[0019] FIG. **5**A is a view showing an example of the schematic arrangement of an emitted light amount calculating part;
[0020] FIG. **5**B is a graph showing an example of a concept of contrast value transition in infrared light;
[0021] FIG. **5**C is a graph showing an example of a concept of luminance value transition on an image sensor **31** corresponding to a focus lens position;
[0022] FIG. **6** is a flowchart showing an example of autofocus in the first embodiment;
[0023] FIG. **7** is a view showing an example of the schematic arrangement of a fundus camera according to the second embodiment;
[0024] FIG. **8** is a block diagram showing an example of the control arrangement of the fundus camera according to the second embodiment; and
[0025] FIG. **9** is a flowchart showing an example of autofocus according to the second embodiment.

## DESCRIPTION OF THE EMBODIMENTS

[0026] The preferred embodiments of the present invention will be described below with reference to the accompanying drawings.

### First Embodiment

[0027] A fundus camera as an ophthalmic apparatus according to the first embodiment will be described with reference to FIGS. **1** to **9**. The schematic arrangement of this camera will be described first with reference to FIG. **1**. FIG. **1** is a schematic view for explaining the arrangement of the fundus camera according to the first embodiment.

[0028] A fundus camera **100** is roughly constituted by an imaging light source part **101**, an observation light source part **102**, an illumination optical system **103**, an imaging/illumination optical system **104**, an imaging optical system **105**, and an internal fixation lamp part **106**. The light beam emitted from the imaging light source part **101** or the observation light source part **102** illuminates a fundus portion of an object to be examined through the illumination optical system **103** and the imaging/illumination optical system **104**. An image of the fundus portion is formed on an image sensor **31** through the imaging/illumination optical system **104** and the imaging optical system **105**.

[0029] The imaging light source part **101** generates ring illumination of white light with the following arrangement. In the imaging light source part **101**, reference numeral **11** denotes a light amount detection part which is a sensor using a known photoelectric conversion element such as a silicon photocell (SPC) or photodiode (PD); **12**, a mirror which is formed by depositing aluminum or silver on a glass plate or from an aluminum plate or the like; and **13**, an imaging light source which is an illumination light source for illuminating the fundus for imaging. As the imaging light source **13**, for example, a xenon lamp with xenon (Xe) being sealed in a glass tube is used. The imaging light source **13** can obtain white light with a sufficient intensity for recording a fundus image at the time of imaging by emitting light upon application of a voltage. Reference numeral **14** denotes an imaging condenser lens which is a general spherical lens; **15**, an imaging ring slit which is a flat plate having an annular opening; and **16**, an imaging crystalline lens baffle which is also a flat panel having an annular opening. The imaging condenser lens **14** condenses a light beam toward the fundus of the eye to be examined. The imaging ring slit **15** then forms the light beam into an annular shape when it passes through the anterior ocular segment of the eye. The imaging crystalline lens baffle **16** limits a light beam projected on the crystalline lens of the eye to prevent unnecessary reflected light from the crystalline lens of the eye from being depicted in a fundus image.

[0030] The observation light source part **102** generates ring illumination of infrared light with the following arrangement. In the observation light source part **102**, reference numeral **17** denotes an observation light source which is an illumination light source used for observing the fundus. This is a light source capable of continuously emitting light like a halogen lamp or LED and outputs infrared light depending on the characteristic of the device or filter. In this specification, an illumination light source is a light source which illuminates the fundus of the eye to be examined and is a generic term of the imaging light source **13** and the observation light source **17**. Reference numeral **18** denotes an observation condenser lens which is a general spherical lens; **19**, an observation ring slit which is a flat plate having an annular opening; and **20**, an observation crystalline lens baffle which is also a flat panel having an annular opening. These components are similar to those of the imaging light source part **101** except that these light sources differ in type. In the observation light source part **102**, the observation condenser lens **18** condenses the light output from the observation light source **17**, and the observation ring slit **19** shapes the light beam at the anterior ocular segment. The observation crystalline lens baffle **20** prevents reflected light from the crystalline lens from being depicted in a fundus image.

[0031] The illumination optical system **103** relays the light beam generated by the imaging light source part **101** and the observation light source part **102** and generates index images for focusing a fundus image. In the illumination optical system **103**, reference numeral **21** denotes a dichroic mirror which transmits infrared light and reflects visible light. The dichroic mirror **21** reflects the light beam of visible light generated by the imaging light source part **101**, and transmits the light beam of infrared light generated by the observation light source part **102**. Each light beam is then guided to the illumination optical system **103**. Reference numeral **22** denotes a first illumination relay lens; and **24**, a second illumination relay lens. These lenses form ring illumination into an image on the eye.

[0032] Reference numeral **23** denotes a split unit which includes a focus index light source **231** for projecting focus indices, a prism **232** for splitting light emitted by the focus index light source **231**, and a focus index mask **233** indicating the outer shapes of focus indices. The split unit **23** includes a moving mechanism for shifting/moving the focus indices in the optical axis direction by moving the focus index light source **231**, the prism **232**, and the focus index mask **233** in an arrow direction **234** in FIG. **1**. The split unit **23** further includes an entering/retreating mechanism which causes the split unit **23** to enter the optical path of the illumination optical system **103** and to retreat from it. The moving mechanism includes a split shift driving motor M1 and a split position sensor S1, shifts the split unit **23** to focus on each focus index, and detects the stop position. The entering/retreating mechanism includes a split entering/retreating driving motor M2 which causes the split unit **23** to enter/retreat with respect to the optical path of the illumination optical system **103**. The entering/retreating mechanism causes the split unit **23** to enter the optical path of the illumination optical system **103** to project split indices in an observation image at the time of fundus observation. At the time of fundus imaging, the entering/retreating mechanism causes the split unit **23** to retreat from the optical path of the illumination optical system **103** so as to prevent each focus index from being depicted in a captured image. Reference numeral **25** denotes a cornea baffle which prevents unnecessary reflected light from the cornea of the eye to be examined from being depicted in a fundus image.

**[0033]** The imaging/illumination optical system **104** projects an illumination light beam on the fundus of an eye **28** to be examined and guides a fundus image of the eye to be examined. In the imaging/illumination optical system **104**, reference numeral **26** denotes a perforated mirror whose peripheral portion is a mirror and central portion is a hole. The light beam guided from the illumination optical system **103** is reflected by the mirror portion of the perforated mirror **26** and illuminates the fundus of the eye to be examined through an objective lens **27**. The illuminated fundus image of the eye to be examined returns to the objective lens **27** and is guided to the imaging optical system **105** through the hole in the central portion of the perforated mirror **26**.

**[0034]** The imaging optical system **105** forms a fundus image of the eye to be examined on the image sensor upon focus adjustment. In the imaging optical system **105**, reference numeral **29** denotes a focus lens which is a lens for focus adjustment of an imaging light beam passing through the central hole of the perforated mirror **26** by moving in an arrow direction **291** in FIG. **1**. Reference symbol M3 denotes a focus lens driving motor; S3, a focus lens position sensor which performs focusing by driving the focus lens **29** and detects its stop position. Reference numeral **31** denotes an image sensor which photoelectrically converts imaging light. A processing circuit (not shown) A/D-converts the electrical signal obtained by the imaging element **31** into digital data. A display device (not shown) then displays the data at the time of observation with infrared light. This signal is stored in a recording medium (not shown) at the time of imaging.

**[0035]** In the internal fixation lamp part **106**, a half mirror **30** branches an optical path from the imaging optical system **105**, and an internal fixation lamp unit **32** faces the optical path. The internal fixation lamp unit **32** is constituted by a plurality of LEDs and turns on an LED at a position corresponding to the visual fixation part selected by the examiner using a fixation lamp position designation member **66**. By letting the object fix his/her vision to the turned-on LED, the examiner can obtain a fundus image in a desired direction.

**[0036]** The above schematic arrangement is held in one housing to form a fundus camera optical part. The fundus camera optical part is mounted on a sliding base (not shown) to allow positioning with the eye **28**. The examiner operates a focusing operation member **33** to position the fundus camera optical part. A focusing operation member position sensor S4 can detect the operation position of the focusing operation member **33**.

**[0037]** The above description is about the schematic arrangement using FIG. **1**. The control arrangement of the fundus camera **100** will be described next with reference to FIG. **2**. FIG. **2** is a block diagram for explaining the control arrangement of the fundus camera **100** according to the first embodiment.

**[0038]** A CPU **61** controls the following operation of the fundus camera **100**. An imaging light source control circuit **62** charges energy for the emission of light by the imaging light source **13** before imaging. The imaging light source control circuit **62** discharges charged electric energy at the time of imaging to cause the imaging light source **13** to emit light. The light amount detection part **11** detects the emitted light amount of the imaging light source **13**, and issues an instruction to stop light emission to the CPU **61** when the emitted light amount of the imaging light source **13** reaches the emitted light amount limited by an emitted light amount calculating part **70**. Upon receiving the instruction to stop light emission from the light amount detection part **11**, the CPU **61** stops light emission from the imaging light source **13** via the imaging light source control circuit **62**. Both the imaging light source control circuit **62** connected to the imaging light source **13** and an observation light source control circuit **69** connected to the observation light source **17** are connected to the CPU **61** which also serves as the emitted light amount calculating part **70**, thereby performing control such as light amount adjustment and ON/OFF control for the imaging light source **13** and the observation light source **17** as described above. An M2 driving circuit **64** drives the split entering/retreating driving motor M2 so as to cause the split unit **23** to enter/retreat with respect to the illumination optical system **103** before and after imaging. A power switch **67** is a switch for selecting power supply state for the fundus camera. An imaging switch **68** is a switch for executing imaging by the fundus camera.

**[0039]** When the examiner operates the focusing operation member **33**, the focusing operation member position sensor S4 can detect the stop position of the focusing operation member **33**. An M1 driving circuit **63** drives a split shift driving motor M1 to move the split to a position corresponding to an output from the focusing operation member position sensor S4 under the control of the CPU **61**. Like the M1 driving circuit **63**, an M3 driving circuit **65** drives the focus lens driving motor M3 to move the focus lens **29** to a position corresponding to an output from the focusing operation member position sensor S4 under the control of the CPU **61**. In the manual focusing mode, the CPU **61** controls the split shift driving motor M1 and the focus lens driving motor M3 in accordance with outputs from the focusing operation member position sensor S4, as described above. In the autofocus mode, the CPU **61** controls the focus lens driving motor M3 via the M3 driving circuit **65** based on a detection result from a focus detection part **71** inside the CPU **61**. That is, the fundus camera **100** of this embodiment has an autofocus function of automatically executing focus adjustment.

**[0040]** In an imaging part **78**, an A/D conversion element **73** converts an output from the image sensor **31** into a digital signal, which is stored in a memory **74** and output to a photometric value calculation part **75**. Note that the A/D conversion element **73**, the memory **74**, and the photometric value calculation part **75** are connected to the CPU **61**. An image memory **72** is connected to the CPU **61**. The image memory **72** stores the still image captured by the image sensor **31** as a digital image.

**[0041]** The imaging part **78** includes a monitor **77** for displaying the infrared observation image, visible captured image, and the like captured by the image sensor **31** and an imaging part control part **76**, in addition to the image sensor **31**, the A/D conversion element **73**, the memory **74**, and the photometric value calculation part **75**. The imaging part **78** is detachably fixed to the housing of the fundus camera optical part with a mount portion (not shown). An electrical block will be described below with reference to FIG. **2**.

**[0042]** The fundus image of the eye to be examined which is displayed on the monitor **77** will be described next with reference to FIG. **3**. FIG. **3** is a view showing the the fundus image of the eye to be examined and a focus detection range **771** which are displayed on the monitor **77** of the fundus camera **100** according to the first embodiment.

**[0043]** At the time of fundus observation, the apparatus presents a frame indicating the focus detection range **771** to the examiner upon superimposing it on the fundus image obtained by the imaging part **78**. This makes it possible to visually present the focus detection position to the examiner, thereby improving the operability in autofocus. Note that the examiner can manually change the focus detection range, and may set a specific region on the fundus of the eye to be examined or the overall fundus as a focus detection range. The fundus image of the eye to be examined which is displayed on the monitor **77** has been described above with reference to FIG. **3**.

**[0044]** The schematic arrangement of the focus detection part **71** and the principle of contrast detection will be described next with reference to FIGS. **4**A and **4**B. FIG. **4**A shows the schematic arrangement of the focus detection part **71** according to the first embodiment. FIG. **4**B shows the principle of contrast detection according to this embodiment. Assume that the embodiment uses the luminance differences between adjacent pixels as contrasts and uses the largest luminance difference value among luminance data in a predetermined range as a contrast value. Note however that it is also possible to use, as a contrast value, a value other than the largest luminance difference value among luminance data in a predetermined range.

**[0045]** As shown in FIG. **4**A, the focus detection part **71** is provided with a focus detection range decision part **711** which sets a specific position on the fundus of the eye **28** as a focus detection target. The examiner can decide the focus detection range **771** by operating the operation input part. In addition, the focus detection part **71** incorporates a focusing evaluation value storage part **712** which stores the contrast values of a fundus image and the positions of the focus lens **29**. This embodiment performs focus detection by detecting the contrast value of the fundus image itself which is formed by an imaging light beam.

**[0046]** The graph of FIG. **4**B represents the contrast value transition relative to the position of the focus lens **29** moved by the focus lens driving motor M**3**. As is obvious from FIG. **4**B, the contrast value is maximized at a focal position P**2**, whereas the contrast value is reduced at a position P**1** where the amount of defocusing is large. This embodiment can perform focus detection without influence of aberration of the eye to be examined by using this principle of contrast detection. This is because the position of the focus lens **29** moved to the focal position P**2** by the focus lens driving motor M**3** coincides with:

**[0047]** the position where the examiner can observe the fundus image displayed on the monitor **77** most clearly; and

**[0048]** the position of the focus lens **29** at which he fundus image displayed on the monitor **77** after imaging can be made most clearly. The schematic arrangement of the focus detection part **71** and the principle of contrast detection have been described above with reference to FIGS. **4**A and **4**B.

**[0049]** The emitted light amount calculating part **70** will be described next with reference to FIGS. **5**A to **5**C. FIG. **5**A shows the schematic arrangement of the emitted light amount calculating part **70** according to the first embodiment. FIG. **5**B is a graph showing a concept of contrast value transition in infrared light. FIG. **5**C is a graph showing a concept of luminance value transition on the image sensor **31** corresponding to focus lens positions.

**[0050]** The A/D conversion element **73** A/D-converts an output from each pixel of the image sensor **31**. The memory **74** temporarily stores the digital data. The photometric value calculation part **75** outputs, as a photometric value, the maximum value of the luminance values in a focus detection range from the pixel outputs stored in the memory **74** to the emitted light amount calculating part **70**. However, the acquisition of a photometric value is not limited to this. For example, a dedicated actinometer may he placed to measure the amount of reflected light from the fundus. As shown in FIG. **5**A, the emitted light amount calculating part **70** includes a light amount memory **79** which stores a reference value for an observation light amount which is determined suitably for focus detection, and decides the emitted light amount of observation light by comparing a photometric value with the reference value.

**[0051]** If, for example, a photometric value is larger than the reference value, the emitted light amount calculating part **70** determines that the amount of observation light illuminating the fundus is large, and decides an emitted light amount so as to reduce the light amount to prevent luminance value saturation. In contrast, if a photometric value is smaller than the reference value, the emitted light amount calculating part **70** determines that the amount of observation light illuminating the fundus is small, and decides an emitted light amount to increase the light amount to facilitate detection of a maximal point of contrast values.

**[0052]** Contrast value transition when the contrast value of a fundus image of the eye to be examined is calculated by using infrared light will be described below. FIG. **5**B shows contrast value transition relative to the position of the focus lens **29** moved by the focus lens driving motor M**3** when infrared light is used as observation light. Although the description with reference FIG. **4**B uses a graph or ideal contrast value transition for the explanation of the principle of contrast detection, a contrast value difference D**1** in FIG. **5**B is smaller than that in the graph of FIG. **4**B. In addition, as indicated by a solid line L**1** in the graph of FIG. **5**C, as the position of the focus lens shifts to the hyperopic side in terms of focus, the luminance value captured by the image sensor **31** decreases. As the luminance value decreases and the contrast value difference D**1** decreases, it becomes more difficult to detect the peak of contrast values. This makes it difficult to perform accurate focusing.

**[0053]** The light amount memory **79** incorporated in the emitted light amount calculating part **70** stores both the reference value for observation light amounts which is determined suitably for focus detection and luminance variation values on the image sensor **31** which correspond to the positions of the focus lens **29**. The emitted light amount calculating part **70** decides the emitted light amount of observation light by comparing the photometric value calculated by the photometric value calculation part **75** with the reference value for observation light amounts which is stored in the light amount memory **79**. In this case, the emitted light amount calculating part **70** decides the emitted light amount of observation light corresponding to the focus lens position by using the luminance variation value on the image sensor **31** corresponding to the position of the focus lens **29** which is stored in the light amount memory **79**. That is, the emitted light amount calculating part **70** changes the amount of observation light in accordance with the position of the focus lens. For example, the CPU **61** adjusts the emitted light amount of observation light by the observation light source **17** to match the luminance value indicated by a dotted line L**2** in FIG. **5**C, thereby canceling out variations corresponding to the positions of the focus lens.

**[0054]** Although variation values are stored in the light amount memory **79** in advance, the present invention is not limited to this. For example, the apparatus may measure the luminance on the image sensor **31** after the movement of the focus lens **29**, compare the measured luminance with the reference value stored in the light amount memory, and store the difference between the measured luminance and the reference value in the light amount memory **79**. That is, the apparatus may store the difference between the reference value and the luminance measured in real time in the light amount memory **79** and change the observation light amount based on the difference between the reference value and the measured and stored luminance.

**[0055]** Although this embodiment uses infrared light as observation light, the present invention is not limited to this. Even when calculating the contrast value of a fundus image of the eye to be examined by using visible light, the apparatus may change the emitted light amount of observation light in accordance with the focus lens position in the same manner as described above.

**[0056]** In this embodiment, the light amount memory **79** stores both the reference value for observation light amounts and luminance variation values on the image sensor **31** which correspond to the positions of the focus lens **29**. However, the present invention is not limited to this. The light amount memory **79** may store only luminance variation values on the image sensor **31** which correspond to the positions of the focus lens **29**, and the emitted light amount calculating part **70** may decide the emitted light amount of observation light corresponding to the focus lens position by using such a variation value.

**[0057]** This embodiment is configured to set luminance values like those on the dotted line L**2** shown in FIG. **8** by controlling the emitted light amount of observation light from the observation light source **17** in accordance with variations in luminance values on the image sensor **31** in correspondence with the positions of the focus lens. However, the present invention is not limited to this. For example, the imaging part control part **76** may adjust the gain of the image sensor **31** in accordance with the luminance variation values on the image sensor **31** which are stored in the light amount memory **79** in accordance with the positions of the focus lens **29**. For example, it is possible to implement this operation by making the emitted light amount calculating part **70** inform the imaging part control part **76** of variation values corresponding to the positions of the focus lens **29** and then making the imaging part control part **76** control the gain of the image sensor **31** in accordance with the variation values. In this case, for example, the apparatus obtains values which almost match the luminances of the images at the respective positions of the focus lens **29** from the images obtained in advance upon moving the focus lens **29**, and uses such values as variation values. The apparatus then stores the positions of the focus lens **29** and variation values in the light amount memory **79** in correspondence with each other.

**[0058]** The apparatus may offset the contrast value which is stored in the focusing evaluating value storage part **712** and makes transition in accordance with the focus lens position based on the variation values stored in the light amount memory **79** instead of controlling the emitted light amount of the observation light source **17** or the gain of the image sensor **31** in the above manner. In this case, the emitted light amount calculating part **70** informs the focus detection part **71** of a luminance variation value on the image sensor **31** which is stored in the light amount memory **79** in correspondence with the position of the focus lens **29**. The focus detection part **71** offsets the contrast value stored in the focusing evaluation value storage part **712** based on the informed variation value. For example, it is possible to change the contrast value by performing tone conversion for the obtained image. In this case, for example, the apparatus obtains a tone conversion characteristic which almost matches the luminances of the images at the respective positions of the focus lens **29** from the images obtained in advance upon moving the focus lens **29**. The apparatus then stores these tone conversion characteristics in the light amount memory **79** in correspondence with the positions of the focus lens **29** and the variation values. Note that it is possible to combine some or all of the above control schemes, that is, control on the emitted light amount of the observation light source **17**, control on the gain of the image sensor **31**, and offset control on contrast values.

**[0059]** The emitted light amount calculating part **70** have been described above with reference to FIGS. **5**A to **5**C. Autofocus processing by the fundus camera **100** according to this embodiment will be described next with reference to FIG. **6**.

**[0060]** When the examiner issues an instruction to start autofocus, the photometric value calculation part **75** calculates the maximum value of luminance values in a focus detection range as a photometric value from the pixels stored in the memory **74**, and outputs the photometric value to the emitted light amount calculating part **70** in step **S601**. In step S**602**, the emitted light amount calculating part **70** compares the reference value for emitted light amounts which is stored in the light amount memory **79** with the photometric value calculated in step S**601** to decide the emitted light amount of observation light from the observation light source **17** so as to match, for example, the photometric value with the reference value. In addition, in step S**602**, the emitted light amount calculating part **70** compares the photometric value calculated in step S**601** with the luminance variation value on the image sensor **31** which is stored in the light amount memory **79** in correspondence with the position of the focus lens **29**. The emitted light amount calculating part **70** then decides the emitted light amount of the observation light source **17** so as to compensate for the variation value corresponding to the position of the focus lens **29**. In step S**603**, the emitted light amount calculating part **70** controls the observation light source control circuit **69** so as to irradiate the fundus with the amount of observation light decided in step S**602**. That is, the emitted light amount calculating part **70** controls the observation light amount so as to match the photometric value with the reference value stored in the light amount memory **79**. With this operation, the apparatus irradiates the fundus with observation light decided in step S**602** in accordance with the position of the focus lens **29**.

**[0061]** In step S**604**, the focus detection part **71** calculates a contrast value based on the image obtained from the imaging part **78**. In step S**605**, the focus detection part **71** records the contrast value calculated in step S**604** and the position of the focus lens **29** on the focusing evaluation value storage part **712**. In step S**606**, the focus detection part **71** detects whether the contrast values recorded on the focusing evaluation value storage part **712** in step S**605** include a maximal point like the position P**2** shown in FIG. **4**B.

**[0062]** If the focus detection part **71** does not detect any maximal point in step S**606**, the process advances to step S**607**, in which the CPU **61** changes the focus lens position by driving the focus lens **29** by a predetermined moving amount. In step S**608**, the CPU **61** adjusts the emitted light amount of observation light from the observation light source **17** based on the relationship between focus lens positions and luminance values, as shown in FIG. **5**C, and adjusts the contrast value by canceling out the variation corresponding to the position of the focus lens. The process then returns to the processing in step S**604**. Subsequently, the CPU **61** repeats steps S**607**, S**608**, S**604**, and S**605** until the detection of a maximal point of contrast values in step S**606**.

**[0063]** If the focus detection part **71** detects a maximal point in step S**606**, the process advances to step S**609**. In step S**609**, the focus detection part **71** calculates the moving amount of the focus lens **29**. In this case, the moving amount of the focus lens **29** is the driving amount of the focus lens to the detection position of the maximal point. In step S**610**, the CPU **61** drives the focus lens **29** in accordance with the moving amount of the focus lens **29** calculated in step S**609** to move the position of the focus lens **29** to the position of the maximal value of contrast values. With the above operation, even if eyes **28** of different objects have individual differences in aberrations such as aspherical aberration and astigmatism, it is possible to perform focus adjustment in accordance with such aberrations. Note that the emitted light amount calculating part **70** controls the emitted light amount of the imaging light source **13** based on the observation light amount variation value at the position of the focus lens **29** calculated in step S**609**. For example, the emitted light amount calculating part **70** changes the emitted light amount of the imaging light source **13** by the observation light amount variation value at the position of the focus lens **29**. Note that it is possible to obtain the observation light amount variation value at the position of the focus lens **29** from the variation values stored in the light amount memory **79** by using an approximate expression. The apparatus then performs imaging with this controlled light amount.

**[0064]** The above autofocus operation is especially effective in a non-mydriatic fundus camera designed to perform observation by using infrared light. Since the contrast of medium and large vessels on the fundus is low relative to infrared light, a contrast value difference is difficult to appear with respect to focus lens positions. It is therefore difficult to detect the position P**2** corresponding to the maximal point shown in FIG. **4**B in autofocus. It is therefore necessary to increase the emitted light amount of the infrared LED for illuminating the fundus to increase the contrast of an observation image as much as possible. If, however, the fundus becomes brighter than necessary, luminance value saturation occurs, leading to the failure to correctly calculate a contrast value. In contrast to this, the fundus camera **100** according to this embodiment prevents luminance value saturation in advance by calculating and controlling a proper observation light amount before the calculation of a contrast value, and corrects an observation light amount with respect to the luminance value which varies in accordance with the position of the focus lens **29**. This makes it possible to stably calculate a contrast value and allows to perform accurate focus detection.

## Second Embodiment

**[0065]** A fundus camera **100** according to the second embodiment will be described in detail next with reference to FIGS. **7** to **9**. The first embodiment has exemplified the arrangement for removing the influence of variations (FIG. **5**C) in luminance value in accordance with focus lens positions by adjustment on the emitted light amount of the observation light source **17**, and adjustment of the gain of the image sensor **31**, and/or offset adjustment on measured contrast values. The second embodiment is configured to remove the influence of variations in luminance value (FIG. **5**C) in accordance with focus lens positions by moving an observation light source **17**.

**[0066]** The fundus camera **100** according to the second embodiment is configured to move the observation light source **17** in the direction indicated by an arrow **171** in FIG. **7** relative to an observation light source part **102** in accordance with the luminance variation value on an image sensor **31** which is stored in a light amount memory **79** in an emitted light amount calculating part **70** in correspondence with the position of the focus lens **29**. This controls the amount of observation light which irradiates the fundus of the eye to be examined. When increasing the amount of observation light, the fundus camera **100** moves the observation light source **17** in the direction to approach the eye to be examined. When decreasing the amount of observation light, the fundus camera **100** moves the observation light source **17** in the direction to separate from the eye.

**[0067]** The schematic arrangement of the fundus camera **100** according to the second embodiment will be described with reference to FIG. **7**. The fundus camera **100** according to the second embodiment includes a mechanism for moving the observation light source **17** in the direction indicated by the arrow **171** in FIG. **7**, in addition to the arrangement of the first embodiment (FIG. **1**), in order to control the amount of observation light which irradiates the fundus of an eye **28** to be examined. Reference symbol M**5** denotes an observation light source driving motor which moves the observation light source **17** in the direction indicated by the arrow **171**; S**5**, an observation light source position sensor which detects the stop position of the observation light source **17** moved by the observation light source driving motor M**5**. Other arrangements are the same as those described in the first embodiment (FIG. **1**).

**[0068]** The control arrangement of the fundus camera **100** according to the second embodiment will be described next with reference to FIG. **8**. FIG. **8** is a block diagram showing the control arrangement of the fundus camera **100** according to the second embodiment. In addition to the control arrangement (FIG. **2**) described in the first embodiment, the control arrangement of the fundus camera **100** according to the second embodiment includes an M**5** driving circuit **201** controlled by a CPU **61**, the observation light source driving motor M**5**, and the observation light source position sensor S**5**.

**[0069]** The M**5** driving circuit **201** drives the observation light source **17** via the observation light source driving motor M**5** based on the luminance variation value on the image sensor **31** which is stored in the light amount memory **79** incorporated in the emitted light amount calculating part **70** in accordance with the position of a focus lens **29**. The observation light source position sensor S**5** is based on an output from a focus lens position sensor S**3**. The observation light source **17** is driven in accordance with the position of the focus lens **29**. Other components are the same as those of the control arrangement (FIG. **2**) described in the first embodiment of the present invention.

**[0070]** Autofocus processing by the fundus camera **100** according to the second embodiment will be described next with reference to the flowchart of FIG. **9**.

**[0071]** When the examiner issues an instruction to start autofocus, a photometric value calculation part **75** calculates the maximum value of luminance values in a focus detection range as a photometric value from the pixel outputs stored in a memory **74**, and outputs the photometric value to the emitted light amount calculating part **70** in step S**901**. In step S**902**, the emitted light amount calculating part **70** compares the reference value for emitted light amounts which is stored in the light amount memory **79** with the photometric value calculated in step S**901** to decide the emitted light amount of the observation light source **17** so as to match the photometric value with the reference value. In addition, in step S**902**, the emitted light amount calculating part **70** compares the photometric value calculated in step S**901** with the luminance variation value on the image sensor **31** which is stored in the light amount memory **79** in correspondence with the position of the focus lens **29**. The emitted light amount calculating part **70** then decides the position of the observation light source so as to compensate for the variation value corresponding to the position of the focus lens **29** based on this comparison result. In step S**903**, the CPU **61** controls an observation light source control circuit **69** to irradiate the fundus with the amount of observation light decided in step S**902**. In step S**903**, the CPU **61** drives the observation light source driving motor M**5** via the M**5** driving circuit **201** to move the observation light source to the position decided in step S**902** which corresponds to the position of the focus lens **29**.

**[0072]** In step S**904**, the focus detection part **71** calculates a contrast value. In step S**905**, the focus detection part **71** records the contrast value calculated in step S**904** and the position of the focus lens **29** on a focusing evaluation value storage part **712**. In step S**906**, the focus detection part **71** detects whether the contrast values recorded in step S**905** include a maximal point like the position P**2** shown in FIG. **4**B.

**[0073]** If the focus detection part **71** does not detect any maximal point in step S**906**, the process advances to step S**907**, in which the focus detection part **71** changes the focus lens position by driving the focus lens **29** by a predetermined moving amount. In step S**908**, the focus detection part **71** adjusts the contrast value. More specifically, the M**5** driving circuit **201** drives the observation light source **17** via the observation light source driving motor M**5** in accordance with the amount of variation in luminance value in accordance with the position of the focus lens **29**, an output from the focus lens position sensor S**3**, and an output from the observation light source position sensor S**5**. In this manner, the apparatus performs control to place the observation light source **17** at a position to cancel out the amount of variation in luminance value at the position of the focus lens **29**. Subsequently, the apparatus repeats steps S**907**, S**908**, S**904**, and S**905** until the detection of a maximal point of contrast values in step S**906**.

**[0074]** If the focus detection part **71** detects a maximal point in step S**906**, the process advances to step S**909**. In step S**909**, the focus detection part **71** calculates the moving amount of the focus lens **29**. In this case, the moving amount of the focus lens **29** is the driving amount of the focus lens to the detection position of the maximal point. In step S**910**, the focus detection part **71** drives the focus lens **29** in accordance with the moving amount of the focus lens **29** calculated in step S**909** to move the focus lens **29** to the position of the maximal value of contrast values. With the above operation, even if eyes **28** of different objects have individual differences in aberrations such as aspherical aberration and astigmatism, it is possible to perform focus adjustment in accordance with such aberrations. Note that in this case, as in the first embodiment, the emitted light amount calculating part **70** may control the emitted light amount of the imaging light source **13** based on the observation light amount variation value at the position of the focus lens **29** calculated in step S**909**.

**[0075]** As in the first embodiment, the above operation is especially effective in a non-mydriatic fundus camera designed to perform observation by using infrared light. Since the contrast of medium and large vessels on the fundus is low relative to infrared light, a contrast value difference is difficult to appear with respect to focus lens positions. It is therefore difficult to detect the position P**2** corresponding to the maximal point shown in FIG. **4**B in autofocus. It is therefore necessary to increase the emitted light amount of the infrared LED for illuminating the fundus to increase the contrast of an observation image as much as possible. If, however, the fundus becomes brighter than necessary, luminance value saturation occurs, leading to the failure to correctly calculate a contrast value. In contrast to this, the fundus camera **100** according to the second embodiment prevents luminance value saturation in advance by calculating and controlling a proper observation light amount (emitted light amount) before the calculation of a contrast value, and corrects an observation light amount with respect to the luminance value which varies in accordance with the position of the focus lens **29** by changing the position of the observation light source **17**. This makes it possible to stably calculate a contrast value and allows to perform accurate focus detection.

**[0076]** Aspects of the present invention can also be realized by a computer of a system or apparatus (or devices such as a CPU or MPU) that reads out and executes a program recorded on a memory device to perform the functions of the above-described embodiment(s), and by a method, the steps of which are performed by a computer of a system or apparatus by, for example, reading out and executing a program recorded on a memory device to perform the functions of the above-described embodiment(s). For this purpose, the program is provided to the computer for example via a network or from a recording medium of various types serving as the memory device (for example, computer-readable storage medium).

**[0077]** 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.

**[0078]** This application claims the benefit of Japanese Patent Application No. 2012-237265, filed Oct. 26, 2012, which is hereby incorporated by reference herein in its entirety.

What is claimed is:

**1**. An ophthalmic apparatus comprising:

an illumination optical system which projects an illumination light beam from an illumination light source onto a fundus of an eye to be examined;

an imaging optical system which guides reflected light from the fundus to imaging unit;

a calculation unit configured to calculate a contrast value of a fundus image formed by said imaging unit;

a focusing unit configured to focus said imaging optical system on the fundus by moving a focus lens in an optical-axis direction of said imaging optical system based on a contrast value obtained by said calculating unit; and

an adjusting unit configured to adjust the contrast value obtained by said calculating unit based on a position of the focus lens in the optical-axis direction.

**2**. The apparatus according to claim **1**, wherein said adjusting unit adjusts the contrast value by controlling a light amount of the illumination light source in accordance with the position of the focus lens.

**3**. The apparatus according to claim **1**, wherein said adjusting unit adjusts the contrast value by controlling a gain of said imaging unit in accordance with the position of the focus lens.

**4**. The apparatus according to claim **1**, wherein said adjusting unit adjusts the contrast value by changing an offset to be provided for the contrast value in accordance with the position of the focus lens.

**5**. The apparatus according to claim **1**, wherein the illumination light source is provided to be configured to move in the optical-axis direction of said illumination optical system, and

said adjusting unit adjusts the contrast value by moving the illumination light source in accordance with the position of the focus lens.

**6**. The apparatus according to claim **1**, further comprising a photometric unit configured to photometrically measure the reflected light from the fundus,

wherein said adjusting unit adjusts the light amount of the illumination light source based on a photometric value obtained by said photometric unit.

**7**. The apparatus according to claim **6**, wherein said photometric unit acquires, as the photometric value, a maximum luminance value from a specific range of an image obtained from said imaging unit.

**8**. A control method for an ophthalmic apparatus including an illumination optical system which projects an illumination light beam from an illumination light source onto a fundus of an eye to be examined and an imaging optical system which guides reflected light from the fundus to imaging unit, the method comprising:

a calculation step of calculating a contrast value of a fundus image formed by the imaging unit;

a focusing step of focusing the imaging optical system on the fundus by moving a focus lens in an optical-axis direction of the imaging optical system based on a contrast value obtained in the calculation step; and

an adjusting step of adjusting the contrast value obtained in the calculation step based on a position of the focus lens in the optical-axis direction.

**9**. A non-transitory computer-readable storage medium storing a program for causing a computer to execute each step in a control method for an ophthalmic apparatus defined in claim **8**.

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